RESEARCH ON RELATIONSHIPS BETWEEN TRANSPORTATION INFRASTRUCTURE & INCREASES IN VEHICLE MILES TRAVELED: THE EFFECTS OF HIGHWAY CAPACITY EXPANSION ON LAND DEVELOPMENT

Final Technical Report for the U.S. Environmental Protection Agency

by

Center for Transportation Research, The University of Texas at Austin

Dr. Kara M. Kockelman
Department of Civil Engineering, The University of Texas at Austin
Campus Mail Code C1761, Austin, Texas 78712, Tel: (512) 471-0210, Fax: (512) 475-8744
Email: kkockelm@mail.utexas.edu

Brian ten Siethoff, M.S.C.E.
Department of Civil Engineering, The University of Texas at Austin
Campus Mail Code C1761, Austin, Texas 78712, Tel: (512) 232-4252, Fax: (512) 475-8744
Email: bsiethoff@yahoo.com

Dr. C. Michael Walton
Department of Civil Engineering, The University of Texas at Austin
Campus Mail Code C1761, Austin, Texas 78712, Tel: (512) 471-1414, Fax: (512) 471-4995
Email: cmwalton@mail.utexas.edu

Dr. Hani S. Mahmassani
Department of Civil Engineering, The University of Texas at Austin
Campus Mail Code C1761, Austin, Texas 78712, Tel: (512) 475-6361, Fax: (512) 471-0592
Email: masmah@mail.utexas.edu

Acknowledgements

This research was partially funded by a grant from the U.S. Environmental Protection Agency for a study of induced demand. Additional support came from the Advanced Institute for Transportation Research at the Center for Transportation Research, an affiliate of The University of Texas at Austin.

Monique Stinson assisted with data collection; Siva Srinivasan and Karthik Srinivasan helped with model specification and interpretation.

Special thanks to Steve Ross, Ben Heimsath, Charles Heimsath, and Bob Liverman for taking time out of their busy schedules for interviews. Steve Colman, Lewison Lem, Bob Noland, Mike Hansen, Robert Cervero, Patricia Moktarian, and Marlon Boanet gave help and advice along the way.

The Effects of Highway Capacity Expansion on Land Development

Abstract

Recent research has yielded evidence that freeway capacity expansions may generate, or induce, demand for travel that did not exist prior to the expansion. The phenomenon of induced demand has important implications for congestion and air quality. This paper presents a three-pronged approach to understanding the impacts of capacity expansions on development by examining capacity expansions and land development in Austin, Texas. First, nine years of building permit data are analyzed. Second, seventeen years of tax assessment records for parcels along an improved highway are studied. Third, four real estate professionals with diverse perspectives of the land markets were interviewed, and the findings from these conversations are presented.

Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

Recent research has yielded evidence that freeway capacity expansions may generate, or induce, demand for travel that did not exist prior to the expansion. The phenomenon of induced demand has important policy implications. Municipalities faced with scarce resources can only afford to fund the most necessary and beneficial projects in a region. Those projects adding to network congestion are probably not cost-efficient, yet planners have not been able to accurately project traffic flows, in large part due to the unknown effects of induced demand. In addition, the conditions of the National Environmental Policy Act (NEPA) prohibit additional highway capacity in areas that no longer attain air quality standards, and the U.S. Environmental Protection Agency requires non-attainment areas to prove that new highway capacity will not worsen regional air pollution, as induced traffic may.

While many studies have attempted to prove by various methods that induced demand does indeed exist (see, e.g., Hansen and Huang, 1997; Noland and Cowart, 1999; and Fulton et al., 2000) few have attempted to study the impacts of capacity expansions on land use in this context. Changes in land use are expected to accompany significant shifts in travel options; therefore, an understanding of land use-transportation interactions is an essential part of appreciating induced demand. This is particularly true if one defines induced demand as totally new demand rather than time-, mode-, route-, or destination-shifted demand (DeCorla-Souza, 2000).

This paper presents a three-pronged approach to understanding the impacts of capacity expansions on development by examining data in the Austin, Texas, metropolitan area. First, building permit data over a period of nine years is analyzed to determine if added highway capacity altered development patterns. Second, seventeen years of tax assessment records for parcels in a rapidly developing corridor are studied to gauge the effects of a major capacity expansion on surrounding real estate values. Third, four real estate professionals with diverse perspectives of the Austin land market were interviewed, and the most interesting findings of these conversations are presented here.

1.1 Study Objectives

The objective of this research is to determine the effects of highway capacity expansions on development. Specifically, the effects of improvements in transportation infrastructure on the timing and location of developments is examined here.

1.2 Overview

The five remaining chapters all analyze the effects of highway capacity expansions on development from different perspectives. A literature review discussing basic land use-transportation interactions is presented in the first chapter, along with an introduction to induced demand and its implications. A time-series regression analysis of city-wide permitting data is then performed in order to determine whether development patterns shifted in response to two major facility expansions. Next, a similar analysis of tax assessment data for parcels in a corridor that underwent significant improvement is presented. Finally, the results of a survey of four real estate professionals are discussed, prior to the summary and conclusions.

CHAPTER 2: LITERATURE REVIEW

Travel is a derived demand, created as a result of the interaction between land use patterns and transportation systems. Modifications to the transportation system may lead to changes in land use and travel behavior. It has been hypothesized that totally new travel might be "induced" by transportation system improvements over time.

This chapter introduces several basic land use and location theories and describes how transportation and land use are related. Induced demand, a much-debated issue, is introduced and defined, and its implications for transportation and land use policy are discussed briefly below.

2.1 Economic Theories of Land Use and Location

Location theory has its roots in Von Thünen's (1826) classic work, which studied the relationship between agricultural land allocation, distance to commodities markets, and prices of agricultural goods. Von Thünen was among the first to establish a connection between land price and distance from a commercial center, arguing that the cost of transporting commodities to markets determines the rents that farmers and other producers can afford to pay, and how far from a market the farmer can afford to buy land.

The classical model of industrial location, developed by Weber (1929), requires a minimization of transport costs for both inputs and outputs, given an optimal level of production. Weber's model of industrial location assumes that transport costs are linearly related to distance, and uses simple geometry to determine the location of a production facility.

Christaller (1933) and Lösch (1940) took different approaches to explain the geometric and hierarchical arrangement of market areas with their central place theories. At the root of these theories was the idea that transportation infrastructure determines the market area of an activity center and the uses of the land surrounding the center. In addition, central place theory allowed for the multi-centered regions that best represent today's conurbations, and it suggested a minimization of transport costs.

Alonso (1964) analyzed the economics of land use in a modern urban area. Since the late 1800's the shift from an agricultural to a more city-centered economy has led to an even more complex relationship between land rents and transportation costs. Alonso argued that the travel time, travel cost, and accessibility are not the only determinants of land rent; quality of schools, perceived safety, and other noneconomic factors may have equal or greater influences on land values. Thus, in an analysis of the effects of transportation improvements on land values, he said, these noneconomic factors must be taken into account.

Giuliano (1986) discussed the development of employment subcenters in suburban areas. Improvements to radial highways have allowed commuters to live further from work while maintaining the same travel time, thus promoting the low density housing common to suburban areas. Meanwhile, market-dependent firms and employers have followed the flow of residents and employees from the central business district to the suburbs. Transportation improvements enlarged their market areas and accelerated the process of decentralization. However, instead of allowing perpetual decentralization, the new radial highways and beltways have encouraged the development of multi-centered regions. Employment and retail subcenters have grown at major intersections in the suburban highway network. This centralization of businesses has in turn attracted relatively high-density residential development to the immediate vicinity of the subcenters.

While access to an adequate pool of labor is probably indispensable for most firms, transportation costs and customer access may be of secondary importance for certain types of businesses. For example, in transport costs are only a small component (less than five percent) of overall production costs for some manufacturing firms (Button 1993). Manufacturers often lack the resources to undertake an extensive location choice process, instead choosing a satisfactory but suboptimal location. In contrast, transport costs make up ten percent or more of total costs for service-oriented firms (Button, 1993). Therefore, compared to manufacturers, firms in the service sector are likely to consider location choice more carefully and respond to transportation improvements. Button also asserted that high-technology firms are especially sensitive to transportation networks, given their need to retain scarce skilled labor and ship their products to international markets; this is particularly relevant to places like Silicon Valley, California, and Austin, Texas (see, e.g., Carey and Mahmassani, 1987).

Both Mahmassani and Toft (1985) and Button (1988) have examined the development cycle, travel needs, and locational behavior of high-tech companies. Mahmassani and Toft (1985) described a three-stage process that begins with research and development, where access to scientific personnel is very important. The second stage involves early commercialization of the technology, when access to venture capital, business expertise, and specialized resources is critical. Their final stage is product diffusion and mass manufacture, where high-tech firms are most like traditional manufacturers in their transport needs.

Button (1988) also used a "Product Life-Cycle Approach" to describe the unique qualities of such companies that influence their location decisions, but he added a fourth stage, to describe the decline of such firms. He argued that the first phase, which describes firms heavily involved in research and development, characterizes high-tech start-ups in Austin and Houston, as well as divisions of established, multinational corporations (such as Intel or IBM) that have offices located in these areas. R&D firm location is determined by local quality of life and commute times as well as proximity to airports and accessibility (via air) to other tech areas. In a firm’s second stage, the growth phase, proximity to venture capital sources becomes more important. Also, because production begins and expands in this phase, high-speed transport is necessary to keep inventory costs low. Location costs in the second stage can be minimized by exploiting economies of agglomeration.

According to Button (1988), and consistent with Mahmassani and Toft (1985), once a firm reaches maturity and full-scale production supercedes R&D, the firm's location decisions can be modeled by more traditional means. At this point access to national and international markets becomes most important, since both inputs and customers can be anywhere on the globe. Since inputs and outputs are both fragile and of high-value, reliable freight shipments (by land and air) are essential. Button argued that just-in-time inventory practices have resulted in an increased reliance on air transport, which suggests an increasing influence of airport accessibility on location decisions. Skilled workers remain necessary; and, while locating near other high-tech firms can be beneficial, labor shortages can result in higher costs for firms in areas with a large concentration of high-tech industries. Consider, for example, Dell Computer Corporation's recent decision to build and expand factories in Nashville, Tennessee, instead of constructing additional facilities near its existing Austin, Texas, facilities. Dell is anticipating less competition and lower wages for skilled workers in Tennessee.

In the final, "product decline" phase of a tech company, "a need to retain margins as long as possible in a shrinking market" (Button, 1988, pg. 107) dominates management decisions regarding transportation. This phase may endure for many years depending on firm and market evolution. Overall, the four phases suggest very different location strategies, which may be relevant for the sites and data investigated in later chapters of this report.

2.2 Transportation—Land Use Interactions

Transportation and land use are inextricably linked. Modifications to the transportation system can affect the accessibility of land, and significant changes in accessibility may result in changes in land use over time. Activity patterns adjust to the new land uses, and the demand for travel to and from the new land uses can impact the transportation system. Two-way interactions between transportation and land use make it difficult to determine whether transportation is influenced by land use or vice versa. Any study of transportation impacts must consider these interactions and their long-term effects.

As the transportation system has evolved over time, so has the form of the modern city. Adams' (1970) four-stage structural-evolution model showed a parallel between technological advances in transportation and city form, from the circular shape of the walking and horsecar cities to the star shape of streetcar-era cities to today's more uniform distribution of development attributable to an extensive network of arterials roads, radial freeways and beltways.

Hartshorn (1992) described how the freeway has shaped suburbs over time, allowing multiple centers to develop in regions where the central business district (CBD) once served as the single, dominant center. Radial highways built during the 1950s and 1960s provided easy access to inexpensive land on the periphery of the city for housing, which gave rise to the so-called "bedroom community". In turn, employers and retailers followed employees and consumers to the suburbs, providing jobs as well as shopping and cultural opportunities that made these communities independent of the city center. During the 1970s and 1980s rapid growth and development in the suburbs established suburban "town centers," which today compete directly with the CBD for economic activity.

As construction on the radial highways progressed, beltways and ring roads were also being constructed. Major suburban centers have developed at the intersections of radial freeways and beltways. According to the well-known Payne-Maxie Consultants (1980) study of American beltways, the development attracted by these ring roads may not be attracted from outside the region. Instead, their report concluded that beltways may merely redistribute development, shifting growth from the CBD to the suburbs and thus contributing to the decentralization of cities. After the construction of a beltway, the star-shaped urban form that had evolved in response to radial freeways evolves to a more even distribution of growth around the region.

Numerous empirical studies have attempted to model the effects of highway investments on nearby land use and real estate values. (See Huang [1994], and TRB [1995] for a summary of recent highway capitalization studies.) In his extensive literature review, Huang (1994) found that virtually every major land use study came to the conclusion that transportation improvements positively affect the value of nearby land. While the estimates of those effects ranged from almost nonexistent to over a 10 percent increase in property values over the region-wide sale prices, it was difficult for Huang to compare the models due to differences in externalities across regions.

In a study of median housing prices and monthly rents in the San Francisco Bay Area, Kockelman (1997) showed a strong positive association between accessibility and land prices, after controlling for a wide variety of other variables, including parcel size and square footage of development. Homeowners and renters do value improvements to the transportation network, whether their perception of the travel benefits is direct or indirect.

This research examines commercial and industrial property responses to a major capacity expansion of a roadway facility in Austin, Texas, by analyzing parcel-level real estate assessment data over a 17-year period.

According to classical economic theory, when a highway is initially built, large parcels of land that previously had poor accessibility—or none at all—are suddenly underpriced. The market immediately responds: the area is quickly developed and the real estate market establishes a new equilibrium based on the new transportation technology. The land-value impacts that are experienced can be significant (Giuliano, 1989).

According to the same theory, major improvements to existing transportation infrastructure should also have a strong, positive effect on nearby real estate values. However, the impacts may be highly localized and of a much lesser degree than those caused by the original construction (see Landis, et al. [1995] and Tomasik [1987]).

Huang (1994) concluded that two simultaneous but opposing effects tend to decrease property value effects of highway infrastructure as a transportation network expands. First, the total accessibility of a region increases, making the region more attractive and raising property values. Second, as the supply of parcels with superior access increases, the marginal willingness to pay for these parcels decreases and prices decrease. As the highway system expands perpetually, the second effect will eventually overshadow the first, and the net benefits to land values will decrease. The research presented here in Chapter 4 attempts to measure these land value changes in response to a major capacity expansion in Austin, Texas.

Hansen et al. (1993) studied the land use impacts of highway capacity expansions for several corridors in California. According to the study, developers claimed that the possibility of a freeway expansion or upgrade had little or no impact on their development decisions—the development would have occurred with or without the road construction. City planners interviewed by Hansen et al. concurred with the developers. "None of the planners interviewed believe that the capacity expansion of the adjacent freeway directly accelerated the growth in their city, or that growth would somehow have been hindered in the absence of the improvement." (Hansen et al., 1993, pg. 5-3)

The authors admitted, "It is also possible that developers did value the freeway improvement project but did not acknowledge this, out of concern for the political ramifications of doing so." (Hansen et al., 1993, pg. 5-29) Since developers did state that commute times and other accessibility measures play an important role in their development decisions, it also is possible that some developers fail to recognize the relationship between highway capacity expansions and the factors that make specific parcels of land more valuable and marketable. This research attempted to answer some of the questions posed by Hansen. The interview subjects included a broad cross-section of real estate professionals, ranging from a developer to a market analyst to a city planning commissioner.

Hansen et al. (1993) also used analysis of permitting data in the corridor to gauge the impacts of the road construction on land development. In the period immediately after the capacity expansion, both residential and commercial development experienced dramatic increases (approximately 50% in each case) followed by a tapering off of permitting activity over time. The data analysis offered a stark contrast with interview results and suggests that developers in fact do respond to transportation improvements in their timing or location decisions. One possible reason for the disparity is the lack of developers' perception of the direct benefits of transportation improvements, as discussed above. Interviews with real estate professionals that were conducted as a part of this research support Hansen's findings. Specifically, the interviewees suggested that in Austin, road construction has no significant impact on development. Other factors, such as market rents and occupancy rates may be much more significant (C. Heimsath, 2000).

The conclusions of Hansen et al. (1993) do not refute the theory that investments in expanded highway capacity have no net impact. The analysis of permitting data from the entire Austin region, presented in Chapter 3 of this paper, attempts to determine if changes in the rate of development in one corridor reflect redistribution from another part of the region or instead signify a temporary acceleration of development that would have occurred anyway.

