CHAPTER SEVENTEEN

Urban Transportation and Land Use

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17.1 INTRODUCTION

This chapter is an introduction to the economics of the connection between urban transportation and land use. The nature of the transportation system strongly influences the patterns of land use in an urban area. Indeed, the long-run histories of urban areas sometimes are identified with the dominant mode of transportation of the time; the age of rail, the age of the automobile, and so on. Suppose that we wish to investigate the effect of an improvement in the urban transportation system on the urban land-use pattern. How does one go about studying this question? The purpose of this essay is to discuss the methods that are employed in this area of applied research.

This essay largely concentrates on this influence – the direction of causation from transportation system to land-use pattern. However, it is also true that the pattern of land use influences both the performance of an existing transportation system in the short run and the investments in transportation that are made in the long run. This direction of causation – from land-use patterns to transportation system performance and investment analysis – has been emphasized in the related field of urban transportation planning, but is discussed only briefly here.

The analysis of the effect of transportation on land use involves the fundamental concept in urban economics that was introduced by Alonso (1964) – bid rent. The economic reason for the existence of cities is to bring people and economic activities into proximate locations. Higher accessibility (lower transportation costs) of an urban site to desirable destinations increases the rent that is offered for that site. The urban economy is made up of different “sectors” such as households (of various types), businesses in the various industries, and governmental entities. Bid rent is defined as the maximum amount that a household or firm is willing to offer for a unit of land, given a level of utility (for a household) or profits (for a
firm). All have their own hypothetical bid rent for each urban site. If the land market is permitted to function so that the highest bidder occupies the site, then both the allocation of the land to a particular use (e.g., housing, retail trade, and so on) and the intensity of that use (e.g., the ratio of floor space to land) are determined by the market. In this essay, land use is defined as both type and intensity of land use. Population density is the measure of land-use intensity that is used most often.

The essay is organized as follows. The next section is a brief discussion of the regulation of land use that is employed in nearly all of the urban areas in the United States, and a short introduction to urban transportation planning. This is followed by a discussion of the economics of the effects of transportation improvements on urban land use. The essay concludes with a brief review of empirical studies and suggestions for further research.

17.2 ZONING AND URBAN TRANSPORTATION PLANNING

As noted above, the use of urban land has two distinct components; the allocation of land to particular uses and the intensity of that use. With the exception of the City of Houston (which does not have zoning), both components are regulated in detail by local zoning ordinances in all major metropolitan areas in the USA. Zoning became widespread in the 1920s, and most local zoning ordinances now specify the type of land use to which a parcel of land has been exclusively allocated. The US Supreme Court ruled in 1926 that zoning is a legitimate exercise of the police power granted to local governments by the state government. Early zoning ordinances specified a hierarchy of land uses (e.g., single-family residential, apartment buildings, commercial, industrial), and permitted “higher” uses in areas zoned for “lower” uses. In effect, single-family houses could be constructed anywhere. Such a hierarchy was based on the idea that the amount of negative externalities produced by land uses followed this ranking (in reverse order). However, these hierarchical ordinances were replaced by exclusive zoning over time. For example, the original zoning ordinance of the City of Chicago from 1923 was hierarchical, and this ordinance was replaced by exclusive zoning in 1957. Land uses that did not “conform” to the new zoning ordinance were required to be eliminated within a certain time period (although this was not enforced completely).

Many zoning ordinances also regulate the intensity of land use. For example, the 1957 Chicago zoning ordinance specifies that land allocated to residential use must adhere to a particular “floor-area ratio” (the ratio of floor space to land area). Eight floor-area ratios are used, ranging from 0.5 to 10.0. If the floor-area ratio is limited to 0.5, a two-story house can cover 25 percent of the lot. If the floor-area ratio is 10, then an apartment building that covers 25 percent of the lot can be 40 stories tall. Commercial and industrial floor-area ratios vary from 1.2 to 7.0, except in the central business area, where the top ratio is 16.0.

