IMPACT OF TRANSIT-ORIENTED INFRASTRUCTURE INVESTMENTS ON PROPERTY VALUATIONS

by

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ABSTRACT

IMPACT OF TRANSIT-ORIENTED INFRASTRUCTURE

INVESTMENTS ON PROPERTY VALUATIONS

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The population explosion of the second half of the last century brought about increased human activity. Much of the attendant increased access to activities has been facilitated by the incredible technological advances in the automobile, which depends almost entirely on fossil fuels. Supplies of fossil fuel are limited and the automobile has led to urban sprawl, traffic congestion, and reduced quality to life in cities (1). This type of development is unsustainable. Transit-oriented development (TOD) is one of the neo-urbanism response instruments. The question is: “How well do these urban forms perform in North-Central Texas? In response, this study has developed an econometric disaggregate model for the assessment of the impact of TODs on micro-level property valuation. Two TODs in the region, Addison Town Center and Plano Transit Village are case analyzed in a disaggregate framework with Richardson as the control site. The analysis test the hypothesis, among others, that: “TODs have positive impacts on property values.” Findings support this thesis. Efficient simple fixed effects model estimates show positive coefficients for unconditional and conditional proxy variables for the impact of TODs on property valuation for properties within a ¼-mile radius of each TOD center.

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LIST OF ACRONYMS

ACE – autocorrelated error

ARCH – autoregressive conditional heteroskedastic

ARIMA – autoregressive integrated moving average

ARMA – autoregressive-moving average

ATC – Addison Town Center

BE – between effects

BLUE – best linear unbiased estimator

CA – Cellular Automata

DART – Dallas Area Rapid Transit

DFW – Dallas-Fort Worth

DR – Downtown Richardson

FE – fixed effects

FGLS – feasible generalized least squares

GARCH – generalized autoregressive conditional heteroskedastic

GIS – geographic information system

GLS - generalized least squares

JD – joint development

LU – land use

LUT – land use and transportation (land use-transportation)

LUTRAQ – Land Use, Transportation, Air Quality

MAS – Micro-Analytic Simulation

MARTA – Metropolitan Atlanta Rapid Transit Authority

METROPILUS – Metropolitan Integrated Land Use System

MPO – metropolitan planning organization

MSMUIO – Multisectoral Spatial Modeling Using Input-Output

MUD – mixed-use design

NCTCOG – North-Central Texas Council of Governments

NOx – nitrogen oxide

OLS – ordinary least squared

PTV – Plano Transit Village

RATS – Regression Analysis of Time Series

RE – random effects

RMSE – root mean squared error

SD – sustainable development

SLEUTH – Slope Land Use Exclusion Urban Extent Transportation and Hill Shade model

STARIMA – structural autoregressive integrated moving average

TAR – threshold autoregressive

TEA 21 – Transportation Equity Act of the 21st Century

TOD – transit-oriented development

TRANPLAN – Transportation Planning

UGB – urban growth boundary

VAR – Vector autoregression

VIF – variance inflation factor

VMT – vehicle-miles-travelled

VOC – volatile organic compounds

CHAPTER 1

INTRODUCTION AND PROBLEM DEFINITION

1.1 Introduction

The strategic goal of many metropolitan planning organizations (MPOs) in using transit-oriented developments (TODs) is to achieve regional smart growth by reducing vehicle miles travelled (VMT) at micro (local) levels per employee, resident, or household. It is an accepted fact these days that characteristics of an urban core, such as higher densities, mixed-land uses, and increased transportation alternatives, all lead to reduced overall VMT (1, 2). Nonetheless, how to achieve overall VMT reduction at costs acceptable to a local community remains an open question, and is part of the *raison d'être* for this study. Current literature on the methods of how to achieve smart growth is conflicted (e.g., 1, 2). There is, however, some consensus that achieving it in land use requires promoting higher densities, mixed-land uses and increased transportation alternatives (3, 4, 5, 6, 7). Are these methods cost-effective for small communities? What, if any, impact do these methods have on local property values? These are some of the questions this study answers.

Another objective for this study is to develop a theoretically-sound method to show the economic impact on property values of current TOD projects. Through the newly developed methodology, the research is able to show positive economic impacts on property values of current TOD projects. Positive impact on local property values has the potential to attract more federal aid for TODs at the micro-level and more public-private partnerships for such projects.

In the past, lack of appropriate analytical tools, which support the modeling and the analysis of spatiotemporal data, had considerably limited the assessment of land use-transportation interactions in development project evaluations. Many current mainstream planning methodologies are redundant and lack efficacy in addressing current problems within the context of TOD and other smart growth designs (8, 9). Many planning methodologies are unsatisfactory ad hoc heuristic procedures. Developing a standardized methodology including a model for assessing the impact of TOD projects on property values in “reasonable proximity” (e.g., ¼-mile, ½-mile and 1-mile radius) of the projects, lends significance to this project.

1.1.1 Overview

The population explosion of the second half of the last century brought about increased human activity. Much of the attendant increased access to activities has been facilitated by the incredible technological advances in the automobile, which depends almost entirely on fossil fuels. Supplies of fossil fuel are limited and the automobile has facilitated urban sprawl, low density residential development and traffic congestion (1, 3, 4, 5). In real ways, autocentric development has reduced the quality to life in our cities because of emitted pollutants harmful to all life (6, 9, 10). This pattern of development is unsustainable. Transit-oriented development (TOD) is one of the neo-urbanism response instruments. The question is: “How well do these urban forms perform in North-Central Texas? In response, this study has case analyzed two TODs in the region. Addison Town Center (Dallas County) and Plano Transit Village (Collin County) are analyzed with Richardson (Dallas County) as the control site, to test the hypothesis that: “TODs as neo-traditional policy instruments have positive impact on property valuations.

In several studies, there is shown to be accelerated depletion of natural resources and reduction in quality of life in urban areas. This pattern of development in which there is almost total reliance on fossil fuels is untenable (2, 5, 6). Clearly, there is an urgent need to change these trends, including drastic changes in personal lifestyles and city forms to arrest a worsening scenario. Whether a believer or a skeptic in the eroding quality of life issues ascribed to automobile use, everyone wants an answer to the question: “How do we know we are developing our neighborhoods smartly with these neo-traditional designs?” A major objective of this study, therefore, is to develop a viable methodology to show the impact on property valuation of current TOD projects financed with transportation infrastructure investment.

This study agrees with suggestions from others of the need for land use redesign to foster smart growth in the wake of increased automobile impact on quality of life (e.g., 1, 10-12). However, Crane (12) among others offers no better than the same old method of evaluating each development as a separate entity to determine whether its net impact on auto use is positive or negative. This study argues that such methods are inefficient and outdated and are the exact antithesis of the direction new-urbanism designs assessment programs should take. In their place, the study proposes the development of a viable methodology replete with models to show the economic impact of at least two such projects in a comparative case study regime with at least one control to confirm the moderating effect of TODs.

This study is different from previous studies because it develops a methodology at the micro-scale that creates a systematic evaluation process for neighborhoods without resorting to complex intractable equations. The approach includes an analytical framework that combines spatiotemporal analysis in a single econometric structure without the need for multiple models needing bridging models. While land use and transportation are still separate disciplines with different jargons, the framework of this study uses the unified language of econometrics to assess LUT interactions impact without loss of identity for components. It is simple, flexible and affordable by small community planners; and adaptable to macro-level impact assessment.

1.2 Land Use-Transportation Planning: NCTCOG Program Perspective

As shown in Table 1.1, the Mobility 2030 plan also shows the Dallas-Fort Worth (DFW) Metropolitan Planning area forecasted to be a high growth region and to grow to nearly 8.5 million people and 5.3 million jobs by the year 2030, producing nearly a 63% increase in population and a 64% increase in employment using 1990 as the base year (13). Avoiding the negative impacts of the accelerated growth on the region requires the North-Central Texas Council of Governments (NCTCOG) to plan to accommodate the growth trend. As a result, NCTCOG is showing increasing interest in neo-traditional higher densities. TODs, joint development (JDs) and brownfields redeployment, combine with transportation choices to provide the character of new-urbanism core designs. These core designs are deemed effective in reducing auto emissions by overall VMT reduction (1, 2, 3, 4, 5, 12).

Table 1.1 Mobility 2030 Growth Projections

Indicators	Projected Growth
New Schools	500
New Homes	570000
New Hospitals	28
New Malls	11
New Neighborhood Retail Centers	267
New Multi-Family Units	315000
New Transportation Facilities	$70 billion +
Class A Office Space	46,000,000 sq. ft
2025 Population Forecast	7,952,070
Off-Street Bicycle Trails	644-mile network

NCTCOG is no different from other Metropolitan Planning Organizations (MPOs) in their planning activities. Current mainstream planning methods in use by NCTCOG and typically by most MPOs are little different from modeling methods of the 1950s and1960s. These methods still insist on creating separate individual land use and transportation (LUT) models and tying them with link models to “integrate” the model strings into performing typically in tandem (8, 14). NCTCOG uses METROPILUS for land use planning and the four-step conventional method for transportation (15). It uses some of its regional transportation investment funds for land use projects, which promote integrated LUT development as sustainable outcomes. In particular, the MPO’s target is to reduce VMT as a way to tackle rising air quality problems, traffic congestion, and quality of life issues in the region.

Much of North-Central Texas is in nonattainment of ozone. Lowering VMT equates to reductions in auto volatile organic compounds (VOCs) and nitrogen oxide (NOx) emissions, the two most important precursors to ozone formation. VMT reduction improves quality of life by drops in NOx and VOCs, themselves very harmful to people. As a result, NCTCOG emphasizes planning strategies that aid in VMT reduction.

In the North-Central Texas, there was a 9.1% increase in the VMT between 1993 and 2002 (2). This trend has resulted in increased concern over environmental issues in the region. In particular, NCTCOG has trepidation over traffic congestion, air quality deterioration and other negative externalities of automobile use. As a result, regional planning objectives include (16):

- LUT practices that promote economic development with efficient use of resources.
- Transportation planning based on addressing the attendant impacts on land use of congestion, VMT and alternative modes.
- Planning that balances access, finance, mobility, environmental quality and affordability.

For achieving these objectives, NCTCOG focuses on the following (17):

a) Improving rail access, bus service and walkability;

b) Providing technical and financial support for: mixed-use developments, TOD, Infill and Brownfields redevelopment for low income housing and joint developments.

c) Preserving rural green areas and promoting freight-oriented development.

d) Initiating and supporting the integration of pedestrian and bicycle friendly land use; and

e) Using transportation system management engineering strategies.

NCTCOG uses some of the regional government's transportation investment funds for land use projects that promote alternative transportation modes. The fund is known as the sustainable development funding program and is a component of the transportation discretionary funds. This investment in land use projects that promote alternative transportation modes is meant to reduce automobile use, as a means to specifically address concerns about mounting air quality problems, traffic congestion, and quality of life issues.

1.3 Problem Statement and Research Objectives

Although macro-level analysis does not lack variety, current integrated land use-transportation operational models have several problems, including the following:

1. Oftentimes, model integrations are inhibited by different aggregation methods, with final resolution of the global system relying solely on the weakest link (14).

2. Macro models dominate the research environment.
3. Current planning methods – 1950s/60s travel demand models, which are obsolete for micro-level land use and transportation (LUT) interactions impact assessment.
4. Macro-level analytical models are too expensive to use at the micro-level.
5. Analytical integrated LUT models typically consist of separate transportation and land use models, with a “bridging” third model to make the first two models act in tandem.
6. Test of TOD efficacy requires proxies or indicators. There is no consensus on either.
7. Lack of historical data in suitable format limits micro-level LUT and TOD evaluations.
8. In spite of GIS, there is still a lack of micro-scale spatiotemporal LUT impact data.
9. There is a lack of research efforts and funding for TOD impact assessment.
10. Available data has problems: much of it has limited detail and typically soon is outdated.

Current property valuation modeling mostly consists of hedonic models that are mostly OLS models. OLS models have several serious issues in LUT interactions impact modeling and do not adequately provide the answers sought in TOD impact on property value assessment. Much of these issues are common to property valuation. They include (18):

1) Spatiotemporal variations in land markets are a problem for OLS, which ignores them.
2) Endogeneity is basic to non-experimental study and leads to biased results.
3) Panel data implies possible autocorrelated errors (ACEs). OLS is inadequate for ACEs.
4) OLS is generally inconsistent under omitted variables, a frequent problem in panel data.
5) In particular, there is no OLS micro-model TOD model that addresses ACE problems.
6) When OLS errors are ACE and serially correlated, they lead to an inefficient model.
7) OLS models ignore time lags, location and are inadequate for residual errors.
8) Also, when control variables have highly correlated. OLS leads to larger variations in β.

The questions of micro-level TOD assessment and problems arising from current LUT methods lead to the fundamental underpinning of this study, which is the development of: “An econometric disaggregate model for the assessment of the impact of transit-oriented development on micro-level property valuation." The study uses an econometrics approach to answer some of the questions posed by the inadequacies of OLS in the assessment of TOD impact on property valuation. The rationale, therefore, for the study, lies in the need to know how well we are developing when TOD policies are present, which is best articulated by the arguments of Bartik and Bingham (19), who as synthesized by Fasenfest (20), argue in effect that: *"If we cannot measure the effectiveness of a program or policy, how can we hope to know whether we are having a positive impact on a community?"* Logically, if program assessment is crucial to knowledge of its effectiveness, then it stands to reason that developing a plausibly more efficient approach to measure such effectiveness is a significant leap forward. To achieve its principal objective, two TOD project sites and a third control site are selected as case studies to assess the impacts on property value of current TOD projects and to test the hypothesis that: *TOD policies have positive impact on property values*. Specifically the research goals include:

1) Identifying suitable variables for the assessment of TODs at the micro-level.
2) Identifying appropriate methodology to handle both quantitative and qualitative assessment of property development policy objectives that shape TODs at the micro-level.
3) Developing a framework based on the proposed methodology to implement procedures for evaluating, integrating and monitoring factors that affect property values when TOD projects are implemented within the DFW region.
4) Performing an ex-post facto case study assessment of the impact of two different TOD projects on property valuations at ¼-mile, ½-mile, and 1-mile buffers around the center of each project site using the proposed methodology.
5) Analyzing and identifying the type of dependencies existing among variables, and incorporate mathematical formulations in models to emulate the dependencies.
6) Specifying a best fit model for the data, which produces more accurate forecast results?
7) Identifying issues for future research and development for the development and application of TOD impact assessment on property values at the micro level.

The idea of this research is to create models that accurately assess the impact of TODs on property values. Given the fact that there is now no such a model, the newly-developed methodology showing positive economic impacts on property values in current TOD projects is a significant finding. This potentially could attract more federal aid for TODs and more public-private funding partnerships for such projects when all data is collated.

1.4 Project Location and Sites Selection

The project sites are located in the Dallas-Fort Worth (DFW) area of the North-Central Texas planning region. Up to 500,000 new residents relocated to the DFW area between 1990 and 1996. The area is the nation's ninth largest metropolitan area (in 2010), with a total population of about 6.5 million (21). The population increase projected for the area by the year 2030 is about 4 million.

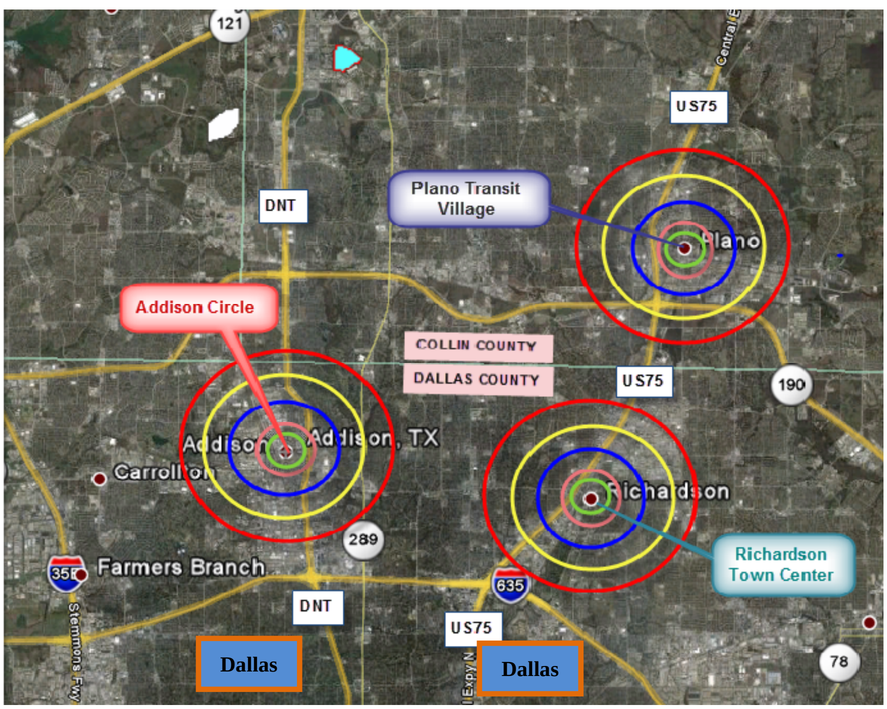

Figure 1.1 Project Sites Location – Google Map

The DFW area is considered one of the nation's fastest growing urban areas (21, 22), which has an area of 12,800 square miles and consists of 225 cities and several hundred political jurisdictions. The 2010 census showed an actual growth of about 23.2% in the 10-year from 2000 (22) to 2010. Therefore, to avoid the negative impacts on the region of the accelerated growth rate, NCTCOG needs to properly plan for the expected growth.

In order to choose the study sites, the following criteria were set as sufficient site selection conditions: (a) Study sites must be funded by NCTCOG; be located in a suburban area; and be a new development. (b) Study sites must have historical data in the NCTCOG database for the analysis. Based on these conditions, Addison Town Center and Plano Transit Village (see Figure 1.1) are chosen from the NCTCOG project lists for the analysis. Buffers of a quarter of mile, half mile and one mile are drawn to ensure that the study limits do not overlap each other as shown in Figure 1.1.

1.4.1 Addison Town Center: Bus-only Transit-Oriented Development

As shown in the Google Map (Figure 1.2), Addison is surrounded by the communities of Dallas in the south, Farmers Branch in the south-west, Carrolton in the west, Richardson in the east and Plano in the north-east. The Addison Town Center is located about ¼-mile (1330 feet) east of the Addison Airport (a major transportation hub), less than ¼-mile (1318 feet) west of the Dallas North Tollway and about 2.5 miles north of IH 635. All measurements are Euclidean.

Addison Circle is an urban plaza, which has multi-use high-rise buildings that combines offices and retail stores with residential housing and social centers. The center of the Addison Monument, which is located in the middle of the Addison Traffic Circle (Figure 1.2a), is chosen to be the center of the Addison Town Center project site. This is because the Circle distributes most automobile traffic in the city center. It is also the center of activities for a suburban town whose variety of land uses includes 2,020 multi-family units, 407 town and condominium homes, 550,000 sq. ft. of office buildings, and 75,000 square feet. of retail stores.

A special feature of Addison is a DART bus station within a walkable distance of City Hall, entertainment centers, offices, restaurants and parks. Addison is a TOD community with parks, tree-lined sidewalks and pedcycle-friendly streets (see Figures 1.2 (a) and (b)), reminiscent of a mixed-use settlement based on a policy of smart growth.

This study hypothesizes that Addison has a positive impact on property valuation, made manifest by the fact that the rate of growth of property values near the TOD center rise faster (because of the SD policy) than rates for more distant properties, all things being equal.

(a) (b)

Figure 1.2 (a) Addison Traffic Circle Monument; and (b) Condominiums

The rumor that a transit-oriented development (TOD) would be built in the center of the Town of Addison started in 2003, and the policy implementation, in the form of planning, design and construction went into effect by 2004, which is considered the year the Addison Town Center TOD project policy went into effect (23). By the end of that year, the Addison TOD is considered substantially occupied and in operation.

1.4.2 Plano Transit Village: Bus and Light Rail Transit-Oriented Development

The special feature of the Plano Transit Village is a DART light-rail (LR) station (see Figures 1.3 (a) & (b)) within a walkable distance of the Plano City Hall, which is chosen to be the center of the TOD for this study. It is within walking distances of socioeconomic activities such as offices, art galleries, museums, restaurants, large parks for relaxation, etc. Some of the office buildings have ground floor retail stores (Figure 1.3 (b)).

Plano is also a pedcycle-friendly suburban settlement (see Figure 1.3 (c)) that consists of shopping, dining, offices, apartment living (see Figure 1.3 (b)), town homes and parks; and is reminiscent of a mixed-use redesigned by a smart-growth TOD policy. The rumor that a transit-oriented development (TOD) would be built in the center of the City of Plano started by 1999, and the policy implementation, in the form of planning, design and construction went into effect by 2003, which is considered the year the Plano Transit Center (Plano) TOD project policy went into effect (24). By the end of that year, the Plano TOD is considered substantially occupied and in operation.

(a) (b) (c)

Figure 1.3 (a) Plano Transit Village; (b) Light Rail Station and (c) Walkability friendly Village

Plano is a bus and light rail transit service TOD. It is posited that the settlement has more positive impact on property valuation than a TOD such as Addison Town Center, with bus-only transit service. Plano is also posited to have a more positive impact on property valuation than Richardson, which has a bus and light rail transit service but no SD policy.

1.4.3 Downtown Richardson: Bus and Light Rail Service – Control Site

Downtown Richardson is quite modern, with retail shops and transit stations (see Figures 1.4 (a) & (b)). It is located between Addison to the west and Plano to the north-east and is within minutes of all the amenities of Dallas-Fort Worth. Richardson is the control site because it has retail stores and office buildings close to residential areas. It is privately developed, has a bus-rail transit service and is between the study sites.

Richardson however, has no TOD policy in place. Due to the fact that these sites are in a relatively common economic and geographic region, only one control site is deemed necessary. Richardson was founded in 1873 (25). It has room to grow. Currently, its commercial site plan approvals exceed 5 million square feet city-wide, with over 500 high tech companies because the city is considered well-positioned to attract high-quality development. In this study, City Hall is the project control site center, because it is the seat of administration, and within walking distance of socioeconomic activities.

(a) (b) (c) (d)

Table 1.4 (a) Downtown Richardson; (b) Light rail Station; (c) Office Complex; (d) Park

1.5 Research Questions

The goals and objectives of the study synthesize the research into several questions from the conceptual framework. Among them are the following:

1) What is a transit-oriented development (TOD)?
2) Does land value respond to transit-oriented development?
3) What is the most efficient model developed by this study for property valuation?
4) What other variables beyond those in this study may be important in TOD valuation?
5) What attribute (i.e., variable) of TOD contributes the most to property valuation?
6) How valued is holding property before or after TOD policy at the project sites?
7) How does proximity from the center of a TOD influence property valuation?
8) How does proximity of TOD to a highway influence property valuation?
9) Can an econometric model for property value be formulated when a TOD is present?

1.6 Organization of the Research

This study is organized into five chapters. Chapter 1 introduces the research and concept, provides a description of the problem being investigated, the objective of the study, and makes a general introduction into the subject of land use-transportation (LUT) planning.

Chapter 2 considers the current debates and issues that bear on the topic of impacts of TOD infrastructure projects on neighborhood land valuation. It provides a literature review on the subject of LUT planning, a brief historical look at various LUT models and variables, and provides a basis for the development of LUT interactions impact assessment models. Chapter 3 describes the conceptual framework and models the development of the proposed LUT for micro-level (local) communities. The discussion centers on the modeling methodology and its theoretical basis. Chapter 4 summarizes model calibrations and results. Chapter 5 presents the discussion of process, results, conclusions and recommendations for future research efforts.

1.7 Summary

In summary, this chapter presents an overview of the study. It introduces the North-Central Texas planning region and its metropolitan planning organization (MPO). In addition, Chapter 1 also includes the following:

1. A summary of LUT issues and issues in assessment of TOD impact on property valuation.
2. An overview of micro-level planning and LUT infrastructure investment impact in the region.
3. Significant statement and the definition of the problem under investigation.

In the process of defining the research problem, the chapter highlights the problems a researcher faces in trying to create a model to assess the impact of TODs on property valuation at the micro-level. In the chapter also, the objectives of the study are defined along with the project location and sites. The chapter concludes with a brief synopsis of the organization and scope of the study.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Background and Scope of the Review

This review of literature examines past and present research modeling efforts in land use and transportation (LUT) interactions in order to identify the current state of knowledge, mainly with respect to the impacts such interactions are likely to have on development projects. Therefore, the objective is threefold:

1. Identify gaps in the understanding of LUT interaction as a guide to further research.
2. Review information on the impact of these interactions when a TOD is present.
3. Identify LUT variables and models that provide the theoretical basis for developing a model for micro-level LUT interactions' impact on property value moderated by TOD.

Although all three objectives require serious efforts, the first two require even more as there is a huge amount of material in the form of books, newspaper and journal articles on LUT mostly treated as separate entities in the literature. In parallel with the professional literature, there is a great deal of operations research literature devoted to systems analysis and planning (e.g., 26), which specifically considers land use and transportation (e.g., 11, 27-31). Blunden (28) has observed that adding the voluminous reports of transportation studies of recent decades to review for a study, bequeaths the researcher a formidable task in terms of quantity alone of material to rummage through. Notwithstanding the enormity of the task, therefore, this review is limited both by scope and information salient to the study.

2.2 Land Use and Transportation Interactions Research Perspectives

Urban land use problems are generally attributed to high levels of automobile use, resulting from the impact of conventional transportation habits and systems. Automobile use is believed by many to be responsible for urban sprawl, and environmental degeneration and quality of life degradations, especially in urban and suburban areas (e.g., 1, 10, 13, 30-37). Awareness of these problems has caused practitioners to become increasingly conscious of the fact that urban structure, land use development patterns, and population density have a significant aggregate influence on travel behavior (1, 2, 38, 39). Nonetheless, results of policy interventions to address these problems are generally seen to be mixed.

One of the most cited cases of policy intervention to influence travel behavior is Portland, Oregon's “Making the Land Use, Transportation, Air Quality Connection” (LUTRAQ) project. This project is lauded as one of the most successful cases where policy intervention targeting land use-transportation interaction influences travel behavior. The policy intervention is a regional effort to examine non-traditional alternatives to meeting mobility needs. It is spearheaded by a public interest group, The 1000 Friends of Oregon (40) in response to a proposed highway bypass project in Portland (41-43). The LUTRAQ effort successfully resulted in an alternative transportation project, which accentuates improvements in transit, transportation demand management along with complementary changes in land use policy, a parking surcharge for single occupant vehicles of $3 per day, and free transit (40, 44).

An important tool in Portland's policy intervention strategies is an urban growth boundary (UGB) established by Portland METRO, the regional MPO, within their jurisdiction. The UGB promotes greater densities and urban design within the boundary, while limiting the extension of urban services outside the boundary. These growth parameters permit closer coordination among the many levels of decision-making involved in developing community infrastructure and development policy. In spite of its highly acclaimed success, the UGB’s impacts are not without controversy. Recently, there has been controversy that suggests that the level of affordable housing in Portland has suffered significantly because of policy-induced developable land shortages. However, the most meticulous study to date of the growth boundary effect on housing shows only modest gains in price hikes (39). Nevertheless, there is a possibility that the LUTRAQ project could encourage future sprawl along the new transit routes.

Further studies of the Portland case also exhibit weak impacts. For instance, the expected impact of the reduction in automobile travel due to the deployment of mass transit is at best modest. Indeed, based on an analysis of the data subject three-stations in Portland, the key variable, “distance of home from station,” shows coefficient signs opposite to what the researchers expected. The data is massaged to include only homes within ½-mile and 1-mile buffers of the stations to get some weak agreement. The expectations was that property values increase by about $0.76 for every foot closer to light rail in the ½-mile and 1-mile buffers. In addition, a similar study using the same property values and the same stations in Portland found no statistically significant property value premium for station proximity (45). Several other studies of the Portland case show mixed results. Some show positive agreement with the theory (e.g., 46, 47) and others show no significant results to support it (e.g., 48).