Other studies have come to similar conclusions. In a review of more recent literature on the economic impacts of highway construction, Boarnet (1997) concluded that road improvements have had little economic impact at the regional level, and local impacts come at the expense of other areas in the immediate region. He debases the popular belief among politicians that new or expanded highways bring wholly new development to a metropolitan area. First, it is difficult to determine causality: do highways lead to economic growth, or vice versa? Highways are often planned for corridors where future growth is projected. Moreover, as is increasingly the case, transportation agencies faced with scarce resources can only afford to improve roads in areas where growth has already led to severe congestion. Boarnet also claims that, since residential and firm location can take from ten to fifty years to adjust to a new equilibrium, the growth patterns we observe today "could be an artifact of [the first round of interstate highway construction] rather than the result of current projects." (Boarnet, 1997, pg. 482)

In an earlier paper, Boarnet (1995) contrasted the post-WWII highway construction boom—and the subsequent economic growth—with highway construction in the twenty-first century. The original construction of the National System of Interstate and Defense Highways contributed to rapid suburban growth and a dramatic shift in urban form. Today, however, the extent of transportation connectivity in every part of the nation may allow for only small overall economic benefits in response to incremental additions to the road network.

Boarnet (1997) suggested that highway improvements today merely redistribute economic activity that would have occurred elsewhere in the region absent the improvement. In some cases, the areas that feel a negative impact are immediately adjacent to a highway corridor or node where a major improvement has occurred. Economic activity is not attracted from outside the region, Boarnet maintains, but rather is attracted to the vicinity of the highway at the expense of some other part of the metropolitan area. However, due to the complexity of land use-transportation interactions, no research to date has been able to support this assertion.

An alternate viewpoint maintains that an investment in expanded highway capacity often stimulates entirely new land development that would not otherwise have occurred. This increase in development can ultimately lead to what is commonly called “induced demand” for travel. The phenomenon of induced demand is the primary motivation for this research.

2.3 Induced Demand

The definition of “induced travel” is itself a subject of controversy and confusion. Whether to include what has traditionally been called “latent demand” in the definition of induced demand is the first dilemma. Latent demand comes from shifts in travel mode, departure time, destination, or route, for example, in response to a transportation improvement (DeCorla-Souza, 2000; Fulton et al., 2000; Noland and Cowart, 2000). All of these effects are a direct result of the travel cost reductions on new or improved facilities.   However, when considering the transportation network as a whole, there is as yet no evidence that behavioral shifts due to latent demand induce completely new activity and generate totally new trips.

DeCorla-Souza (2000) defined induced travel in the most rigid, and exclusive, manner. He made a clear distinction between: personal and vehicle travel, trips and vehicle miles traveled (VMT), daily and peak-period VMT, region-wide and corridor-specific travel, and short-term and long-term effects.

DeCorla-Souza avoided measuring induced travel in terms of person trips, time-of-day splits, and trips specific to one corridor, arguing that a change in each of these metrics could be explained by travelers changing the mode, departure time, or route of their trips, respectively, and would not involve entirely new demand for travel. According to DeCorla-Souza, latent demand, and any behavioral shift that occurs as a result of it, is not synonymous with induced demand. This is the definition used here. Further, DeCorla-Souza maintained that induced demand must be observed at a region wide, as opposed to a corridor-specific, level, and the effects must be measured over a sufficiently long period of time. His definition of induced travel was an "increase in daily vehicle miles of travel…in the long-term at the region-wide level resulting from an expansion of highway capacity." (DeCorla-Souza, 2000, pg. 17) Note that induced demand may result from any improvement in the transportation network; it is not limited to highways.

Using DeCorla-Souza's definition, an "increase in daily VMT" may be due to several short-term behavioral shifts. Colman (2000) described the induction in terms of the traditional 4-step transportation planning model:

1. Trip Generation: The improved facility may now offer improved access to some destination that was previously inaccessible or relatively difficult to access due to travel time or cost. The improvement might generate totally new travel or new trips that may represent an increased frequency of travel to a current destination, such as a grocery store.

2. Trip Distribution: The new facility may allow for trip lengthening, where a traveler changes her destination to a more distant location, or for trip chaining, where the origin and destination remain the same but one or more stops are added along the way.
3. Mode Split: When a capacity expansion (such as an additional travel lane) eliminates the time advantage of carpooling or using mass transit, carpoolers and/or transit users may begin driving solo along the same route to work each day, with quite a dramatic effect on total VMT. Conversely, a transit improvement might take drivers off the highway facility, prompting other drivers to use it in their place.
4. Traffic Assignment: If a transportation improvement reduces travel time sufficiently that a traveler now takes a longer route (but maintains or reduces his or her travel time), region-wide VMT will increase.

Dowling, et al. (1994), found changes in departure time and route choice to be most affected by highway improvements. Lesser effects include alterations in mode choice, trip destination, and trip frequency. Changes in trip generation rates are less likely to make a significant contribution to induced demand. This claim has been supported by recent trip generation models (e.g. Kockelman 1998), which found that differences in accessibility do not affect trip generation rates, after controlling for travel times and a household's travel budget.

In the long term, a household may purchase additional vehicles and relocate its residence, and individual workers may change their employment locations in response to a capacity expansion. For example, if a household can now move to more affordable housing further from the job center, it may be able to buy an additional car even while maintaining its commute time. Instead of carpooling to work together, a husband and wife may now commute separately, and one or both may even decide to take a job at a better firm in a different part of the region. Now not only has the household's commute distance increased, but also the household has two vehicles and its daily VMT has more than doubled. While the above is an extreme example, it represents components of reasonable long-term behavioral shifts in response to transportation infrastructure improvements.

Perhaps the least understood and most debated piece of the induced demand puzzle is the effect of capacity expansions (and reductions, for that matter) on land use patterns and development trends. The ability to predict land use and land development patterns is fundamental to the creation of sound travel forecasting models. The connection between transportation and land use has been well established, but, before tenable predictions about future demands on a transportation facility can be made, the following questions must be answered: How do major transportation improvements affect the timing and location of development decisions? Also, how do households and firms alter their location decisions as a result of a change in the transportation system?

Some contend that expansions in the freeway system have no net effects on development from a regional perspective. Development occurs in response to economic factors such as average rent and occupancy, which fluctuate according to regular business cycles. Changes in the transportation network only serve to redirect and redistribute growth rather than attract entirely new growth to a region that would not have otherwise occurred (see, e.g., Hansen et al., 1993; Boarnet, 1997; C. Heimsath, 2000). For example, Damm et al. (1980) concluded that land value increases and development in the vicinity of the Washington Metro's new stations came at the expense of other areas.

Prior research has attempted to determine if new highway construction leads to induced VMT. Fulton et al. (2000) seemed to establish a causality between lane-mile growth and increases in VMT in Mid-Atlantic states. Their results suggest that lane-mile growth is a significant predictor of VMT increases, with elasticities in the range of 0.2 to 0.6.

The basic policy issue concerns whether the money spent on the improvement is worthwhile, given the possible negative long-term effects on development patterns, system wide congestion, and regional air quality. These questions are raised by recent analyses of induced travel effects (Fulton et al., 2000; Noland and Lem, 2000; Colman, 2000; DeCorla-Souza, 2000) and are at the heart of the debate over induced demand.

Noland and Lem (2000) discussed the role that federal environmental regulations have played in shaping the debate. The National Environmental Policy Act (NEPA) of 1970 and the advent of the Environmental Impact Statement (EIS) have forced highway builders to consider the long-term environmental impacts of new road construction. Increasingly, and especially in air quality non-attainment areas, the burden is on the state departments of transportation to show that major capacity expansions will not only relieve congestion, but also will not induce demand that in the future may produce more congestion and pollution than no-build alternatives.

Several researchers have called for improvements in the practice of travel demand forecasting in order to better account for latent and induced demand (see, for example, Noland and Lem, 2000; DeCorla-Souza, 2000; and Dowling Associates, 1994). Rodier et al.'s results (2000) suggest that about 50% of the unpredicted latent and induced travel effects in TRANUS-based models of Sacramento, California's, future development was captured simply by properly applying existing travel forecasting models. The other 50% of their estimated future VMT was not predicted from the travel demand models; it came from the land use component of the model. This suggests that an understanding and formal recognition of land use feedbacks may be critical to proper predictions and policy.

2.4 Summary

This chapter has introduced the connection between land use, location decisions, and transportation systems. Highway investments have been shown to have substantial, measurable impacts on adjacent land values, but whether these localized impacts translate into *net* regional benefits is debatable. Development attracted to new highways and other transportation facilities may merely represent a redistribution of growth from other parts of a region.

Induced demand is a much-debated topic, from the fundamentals of what the term includes to whether it even exists. Some stakeholders and policy makers, ranging from city public works departments to Congress, still have yet to accept that highway construction in modern cities may not relieve congestion. The state of the practice in travel forecasting is being updated to reflect new knowledge, but much work remains to be done in explaining the many unknowns in the realm of transportation-land use interactions.

In the existing literature, residential property is the focus of research into the land value impacts of transportation improvements. Here, a broad cross-section of land uses is considered because changes in the transportation system affect all land uses, from residential to heavy industry.

Previous literature has analyzed specific corridors or compared two or more subregions in a state. Chapter 3 of this paper analyses permitting data on a region-wide basis in an attempt to gauge the broader impacts of transportation improvements on development.

CHAPTER 3: TRANSPORTATION SYSTEM IMPROVEMENTS AND PERMITS ISSUED

3.1 Introduction

One of the most fundamental ways to study the effects of transportation improvement on development is to consider permitting activity. Developers apply for building permits before construction begins, well in advance of building occupancy. By studying permitting activity, one can examine the anticipation of and response to new highway capacity by developers.

Hansen *et al.* (1993) studied eight freeway corridors in California that underwent major capacity expansions, analyzing permitting data over a twenty-five-year period bracketing the construction. The long time span allowed for a sufficient period before and after the construction to gauge long-term effects. Hansen found that in the years after a capacity expansion, permitting activity accelerated, but his methods were unable to reveal whether the development was entirely new or merely a redistribution of activity from areas outside the immediate vicinity of the corridors. This research differs from the study performed by Hansen *et al.* in that permitting data from the entire city of Austin is used here, and indicator variables are inserted to determine if local expansions have an effect on permitting activity.

The two facilities that were built during the study period were the northern and southern extensions of Loop 1, also called MoPac Expressway after the Missouri Pacific Rail Line that runs in the median of the highway (Figure 1). Both extensions increased accessibility to large tracts of undeveloped land, which have since experienced rapid development.

The remainder of this chapter contains an introduction to the data sources and a brief description of the permitting data sets. The model specifications are described, and followed by a summary of their results and conclusions.

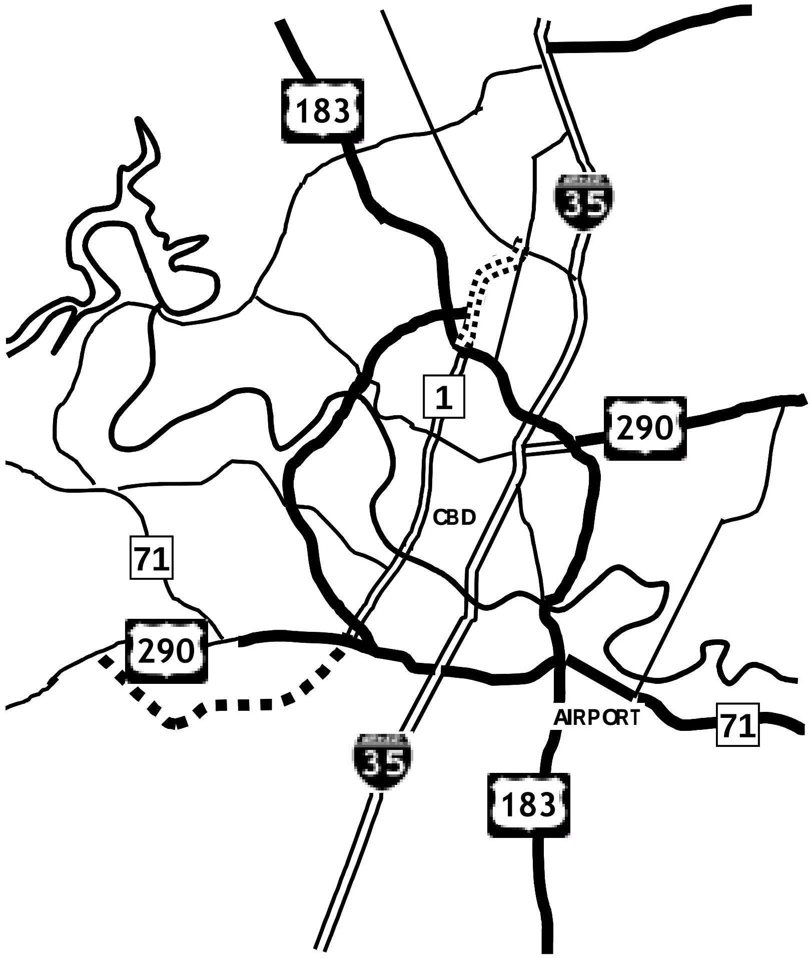

Figure 3.1: Map of Greater Austin, Showing Major Transportation Facilities.
The dashed lines indicate the northern and southern extensions of the Loop 1 freeway.

3.2 Data Assembly

3.2.1 Data Sources

The City of Austin publishes an annual summary of permitting data, *Growth Watch* (City of Austin, 1987-1995), which is the primary data source for this research. *Growth Watch* lists the number of building permits issued annually in each census tract for single-family detached homes, single-family attached homes, and multi-family homes. Another table lists the square footage of permits authorized for each census tract in three nonresidential categories: office, mercantile, and industrial. The City published this annual summary of building permits by census tract between 1987 and 1995, so those years became the limits for the statistical analysis conducted here. (After 1995, the number of permits was no longer recorded by census tract.)

Also listed on the City of Austin's web site (City of Austin, 2000) are data for each of 26 planning areas from the 1990 Census of Population and a 1990 citywide land use survey. (A map of these planning areas can be found in Appendix A.) For each planning area, the square miles of land in each of 12 land use categories is listed, along with as the number of units of single-family detached, single-family attached, and multi-family housing units occupied in 1990. The web site also contains various socio-demographic characteristics, such as annual income and age of housing stock in each planning area.

The Texas Department of Transportation (TxDOT) publishes annual average daily traffic counts for various points along each state-maintained highway in the Austin region. Along with this data, information about the capacity of each state highway was used to calculate an annual average volume-to-capacity (V/C) ratio for at least one major facility in each planning area. (See Appendix B for a listing of the arteries used in the V/C calculations, as well as the assumptions underlying the calculations.) Where possible, one radial and one transverse facility were used. These V/C ratios were then averaged for each planning area as a measure of congestion.

In order to control for variations in socio-economic characteristics across planning areas, data on median income and median age of housing stock from a City of Austin (2000) summary of census data were added to the data set. Travel distances to the central business district (CBD), Robert Mueller Municipal Airport (which was replaced by a new international airport several years after the study period), and the "Golden Triangle" (a major retail and employment subcenter bounded by Loop 360, Loop 1, and U.S. 183 in Northwest Austin) were also considered. For residential models the distances were taken from the population centroid of each planning area, and for nonresidential models the distance was taken from the area centroid. All distances were along existing roadways, as opposed to airline or Euclidean distances.

3.2.2 Sample Formation

Due to the wealth of building information available at the planning-area level, census tract data were aggregated into these. In every year, the majority of census tracts experienced no development; therefore, the aggregation also served to eliminate a large number of zero values in the data. The data lends itself well to a serial panel analysis, since for each planning area the data are available every year.

For each of the years, a binary response variable was created, indicating whether any development had occurred in each of the six development categories (single-family detached, single-family attached, multi-family, office, mercantile, and industrial). A variable of transportation density was taken to be the fraction of the planning area dedicated to transportation uses.

In addition to indicator variables for the North and South MoPac corridors, other locational indicator variables were included, indicating which planning areas contained the high-traffic, high-growth U.S. 183 North and U.S 290 West corridors and the Loop 360 technology corridor. Please see Table 3.1 for a more complete description of these variables.

3.2.3 Characteristics of the Data Set

Though planning areas were rather large (averaging over 50 square miles here), there were many areas in which no development occurred in a given year. Table 1 shows a summary of the observations in each development category with zero development, where an observation is defined as one year in one planning area. There were nine years in the study period and 26 planning areas, for a total of 234 observations.