Courts have ruled consistently that, provided that the zoning ordinance covers the entire jurisdiction, local governments (usually the municipal government)
have the power to specify both the type and intensity of land use for every land parcel. As such, the urban land market would appear to be the most regulated market in which private property is bought and sold. However, an important issue that is unresolved is whether the zoning ordinance “follows the market” in some sense and produces a pattern of land use that comes close to replicating the pattern that an unregulated market would produce.

The other area of local government activity that is of immediate relevance to this essay is urban transportation planning. A series of federal laws were enacted that, since 1965, have required every metropolitan area in the USA to have a Metropolitan Planning Organization (MPO), with duties that include the preparation of a transportation plan for the entire metropolitan area. This plan must include a long-range component on the order of 20 years, be updated annually, cover all modes of transportation, and include short-range plans for improvements in transportation systems management and programs and projects for the upcoming year. The staff members of the MPO are engaged daily in the study of the urban area – its growth, its changing spatial patterns, and its transportation problems. These people are valuable resources for urban economists.

The basic urban transportation planning (UTP) process can be outlined as follows:

1. Forecast metropolitan population and employment for the target year.
2. Allocate population and employment to small analysis zones according to land availability, zoning, and other factors.
3. Specify alternative transportation programs given steps 1 and 2 (including the null alternative). Determine the cost of each alternative.
4. Use demand forecasting models to predict travel flows for the target year for each alternative program (including the null alternative). This step involves the use of models to predict trip generation from origin zones and trip distribution to destination zones, as well as the choice of mode and route.
5. Estimate user benefits and compare costs and benefits for each alternative project or program.

All metropolitan areas in the USA must undertake studies that follow these basic steps, if for no other reason than to qualify for the federal transportation funds to which they are entitled. Note that there is a close connection between land use and transportation in these types of studies, but that this connection normally runs from projections of land-use patterns (population and employment by zone) to trip generation to transportation flows and transportation system performance (e.g., congestion levels). Future travel demand is predicted from forecasts of land uses, and most of the studies have made little or no effort to make land-use forecasts sensitive to transportation system performance; there is no “feedback.” As Kain (1998) noted, the models of land use employed by transportation planners were insensitive to transportation system performance, so it made little sense to require full consistency between the land use and the transportation system forecasts. Literally dozens of models and systems of models have been developed for the UTP process, and these models have been
reviewed – sometimes critically – by urban economists such as Lowry (1972), Anas (1987), and Kain (1998).

17.3 Effects of Transportation Improvements on Urban Land Use

Suppose that a major transportation improvement is planned. The project could be a new link in the urban highway system or a new mass transit facility. What impacts will the completed project have on land use? What economic models are employed to conduct the study?

An issue that must be resolved first is the geographical scope of the study. Will the effects of the transportation project be only nearby in some sense, or will the effects be broader – possibly affecting the entire urban area? For example, will the transportation project attract households and firms to its immediate area and cause reductions in other locations? On the other hand, can we safely assume that the negative impacts on other locations are negligible? In essence, must we specify a general equilibrium model of the urban land market, or can we work with a partial equilibrium model in which these “other” locations are ignored? There is no general answer to the question, but each case must be examined on its own. The construction of an entire modern highway system in a metropolitan area, such as those completed in the 1960s in the USA, would clearly call for a model of the land market of the whole urban area. On the other hand, a study of the construction of a single mass transit line in a large urban area might only require a partial equilibrium model. This discussion shall proceed under the assumption that a partial equilibrium model is sufficient to capture the effects of the transportation project. Other chapters in this book provide general equilibrium models of the urban land market.

The impacts of a transportation project on urban land use can be broken down into four stages:

- impacts on bid rent for the different types of land use;
- impacts of changes in bid rent on market values for land;
- effects of changes in market values on the allocation of land to the various uses; and
- effects of changes in market values on the intensity of land use.

Each category is discussed in turn.