Studies that support the “policy intervention theory” indicate that, when compared to increasing highway capacity, the LUTRAQ alternative has resulted in 22.5% fewer work trips made in single occupant vehicles, 27% more trips made on transit and by non-motorized transportation modes, 18% less highway congestion, and 10.7% fewer vehicle hours of travel per afternoon peak hour (40, 44).

Pushkarev and Zupan (49) compare transit unit costs as well as intercity transit trip generation rates in an effort to develop “land-use threshold” values necessary to justify types of financing variations in transit investments. The researchers use land-use factors such as size of the CBD, distance of a development to the CBD, and residential densities, and conclude that these factors are determinants of public transportation demand. In a similar study, Smith (50) also concludes that residential densities significantly influence public transportation demand. Nevertheless, evidence supporting the effectiveness of policy tools that target land use as a way to positively influence travel behavior is still either scant or mixed (51, 52). In contrast to the Smith (50) study, others using different data, conclude that density and form do not explain variations observed in transit demand and VMT (e.g., 53, 54).

Pushkarev and Zupan (55) in a later study, investigate financial viability of fixed guide-way transit systems. The researchers compare the six U.S. regions having rail transit (namely, the New York, New Jersey, Chicago, Philadelphia, San Francisco, Boston and Cleveland) to other U.S. urban areas. Total population of the study area is over two million people. The study concludes that a strong transportation (transit) effect exists, in which one additional passenger-mile on transit results in reductions in driving of up to four miles. However, the study uses demand-based threshold criteria premised on two rather restrictive assumptions: (a) a monocentric city where all trips to work are directed toward the central business district, and (b) completely segregated residential and nonresidential land-uses. Both assumptions are opposed to current realities in American cities, where major urban areas are multi-centered and some neighborhoods mix land uses together. Unfortunately, these unrealistic assumptions have not dimmed its impact because it is widely quoted as an authoritative work on the feasibility of proposed railway projects (56).

Friedman, Gordon, and Peers (57) investigate the impact of community density on household travel by comparing household travel patterns of post-World War II suburbs (dubbed “standard” by the authors) to more traditional communities. By standard suburbs, Friedman et al are referring to suburbs that sprung up soon after World War II, and which rely on traditional city centers (or downtowns). These are typically described by the central place theory as centers from which all activities emanate to the suburbs. The study concludes that: (a) household daily transit and auto trip rates in standard suburbs are significantly higher than in traditional neighborhood households, and (b) auto travel is significantly higher in standard than in traditional suburbs. The latter conclusion may be because cities are farther apart. In any case, the main problem with the Friedman et al. (57) study is that it fails to explain differences in trip-rates for two neighborhood resident types.

Kockelman (52) investigates the relationship between various aspects of urban form and travel. Her study’s model specifications include variables such as: accessibility; what she called “land use-balance;” land-use mixing; and urban density. She concludes that: (a) mixed-uses, accessibility, and land use-balance each impact travel behavior; (b) urban density impacts auto ownership, but not travel behavior without the moderating effect of accessibility; (c) land-use balance, mixed-use, and accessibility are each more significant for forecasting travel behavior than household and traveler characteristics. Kockelman’s study has some implications for this research as it investigates the interrelationship in LUT demand, and defines several variables that describe the built environment. However, the study too has some problems:

- Model variables have weak explanatory powers, suggesting that other unspecified factors could explain variations in the data better.
- There is modeling inconsistency as automobile ownership is analyzed using linear regression while mode choice is analyzed with a binary logit model. These problems invalidate the theoretical basis and any derived link between the models.

To summarize, while these studies vary in the explanatory variables used, several of them share common problems including the following:

1. Most of the studies do not investigate the temporal nature of the impacts they purport to evaluate. An important issue in land use-transportation evaluation is how to balance the values of impacts that occur at different points in time.
2. Many of the conclusions drawn from these studies are simplistic. For instance, explaining the impact of transportation investment on land use by just one or two variables ignores many factors that may account for this trend (58).

Some studies focus solely on transportation, blaming it for sprawl and thus ignoring other equally important factors in the land use transportation interactions. For example, sprawl is considered by many studies as a consequence not just of transportation but of independent variables such as fragmented local government, poor planning and exclusionary zoning often prevalent at the micro level (59). In spite of the mixed nature of the results discussed above TOD arguments support the theory that land use planning is a key instrument in resolving adverse LUT interactions impact. For this reason, some planning approaches promote methods such as mixed-uses and TOD options that intensify urban and corridor development to support transit use and higher density developments (e.g., 60, 61). These TOD options are now preferred over current lower density designs prevalent in the west and south of the USA.

In spite of the fragmented nature of the literature on LUT, there is still a significant amount of information on LUT interactions of all sorts. However, this study limited in scope, only focuses on the pertinent studies to clarify the complex interrelationship in LUT.

2.2.1 The Impact of Transportation on Land Use

Several studies show that transportation significantly impacts land use development (e.g., 30, 62-72). These impacts can be positive (e.g., mobility, accessibility, etc.), or negative (e.g., congestion, air pollution, etc.). However (as discussed in preceding sections), these and other studies fail to reach any consensus and consistent conclusions about LUT interactions impact (e.g. 27, 49, 57, 73). Any further discussion of these studies is beyond the scope of this study. The interested reader can access more information on transportation's impact on land use in the "extra reference" section of this study (62-64, 68, 69, 71, 72, 74).

2.2.2 Categories of Land Use-Transportation Models

The judgment to use one macro model or the other in formulating policy decisions depends on several things (75). These may include construct validity, relevance of indicators, theoretical basis of variables, accuracy of results and their contributions to area planning needs. To aid in the choice of a model, a three principal criteria strategy has evolved (75, 76):

1) The model must be sensitively reasonable and internally reliable, having clearly grounded theories and assumptions and able to detect vital sensibilities.
2) The model must have the capability to generate estimates of sociodemographic variables including such indicators as households, populations, and employment.
3) Zoning disaggregation must be adequate to support planning terms, while remaining flexible for reaggregation up to the level of basic planning units and political districts.

LUT models normally can address the last two criteria in the list above but are incapable of fully satisfying the first principle (77). In addition, the list fails to identify modeling ability to assess both policy and traditional planning alternatives as significant. There is a diversity of approaches and models, both qualitative and quantitative, for the assessment of LUT interactions as they impact property valuation. Although the literature flourishes in discussions about integrated LUT models, they are quite limited in number. Several studies have reviewed them and are classified here into the following categories (e.g., 75, 76):

1) Cellular Automata (CA) models

These represent a dynamic system in which discrete cellular states are updated according to a cell's own state as well as that of its neighbors. CA models are useful for representing relationships between a location and its immediate environment, permitting rapid simulation of large-scale cell-based systems (78-81). An example of a CA model is the Slope Land Use Exclusion Urban Extent Transportation and Hill (SLEUTH) Shade model. Present CA methods lack statistical and theoretical foundations.

2) Visioning, "What if" Analysis and Delphi Panels

Visioning is a widely used community-oriented planning technique for creating regional LUT goals. It is not a forecasting tool (82-84). Rather, it offers local people the opportunity to "imagine and create" a regional future, which contains the interests of all stakeholders. Typically, visioning creates self-fulfilling project development strategies. Community visions are characteristically based on community preferences (84).

Some models emphasize "What if" scenario analysis that is defined as an unambiguous planning tool for policy-based decision deliberation. It determines clear policy choices and defines alternatives assuming that predictions about the future are accurate (e.g., 85, 86).

Another qualitative project assessment tool is the Delphi Panel process (87, 88). The process develops as a committee process that develops a comprehensive understanding of the information necessary from experts within an organization to build consensus around an issue.

3) The Lowry Model and Related Developments

Several studies agree that all modern urban land use models have their origins in the Lowry Model of the Metropolis (89), which was developed for the city of Pittsburgh, Pennsylvania in 1964 (e.g.,75, 76, 89). The original Lowry model is a spatial-economic model that integrates the spatial distribution of socioeconomic and demographic activities (particularly employment, and the "non-basic" services) and land use in an iterative process. (Southworth, 75). Several models are successor models to the Lowry model (e.g., 90-92). Some of them attempt to deal with the time lag issue, although in a very weak way (75). In land use-transportation interactions, a time lag is the time it takes the full impact of an infrastructure project to be felt by the area. Current LUT models do not take lags into consideration.

4) Normative Planning and Related Mathematical Programming Developments

Normative approaches in LUT interactions de-emphasize the prediction of future outcomes, or the replication of current or past ones (e.g., 75, 92). Several models come from normative concepts. For example, the Technique for the Optimum Placement of Activities in Zones (TOPAZ) models include, linear programming (e.g. 92-96).

5) Multisectoral Spatial Modeling Using Input-Output (MSMUIO) Frameworks

The MSMUIO is an intersectoral economic analysis approach (e.g., 96-98). It furnishes a general format to integrate basic industrial activities, and exogenous input variables of the Lowry-based urban land use models. The MEPLAN (e.g., 97-99), TRANUS, and Kim (96) models are examples of the MSMUIO type models. Other operational variants of intersectoral-interzonal I-O modeling can be found in several other studies (e.g., 100, 101).

6) Contributions from Urban Economics

Kim (96) created an Integrated Urban Systems Model for Chicago by combining the general urban system equilibrium ideas of Mills (102) with the probabilistic spatial interaction approach of Wilson (103), the combined transportation-facility location models of Boyce et al. (104) and the equilibrated network's supply and demand method of Beckman et al. (105). The resulting model is a complex but computationally tractable model that is grounded in urban economic principles. However, like the others, it is untested as a tool for assessing the impact of TOD on property values. It is also, like the others in preceding paragraphs, too complex and expensive for micro-level LUT analysis.

7) Micro-Analytic Simulation

A whole host of models attempt to simulate reality (106-111). A Micro-Analytic Simulation (MAS) model has two principal advantages (75):

1) It allows the researcher to incorporate a number of dimensions for both individuals and their choice processes, which would otherwise require an excessive disaggregation;
2) It is relatively easy to implement. For instance, all that is required to create a software program to simulate a particular process using Monte Carlo simulation, is an appropriate random number generator subroutine, a probability distribution, a routine for allocating values between 0.0 and 1.0 to randomly select choices on the basis of this distribution, and a routine for collecting the results of the exercise (e.g., 109-111). However, further review of these is beyond the scope of this study.

8) Micro-scale Modeling tools

The development of micro-scale analysis tools are costly and time consuming. Currently, for the most part, similar approaches to model development for macro-level analysis are used across the board. Often, this approach results in an over investment of meager small area resources on elaborate models. In the meantime, there is still in adequate investment in research for micro-level LUT impact assessment. Some current notable efforts include:

1) Quick Response Techniques – These use transferable factors from surveys, etc.
2) Microsimulation Planning for Small Communities – These simulate entire planning networks for small and medium-size areas and sometimes could be used for macro-level analysis.
3) Sketch Planning Methods **–** Examples found in several studies (e.g., 112-115).

4) Holding Capacity Logistic Curve method – The model uses Gompertz (logistics) curves and the concept of holding capacity to allocate to parcels or to larger areas (113, 114).

Other possible micro-level LUT interactions impact analysis toolsets include models in a host of studies (e.g., 99, 105, 109, 115-117).

2.2.3 The Dallas/Fort Worth Land Use Model

The Metropolitan Integrated Land Use System (METROPILUS) is the NCTCOG Dallas/Fort Worth land use model in use since the early 1980s (15). It is the most modern of the new urban simulation models. METROPILUS typically integrates three models, namely: DRAM, which is a residential location model; EMPAL, which is an employment location model; and LANCON, which is a land consumption model. They are operated on an ArcView platform in a user-friendly graphical interface environment. Perhaps the most egregious problem the model package has is that it more often than not produces erratic results.

2.3 Sustainable Development Concepts and Proxies

Urban transport problems resulting from high levels of mobility and car usage are major challenges facing most metropolitan areas globally (42, 43). Babalik-Sutcliffe (10) argues that many of the transport policies and measures intended to restrict automobile use appear to have limited effectiveness because urban form, development patterns, and urban density levels affect travel behavior, in particular auto travel, to a considerable degree. Several other studies agree with this notion but dispute the impact level (e.g., 118-120).

Part of the problem in determining any level of sustainable development at a regional level is that different regions, nations and economic sectors perceive it within the context of their priorities at a particular time (e.g., 121-126). In 1987, the United Nations World Commission on the Environment and Development, reporting to the General Assembly, warned that (121):

> *A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs.*

Since this warning, a major concerted global political effort to "save the resources of the planet for future generations," failed at Kyoto, in Japan, in December of 1997 (123). However, since Kyoto, a plethora of theories and definitions for sustainable development (SD) has sprung up in both the USA and abroad (e.g., 124-126). This report defines SD as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (Brundtland, 121).

2.3.1 Neo-traditionalist Urban Development Designs

The neo-traditionalist strain of New Urbanism (NU) is a design philosophy that espouses context-appropriate architectural development, regional open space planning for neighborhoods and cities. It also promotes high-density mixed-use communities, suburbs, and development for jobs-housing (127-130).

A JD is simply defined as a form of TOD that is usually placed on top of, above, or adjacent to property that belongs to a transit system organization. They are joint ventures where the property or its services are managed collaboratively for the mutual benefit of the residents and the transit organization (60, 130).

Mixed-use design is when the design of a community encourages the development of a mixture of retail shops, offices, apartments, recreation centers and homes in a dense, but pedcycle-friendly atmosphere in the same neighborhood (e.g., 39, 60, 63). TODs and JDs are variants of the mixed-use design distinctively tied to transit stations.

2.3.2 Transit-Oriented Development

In the USA, part of the problem with the new urban design philosophies embodied in designs such as TODs, "new suburbs" or "neotraditional" community design, is that the concepts are still being defined. This is especially true of TODs, which have no universally accepted definition (3, 60, 69). Almost everyone agrees that a TOD can best be described by its most common traits, which include being a compact, mixed-use development in close proximity to transit facilities, and having high-quality walking environments (60). A quarter of a mile limit is considered the typical walking distance for bus transit, and half a mile is considered the typical walking distance for rail transit (131-133). These distances set the frontal limits on bus-only transit and bus-light rail transit TODs in this study, as elsewhere.

Today, TOD is seen largely as a neo-urbanism design whose concept is still being defined. The diversity in TOD definition is seen in the following examples from two major USA transit agencies (60):

1) Atlanta – The Metropolitan Atlanta Rapid Transit Authority (MARTA) definition: TOD is a "Broad concept that includes any development that benefits from its proximity to a transit facility and that generates significant transit ridership."
2) Chicago RTA – Northeast Illinois: TOD is a "development influenced by and oriented to transit that benefit from the market created by transit patrons."

The arguments in favor of TODs are generally based on the assumptions that LUT interactions, density, proximity of services, street networks, and other urban structural variables impact, travel patterns (e.g., 4, 5, 35, 60, 73, 134, 135). From this premise, several TOD definitions have been proffered by many studies (e.g., 127, 134). Essentially, these describe a TOD as a mixed use, relatively high density, pedestrian-oriented neighborhood that is situated within ½ a mile of a rail, or other mass transportation. Its urban environment encourages and eggs on transit use and walkability. Based on Evans et al. (136) and Renne and Wells (127), this study defines it as follows:

> *"A transit-oriented development is a higher-than-normal-density development that has pedcycle priority and walkability friendliness designed into its urban form that is located within walking distance (up to a mile) of a rail, bus, or other mass transit station or stop."*

The literature shows that TODs have several barriers to successful implementation. The barriers can typically be grouped into fiscal, organizational and political (60) and include the following (60, 127, 137, 138):

- "congestion conundrum" – population density so high it leads to high resource competition;

- logistical dilemma – services become insufficient and their provision is inefficient
- TODs rationalization of parking – for instance, walkability may require augmenting by transit station parking to increase light rail ridership;
- “Class clash” – reduce VMT programs may mean different things to economic classes.

Financing TODs is still in its infancy, and efforts may be public or private with public-private partnerships becoming the rule. Public TOD financing is primarily from federal and state allocations through regional MPOs (e.g., 138). Private developers can take controlling interests in TOD projects. Besides worsening traffic congestion, the market for TOD is driven by shifting demographics and receptive public policies.

2.4 Summary

In summary, there is general agreement among many researchers that transportation investment and urban land use interactions impact both economic development and the quality of life of urban residents. There is also a fair degree of common agreement that some of the impacts are positive (e.g., mobility, accessibility to activity centers, etc.), and some of it very negative (e.g., congestion, air pollution, etc.). What is in dispute is the degree to which this has either positive or negative impacts on livability and resources.

It is, however, evident that a community cannot wait for the questions of degree to be resolved before acting to reduce the negative interactions impacts of LUT, which are evident notwithstanding the arguments against it. TODs, JDs, MUDs and the general neo-traditionalist strain of NU design philosophy products are all meant to reduce or eliminate the negative impacts of LUT interactions impact. In the literature, what is in short supply is information on how to assess LUT impacts on property valuation at the micro-level, when TODs are present.

CHAPTER 3

PROPOSED TOD IMPACT ESTIMATION MODEL: THEORETICAL FRAMEWORK

3.1 Modeling Conceptual Framework

Two recent neotraditional (transit-oriented development) communities – one in Dallas County (Addison Town Center) and the other in Collin County (Plano Transit Village) – are analyzed. This is to test the hypothesis that transit-oriented developments (TODs) have positive impacts on local property valuation. This premise holding true from the analysis, permits the conclusion that in at least this instance some areas in the region are developing sustainably.

This is a quasi-empirical research study. Its conceptual framework is shown in Figure 3.1, in which the loopback nature of land use-transportation (LUT) interactions impact assessment is vividly portrayed. The research modeling process addresses the estimation of relationships between the rates of change (i.e., natural logarithmic) of property value as the dependent variable, regressed on several other variables as explanatory variables. The control variables include land uses, distance to a highway and land area, among others. The control variables also have spatiotemporal characteristics corresponding to the different project areas.

A standardized methodology is developed including a model for assessing the impact of TODs on property values at the micro-level. Models are developed from data for properties within "reasonable proximity" (i.e., ¼-mile, ½-mile and 1-mile cordons) of the centers of the two TODs and a third control site in North-Central Texas. Such neo-traditional designs are proxies for sustainable development (SD). The TOD sites are ex-post facto evaluated using a third site as the experimental control. Truly empirical studies are of two categories. They may be:

1) Before-and-after studies. This normally involves the study of the impact of a given facility in a given location. Such a study requires analysis of a subject before a treatment (e.g., TOD policy) and a second analysis after the treatment is applied.

2) Comparison of two "equivalent" locations. This is typically known as the with-and-without studies. It entails two or more locations with one which remains without the treatment meted out to the others, i.e., a control site. There are software packages such as Stata used in this study, which simultaneously perform both analyses.

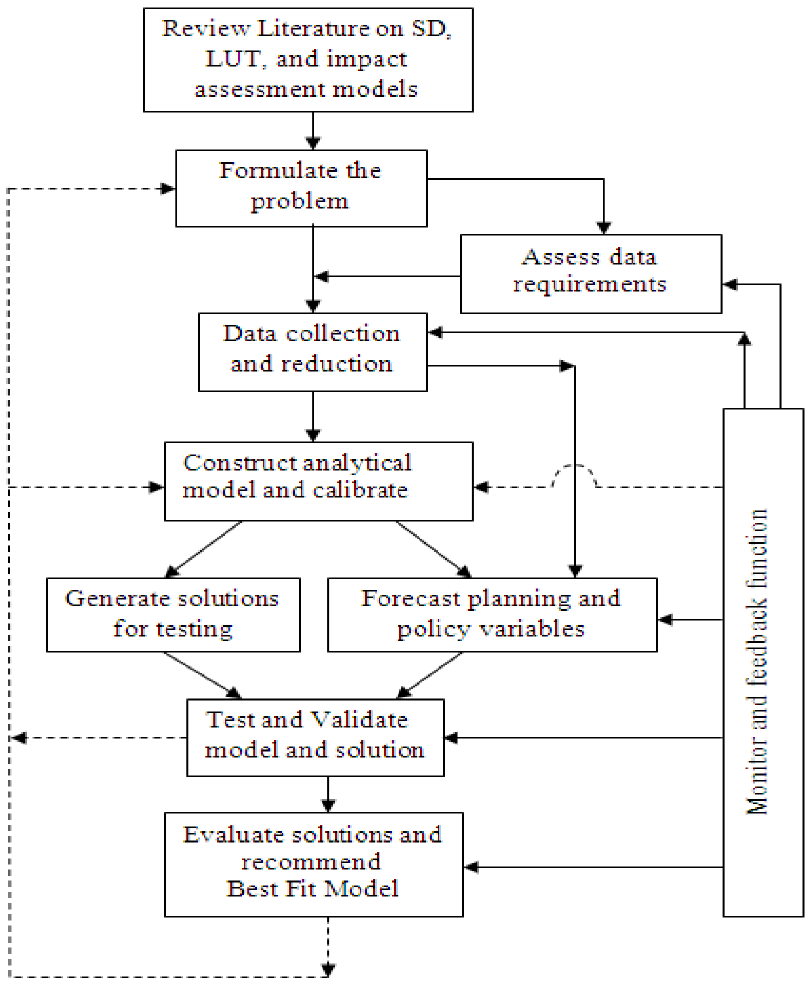

Figure 3.1: Conceptual Framework (139)

As a quasi-empirical effort, this study has co-opted both methods to improve upon the statistical power of the modeling process. Conceptually, the modeling framework is econometric and generally has the basic structure of any of several econometric processes depending on the nature of the data. For instance, it may take on the structure of the general first-order and/or serial and spatial autoregressive distributed lag model in vector form for a cross-section of observations at time t, or a simple panel subject to fixed effect analysis.

Because of data limitations, this study is limited to TOD projects funded by the metropolitan planning organization (MPO), the North-Central Texas Council of Governments (NCTCOG), which is either the prime mover for mixed-use developments in North-Central Texas, or is an active partner with other agencies and developers in bringing them about because of their perceived positive impact on local communities. Evaluation of a TOD pertaining to land use-transportation (LUT) interaction programs can be categorized into two groups (140):

(1) Ex-post facto evaluation: this is usually difficult to undertake. To be useful, ex-post facto evaluation must specify a "but for scenario" that allows the attribution of an outcome to a development program. Ex-post facto analyses must also include "What would have happened ...” evaluations. The basic answer sought in such an analysis is the difference in the observed and expected outcomes based on the counterfactual identifications. This difference is an attribute of the program.

(2) Ex-ante evaluations. These are the pre-program or pre-incentive analyses that are ever more in high demand by decision makers, before a program hits the ground or before an incentive is considered disbursable. An ex-ante analysis is far more complex.

Both methods permit analysis of the “with-and-without” and the “comparable locations” methods/conditions for policy measure assessments in LUT interactions impact assessment. Both methods meet the rigorous requirements for the taxonomy of the actual impacts of land use on transportation facilities and the impact of transportation on land use, in the LUT interactions impact assessment genre. Nevertheless, the analytical method of choice in this study is ex-post facto evaluation because it fits better into the conceptual framework of keeping it sound but simple at the micro-level. Study objectives are achieved through the following tasks:

1) Task 1: Review literature
2) Task 2: Evaluate data requirements and collect data

3) Task 3: Data analysis and model Calibration

4) Task 4: Model validation

3.2 Model Development

Model development starts with a detailed review of literature to identify current practices and limitations in assessing how land use-transportation (LUT) interactions and TOD projects impact land value at the local (micro) level. Once TOD "orientors" are identified in the review of literature, variables suitable for micro-level evaluation are chosen based on orientor relevance in the interaction system, which in this case happens to be LUT interactions impact. No new variables are created. The idea is that there is more than enough information exists in the literature on LUT impact assessment so that proven variables can be co-opted from existing studies and used in this study without having to develop new variables. In that regard, this is a coupling study. However, in so far as those variables are used in this study to assess LUT interactions impact on property valuation when TODs are present, this is a fresh effort.

Market forces play a crucial role in land development, location choice and accessibility. It is, therefore, highly necessary to incorporate these processes unambiguously in a simple but efficient model that assesses LUT impact. This is possible because at the micro-level where distortions, which affect socio-economic forces, are easily discernible, a simple but more accurate understanding of urban system dynamics in the context of sustainability is achievable. That is the essence of this conceptual framework. Making the link between the assessment of TOD and transportation interactions impact on property valuation has never been done before. It stands to reason that establishing a simple econometric and "singularly integral" model, such as the fixed effects LUT models developed in this study, is in some measure an important contribution to TOD and micro-level LUT interactions impact assessment in property valuation.

The initial model calibration starts with OLS regression. Following that, calibration takes on the form of estimation using a panel structure in combination with fixed effects (FE) econometric methods. The cross-sectional nature of the spatiotemporal dataset typically has inherent problems that violate several of the Gauss-Markov assumptions on which the initial OLS multiple regression modeling is based (141, 142). This renders OLS models on panel data less efficient and more biased, and justifies looking for other model structures suitable for best-fitting to the data. For instance, given the cross-sectional nature of the data, it is highly likely that regression models fitted by OLS could exhibit heteroskedasticity, panel autocorrelation, and contemporaneous errors (141, 142). Tests prove that to be the case for this study.

Briefly, the econometric OLS model specification process is iterative and stepwise in nature (143). A disaggregate analysis is performed using the parcel data. Several selected variables are regressed on “property value” (Y per year per acre), measured in dollars as the dependent variable. The models are followed by a battery of “econometric” tests, which are hypothesis routines in econometric software packages. The tests identify possible errors in the models and direct the model analysis towards structures that serve as remedies for violations in the Gauss-Markov assumptions.[1]

The tests show that regular OLS fit to the datasets is problematic, with the models exhibiting correlations between control variables (i.e., multicollinearity) in violation of the Gauss-Markov assumptions. OLS also leads to heteroskedasticity, panel autocorrelation and biased results. The cross-sectional nature of the data and the obvious time invariant nature of some significant predictors stemming from the data structure produce a less efficient model fit.

Because of the inherent problems of panel data coupled with the time series nature of the data, the statistical program, Stata is preferred for the computations. Its various routines are capable of testing for multiple regression errors and providing simple yet efficient ways to eliminate errors. For instance, contemporaneous errors (heteroskedasticity) are tested for using Breusch-Pagan test for independence (144, 145). Another important test for panel data analysis that lets the researcher decide between fixed effects (FE) and random effects (RE) is the

[1] See Chapter 5 for study assumptions.

Hausman Specification test (141, 145). These error tests found that corrections are necessary in the modeling process and that all data could be best fitted with FE for this study.

Data analysis and model calibration adhere to the following tasks:

1) Develop framework for TOD impact on property value at micro level.
2) Identify limitations in TOD projects assessment at local level.
3) Identify suitable TOD variables for micro-level assessment.
4) Ex-post facto evaluate two TOD project sites and one control site.
5) Analyze temporal patterns of LU for TOD in the presence of time trend.
6) Use an econometric approach to specify the best fit (time series-panel) model.
7) Explore possible consistent and efficient variable relationships by the econometric approach, such as the Box-Jenkins philosophy of parsimony and test for stationarity and/or invertibility, autoregression, correlation, heteroskedasticity, etc., to identify model structure.
8) Use fixed effect (FE) methods to annul problems of random versus non-random sampling.
9) Eliminate OLS problems through the use of the Box-Jenkins philosophy of parsimony.

The models in this study use “The property value” as the dependent variable. In this, the study is on firm theoretical grounds according to other studies (e.g.146).[2]

3.2.1 Choice of Analytical Technique

The choice of an analytical technique begins with the literature review. Appropriate methods for assessing LUT impacts of TODs and how these affect land value are identified in the review to be used in choosing an analytical technique. Accordingly, the ex-post facto evaluation methodology in the form of a *before-and-after* study, combined with a *with-and-without* is the method of choice. This combination provides a sound theoretical grounding. The resulting process embodies simplicity and flexibility and does not require advanced training

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[2] Paifomak and Lave (146) articulated the reason best: “Because of the inherent long-term trends in economic time series, the best way to understand the structure of an economic relationship is to explain changes in variables, not their full levels.”

beyond rudimentary econometrics. The method is flexible enough so that other independent variables may be added later to the predictive models developed. That of course depends on data availability and how researchers see different explanatory variables fit in their attempt to describe variability embodied in dependent variables perceived to be more relevant.