For both single-family attached units (2-3-4 plexes) and multi-family units, more than 80% of the observations registered zero development. Similarly, no industrial development occurred in 82% of the observations.

Table 3.1: Summary of Variables Used in the Permitting Analysis.

Dependent Variables	**Description**
Number of Residential Permits:	
Detached Single-Family	
Attached Single-Family	Includes duplexes, threeplexes, and fourplexes, and townhomes.
Multi-family	Includes apartment buildings and condos.
Square Footage of Nonresidential Permits	
Office	
Mercantile	Also retail
Independent Variables	**Description**
Undeveloped Area	Square Miles of land in each planning area that is undeveloped.
Distance to CBD Distance to Arboretum Subcenter	All distances were measured from the population centroid of the planning area for residential models, and from the area centroid of the planning area for nonresidential models.
Distance to Airport	Duration of study was 1987 to 1995, when Robert Mueller Municipal Airport was in operation. (Note: A new commercial airport in Southeast Austin replaced Robert Mueller Airport in 1999.)
Density of Transportation Network	Square Miles of land in each planning area dedicated to transportation divided by total area.
Congestion Index	Volume-to-capacity (V/C) ratio calculated for each planning area using flow and capacity data. See Appendix B for details.
Corridor Indicators:	
Capital of Texas Highway	A magnet for growth related to technology and internet firms, running from north to south in West Austin.
Ben White Blvd.	Texas 71 and US 290 West provide a major cross-town link in South Austin.
Research Blvd.	US 183 runs from I-35 in North-Central Austin to the northwestern suburbs.
North MoPac Freeway Extension South MoPac Freeway Extension	Both the northern and southern extensions of Loop 1 opened to traffic in 1991, during the study period.
Square Miles of Single-Family Land Use Square Miles of Multi-Family Land Use Square Miles of Office Land Use Square Miles of Commercial Land Use Square Miles of Industrial Land Use	All land use variables were used in raw form (square miles of land use) and as a percentage of total square miles of land in each planning area.
Time Trend	Takes value of 0 in 1987 and 8 in 1995.

Table 3.2: Number of Observations with No Permits Issued in Each Category

Development Type	Single-Family Detached	2-3-4 Plex	Multi-Family	All Residential	Office	Mercantile	Industrial	All Non-residential
Number of Observations with No Development	46	191	197	43	107	91	192	52
% of Total	20%	82%	84%	18%	46%	39%	82%	22%

Overall, few single-family attached units were constructed in the entire city during the study period. Figure 2 shows the total number of residential building permits issued in each category each year. The chart indicates that residential development in Austin rose out of a recession in the early 1990s with near exponential growth; thus the use of a second-order time-trend variable seems appropriate. Simply plotting the permitting data over time, there is no evidence of a trend in the regional nonresidential development (Figure 3) when considering the entire Austin area; however, since the data analyzed consists of square footage of permits authorized, a single large retail or office project in any given year can drastically influence the data. Any given planning area may have many years of no development interspersed with one or two years of large-scale development.

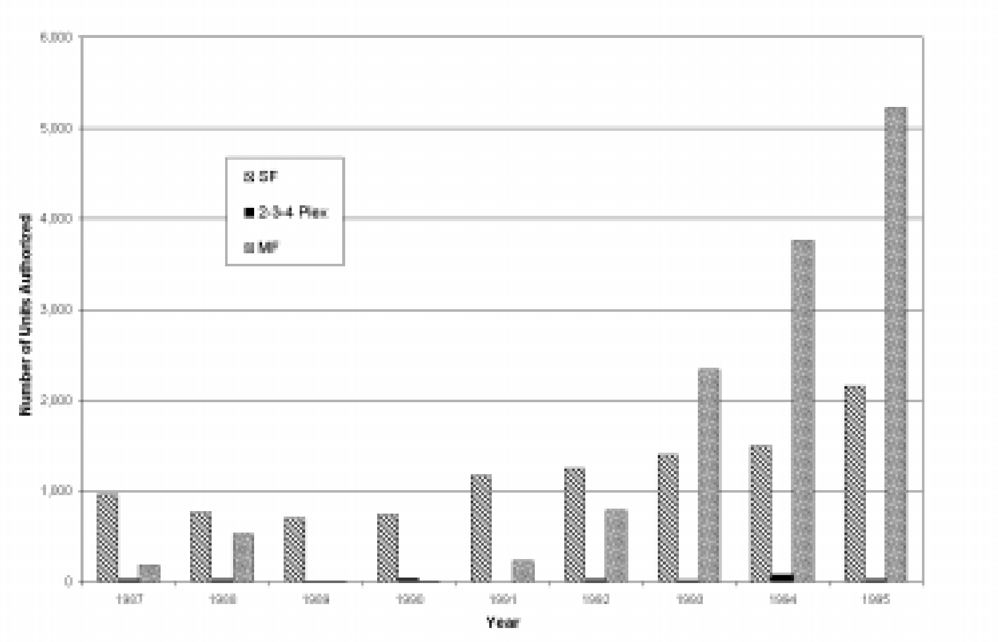

Figure 3.2: Austin Regional Residential Development Trends, 1987-1995

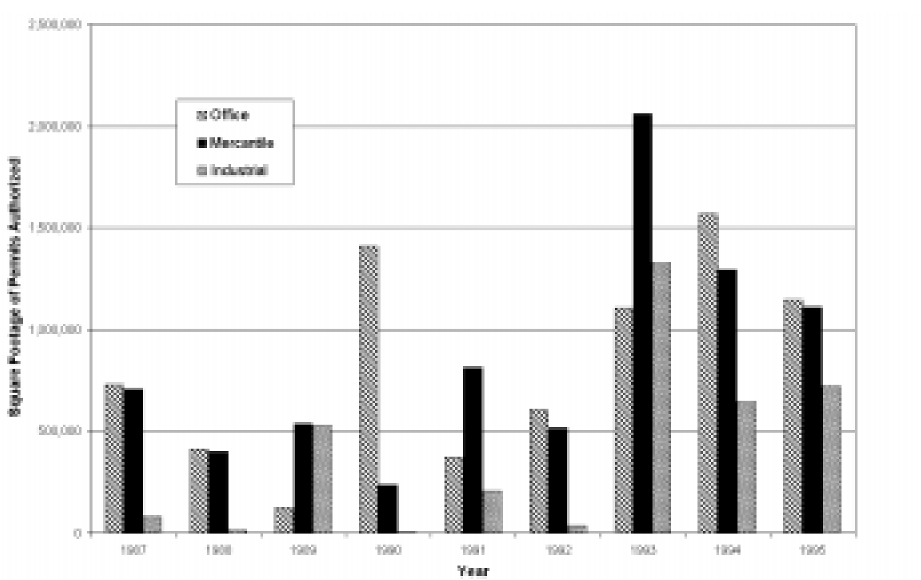

Figure 3.3: Austin Regional Nonresidential Development Trends: 1987-1995

3.3 Empirical Analysis

The presence of both zeros and very high permitting values complicates data analysis. Simple linear models for continuous response are impossible, because the data are often bounded by zero. The residential permitting data consisted of a count of permits issued in each planning area each year. A tobit specification, in which the lower tail of the distribution is truncated at zero, was used to analyze the residential permitting data.

The single-family attached (duplex, triplex, and four-plex) data are somewhat unique in that they contain relatively low numbers of permit values for all observations. Therefore, a negative binomial model for the single-family attached data is also presented for the single-family-attached data.

The nonresidential data consists of square footages of improvements permitted each year. Since the values are either zero or very high numbers, a tobit specification seems less appropriate here. Instead, a two-stage analysis was used for the nonresidential data. The method is based on Heckman (1979) and is described below.

All models presented in this chapter were estimated using Limdep 7.0.

3.3.1 Tobit Model Description

The form of the tobit model with random-effects is:

$$y^*_{i,t} = \beta' \mathbf{x}_{i,t} + v_{i,t} + u_i$$
$$y_{i,t} = \max\left[0, y^*_{i,t}\right]$$

Both error terms, $v_{i,t}$ and u_i, are assumed to have a normal distribution with mean zero and variances σ_v^2 and σ_u^2. The u_i term is an area-specific effect and is assumed constant over time. The lower tail of the dependent variable, $y^*_{i,t}$'s, distribution is truncated at zero, which means that if $y^*_{i,t}$ is less than zero, then the value of $y_{i,t}$ is zero. No negative values are allowed. This specification was used to model the number of permits granted for the three residential types of buildings.

3.3.2 Negative Binomial Model Description

The data for the number of single-family attached units (also called 2-, 3- or 4-plexes) permitted per year appears to support a negative binomial model, since the data range from 0 to 36 permits per year in any given planning area. Since we are still using panel data, we use a fixed-effects form of the negative binomial model (Greene, 1998):

$$\lambda_{i,t} = e^{\beta' \mathbf{x}_{i,t} + u_i + \varepsilon_{i,t}}$$

The number of permits issued is assumed to follow a negative binomial distribution with mean value $\lambda_{i,t}$ and dispersion parameter α, such that:

$$\mathrm{Var}[y_i] = \mathrm{E}[y_i]\{1 + \alpha \mathrm{E}[y_i]\}$$

Limdep Version 7.0 was used to estimate this model.

3.3.3 Heckman's Two-Stage Model Description

In order to ensure that the zero observations do not unduly influence the models of nonresidential square-foot permitting models, a two-stage model was used to first model the probability that an area experienced any development and then appropriately examine the level of development in areas that did experience development. This second stage of the model was done using Heckman's (1979) correction method[1] in a linear regression model. Thus, the two-

---

[1] The method was developed by Heckman (1979) and modified by Greene (1981). It has been called the "Heckit" estimation method (Greene, 1998).

stage model predicts the probability that development occurs and the expected amount of development (in that planning area and in that year).

The first stage is a binomial probit model of development, the two responses being develop or not develop. Since panel data were used in the analysis, a random-effects binary probit model was run. The form of the model is the following (Greene, 1998):

$$z_{i,t}^{*} = \gamma' \mathbf{w}_{i,t} + u_i + v_{i,t} = \gamma' \mathbf{w}_{i,t} + \varepsilon_{1,i,t}$$

$$\text{where } \quad i = 1, \ldots, N$$

$$t = 1, \ldots, T$$

$$\gamma = \frac{\gamma^{*}}{\sigma_v}$$

$$z_{i,t} = 1 \text{ if } z_{i,t}^{*} > 0 \text{ and } 0 \text{ otherwise}$$

$$\text{Var}[u_i + v_{i,t}] = \text{Var}[\varepsilon_{1,i,t}] = \sigma_u^2 + \sigma_v^2 = \sigma_1^2$$

$$\text{Corr}[\varepsilon_{1,i,t}, \varepsilon_{1,i,s}] = \frac{\sigma_u^2}{[\sigma_u^2 + \sigma_v^2]}$$

One assumes that $v_{i,t}$ and u_i follow a normal distribution with mean 0 and variance σ_v^2 and σ_u^2, respectively. Using the probit coefficients, one computes the inverse Mills ratio as follows:

$$\hat{\lambda}_i = \frac{\varphi\left(\hat{\gamma}' w_{i,t} / \sigma_u\right)}{\Phi\left(\hat{\gamma}' w_{i,t} / \sigma_u\right)}$$

The model that then applies to the observations where development occurs is the following:

$$\begin{aligned}
\mathrm{E}\left[\text{SF Permitted}_{i,t} \middle| \text{development}_{i,t} \text{ permitted}\right] &= \mathrm{E}\left[\mathrm{SF}_{i,t} \middle| z^*_{i,t} > 0\right] \\
&= \mathrm{E}\left[\mathrm{SF}_{i,t} \middle| \varepsilon_{1,i,t} > -\gamma' \mathbf{w}_{i,t}\right] \\
&= \beta' \mathbf{x}_{i,t} + \mathrm{E}\left[\varepsilon_{2,\mathrm{i,t}} \middle| \varepsilon_{1,i,t} > -\gamma' \mathbf{w}_{i,t}\right] \\
&= \beta' \mathbf{x}_{i,t} + \rho\sigma_{\varepsilon}\gamma_{i,t}(\alpha_u) \\
&= \beta' \mathbf{x}_{i,t} + \beta_{\lambda}\lambda_{i,t}(\alpha_u)
\end{aligned}$$

where

$$\alpha_u = \frac{-\hat{\gamma}' \mathbf{w}_{i,t}}{\sigma_u}$$

Thus, one has:

$$y_{i,t} \middle| z^*_{i,t} > 0 = \beta' \mathbf{x}_{i,t} + \beta_{\lambda}\lambda_{i,t}(\alpha_u) + \zeta_{i,t}$$

In order to obtain consistent and fully efficient estimates of the model parameters, maximum likelihood estimation is used in the second step (Greene, 1998) via Limdep software (Limdep, 1998).

3.3.4 Empirical Results of Permitting Models

Table 3.3 shows the results of the tobit models for the single-family detached residential data, and Table 3.4 shows the results of a multi-family residential model. The amount of undeveloped land available for development in a planning area is estimated to increase the number of single-family permits issued in a given year as one would expect. However, it is associated with a decrease in the number of duplexes, triplexes, and four-plexes permitted. This may very well be because attached housing is only built where land is scarce, and the larger tracts tend to be the less developed and further from the urban core. Thus, the amount of undeveloped land serves as a proxy for access rather than allowing us to estimate its effects, ceteris paribus.

The likelihood of development decreases with increasing distance from the CBD and The Arboretum (a major suburban subcenter) in the single-family and multi-family models.

However, the number of single-family and multi-family building permits issued increases with increasing distance from the airport, perhaps because of noise effects. These simple distance measures of accessibility proved to be some of the most helpful explanatory variables used here.

The square of the time trend variable was statistically significant at a 20% level in all models (i.e., p-value <0.2). As time progressed, the number of permits issued in each residential category increased. A first-degree time trend variable was also tested, but in all three cases the second-degree term produced a significantly better log likelihood value, indicating a better fit to the data.

The South and North MoPac (Loop 1) indicators were insignificant in all residential models, suggesting that the construction of the extensions had little or no impact on permitting activity in adjacent planning areas. However, no data was available from neighboring Williamson County, which may have benefited from the improved access to Austin via the North MoPac extension more than the northern part of the Austin. In addition, the data were spatially rather coarse. A larger and spatially more disaggregate data set may better illuminate such effects, in statistically and practically significant ways.

The average age of residential structures and median income of the residents of each planning area also were not statistically significant variables in these regressions. And, the percentage of land dedicated to each land use in each planning area, the congestion index, and the transportation network density variables were not found to be statistically significant in the residential permitting models.

Two additional parameters were estimated for each tobit model. The parameters $\hat{\sigma}_v$ and $\hat{\sigma}_u$ are the standard deviation estimates of area-specific and other unobserved heterogeneity. Their magnitude in the population suggests that much variation remains unexplained and much may be very site-specific.

The negative binomial model for 2-, 3-, and 4-plex development yielded a similar set of unusual results (see Table 3.5). The amount of undeveloped land has a negative coefficient (as in the tobit model), indicating that planning areas with more undeveloped land are more likely to have 2-, 3-, and 4-plex development. Possibly, the amount of undeveloped land is proxying for low-value, peripheral planning area's land, where high-density development is not economically feasible.

The time trend variable and the transportation network density variable are both significant as well. As time progresses, 2-, 3-, and 4-plex development happens more often. And, as the density of the transportation network increases, the number of 2-, 3-, and 4-plexes is expected to fall. Higher density developments, both residential and nonresidential, may replace 2-, 3-, and 4-plexes as access improves.

Tables 3.6 and 3.7 show the results of the two-step sample selection models for nonresidential development. The nonresidential sample selection models yielded unexpected results. Although several variables were significant, the two parameters listed in the last two rows of Tables 3.6 and 3.7 indicate that the sample selection model is not helpful for analyzing this data. The value σ_2 is the standard error of the continuous variable in the second-stage linear regression, and the rho (ρ) from this second stage refers to the correlation between the error terms in the probit selection equation and in the continuous linear regression. If ρ is close to zero, as it is here, it implies that there little or no need to correct for selection; the probit and least squares can be estimated independently with little error. Also, σ_2 has a relatively high magnitude (versus several of the coefficients in the models), indicating that much of the variance in the sample selection model is unexplained by the explanatory variables controlled for here.

In the models of office permits, the north MoPac (Loop 1) and Capital of Texas Highway (Loop 360) indicator variables have very high values, indicating a tendency for more office development to occur in those areas than in other parts of the city. Since the end of the study period, the Capital of Texas Highway corridor has become a magnet for high-tech firms in Austin. The presence of industry in a planning area also attracted office development. High-tech manufacturers in Austin have located research and development offices near existing factories to facilitate communication and cooperation among separate divisions of the company.