A pattern of land use (both land allocation and intensity of use) already exists in the vicinity of the proposed transportation project. Once the project is completed, households and firms will change their bid rents for locations proximate to the new transportation facility. For the most part, we expect that annual bid rents will increase to match the annual savings in transportation costs experienced by the households or firms, but it may be that some sites near the new facility are affected negatively by noise or congestion. We leave open the possibility that negative effects can occur.
We hypothesize that changes in bid rent will occur only once the transportation facility is ready for use, but that market values for land will change prior to “opening day.” Most studies have examined market values rather than annual rents. Assume that the transportation project is announced at some point in time, and it is completed at a later date. The change in land value for a given land use at a time prior to opening is

$$\Delta V_a = \Delta V_t/(1 + r)^{t-a} = \Delta R_t/r(1 + r)^{t-a}$$, (17.1)

where $t$ is the year in which the transportation project opens, $a$ is the year under study, $r$ is the real discount rate, and $\Delta R$ is the permanent change in land rent from time $t$ forward – assume that it is a positive amount in this example. The facts about the transportation project are known with certainty prior to time $a$; the date of completion is known to be $t$, and the features of the project are known (e.g., travel time savings, fares, and so on). Equation (17.1) simply says that the addition to land value at time $t$ is discounted back to time $a$. Rents do not rise before opening day, but land values do rise in anticipation of the increase in rents. Land value jumps when the project is announced, and rises at rate $r$ up to opening day.

The empirical estimation of the effect of a transportation improvement on land values requires a statistical model that controls for other possible influences on land values. A simple before-and-after comparison will likely yield biased results. Furthermore, cross-section analysis of only the “after” period will also likely generate biased estimates. A better method might be called a generalized before-and-after method.

Suppose that land values in a particular use (e.g., residential) are determined in the “before” period prior to the announcement that the transportation project will be built according to

$$\ln V_b = \beta_0 + \beta_1 X_{1b} + \ldots + \beta_n X_{nb} + \delta_b D + \epsilon_b$$, (17.2)

where $V_b$ is the land value at a location (with the subscript for location omitted), $X_{1b}$ through $X_{nb}$ are various variables that influence land value, $\beta_1$ through $\beta_n$ are coefficients, $D$ is the proximity of the site to the future transportation facility, $\delta_b$ is a coefficient, and $\epsilon_b$ is a normally distributed error term with zero mean and constant variance. Note that the $X$ variables take on values that are specific to the “before” period, but some of these variables (such as distance to the central business district) have the same numerical values in the “before” and “after” periods. And note that the model assumes that $\ln V_b$ might be related to proximity to the transportation facility in the “before” period. Coefficient $\delta_b$ might be different from zero. Obviously, in the “before” period land values cannot be related to proximity to the future transportation facility for the reason that transportation costs are lower, because such information is not available. But there might be other factors, such as proximity to employment or shopping or other local factors, that generate a relationship between $\ln V_b$ and $D$. This possibility should not be ruled out beforehand.
The equation for land value after the nature of the transportation project is fully known is assumed to be

$$\ln V_a = \alpha_0 + \alpha_1 X_{1a} + \ldots + \alpha_n X_{na} + \delta_a D + e_a$$  \hspace{1cm} (17.3)

where the subscript \(a\) attached to the variables refers to the values of the variables in the “after the project is known” period, \(\alpha_i\) through \(\alpha_n\) are coefficients in the “after” period, and \(\delta_a\) is the coefficient of proximity to the transportation project. The statistical model represented by equations (17.1) and (17.2) permits all variables to have different effects on land values in the two periods. The effect of the transportation improvement in partial equilibrium in percentage terms is measured as \(\delta_a - \delta_b\), the change in the effect of proximity to the transportation project. Following equations (17.1), (17.2), and (17.3), the percentage change in land value at time \(a\) attributable to the transportation improvement can be written as follows:

$$\Delta V_a / V_a = \delta_a - \delta_b = \Delta V_t / V_t (1 + r)^{-t - a},$$ \hspace{1cm} (17.4)

where \(t - a\) is the number of years prior to the opening of the transportation facility.