The key to an econometric model specification is to know how the data is to be used to forecast the mean and variance of the variables, conditional on past information (146, 147). It is also the only real challenge in the methodology in the conceptual framework of this research. However, this is remedied by using the simple knowledge that econometric model specification is itself an iterative process and stepwise in nature. It involves testing for linear versus nonlinear dependence using a simple condition such as the Box-Jenkins philosophy of parsimony.

Many econometric structures may be considered for the mean of variables, with each fitted to the data to identify the best-fit to estimate expected variables values. A model can take on the structure of a simple linear model. Or it can be specified either as a spatiotemporal linear model such as fixed effects (FE), random effects (RE), between effects (BE), auto-regressive (AR), or moving average (MA). Depending on the nature and availability of data, the researcher with little more than a rudimentary knowledge in econometrics has at his disposal other more advanced specification possibilities including (141, 142, 147, 148):

- combined autoregressive-moving average (ARMA),
- autoregressive integrated moving average (ARIMA),
- a spatiotemporal nonlinear model such as a threshold autoregressive (TAR) structure,
- autoregressive conditional heteroskedastic (ARCH) structure, and
- generalized ARCH (GARCH).

In econometrics, FE is almost always statistically a good model to fit to a panel dataset because it furnishes consistent results (148, 149). However, it may not be the most efficient model to fit to the data. RE is a more efficient estimator and typically results in better P-values. This means that when it is statistically appropriate to do so, it is justifiable to fit an RE model to a panel dataset. By and large, fitting simple multiple regression models to panel datasets almost always involves making a choice between FE and RE. Making the choice usually means performing a Hausman specification test.

The Hausman test is a hypothesis test that distinguishes between FE and RE by verifying the more efficient of the two models (145, 149). The test identifies the less efficient but consistent model from the more efficient and also consistent mode. In Stata, a Hausman test comparing FE and RE requires first estimating the FE model, saving the parameters and comparing the parameters estimated from fitting the RE model to the same dataset. The null hypothesis is that the coefficients of efficient RE estimators are equal to the coefficients of the consistent FE estimators. i.e.:

H_0: $\beta_{RE} = \beta_{FE;}$ H_a: $\beta_{RE} \neq \beta_{FE}$

If H_0 is not rejected, then the P-value is insignificant so that Prob $> \chi^2 >$ 0.05. Then it is appropriate to use the RE model. On the other hand, if the alternate hypothesis is true, so that the P-value is significant, Prob $> \chi^2 <$ 0.05. In that case, the FE model is a better fit to the data.

One key principle behind much of spatiotemporal series modeling is that location in space is important. This is not reflected in the OLS model in Equation 3-1. The *n* variables in this research reflect time series from *n* areas, and this study posits that an econometric structure is needed for the model best fit to the data. Bayesian, structural vector autoregressive, the new field of CO-integration, STARIMA and simple FE/RE panel methods are possibilities depending on the structure and characteristics of the dataset (149, 150).

3.2.1.1 Panel Data Econometrics Method

Because of the cross-sectional nature of land valuation data, data analysis involves longitudinal modeling. This requires the data to be reshaped into panels, which is why panel data is also known as longitudinal data or cross-sectional time series data. Typically, it is data that contains multiple instances of subjects (people, land parcels, firms, countries, etc.) observed at multiple time periods (141, 142, 149). An example is the geospatial data and spatiotemporal appraisal data for parcels used in this study, which includes distance to the nearest highway, land uses and other predictors, to name but a few. In the sampling, the data for each parcel of each project site is collected over a period of several years.

The choice of paneling the data stems from several issues, not least among which is the fact that the panel structure has its own econometric procedures and software programs that permit researchers to benefit from the different types of information due to the data structure. The Stata software requires to be told that the dataset for analysis has a spatiotemporal panel structure using the command "*tsset*." One variable must be provided that uniquely identifies subjects of the panel (e.g., propid) and one other to identify the time variable (e.g., year). In this study, "propid" identifies parcels and is short for property identification; and "year" is short for "appraisal year." The data is "*tsset*" to be recoded into the panel variables (*propid* and *year* in this study). The data is rearranged into what is called the *long form* as opposed to the *wide form* in which raw data is procured. This *long form* also establishes the demonstrable panel nature of the dataset. Besides the ease of computations, the panel data process is preferred because of several additional benefits. Paneling:

- makes the dataset more informative (i.e., more variability, less collinearity, more degrees of freedom), so that estimates are more efficient.
- allows the study of each variable dynamic (e.g. separate age and time trend effects).
- provides useful information on the time-ordering of events.
- permits the control for individual unobserved heterogeneity, the major problem of non-experimental research such as this study.

3.2.1.2 Fixed Effects Model

The FE model structure is different from OLS. Time effects are accounted for in individual controlling group effects and the definition of the error term, u is different. The fixed effects (FE) model is used when it is necessary to control for omitted variables that differ between subjects but are constant over time or time-invariant (149), as is true in this study.

FE allows the researcher to introduce changes in the variables over time in order to assess the impacts of the independent variables on the dependent variable. For that reason, FE is the key method used for the analysis of panel data. It is so too in this study and is based on certain assumptions, which in particular include the following (141):

A. For each i, the model is:

$$Y_{it} = \beta_1 X_{1it} + \beta_2 X_{2it} + ... + \beta_k X_{itk} + a_i + u_{it}, \quad t = 1, 2, ..., T \qquad ...3.1$$

Where: $\beta_1, \beta_2, ..., \beta_k$ = the parameters to estimate,

α_i = 1 × n = vector – idiosyncratic error terms (normally distributed);

u_{it} = 1 × n = vector – error terms and is normally distributed, and;

$e_i = \alpha_i + u_{it}$

B. We have a random sample from the cross-section

C. Each explanatory variable changes over time (for at least some i), and no perfect linear relationships exists among the explanatory variables.

D. For each t, the expected value of the idiosyncratic error giving the explanatory variables in all time periods and the unobserved effect is zero: $E(u_{it} \mid X_{it}, a_i) = 0$

E. $Var(u_{it} \mid X_{it}, a_i) = Var(u_{it}) = \sigma^2_{it}, for\ all\ t = 1, 2, ..., T$

F. For all $t \neq s$, the idiosyncratic errors are uncorrelated (conditional on all explanatory variables and a_i): $Cov(u_{it}, u_{is} \mid X_{it}, a_i) = 0$.

G. Conditional on X_i, and a_i, the u_{it} are independent and identically distributed as $Normal(0, \sigma^2_{it})$.

The between effects (BE) technique is called for when it is necessary to control for omitted variables that change over time, but remain constant between subjects. This permits the researcher to utilize variations between subjects in order to assess the impact of the omitted predictor variables on the response variable.

Because of the presence of significant spatiotemporal factors in the data series for regression, the presence of autocorrelated errors (ACEs) is considered because they could be problematic (151). It is, therefore, important to investigate their presence in the modeling process in order to choose the best-fit model. To do this, the Box-Jenkins philosophy of parsimony is used, which follows some or all the three simple generalized procedures of identification, estimation and diagnostic checking (148, 152).[3]

3.2.2 Research Method

This study focuses on an ex-post evaluation of two case studies in the Dallas/Fort Worth urban area. The socioeconomic and development characteristics are taken into consideration to determine what factors, if any, distinguish a "sustainable" development (SD) from a "non-sustainable" one relative to a TOD as a proxy development for SD. The study conducts two case studies with a common control site. The two sites, Plano and Addison, are selected from a list of sustainable development projects funded by NCTCOG. The study's control site, Richardson, has a similar development background and spatial characteristics as the study sites and has the following additional characteristics. It is not funded by NCTCOG; it is growing on its own and is not a mixed-use settlement or any other form of SD proxy thereof.

To develop the thesis of this study, several hypotheses are posited. The main proposition is: "That with all other factors held constant, transit-oriented development policy has a positive impact on property values in North Texas.[4] Several sub-propositions could be derived from the main proposition. However, because of the limited scope of this study, other theories developed from the main premise include the following. Given all things held constant:

<u>Proposition 1:</u>

H_0: It is posited that the change in property values in a bus-light rail transit TOD is the same in a ¼-mile radius cordon as property values beyond ¼-mile radius cordon.

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[3] For more on the Box-Jenkins process, see Hamilton (148, p. 108).

[4] Total property value per acre (tvpa) = property value = land value + improved value

H_a: The change in property values in a bus-light rail transit TOD is higher in a ¼-mile radius.

Proposition 2:

H_0: It is posited that in a bus-only transit TOD, the change in property values in a ¼-mile radius cordon is the same as it is beyond the ¼-mile radius buffer.

H_a: In a bus-only transit TOD, the change in property values in a ¼-mile radius cordon is higher than it is beyond the ¼-mile radius buffer. .

Proposition 3:

H_0: It is posited that the rise in property values in a TOD in the *"before-policy-years"* is equal to the rise in the property values in the *"after-policy-years."*

H_a: The rise in property values in the *"after-policy-years"* of a TOD is higher than the rise in property values in the *"before-policy-years."*

Proposition 4:

H_0: It is posited that the rise in property values in a ¼-mile radius cordon of a bus-only service TOD is the same as the rise in property values in a ¼-mile radius cordon of a light-rail and bus transit service non-policy neighborhood.

H_a: The rise in property values in a ¼-mile radius cordon of a bus-only service TOD is higher than the rise in property values in a ¼-mile radius cordon of a light-rail and bus transit service non-policy neighborhood.

Proposition 5:

H_0: It is posited that rise in property values in a ¼-mile radius cordon of a light-rail and bus combined transit service TOD is equal to property values in a ¼-mile radius of a light-rail and bus combined transit service non-policy settlement.

H_a: The rise in property values in a ¼-mile radius cordon of a light-rail and bus combined transit service TOD is higher than property values in a ¼-mile radius of a light-rail and bus combined transit service non-policy settlement.

Proposition 6:

H_0: It is posited that the drop in TOD property values of properties nearer a highway is equal to the drop in property values for properties relatively farther away from the same highway.

H_a: The drop in TOD property values of properties nearer a highway is higher than the drop in property values for properties relatively farther away from the same highway.

3.2.2.1 Participants

Participants include the Collin County Appraisal District personnel, the Dallas County Appraisal District personnel and property owners within the one-mile buffers of each project site center in the appraisal districts. The City GIS section heads and personnel in Plano and Richardson provided GIS shapefiles for their respective sites. NCTCOG SD personnel had a small role in the study at the outset.

3.2.2.2 Procedure

Based on the conceptual framework outlined in preceding sections, the following procedure was followed to accomplish the objectives of the study:

1) **Task 1: Review of literature**

A detailed review of literature is undertaken. Several studies reviewed identify current TOD projects and practices (e.g., 7, 16, 60, 66, 74, 134, 135); while others indicate limitations in assessing how land use-transportation interactions impact property values at the local (micro) level.[5] Findings of the literature review are included in Chapter 2. The review and other sections of this study identify suitable TOD variables and indicators for micro-level evaluation. Appropriate methodologies from the proposed framework for assessing LUT impacts of TODs, and how these affect property values are also identified.

2) **Task 2: Evaluate data requirements and collect data**

Data requirements include developing a temporal GIS database to support the management of historical data pertaining to selected variables for the study sites, namely Plano Transit Village, Addison Town Center and Downtown Richardson (the control site).

[5] (e.g., 75, 104, 107, 110, 108, 113, 114, 115)

This temporal GIS manages the variables used in this research and for each site. The spatiotemporal data for the three project sites are geocoded and are collected for several years at the parcel level. The data can be managed at the parcel level, on a year to year basis using the GIS coded database.

For the TOD sites, at least one of the data years is *before* and at least one more the *after* SD policy implementation year (i.e., the after-policy-year) in the form of the TOD. Data is controlled for systematic differences in study and control sites. The basis for the geospatial data collection is a set of spatial data buffers set at a quarter of a mile, half a mile, and a mile from the center of the development. The buffers permit the study of spatial impacts of land use transportation (LUT) interactions. The quarter of a mile limit is chosen because it is the typical walking distance for bus transit, and the half a mile distance is chosen because it is the typical walking distance for light rail transit. The third cordon of a mile is set to examine if the development's impact spreads beyond half a mile.

Until recently, when the geographic information system (GIS) became available, there was a marked lack of tools to support analysis of spatiotemporal data at the micro-level (1). Spatiotemporal data analysis in the case of property valuation requires a database that keeps up with the dynamic information around real property. Such data is available in the market in a fragmented form. Geo-spatial data (e.g., shapefiles, geocoding address tables, reference data, maps, etc.), is sold separately from real estate information (e.g., total property value, improvement value, ownership, etc.). The question is whether the need for accurate data can be addressed at the local level by creating a database to monitor property valuation of TODs to assess their SD impact on the neighborhood. With the advent of GIS, such a database can now be developed that is updatable annually, or even monthly to keep and operate an accurate spatiotemporal database at the micro-level. It is part of the objectives of this project to develop such a database.

3) Task 3: Data analysis and model calibration

Data analysis begins with an initial fitting of a simple regression (OLS) model to the dataset. Manipulation of the OLS models permits the identification of the econometric model structures that would yield better fits to the dataset. It establishes the initial relationships between property value, improvement value, parcel area, distance to the nearest highway and other variables including the distance from each parcel to the center of the development. The natural logarithm of property value is the dependent variable (y).[6] The logarithmic transformation is used in the analysis in order to get an approximate percentage effect (141, p. 453). The independent variable set (x_n) includes dummy variables, the natural log of continuous others such as distance to center of the site,[7] area of property, etc., and interactions variables.

Because of the cross-sectional nature of land values, data analysis involves longitudinal modeling. The modeling approach is econometric and is based on the Box-Jenkins philosophy of parsimony. In the Box-Jenkins process, efforts are made to test for the validity of the Gauss-Markov assumptions (141, 142). From the initial OLS analysis test results, several of them are found to be violated. This implies that the OLS model is at least biased and certainly unreliable, unless steps are taken to correct for the violations. Because of the presence of significant spatiotemporal factors in the regression series, the presence of autocorrelated errors (ACEs) is expected to cause serious problems. It is necessary, therefore, to investigate the presence of ACEs in the process for choosing the best-fit model. The test consists of the Wooldridge (151) test of first order ACE.

The Box-Jenkins philosophy of parsimony modeling approach can be summarized in the following three simple steps (141, 143, 147, 148):

(a) **Identification**. This is the stage where efforts are made to determine what sort of model to use for the data generating process. Typically, data is plotted and eyeballed to

[6] Total property value per acre (tvpa) = property value = land value + improved value

[7] See Section 3.2.2.7 for site selection criteria.

determine stationarity. Empirical ACF and partial autocorrelation functions are compared to theoretical models to get an idea of what model to expect. The Hausman test is performed to determine the appropriate choice between fixed effects and random effects approaches (141, p. 493). An initial OLS regression model fit to the data is usually helpful then because it gives an idea of what variable relationships to expect.

(b) **Estimation**. . Efforts in this step are made to try to fit candidate models to the data, iteratively, guided by parsimony, and goodness-of-fit. As a general rule, this includes tests of stationarity or invertibility, goodness-of-fit measures and specification tests.

(c) **Diagnostic checking.** This involves statistical validation through hypothesis testing. Normally it requires looking at the residuals for signs of errors. In-sample forecasting is another diagnostic tool. Statistical tests of validity are performed, including the chi-squared hypothesis test. Because of the large number of data pints (between 17,000 and 21,000), between four and a half to 10 percent of the data is used for site tests.

This is a quasi-experimental study, which therefore requires consideration of the time periods "*before"* and "*after"* completion of the development in order to better identify the impacts associated with "transit-oriented" development. Examining both cases permits the researcher a more thorough and effective assessment of the actual impact of the development. The *before*-data starts in a year preceding the policy TOD.

4) Task 4: Model validation

Model validation entails the chi-squared test and other relevant statistical validity and specification tests as discussed in subsequent paragraphs.[8] The results can help answer the question of how well the models can be used to predict the natural log transformed total property value for another mix-use site.

(a) Evaluate transferability of models – The dataset from the Addison Town Center site is used to test the transferability of the model fitted to the Plano Transit Village site. The

[8] See Section 4.2 in chapter 4 for the various tests.

main objective of the test is to evaluate whether or not the modeling result from one TOD site is applicable to another mixed-use site. If the model created is successful in predicting the mean total property value of the other TOD site, then it is deemed transferable. If not, other significant variables influencing the total property value rates need to be considered. For this study, the coefficients obtained from the Plano Transit Village models are applied to the parcel data for the Addison Town Center to test the transferability of the model and vice versa.

(b) Compare property values and regression coefficients – This includes comparisons made for project sites, of property value rates for distances demarcated by buffer distances into levels of proximity to each TOD center. These are also compared to property value rates of the control.

(c) Report results – A summary of results, conclusions and recommendations are made.

3.2.2.3 Data Considerations and Requirements

Data requirements include developing a temporal GIS database. Spatial data processing and analysis are performed using ESRI's ArcInfo of ArcGIS 9.3. Parcel realty data collected by year comes in tabular (or coma delimited) format and is reduced and processed in Microsoft Access The processed data consists of spatiotemporal data with desired explanatory variable data information for at least two years for each parcel flanking the policy-year under review. The spatiotemporal dataset for each project site consists of data for some or all of the variables in Table D-1 of the appendix.

The dependent variable for each model is the logarithmic transform in property value, which is land value plus improvement value per acre. It permits getting an approximate percentage effect. The transformation also establishes a firm theoretical basis for the research.[9] Socioeconomic development characteristics are considered only to the extent that factors are discerned that distinguish neighborhoods with "sustainable" development from "non-

[9] For comments on theoretical basis, see Paifomak & Lave (146).

sustainable" ones. The variables identified are used to determine the degree of positive or negative TOD impact assessed on property valuation, based on bus-only versus bus-and-rail transit service mediating the predicted impacts. Selected controls include:

1. improvement value ($), land value ($)
2. total property area (acres) = improved area (acres) + land area (acres)
3. Variables that could be interacted with improved parcel land area include:
   - Time trend, which for Plano for instance is coded 0 for 1999, 1 for 2001, and so on.
   - Land uses include: single family, mobile homes, condominium, townhomes, multi-family, residential duplex, farm and ranch, and commercial buildings.
   - Distance to highway (miles).
   - Distance to the center of the development (represented by buffer dummies).

To support the management of historical data for the selected variables listed above (and others in Table D-1) for each site, a geographic information system (GIS) database is developed. The GIS database manages the variables on a year to year basis and can provide critical insight into the spatial and temporal impacts of each TOD on selected variables.

As can be seen in Table D–2 of the Appendix, the Plano *before-policy*-years data collected are for 1999, 2001 and 2002 to just before 2003. In 2003, revitalization based on the TOD policy measure was considered to be substantially completed. At this point, the Plano was considered substantially operational. Data is available for all the *before*-years for Plano. The *after*-years include 2003, 2004, 2005, 2006, 2007, 2008 and 2009. Data for the Plano *after*-years was available for all but 2004.

For Addison, the *before*-years were 2003, 2004 to just before 2005 when revitalization based on the TOD policy measure was considered to be substantially completed and the community considered substantially operational. Data is available for the Addison *before*-years 2003 and 2004 (see Table D–2). The *after*-years are 2005, 2006, 2007, 2008 and 2010, with data available for each.

As mentioned before, to study the spatial impacts, data was acquired at the parcel level. The land use and traffic data are available at different levels of spatial aggregation including census tracts, traffic analysis zones (TAZ) and parcels depending on the data type. In spite of that, data at the parcel level was chosen because it is more complete, more accurate given the sources (county appraisal districts, realtors, local public works agencies, etc.) and is more readily available. Also, it has fewer gaps compared to data options at bigger scales. The analysis in this study is a disaggregate one.

To perform an accurate disaggregate data analysis many data points are required. The best candidate for such data is parcel data from NCTCOG or better yet from the CCAD or DCAD. Other data sources exist in the private domain but their accuracy is in doubt. The state of Texas and federal agencies are also sources of data for LUT, but because their emphasis on the regional, their data collection efforts and accuracy largely reflect that scale.

3.2.2.4 Variable Selection

Variable selection depends largely on the literature review in LUT studies at the micro-level that are considered pertinent (e. g., 27, 39, 48). Candidate independent and dependent variables are listed in Table A–2. However, additional independent variables may be considered for describing the variability in the dependent variable. Some of the recommended candidate variables (e.g., total property value) are normalized by area (calculated in acres). Data is collected pertaining to selected variables, which included 74 variables for each parcel in Plano and Addison, and 69 for Richardson. Only 23 for Plano, 22 for Addison and 10 for Richardson of the variables are used as site-specific quantifiable regressors. The following is a summary of selected quantifiable variables included in the analytical computations:

- Total property value (tvpa) in dollars per acre = land value + improved value
- Time trend (unit less; coded from 0 for 1999 to 8 for 2009 for Plano; coded from 0 for 2003 to 7 for 2010 for Addison; and coded from 0 for 2001 to 8 for 2009 for Richardson)

- Land use variables and their state and Stata codes include the following: single family (A1) – lu1; mobile home (A2) – lu2; condominium (A3) – lu3; multi-family (B1) – lu4; and duplex (B2) – lu5. Others include vacant lots – lu6; farm and ranch (E) – lu8 and commercial (F) – lu7. Land use variables are coded 0 and 1 as dummies.
- Age of improvement or years since construction completion (in years to the appraisal)
- Distance to highway and distance to center of TOD (each measured in Euclidean feet)

3.2.2.5 Data Collection

The scope of this study is limited to NCTCOG projects for which Data is available. This limits the study and data collection scope to only two TOD sites and one control site which meet all criteria. While data availability limited the scope of the research, it presented the advantage of not widening the study to limits that may not have suitable data available. Procuring datasets for the three sites required overcoming proprietary rules over appraisal data. Table A–2 (in Appendix A) shows an example of the type of data collected for each parcel.

Several studies suggest that any attempt to assess changes in socioeconomic development (such as this study has done) requires some definition of variables (or indicators) (e.g., 123-125). This is still very difficult because conspicuously missing from the literature, is SD indicators and variable sets specifically for LUT interactions impact assessment at the micro level. Nevertheless, based on review of literature, a candidate set of suitable independent and dependent variables are identified for LUT. Flexibility of the method allows other variables to be added at will to the final predictive models.

The basis for the geospatial data collection is a set of buffers ¼-, ½-, 1-mile from each site center. The cordons permit the study of the spatial impacts of the LUT interactions. The inner spatial data cordon is set at a ¼-mile because it is the typical walking distance for bus transit. A ½-mile distance cordon is set because it is the typical walking distance to a light-rail transit station. The third cordon of a mile is set to examine if the impact of the development center spreads outside the ½-mile cordon. The data can be acquired at different levels of aggregation (e.g., census tracts, traffic analysis zones or parcels) depending on the data type. The dataset available for this study is aggregated at the parcel level.

Parcel data for Plano is provided by the Collin County Appraisal District (CCAD) and the City of Plano, while datasets for Addison and Richardson come from the Dallas County Appraisal District (DCAD). Year-specific parcel appraisal data from CCAD and DCAD come in coma-delimited format and are geocoded unto the corresponding shapefiles to produce the required spatiotemporal datasets for each site. A spatiotemporal GIS database is created to manage geocoded data for selected variables.

3.2.2.6 Data Accuracy

The data available for this study is rich enough to use in a convincing ceteris paribus analysis. The data is on a parcel scale and is sufficient for developing disaggregate LUT models for the analysis of buffer rings simultaneously within project sites. The natural logarithm transformation is used for the dependent variable (property value) and for several continuous independent variables including highway distance (ft.), distance to center of a project (ft), total area (acres) and improved area (acres). The total property value is selected because its values are available at the appraisal level for all years. The majority of the improved values have missing values or gaps that would render a model at best highly biased. Also, land-value-only models look less promising and are left for consideration in future research efforts.

3.2.2.7 Defining a Project Site and the Center of the Site

The center of each project site is selected so that it is the most accessible place within the development. In case of the Plano and Richardson (the control site), the centers are determined to be the respective City Halls. For Addison, the Addison Circle monument is the center. The latter is the hub of frequent visits and gatherings for picnics. It is within walking distances of restaurants, amusement parks, single and multi-family homes and transit stations.

3.2.2.8 Criteria for Selecting a Control Site

The following hierarchy describes the measured criteria in choosing a control site:

1) A control site must not include any type of sustainable development (SD) proxy or mixed land use. It must be mainly residential with few commercial land uses.
2) The type and amount of development flanking the control site must be similar to the type and amount flanking the study sites (providing similar external impacts).
3) A control site has to be developing on its own and with no external funding source that could weigh on it to adopt the type of strategies reminiscent of SD proxies. The NCTCOG represents one possible source of this funding.
4) A control site's history has to resemble that of the TOD sites. That means access to activities, should have begun at a similar time as the development of the study sites.
5) A control site must be within the same or neighboring jurisdiction as the study sites.
6) A control site must have similar proximity (i.e., access and egress) to highways, railways and other major transportation facilities as do the study sites.
7) A control site may have similar demographic and socioeconomic characteristics as the study sites prior to development, including the following: population density, median age, ethnicity variation, median income, house hold size, and employment density.
8) A control site must have the same data types as the study sites, and the data should have comparable data availability for similar years as the study site.

3.2.2.9 Criteria for Selecting Cordons

The cordons are determined by the following:

1) When the extent of the development is completely occurring within 0.5 mile from the center of the development, the standard cordons are set at ¼ mile, ½ mile, and a mile from the center of the development.

2) When the size of the development is beyond 0.5 mile, but within a mile, an additional cordon is set at 1.5 miles from the center. The outer most cordons must be beyond the development limits by at least 0.5 mile to effectively measure the extent of the impact.

To study the spatial impacts, spatial data buffers are set at a quarter of a mile, half a mile, and a mile from the center of the development. The quarter of a mile spatial data buffer limit is chosen because it is the typical walking distance for bus transit, and the half of a mile distance is chosen because it is the typical walking distance for rail. The third cordon of a mile is set to examine if the development's impact spreads beyond typical walk distances.

3.3 Summary

To summarize, the framework for the modeling process as clearly established is based on using econometric models to assess landed property valuation. Several works have done so in the literature, clearly establishing a de facto theoretical basis for the study. In that sense too, this is a coupling study. Nevertheless, applying econometric methods to assess LUT interactions impact on property valuation at the micro-level, when TOD moderates the impact, makes this a fresh effort. The establishment of a new framework to systematize the process is also a fresh effort for TOD impact assessment. The variables adopted have already been defined in other studies (e.g., 153) and have been assumed them without changes. This subjects this study to some of the defects of those works, from direct co-option.

CHAPTER 4

PROPOSED TOD IMPACT ESTIMATION MODEL: FIELD VALIDATION AND RESULTS

4.1 Disaggregate Analysis: Proposed Model Calibrations

A disaggregate analysis is performed using parcel data for each of the project sites. Much of the process tasks have already been defined or detailed in Chapter 3. In addition to those procedures, data analysis and model calibrations include the following methods in brief:

1) Analyze temporal patterns of LU for TOD in the presence of time trend.
2) Use an econometric approach to specify the best fit (time series-panel) model.
3) Use fixed effects (FE) methods to annul problems of random versus non-random sampling.
4) Explore possible consistent/efficient variable relationships by an econometric approach.
5) Eliminate ordinary least squares (OLS) problems through the use of the Box-Jenkins philosophy of parsimony.

Logarithmic transformations of several selected continuous variables and dummy variants of several land use and temporal variables are regressed on the natural logarithmic transform of "total property value" (per acre per year in US Dollars) as the dependent variable. The variables used for the models for each site are site-specific and model-specific.