Table 3.7 shows the results of the two-stage model for mercantile development. The negative coefficient for square miles of undeveloped area suggests a tendency for mercantile development to concentrate near a city's core instead of at the fringes. Also, as distance to the Arboretum Subcenter, a major retail hub, increases, the amount of mercantile development decreases. Northwest Austin, where the Arboretum is located, has been the largest growth area in the Austin region.

Retail development has followed the population growth not only in Northwest Austin but also in Southwest Austin, as indicated by the positive coefficient on the Ben White indicator. Austin's second-largest concentration of retail developments lies near the intersection of Ben White Blvd. (US 290) and Loop 1 (MoPac Expressway). See Figure 3.1 for a map of the Greater Austin area. The South MoPac indicator had a negative coefficient for the mercantile probit model. This can be explained in part by the concentration of retail development along Ben White Blvd., which also serves the population along South MoPac.

The selection model for mercantile development has only one statistically significant variable, distance to the CBD. Larger retail developments such as "big box" power centers, are often built in suburban areas, where land is less expensive than in the CBD. The distance from the CBD may also be a proxy for the amount of undeveloped land available for development.

Table 3.3: Results of Random-Effects Tobit Model for Single-Family Detached Residential Development

Dept. Variable: Number of Detached Single-Family Residences Permitted				
Type of Model:	Random-Effects Tobit			
Number of Cross-Sections, Time Series: 26,9				
Number of Observations: 234				
Log Likelihood Function:	-1063.609			
Restricted Log Likelihood:	-1118.217			
Pseudo R-Squared:	0.05			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	46.03	14.74	3.12	0.00
Undeveloped Area	0.47	0.08	5.53	0.00
Distance to CBD	-15.09	3.36	-4.49	0.00
Distance to Arboretum Subcenter	-7.13	1.03	-6.93	0.00
Distance to Airport	14.14	3.64	3.88	0.00
$(\text{Time Trend})^2$	0.63	0.10	6.61	0.00
σ_v	51.72	1.69	30.69	0.00
σ_u	78.36	11.01	7.12	0.00

Table 3.4: Results of Negative Binomial Fixed-Effects Model for Single-Family Attached Residential Development

Dependent Variable: Number of Single-Family Attached Units Permitted				
Number of Cross-Sections, Time Series: 26,9				
Number of Observations: 234				
Negative Binomial Model				
Log Likelihood Function:	-223.23			
Restricted Log Likelihood:	-604.88			
Pseudo R-Squared:	0.63			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	-0.7323	2.6875	-0.2720	0.785
Square Miles of Undeveloped Area	-0.3190	0.5208	-0.6130	0.540
Time Trend	0.1484	9.22E-02	1.6090	0.108
Density of Transportation Network	2.7450	14.0172	0.1960	0.845
Overdispersion Parameter, α	11.4189	2.1197	5.3870	0
Negative Binomial Model with Fixed-Effects				
Log Likelihood Function:	-138.94			
Restricted Log Likelihood:	-222.82			
Pseudo R-Squared:	0.38			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Square Miles of Undeveloped Area	-0.7937	0.2587	-3.0680	0.002
Time Trend	6.71E-02	5.00E-02	1.3430	0.179
Density of Transportation Network	-10.4009	1.5425	-6.7430	0

Table 3.5: Results of Random-Effects Tobit Model for Multi-Family Residential Development

Dependent Variable: Number of Multi-Family Units Permitted				
Type of Model:	Random-Effects Tobit			
Number of Cross-Sections, Time Series: 26,9				
Number of Observations: 234				
Log Likelihood Function:	-330.1397			
Restricted Log Likelihood:	-332.1115			
Pseudo R-Squared:	0.01			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	-378.77	411.44	-0.92	0.36
Distance to CBD	-120.30	82.87	-1.45	0.15
Distance to Arboretum Subcenter	-90.21	42.17	-2.14	0.03
Distance to Airport	119.59	84.93	1.41	0.16
$(\text{Time Trend})^2$	11.39	2.38	4.78	0.00
σ_v	532.68	53.34	9.99	0.00
σ_u	287.07	233.72	1.23	0.22

Table 3.6: Results from Two-Stage Sample Selection Models for Square-footage of Office Space Permitted

Stage 1 Model: Random-Effects Probit				
Dependent Variable: Binary, Presence of Development				
Log Likelihood Function:	-141.3179			
Restricted Log Likelihood:	-161.3407			
Psuedo R-Squared:	0.12			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	1.42	0.40	3.58	0.00
Distance to CBD	-0.09	0.04	-2.19	0.03
Distance to Arboretum Subcenter	-0.06	0.03	-1.85	0.06
ρ	0.18	0.12	1.59	0.11
Stage 2 Model: Random-Effects Probit				
Dependent Variable: SF of Office Space Permitted				
Log Likelihood Function:	-1662.9682			
Restricted Log Likelihood:	-1677.1517			
Adjusted R-Squared:	0.14			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	12519.3	52067.8	0.240443	0.809987
Capital of Texas Highway Indicator	120516	39085.7	3.08338	0.002047
North Mopac Indicator	80300.9	45391	1.76909	0.076878
Percentage of Planning Area Dedicated to Industrual Use	823394	426928	1.92865	0.053775
σ_1	120367	5386.16	22.3474	2.89E-15
$\rho_{1,2}$	-0.094308	0.503545	-0.187287	0.851435

Number of Cross-Sections, Time Series: 26,9

Number of Observations: 234

Table 3.7: Results from Two-Stage Sample Selection Models for Square-Footage of Mercantile Space Permitted

Variable Description	Estimate	Std. Error	t Value	Pr > |t|
Stage 1 Model: Random-Effects Probit				
Dependent Variable: Binary, Presence of Development				
Log Likelihood Function:	-123.9226			
Restricted Log Likelihood:	-156.3701			
Psuedo R-Squared:	0.21			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	1.05	0.37	2.88	0.00
Square Miles of Undeveloped Area	-0.01	0.00	-2.31	0.02
Distance to Arboretum Subcenter	-0.10	0.03	-2.94	0.00
Ben White Blvd. Indicator	1.66	0.71	2.34	0.02
South MoPac Extension Indicator	-1.18	0.77	-1.53	0.13
Percentage of Planning Area Dedicated to Industrual Use	0.85	0.46	1.85	0.06
ρ	0.18	0.13	1.41	0.16
Stage 2 Model: Random-Effects Probit				
Dependent Variable: SF of Mercantile Space Permitted				
Log Likelihood Function:	-1874.9907			
Restricted Log Likelihood:	-1882.015			
Adjusted R-Squared:	0.06			
Variable Description	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Constant	-925.68	38406.10	-0.02	0.98
Distance to CBD	8539.37	4517.30	1.89	0.06
σ_2	121459.00	5933.64	20.47	2.89E-15
$\rho_{1,2}$	-0.08	0.35	-0.24	0.81

Number of Cross-Sections, Time Series: 26,9
Number of Observations: 234

A tobit model was also run, in an attempt to better fit the data; however, none of the variables was found to be statistically significant for office, mercantile, or industrial development when using a tobit specification. Note that no results appear for the industrial development sample selection model because none of the variables was significant.

Although the results are disappointing, it is useful to know that the variables specified here, while seemingly related to permitting activity, may not be reliable predictors of development when considering data on the planning area level. Variables such as average market rents and occupancy rates might be more useful in this type of analysis than the characteristics of each planning area, but these data were not available (although they were sought).

3.4 Summary and Conclusions

This chapter has presented an analysis of permitting data from the City of Austin, Texas, over a nine-year period. The permitting data was originally taken from census tract-level information, but it was aggregated into the 26 City of Austin planning areas so that other land-use data could be used in the models. (Unfortunately, this land-use data failed to be statistically significant in the model results.)

Even when the data was aggregated, there were many planning areas that experienced no development for several years. Thus, a tobit model was used for the residential permit count data along with a negative binomial model for single-family attached housing permits. A two-stage sample selection model was used for the nonresidential data, which was in the form of annual square footage permitted.

Indicator variables for the North and South MoPac (Loop 1) extensions were included in the models to test if the new facilities had an impact on permitting activity in adjacent planning areas. The output from the residential models suggests that the extensions had no impact on development activity. However, since the models presented here offer relatively poor prediction of permitting levels, it would not be prudent to conclude that highway expansions have no impact on development. It may be that more spatially disaggregate and/or larger data sets would better expose the underlying relationships.

Other useful variables, such as average rent and occupancy rates, also could be included in the models to provide a better fit. The analysis presented here was limited by available data, which described each planning area's demographic characteristics instead of its economic characteristics. In order to measure the impact of highway network expansions on development activity, a finer level of detail is probably required.

The influence of high-tech industry in Austin's land market is reflected in the high coefficients on the indicator variables for the Capital of Texas Highway (Loop 360) and North MoPac (Loop 1) corridors, which are home to many high-tech offices. In addition, the tendency of high-tech manufacturers in Austin to locate research and development offices near existing factories (and vice-versa) is observed in the models. In the office development model, the square miles of industrial development in the planning area is a statistically significant predictor that office development will occur there.

CHAPTER 4: ANALYSIS OF ASSESSMENT DATA

4.1 Introduction

There have been numerous studies on the effects of transportation improvements on real estate values. (See Huang [1994], and TRB [1995] for a summary of recent highway capitalization studies.) Most analyze the effects of highway expansions or original construction on residential sale prices, with the goal of establishing the economic impacts of highway construction.

In the context of this research, the real estate value analysis can be used to determine whether a highway's expansion has an effect on land values in anticipation of construction or completion of a project. This chapter presents three models of the property-valuation impacts of highway capacity expansion. The data includes assessments of land, improvement to the land, and total property value. All properties come from the U.S. 183 corridor in northwest Austin, Texas.

4.2 Description of Study Corridor

Over the last decade, the U.S. 183 (Research Boulevard) corridor in Northwest Austin experienced rapid commercial growth. Several major employers in the high-tech sector have recently located in business parks in the corridor or have announced plans to relocate there. In addition, over two million square feet of retail space have been added to the corridor in the 1990's, including a regional shopping center and a large mixed-use office/retail center. Yet large tracts of land near U.S. 183 remain undeveloped.

As part of a major facility improvement, the highway was expanded (in segments) from a four-lane divided highway to a six-lane controlled-access facility with dual three-lane frontage roads. The expansion represents a more than doubling of capacity. The Texas Department of

Transportation began to acquire land for additional right of way in 1987; construction began in 1992 and was completed in 1997. The northernmost sections of the roadway are still under construction, but no data were taken for the areas adjacent to those sections.

Figure 4.1 shows a map with the location of U.S. 183 and the extent of its expansion. Figures A.2a through A.2c in Appendix A show detailed maps of the study corridor including dates of construction and the sequence of construction phases.

4.3 Data Assembly

4.3.1 Data Sources

The primary data source for this portion of the analysis was the Travis (County, Texas) Central Appraisal District (TCAD) records (TCAD, 2000). The State of Texas requires the appraisal district to keep yearly updated records of the data on which they base property tax assessments. For 1991-1999, the records were stored on computer, and for years prior to 1991, the data was collected from microfiche at the Austin History Center.

Since tax assessment values were used, rather than actual purchase prices, the data is only an approximation of market values during the study period. Purchase prices in Travis County are not available to the public due to Texas state statutes protecting privacy and property.

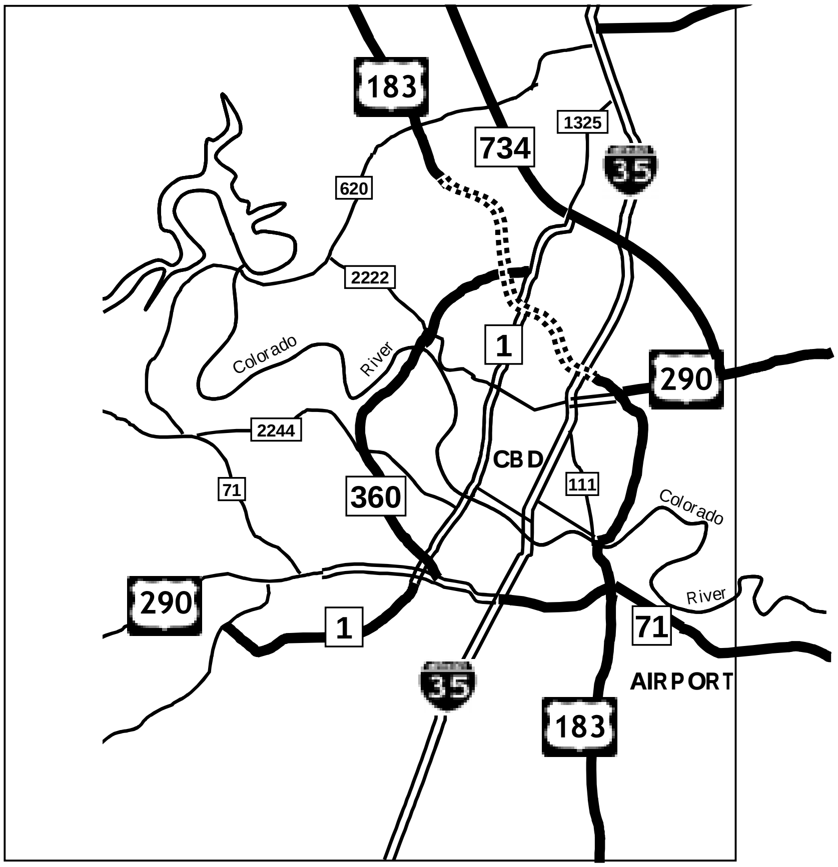

Figure 4.1 Map of Austin Area with Major Transportation Arteries.
Dashed lines indicate the extent of construction on US 183.

TCAD maintains records of assessed values of land and any improvements on that land, and has separate listings of what it considers to be market values of the land and improvements. Since the only consistent data were for appraised values, those are the numbers used in this analysis. In addition to appraised values, information about property acreage, square footage of improvements, and property use was collected. TCAD also lists the “effective year of construction”, which is the age of structures on the property after taking into account, for example, any renovations or additions that have been made to the original construction, after controlling for square footage.

Data were collected for every parcel with frontage on Research Blvd. (U.S. 183), plus a random sample of roughly 10 percent of the parcels within a half-mile band surrounding the facility. The random sample of parcels was area-weighted to ensure that larger parcels were more likely to be selected than smaller parcels (in proportion to their areas), and the results of the sample were checked to ensure that they accurately represented a diverse cross-section of the parcels in the study corridor.

Using plat maps, also obtained from TCAD, several parcel-level access measures were obtained, including the street distance from the parcel to the study facility and whether or not the parcel is located on a corner lot along the facility. The "corner lot" variable was further specified to distinguish lots on major, crossover streets (i.e., those that cross the facility via an underpass) from lots on lesser, non-crossover streets (i.e., those that dead-end into the facility's frontage roads).

Figure 4.2 shows a typical cross-section of the study facility, which is standard for urban freeways in Texas. Parcels A and B are situated at the corners of a minor street and a one-way frontage road, at an unsignalized intersection. We require that the minor street have another outlet so that parcels A and B could be accessed either from the major facility or via some other route through the bordering neighborhood. If the minor intersecting street had no other outlet, parcels A and B were not considered to be corner lots for the purpose of this analysis. In contrast, parcels C, D, E, and F have excellent access, due to an underpass connecting the two sides of the highway and signalized intersections on the frontage roads. Both cross traffic on the minor cross-street and u-turning or left-turning traffic from the frontage roads can access any of the four parcels.