Several restrictive assumptions can be made that will make the simple before-and-after comparison yield unbiased results. Suppose that proximity to the transportation project is measured simply as a dummy variable \((D = 1\) for proximate, 0 otherwise). Also assume that \(\beta_1 = \alpha_1, \ldots, \beta_n = \alpha_n\) and that none of the \(X\) variables changes from “before” to “after.” Given these restrictive assumptions, we can write

$$\ln V_a - \ln V_b = (\alpha_0 - \beta_0) + (\delta_a - \delta_b) + e_a - e_b.$$ \hspace{1cm} (17.5)

The percentage change in land value simply consists of a general inflation factor and the added change associated with proximity to the transportation facility. (Note that this simple before-and-after method can be used provided that a control group of locations has been selected to provide an estimate of the general inflation in land values.) In general, the problem with the simple before-and-after method is one of specification error through the omission of variables. The omission of relevant variables leads to bias of unknown direction and magnitude in the estimated coefficients of the included variables.

The cross-section estimation of equation (17.2) will yield an estimate of \(\delta_a\), which is an unbiased estimate of the partial equilibrium effect of the transportation facility if \(\delta_b = 0\); that is, if there is no pre-project effect of proximity to the facility on land values.

Does economic theory predict the magnitude of the change in land value shown in equation (17.5), and the expected change in the intensity of land use as well? The answer is yes, and as we shall see, the change in land value will depend upon whether the intensity of land use is permitted to increase with the value of land. Consider a numerical example involving a block of single-family houses
located near a transit station on a new mass transit line. Suppose that each house is worth $120,000, and that the value of the lot on which each house rests is $24,000 of that value (i.e., 20 percent of the property value, which is fairly typical). The cost of building the house is $96,000. Assume that the new transit line will save each household 30 minutes per workday in travel time. This translates into 120 hours per year (for 240 work days) and, if travel-time savings are valued at $12.50 per hour, into $1,500 per year. Competition in the housing market means that annual rent for houses on the block will go up by this amount. The value of each house on the block will go up by $1,500 divided by the real interest rate. If the real interest rate is 5 percent, then the value of a house will go up by $30,000 – from $120,000 to $150,000. If no change in land-use intensity is permitted by the zoning officials, this is the end of the story. House values rise by the value of the travel-time savings. The (imputed) value of the land underneath each house has gone up from $24,000 to $54,000.

Given the transportation improvement, the demand for housing on the block has increased. Households are now willing to pay $150,000 for a housing unit on the block of quality equal to the existing units. This represents a 25 percent shift upward in the demand curve, from $120,000 to $150,000. The demand curve for housing on an individual block is perfectly elastic at the demand price because an individual block contains only a small fraction of housing supply. Housing suppliers have an incentive to respond to this increase in demand by supplying more housing units on the block. It is known that the long-run supply elasticity for housing units on a fixed land area is about 4.0; that is, a 25 percent increase in the demand price will call forth a 100 percent increase in housing units supplied (a doubling of units). Figure 17.1 depicts this demand shift and supply response.

Therefore, suppose that there is no zoning constraint, and the intensity of land use is increased by building a second house on each lot, tearing houses down to be replaced by duplex units, and so on. Because each house now occupies only 50 percent of a lot, in order to make each new house equal in value in the market to the older houses, somewhat nicer or larger interior space must be created. In particular, suppose that the construction cost of a new house is $120,000. Each house is worth $150,000, but now each lot contains two houses worth a total of $300,000. Since each house, excluding the land value, costs $120,000 to build, this means that the value of the lot is now $300,000 minus $240,000, which equals $60,000.

In the end, the transportation improvement has increased the value of land from $24,000 to $60,000 per lot. This total increase consists of two parts – the increase at a given intensity of land use to $54,000, and a further increase to $60,000 that is a result of the doubling of land-use intensity. Note that the value of the land has increased by 150 percent, and that the amount of capital has increased from $96,000 to $240,000 – an increase of 150 percent. The outcome that land value and the amount of housing capital per unit of land increase by equal percentages is consistent with available empirical evidence from the housing market. Also note that the value of the land remains at 20 percent of the total value of the property.
The effects of changes in land values on land use doubtless take years to materialize, if ever. As noted above, there can be a change in the allocation of land to alternative uses as well as changes in the intensity of use within a land-use category. Changes in the allocation of land to alternative uses operate through the zoning process, so an empirical study of this effect is a description of the behavior of the zoning officials in response to requests for zoning changes. One would presume that land-use zoning would be responsive to land-value increases that are larger for one type of land use compared to others. However, this process may be very slow and incomplete. Also, the effect of an increase in land values in a given land-use type may take many years. An increase in land value creates an incentive to increase land-use intensity, of course, but such a change often will require demolition and new construction. The market incentive to demolish exists if the market value of the raw land (less demolition costs) exceeds the market value of the old property – including both the structure and the land. Large increases in land values are often needed to satisfy this condition.