The initial model is an OLS regression. The OLS model helps establish (i.e., identify) a structure for the most suitable data fit based on several statistical hypothesis tests. By "most suitable" is meant the best-fit-model to the dataset that minimizes errors that violate tenets of the OLS Gauss-Markov assumptions. The econometric specification process is iterative and stepwise in nature (141).

In using an econometric model specification for the best-fit model, many possible specification structures are considered such as OLS, ARCH/GARCH, fixed effect (FE), random effect (RE) to fit a model to the data that corrects for possible OLS problems (141, 147-152, 154). In developing the model fit to the datasets available for this study, several important principles are borne in mind to both simplify model calibration and speed up the processes. While recourse to every one of these principles may not always be necessary for every project situation, at least a few could always be useful in reducing to basics for engineers and planners who are not expert econometricians, the procedures emanating from the conceptual framework of this study. These principles include the following:

1) For the most part, FE models with groupwise heteroskedasticity cannot be efficiently estimated with OLS. Typically, the White and/or the Breusch-Pagan test are used to test for heteroskedasticity (141, 142, 144, 147). In this study, the Breusch-Pagan test is performed.
2) Because of the large sample sizes, the first order autocorrelation is best tested for with the Wooldridge's test. ACEs usually plague errors of large samples of panel data. Although generalized least squares (FGLS) model may be fitted in such cases, the FE model specification is used to correct for the problem because it is simpler to explain the results.
3) The Hausman test is performed to determine the appropriate choice between FE and RE approaches. Although the presence of time invariant variables is a strong indication of within effects, the Hausman test is used in the interest of completeness and affirmation.

All calibration computations are carried out in Stata, a general-purpose statistical software package that is very popular in econometrics and offers users a clean graphical interface. Stata also allows users to run commands in batch mode by using the ".do" file. The software is command-based, and is available in Windows.

4.1.1 Plano Model Calibration

The rumor that a TOD would be built in the center of the City of Plano based on a bus-and-light rail combined transit service started by 2002, and the policy implementation, in the form of planning, design and construction went into effect by 2003. By the end of that year, the Plano Transit Village was considered substantially completed and occupied. The year 2003 is, in this study, the *after-policy-year* for SD in the form of TOD became substantially operational. It is the base year for the *before-and-after* analysis for Plano.

The Plano site is used to create an OLS model to analyze two buffer rings (A =¼ -mile and B =½-mile) for the settlement simultaneously with a third ring (Ring C = 1-mile) serving as the reference ring, to which relative values for the other two are compared. Table A–3 shows the distribution of parcels in the cordon rings, with most parcels concentrated in ring C.

Plano dataset consists of 17,139 data points, as shown by yearly breakdown in Table A–4, and does not equal the number of data points used in the models. This is because qualitative data, unless coded into the models, is dropped from the analysis. Several qualitative variables are not needed or included in the models, as can be seen in comparing Appendix Table A-1 with the list of individual variables used in each model. In addition, the dataset for the project site is an unequal panel set (see Table A–5).

In the specific case of FE modeling, single entity groups are dropped from the process data as a requirement. One of the rationales in favor of using FE is that it is not a problem particularly in large samples, when unequal panel data is analyzed using the FE model. The process drops single entity groups without the loss of model accuracy or consistency. In particular, the problem of selection bias is a none-issue as the process is none-random when the FE model is used as in this case.

The Plano raw dataset also consists of 74 quantitative and qualitative variables (see Table A-1 in the appendix). From the pool of 74 variables, one of them, which is total property value (i.e., its log transform), is used as the dependent variable for all the models in this study. Seventeen others (in the list listed below), which include generated interaction terms and dummy variables are used in model development and estimation as predictors. The choice of predictor variables is based on several determinants including the following:

- Previous studies must indicate its previous usage in a model development (e.g., 148). This is to avoid the proverbial reinvention of the wheel in the limited scope of this study.

- The variable must be considered suitable through the Box-Jenkins and the stepwise project identification processes outlined in previous sections.

Those of the Plano and other project site variables not used in the modeling process, are mainly qualitative and can be left out without loss of certeris paribus essence, accuracy and reasonability in model development.

4.1.1.1 OLS Regression Model Calibration for Plano, Addison and Richardson

The ordinary least squares (OLS) regression is performed on Plano, Addison and Richardson. The general form of the OLS regression used in this study for each site is as shown in Equation 4.2, which is shown below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5, \ldots, \beta_k X_k + u \qquad \ldots 4.2$$

Y = the dependent variable = log(total property value per acre per year)

X_1, X_2 ... Xn = log(continuous independent) or dummy variables

β_0, β_1, β_2 ... β_n = estimated elasticities of explanatory variables

u = error term (includes other terms that affect *total property value)*.

Using the "*stepwise"* command found in Stata, variables are tested for their relevance in each site's model. The "*stepwise"* function permits entering several variables at a time into a model equation and viewing their relative significance. The command option *"pe(n)"* for the function specifies the significance level for an added variable to the model. Only provisos with the characteristics that "p < *pe(n)"* (see Tables A–6, B–6 and C–6) are eligible for addition to the final model (143). This serves as an aid for achieving parsimony. A regression model for Plano is obtained for Rings A, and B, with C serving as the reference ring for comparison of results.

4.1.1.2 Plano FE Model Calibration

The FE regression for Plano, Addison and Richardson is performed in Stata. The following are examples of the quantifiable variables used in the Plano FE regression model:

Y **=** lntvpa = log(total property value/acre) in US$/acre

x_1= age = Age of Improvement at appraisal

x_2 = afd = Dummy variable for TOD policy year

x_3 = lndhwy = log(Euclidean distance to the nearest highway)

x_4 = afdrdum1 = Interaction term (afd x Ring A dummy variable)

x_5 = afdrdum2 = Interaction term (afd x Ring B; reference dummy variable)

afdrdum3 = Interaction term (afd x Ring C; reference dummy variable)

x_6 = lntsfa = log(total area in acres)

x_7 = lu1 = single family residential (value of 1 or 0)

lu2 = residential mobile home (value of 1 or 0)

X_8 = lu3 = multi-family (value of 1 or 0)

x_9= lu4 = vacant lots (value of 1 or 0)

X_{10} = lu5 = duplex (value of 1 or 0)

x_{11} = lu6= vacant lot (value of 1 or 0)

x_{12} = lu8= Farm-ranch (value of 1 or 0)

x_{13} = yd1 = year=2001= year dummy

x_{14} = yd2 = year=2002= year dummy

The cross-sectional nature of the data and its time invariant variables suggest looking at either random effect (RE), fixed effects (FE), or generalized least squares (GLS), for further improvement in the Plano model. Since fixed effects have not been controlled for, FE and RE are the first two candidate structures for further investigation.

The FE model structure is different from OLS. Time effects are accounted for in individual controlling group effects and the definition of the error term, u is different. The basic theoretical FE equation fitted to the Plano dataset and used in this project is:

$$Y_{it} = \beta_1 X_{1it} + \beta_2 X_{2it} + ... + \beta_k X_{itk} + a_i + u_{it}, \quad t = 1,2,...,T \qquad \text{… 4.3}$$

where: Y_{It} = 1 × n vector – observation per spatial unit in the t^{th} time period;

X_{it} = 1 × n vector – independent variable;

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ = response parameters;

α_i = 1 × n = vector – idiosyncratic error terms (normally distributed), and;

u_{it} = 1 × n = vector – error terms and is normally distributed, and;

$e_i = \alpha_i + u_{it}$.

4.1.1.3 Plano FE Regression Model Calibration Results

Plano is used for this modeling emphasis because it is a TOD that is serviced by both light-rail and bus transit and because it has available data for most years under analyses. This translates into the following project specific Plano FE model with logarithmic transformation of continuous variables:

$$\begin{aligned} \text{lntvpa} = {} & \beta_0 + \beta_1\text{age} + \beta_2 tt + \beta_3\text{afd} - \beta_4\text{lndhwy} + \beta_5\text{afdrdum1} + \beta_6\text{afdrdum2} \\ & + \beta_7\text{lntsfa} + \beta_8\text{lu1} + \beta_9\text{lu2} + \beta_{10}\text{lu4} + \beta_{11}\text{lu6} + \beta_{12}\text{lu8} + \beta_{13} yd1 \\ & + \beta_{14} yd3 + \beta_{15} yd5 + \beta_{16} yd6 + \beta_{17} yd7 + \beta_{18} yd8 \end{aligned} \quad \ldots 4.4$$

Where $\beta_0, \beta_1, ..., \beta_{tk}$ *and* δ_1 = response parameters and variables are as defined above.

Table 4.1: Plano FE Regression Model Coefficients

Variable	PTV FE Robust
age	-0.0004
	(0.249)
afd	0.358
	(0.000)
lndhwy	-0.315
	(0.000)
afdrdum1	0.068
	(0.000)
afdrdum2	0.037
	(0.000)
lntsfa	-1.151
	(0.000)
lu1	-0.021
	(0.544)
lu2	–
	–
lu3	-0.452
	(0.000)
p-values in parentheses	

Table 4.1 – *Continued*

Variable	PTV FE Robust
lu4	0.02
	(0.270)
lu5	0.052
	(0.343)
lu6	0.029
	(0.146)
lu8	0.059
	(0.572)
year=2001	0.193
	(0.000)
year= 2002	0.282
	(0.000)
year=2003	–
	–
year=2005	0.024
	(0.000)
year=2006	0.041
	(0.000)
year= 2007	0.071
	(0.000)
year=2008	0.079
	(0.000)
year=2010	–
	–
Constant	13.822
	(0.000)
p-values in parentheses	

Table 4.1 is the summary of results for the Plano FE model calibration. The Plano FE model consists of a constant term, 23 variables and 18 parameters. The variables, rd3, afdrdum3 and lu7 are reference dummy variables for the buffer, year-after-buffer TOD proxies and land use dummies respectively. Those of the Plano variables not used in the modeling process, are mainly qualitative and left out without loss of accuracy in the model relationships.

Of the 11 variables used in the FE regression process, three coefficients (age, lndhwy and lntsfa) are negative, while the other eight are positive with three others (rd3, afdrdum3 and lu2) acting as references. The variable coefficients on continuous variables are elasticities, indicating that a 1% increase in the parameter of a variable increases the rate of property value by a percentage equal to the value of the variable coefficient multiplied by 100 (for a dummy variable) or by a percentage equal to the magnitude of the coefficient on a continuous variable. The Plano FE regression equation is Equation 4.5, and the algebraic form of it is Equation 4.6.

$$\begin{aligned}\ln tvpa = &13.822 - 0.0004age + 0.358afd - 0.315\ln dhwy + 0.068afdrdum1 + 0.037afdrdum2 \\ &- 1.151\ln tsfa - 0.021lu1 - 0.452lu43 + 0.020lu4 + 0.052lu5 + 0.029lu6 + 0.059lu8 \\ &+ 0.193yd2 + 0.282yd3 + 0.024yd5 + 0.041yd6 + 0.071yd7 + 0.079yd8\end{aligned} \quad \ldots 4.5$$

$$\begin{aligned}\ln tvpa = &13.822 - 0.0004X_1 + 0.358X_2 - 0.315X_3 + 0.068X_4 + 0.037X_5 - 1.151X_6 \\ &- 0.021X_7 - 0.452lX_8 + 0.020X_9 + 0.052X_{10} + 0.029lX11 + 0.059lX_{12} + 0.193X_{13} \\ &+ 0.282X_{14} + 0.024X_{15} + 0.041X_{16} + 0.071X_{17} + 0.079X_{18}\end{aligned} \quad \ldots 4.6$$

The FE robust negative parameters include those for age (-0.04%), lndhwy (-0.315%), lntsfa (-1.15%). Of the three coefficients, only lntsfa (p-value = 0.0) is statistically highly significant. The coefficients on both age (p-value = 0.249) and lndhwy p-value = 0.00) are statistically insignificant. The negative sign on age is statistically highly significant but minuscule and therefore inconsequential in its impact on lowering total property value per acre (lntvpa).

The highest negative impact on the Plano lntvpa is due to proximity to a highway. The total property value is reduced by about 0.32% for every 1% closer a property is to a freeway. The sign on *lndhwy*, the log transform of the distance of a property to the nearest highway, is negative suggesting that the closer you are to a highway, the lower your property value drops. This is as is expected and is the finding of several studies (e.g., 156, 157, 158). A highway's proximity has a measurable although a statistically insignificant impact on property location in Plano as it gets closer to the center of the TOD. For every 1% decrease in the distance to a highway, the property value per acre falls by about 0.32%. The drop in property value is statistically highly significant (with a p-value = 0.0).

However, the parameter of the highest interest is that for the dummy variable *afd* (after-year). Its parameter measures the unconditional after-policy-years effect of TOD policy introduction as PTV. Without other parameters, the parameter β_3 (on *afd*) is the difference-in-differences estimator (141, p. 453). The sign on this parameter is positive (afd = 0.358, p-value

= 0.00) and statistically highly significant. It shows that on the average, since the institution of the TOD policy property value in Plano has gone up by 35.5% for the years following the policy.

The other important parameter for measuring the policy impact of the TOD is the *afdrdum1*. This interaction term measures the conditional impact of the policy on property valuation in the years following substantial completion of the TOD. The term measures the TOD policy impact on owning property within the ¼-mile cordon relative to properties outside but within a 1-mile radius of the development center.

In the policy- after-years, for every 1% increase in the total property value in Ring C, the value of property within the ¼-mile cordon from the center of Plano (afdrdum1) rises by about 6.8%. This increase is statistically highly significant (p-value = 0.00) and appreciable. The two variables, afd and afdrdum1 show that there is a clear and direct positive correlation between TOD policy and the increase in property values per acre in Plano. This is an affirmation of the hypothesis that the TOD policy initiative produces a positive (increasing) impact on the f total property values in Plano.

Meanwhile, for every 1% increase in the distance to a highway from the center of Plano, property value per acre falls by about 0.32%. This decrease while miniscule, is statistically highly significant (p-value = 0.00). This shows that the farther property is away from a highway in the Plano TOD, the higher is its value per acre.

4.1.2 Addison FE Model Calibration

The model calibration procedures for Addison Town Center (ATC) follow the same methods and processes as those for Plano. The rumor that a TOD would be built in the center of the Town of Addison started by 2003, and the policy implementation, in the form of planning, and design went into effect by 2004. Construction of the ATC was considered substantially completed and the settlement occupied in 2004. By the end of that year, Addison TOD was considered fully commissioned. The year 2004 is, in this study, the *after-policy-year* for ATC as a TOD. It is the base year for the *before-and-after* analysis of Addison.

The preceding year, 2003 is the *before* year in the *before-and-after* disaggregate analysis. The aim of the analysis, as in the Plano case, is to create a model for the analysis of the log transform of property values per (lntvpa) for Addison. Accordingly, a related objective is to test the hypothesis that a light-rail and bus combined transit service TOD has a positive impact on property in the settlement, moderated by tvpa, with Richardson as the control site.

The Addison site is used to create first an OLS and then an FE model to analyze two buffer rings (A =¼ -mile and B =½-mile) for the settlement simultaneously. As before, a third ring (Ring C = 1-mile) serves as the base ring, to which relative values for the other two are compared. Table B–3 shows the distribution of parcels by cordon, with most parcels in ring C.

Addison Town Center presents an opportunity for creating reasonably good models. Once built, the models can be used to compare Addison to Plano, the other TOD in this study and to draw reasonable conclusions from the tests of hypothesis. One hypothesis tested is that a bus and light-rail combined transit service TOD, has a greater positive impact on property valuation in north-central Texas than a bus-only TOD. The comparison between Addison and Plano is rather apt, giving that the former is a bus-only TOD and the latter is a bus-LR combo transit service TOD. Although Addison and Plano are different settlements, shared TOD properties permit the investigation of the possibility of model transferability between the two datasets. For the test of this theory the Plano FE model is fitted to the Addison dataset.

4.1.2.1 Addison FE Model Calibration Results

The Addison raw dataset also consists of 74 quantitative and qualitative variables (see Table B-1 in the appendix). From the 74 variables, the log transform of property value per acre is the dependent variable for the FE model. 22 others (listed below), including generated interaction terms and dummy variables are the predictors. The dataset also consists of 20,763 data points (Table B–2 and Table B–3), as shown by yearly breakdown in Table B–2. It is an unequal panel dataset (see Table B–4). One rationale in favor of using FE is that unequal panel data is not a problem particularly in large samples. The process FE drops single entity groups as redundant.

The choice of predictor variables is based on the same principles and procedures as for the Plano. Those of the Addison variables not used in the modeling process are mainly qualitative and can be left out without loss of certeris paribus essence and accuracy in model development. The following are examples of the Addison quantifiable variables used in the FE model. All parameter and variable definitions are as in the Plano case.

Y **=** lntvpa = log(total property value/acre) in US$/acre

x_1= age = Age of Improvement at appraisal

x_2 = afd = Dummy variable for TOD policy year

x_3 = lndhwy = log(Euclidean distance to the nearest highway)

x_4 = afdrdum1 = Interaction term (afd x Ring A dummy variable)

x_5 = afdrdum2 = Interaction term (afd x Ring B; reference dummy variable)

afdrdum3 = Interaction term (afd x Ring C; reference dummy variable)[10]

x_6 = lntsfa = log(total area in acres)

x_7 = lu1 = single family residential (value of 1 or 0)

X_8 = lu2 = residential mobile home (value of 1 or 0)

lu3 = residential condominiums (value of 1 or 0)

x_9= lu4 = multi-family (value of 1 or 0)

X_{10} = lu6 = vacant lots (value of 1 or 0)

x_{11} = lu8 = farm-ranch (value of 1 or 0)

x_{12} = yd1 = year=2001 = year dummy

In the *stepwise* OLS regression for Addison to identify suitable variables for the impact analysis of the TOD, n =0.10 (see Table B–6). The value helps produce parsimony in the OLS model for Rings A and B, with Ring C serving as the base ring. Postestimation analytical tests

[10] A reference dummy variable is left out of a model as a base for a group of dummies.

including Breusch-Pagan and Hausman tests on the Addison OLS model indicate that the model violates several Gauss-Markov assumptions. The process shows too that the Addison OLS model has of endogeneity bias, heteroskedasticity and serial correlation problems, and can therefore not be BLUE. The cross-sectional nature of the data suggests looking at RE, FE, or GLS for improvement in the Addison model. FE have not been controlled for in this data either. FE and RE are among structures to further investigate.

The Hausman specification test for the suitability of RE versus FE fit to the data are shows FE to be the most suitable model structure fit to the Addison data. The basic theoretical FE equation fitted to the Addison dataset is the same equation (I.e., Equation 4.2) that is used for the Plano FE model. Equation 4.7 is the specific FE regression model computed for Addison and is structurally the same as the Plano model.

$$\begin{aligned} ntvpa = {} & \beta_0 + \beta_1 age + \beta_2 tt + \beta_3 afd - \beta_4 lndhwy + \beta_5 afdrdum1 + \beta_6 afdrdum2 \\ & + \beta_7 lntsfa + \beta_8 lu1 + \beta_9 lu2 + \beta_{10} lu4 + \beta_{11} 1u6 + \beta_{12} lu8 + \beta_{13} yd1 \\ & + \beta_{14} yd3 + \beta_{15} yd5 + \beta_{16} yd6 + \beta_{17} yd8 \end{aligned} \qquad \text{… 4.7}$$

Where $\beta_{tk}, \delta_1, \delta_2, \eta_n$ = response parameters and variables are as defined above.

The Addison FE model consists of a constant term, 21 variables and 16 parameters. The variables, rd3, afdrdum3 and lu7 are “reference dummy” variables for the buffer, the “year-after- SD policy” and cordon interaction term and land use dummies, respectively. Those of the Addison variables not used in the modeling process are mainly qualitative and can be left out without the loss of ceteris paribus in the model relationships.

Table 4.2 is a summary of the Addison FE model calibration results. The computed FE model for the Addison is shown in Equation 4.8 below, while the algebraic form of the same Addison regression equation is Equation 4.9.

$$\begin{aligned} \ln tvpa = {} & 16.529 - 0.041 age + 0.097 afd - 0.140 ndhwy + 0.082 afdrdum1 - 0.052 afdrdum2 \\ & - 0.850 \ln tsfa - 0.176 lu1 - 0.350 lu2 + 3.323 lu4 - 1.022 lu6 - 0.016 lu8 \\ & + 0.044 yd1 + 0.020 yd3 + 0.027 yd5 + 0.365 yd6 + 0.461 yd8 \end{aligned} \qquad \text{…4.8}$$

$$\ln tvpa = 16.529 - 0.0041X_1 + 0.097X_2 - 0.140X_3 + 0.082X_4 - 0.0527X_5 - 0.8501X_6 - 0.176X_7 - 0.350X_8 + 3.323X_9 - 1.022X_{10} - 0.016X11 + 0.044lX_{12} + 0.020X_{13} + 0.027X_{14} + 0.365X_{15} + 0.461X_{16} \quad \ldots 4.9$$

Table 4.2 Addison FE Model Coefficients

Variable	ATC FE Robust
age	-0.041
	(0.000)
afd	0.097
	(0.000)
lndhwy	-0.14
	(0.275)
afdrdum1	0.082
	(0.153)
afdrdum2	-0.052
	(0.000)
lntsfa	-0.85
	(0.000)
lu1	-0.176
	(0.498)
lu2	-0.35
	(0.396)
lu4	3.323
	(0.000)
lu6	-1.022
	(0.000)
lu8	-0.016
	(0.967)
year=2003	0.044
	(0.000)
year=2005	0.02
	(0.099)
year=2006	–
	–
year= 2007	0.27
	(0.000)
year=2008	0.365
	(0.000)
year=2010	0.461
	(0.000)
Constant	16.529
	(0.000)
p-values in parentheses	

The negative sign on age (see Table 4.2) shows that within the core ¼-mile cordon considered to be the limits of the TOD, the log transform of property value per acre goes down as it gets older. There is however, no particular rule by which this is happening relative to the project center. This violates some property valuation theories, in particular, the bid-rent theories. The negative sign on age is also expected when the policy impact tapers down with years beyond a threshold that includes at the minimum, the last year in the analysis. In the Addison case, that year is 2010. It makes sense to expect that beyond that year, the older the property, the lower its value per acre goes down. In the case of a non-TOD neighborhood, this could be considered the lowering of property value with the aging of a policy of proper care.

The parameter of the highest interest for Addison is that for the *policy-after-year* dummy variable *afd.* Its parameter measures the unconditional policy-after-years effect of the TOD on Addison property values. The sigh on the parameter is positive (9.7%) and is highly significant (p-value = 0.000) both statistically and in its magnitude. It shows that on the average, since the institution of the TOD policy as ATC, the rate of total property value per acre goes up by 9.6% in the years immediately after the policy.

The other important parameter for measuring the policy impact of Addison as a TOD is *afdrdum1*. This interaction term (as in the Plano case) measures the conditional impact of the TOD policy on property valuation in the years following its institution. The term measures the policy impact on owning property within the ¼-mile cordon relative to properties outside but within a 1-mile radius of the TOD center. In the policy after-years, for every 1% increase in the rate of total property value in Ring C, the value of property within the ¼-mile cordon from the center of Addison rises by about 8.2%. This increase is statistically significant (p-value = 0.153).

From the Addison FE model results, the two variables, afd and afdrdum1 show that there is a direct positive correlation between TOD policy and the increase in property values in Addison. The nature of that increase seems to be moderate, relative to property values per acre which are in mostly high six and seven figure price range. Nevertheless, it is in this study, an affirmation of the hypothesis that the TOD policy initiative produces a positive (increasing) impact on the log transform of total property value in Addison.

4.1.3 Richardson Model Calibration

The model calibration procedure for Richardson follows the same procedures as those for Plano and Addison. The main difference is that no policy proxies are introduced since there is no TOD policy in place in Downtown Richardson (DR) as in the cases of Plano and Addison. Also, besides a general look at any pattern from year to year, no before and after assessment is possible in this case. OLS and FE models are developed for the Richardson too, using two buffer rings (A =¼ -mile and B =½-mile) for the settlement as in the first two instances with a third ring (Ring C = 1-mile) serving as the base ring.[11]

Table C-2 shows the distribution of parcels in the Richardson cordon rings. The base ring is used as the anchor for the relative comparison of estimated parameter values for variables measured by the other two rings. Of the two study sites funded by NCTCOG (and a control site), Addison is selected to create this model because it is within the same area as Plano. It is a bus-only transit-oriented development (TOD), has data available covering the years under analyses and is the control site.

The choice of predictor variables is based on the same principles and procedures as for Plano. Those of the Richardson variables not used in the modeling process are mainly qualitative and can be left out without loss of certeris paribus and causal effect legitimacy and accuracy in model development. The Richardson raw dataset consists of 69 quantitative and qualitative variables as shown in Table C-1 in the appendix. From the 69 variables, property value per acre (i.e., its log transform) is used as the dependent variable for the model. Eight others (listed below), include interaction and dummy predictors.

The Richardson data has a total of 21,288 data points (see Tables C–2 and C–3). It is also an unequal panel (see Table C–2), which as before is not considered a problem, when

[11] The Richardson City Hall is the Richardson project site center for this study.

data is analyzed using the FE model. All parameter and variable definitions are as for Plano. Below are the quantifiable FE model variables for Richardson.

Y **=** lntvpa = log(total property value/acre) in US$/acre

x_1= age = age of improvement at appraisal

x_2 = lndhwy = log(Euclidean distance to the nearest highway)

x_3 = lntsfa = log(total area in acres)

x_4 = lu4 = multi-family (value of 1 or 0)

x_5 = lu5 = duplex (value of 1 or 0)

x_6= lu7 = commercial (value of 1 or 0)

lu8 = farm-ranch (value of 1 or 0; reference dummy variable)

X_7 = yd1 = y=2001 = year-dummy

X_8 = yd2 = y=2002 = year-dummy

4.1.3.1 Richardson FE Regression Model Calibration Results

Richardson is used for the modeling as the control site. This is because Richardson is serviced by both light-rail and bus transit without having a TOD policy. It is also within the same general area as the other sites; it has comparable demographic and socioeconomic properties with the PTV and ATC; and because data is available for most years under review.

The regression for Richardson is performed in Stata for Rings A and B, with Ring C serving as the base ring for the relative comparison of results. As before, first, OLS is performed using the *stepwise* process. The eligibility criterion for variables in the Addison model is that only terms with p < *pe(n)* < *0.20* are eligible for addition to the final model (see Table C–6), to aid in achieving parsimony. Postestimation tests are done on the OLS model parameters.

Postestimation analytical tests including Breusch-Pagan and Hausman tests on the Richardson OLS model indicate that the model violates several Gauss-Markov assumptions. The process shows that the Richardson OLS model has endogeneity bias, heteroskedasticity and serial correlation problems, and can therefore not be BLUE. The cross-sectional nature of the data suggests looking at RE, FE, or GLS for improvement in the DR model. Because FE has not been controlled for in this data, FE and RE are structures for further investigation.

The Hausman specification test compares RE and FE fit to the data. The test chooses FE as the most suitable model structure to fit to the Richardson data. The FE model structure is different from OLS. Time effects are accounted for in individual controlling group effects and the definition of the error term, u is different. The basic theoretical FE equation fitted to the Richardson dataset differs from those for Plano and Addison in two ways. First, there is no unconditional SD proxy "*policy-after-year*" (afd) dummy variable because there is no TOD policy in place for the settlement. Secondly, there are no conditional proxy interaction terms such as afdrdum1, afdrdum2 and afdrdum3 as is the case in the Plano and Addison FE models, for the same reason. The Richardson FE specific model equation is Equation 4.10 below:

$$\begin{aligned} \text{lntvpa} = {} & \beta_0 + \beta_1 \text{age} + \beta_2 \text{afd} - \beta_3 \text{lndhwy} + \beta_4 \text{lntsfa} + \beta_5 \text{lu4} + \beta_6 \text{1u5} \\ & + \beta_7 \text{lu7} + \beta_8 yd1 + \beta_9 yd2 + \beta_{10} yd3 + \beta_{11} yd4 + \beta_{12} yd5 + \beta_{13} yd6 \\ & + \beta_{14} yd7 + \beta_{15} yd8 + \beta_{16} rd1yd3 + \beta_{17} rd1yd4 + \beta_{18} rd1yd5 + \beta_{19} rd1yd6 \end{aligned} \quad \ldots 4.10$$

β_{tk} = response parameters and variables as defined above.