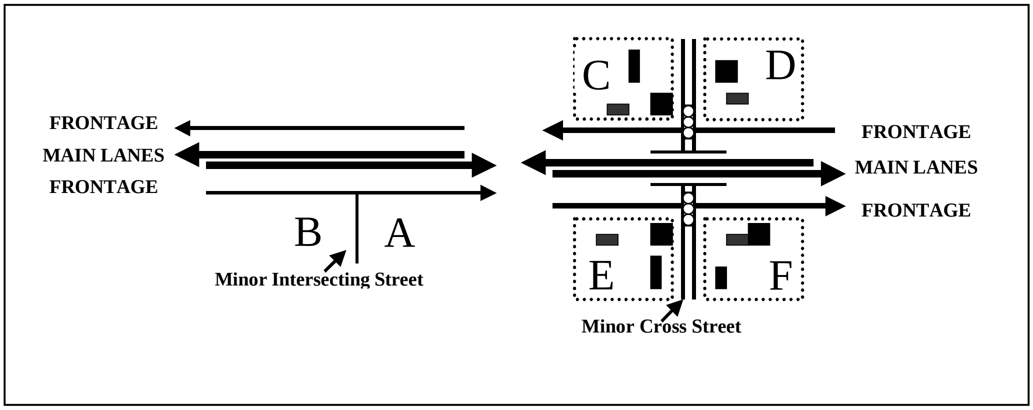

Figure 4.2: Corner Parcels Designations.
Parcels A and B have less accessibility than C, D, E and F

4.3.2 Sample Formation

The TCAD assessment data forms the basis for the data set. The data were organized into three files: one with land values only, a second with improvement values only, and a third with both land and improvement values.

Land uses were coded into eleven categories, as follows:

1. Detached single-family dwelling
2. Apartment Building
3. Retirement Home or Day Care Center
4. Convenience Store, Gas Station, or Auto Service Center
5. Small to Medium Store or Neighborhood Shopping Center
6. Small Office
7. Showroom, Warehouse
8. Bank
9. Restaurant or Night Club (includes fast food restaurant)
10. Grocery Store, Discount Store, or Department Store
11. Mid- to High-Rise Office

The eleven categories are not an exhaustive listing of possible land uses; rather, the categories represent all land uses present in the U.S. 183 corridor during the period of the study. For the land and total value models, any undeveloped parcels were assigned to category 0 (zero).

For parcels adjacent to each section of construction of the roadway, the years since right-of-way annexation, start of construction, and construction completion were calculated, with each time-based variable taking a value of zero for years before each event. These variables are useful to determine whether the annexation of right of way (indicating the first major step taken towards construction of the facility), the start of construction, and/or the completion of construction affected the real estate market.

4.3.3 Characteristics of the Data Set

The final data set contains 3,546 observations of improvement-related data, with 399 unique parcels. Of these 399 parcels, 89 form a complete panel of improvement-value data over the 18 years of the study period (for a total of 1,602 observations). For both the land-value model and the total-parcel-value model, (which includes the value of the land plus the value of any improvements), there are 317 unique parcels comprising a total of 3,061 observations; 90 of these parcels have complete panels. The incomplete panels have data missing for several years at the beginning and/or end of the time series.

The primary explanation for missing data is parcel subdivision, which eliminates a record for the old, large parcel and creates several unique records for the new, smaller parcels. Historical plat maps were not available to determine which parcels were subdivided or whether parcels were combined into one large parcel.

Since the software used to perform the regression is only capable of handling complete panels in a serial panel regression, two data sets were compiled. The first data set consisted only of complete panels, and was used to run a time series cross sectional regression in SAS 8.0. A second data set, which contained both complete and incomplete panels, was used in an autoregressive model. The two procedures will be described in detail below.

Figures 4.3 and 4.4 show the data set's average assessed land values per acre and average improvement values per (improved) square foot, respectively, for each year in the study period. In 1986, when the Texas Department of Transportation began to acquire the additional right of way needed for the expanded facility, property values rose significantly. For seven years after the right of way acquisition, property values declined from their speculative levels, remained flat during the mid-90's and then rose again at the end of the decade.

The value of improvements on the parcels followed a similar, although less dramatic, course. After a peak in 1986, the improvement values dropped throughout the late 80's, before rising again through the 90's.

The government's right-of-way acquisition may have inflated the market more than actual capacity. The market may have overreacted in the years leading up to the acquisitions and condemnations and lost value later. The possibility of speculation in the market may render this data very difficult to analyze.

Table 4.1 contains definitions and summary information for the variables used in the analysis.

Table 4.1: Summary of Variables Used in the Assessment Data Analysis.

Dependent Variables	**Description**
Improvement Value	Sum of the assessed values of all improvements on a parcel.
Land Value	Assessed value of parcel.
Total Value	Sum of the land and improvement values
Independent Variables	**Description**
Sq. Feet of Improvement	Sum of the square footage of all improvements on a parcel.
Age of Improvement	Takes into account any substantial improvements or additions made to structures which reduce the overall age of the improvements. For multiple structures on one parcel, the age is weighted based on square footage of each improvement.
Land Uses:	
Single-Family	Both attached and detached units are included in this category.
Multi-Family	Includes both multi-family rental units and condos.
Retirement/Day Care	Retirement homes and day care centers.
Conv. Store/Gas Sta.	Also includes minilubes and service stations.
Small-Med Store	Stores less than 25,000 square feet, including small neighborhood shopping centers
Small Office	Offices less than 38,000 square feet.
Showroom/Warehouse	Includes car dealerships and manufacturing warehouses.
Bank	Bank branch offices and drive-thrus.
Restaurant/Night Club	Includes bars, full-service restaurants, fast food restaurants, and night clubs.
Grocery/Discount Store	Includes "big box" retailers, discount stores, and grocery stores over 25,000 square feet.
Large Office	Offices more than 38,000 square feet, including buildings up to 6 stories.
Land Area (acres)	Total area of parcel, in acres.
Time Trend	Ranges from 0 in 1982 to 17 in 1999.
Number of Years Since:	
ROW Acquisition	Additional right-of-way for frontage roads was acquired by the Texas Department of Transportation in 1986.
Construction Start	Construction start and completion dates vary by segment, and can be found in Figures A.2a through A.2c in Appendix A.
Construction Completion	
Distance from Facility ^2	Distance in miles from facility along street network, raised to the second power.
Corner with Signal Indicator	Indicator variable for parcels on corners with traffic signals and underpasses or crossovers.
Corner without Signal Indicator	Indicator variable for parcels on corners without traffic signals or underpasses or crossovers.

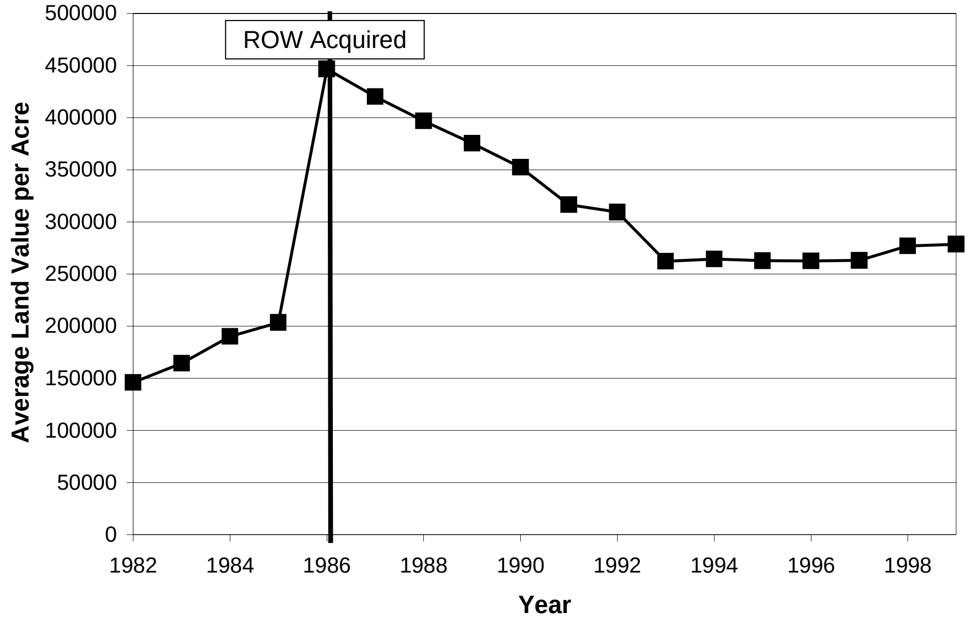

Figure 4.3: Average Assessed Land Values per Acre

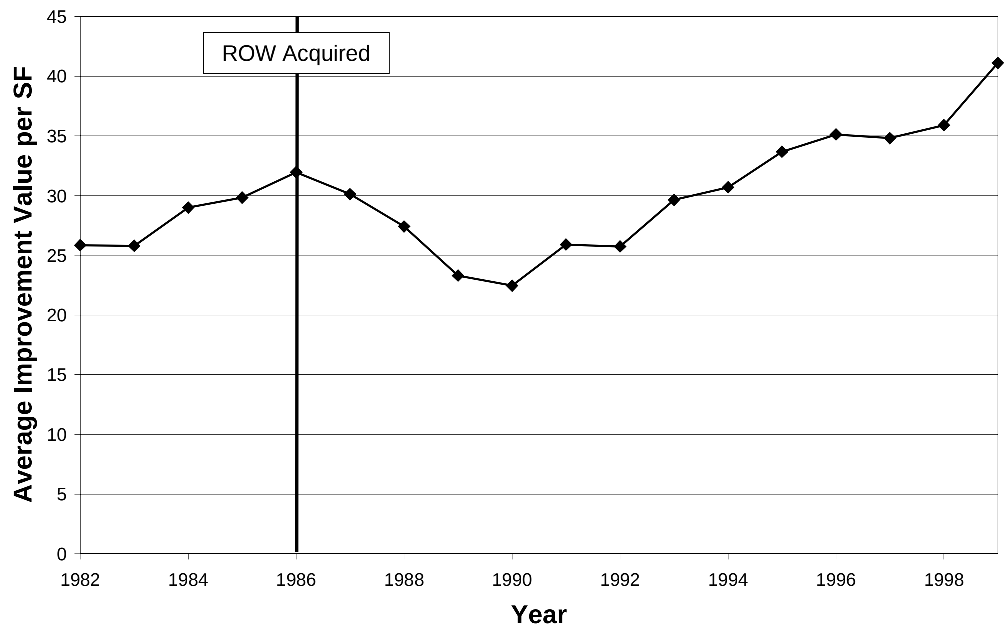

Figure 4.4: Average Assessed Improvement Value per Square Foot

4.4 Empirical Analysis

The land values are thought to be fundamentally related to the parcel acreages, so parcel areas were interacted with all other independent variables in the land value model. Likewise, the square footage of improvements on each parcel was interacted with the independent variables in the improvement value model. For the total value model, all of the land-value and improvement-value models' interacted terms were included, along with a constant.

First, using only complete panels, several time series cross-sectional (TSCS) regressions were performed using the TSCS procedure in SAS 8.0. Then, using all of the data, including incomplete panels, linear regression models with autocorrelated error terms were estimated by manipulating linear models in SAS 8.0 using a two-step least-squares process.

4.4.1 TSCS Regression

Panel data with time series observations were modeled here according to the following general structure:

$$y_{it} = \boldsymbol{\beta}'\mathbf{x}_{it} + u_{it}$$

$$\begin{aligned} \text{where} \quad i &= \text{cross section,} \\ t &= \text{time interval, and} \\ k &= \text{variable type.} \end{aligned}$$

In this analysis, the error term u_{it} is specified in two different ways. First, a two-way random-effects model is specified, where:

$$u_{it} = v_i + e_t + \varepsilon_{it} \ .$$

All three right-hand-side error terms are assumed to have zero means and constant (though distinct) variances, but the first accommodates parcel-specific variations, the second recognizes time-specific variations, and the third is assumed to vary randomly and independently across all observations. This two-way random-effects model is estimated using the method of Fuller and Battesse (1974). The second serial panel model estimation uses the Da Silva (1975) method. The Da Silva specification is similar to the Fuller-Battese method but allows a moving average (MA) correlation in the error terms. Both a MA(1) and MA(2) model were tested.

The error terms have the following structure:

$$\text{MA(1)}: e_{i,t} = \rho_1 u_{i,t-1} + u_{i,t}$$
$$\text{MA(2)}: e_{i,t} = \rho_2 u_{i,t-2} + \rho_1 u_{i,t-1} + u_{i,t}$$

where the $u_{i,t}$'s are purely "white noise" (independent random error terms).

4.4.2 Autoregressive Models for Incomplete Panels

In order to make use of all data available, autoregressive (AR) models were also specified. Since common regression software packages are unable to handle incomplete panels, the dependent and independent variables were transformed in order to produce the desired AR model coefficients. However, cross-section-specific effects are not accommodated in the specification used here, so the estimates are not maximally efficient (assuming such a structure governs).

First, an ordinary least squares (OLS) regression was run on the entire data set, using the same dependent variables as in the serial panel analysis. The residuals u_{it} were calculated for each year *t* and each cross section *i*. These residuals were regressed on the residuals from year *t-1*, using the equation:

$$u_{it} = \alpha + \rho u_{i,t-1}.$$

Next, the dependent and independent variables were transformed, using the equations:

$$y_{it}^* = y_{it} - \rho\, y_{i,t-1}$$
$$x_{it}^* = x_{it} - \rho\, x_{i,t-1}$$

Finally, these transformed variables were used in a second OLS regression to estimate the desired coefficients.

4.4.3 Empirical Results

Table 4.2 shows a comparison of model outputs for the three different panel models that used total value as the dependent variable. Table 4.3 shows the results of the land value models, and Table 4.4 shows the results of the improvement value models. The two-way random-effects model produces the most intuitive results in all three cases. The MA models do not appear to be useful in this analysis, but the outputs from the MA models are shown in Appendix C, Tables C.1-C.3, for purposes of comparison. All of the results discussed in this section refer to the two-way random-effects models, rather than to the results of the autoregressive models.

For the total-value model, all of the land use indicator variables are relative to single-family land use. Retirement homes and day care centers are estimated to have the highest improvement values per square foot, at $14.45 per square foot, relative to single-family homes. The extremely high value attributed to these types of land uses may be due to the installation of specialty equipment as well as strict building codes. Grocery stores and discount stores (at $2.54 per square foot) also are estimated to have a higher cost per square foot than single-family homes in this corridor. The indicators for multi-family homes and convenience stores and gas stations were statistically insignificant.

In the improvement value model, the improvement values per square foot have different signs than in the total value model. In fact, the retirement home and day care center indicator is statistically insignificant, along with the restaurants and nightclubs indicator, the bank indicator, the small office indicator, and the convenience store indicator. Since the age of the structure is already considered in the model, a possible explanation for the disparity between the improvement and total value model coefficients is the fact that the total values are influenced by the sharp increase in land values in 1986. Considered separately, the improvement values more accurately respond to the real estate market and the coefficients on the indicator variables are probably more reliable.

The four time trend variables include a base time trend, the number of years since right of way (ROW) acquisition, the number of years since construction start, and the number of years since construction completion. In the total-value model and the land-value model, the coefficients on the time trend variables indicate that the price of land per acre declines in the years following ROW purchases and condemnations, remains relatively flat during construction, and then rises again following construction. These results accurately reflect the fluctuations in average land price per acre, as shown in Figure 4.4. Similar results are obtained from the time-trend variables in the improvement-value model—all of which are significant—although it is not as clear how construction or right of way acquisition should influence improvement values (since these should not be tied to the parcel location, which is captured in land valuations).

As the square of the distance from the facility increases, the price of land drops quite dramatically in the total value model. In the land value model, the land price per acre also drops with increasing distance from the facility. When improvement values are considered separately from land values, the distance from the facility has no influence on improvement values per square foot. This is expected, if improvement values are to be independent of location.

Land on signalized and unsignalized corners is estimated to have almost $230,000 per acre greater value than land located mid-block. Interestingly, land on unsignalized corners had a higher value than land on signalized corners (a $230,000 premium for unsignalized corners vs. a $150,000 premium for signalized corners). After carefully examining the data set and parcel locations on plat maps, it was discovered that unsignalized corners in the U.S. 183 corridor are often located in industrial parks and major commercial centers. Thus, the unsignalized corner variable generally selected much more valuable parcels than the convenience stores and gas stations commonly located at signalized intersections. The value of improvements per square foot was less at signalized intersections than at unsignalized intersections ($2.71 per square foot vs. $0.08 per square foot, respectively). Finally, as age of structures increased, their value per square foot decreased at $1.20 per square foot per year.

Since only two years of data were collected after the completion of the project, it was not possible to examine all the new development that may have been induced by the expansion. A longer period of study would be useful. Also, facilities in different regions of the city and in different parts of Texas and the United States would help to control for any corridor-specific fluctuations. No control facility was used in the study, complicating the interpretation of the data with respect to induced demand. It is difficult to make any conclusive findings about development patterns without a control corridor with which to make comparisons. However, since every corridor is a component of the same network, a suitable control corridor may not exist.

It can be concluded, though, that land values reacted rather dramatically in this corridor to the government's entrance into the land market. This reaction may have weakened any later gains one would expect. Controls for bank lending practices and the general Austin economy might be useful in such models to capture fluctuations in the land market.

Table 4.2: Two-Way Random-Effects and AR (1) Model Results for Total Value

Model:		Two-Way Random Effects				First Order Autoregression (AR[1])			
Dependent Variable:		Total Value (Land + Improvement)				Total Value (Land + Improvement)			
Number of Cross Sections & Time Series:		90, 18				317, variable			
Number of Observations:		1,620				2,271			
R-Squared (Adjusted R-Squared):		0.62				0.61 (0.61)			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Error**	**t Value**	**Pr > |t|**
Intercept	1	220,782.80	45,224.60	4.88	0	84,436.00	13,846.00	6.10	0
Sq. Feet of Improvement	1	19.12	1.94	9.86	0	43.50	3.72	11.70	0
Variables Interacted with Sq. Feet of Improvement:									
Time Trend	1	-0.36	0.07	-4.93	0	0.38	0.25	1.56	0.119
Land Uses:									
Multi-Family	1	2.28	3.11	0.73	0.464	-8.74	3.31	-2.64	0.008
Retirement/Day Care	1	14.45	2.96	4.88	0	-14.67	58.03	-0.25	0.801
Conv. Store/Gas Sta.	1	1.64	2.24	0.73	0.463	-30.19	33.27	-0.91	0.364
Small-Med Store	1	-3.16	1.98	-1.59	0.111	-2.42	3.17	-0.76	0.446
Small Office	1	-1.77	1.83	-0.97	0.333	-2.85	5.78	-0.49	0.623
Showroom/Warehouse	1	-2.48	1.79	-1.39	0.165	-7.56	3.48	-2.17	0.030
Bank	1	-4.63	1.84	-2.51	0.012	28.97	38.86	0.75	0.456
Restaurant/Night Club	1	-2.91	1.79	-1.63	0.103	3.36	23.27	0.14	0.885
Grocery/Discount Store	1	2.54	1.34	1.90	0.058	-9.38	4.06	-2.31	0.021
Age of Improvement	1	-1.20	0.20	-5.88	0	-0.87	0.10	-8.39	0
Land Area (acres)	1	-25,803.60	31,434.90	-0.82	0.412	-123,318.00	9,871.15	-12.49	0
Variables Interacted with Land Area (Acres):									
Time Trend	1	84,775.78	3,053.70	27.76	0	50,557.00	1,924.82	26.27	0
Number of Years Since:									
ROW Acquisition	1	-122,362.00	4,151.20	-29.48	0	-36,882.00	1,673.42	-22.04	0
Construction Start	1	50,760.39	2,993.60	16.96	0	-20,202.00	1,785.81	-11.31	0
Construction Completion	1	15,167.75	6,450.90	2.35	0.019	51,652.00	11,456.00	4.51	0
Distance from Facility ^2	1	-189,905.00	120,442.00	-1.58	0.115	-511,261.00	181,731.00	-2.81	0.005
Corner with Signal Indicator	1	150,622.70	29,026.00	5.19	0	53,063.00	44,775.00	1.19	0.236
Corner without Signal Indicator	1	227,387.00	35,328.40	6.44	0	-96,206.00	9,461.21	-10.17	0

Table 4.3: Two-Way Random-Effects and AR(1) Model Results for Land Value Only

Model:		Two-Way Random Effects				First Order Autoregression (AR[1])			
Dependent Variable:		Land Value				Land Value			
Number of Cross Sections & Time Series:		90, 18				317, variable			
Number of Observations:		1602				3148			
R-Squared (Adjusted R-Squared):		0.62				0.32 (0.32)			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Intercept	1	120,700	26,711	4.52	0	70,286	11,991	5.86	0
Land Area (acres)	1	8,897	9,196	0.97	0.333	-111,193	9,018	-12.33	0
Variables Interacted with Land Area (Acres):									
Time Trend	1	71,045	1,995	35.62	0	42,041	1,626	25.86	0
Number of Years Since:									
ROW Acquisition	1	-102,960	2,981	-34.54	0	-31,976	1,304	-24.52	0
Construction Start	1	30,645	2,173	14.1	0	-2,647	1,625	-1.63	0.103
Construction Completion	1	5,462	4,824	1.13	0.258	-11,531	9,498	-1.21	0.225
Distance from Facility ^2	1	-125,097	60,612	-2.06	0.039	-111,660	202,033	-0.55	0.581
Corner with Signal Indicator	1	87,385	13,772	6.35	0	50,459	51,191	0.99	0.324
Corner without Signal Indicator	1	154,853	20,202	7.67	0	-102,635	7,597	-13.51	0

Table 4.4: Two-Way Random Effects and AR(1) Models for Improvement Value

Model:		Two-Way Random Effects				First Order Autoregression (AR[1])			
Dependent Variable:		Improvement Value				Improvement Value			
Number of Cross Sections & Time Series:		89, 18				399, variable			
Number of Observations:		1602				3148			
R-Squared (Adjusted R-Squared):		0.57				0.87 (0.87)			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Intercept	1	41,474.12	23,135.70	1.79	0.073	14,756.00	5,880.11	2.51	0.012
Sq. Feet of Improvement	1	25.82	1.29	19.95	0	26.92	0.91	29.46	0
Variables Interacted with Sq. Feet of Improvement:									
Time Trend	1	0.70	0.09	7.43	0	1.86	0.21	8.84	0
Number of Years Since:									
ROW Acquisition	1	-1.06	0.13	-8.22	0	-1.21	0.24	-5.07	0
Construction Start	1	1.31	0.10	13.62	0	-0.48	0.15	-3.31	0
Construction Completion	1	0.32	0.21	1.48	0.138	2.72	0.31	8.90	0
Distance from Facility ^2	1	-11.58	4.69	-2.47	0.014	-11.98	3.41	-3.51	0
Corner with Signal Indicator	1	0.08	1.63	0.05	0.962	4.61	0.51	9.03	0
Corner without Signal Indicator	1	2.71	1.38	1.96	0.050	0.75	1.09	0.69	0.493
Land Uses:									
Multi-Family	1	-5.37	0.67	-7.96	0	-8.66	0.63	-13.73	0
Retirement/Day Care	1	-3.67	24.84	-0.15	0.883	-13.83	5.40	-2.56	0.010
Conv. Store/Gas Sta.	1	-7.24	7.11	-1.02	0.309	-12.19	9.96	-1.22	0.221
Small-Med Store	1	-4.46	1.24	-3.60	0.000	-8.20	0.53	-15.42	0
Small Office	1	1.60	2.79	0.58	0.565	-5.73	2.32	-2.47	0.014
Showroom/Warehouse	1	-6.56	1.22	-5.38	0	-8.17	0.71	-11.44	0
Bank	1	12.19	17.40	0.70	0.484	34.39	8.64	3.98	0
Restaurant/Night Club	1	13.81	14.80	0.93	0.351	0.95	8.20	0.12	0.908
Grocery/Discount Store	1	-5.38	1.35	-3.99	0	-7.92	1.04	-7.64	0
Age of Improvement	1	-0.42	0.04	-10.13	0	-0.60	0.03	-22.87	0

4.5 Summary of Assessment Data Analysis

This chapter has presented an analysis of panel data for parcel-level land and improvement values along the U.S. 183 corridor in northwest Austin, Texas. The land and improvement data were obtained from Travis County tax assessment records and therefore are not a perfect reflection of actual market values. However, the number of observations is higher due to yearly recording (versus having to wait until a property is sold).

Various panel analyses were performed on the data. A manual autoregressive procedure allowed all data to be analyzed, and smaller data sets, consisting only of complete panels, were fit to models using a DaSilva time-series cross-sectional procedure. A Fuller-Battese two-way random-effects model produced the most intuitive results.

A preliminary analysis of average land prices found significant changes in land prices in response to right of way acquisition by the Texas Department of Transportation. The subsequent statistical analysis confirmed that the year of land acquisition is a significant event in land price adjustments.

All variable coefficients had intuitive signs and magnitudes, but the hierarchy of land uses changed between the total value and improvement value models, most likely due to the land-price spike evident in the year of right-of-way acquisition by TxDOT. As expected, the price of land on corners and the price of land with frontage on the major facility were much higher than other land.

An analysis of improvements to land and changes in land uses would highlight development differences and permit more conclusions related to development inducements due to corridor expansions.

CHAPTER 5: PERSPECTIVES OF REAL ESTATE PROFESSIONALS

5.1 Introduction

The previous two chapters examined the impacts of highway capacity expansion on development from a quantitative perspective. Land value models and permitting models are important tools in determining the extent of transportation improvement impacts on land use, but it is also useful to consider qualitative aspects of development.

This chapter presents major findings from a series of in-person interviews with real estate professionals in the city of Austin, Texas. The interview subjects were chosen from a wide range of disciplines related to development. Bob Liverman, formerly a principal in Trammell Crow Corporation's Austin office, now owns his own development firm, The Liverman Company. Steve Ross, formerly an independent developer handling small retail projects around Austin, now teaches a land development course for the Community and Regional Planning Department of the University of Texas at Austin School of Architecture. Charles Heimsath is president of Capital Market Research, an independent real estate market analysis and consulting firm. Ben Heimsath is a member of the Austin Planning Commission, an advisory and quasi-judicial board with the power to make and amend the City of Austin's master plan, recommend approval or disapproval of proposed zoning changes, and control land subdivision (City of Austin, 2000). Finally, Rachel Rawlins, a former member of the Austin Planning Commission, currently practices planning and land use law and teaches a planning law course at The University of Texas.

Although the information obtained from the interviews is interesting to consider when investigating land use and transportation interactions, it is important to note that the results presented here are based on the opinions of a small sample of professionals, and may not represent the perspectives of everyone in the development community. A questionnaire was prepared for each interview, but the meetings were conducted in an informal manner that allowed for casual conversations rather than strictly controlled experiments.

Another important caveat: All of the subjects were very familiar with the City of Austin, but their opinions may not apply to every city in the country or even in Texas. Markets like Houston are almost entirely controlled by a few large developers, while Austin has a more open market that offers many opportunities for small-time entrepreneurs and speculators (Liverman, 2000; Ross, 2000b).

That said, the goal of the interviews was to determine what effects, if any, improvements to transportation infrastructure have on developers' timing and location decisions.

5.2 Findings

A universal belief among the professionals was that access to transportation is a necessary, but not sufficient condition for development. The quality of the access may not be important to many land consumers, most notably homeowners, who are willing to suffer relatively long delays before considering a relocation (C. Heimsath, 2000). This observation implies that residential developers and land consumers may not value transportation costs as highly as other factors, such as rent or the quality of area schools (Ross, 2000b; Alonso, 1964). However, a large development corporation in Austin was able to purchase and develop land at every major intersection on the north extension of the MoPac Expressway (refer to Figure 3.1 for map). Apparently, this developer did value access highly and was willing to pay land speculators for the right to develop the land (Liverman, 2000)

The North MoPac example is a case where many development decisions clearly preceded highway construction. Often, causality cannot be clearly established. Development may be spurred by the expectation of future roadway construction in some cases, but other factors must also be considered. Boarnet (1997) posits that today's suburban development patterns may still be due to residual effects from the original construction of the interstate highway system. Such development lags can make it impossible to separate the effects of original road construction from subsequent expansions. Likewise, improvements elsewhere in the network may shift development away from a corridor temporarily or may impact congestion system wide (Boarnet, 1997). If these are not controlled for, the picture remains incomplete.

Another challenge facing land use analysis is the current state of transportation funding. Often transportation agencies such as Metropolitan Planning Organizations (MPOs) and state Departments of Transportation (DOTs) must take a reactive approach to transportation planning rather than a proactive one (B. Heimsath, 2000). It is difficult to establish any causality when road expansions are prioritized and built based on existing, rather than predicted, conditions.

The effects of existing congestion on development were not determined in these interviews. The findings of Hansen et al. (1993) suggest that developers build their projects with the assumption that access routes will eventually be improved when the need arises (sometimes due to the traffic generated by their own development). As the transportation network becomes more complete and ubiquitous, developers have little incentive to lobby for additional access routes or highway expansions. In fact, developers may value road improvements but fail to acknowledge this due to possible political ramifications of admitting knowledge of the causality (Hansen et al., 1993).

Transportation access is an important criterion for siting a development, but zoning and other development regulations are the ultimate constraints. Along with the zoning laws, the relative ease with which the permitting process can be negotiated is extremely important in determining the nature of a development. In Austin, variances are only granted in extraordinary cases (B. Heimsath, 2000). Due to pyramid-type zoning laws, the industrial zoning adjacent to existing rail lines allowed almost any type of development at Dallas light rail stations. In contrast, Austin would have to rewrite zoning ordinances and overcome fierce neighborhood opposition in some central city neighborhoods in order to take advantage of light rail's development opportunities (B. Heimsath, 2000).

Intangible factors, such as bias by real estate agents toward certain sections of town, reputation of local school districts, quality of recreational facilities, etc., may be much more important to determining development location than the present or proposed state of the transportation system. Timing is highly dependent on the availability of financing. Unlike in the more speculative 1980's, today's more cautious lenders require that market rents and projected occupancy rates will support the project financially (Liverman, 2000). Since business cycles operate somewhat independently of transportation improvements, average rent and occupancy data can be important predictors of development (C. Heimsath, 2000).

Utilities are playing an increasingly important role in development decisions (Liverman, 2000). Municipalities use utility connections (or the lack thereof) to regulate development and developable locations, regardless of zoning. Nonetheless, communications infrastructure, most notably fiber optic lines and other broadband conduits, are overshadowing the importance of traditional utilities such as power, gas, water, and sewer. Even if developers have ignored the value of transportation access in the past, the presence of high-speed telecommunications infrastructure has become a key marketing tool in today's commercial and residential developments (Liverman, 2000).

5.3 Summary

All interview subjects agreed that transportation has an underlying and possibly indirect role in determining the timing and location of developments. Sites would not even be considered for development without basic transportation access. However, factors such as zoning and permitting regulations, quality of schools, and prejudices for or against certain communities may play a much more important role in location decisions than transportation access or planned improvements. Austin is a relatively land- and transportation-abundant region, so factors other than transportation carry greater weight. It may be that in more transportation- or landconstrained environments decisions regarding transportation expansion more strongly influence location decisions.

Business cycles and availability of financing also strongly influence timing decisions. Establishing a clear connection between transportation improvements and development trends is difficult, due to the nature of transportation funding allocations today and the difficulty separating residual effects of past improvements (or improvements elsewhere in the network) from those of recent expansions.

And, as the transport of information becomes more important than the transport of goods and people, utilities, and, in particular, telecommunications infrastructure, may play a much greater role in development location decisions.

CHAPTER 6: SUMMARY AND CONCLUSIONS

This research has presented, in three forms, an analysis of several effects of highway capacity expansion on development. After a review of relevant literature, an analysis of building permit data from the City of Austin was performed over a panel of planning areas. Parcel-level tax assessment records were also studied to determine the effects of a major capacity expansion on real estate values along a highway corridor. Finally, several interviews with real estate professionals were summarized.

The main findings of this study are as follows:

- Any relation between development permitting and two road expansions, one in North Austin and the other in Southwest Austin, was not found. The spatially aggregate nature of the observations may have limited this analysis.
- Some evidence of the influence of high-tech industry on the Austin land market was found. In the models of office permits, the north MoPac (Loop 1) and Capital of Texas Highway (Loop 360) indicator variables have very high values, reflecting the rapid development of high-tech corridors in the region. In addition, the tendency of high-tech manufacturers in Austin to locate research and development offices near existing factories is reflected in the models. Square miles of industrial development is a predictor of office development in Austin.
- Proximity to the Arboretum Subcenter and the CBD rated positively for single-family detached and multi-family models. Proximity to the airport, however, was predicted to be a deterrent to development.
- The low ρ^2 values in the permitting models suggest a high variability in land markets from year to year.
- A strong relation between the Texas Department of Transportation’s acquisition of right of way for a new facility and an increase in land prices was found.

- Real estate professionals were unanimous in their assertions that accessibility is a necessary but not sufficient condition for development. Many other factors play an equal if not more important role in the timing and location of development.

Of all the pieces of this research, the interviews yielded the most interesting results. All of the interview subjects agreed that land use and transportation planning need to be better coordinated in the future.

An understanding of transportation-land use interactions is complicated by residual effects of previous expansions and even expansions of other links in the network. It is important to consider past business cycles and current information about vacancy rates and market rents in order to accurately predict development patterns and, especially, development timing. Transportation changes alone cannot be used to model land use shifts, because there are many unknowns in land development that cannot be quantified.