The FE model for the Richardson consists of a constant term and 14 parameters, with rd1 (¼-mile cordon) and rd2 (½-mile cordon) omitted for collinearity. The FE regression is performed using the *xtreg* command in Stata, with the *fe* option. The regression coefficients from the model are obtained for the variables identified by the OLS process. A regression model for Plano is obtained for Rings A, and B relative to Ring C as the base ring for the results comparisons. Of the 69 variables, 23 are used in the model development and estimation. Those of the Richardson variables not used in the modeling process are mainly qualitative and can be left out without loss of ceteris paribus in the model relationships.

The FE model for Richardson consists of a constant term and 18 parameters. For the Richardson FE model, omitted variables include rd1, rd2, lu3, lu7 and lu8. Some omissions (e.g., rd1, rd2,) occur in the FE modeling process due to collinearity, while others (e.g., lu2 and lu3) are dropped by the stepwise process due to unsuitability of the variables for the model.

Table 4.3 is a summary of the results of Richardson FE model calibration. The RMSE is 0.1242, implying model transferability. The estimated Richardson FE regression equation is 4.11 and the algebraic form of the FE Equation is Equation 4.12.

$$\begin{aligned} \text{lntvpa} &= 10.829 + 0.016\text{age} + 0.066\,\text{lndhwy} - 0.978\,\text{lntsfa} - 0.036\text{lu4} + 0.077\,lu5 \\ &+ 0.138\,lu7 - 0.173\,yd1 - 0.056\,d1yd2 + -0.057\,yd3 - 0.057\,yd4 \\ &- 0.021 yd5 - 0.008\,yd6 + 0.015\,yd7 + 0.021 yd8 - 0.163\,rd1yd3 \\ &- 0.190\,rd1yd4 - 0.242\,rd1yd5 - 0.117\,rd1yd6 \end{aligned} \quad \ldots 4.11$$

$$\begin{aligned} \text{lntvpa} &= 10.829 + 0.016_{1} + 0.066\,X_2 - 0.978\,X_3 - 0.036\text{X}_4 + 0.077\,X_5 \\ &+ 0.138\,X_6 - 0.173\,X_7 - 0.056\,X_8 + -0.056\,X_9 - 0.056\,X_{10} \\ &- 0.021 X_{11} - 0.008\,X_{12} + 0.015\,X_{13} + 0.021 X_{14} - 0.163\,X_{15} \\ &- 0.190\,X_{16} - 0.242\,X_{17} - 0.117\,X_{18} \end{aligned} \quad \ldots 4.12$$

Of the 23 variables in the FE DR model, two have negative parameters; two are dropped for collinearity, while six are positive. The negative parameters include lntsfa (-0.98%, p-value = 0.00), lu4 (-3.6%, p-value = 0.649)), and six out of the eight year dummies in the model. From 2001 to 2006, all the years show negative parameters, which mean that in the period, property values were on the average declining. The ¼-mile ring dummies for these years show statistically significant but negative values too. These include rd1yd3 (-16.3%, p-value = 0.095), rd1yd4 (-19.0%, p-value = 0.038), rd1yd5 (-24.2%, p-value = 0.006) and rd1yd6 (-11.7%, p-value = 0.174). Except for the first and the fifth year of the Richardson year dummies, all parameters are negative and statistically significant.

Again, the variable coefficients on continuous variables are elasticities of property value. The coefficients indicate that a 1% increase in the parameter of a variable increases the property value by a percentage equal to the coefficient multiplied by 100 (for a dummy variable) or by a percentage equal to the magnitude of a continuous variable coefficient.

The parameter*, lndhwy* (0.7%), shows a positive impact on the property value. It is also statistically insignificant (p-value = 0.498). This could be an indication that without a TOD policy in place, being closer to a highway provides easier access to transportation. However, its actual impact on property value rates is small (about 0.07%). This is the most radical departure from the results obtained in OLS.

Table 4.3 Richardson FE Model Coefficients

Variable	FE Robust
age	0.016
	(0.000)
lndhwy	0.066
	(0.498)
lntsfa	-0.978
	(0.000)
lu4	-0.036
	(0.649)
lu5	0.077
	(0.119)
lu7	0.138
	(0.096)
year=2001	-0.173
	(0.000)
year=2002	-0.056
	(0.055)
year=2003	-0.057
	(0.023)
year=2004	-0.057
	(0.007)
year=2005	-0.021
	(0.211)
year=2006	-0.008
	(0.535)
year=2007	0.015
	(0.102)
year= 2008	0.021
	(0.000)
rd1yd3	-0.163
	(0.095)
rd1yd4	-0.19
	(0.038)
rd1yd5	-0.242
	(0.006)
rd1yd6	-0.117
	(0.174)
Constant	10.829
	(0.000)
p-values in parenthesis	

4.2 Model Validations

Model validation takes the form of hypothesis tests of validity. Because of the large data set sizes involved (e.g., 17,011 data points for Plano), validity test data for each site comes from randomly setting aside 8.5% to 11% of each dataset. The randomization and collection of validation data consist of a simple process:

1. First, a unique serial number (SN) is assigned to each data point in a dataset.
2. Random numbers are generated however many of them needed for the fraction of data considered for each model validation.
3. Compare random numbers to data point and pick points matching the random numbers.

Several specification and/or validation tests are performed on each model. Among them, the Breusch-Pagan and the Hausman are the postestimation tests for the initial OLS model and the chi-squared is the main test of model validity. The Breusch-Pagan test tests for heteroskedasticity, while the Hausman is a specification test to choose between FE and RE structures. The root mean squared error (RMSE) is used for model transferability. In this study, the variance inflation factor (VIF) and tolerance (1/VIF) are the only tests that do not involve residuals. They are more of validators than tests, since they do not provide any inferential results, for instance, such as *p*-values. The VIF indicates the amount by which the variance of a single parameter is inflated as a result of possible correlations across predictors. The smaller the VIF is, the lower is the possibility of cross correlations in the controls.

4.2.1 Plano Model Validation

Below are results of selected specifications and validity tests for Plano. Since the number of parameters used in estimating the expected frequencies is m = 1 (i.e., z of the normal distribution), the degrees of freedom, $df = N(T - 1) - k$ (141).

1) Variance Inflation Factor and Tolerance

Table A-7 shows the summary results of the Plano model variance inflation factor computation. The results show that each variable has a VIF less than 6.0, which is equivalent tolerances no lower than 0.16. This shows that each variable is identified as reasonably contributing to the model in estimating total property value rates for Plano. The results also indicate that multicollinearity is relatively placid for the Plano variables, since the highest VIF value is 5.11 (for *afd*). We conclude that the Plano FE model is a good fit to the Plano dataset.

2) Hausman Specification Test Results

The full Plano Hausman test computations of the FE and the RE respectively are shown in Appendix Tables A–8 and A–9. Table A–10 summarizes coefficients of the first two tests results and compares variances for both FE and RE to test the following hypothesis that:

H_0: Both the FE and RE models are consistent and efficient estimators.

H_a: Only the fixed effects model is consistent.

The Test Statistic is: $\chi^2(18) = (b - B)' \{(V_b - V_B)^{(-1)(b-B)}\}$ = 2086.56

$\Pr ob > \chi^2 = 0.00$.

Note that ($V_b - V_B$ is not positive definite). Based on the sample data and under the assumption that the 10% level of significance is appropriate, the null hypothesis is rejected. It can be concluded that the FE model fits the Plano data better than the RE structure.

3) Breusch-Pagan / Cook-Weisberg Test

Table A–11 shows the summary of computations for the Breusch-Pagan test for Plano

One assumption of OLS is: $V(\varepsilon_j) = \sigma^2$ for all j. i.e. homoskedastic

H_0: homoskedastic (i.e., constant variance)

H_a: heteroskedastic

Test Statistic: $\Pr ob > \chi^2 < 0.05$;

Result shows: $\chi^2(20) = 44359.47$

$\Pr ob > \chi^2 = 0.00 < 0.05$

That is, reject the null and conclude that there is heteroskedasticity in the data.

4.2.2 Addison Model Validation

This section presents some selected specification, postestimation and validation test performed on Addison models, with brief synopsis of the test results. As the control site, RD is used to distinguish SD policy (TOD) effects in differences in the Plano and Addison models based on the *with-and-without* scenario.

1) Variance Inflation Test (VIF)

Table B-5 shows the summary results of the Addison model variance inflation factor and Tolerance (1/VIF) computations. The results show that each variable has a VIF less than 5.0. This suggests that no variable has a tolerance lower than 0.2. This in principle shows that each variable is identified as reasonably contributing to the model as an explanatory variable in estimating total property value rates for Addison. In this case too, multicollinearity is relatively mild, since the highest of the VIF values is 4.17. This value is less than 50% of the typical cut off value of 10, which is considered the threshold for very high. In this case too, the multicollinearity is relatively mild as none of the VIFs is ≥ 10, or excessively high.

2) Hausman Specification Test

The full Addison Hausman test computations are shown in Appendix Tables B–7 and B–8. These tables are summaries of the FE and the RE computation results respectively for the Hausman test. Table B–9 summarizes coefficients of the first two tests results and compares variances for both FE and RE to test the following hypothesis:

H_0: Both the FE and RE models are consistent but the RE estimator is more efficient for DR.

H_a: Only the fixed effects model is consistent for Addison.

Test: Ho: difference in coefficients not systematic

$$\chi^2(16) = (b - B)\{(V_b - V_B)^{(-1)}(b-B)\} = -75.85$$

$$\Pr ob > \chi^2 < 0.00$$

Data fails to meet the asymptotic assumptions of the Hausman test; see suest for a generalized test. Based on the sample data and under the assumption that the 10% level of significance is appropriate, the null hypothesis is rejected. It can be concluded that the FE model fits the Plano data better than the RE structure.

3) Breusch-Pagan / Cook-Weisberg Test

Table B–10 shows the summary of computations for the Breusch-Pagan test for Addison

One assumption of OLS is: $V(\varepsilon_j) = \sigma^2$ for all j. i.e. homoskedastic

H_0: homoskedastic (i.e., constant variance)

H_a: heteroskedastic

Test Statistic: $\Pr ob > \chi^2 < 0.05$

Result shows: $\chi^2(20) = 13987.77$

$\Pr ob > \chi^2 = 0.00 < 0.05$

That is, reject the null and conclude that there is heteroskedasticity in the data.

4.2.3 Richardson Model Validation

This section presents some selected validation test results for tests performed on the Richardson models. As the control site, DR is used to distinguish differences in TOD policy effects in the Plano and Addison models based on the *with-and-without* scenario.

1) Variance Inflation Test (VIF)

Table C-5 shows the summary results of the Richardson model variance inflation factor and Tolerance (1/VIF) computations. The results show that each variable has a VIF less than 5.0. This suggests that no variable has a tolerance lower than 0.2. This in principle shows that each variable is identified as reasonably contributing to the model as an explanatory variable in estimating total property value rates for Richardson. In this case too, multicollinearity is relatively mild. This value is less than 50% of the typical cut off value of 10, which is considered the threshold for very high. In this case too, the multicollinearity is relatively mild as none of the VIFs is ≥ 10 i.e., very high.

2) Hausman Specification Test

The full Richardson Hausman test computations are shown in Appendix Tables C–7 and C–8. These tables are summaries of the FE and the RE computation results respectively for the Hausman test. Table C–9 summarizes coefficients of the first two tests results and compares variances for both FE and RE to test the following hypothesis:

H_0: Both the FE and RE models are consistent estimators but the RE estimator is more efficient for Addison.

H_a: Only the fixed effects model is consistent for Addison.

The Test Statistic is: $\chi^2(8) = (b-B)' \{(V_b - V_B)^{(-1)(b-B)}\}$ = 1095.18

$\Pr ob > \chi^2 = 0.00$

$V_b - V_B$ is not positive definite

3) Breusch-Pagan / Cook-Weisberg Test

Table C–10 shows summary of computations for the Breusch-Pagan test for Richardson.

One assumption of OLS is: $V(\varepsilon_j) = \sigma^2$ for all j. i.e. homoskedastic

H_0: homoskedastic (i.e., constant variance)

H_a: heteroskedastic

Test Statistic: $\Pr ob > \chi^2 < 0.05$

$\chi^2(20) = 44359.47$

Result shows: $\Pr ob > \chi^2 = 0.00 < 0.05$

That is, reject the null and conclude that there is heteroskedasticity in the data.

4.3 Summary Results and Comparison of FE Models

A comparison of the models for Plano, Addison and Richardson is essential to differentiate the impacts due to TOD policy from those that are not. Based on the RMSE (which are statistically zero in each case) the FE model for Plano can be concluded to fit both data sets, with variations that can be explained away by unaccounted for site specific characteristics.

This is an indication of model transferability between Plano and Addison. The relation between Richardson and either Plano or Addison is a very marked departure from the closer relationship in terms of model transferability between Plano and Addison. It is clear that the Richardson is incapable of being fitted with the Plano or Addison models, as there seem to be no correlation in their outputs. For both Plano and Addison, the results of interest include:

1) Age – The coefficients on age for both TODs are negative, showing that older homes have lower values. Age however is significant and positive for Richardson's property values.
2) The Richardson FE indicates that no matter your proximity to the settlement center, if you are in any of the cordons, your property value drops in Richardson. This is due to the fact that Richardson has no TOD policy. This is not the case in Plano or Addison, where property values are on the rise particularly in the ¼-mile cordons.
3) *Policy-year-after* dummy (afd) – The coefficient on afd are significantly higher for Plano (35.8%, p-value = 0.00) than for Addison (9.7%, p-value = 0.00). This means that after the policy year, property value increases in both TODs. The afd does not apply to Richardson..
4) FE afdrdum1 and afdrdum2 coefficients are even more interesting than the unconditional afd. For Plano, the coefficients on the conditional SD impact proxies, afdrdum1 (6.8%, p-value = 0.00) and afdrdum2 (3.7%, p-value = 0.00), are both positive. Both parameters are also statistically highly significant. The positive values of these parameters for Plano indicate the positive impact of the TOD policy on property values.
    5) Year-dummies – All year-dummies are positive for Plano. They include the:
    6) year=2001 (yd2 = 19.3%, p-value = 0.00)
    7) year=2002 (yd3 = 28.2%, p-value = 0.00)
    8) year=2005 (yd5 = 2.4%, p-value = 0.00)
    9) year=2006 (yd6 = 4.1%, p-value = 0.00)
    10) year=2007 (yd7 = 7.1%, p-value = 0.00)
    11) year=2008 (yd8 = 7.9%, p-value = 0.00)

Table 4.4: Comparison of FE Model Coefficients for Plano and Addison

Variable	PTV FE Robust	ATC FE Robust
age	-0.0004	-0.041
	(0.249)	(0.000)
afd	0.358	0.097
	(0.000)	(0.000)
lndhwy	-0.315	-0.14
	(0.000)	(0.275)
afdrdum1	0.068	0.082
	(0.000)	(0.153)
afdrdum2	0.037	-0.052
	(0.000)	(0.000)
lntsfa	-1.151	-0.85
	(0.000)	(0.000)
lu1	-0.021	-0.176
	(0.544)	(0.498)
lu2	–	-0.35
	–	(0.396)
lu3	-0.452	–
	(0.000)	–
lu4	0.02	3.323
	(0.270)	(0.000)
lu5	0.052	–
	(0.343)	–
lu6	0.029	-1.022
	(0.146)	(0.000)
lu8	0.059	-0.016
	(0.572)	(0.967)
year=2001	0.193	–
	(0.000)	–
year= 2002	0.282	–
	(0.000)	–
year=2003	–	0.044
	–	(0.000)
year=2005	0.024	0.02
	(0.000)	(0.099)
year=2006	0.041	–
	(0.000)	–
year= 2007	0.071	0.27
	(0.000)	(0.000)
year=2006	0.041	–
	(0.000)	–
year= 2007	0.071	0.27
	(0.000)	(0.000)
p-values in parenthesis		

Table 4.4 – *Continued*

Variable	PTV FE Robust	ATC FE Robust
year=2008	0.079	0.365
	(0.000)	(0.000)
year=2010	–	0.461
	–	(0.000)
Constant	13.822	16.529
	(0.000)	(0.000)
p-values in parenthesis		

The first two years of the rumor for a TOD policy, property values went up very high. This is expected, as the prospect of higher quality of living provided by transportation improvement investment impacts property values in a very positive manner. Several studies show that transportation improvement typically leads to higher neighborhood real property values within the immediate peripheries of a settlement (155, 156). According to these studies, the value of real property is expected to be highest in city business district centers and should decrease with distance from the center. Plano seems to be following conventional wisdom.

Year-dummies are also positive and significant for Addison. They include the following:

- year=2003 (yd1 = 4.4%, p-value = 0.00)
- year=2005 (yd3 = 2.0%, p-value = 0.0.099)
- year=2007 (yd5 = 27.0%, p-value = 0.00)
- year=2008 (yd6 = 36.5%, p-value = 0.00)
- year=2010 (yd8 = 46.1%, p-value = 0.00)

The very high values for Addison are as much due to the TOD as they are due to the impact of the Dallas North Tollway (DNT). According to Baldwin et al. (158), the distance to a highway very close by may have a positive impact on property value when it acts as a transportation improvement. In the case of Addison, the Dallas North Tollway (DNT) is acting as a transportation improvement for the TOD because it is within a ¼-mile from the center of the TOD. Addison is benefiting from the better access, provided by the DNT to the relatively huge Dallas urban area. The TOD can be said to be pulled closer to the Dallas CBD, than Plano is with the not so efficient freeway. Also, the relatively tighter connection of Addison to the Dallas CBD created by the DNT creates an attendant increase in demand for property and its value. This follows the lower transportation cost, which accompanies improved access to more activities, a broader labor market and bigger choices and opportunities in markets for goods and services presented by Dallas.

On the other hand, year dummies and their interactions for Richardson indicate negative impacts of the community on property values. The year dummies show the following:

- year=2001 (yd1 = -17.3%, p-value = 0.00)
- year=2002 (yd2 = -5.6%, p-value = 0.0.055)
- year=2003 (yd3 = -5.7%, p-value = 0.023)
- year=2004 (yd4 = -5.7%, p-value = 0.007)
- year=2005 (yd5 = -2.1%, p-value = 0.211)
- year=2006 (yd6 = -0.8%, p-value = 0.535)
- year=2007 (yd7 = -1.5%, p-value = 0.102)
- year=2008 (yd8 = -2.1%, p-value = 0.00)

The interaction terms of interest indicate negative values and include the following:

- year=2003 (rd1yd3 = -16.3%, p-value = 0.095)
- year=2004 (rd1yd4 = -19.0%, p-value = 0.038)
- year=2005 (rd1yd5 = -24.2%, p-value = 0.006)
- year=2006 (rd1yd6 = -11.7%, p-value = 0.174)

These values show that in the years corresponding to the TOD policy implementations in Plano and Addison, property values were dropping in Richardson, and in particular, within the ¼-mile cordon of downtown. The relative drop in property values in Richardson, which has both bus and light rail transit services relative to Plano and Addison could be explained by Richardson's no TOD policy service.

4.4 Summary

Much of the computations in this study are performed in Chapter 4, which also presents model calibration results for each site. These results are summarized with important variable parameters given detailed interpretations. Validation largely consists of statistical hypothesis tests, which are also presented along with various test results and significance.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Conceptual and Modeling Framework Rationale

Fixed effects (FE) econometric model structures are identified based on manipulation of OLS models. The idea is to establish initial relationships between the dependent variable (property value per acre) and various independent variables. The latter include: logarithmic transform of continuous independent variables (x_n) (e.g., distance to the nearest highway); and dummy variables for others (e.g., buffer distances around development sites, etc.). The main reason for using the logarithmic transform of the dependent variable is to impose a constant percentage impact on the explanatory variables (141).

Because of the cross-sectional nature of land values, data analysis involves longitudinal modeling and is based on the Box-Jenkins philosophy of parsimony (BJPP), popularly used for the purposes of estimating and predicting expected values for a univariate time series (141, 147, 150, 154). In the BJPP process, tests are performed to identify the validity of the Gauss-Markov OLS assumptions. Violations of the assumptions are indications that the OLS models are at the least inefficient, unreliable, or biased unless correction are made for the violations. As the tests show Gauss-Markov assumptions to be violated in each case, processes to alleviate particular issues that lead to the violations emerge. This process is simple and inexpensive.

1) Several specification structures could improve on OLS results and provide better fits. Because of the presence of significant spatiotemporal factors in the regression series, the presences of autocorrelated errors (ACEs) are expected to cause problems. It is necessary, therefore, to investigate the presence of ACEs in the process for choosing the best-fit model. The ACE test is the one formulated by Wooldridge (151).

2) Generally, empirical studies of the impact of a given system at a given locality are for the most part *"before-and-after"* studies. A less common approach is to analyze comparable sites, at two or more of which the resource provisions were made and at least one (the control site) at which such a provision is absent. Both methods approximate a "with-and-without" analysis, which is a necessary condition for a more precise sorting out of the actual impacts of the policy provision. Studies argue that *before-and-after* studies are inexorably affected by copious other urban/suburban variables. These are often constantly in a state of unpredictable flux at any given location. Consequently, for instance, it is difficult to make the leap that even the two most similar settlements are ever so completely the same as to lack differences. It is virtually impossible to reasonably conclude that the differences in two settlements can be ascribed solely to the presence of a particular transportation system. This condition is why the "*before-and-after"* and "*with-and-without"* methods are combined in this study. The combinatory power of the two is assumed to provide for a more sound certeris paribus causal-effects analysis. This improves on the validity of the research beyond the usual statistical test of validity typical of similar studies at the macro-level.

3) Autocorrelation errors (ACEs) factors are not a problem in this study based on tests of the OLS. However, the effect of ACEs could factor significantly in a model, if they sufficiently impact the fit of the econometric equation to the dataset. That is not likely in this study where the raw data are collected at yearly intervals, which are longer than the shorter (e.g., hourly, daily, or even weekly) intervals for which ACEs can be critical. Nevertheless, the questions to be looked at by and large include; "Are the errors in the regression model positively autocorrelated? If so, are the correlations serial?" Yes answers to these questions is why the use of OLS is terminated, as it has a number of important consequences:

   a. The OLS regressions coefficients remain unbiased. However, they no longer possess the minimum variance property and could be quite inefficient.

   b. The MSE is considered seriously underestimating the variance of the error term (μ_t).

c. $S(b_k)$ calculated according to the procedures seriously underestimate the true standard deviation of the regression coefficients.

d. Confidence intervals for the t- and F-tests are no longer strictly applicable.

4) The panel nature of the dataset invites simple but effective econometric model structures that effectively eliminate much of the Gauss-Markov violations of OLS. For instance, the fact that some or indeed all model regressors may be correlated among each other is in itself not an inhibition to a good model fit. Nor does it impact inferences about mean responses and predictions for new data, as long as these are made within the immediate vicinity of the observations. However, the problem is that the estimated parameters tend to have larger than “normal” sampling variations when the control variables are highly correlated. This is the case in some of the variables in this study. The result could conceivably be that only very imprecise information is derived from such models. For instance, normal interpretation of a parameter as a measure of the expected value of a regressand when a change is ascribed to a regressor is no longer fully valid when there is multicollinearity (141, 142). Methods to reduce multicollinearity in LUT interactions impact assessment models as applied to SD analysis are left to future follow on studies. However, that problem is moot in this study because the FE structure used adequately addresses the question, making it completely irrelevant.

5) As observed in previous sections, the assessment of TOD projects ultimately requires a significant proportion of the evaluation process to be spent on analysis of the impact of transportation on land use. To be viable, therefore, a TOD project evaluation requires analyses of spatiotemporal (historical) data of land use and transportation interactions (74, 159, 160). This need is affected by the zest researchers (especially academics) have for complex computational approaches to LUT planning analysis sometimes. This is the case, even when this is totally unnecessary sometimes. In several studies, this need for spatiotemporal analysis has been interpreted to mean the search for sophisticated, complex

mathematical solutions to sometimes intractable formulations. In this study, we show by a simple econometric analysis that this could be achieved through the inclusion of such variables as dissimilarity indices (not used hear), "distance to highway" and "distance to TOD center" among others, and is not complicated.

5.1.2 Assumptions

Several assumptions are made in this study. Some are about the socio-economy of the project sites chosen; others about the data; and still others by virtue of the modeling methodology adopted. Among the assumptions are the following:

A. The literature review is the sole source of identification of LUT variables considered suitable for the available data, without having to develop new variables for SD policy assessment. It is assumed that enough variables are already defined to facilitate a causal-effect study.

B. The modeling process starts with OLS regression. Below is a brief précis of the Gauss-Markov assumptions implicit in multivariate processes as in this study (141, pp. 105-105):

   1. **There is Linearity and weak dependence**. This means that the process follows the linear form: $y_t = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} + ... + \beta_k x_{tk} + \mu_t$;

      where, the term μ_t given by $\{\mu_t : t = 1,2,...n\}$, is a sequence of disturbances or errors.

   2. **Random sampling.** The process $\{(x_{ti}, x_{t2}, ..., x_{tk}, y_t): t = 1, 2, 3... n\}$ is stochastic and the data is, therefore, a random sampling of n observations in accordance with assumption 1 above. This ensures that the data can be used to estimate β_j and that the data is representative of the population modeled in the first assumption.

   3. **No perfect collinearity**. No independent variable is constant, nor is any a perfect linear combination of the others. This assumption allows us to know just by looking at the data whether the dataset is suitable for computing estimates of parameters of interest.

   4. **Zero conditional mean**. The regressors are contemporaneously exogenous. That is, there is no endogeneity in independent variables.

5. **Homoskedasticity.** The errors are contemporaneously homoskedastic. That is, there is no heteroskedasticity in the errors.

6. **No serial correlation.**

Because of the temporal nature of the data and the use of time variables in the models, time series specific Gauss-Markov assumptions are implicit in the study (141, pp. 400-401):

(1) **Linearity and weak dependence.** The process $\{(x_{t1}, x_{t2}, ..., x_{tk}, y_t): t = 1, 2, ...n\}$ is stochastic and follows the linear model $y_t = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} + ... + \beta_k x_{tk} + \mu_t;$ where the term u_t given by $\{\mu_t : t = 1,2,...n\}$, is a sequence of disturbances or errors.

(2) **No perfect collinearity.** No independent variable is constant, nor is any a perfect linear combination of the others.

(3) **Zero conditional mean.** The regressors are contemporaneously exogenous, i.e., $E(u_t \mid x_{t1}, ..., x_{tk}) = 0$

(4) **Homoskedastic**. The errors are contemporaneously homoskedastic, i.e., $Var(u_t \mid x_t) = \sigma,^2$ where $x_t = (x_{t1}, x_{t2}, ..., x_{tk})$.

(5) **No serial correlation**, i.e., for all $t \neq s, E(u_t, u_s \mid x_t, x_s) = 0.$

Efforts must be made to test for the validity of the Gauss-Markov assumptions. When several of them are violated, the model may be biased and certainly unreliable, unless steps are taken to correct for the violations. For OLS to be correctly applied, the errors have to be independent and homoskedastic. Those conditions are so uncommon, that it is impractical to expect OLS to be adequate for any spatiotemporal modeling and certainly the ones developed in this study (147).

C. This study combines the *before-and-after* and the *with-and-without* approaches under the assumption that the combinatory power of the two approaches develops a more reasonable certeris paribus analysis and improves on the validity of this study.