In the future it will be interesting to see how telecommunications and the transportation of information impact the role of roads and highways in firm and household location decisions. While early predictions about telecommuting have overstated its near-term impact on highway congestion, telecommunications infrastructure may challenge traditional transportation infrastructure for dominance in the location equation as we move further toward an information-based economy.

APPENDIX A: MAPS

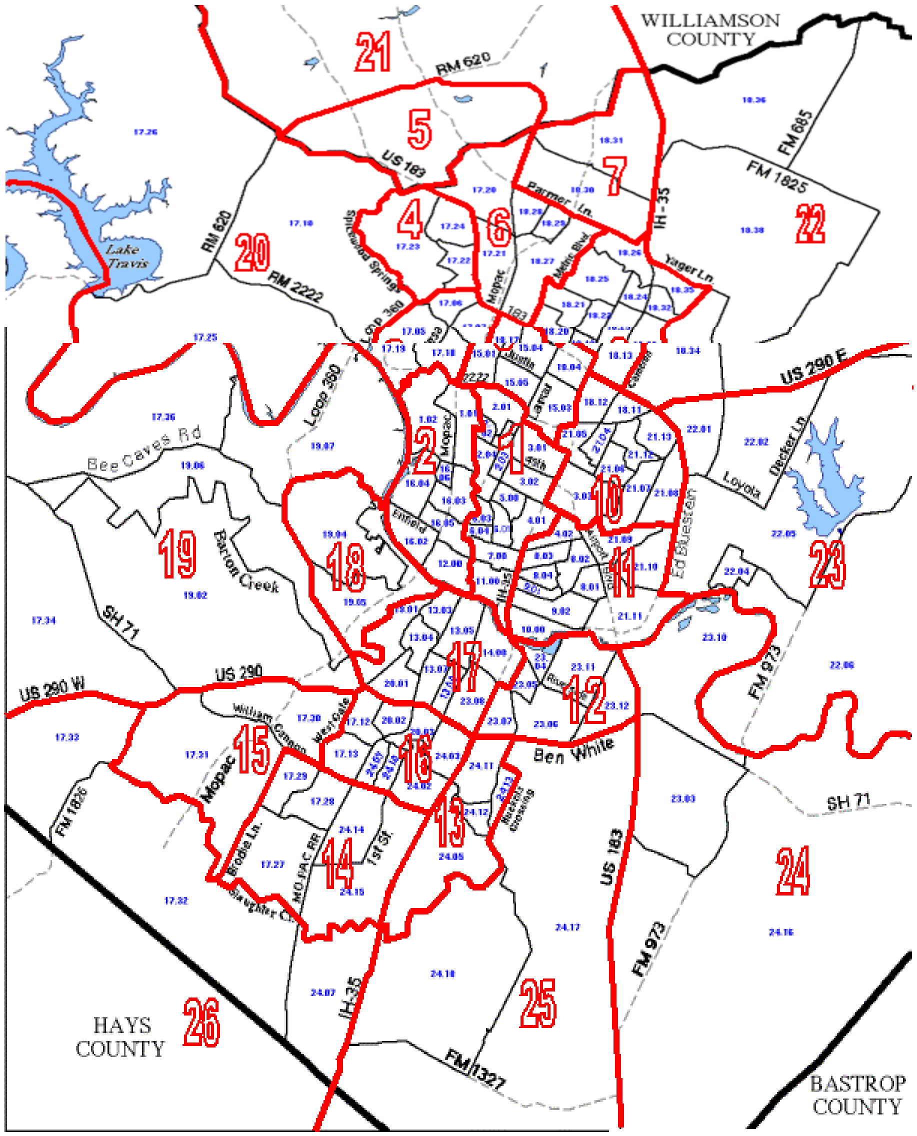

Figure A.1: City of Austin Planning Areas

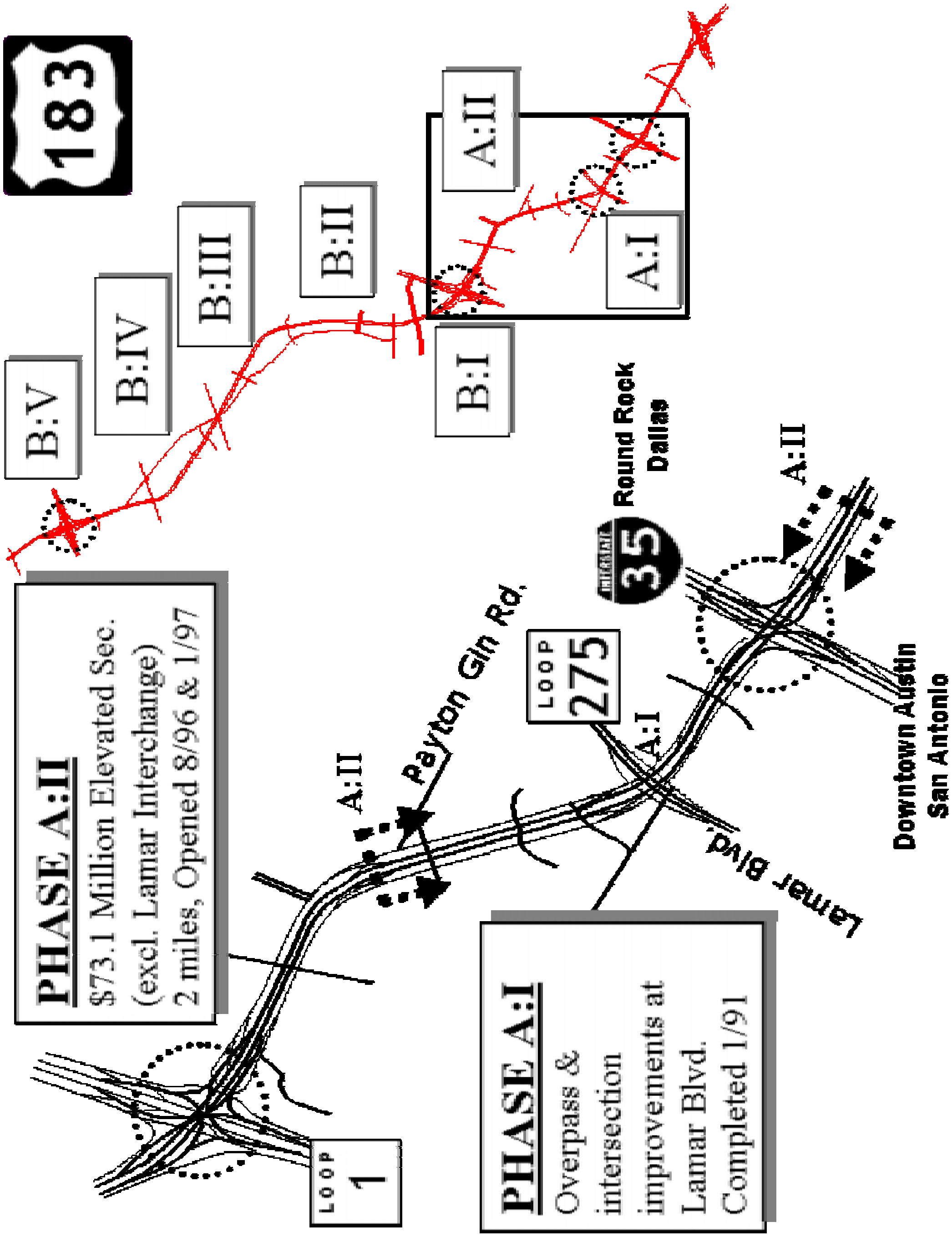

Figure A.2a: U.S. 183 (Research Blvd.) Construction Phases AI and AII

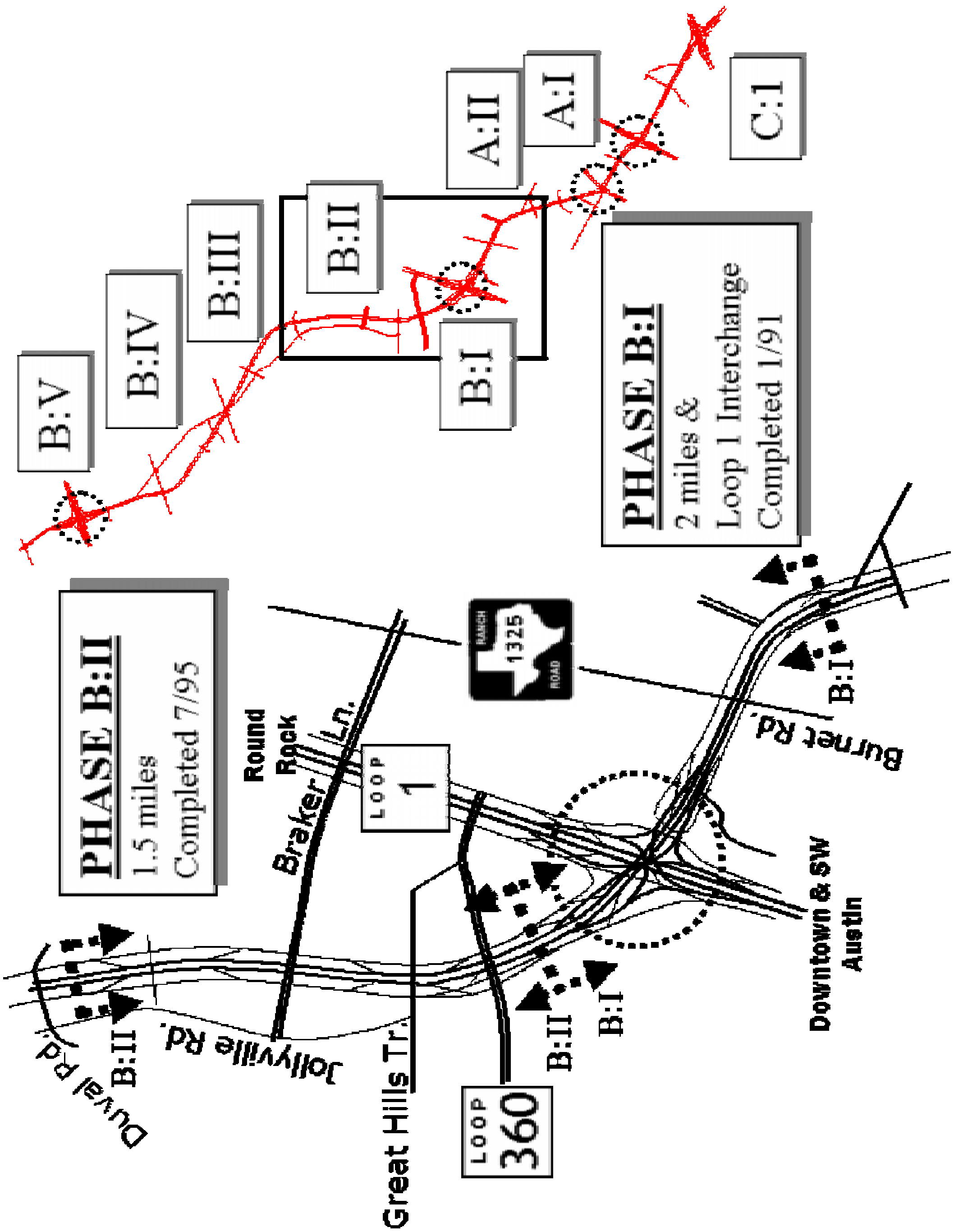

Figure A.2b: U.S. 183 (Research Blvd.) Construction Phases BI and BII

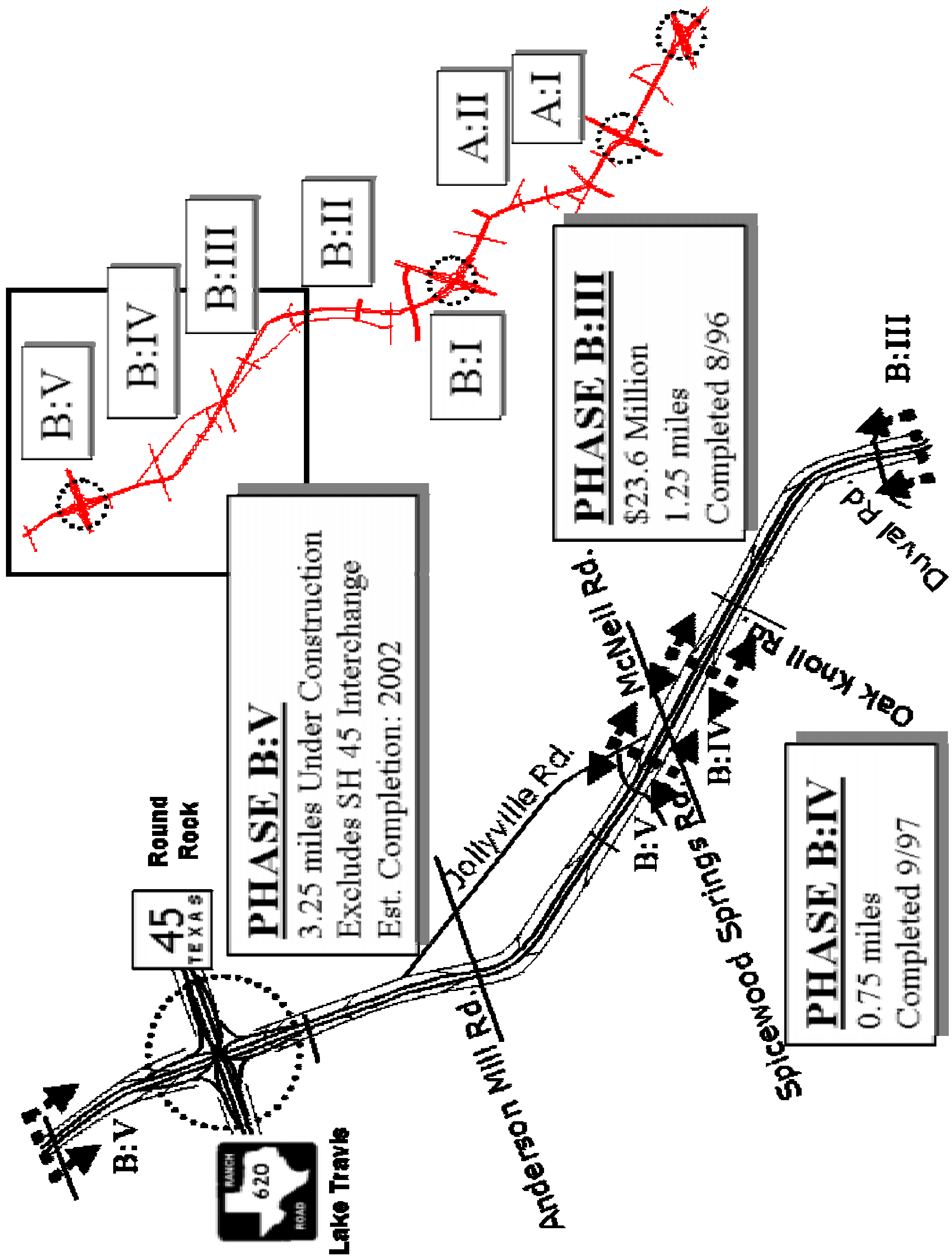

Figure A.2c: U.S. 183 (Research Blvd.) Construction Phases BIII through BV

APPENDIX B: CONGESTION INDICES

The Texas Department of Transportation (TxDOT) publishes annual average daily traffic counts for various points along each state-maintained highway in the Austin region. Along with this data, information about the capacity of each state highway was used to calculate an annual average volume-to-capacity (V/C) ratio for at least one major facility and one transverse arterial in each planning area.

Table B.1 lists the facilities in each planning area from which flow data were taken, along with the flow measurement points on the roadways. The capacities of the roads in each year were determined from historical maps and various newspaper articles published over the course of the study period. The capacity assumptions for each type of facility are listed in Table B.2. Using the volume counts and the capacities, V/C ratios were calculated for each facility, and then averaged across each planning area.

Table B.1: Facilities and Locations at which Flows Were Measured

Planning Area	Facility	Flow Measurement Point
1	IH 35	Town Lake
1	1st Street	Congress
2	MoPac	35th Street
3	2222	Balcones
4	183	Braker
5	183	Travis/Williamson County Line
6	FM 1325	Duval
7	FM 1325	Wells Branch
8	IH-35	Braker
8	Spur 275 (N. Lamar Blvd.)	Rundberg
9	Spur 69	Airport Blvd.
10	Airport	IH-35
10	US 290 E	Cameron
11	Airport	US 183
11	US 183	Airport Blvd.
12	IH 35	Town Lake
12	TX 71 E	Montopolis
13	TX 71 E	Montopolis
13	IH-35	S. of Ben White
14	IH-35	William Cannon
14	S. Congress	William Cannon
15	290 W	Mopac
15	Mopac	William Cannon

Planning Area	Facility	Flow Measurement Point
16	IH-35	S. of Ben White
16	Ben White	IH-35
17	IH 35	Town Lake
17	Loop 343 (S. Lamar Blvd.)	Oltorf
18	2244	Mopac
18	Loop 360	Mopac
19	2244	Loop 360
19	TX 71 W	Oak Hill Y
20	RM 2222	Loop 360
20	RM 620	W. of US 183
21	US 183	N. of RM 620
21	RM 620	E. of US 183
22	IH-35	Parmer Ln
22	US 290 E	US 183
23	FM 969 (MLK)	US 183
23	FM 973	FM 969
24	TX 71 E	FM 973
24	FM 973	FM 812
25	IH-35	Slaughter Ln
25	FM 1327	FM 1625
26	IH-35	Slaughter Ln
26	FM 2304	N. of Manchaca

Table B.2: Capacity Assumptions for Various Facilities

Facility Type	Typical Cross-Section	Hourly Capacity Per Lane
Freeway	Six Controlled-Access Lanes	2000
	Six Frontage Road Lanes	800
Parkway	Six Controlled-Access Lanes	1800
Suburban Arterial Divided	Four to Six Lanes with Shoulders	1200
Suburban Arterial Undivided	Four Lanes, No Center Turn Lane	900
Urban Arterial Divided	Four to Six Lanes	800
Urban Arterial Univided	Four Lanes Plus Center Turn Lane	600

APPENDIX C: ADDITIONAL MODEL OUTPUT

Table C.1: MA(1) and MA(2) Model Results for Total Assessed Value

Model:		First-Order Moving Average (MA[1])				Second-Order Moving Average (MA[2])			
Dependent Variable:		Total Value (Land + Improvement)				Total Value (Land + Improvement)			
Number of Cross Sections & Time Series:		90, 18				90, 18			
Number of Observations:		1,620				1,620			
R-Squared (Adjusted R-Squared):		0.54				0.55			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Error**	**t Value**	**Pr > |t|**
Intercept	1	19,030.82	34,108.00	0.56	0.577	155,724.50	34,287.20	4.54	0
Sq. Feet of Improvement	1	57.63	0.19	295.67	0	32.47	0.24	137.19	0
Variables Interacted with Sq. Feet of Improvement:									
Time Trend	1	-0.16	0.01	-23.73	0	-1.17	0.01	-160.72	0
Land Uses:									
Multi-Family	1	-13.21	0.23	-58.24	0	-18.84	0.21	-89.39	0
Retirement/Day Care	1	-11.11	0.25	-43.94	0	-13.89	0.20	-69.59	0
Conv. Store/Gas Sta.	1	-9.00	0.18	-49.82	0	-30.61	0.23	-135.14	0
Small-Med Store	1	-2.67	0.31	-8.67	0	-16.64	0.24	-69.62	0
Small Office	1	-17.02	0.37	-45.79	0	-11.39	0.30	-38.58	0
Showroom/Warehouse	1	-30.12	0.33	-91.84	0	-10.96	0.36	-30.81	0
Bank	1	-14.28	0.32	-44.21	0	-21.46	0.27	-78.12	0
Restaurant/Night Club	1	4.54	0.19	24.42	0	-12.84	0.20	-65.15	0
Grocery/Discount Store	1	5.76	0.07	83.25	0	-7.57	0.09	-86.41	0
Age of Improvement	1	-3.08	0.02	-141.33	0	1.29	0.02	54.96	0
Land Area (acres)	1	85,297.28	7,182.90	11.88	0	53,151.58	6,587.00	8.07	0
Variables Interacted with Land Area (Acres):									
Time Trend	1	-6,004.74	953.90	-6.30	0	123,531.30	812.00	152.14	0
Number of Years Since:									
ROW Acquisition	1	-21,075.80	1,328.20	-15.87	0	-185,877.00	1,095.10	-169.73	0
Construction Start	1	24,545.90	758.30	32.37	0	-43,355.20	873.90	-49.61	0
Construction Completion	1	189,191.80	1,577.50	119.93	0	332,866.80	1,921.60	173.23	0
Distance from Facility ^2	1	-1,914,292.00	78,964.40	-24.24	0	-2,158,948.00	78,368.70	-27.55	0
Corner with Signal Indicator	1	281,323.60	7,820.00	35.97	0	179,637.90	7,240.40	24.81	0
Corner without Signal Indicator	1	-188,296.00	7,651.90	-24.61	0	-447,833.00	7,697.20	-58.18	0

Table C.2: MA(1) and MA(2) Model Results for Land Value Only

Model:		First-Order Moving Average (MA[1])				Second-Order Moving Average (MA[2])			
Dependent Variable:		Land Value				Land Value			
Number of Cross Sections & Time Series:		90, 18				90, 18			
Number of Observations:		1602				1602			
R-Squared (Adjusted R-Squared):		0.18				0.51			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Intercept	1	310,913	24,261	12.82	0	113,428	25,293	4.48	0
Land Area (acres)	1	124,117	5,362	23.15	0	34,020	9,690	3.51	0
Variables Interacted with Land Area (Acres):									
Time Trend	1	-28,795	879	-32.76	0	65,778	2,582	25.48	0
Number of Years Since:									
ROW Acquisition	1	38,131	1,235	30.88	0	-99,335	3,980	-24.96	0
Construction Start	1	44,410	681	65.27	0	33,662	3,085	10.91	0
Construction Completion	1	-137,500	2,267	-60.64	0	-18,620	5,188	-3.59	0
Distance from Facility ^2	1	-110,817	50,200	-2.21	0.027	-126,020	56,964	-2.21	0.027
Corner with Signal Indicator	1	-239,073	5,715	-41.83	0	92,698	13,471	6.88	0
Corner without Signal Indicator	1	-287,539	5,814	-49.45	0	183,413	21,403	8.57	0

Table C.3: MA(1) and MA(2) Model Results for Improvement Value Only

Model:		First-Order Moving Average (MA[1])				Second-Order Moving Average (MA[2])			
Dependent Variable:		Improvement Value				Improvement Value			
Number of Cross Sections & Time Series:		89, 18				89, 18			
Number of Observations:		1602				1602			
R-Squared (Adjusted R-Squared):		0.32				0.29			
Variable Description	**DF**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**	**Estimate**	**Std. Error**	**t Value**	**Pr > |t|**
Intercept	1	-21,913.20	20,207.80	-1.08	0.278	-132,465.00	20,372.00	-6.50	0
Sq. Feet of Improvement	1	35.67	0.56	63.51	0	40.84	0.61	67.26	0
Variables Interacted with Sq. Feet of Improvement:									
Time Trend	1	2.59	0.03	78.83	0	1.19	0.03	42.26	0
Number of Years Since:									
ROW Acquisition	1	-4.34	0.04	-107.91	0	-1.74	0.03	-51.60	0
Construction Start	1	1.81	0.03	54.69	0	-2.26	0.03	-67.54	0
Construction Completion	1	1.87	0.05	36.16	0	7.10	0.07	107.86	0
Distance from Facility ^2	1	-70.09	2.34	-29.99	0	-94.39	2.47	-38.20	0
Corner with Signal Indicator	1	-12.89	0.27	-47.96	0	29.42	0.51	58.23	0
Corner without Signal Indicator	1	46.06	0.33	138.71	0	16.19	0.34	47.54	0
Land Uses:									
Multi-Family	1	-0.37	0.05	-6.91	0	-0.65	0.07	-8.78	0
Retirement/Day Care	1	-10.11	2.56	-3.95	0	-8.56	2.63	-3.26	0
Conv. Store/Gas Sta.	1	-20.30	0.83	-24.49	0	-27.84	0.99	-27.98	0
Small-Med Store	1	-17.73	0.55	-32.04	0	-23.92	0.59	-40.35	0
Small Office	1	-9.64	0.56	-17.27	0	-21.65	0.60	-35.91	0
Showroom/Warehouse	1	-20.41	0.55	-36.98	0	-26.29	0.59	-44.50	0
Bank	1	26.41	2.17	12.16	0	27.96	2.23	12.54	0
Restaurant/Night Club	1	-15.13	1.32	-11.45	0	-29.04	1.73	-16.81	0
Grocery/Discount Store	1	-26.15	0.56	-46.92	0	-18.03	0.60	-30.22	0
Age of Improvement	1	-0.33	0.01	-40.68	0	0.15	0.01	15.09	0

REFERENCES

Adams, J. S. 1970. “Residential Structure of Midwestern Cities.” *Annals of the Association of American Geographers,* 60, 37-62.

Alonso, W. 1964. *Location and Land Use*. Harvard University Press: Cambridge, MA.

Boarnet, M.J. 1997. “Highways and Economic Productivity: Interpreting Recent Evidence.” *Journal of Planning Literature* 11 (4), 476-486.

Button, K.J. 1988. “High-Technology Companies: An Examination of Their Transport Needs.” *Progress in Planning* 29 (2), 79-146.

Button, K.J. 1993. *Transport Economics, 2nd Edition*. Edward Alger: Aldershot, England.

Carey, D.; and Mahmassani, H. 1987. “Air Travel Considerations in Planning for Technology-Bound Economic Development: A Case Study of Austin, Texas.” *Regional Science Perspectives* 17 (1): 20-41.

Christaller, W. 1933. *Die Zentralen Orte in Suddeutchland*. [Baskin, C.W., translator 1966. *Central Places in Southern Germany*. Prentice Hall: Englewood Cliffs, NJ.]

City of Austin 1987-1995. *Growth Watch*, City of Austin Office of Long Range Planning: Austin, TX.

City of Austin 2000. Long Range Planning Web Site. http://www.ci.austin.tx.us/planning/

Colman 2000. “Induced Travel Demand: What Do We Know? What Does it Mean for Air Quality?” Presentation to the University of Texas Student Chapter of The Institute of Transportation Engineers, October 25, 2000.

Damm, D.; Lerman, S.R.; Lerner-Lam, E.; and Young, J. 1980. “Response of Urban Real Estate Value in Anticipation of the Washington Metro.” *Journal of Transport Economics and Policy* 14 (3): 315.

Da Silva, J.G.C. 1975. "The Analysis of Cross-Sectional Time Series Data," Ph.D. dissertation, Department of Statistics, North Carolina State University.

DeCorla-Souza, P. 2000. “Induced Highway Travel: Transportation Policy Implications for Congested Metropolitan Areas.” *Transportation Quarterly* 54 (2), 13-30.

Dowling Associates 1994. “Effects of Increased Highway Capacity on Travel Behavior.” Prepared for the California Air Resources Board. Oakland, CA.

Dyett, M.V. 1991. *Effects of Added Transportation Capacity on Development. The Effects of Added Transportation Capacity: Conference Proceedings*, Bethesda, MD, 97-99

Fuller, W.A. and Battese, G.E. 1974. "Estimation of Linear Models with Crossed-Error Structure," *Journal of Econometrics*, 2, 67-78.

Fulton, L.; Meszler, D.; Noland, R.; Meszler, D.J., and Thomas, J. 2000. "A Statistical Analysis of Induced Travel Effects in the U.S. Mid-Atlantic Region." *Journal of Transportation and Statistics* (3) 1, 1-14.

Giuliano, G. 1989. "New Directions for Understanding Transportation and Land Use." *Environment and Planning A* 21, 145-159.

Greene, W.H. 1981 "Sample Selection Bias as a Specification Error: Comment" *Econometrica* 49 (3), 795-798.

Greene, W.H. 1990. *Econometric Analysis, Third Edition*. Macmillan: New York, NY.

Greene, W.H. 1998. *Limdep Version 7.0 Help File*. Econometric Software

Hansen, M.; Gillen, D.; Dobbins, A.; Huang, Y.; and Puvathingal, M. 1993. "Air Quality Impacts of Urban Highway Capacity Expansion: Traffic Generation and Land Use Changes." Institute of Transportation Studies: Berkeley, CA.

Hansen, M. and Huang, Y. 1997. "Road Supply and Traffic in California Urban Areas." *Transportation Research-A*, 31 (3), 205-218.

Hartshorn, T.A. 1992. *Interpreting the City*. Wiley: New York, NY.

Heckman, J. 1979. "Sample Selection Bias as a Specification Error." *Econometrica* 47 (1), 153-161.

Heimsath, B. 2000. Parliamentarian, Austin, TX, Planning Commission. Personal Interview (October 18).

Heimsath, C. 2000. President, Capital Market Research, Austin , TX. Personal Interview (October 18).

Henk, R.H. 1989. "Quantification of Latent Travel Demand on New Urban Facilities in the State of Texas." *ITE Journal* (9) 24-28.

Huang, W. 1994. "The Effects of Transportation Infrastructure on Nearby Property Values: A Review of the Literature." Institute of Urban and Regional Development: Berkeley, CA.

Kockelman, K.M. 1997. "Effects of Location Elements on Home Purchase Prices and Rents in San Francisco Bay Area." *Transportation Research Record* (1606) 40-50.

Kockelman, K.M. 1998. “A Utility-Theory-Consistent System-of-Demand Equations Approach to Household Travel Choice.” PhD Dissertation in the Department of Civil Engineering, U.C. Berkeley; Berkeley, California.

Landis, J., Guhathakurta, S., Huang, W., and Zhang, M. 1995. “Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems.” The University of California Transportation Center, University of California at Berkeley: Berkeley, CA.

Levinson, D. M. and Kanchi, S. 2000. “Whence Induced Demand?” *International Association of Travel Behavior Research, Conference Proceedings*, Brisbane, Australia.

Limdep 1998. *Limdep Version 7.0*. Econometric Software.

Liverman, B. 2000. Principal, The Liverman Company. Personal Interview (May 24).

Lösch, A. 1940. *Raumliche Ordnung der Wirtschaft* [Woglom, W.H., translator (1967) *The Economics of Location*. Wiley, New York, NY.]

Mahmassani, H.; and Toft, G.S. 1984. “Transportation Requirements for High Technology Industrial Development.” *Journal of Transportation Engineering* 111 (5): 473-484.

Noland, R. and Cowart, W. 2000. *Proceedings of the 79th Annual Meeting of the Transportation Research Board*, Washington, D.C. Paper Number 00-1288.

Noland, R. and Lem, L. 2000. “Induced Travel: A Review of Recent Literature and the Implications for Transportation and Environmental Policy” The U.S Environmental Protection Agency, Washington, D.C.

Payne-Maxie Consultants and Blaney-Dyett Urban and Regional Planners 1980. *The Land Use and Economic Development Effects of Beltways. Final Report* DOT-OS-90079, prepared for the U.S. Department of Transportation and U.S. Department of Housing and Urban Development. U.S. Government Printing Office, Washington, D.C.

Parks, R.W. 1967. "Efficient Estimation of a System of Regression Equations when Disturbances Are Both Serially and Contemporaneously Correlated," *Journal of the American Statistical Association*, 62, 500-509.

Rodier, C.J.; Abraham, J.E.; and Johnston, R.A. 2000. Anatomy of Induced Travel: Using an Integrated Land Use and Transportation Model. Working Paper, submitted to the Annual Meeting of the Transportation Research Board, Washington, D.C. 2000.

Ross, S. 2000a. *Course Notes for CRP 389C: Research in Land Development* The University of Texas at Austin Department of Community and Regional Planning.

Ross, S. 2000b. Personal Interview. October 4, 2000.

SAS 2000. SAS/ETS Statistical Analysis Software. SAS Institute: Cary, NC.

Tomasik, J. 1987. "Socioeconomic and Land Values of Urban Freeways in Arizona." Phoenix, AZ: Arizona Department of Transportation.

Transportation Research Board (TRB) *Special Report Number 245 1995. Expanding Metropolitan Highways*. Washington, DC: National Academy Press.

TCAD 2000. Travis County, Texas, Central Appraisal District web site: www.traviscad.org.

Von Thünen, J.H. 1826. *Der Isolierte Staat*. [Hall, P., editor; Wartenberg, C.M., translator 1966. *The Isolated State*. Pergamon Press: New York, NY.]

Weber, A. 1929. *Theory of the Location of Industries* translated by C.J. Friedrich. Chicago, IL: University of Chicago Press.