D. Some variables may have a key impact on the dependent variable, yet including them in an OLS regression directly may be impossible. For instance, although quality is a predictor in property valuation, it is hard to quantify it. Because we cannot adequately control for quality in our OLS regression, we know then that we have an omitted variable bias, because omitted quality is correlated with both property value and area. When we use the FE model, in the parlance of econometrics, we are making the identifying assumption that unobservable factors, which might simultaneously affect the dependent and independent variables in the regression, are time-invariant (141, 143). In so doing, we are attempting to omit variable bias by focusing on within variation. One key assumption we are making by doing this is that there are no changes in the quality or the demand for property over time within each parcel that we cannot control for.

5.1.3 Sources of Modeling Error

Regression modeling is always subject to errors of an imperfect process that is still evolving. Several process errors could affect any modeling exercise such as this. They include:

1) Unforeseen modeling errors

The impact of any SD or its proxies such as TOD or a JD usually extends beyond land use and property valuations. It may include safety, quality of life (livability) issues, economic development, environmental impact, mobility, accessibility and sustainability (61, 162). An accurate depiction of all these components in a model is a herculean undertaking even at the micro-scale. Addressing every issue in a study like this one defeats the very purpose for which a different set of modeling parameters are needed at the micro-level. Unforeseen errors therefore remain unaddressed.

2) Stepwise OLS regression errors

This study uses a stepwise process for the OLS regression procedure to choose the variables for the models. The procedure has the shortcomings of correlated hypothesis testing and fails to examine some possible model variables (143). Results produced from the process can be misleading, since not all possible variable subsets are considered. A more thorough look at how to improve the stepwise process to improve the “ceteris paribus” nature of variables used in models is beyond the conceptual framework of this study. It too is left to future studies.

3) Serial correlation

One source of error that is symptomatic of other errors in regression models is serial correlation. It is investigated for the series during identification. The fact that some or indeed all of the regressors are correlated among each other is in itself not an inhibition to a good model fit to the data. Nor does it impact inferences about mean responses and predictions for new data, as long as these are made within the immediate vicinity of the observations as is true in this case. However, the problem is that estimated parameters tend to have larger than “normal” sampling variations when the control variables are highly correlated such as is the case in the OLS models in this study. The result is that only very imprecise information can be derived from such models. Therefore, while the OLS models in the study are consistent, they are woefully in efficient especially due to the spatiotemporal panel nature of the data and because number (2) of the Gauss-Markov assumptions in the last section are readily violated by several variables.

4) Autocorrelated errors may cause problems

When a time series is involved in regression modeling, such as is the case in this study, the presence of autocorrelated errors (ACEs) can cause problems. Although ACEs were tested for and found not to be assessed in this study, our test only shows that there is a good chance ACEs are not critical in this study models. A more advanced and thorough investigation into their influence, however imperceptible, has been left to future follow up research. In particular, a study is required to investigate their presence in a regression process that has a significant temporal factor such as this. This is one of those inquiries that need not complicate a micro-level such as this that is designed to produce reasonable analysis without computational complexities. For the standard OLS regression analysis used in this study and the dataset used, autocorrelation of factors do not create problems. The effect of the autocorrelation errors, may factor significantly in a model, only if they sufficiently impact the fit of the model to the data set. There is always the possibility of misspecification, which could result in that scenario.

5) Other sources of error

Other sources of error are those intrinsic in the model building process. They include but are not limited to the following (139):

1) Measurement errors – fall into the following two categories:

- Random effect errors – These crop up just because the research involves samples and not the populations. They are a function of the sample size and of the intrinsic variability of the parameters, but they do neither impact average values of parameters, nor their variances. Although these errors adversely affect the degree of confidence associated with parameter means, their influence on the accuracy of a study in nominal.
- Sampling bias. This type of measurement error affects both the averages and the variability of the averages of the predicted parameters. It should not be a problem for the BCH model, which did not require any sampling.

2) Computational errors. Because calibration of FE models involves iteration, computational errors are possible although improbable, with the thorough editorial scrutiny this study was subjected to. These errors are usually characteristic of computational procedures for which exact solutions are intractable. That is not the case for the model equations used here. In any case, in order to minimize computational type errors, spreadsheets are used for computations that need to be done manually. Statistical computations are done by a software program. In any case, their impact is minor, unless in equilibration with certain other problems of the sort not part of the computations in this study.

3) Specification errors. These are inherent in any specification modeling process without exception. However, efforts are made to lessen these to reasonable levels. The idea of the Box-Jenkins philosophy of parsimony is to minimize these. The battery of hypothesis tests also indicate reduced chances of these errors in the final FE models of this study.

4) Transfer errors are generated when spatiotemporal data of one location is used to create a model for another location at another point in time. The transference of the Plano is subject to such an error. a test of transferability with multiple year data is typically used to assess this type of error. This is left to future studies.

5) Aggregation errors. Are of three basic types, which could have affected this study.

   (a) Data aggregation occurs each time data is aggregated in an analysis.

   (b) Options aggregation occurs when for the sake of convenience and simplicity, options of the system in question are lumped together. For instance, when modeling with fixed effects, the impacts of unknown variables are lumped together.

   (c) Model aggregation – Although this is a disaggregate analysis, some amount of aggregation in variable quantities are unavoidable. methods to arrive at the results are possible sources of error, which may be difficult to eradicate entirely. This is particularly troublesome for non-linear models. This type of error is not a concern here since aggregation is minimized and the models in this study are linear.

5.1.4 Model Validity and Generalizability

A change model using the natural logarithm transformation is utilized in this study as the final model for each site. This is considered appropriate because other studies also report using this method and model to be more suitable when economics is involved (e.g., 146).

As studies have observed (e.g., 139), the general method of model validation in the conventional sense is to validate in terms of the goodness-of-fit (R-squared) achieved between observed performance and expected predictions (139). Though this is sometimes necessary, particularly where OLS regression modeling is concerned, it is in no way a sufficient condition for model validation according to several before-and-after studies. Because validation is testing the predictive power of a model, it is important to keep in mind its main purpose, which is a way for the researcher to show that the model is in fact proficient in forecasting, in this case, the total property value or its logarithmic transform.

The objective of validity tests thus focuses on the following (162):

a) the model does not defy theoretical expectations;

b) it does not display any abnormal tendencies; and,

c) it is internally consistent with the assumptions used to create it.

In order to achieve these objectives, validation requires comparing the model outputs to information not used in the model estimation process (139). This is considered both a stringent and a more robust validity test. This validity test has been achieved by making the Plano Transit Village assessment model the main base model. Addison is used to test the validity of the Plano model in this *before-and-after study*. Part of the conceptual framework of the process recommended by this study is to also test validity by a *with-and-without* test. This is achieved by applying the Plano (with SD policy in the form of TOD) model to Addison Town Center (with TOD policy) and Downtown Richardson (RD), which is without a TOD policy). The Richardson model, contrasted with both the Plano and Addison models

Several considerations must go into generalizing the findings reported in this study. Among them are the following factors:

- considerations for the size of the data used;
- the use of a control group;
- the nascence in TOD definition, and;
- the difficulty in determining causality of the effects of the variables used in the study.

This study is a preliminary look at TODs at the neighborhood level, on a small scale. It looks at the impact on land use and property values of transportation infrastructure investment in the north-central Texas study area, moderated by TODs as SD policy instruments. It uses selected LUT variables to explain SD impact on property valuations at the micro-level in two TODs and a control site. By extension, the study is generalizable to settlements of similar spatiotemporal, geo-political and socioeconomic characteristics.

5.1.5 Limitations of the Study

As has been declared, the scope of the study is limited to a preliminary look at TODs as sustainable development proxies and their impact on land use and property values in the study area. It first establishes suitable variables for explaining sustainable development impact on land use and property valuations from the literature without having to define or develop new SD indicators. The assumption is that enough indicators have already been defined, which will prove suitable for the study. This required a review of such studies in which LUT interactions impact indicators and variables are defined. This effort has been reported in Chapter 2.

Because the developments examined are relatively small and because there are relatively few studies of SD at the micro level, the study must rely on the usual regionally-scoped SD evaluations. Fundamentally, my study is limited to projecting or defining variables from macro-level LUT models that have used some or all of the selected response and predictor variables. The limited scope of the study does not permit otherwise.

The assessment of TOD projects ultimately requires that a significant proportion of the evaluation process be spent on the analysis of the impact of transportation on land use. To be viable, therefore, a TOD project evaluation requires analyses of spatiotemporal (historical) data of LUT interactions (1). This analysis is achieved in this study through the inclusion of such variables as “distance to highway” and “distance to TOD center” among others.

In the meantime, we can say with definitude that TODs do have a positive impact on property valuation in Addison and Plano of the Dallas and Collin counties respectively and as such perform well in these cities. There are 17 counties in the NCTCOG planning area of north-central Texas. With data collation in future studies when all 17 counties are analyzed, we can then say with certitude just how well TODs perform in North-Central Texas.

LUT interactions impact model development is a measure of the interdisciplinary practical application of economic theory to transportation and land use analysis (163). The approach projects sociology into transportation planning and development, and makes any research (including this one) into LUT impact assessment a context sensitive undertaking (139). It is not too cautious to suggest, therefore, that the results are limited to the study areas, Plano and Addison. Spatiotemporal modifications may be needed to generalize the results to other areas beyond the two TODs in North-Central Texas.

5.2 Conclusions

In a general way, the following are concluded from this study:

a) It brings scientific and quantitative rigor to the important yet ambiguous concept of TOD assessment in particular and SD policy instruments in general.

b) The particular SD policy instruments used are Transit-oriented developments (TODs). As case study projects, TODs are used by the study to assess the interactions impact of land use and transportation (LUT) infrastructure investment.

c) With specificity, it establishes an analytical toolset that focuses on the singular but critical aspect of the LUT interactions impact on property valuation.

d) The study explores how environmentally friendly new-urbanism concepts such as TODs moderate the LUT-infrastructure investment relationship as it impacts property values.

The research criteria include statistical analyses to assess the strength of variable relationships in the impacts. To the extent that the modeling framework improves the predictive ability of small community planners to forecast the impact of projects, they are getting a much needed foundation for better decision making. With lucidity, they are being provided a wide ranging LUT and SD (e.g., TOD) project assessment tool set. It is suggested that the forecast models of this study are a contribution to the knowledge base for TODs in particular and SD strategic planning and practice in north-central Texas in general. By data collation, the study is extendable to Texas and the nation at large. The knowledge of LUT interactions impact assessment at the micro-level, has in some small measure being advance by this study too.

5.2.1 Conclusions from Specific Research Questions

At the beginning of this research, several questions arose from the literature review and are framed into the research questions. The more specific conclusions and recommendations focus on responding to these questions, which include the following:

1) What is a transit-oriented development (TOD)?

This study defines a transit-oriented development as:

"A higher-than-normal-density development that has pedcycle priority and walkability friendliness designed into its urban form that is located within walking distance (up to a mile) of a rail, bus, or other mass transit station or stop."

2) Does land value respond to transit-oriented development?

Yes it does. Analysis in this study shows that TOD investments influence land values. In Plano Ring A and Addison Ring A, total property values (land + improvement values) increase during the *policy-after-years* more than they did in the before-years. However, the significant factors that impact land values are not examined due to the lack of historical land value data. Therefore, property values are analyzed instead of land values.

3) What is the most efficient model developed by this study for property valuation?

- **Plano –** The most efficient model developed by this study for property value for Plano is the following FE model and its algebraic form respectively, repeated here for effect.

$$\begin{aligned}\ln tv = {} & 13.822 - 0.0004 age + 0.358 afd - 0.315 \ln dhwy + 0.068 afdrdum1 + 0.037 afdrdum2 \\ & - 1.151 \ln tsfa - 0.021 lu1 - 0.452 lu43 + 0.020 lu4 + 0.052 lu5 + 0.029 lu6 + 0.059 lu8 \\ & + 0.193 yd2 + 0.282 yd3 + 0.024 yd5 + 0.041 yd6 + 0.071 yd7 + 0.079 yd8\end{aligned}$$

$$\begin{aligned}\ln tv = {} & 13.822 - 0.0004 X_1 + 0.358 X_2 - 0.315 X_3 + 0.068 X_4 + 0.037 X_5 - 1.151 X_6 \\ & - 0.021 X_7 - 0.452 lX_8 + 0.020 X_9 + 0.052 X_{10} + 0.029 lX11 + 0.059 lX_{12} + 0.193 X_{13} \\ & + 0.282 X_{14} + 0.024 X_{15} + 0.041 X_{16} + 0.071 X_{17} + 0.079 X_{18}\end{aligned}$$

- **Addison –** The most efficient FE model developed by this study for property value for Addison is the following and its algebraic form respectively, repeated here for effect.

$$\ln tv = 16.529 - 0.041age + 0.097afd - 0.140ndhwy + 0.082afdrdum1 - 0.052afdrdum2$$
$$- 0.850\ln tsfa - 0.176lu1 - 0.350lu2 + 3.323lu4 - 1.022lu6 - 0.016lu8$$
$$+ 0.044yd1 + 0.020yd3 + 0.027yd5 + 0.365yd6 + 0.461yd8$$

$$\ln tv = 16.529 - 0.0041X_1 + 0.097X_2 - 0.140X_3 + 0.082X_4 - 0.0527X_5 - 0.8501X_6$$
$$- 0.176X_7 - 0.350X_8 + 3.323X_9 - 1.022X_{10} - 0.016X11 + 0.044lX_{12} + 0.020X_{13}$$
$$+ 0.027X_{14} + 0.365X_{15} + 0.461X_{16}$$

- **Richardson –** The most efficient FE model for property value for Richardson is the following and its algebraic form respectively, repeated here for effect.

$$\text{lntvpa} = 10.829 + 0.016\text{age} + 0.066\text{lndhwy} - 0.978\text{lntsfa} - 0.036\text{lu4} + 0.077lu5$$
$$+ 0.138lu7 - 0.173yd1 - 0.056d1yd2 + -0.057yd3 - 0.057yd4$$
$$- 0.021yd5 - 0.008yd6 + 0.015yd7 + 0.021yd8 - 0.163rd1yd3$$
$$- 0.190rd1yd4 - 0.242rd1yd5 - 0.117rd1yd6$$

$$\text{lntvpa} = 10.829 + 0.016_1 + 0.066X_2 - 0.978X_3 - 0.036X_4 + 0.077X_5$$
$$+ 0.138X_6 - 0.173X_7 - 0.056X_8 + -0.056X_9 - 0.056X_{10}$$
$$- 0.021X_{11} - 0.008X_{12} + 0.015X_{13} + 0.021X_{14} - 0.163X_{15} \quad .$$
$$- 0.190X_{16} - 0.242X_{17} - 0.117X_{18}$$

4) What other variables beyond those in this study may be important in TOD valuation?

According to the literature (e.g., 164), the influence range of other land values is one variable beyond those in the study that may be important for TOD valuation. Cross-corridor access as parameterized by a parcel's corner location is another. Relative locations of signalized intersections and dissimilarity indices are among other variables that could be playing a role in determining land values. The number of bedrooms, other characteristics of the interior that speak to quality of life (e.g., number of bathrooms,) sustainable energy and green fittings, etc., are among other variables that could be playing a role in determining improved values. Together, these set of variables may be contributing to the total landed property valuation. While the error term takes these into account, it does not show the degree to which they impact TOD property valuations. These variables could be included, but they may not be easy to obtain, and the study sites may not have enough examples of them to appropriately value their impact.

5) **What attribute (i.e., variable) of TOD contributes the most to property valuation?**

Factors of TODs that have the most significant effect on property values cannot be assessed for lack of data for more infrastructure sites with different improvements.

6) **How valued is holding property before or after TOD policy at the project sites?**

The impact analysis results indicate that the two TOD sites, which are in suburban areas, have several impacts on the surrounding areas. Many important conclusions can be drawn from this analysis, including the following:

a) A mixed-use project in a suburban area appears to create a new center at the project site; however, most impacts may not affect the outer rings.
b) Based on the results, some variables show that there are sustainable project impacts, with the extent and magnitude appearing to be determined at the two sites by individual characteristics. For example, population and employment densities increase in Addison. However, this may be due to the smaller area of Addison. In any case, there is no way to determine whether employees live on site without a survey to specifically obtain this information. If people live and work within the TOD project, VMT decreases. Rent discount policy implementation may encourage employees to live within the site.
c) The database has some coding errors, which limit the accuracy of data analysis. To improve future analysis, these errors need to be removed or substantially reduced.
d) Disaggregate modeling is used to assess property values at the local level. The Plano FE model shows much promise in transferability to other sites. Limited data collation including a few more projects and a possible ex-ante-assessment is recommended.
e) For Ring A and Ring B, the closer the parcel is to the center of the development the higher the property value. This is true of Plano and Addison and not Richardson.
f) The larger the improvement the higher the property value, which is expected.
g) The impact of the freeway (measured by parcel proximity to the facility) is negative as expected. However, the impact is small, even though it is statistically highly significant

in the case of Plano. In the case of Addison, the impact is miniscule and statistically insignificant. This indicates that the closer a property value drops faster near a freeway.

h) The proximity to the center of the development effect is significant in both Plano and Addison. In the case of Plano, the closer a property is to the center of the TOD within the ¼-mile cordon, the higher its value rises relative to property values in Ring C. The difference is as much as 6.8%, which is considerable, given that many properties are in the seven figure value range. This positive impact continues as one moves away from the TOD center within the ½-mile cordon. In this region, property values increase by 3.7% relative to properties outside of this cordon and in the 1-mile cordon and beyond.

i) The generation of models depending on land value or the improved value as dependent variables requires a complete set of data on improvement and land value, which are now not available. The existing data lacks accurate and adequate improved value and land value for most of the parcels in this study. Investigating then as dependent variables is also left for future research.

j) The distance used in this research is the air (Euclidian) distance between the center of each parcel and the center of the development. The use of the actual (Manhattan) distance along the network requires creating a network for each site. This is outside the scope of this study. Besides, it is doubtful whether the Manhattan distance provides better accuracy in the impact of the variable. GIS with network analysis capability and special functions is recommended for future research of this issue.

k) For better tracking of temporal changes, a complete set of time series data is required. An efficient GIS database development is required and must be an ongoing evaluation program. It could revise data for the variables proposed by this study and add others.

7) Does land value respond to TOD factors of SD?

The significant factors that impact land values are not examined due to the lack of historical land value data. Consequently the total property values are analyzed instead of land values. Our analysis shows that total property (including both land and improvement) values are highly susceptible to sustainable development investments. As seen, average land values at Plano Ring A have increased in the period following the policy after-year as defined in previous sections. The same is true of Addison Ring A. The growth rates in Rings A and B in both cases are measured relative to Ring C as the reference cordon. In both cases, the closer you get to the center of the TOD, the higher rises your total property value rate. This is not the case for Richardson, which does not have an SD policy in place in the form of a TOD, even though it has both bus and light rail transit services.

8) How does proximity from the center of a TOD influence property valuation?

On the average, property in Plano and Addison, increase in value relative to properties 1-mile away as they get closer to the CBD of each TOD, in particular, within the ¼-mile cordons. The impact, while consistently positive for Plano ½-mile cordon, is not significant for Addison. However, even there, any negative impact is insignificant. The positive impacts of proximity in the first cases, are statistically highly significant. This analysis is only true with the FE models, and is not true for the no-policy Richardson.

9) How does proximity of TOD to a highway influence property valuation?

On the average, property in Plano and Addison, reduce in value relative to properties 1-mile away as they get closer to a freeway from each TOD. The impact is negative for both Plano and Addison. Richardson shows a positive coefficient for freeway proximity.

10) Can an econometric model for PV be formulated when TOD is present?

The answer to this question is yes. Both Plano and Addison have best-fitted models with good certeris paribus causal-effect among variables.

5.2.2 Conclusions from Specific Hypotheses

An objective of this study, in the specific cases of Plano and Addison is to test the hypothesis developed from the premise that TODs with light-rail and bus combined or bus-only transit services have equal positive and negative impacts on sustainability, moderated by property valuation with Downtown Richardson as the control site. The alternative hypothesis is that TODs as SD policy instruments have more positive impacts on property values in Plano and Addison than non-policy neighborhoods.

The null for this main hypothesis is rejected. It is therefore concluded that there is sufficient statistical evidence to infer that the alternative hypothesis is true. That is, it can be concluded that TODs as SD policy instruments have more positive impacts on property values in Plano and Addison than non-policy neighborhoods. This is made manifest by the model estimation showing positive the unconditional *policy-after-year* (afd) parameters for both Plano and Addison. For Plano, afd is 36.8% (p-value = 0.00) and for Addison, afd is 8.7% (p-value = 0.00). The conditional cordon dummy interactions (*afdrdum1*) for the impact in the ¼-mile radius from each TOD center also show positive parameters for the years since policy implementation. For Plano, afdrdum1 is 5.8% (p-value = 0.00) and for Addison, afdrdum1 is 9.2% (p-value = 0.107). Note also that "near the center" in this study is defined as property location within ¼-mile radius of a cordon around the center of the project site. The distance measure is Euclidean.

<u>Proposition 1:</u>

H_0: It is posited that the change in property values in a bus-light rail transit TOD is the same in a ¼-mile radius cordon as property values beyond ¼-mile radius cordon.

H_a: The change in property values in a bus-light rail transit TOD is higher in a ¼-mile radius.

Reject the null and conclude that there is statistical evidence to infer that the alternative hypothesis is true. That is, the change in property values in a bus-light rail combination transit TOD is higher in a ¼-mile radius. For Plano, afdrdum1 (6.8%) > afdrdum2 (3.7%).

<u>Proposition 2:</u>

H_0: It is posited that in a bus-only transit TOD, the change in property values in a ¼-mile radius cordon is the same as it is beyond the ¼-mile radius buffer.

H_a: In a bus-only transit TOD, the change in property values in a ¼-mile radius cordon is higher than it is beyond the ¼-mile radius buffer.

Reject the null. Conclude that in a bus-only transit TOD, the change in property values in a ¼-mile radius cordon is higher than it is beyond the ¼-mile radius buffer. For ATC, afdrdum1 (8.2%) > afdrdum2 (-5.2%).

Proposition 3:

H_0: It is posited that the rise in property values in a TOD in the *"before-policy-years"* is equal to the rise in the property values in the *"after-policy-years."*

H_a: The rise in property values in the *"after-policy-years"* of a TOD is higher than the rise in property values in the *"before-policy-years."*

Reject the null. Conclude that there is sufficient statistical evidence to infer that the alternative hypothesis is true. That is, the rise in property values in the *"after-policy-years"* of a TOD is higher than the rise in property values in the *"before-policy-years."* This is evident in the fact that *afd* for Plano is 36.8% (p-value = 0.00); and *afd* for Addison is 9.7% (p-value = 0.00). That is, both are positive and statistically highly significant.

Proposition 4:

H_0: It is posited that the rise in property values in a ¼-mile radius cordon of a bus-only service TOD is the same as the rise in property values in a ¼-mile radius cordon of a light-rail and bus transit service non-policy neighborhood.

H_a: The rise in property values in a ¼-mile radius cordon of a bus-only service TOD is higher than the rise in property values in a ¼-mile radius cordon of a light-rail and bus transit service non-policy neighborhood.

Reject the null. Conclude that there is statistical evidence to infer that the alternative hypothesis is true. The *afdrdum1* is 8.2% (p-value = 0.153) and *afd* is 9.7% (p-value = 0.00). Both are positive for Addison. For Richardson, the interaction terms of the ¼-mile cordon and the year dummies for the first four years of the period under analysis are all negative. These include rd1yd1 (-16.3%, p-value = 0.095); rd1yd4 (-19.0%, p-value = 0.038); rd1yd5 (-24.2%, p-value = 0.006); and rd1yd6 (-11.7%, p-value = 0.174). This is an indication that without a policy, Richardson shows negative property values in the ¼-mile radius cordon.

Proposition 5:

H_0: It is posited that the rise in property values in a ¼-mile radius cordon of a light-rail and bus combined transit service TOD is equal to the rise in property values in a ¼-mile radius of a light-rail and bus combined transit service non-policy settlement.

H_a: The rise in property values in a ¼-mile radius cordon of a light-rail and bus combined transit service TOD is higher than property values in a ¼-mile radius of a light-rail and bus combined transit service non-policy settlement.

Reject the null and conclude that there is statistical evidence to infer that the alternative hypothesis is true. The *afdrdum1* coefficient for Plano is 6.8% (p-value = 0.000), showing that the after-policy-years showed a highly statistically significant rise in property values. For Richardson, the ¼-mile cordon shows very high reductions in property values in most years in the analysis period. These include rd1yd1 (-16.3%, p-value = 0.095); rd1yd4 (-19.0%, p-value = 0.038); rd1yd5 (-24.2%, p-value = 0.006); and rd1yd6 (-11.7%, p-value = 0.174). This means that without a policy, Richardson shows negative property values in the ¼-mile radius cordon.

Proposition 6:

H_0: It is posited that the drop in TOD property values of properties nearer a highway is equal to the drop in property values for properties relatively farther away from the same highway.

H_a: The drop in TOD property values of properties nearer a highway is higher than the drop in property values for properties relatively farther away from the same highway.

Reject the Null in favor of the alternative and conclude that properties nearer a highway fall faster than when the properties are relatively farther away from a highway: lndhwy for Plano is (-0.32%, p-value = 0.00); and lndhwy for Addison is (-0.14%, p-value = 0.275). That is, the impact of distance to a highway is negative in both instances, with the impact statistically highly significant and more negative for Plano than for Addison. The Addison impact is much smaller and statistically insignificant. This is because the TOD center is less than a ¼-mile from the Dallas North Tollway (DNT). In effect, the impact of the DNT on the TOD and property values may be reasonably viewed as statistically uniformly insignificant.

5.3 Recommendations

Several studies (e.g., 161, 165) suggest that any attempt to assess changes in socioeconomic development requires some definition of variables (or indicators). According to Godfrey and Todd (165), the relevance of indicators lies in their ability to pivot and densify the huge intricacies of the “dynamic environment” to a convenient intensity of relevant information. Indicators, observed Warhurst (2002), should help simplify complex information about any system. Singh et al. (2009) recognize that this need is now too obvious. Decision makers and other stakeholders must create measures of effectiveness and models that provide metrics to convey magnitude and direction of current activities in the context of sustainability.

What is conspicuously missing from the literature, however, is the development of SD indicators specifically for LUT interactions impact assessment at the micro-level. Development of a comprehensive list of sorts for SD analysis indicators and variables is recommended. Such a list needs to be free from the vagueness and indeterminacy typical of such indicators at the macro-level. This list would be very useful for certeris-paribus causal-effect micro-level analysis.

While changing travel behavior is one of the key reasons for “sustainable” development, this aspect is outside the scope of this methodology. This is due to the lack of suitable data and funds for collecting the additional data requirements. Such data may include the AADT associated with each particular site. Beyond changes in AADT, the research framework focuses on temporal and spatial changes in land use within project sites and vicinity. While this initial effort relies on ex-post facto analysis, future studies could complete several ex-post facto analyses to permit an ex-ante evaluation for the sake of completeness. The broader question “Does travel with the automobile in fact drop with the relatively new urban (TOD) design, is also left to subsequent studies. With time, and in a follow-up, the developments in this phase could be compared with conventional late-twentieth-century suburbs. This could be based on patterns of form, land use and transportation (including pedcycle and transit access). Other variables to look at in subsequent phases could include the relationship of the two study TODs to existing major urban areas in the DFW metropolis. Issues of livability could be probed for different demographic groups in the region.

Land use and transportation (LUT) are not mutually exclusive but are rather intimately interdependent and integral. They therefore, need to be modeled in an integrated whole, which is a rather difficult exercise. One problem is that land use and transportation are planned separately and have distinctive disciplinary jargons that are hard to reconcile. The more serious problem is that much of the research efforts and finances for LUT are concentrated at the macro-level. At this level, complex mathematical equations are the norm. These are often intractable for the planning technician, or require special technical training. The equations are typically separate for land use and transportation and generally require a bridging set of equations. This makes their use at the micro-scale expensive and lack efficacy. The framework and models in this study present an inexpensive and efficacious process for micro-level. It facilitates the assessment of LUT at the micro-level in general. At the same time, it permits the assessment of the impact of TOD policy on property valuation in particular. The process is flexibility enough so that variables can be added to the models as data becomes available.

The rational for the analytical framework and the choice of modeling structure suggested by this study has been explained. Statistically, fixed effects (FE) structures are always reasonable to fit to panel data, as they always furnish consistent results. However, they may not produce the most efficient model fit to a dataset. Random effects (RE) always give better *p*-values because they are a more efficient estimator. It is prudent to use RE if it can be justified statistically. The Hausman test checks a more efficient model against the advantage in running a less efficient but consistent model form. This is to make sure that the more efficient model also leads to the more efficient choice that at the same time furnishes consistent results.

For this reason, the Hausman test is recommended before making a choice between FE and RE. It makes life that much easier for the planner.

The main task of this study is to create a standardized methodology and a model to analyze the impacts on property valuation of TOD (transportation investment) projects funded by NCTCOG. TODs are SD policies designs. The socioeconomic and spatiotemporal quality of the project sites are considered to determine factors that distinguish “sustainable” developments from “non-sustainable” developments relative to a TOD as an SD policy. While changing travel behavior is one of the key factors for SD, this aspect is outside the scope of this methodology due to insufficient data. Changing travel behavior is left for future research efforts.

With data collation, the Plano and Addison FE models can reasonably be transferred to TODs of similar characteristics in North-Central Texas. When unobserved variables matter, the models are flexible enough that they can be adapted to similar neighborhoods in other regions. With suitable modifications they are transferable to similar neighborhoods for assessment of SD policy investment impact on property valuation. In general, their applicability at the micro-level is recommended when LUT interactions impact on property valuations are moderated by the presence of the appropriate TOD policy. This transfer is limited to bus-only and light-rail and bus combined transit service TODs. Further research is needed to assess the possible adaptation of the framework to assess TODs with other modes (e.g., rapid transit, high-speed rail, etc.).

More public-private partnerships for TODs may come about in North-Central Texas because of the enabling aura of a new simple but effective assessment method. Developers and financiers always seek to lower investments risks or to know what those risks are. It is hoped that this research could abate investor risk aversions for TODs in the region. A show of positive impacts of TODs on property valuation, at the minimum, evokes an aura of a higher quality of life than non-policy neighborhoods. This portrayal is better than the USEPA’s non-attainment of ozone designation for much of the region. It could attract more interest in TODs.

5.4 Summary

In summary, this chapter presents the explanations and conclusions for much of the rational for the conceptual and modeling framework. Results of hypothesis testing are presented here, where it is shown that the main proposition of the study shows TOD policy to have positive impacts on property values in north-central Texas. Other propositions concluded to be accepted on clear statistical evidence include the following:

- The nearer property is to a TOD center the higher the increase in total property value.
- The nearer property in a TOD is to a highway, the faster drops the total property value.

These findings have been shown in this chapter to be so significant that one can reasonably conclude that the Plano FE and Addison models are very good fits for Plano and Addison respectively. The chapter also shows a theoretically simple but sound way that TODs have positive impacts on property valuation. In this regard, it is argued how they have the potential for attracting more federal aid for SD policy projects in the form of TODs.

APPENDIX A

PLANO MODEL COMPUTATIONS

Table A-1 Plano Selected Variable Statistics

Variable	Mean	Std. Dev.	Min	Max	Observations
lntvpa overall	13.0781	0.5303	8.3304	17.2433	N = 17139
between		0.5319	8.8006	16.6616	n = 2288
within		0.1984	10.8939	16.3154	T-bar = 7.491
age overall	34.6856	22.8928	-3.0000	2006.0000	N = 17139
between		17.9630	-0.2500	250.7500	n = 2288
within		15.1387	-216.0644	1789.9360	T-bar = 7.491
rd1 overall	0.0792	0.2701	0.0000	1.0000	N = 17139
between		0.2686	0.0000	1.0000	n = 2288
within		0.0000	0.0792	0.0792	T-bar = 7.491
rd2 overall	0.2518	0.4340	0.0000	1.0000	N = 17139
between		0.4383	0.0000	1.0000	n = 2288
within		0.0000	0.2518	0.2518	T-bar = 7.491
afd overall	0.6271	0.4836	0.0000	1.0000	N = 17139
between		0.1033	0.0000	1.0000	n = 2288
within		0.4789	-0.2300	1.3771	T-bar = 7.491
lndhwy overall	8.0880	0.7663	4.6022	8.9443	N = 17139
between		0.7875	5.0280	8.9435	n = 2288
within		0.0557	6.1543	8.4325	T-bar = 7.491
afdrdum1 overall	0.0501	0.2181	0.0000	1.0000	N = 17139
between		0.1722	0.0000	1.0000	n = 2288
within		0.1341	-0.8071	0.8001	T-bar = 7.491
afdrdum2 overall	0.1593	0.3660	0.0000	1.0000	N = 17139
between		0.2941	0.0000	1.0000	n = 2288
within		0.2384	-0.6740	0.9093	T-bar = 7.491

Table A-1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
lntsfa overall	-1.3161	0.8605	-3.4899	3.1560	N = 17139
between		0.9001	-3.3958	3.1559	n = 2288
within		0.0404	-3.8474	-0.4938	T-bar = 7.491
lu1 overall	0.7314	0.4433	0.0000	1.0000	N = 17139
between		0.4447	0.0000	1.0000	n = 2288
within		0.0803	-0.1436	1.6064	T-bar = 7.491
lu3 overall	0.0020	0.0445	0.0000	1.0000	N = 17139
between		0.0514	0.0000	0.8571	n = 2288
within		0.0262	-0.8552	0.6020	T-bar = 7.491
lu4 overall	0.0136	0.1158	0.0000	1.0000	N = 17139
between		0.1160	0.0000	1.0000	n = 2288
within		0.0124	-0.3614	0.7636	T-bar = 7.491
lu5 overall	0.0125	0.1110	0.0000	1.0000	N = 17139
between		0.1063	0.0000	1.0000	n = 2288
within		0.0198	-0.7375	0.7625	T-bar = 7.491
lu6 overall	0.0217	0.1457	0.0000	1.0000	N = 17139
between		0.1305	0.0000	1.0000	n = 2288
within		0.0921	-0.8354	0.8967	T-bar = 7.491
lu8 overall	0.0002	0.0153	0.0000	1.0000	N = 17139
between		0.0092	0.0000	0.3333	n = 2288
within		0.0127	-0.3331	0.7145	T-bar = 7.491
yd2 overall	0.1248	0.3305	0.0000	1.0000	N = 17139
between		0.0355	0.0000	0.3333	n = 2288
within		0.3297	-0.2085	1.0137	T-bar = 7.491

Table A-1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
yd3 overall	0.1259	0.3317	0.0000	1.0000	N = 17139
between		0.0475	0.0000	1.0000	n = 2288
within		0.3307	-0.3741	1.0147	T-bar = 7.491
yd5 overall	0.1277	0.3338	0.0000	1.0000	N = 17139
between		0.0469	0.0000	1.0000	n = 2288
within		0.3327	-0.3723	1.0166	T-bar = 7.491
yd6 overall	0.1283	0.3344	0.0000	1.0000	N = 17139
between		0.0484	0.0000	1.0000	n = 2288
within		0.3332	-0.3717	1.0172	T-bar = 7.491
yd7 overall	0.0272	0.1628	0.0000	1.0000	N = 17139
between		0.0547	0.0000	0.5000	n = 2288
within		0.1544	-0.4728	0.9161	T-bar = 7.491
yd8 overall	0.1303	0.3367	0.0000	1.0000	N = 17139
between		0.1163	0.0000	1.0000	n = 2288
within		0.3329	-0.3697	1.0192	T-bar = 7.491

Table A–2 Sample Data Collected: Plano 2003, Propid = 741

Variable	Variable Description	Label	Value	Unit
Y	Total value	tvpa	352510.00	US dollars/acre
X_1	Land value	lvpa	145107.00	US dollars/acre
X_2	Improved value	ivpa	207403.00	US dollars/acre
X_3	Property area	tsf	31739.27	Sq. ft.
X_4	Distance to Hwy	dhwy	1249.19	Feet
X_5	Distance to center	dch	2506.05	Feet
X_6	Land Use	*sluc	0 or 1	none
X_7	Year assessed	year	2003	none
X_8	Year was property built	ybuilt	1974	none
X_9	property age	age	29	years
Note: *SLUC = State land use code; GEOID = R-0007-001-00A0-1				

Table A–3 Number of Parcels in Plano Cordons

rdum	*Frequency[12]	Percent	Cumulative
1 = Ring A	1,358	7.92	7.92
2 = Ring B	4,315	25.18	33.10
3 = Ring C	11,466	66.90	100
Total	17,139	100	

Table A–4 Number of Parcels by Year in the Plano Sample

year	Freq.	Percent	Cum.
1999	2,095	12.22	12.22
2001	2,139	12.48	24.7
2002	2,157	12.59	37.29
2003	2,159	12.6	49.89
2005	2,189	12.77	62.66
2006	2,199	12.83	75.49
2007	467	2.72	78.21
2008	2,234	13.03	91.25
2009	1,500	8.75	100
Total	17,139	100	

[12] Note: * Frequency = number of individual parcels or individual property counts in each ring.

Table A–5 Plano Panel Data Structure

Freq.	Percent	Cum.	Pattern
1120	48.95	48.95	1.111.11.11
504	22.03	70.98	1.111.11.1.
293	12.81	83.78	1.111.11111
136	5.94	89.73	1.111.1111.
33	1.44	91.17	.........1.
25	1.09	92.26	......11.1.
18	0.79	93.05	..111.11.11
15	0.66	93.71	11
14	0.61	94.32	1.111.11...
130	5.68	100	(other patterns)
2288	100		X.XXX.XXXXX

Table A–6 Hierarchy of Plano Variables[13]

p < *pe(n)*	Begin	with empty model
p = 0.0000 < 0.1000	adding	lu1
p = 0.0000 < 0.1000	adding	afd
p = 0.0000 < 0.1000	adding	age
p = 0.0000 < 0.1000	adding	rd2
p = 0.0000 < 0.1000	adding	lntsfa
p = 0.0000 < 0.1000	adding	lu5
p = 0.0000 < 0.1000	adding	yd3
p = 0.0000 < 0.1000	adding	yd2
p = 0.0000 < 0.1000	adding	yd4
p = 0.0000 < 0.1000	adding	lu4
p = 0.0000 < 0.1000	adding	lndhwy
p = 0.0000 < 0.1000	adding	rd1
p = 0.0000 < 0.1000	adding	afdrdum2
p = 0.0000 < 0.1000	adding	yd5
p = 0.0001 < 0.1000	adding	afdrdum1
p = 0.0001 < 0.1000	adding	lu6
p = 0.0033 < 0.1000	adding	yd6
p = 0.0305 < 0.1000	adding	lu3

[13] pe = p-value; n = significance level = 0.10 for Plano, i.e., at 90% confidence level.

Table A–7 Plano Model Variance Inflation Factor

Variable	VIF	1/VIF
afd	5.11	0.1955
afdrdum2	3.15	0.3170
rd1	2.99	0.3341
afdrdum1	2.88	0.3468
rd2	2.84	0.3516
lu1	2.42	0.4132
yd8	2.17	0.4613
yd6	2.16	0.4630
yd5	2.15	0.4652
yd4	2.14	0.4669
lntsfa	1.92	0.5216
yd3	1.78	0.5621
yd2	1.77	0.5645
lndhwy	1.36	0.7377
yd7	1.28	0.7836
lu5	1.15	0.8658
age	1.13	0.8883
lu6	1.10	0.9052
lu4	1.08	0.9297
lu3	1.03	0.9690
lu8	1.00	0.9980
Mean VIF	2.03	

Note: Tolerance = 1/VIF

Table A–8 Plano Hausman Specification Test Computation – FE

Fixed-effects (within) regression — Number of obs = 17139
Group variable: propid — Number of groups = 2288

R-sq: within = 0.5339 — Obs per group: min = 1
between = 0.0000 — avg = 7.5
overall = 0.0000 — max = 9
F(18,14833) = 943.86
corr(u_i, Xb) = -0.8770 — Prob > F = 0.0000

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0003674	.0000746	-4.92	0.000	-.0005137	-.0002212
afd	.3578179	.0045199	79.16	0.000	.3489583	.3666775
lndhwy	-.3147221	.0211255	-14.90	0.000	-.3561307	-.2733135
afdrdum1	.0684562	.0087694	7.81	0.000	.0512671	.0856453
afdrdum2	.0373782	.0054679	6.84	0.000	.0266603	.048096
lntsfa	-1.151074	.0275578	-41.77	0.000	-1.205091	-1.097058
lu1	-.0210585	.0149107	-1.41	0.158	-.0502853	.0081682
lu3	-.4520272	.0438677	-10.30	0.000	-.5380134	-.366041
lu4	.0204381	.0899032	0.23	0.820	-.1557833	.1966596
lu5	.0523741	.05667	0.92	0.355	-.0587061	.1634543
lu6	.0287569	.0127504	2.26	0.024	.0037645	.0537494
lu8	.0588315	.0879128	0.67	0.503	-.1134884	.2311514
yd2	.1931253	.0046296	41.72	0.000	.1840508	.2021999
yd3	.2823109	.0046283	61.00	0.000	.273239	.2913829
yd5	.0239869	.0039696	6.04	0.000	.0162061	.0317678
yd6	.0413563	.0039691	10.42	0.000	.0335764	.0491362
yd7	.0707489	.0075252	9.40	0.000	.0559985	.0854993
yd8	.0794573	.0039683	20.02	0.000	.0716789	.0872356
_cons	13.82208	.1752924	78.85	0.000	13.47849	14.16568
sigma_u	1.1128022					
sigma_e	.14560997					
rho	.98316654	(fraction of variance due to u_i)				

F test that all u_i=0: F(2287, 14833) = 66.08 Prob > F = 0.0000

Table A–9 Plano Hausman Specification Test Computation – RE

Random-effects GLS regression		Number of obs	= 17139
Group variable: propid		Number of groups	= 2288
R-sq: within	= 0.4923	Obs per group: min	= 1
between	= 0.0645	avg	= 7.5
overall	= 0.1074	max	= 9
		Wald chi2(20)	= 14007.63
corr(u_i, X)	= 0 (assumed)	Prob > chi2	= 0.0000

lntvpa	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	-.0006052	.0000785	-7.71	0.000	-.0007591	-.0004513
rd1	-.0431365	.0381196	-1.13	0.258	-.1178496	.0315766
rd2	-.2770032	.023316	-11.88	0.000	-.3227017	-.2313046
afd	.3501251	.0046677	75.01	0.000	.3409765	.3592737
lndhwy	-.1545622	.0114541	-13.49	0.000	-.1770118	-.1321127
afdrdum1	.0740012	.0093095	7.95	0.000	.0557549	.0922474
afdrdum2	.0463681	.0058017	7.99	0.000	.0349969	.0577393
lntsfa	-.2334823	.0112681	-20.72	0.000	-.2555674	-.2113973
lu1	-.1655761	.0141937	-11.67	0.000	-.1933952	-.1377571
lu3	-.4370024	.0452465	-9.66	0.000	-.5256839	-.3483209
lu4	.4155412	.0641372	6.48	0.000	.2898346	.5412478
lu5	-.1148695	.0509397	-2.26	0.024	-.2147094	-.0150296
lu6	.0004245	.0132782	0.03	0.974	-.0256003	.0264494
lu8	.0123551	.0930098	0.13	0.894	-.1699408	.194651
yd2	.1869867	.0048034	38.93	0.000	.1775722	.1964012
yd3	.2763205	.0048015	57.55	0.000	.2669098	.2857312
yd5	.0238042	.0042167	5.65	0.000	.0155397	.0320687
yd6	.0425431	.0042155	10.09	0.000	.0342809	.0508054
yd7	.0743192	.0079882	9.30	0.000	.0586625	.0899758
yd8	.0830627	.0042125	19.72	0.000	.0748063	.0913191
_cons	13.92859	.0897097	155.26	0.000	13.75276	14.10441
sigma_u	.43665842					
sigma_e	.14560997					
rho	.8999293	(fraction of variance due to u_i)				

Table A–10 Plano Hausman Specification Test Computation: Coefficients Comparison

	---- Coefficients ----			
	(b) fixed	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
age	-.0003674	-.0006052	.0002378	.
afd	.3578179	.3501251	.0076928	.
lndhwy	-.3147221	-.1545622	-.1601599	.0177508
afdrdum1	.0684562	.0740012	-.005545	.
afdrdum2	.0373782	.0463681	-.0089899	.
lntsfa	-1.151074	-.2334823	-.9175919	.0251488
lu1	-.0210585	-.1655761	.1445176	.0045681
lu3	-.4520272	-.4370024	-.0150248	.
lu4	.0204381	.4155412	-.3951031	.063
lu5	.0523741	-.1148695	.1672436	.0248322
lu6	.0287569	.0004245	.0283324	.
lu8	.0588315	.0123551	.0464764	.
yd2	.1931253	.1869867	.0061386	.
yd3	.2823109	.2763205	.0059905	.
yd5	.0239869	.0238042	.0001828	.
yd6	.0413563	.0425431	-.0011868	.
yd7	.0707489	.0743192	-.0035703	.
yd8	.0794573	.0830627	-.0036055	.

Table A–11 Plano Breusch-Pagan Test for Heteroskedasticity

Source	SS	df	MS
Model	1315.93391	21	62.6635194
Residual	3504.44662	17117	.204734861
Total	4820.38053	17138	.281268557

Number of obs	= 17139
F(21, 17117)	= 306.07
Prob > F	= 0.0000
R-squared	= 0.2730
Adj R-squared	= 0.2721
Root MSE	= .45248

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0050521	.0001602	-31.54	0.000	-.0053661	-.0047381
rd1	-.1470923	.0221387	-6.64	0.000	-.1904865	-.1036981
rd2	-.3032387	.0134296	-22.58	0.000	-.329562	-.2769153
afd	.4342493	.0161643	26.86	0.000	.4025656	.465933
lndhwy	.043383	.0052509	8.26	0.000	.0330906	.0536754
afdrdum1	.1095738	.0269134	4.07	0.000	.0568208	.1623267
afdrdum2	.08525	.0167725	5.08	0.000	.0523742	.1181259
lntsfa	-.1632589	.005562	-29.35	0.000	-.1741609	-.1523569
lu1	-.4963038	.0121302	-40.91	0.000	-.5200802	-.4725274
lu3	.1674765	.0789106	2.12	0.034	.0128037	.3221493
lu4	.3087922	.0309539	9.98	0.000	.2481194	.369465
lu5	-.6595323	.03345	-19.72	0.000	-.7250978	-.5939668
lu6	.1050424	.0249298	4.21	0.000	.0561775	.1539073
lu8	.1406608	.2264968	0.62	0.535	-.3032961	.5846178
yd2	.1822967	.0139187	13.10	0.000	.1550147	.2095787
yd3	.2771672	.0138984	19.94	0.000	.249925	.3044094
yd4	-.1273725	.0152431	-8.36	0.000	-.1572505	-.0974946
yd5	-.046236	.0151812	-3.05	0.002	-.0759927	-.0164793
yd6	-.0190326	.0151887	-1.25	0.210	-.048804	.0107388
yd7	.024727	.0239821	1.03	0.303	-.0222804	.0717344
yd8	.0245843	.0151145	1.63	0.104	-.0050415	.0542102
_cons	12.81146	.0410406	312.17	0.000	12.73101	12.8919

APPENDIX B

ADDISON MODEL COMPUTATIONS

Table B–1 Addison Selected Variable Statistics

Variable	Mean	Std. Dev.	Min	Max	Observations
lntvpa overall	13.5725	1.7809	3.2361	18.1167	N = 20763
between		2.1552	3.2361	17.0579	n = 4501
within		0.6459	3.8025	20.1361	T-bar = 4. 613
age overall	20.4580	10.4200	0.0000	97.0000	N = 20763
between		9.8109	0.0000	93.3333	n = 4501
within		3.0482	0.4580	44.0830	T-bar = 4. 613
rd1 overall	0.0517	0.2214	0.0000	1.0000	N = 20763
between		0.2371	0.0000	1.0000	n = 4501
within		0.0000	0.0517	0.0517	T-bar = 4. 613
rd2 overall	0.1696	0.3753	0.0000	1.0000	N = 20763
between		0.3553	0.0000	1.0000	n = 4501
within		0.0000	0.1696	0.1696	T-bar = 4. 613
afd overall	0.7384	0.4395	0.0000	1.0000	N = 20763
between		0.1470	0.6000	1.0000	n = 4501
within		0.4276	-0.1188	1.1384	T-bar = 4. 613
lndhwy overall	7.3684	0.9513	5.0562	8.8188	N = 20763
between		0.8580	5.0562	8.8188	n = 4501
within		0.1426	4.9455	9.5328	T-bar = 4. 613
afdrdum1 overall	0.0385	0.1924	0.0000	1.0000	N = 20763
between		0.2046	0.0000	1.0000	n = 4501
within		0.0964	-0.7115	0.4385	T-bar = 4. 613
afdrdum2 overall	0.1189	0.3237	0.0000	1.0000	N = 20763
between		0.2684	0.0000	1.0000	n = 4501
within		0.1856	-0.7382	0.5189	T-bar = 4. 613

Table B–1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
lntsfa overall	1.4954	2.4983	-5.8144	5.9062	N = 20763
between		2.0563	-4.8699	5.9062	n = 4501
within		0.4876	-1.6519	8.0596	T-bar = 4. 613
lu1 overall	0.0257	0.1583	0.0000	1.0000	N = 20763
between		0.1385	0.0000	1.0000	n = 4501
within		0.0409	-0.8493	0.9007	T-bar = 4. 613
lu2 overall	0.0665	0.2492	0.0000	1.0000	N = 20763
between		0.1966	0.0000	1.0000	n = 4501
within		0.0730	-0.7906	0.9237	T-bar = 4. 613
lu4 overall	0.0148	0.1209	0.0000	1.0000	N = 20763
between		0.1052	0.0000	1.0000	n = 4501
within		0.0229	-0.8602	0.8482	T-bar = 4. 613
lu6 overall	0.0638	0.2443	0.0000	1.0000	N = 20763
between		0.2000	0.0000	1.0000	n = 4501
within		0.0912	-0.8112	0.9388	T-bar = 4. 613
lu8 overall	0.0010	0.0318	0.0000	1.0000	N = 20763
between		0.0224	0.0000	0.8571	n = 4501
within		0.0157	-0.8561	0.2867	T-bar = 4. 613
yd1 overall	0.1277	0.3338	0.0000	1.0000	N = 20763
between		0.0815	0.0000	0.2500	n = 4501
within		0.3275	-0.1223	1.0027	T-bar = 4. 613
yd3 overall	0.0613	0.2399	0.0000	1.0000	N = 20763
between		0.0644	0.0000	0.2000	n = 4501
within		0.2293	-0.1387	0.9363	T-bar = 4. 613

Table B–1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
yd5 overall	0.1486	0.3557	0.0000	1.0000	N = 20763
between		0.0852	0.0000	0.5000	n = 4501
within		0.3519	-0.3514	1.0236	T-bar = 4. 613
yd6 overall	0.1495	0.3566	0.0000	1.0000	N = 20763
between		0.0875	0.0000	0.5000	n = 4501
within		0.3527	-0.3505	1.0245	T-bar = 4.613
yd8 overall	0.1428	0.3499	0.0000	1.0000	N = 20763
between		0.1794	0.0000	1.0000	n = 4501
within		0.3371	-0.3572	1.0178	T-bar = 4.612

Table B–2 Number of Parcels in the Addison Cordons

rdum	*Frequency	Percent	Cumulative
1 = Ring A	1,073	5.17	5.2
2 = Ring B	3,522	16.96	22.1
3 = Ring C	16,168	77.87	100
Total	20763	100	

Table B–3 Number of Parcels by Year in the Addison Sample

year	Dummies	Freq.	Percent	Cum.
2003	yd1	2,652	12.77	12.8
2004	yd2	2,780	13.39	26.2
2005	yd3	1,273	6.13	32.3
2006	yd4	2,989	14.4	46.7
2007	yd5	3,085	14.86	61.6
2008	yd6	3,105	14.95	76.5
2009	yd7	1,914	9.22	85.7
2010	yd8	2,965	14.28	100
Total		20,763	100	

Table B-4 Addison Panel Data Structure

Frequency	Percent	Cum.	Pattern
1233	27.39	27.39	......1.
1093	24.28	51.68	11.111.1
901	20.02	71.70	111111.1
290	6.44	78.14	11.11111
239	5.31	83.45	0.1111111
144	3.20	86.65	1
141	3.13	89.78	1..111..
106	2.36	92.14	11.111..
81	1.80	93.93	11111111
273	6.07	100	other patterns
4501	100		XXXXXXXX

Table B-5 Addison Model Variance Inflation Factor

Variable	VIF	1/VIF
rd1	4.17	0.239775
afdrdum1	4.03	0.248254
rd2	3.85	0.259711
afdrdum2	3.67	0.272178
afd	2.59	0.386045
age	2.08	0.480215
lu2	2.05	0.487068
lntsfa	1.84	0.544275
yd1	1.72	0.582487
lu6	1.57	0.637081
lndhwy	1.44	0.69489
yd8	1.42	0.704723
yd6	1.4	0.713136
yd5	1.4	0.716119
yd3	1.23	0.809943
lu4	1.12	0.894521
lu1	1.12	0.895967
lu8	1.02	0.984506
Mean VIF	2.1	

Table B-6 Hierarchy of Addison Variables

pe(n) < 0.1000	**Begin**	**with empty model**
p = 0.0000 < 0.1000	adding	rd2
p = 0.0000 < 0.1000	adding	lndhwy
p = 0.0000 < 0.1000	adding	lntsfa
p = 0.0000 < 0.1000	adding	lu6
p = 0.0000 < 0.1000	adding	age
p = 0.0000 < 0.1000	adding	yd8
p = 0.0000 < 0.1000	adding	yd6
p = 0.0000 < 0.1000	adding	yd5
p = 0.0000 < 0.1000	adding	afd
p = 0.0000 < 0.1000	adding	yd3
p = 0.0000 < 0.1000	adding	lu4
p = 0.0000 < 0.1000	adding	rd1
p = 0.0000 < 0.1000	adding	lu8
p = 0.0000 < 0.1000	adding	lu1
p = 0.0000 < 0.1000	adding	lu2
p = 0.0019 < 0.1000	adding	yd1
p = 0.0049 < 0.1000	adding	afdrdum2

Table B-7 Addison Hausman Specification Test Computation – FE

Fixed-effects (within) regression — Number of obs = 20763
Group variable: propid — Number of groups = 4501

R-sq: within = 0.4541 — Obs per group: min = 1
between = 0.1377 — avg = 4.6
overall = 0.1887 — max = 8

F(16,16246) = 844.67
corr(u_i, Xb) = -0.7121 — Prob > F = 0.0000

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0413659	.0020273	-20.40	0.000	-.0453395	-.0373922
rd1	(omitted)					
rd2	(omitted)					
afd	.097387	.0154539	6.30	0.000	.0670956	.1276784
lndhwy	-.1401574	.0287792	-4.87	0.000	-.1965679	-.083747
afdrdum1	.0817818	.040224	2.03	0.042	.0029384	.1606252
afdrdum2	-.0515175	.0225906	-2.28	0.023	-.0957975	-.0072374
lntsfa	-.8495737	.0168862	-50.31	0.000	-.8826724	-.816475
lu1	-.176409	.102465	-1.72	0.085	-.3772517	.0244338
lu2	-.350454	.1001999	-3.50	0.000	-.5468569	-.1540511
lu4	3.322591	.1644029	20.21	0.000	3.000343	3.644838
lu6	-1.02194	.0570573	-17.91	0.000	-1.133778	-.9101011
lu8	-.0160236	.2462331	-0.07	0.948	-.4986675	.4666204
yd1	.0437252	.0148799	2.94	0.003	.014559	.0728914
yd3	.0198903	.018623	1.07	0.286	-.0166129	.0563936
yd5	.2704068	.0135849	19.90	0.000	.2437789	.2970347
yd6	.3645065	.0138377	26.34	0.000	.337383	.3916299
yd8	.4612546	.0162971	28.30	0.000	.4293104	.4931987
_cons	16.52942	.2229754	74.13	0.000	16.09236	16.96648
sigma_u	2.3109031					
sigma_e	.53952447					
rho	.9483097	(fraction of variance due to u_i)				

F test that all u_i=0: F(4500, 16246) = 21.60 Prob > F = 0.0000

Table B-8 Addison Hausman Specification Test Computation – RE

Random-effects GLS regression — Number of obs = 20763
Group variable: propid — Number of groups = 4501

R-sq: within = 0.3162 — Obs per group: min = 1
between = 0.3921 — avg = 4.6
overall = 0.3562 — max = 8

Wald chi2(18) = 11020.43
corr(u_i, X) = 0 (assumed) — Prob > chi2 = 0.0000

lntvpa	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	-.0265203	.001631	-16.26	0.000	-.0297171	-.0233236
rd1	.1754395	.0861803	2.04	0.042	.0065292	.3443498
rd2	1.526781	.0532187	28.69	0.000	1.422474	1.631088
afd	-.4121956	.0207064	-19.91	0.000	-.4527794	-.3716118
lndhwy	-.1539815	.017822	-8.64	0.000	-.1889119	-.1190511
afdrdum1	.0035927	.0565295	0.06	0.949	-.1072031	.1143884
afdrdum2	.0274674	.0318898	0.86	0.389	-.0350355	.0899702
lntsfa	-.2586549	.0085698	-30.18	0.000	-.2754515	-.2418583
lu1	.4660847	.089189	5.23	0.000	.2912775	.6408919
lu2	1.472358	.0727002	20.25	0.000	1.329868	1.614848
lu4	2.106161	.1242855	16.95	0.000	1.862566	2.349756
lu6	-.9233487	.0554394	-16.66	0.000	-1.032008	-.8146895
lu8	-.1089068	.3044336	-0.36	0.721	-.7055857	.4877721
yd1	.070377	.0209624	3.36	0.001	.0292914	.1114626
yd3	.4915315	.0257738	19.07	0.000	.4410158	.5420471
yd5	.7306563	.0186124	39.26	0.000	.6941767	.7671358
yd6	.808014	.0186957	43.22	0.000	.771371	.8446569
yd8	.8784661	.0201171	43.67	0.000	.8390373	.917895
_cons	14.79664	.1336089	110.75	0.000	14.53478	15.05851
sigma_u	.66775081					
sigma_e	.53952447					
rho	.60502657	(fraction of variance due to u_i)				

Table B-9 Addison Hausman Specification Test Computation: Coefficients Comparison

	---- Coefficients ----			
	(b) fixed	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
age	-.0413659	-.0265203	-.0148456	.001204
afd	.097387	-.4121956	.5095826	.
lndhwy	-.1401574	-.1539815	.0138241	.0225969
afdrdum1	.0817818	.0035927	.0781892	.
afdrdum2	-.0515175	.0274674	-.0789848	.
lntsfa	-.8495737	-.2586549	-.5909188	.0145499
lu1	-.176409	.4660847	-.6424936	.0504421
lu2	-.350454	1.472358	-1.822812	.0689544
lu4	3.322591	2.106161	1.21643	.1076171
lu6	-1.02194	-.9233487	-.0985909	.0134911
lu8	-.0160236	-.1089068	.0928833	.
yd1	.0437252	.070377	-.0266518	.
yd3	.0198903	.4915315	-.4716411	.
yd5	.2704068	.7306563	-.4602495	.
yd6	.3645065	.808014	-.4435075	.
yd8	.4612546	.8784661	-.4172116	.

Table B-10 Addison Breusch-Pagan Test for Heteroskedasticity

Source	SS	df	MS
Model	32819.3472	18	1823.29706
Residual	33026.1838	20744	1.59208368
Total	65845.5309	20762	3.17144451

Number of obs =	20763
F(18, 20744) =	1145.23
Prob > F =	0.0000
R-squared =	0.4984
Adj R-squared =	0.4980
Root MSE =	1.2618

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.023473	.0012127	-19.36	0.000	-.02585	-.0210959
rd1	.6741901	.0807799	8.35	0.000	.5158551	.832525
rd2	.8001579	.0457833	17.48	0.000	.710419	.8898968
afd	-1.224078	.032066	-38.17	0.000	-1.28693	-1.161226
lndhwy	-.5185937	.0110427	-46.96	0.000	-.5402382	-.4969491
afdrdum1	-.0561872	.0913655	-0.61	0.539	-.2352708	.1228965
afdrdum2	.1415551	.0518546	2.73	0.006	.0399161	.2431941
lntsfa	-.1748628	.0047511	-36.80	0.000	-.1841754	-.1655502
lu1	.5704751	.0584419	9.76	0.000	.4559244	.6850257
lu2	.4386635	.0503544	8.71	0.000	.339965	.5373621
lu4	1.130222	.0765874	14.76	0.000	.9801049	1.28034
lu6	-2.560337	.0449004	-57.02	0.000	-2.648345	-2.472328
lu8	-2.236261	.2776411	-8.05	0.000	-2.780459	-1.692062
yd1	.1083621	.0343737	3.15	0.002	.0409869	.1757374
yd3	1.130283	.0405584	27.87	0.000	1.050785	1.209781
yd5	1.472941	.0290932	50.63	0.000	1.415916	1.529965
yd6	1.533719	.0290764	52.75	0.000	1.476728	1.590711
yd8	1.592675	.029814	53.42	0.000	1.534238	1.651113
_cons	18.20016	.0847595	214.73	0.000	18.03403	18.3663

APPENDIX C

RICHARDSON MODEL COMPUTATIONS

Table C–1 Richardson Selected Variable Statistics

Variable	Mean	Std. Dev.	Min	Max	Observations
lntvpa overall	13.192	0.5316544	4.652024	15.90921	N = 21288
between		0.5397782	4.706199	15.57325	n = 2430
within		0.1585532	11.58291	19.7839	T-bar = 8.760
age overall	39.214	12.81718	0	67	N = 21288
between		12.99188	0	63	n = 2430
within		2.752328	1.103047	66.99194	T-bar = 8.760
rd1 overall	0.0076	0.0869043	0	1	N = 21288
between		0.0925787	0	1	n = 2430
within		0	0.0076099	0.0076099	T-bar = 8.760
rd2 overall	0.1055	0.3072108	0	1	N = 21288
between		0.3086476	0	1	n = 2430
within		0	0.1055054	0.1055054	T-bar = 8.760
lndhwy overall	7.7618	0.6921032	4.748933	8.686998	N = 21288
between		0.702604	4.748933	8.686998	n = 2430
within		0.0201809	6.689399	8.96726	T-bar = 8.760
lntsfa overall	-1.2491	0.9323846	-3.833798	3.315938	N = 21288
between		0.9959292	-3.833798	3.315938	n = 2430
within		0.0228152	-2.317448	-0.7277255	T-bar = 8.760
lu2 overall	0	0	0	0	N = 21288
between		0	0	0	n = 2430
within		0	0	0	T-bar = 8.760
lu4 overall	0.0052	0.0716992	0	1	N = 21288
between		0.0715744	0	1	n = 2430
within		0.0230598	-0.4392772	0.8801672	T-bar = 8.760
lu5 overall	0.0335	0.1800461	0	1	N = 21288
between		0.1750469	0	1	n = 2430
within		0.035246	-0.8553489	0.9224289	T-bar = 8.760

Table C–1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
lu7 overall	0.1579	0.3646833	0	1	N = 21288
between		0.3668866	0	1	n = 2430
within		0.0576153	-0.7309595	1.046818	T-bar = 8.760
yd1 overall	0.1105	0.3135004	0	1	N = 21288
between		0.057857	0	1	n = 2430
within		0.3126478	-0.1395152	0.9993737	T-bar = 8.760
yd2 overall	0.1109	0.3139668	0	1	N = 21288
between		0.0195169	0	0.25	n = 2430
within		0.3137497	-0.1391394	0.9997495	T-bar = 8.760
yd3 overall	0.1111	0.3142577	0	1	N = 21288
between		0.0189754	0	0.25	n = 2430
within		0.3140673	-0.1389045	0.9999843	T-bar = 8.760
yd4 overall	0.1115	0.3147802	0	1	N = 21288
between		0.0187759	0	0.3333333	n = 2430
within		0.3146121	-0.2218151	1.000407	T-bar = 8.760
yd5 overall	0.1077	0.3100252	0	1	N = 21288
between		0.0284364	0	0.5	n = 2430
within		0.3092198	-0.3922867	0.9966022	T-bar = 8.760
yd6 overall	0.1121	0.3154746	0	1	N = 21288
between		0.0269656	0	1	n = 2430
within		0.3152349	-0.3879181	1.000971	T-bar = 8.760
yd7 overall	0.1121	0.3154746	0	1	N = 21288
between		0.0413584	0	1	n = 2430
within		0.3150262	-0.2212514	1.000971	T-bar = 8.760
yd8 overall	0.1120	0.3153591	0	1	N = 21288
between		0.0351175	0	1	n = 2430
within		0.3148824	-0.388012	1.000877	T-bar = 8.760

Table C–1 – *Continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
rd1yd3 overall	0.0007	0.026536	0	1	N = 21288
between		0.0087045	0	0.1111111	n = 2430
within		0.0250272	-0.1104065	0.8895935	T-bar = 8.760
rd1yd4 overall	0.0008	0.0282484	0	1	N = 21288
between		0.0099214	0	0.1666667	n = 2430
within		0.0265453	-0.1658681	0.8896875	T-bar = 8.760
rd1yd5 overall	0.0009	0.0298625	0	1	N = 21288
between		0.0114486	0	0.2	n = 2430
within		0.0279252	-0.1991075	0.8897814	T-bar = 8.760
rd1yd6 overall	0.0009	0.0306375	0	1	N = 21288
between		0.0125135	0	0.25	n = 2430
within		0.0285491	-0.2490605	0.8898284	T-bar = 8.760

Table C-2 Number of Parcels in Addison Cordons

rdum	Ring	Frequency	Percent	Cum.
1	A	162	0.76	0.76
2	B	2,246	10.55	11.31
3	C	18,880	88.69	100
Total		21,288	100	

Table C-3 Number of Parcel by Year in the Richardson Sample

year	* Frequency	Percent	Cum.
2001	2,352	11.05	11.05
2002	2,360	11.09	22.13
2003	2,365	11.11	33.24
2004	2,374	11.15	44.40
2005	2,293	10.77	55.17
2006	2,386	11.21	66.38
2007	2,386	11.21	77.58
2008	2,384	11.20	88.78
2009	2,388	11.22	100.00
Total	21,288	100.00	

Table C-4 Richardson Data Panel Structure [14]

Frequency	Percent	Cumulative	Pattern
2236	92.02	92.02	111111111
87	3.58	95.6	1111.1111
16	0.66	96.26	1
10	0.41	96.67	0.11111111
9	0.37	97.04	1........
8	0.33	97.37	11
7	0.29	97.65	11111
7	0.29	97.94	11111111.
6	0.25	98.19	...111111
44	1.81	100	other patterns
n = 2430	100		XXXXXXXXX

[14] propid*year uniquely identifies each observation; n = 2430; T = 9;

year: 2001, 2002, ..., 2009; Δ(year) = 1 unit; Span(year) = 9 periods

Table C-5 Richardson Model Variance Inflation Factor

Variable	VIF	1/VIF
lntsfa	2.40	0.416
lu7	2.24	0.446
rd1	1.85	0.540
yd1	1.81	0.551
yd2	1.81	0.554
yd3	1.80	0.554
yd4	1.80	0.556
yd6	1.79	0.558
yd7	1.78	0.562
yd8	1.78	0.563
yd5	1.77	0.565
age	1.45	0.691
lndhwy	1.34	0.746
rd1yd6	1.23	0.814
rd1yd5	1.22	0.821
rd2	1.21	0.829
rd1yd4	1.19	0.837
rd1yd3	1.17	0.853
lu4	1.06	0.943
lu5	1.01	0.991
Mean VIF	1.59	

Table C-6 Hierarchy of Richardson Variables

pe(n) < 0.2000	**Begin**	**with empty model**
p = 0.0000 < 0.2000	adding	lu7
p = 0.0000 < 0.2000	adding	lntsfa
p = 0.0000 < 0.2000	adding	rd2
p = 0.0000 < 0.2000	adding	yd1
p = 0.0000 < 0.2000	adding	rd1
p = 0.0000 < 0.2000	adding	lu4
p = 0.0000 < 0.2000	adding	yd2
p = 0.0000 < 0.2000	adding	yd3
p = 0.0000 < 0.2000	adding	yd4
p = 0.0000 < 0.2000	adding	age
p = 0.0000 < 0.2000	adding	yd5
p = 0.0000 < 0.2000	adding	lndhwy
p = 0.0000 < 0.2000	adding	yd6
p = 0.0353 < 0.2000	adding	lu5
p = 0.0408 < 0.2000	adding	yd7
p = 0.1251 < 0.2000	adding	rd1yd4
p = 0.1461 < 0.2000	adding	rd1yd5
p = 0.1495 < 0.2000	adding	rd1yd3

Table C-7 Richardson Hausman Specification Test Computation – FE

Fixed-effects (within) regression — Number of obs = 21288

Group variable: propid — Number of groups = 2430

R-sq: within = 0.3867 — Obs per group: min = 1

between = 0.0207 — avg = 8.8

overall = 0.0205 — max = 9

F(18,18840) = 659.91

corr(u_i, Xb) = -0.8777 — Prob > F = 0.0000

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	.0164329	.000717	22.92	0.000	.0150276	.0178382
lndhwy	.065862	.0448808	1.47	0.142	-.0221085	.1538324
lntsfa	-.9776625	.0396819	-24.64	0.000	-1.055443	-.8998824
lu4	-.0358942	.041377	-0.87	0.386	-.1169968	.0452084
lu5	.0772309	.0273416	2.82	0.005	.0236388	.1308229
lu7	.1377717	.0173227	7.95	0.000	.1038176	.1717258
yd1	-.172609	.0066747	-25.86	0.000	-.1856921	-.1595259
yd2	-.0556828	.006119	-9.10	0.000	-.0676766	-.043689
yd3	-.0565898	.0056035	-10.10	0.000	-.0675731	-.0456065
yd4	-.0565616	.0051168	-11.05	0.000	-.0665911	-.0465321
yd5	-.0210859	.0047276	-4.46	0.000	-.0303524	-.0118193
yd6	-.0079166	.0043306	-1.83	0.068	-.016405	.0005718
yd7	.0150785	.0040598	3.71	0.000	.0071209	.0230361
yd8	.0213436	.0038919	5.48	0.000	.0137151	.028972
rd1yd3	-.1630911	.0372486	-4.38	0.000	-.2361017	-.0900805
rd1yd4	-.1897858	.0352767	-5.38	0.000	-.2589313	-.1206403
rd1yd5	-.2421043	.0336107	-7.20	0.000	-.3079842	-.1762244
rd1yd6	-.1168728	.0328532	-3.56	0.000	-.1812681	-.0524775
_cons	10.82878	.3542459	30.57	0.000	10.13443	11.52314
sigma_u	1.1333776					
sigma_e	.13198757					
rho	.98661968	(fraction of variance due to u_i)				

F test that all u_i=0: F(2429, 18840) = 105.68 Prob > F = 0.0000

Table C-8 Richardson Hausman Specification Test Computation – RE

Random-effects GLS regression — Number of obs = 21288
Group variable: propid — Number of groups = 2430

R-sq: within = 0.3653 — Obs per group: min = 1
between = 0.0944 — avg = 8.8
overall = 0.1047 — max = 9
Wald chi2(20) = 10952.77
corr(u_i, X) = 0 (assumed) — Prob > chi2 = 0.0000

lntvpa	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	.0075958	.0005669	13.40	0.000	.0064847	.008707
rd1	-.5682382	.1105528	-5.14	0.000	-.7849177	-.3515586
rd2	-.3300924	.0343246	-9.62	0.000	-.3973674	-.2628175
lndhwy	-.0653073	.0147968	-4.41	0.000	-.0943084	-.0363061
lntsfa	-.1457535	.0112833	-12.92	0.000	-.1678682	-.1236387
lu4	.1165838	.0403738	2.89	0.004	.0374526	.195715
lu5	.1207459	.0249458	4.84	0.000	.071853	.1696387
lu7	.291302	.0158969	18.32	0.000	.2601447	.3224593
yd1	-.239397	.0058421	-40.98	0.000	-.2508474	-.2279466
yd2	-.1145286	.0054451	-21.03	0.000	-.1252007	-.1038565
yd3	-.106858	.0050886	-21.00	0.000	-.1168314	-.0968845
yd4	-.0981622	.0047571	-20.63	0.000	-.107486	-.0888384
yd5	-.0545524	.0045125	-12.09	0.000	-.0633966	-.0457081
yd6	-.032427	.0042407	-7.65	0.000	-.0407387	-.0241153
yd7	-.0013873	.0040658	-0.34	0.733	-.0093562	.0065816
yd8	.0130704	.0039614	3.30	0.001	.0053062	.0208345
rd1yd3	-.1551696	.0381599	-4.07	0.000	-.2299617	-.0803775
rd1yd4	-.1827621	.0361398	-5.06	0.000	-.2535948	-.1119294
rd1yd5	-.2366883	.034435	-6.87	0.000	-.3041796	-.1691969
rd1yd6	-.1139857	.0336602	-3.39	0.001	-.1799585	-.0480129
_cons	13.28259	.1166276	113.89	0.000	13.054	13.51118
sigma_u	.47335726					
sigma_e	.13198757					
rho	.92786088	(fraction of variance due to u_i)				

Table C-9 Richardson Hausman Specification Test Computation: Coefficients Comparison

---- Coefficients ----

	(b) fixed	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
age	.0164329	.0075958	.0088371	.0004389
lndhwy	.065862	-.0653073	.1311692	.0423715
lntsfa	-.9776625	-.1457535	-.831909	.038044
lu4	-.0358942	.1165838	-.152478	.0090559
lu5	.0772309	.1207459	-.043515	.0111926
lu7	.1377717	.291302	-.1535303	.0068823
yd1	-.172609	-.239397	.066788	.0032282
yd2	-.0556828	-.1145286	.0588458	.0027917
yd3	-.0565898	-.106858	.0502682	.0023463
yd4	-.0565616	-.0981622	.0416006	.0018846
yd5	-.0210859	-.0545524	.0334665	.0014099
yd6	-.0079166	-.032427	.0245104	.0008777
yd7	.0150785	-.0013873	.0164658	.
yd8	.0213436	.0130704	.0082732	.
rd1yd3	-.1630911	-.1551696	-.0079215	.
rd1yd4	-.1897858	-.1827621	-.0070237	.
rd1yd5	-.2421043	-.2366883	-.0054161	.
rd1yd6	-.1168728	-.1139857	-.002887	.

Table C-10 Richardson Breusch-Pagan Test Heteroskedasticity

Source	SS	df	MS
Model	1216.83044	20	60.8415219
Residual	4800.07622	21267	.225705375
Total	6016.90666	21287	.282656394

Number of obs	21288
F(20, 21267)	269.56
Prob > F	0.0000
R-squared	0.2022
Adj R-squared	0.2015
Root MSE	.47508

lntvpa	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0026552	.0003056	-8.69	0.000	-.0032542	-.0020563
rd1	-.5106011	.0509978	-10.01	0.000	-.6105606	-.4106416
rd2	-.1905648	.0116441	-16.37	0.000	-.2133881	-.1677415
lndhwy	.0306394	.0054463	5.63	0.000	.0199642	.0413147
lntsfa	-.2834959	.0054143	-52.36	0.000	-.2941083	-.2728834
lu2	(omitted)					
lu4	.7494624	.0467568	16.03	0.000	.6578154	.8411093
lu5	-.0382949	.0181675	-2.11	0.035	-.0739046	-.0026853
lu7	.7274636	.0133773	54.38	0.000	.7012431	.7536841
yd1	-.3189879	.0139906	-22.80	0.000	-.3464106	-.2915652
yd2	-.1889767	.0139339	-13.56	0.000	-.2162881	-.1616653
yd3	-.1704389	.0139157	-12.25	0.000	-.1977148	-.1431631
yd4	-.1526066	.0138742	-11.00	0.000	-.1798011	-.1254121
yd5	-.0965418	.0139721	-6.91	0.000	-.1239282	-.0691553
yd6	-.0673262	.013814	-4.87	0.000	-.0944026	-.0402498
yd7	-.0241806	.0137637	-1.76	0.079	-.0511585	.0027973
yd8	.0003895	.0137578	0.03	0.977	-.0265768	.0273559
rd1yd3	-.1943427	.1328283	-1.46	0.143	-.4546962	.0660109
rd1yd4	-.2377125	.1259884	-1.89	0.059	-.4846593	.0092343
rd1yd5	-.1985056	.1203268	-1.65	0.099	-.4343551	.037344
rd1yd6	-.0297139	.1178157	-0.25	0.801	-.2606415	.2012137
_cons	12.72423	.0466574	272.72	0.000	12.63278	12.81568

Note: lu2 omitted because of collinearity

APPENDIX D

MODEL COMPARISONS

Table D–1 Selected Variables for all Project Sites[15]

Variable Name	Storage Type	Display Format	Variable Description
propid	long	%8.0g	Property ID
ownid	long	%8.0g	Owner ID
taxid	str13	%13s	Tax ID
geoid	str17	%17s	GIS ID
year	int	%8.0g	appraisal year
ybuilt	int	%8.0g	year built
age	int	%8.0g	age of property
tt	byte	%8.0g	time trend
tv	long	%8.0g	total value (dep. Var.)
lv	long	%8.0g	land value
iv	long	%8.0g	improved value
tsf	float	%8.0g	total area (sq. ft)
isf	double	%8.0g	improved area (sq. ft)
dhwy	float	%8.0g	distance to nearest frwy.
dcd	float	%8.0g	distance to center of dev
x	float	%8.0g	x-coordinate
y	float	%8.0g	y-coordinate
shape	str7	%9s	polygon shape (GIS)
shapel	float	%8.0g	polygon shape length
shapea	float	%8.0g	polygon shape area
oname	str70	%70s	property owner name
oadd	str61	%61s	property owner address
ocity	str20	%20s	property owner city
ostate	str2	%9s	property owner state
sitadd	str25	%25s	property owner address
sitcity	str5	%9s	property owner city
legdes	str88	%88s	legal description
ludesc	str25	%25s	land use description
sluco	str3	%9s	state land use code
sluc	str2	%9s	land use code
srn	int	%8.0g	random number
rdum	float	%9.0g	Cordon dummies
rd1	byte	%8.0g	rdum== 1
rd2	byte	%8.0g	rdum== 2
rd3	byte	%8.0g	rdum== 3
yd1	byte	%8.0g	year== 1999
yd2	byte	%8.0g	year== 2001
yd3	byte	%8.0g	year== 2002
yd4	byte	%8.0g	year== 2003

[15] * afd = policy-year-after proxy dummy variable: **afdrdum1 = afd x rdum1; ***afdrdum2 = afd x rdum2; afdrdum3 = afd x rdum3 (reference ring C). Richardson has no policy and no afd.

Table D–1 – *Continued*

Variable Name	Storage Type	Display Format	Variable Description
yd5	byte	%8.0g	year== 2005
yd6	byte	%8.0g	year== 2006
yd7	byte	%8.0g	year== 2007
yd8	byte	%8.0g	year== 2008
yd9	byte	%8.0g	year== 2009
*afd	float	%9.0g	after-policy-year
tsfa	float	%9.0g	total area (acres)
isfa	float	%9.0g	improved area (acres)
tvpa	float	%9.0g	total value per acre
ivpa	float	%9.0g	improved area (acres)
lvpa	float	%9.0g	land value per acre
lntv	float	%9.0g	log(total value)
lniv	float	%9.0g	log(improved value)
lnlv	float	%9.0g	log(land value)
lntvpa	float	%9.0g	log(total prop value/acre)
lnivpa	float	%9.0g	log(improved value/acre)
lnlvpa	float	%9.0g	log(land value/acre)
lntsfa	float	%9.0g	log(total acres)
lnisfa	float	%9.0g	log(improved acres)
**afdrdum1	float	%9.0g	afd x rdum1
***afdrdum2	float	%9.0g	afd x rdum2
****afdrdum3	float	%9.0g	afd x rdum3
lntsf	float	%9.0g	log(total area in sq. ft)
lndhwy	float	%9.0g	log(distance to FRWY)
luse1	long	%8.0g	Land use coding
lu1	float	%9.0g	Single family
lu2	float	%9.0g	Res. mobile homes
lu3	float	%9.0g	Res. condominiums
lu4	float	%9.0g	Multi-family
lu5	float	%9.0g	Duplex
lu6	float	%9.0g	Vacant lots
lu7	float	%9.0g	Commercial
lu8	float	%9.0g	Farm-Ranch

Note: Total number of variables: Plano = Addison = 73; and Richardson = 69.

Table D–2 Data Availability

Site	Years											
	1999	2000	01	02	03	04	05	06	07	08	09	10
Plano	√	X	√	√	√	X	√	√	√	√	√	X
Addison	X	X	X	X	√	√	√	√	√	√	√	√
Richardson	X	X	√	√	√	√	√	√	√	√	√	X

Note: Plano = Plano Transit Village; Addison = Addison Town Center; Richardson = Downtown Richardson; √ = data available; X = data unavailable

Table D–3 Selected Test Results for Plano and Addison

Test	Plano	Addison	Richardson
Hausman	RN	RN	RN
Breusch-Pagan	RN	RN	RN

Note: RN = reject the null; and FTR = fail to reject the null

Table D–4 Comparison of Selected Statistics for Plano and Addison

Statistic	PTV FE Robust	ATC FE Robust
R-squared	0.534	0.454
Adj. R-squared	0.533	0.454
N	17139	20763
Rho	0.983	0.948
RMSE	0.136	0.477

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BIOGRAPHICAL INFORMATION

The author earned his Bachelor of Science in Civil Engineering in 1983 at the West Virginia University, in Morgantown USA. He then worked in the Ministry of Works of Sierra Leone on a World Bank/IMF/Government of Sierra Leone funded highways rehabilitation project from 1984 to 1986 as a graduate engineer, and as a team leader in Bridges and Ferries rehabilitation within the interim. He became an Executive Engineer from 1986 to 1989 with responsibility for one of 12 engineering districts in Sierra Leone as District Engineer. Dr. Smith was a German DAAD scholar from 1989 to 1991 when he earned his Master in Infrastrukturplannung from the Universitaat Stuttgart, Germany. The State of Oregon Parks and Recreation and Department of Transportation employed him from 1993 to 1996 as an Engineering Specialist. He worked for the Texas Department of Transportation as an Engineering Assistant and later promoted to Engineer (IV) and Project and Permits Manager from 1996 to 2000. He earned his Professional Engineer license from Oregon in 1997 and from Texas in 2000. In the private sector, Dr. Smith worked for ACE Consultants in Austin, Texas between 2001 and 2003. He then took a position in DMJM-Harris as a Discipline Engineer-Manager between 2003 and 2005 on a 1.2 billion dollar project. In a consulting role, he worked for Earth-Tech on a $500 million transportation project as proprietor of a consulting firm, Godi Global Services and Consulting Engineers, Inc. (GGSCE), between 2001 and 2005. He entered the University of Idaho, where he received a Master of Engineering (MEngr.) in Engineering Management in 2005. He then promptly enrolled in the University of Texas at Arlington (UTA) from where he received a Master of Science in Civil Engineering (MSCE) in August of 2007, before pursuing his PhD in civil engineering (Transportation) at UTA. Since the spring of 2003, the author has owned and managed a civil Engineering Consultancy (GGSCE) from his base in Denton, Texas. Dr. Smith is married and has three grandchildren.