17.4 Empirical Studies

There are many empirical studies of the effect of a new transportation facility on property values or land values. The study by McDonald and Osuji (1995) was the
first to use the “before-and-after” method described above, and also found that residential land values had anticipated the opening of a mass transit line in Chicago. A study by Gatzlaff and Smith (1993) examined the time pattern of the response of housing value to the new Metrorail in Miami. McMillen and McDonald (2004) studied the time pattern of response to the new Midway Line in Chicago, starting 10 years before the opening of the line in 1993 and extending to 1999, 6 years after the line opened.

There are very few studies of the effect of transportation on the allocation of land to various uses. As noted above, one difficulty is that zoning ordinances intervene and potentially alter the allocation of land away from the market-determined outcome. It is reasonable to suppose that zoning follows the market in some aggregate sense, but it is unclear whether zoning follows the market in detail, or whether zoning acts to alter land-use patterns (in pursuit of some planning objective, for example). One approach to this question is to compare land-use allocations with and without zoning, a strategy that has been followed by McMillen and McDonald in a series of studies for Chicago. The study of land use in 1921 (prior to the 1923 zoning ordinance) by McDonald and McMillen (1998) shows that the detailed allocation of land to residential, commercial, and manufacturing use was strongly influenced by proximity to transportation facilities and distance to the CBD. For example, residential use was negatively related, and commercial and manufacturing uses were positively related, to proximity to an elevated train line, a main street, a river or canal, a commuter rail station, and a rail line. Another study of land use in 1921 (McMillen & McDonald 1999), however, found numerous instances of manufacturing and commercial use mixed with residential use, especially in older areas of the city and along major streets and near public transportation. Other studies of land use as determined by zoning, such as McMillen and McDonald (1990, 1991) for suburban Chicago in 1960, show that land use with zoning displays strong similarities to the results of the study of land use for 1921. However, there is less mixing of land uses with zoning than without. The strong influence of the transportation variables is clear in 1960. More detailed empirical studies of actual land-use patterns are needed.

Studies of the effect of transportation facilities on the intensity of land use include McMillen and McDonald (1998a,b). These are studies of gross population density and gross employment density, respectively, in the suburban areas of metropolitan Chicago. They show that both are positively influenced by proximity to transportation facilities such as a commuter rail station, a highway interchange, and O’Hare Airport.

The effects of new mass transit stations on changes in land use have been studied recently, most effectively by Bollinger and Ihlanfeldt (1997, 2003). The first study examines employment and population change in the Census tracts in the Atlanta metropolitan area from 1980 to 1990 as a function of close proximity to the stations of the new transit system, most of which opened between 1979 and 1982. The study concludes that location near a station had no discernable impact on either total population or employment change, but that government employment did increase near the stations targeted for high-intensity land use. The later study shows that the share of metropolitan employment located in a
Census tract did not increase near the transit stations, but that expenditures on highway improvements did lead to a higher employment share in the Census tract. Neither study employed standard measures of land-use intensity such as employment or population density.

17.5 Conclusion

This essay shall conclude with suggestions for further empirical research on urban land use. The first suggestion pertains to data. Researchers should improve the measures of land use and land-use intensity that are used, so that data and theoretical concepts match. Gross population density and gross employment density are useful measures, but other measures that might be considered include:

- net population density
- net employment density
- gross and net employment density by industry sector
- residential floor-area ratio
- floor-area ratio for employment sectors.

The effect of zoning on land use, and whether zoning follows the market, are unresolved questions. Indeed, there is no agreed-upon standard to judge whether zoning follows (or does not follow) the market.

The basic bid-rent model concludes that greater access to transportation leads to higher bid rent for one or more sectors of the urban economy, which in turn changes land use and increases land-use intensity. There are many empirical studies of the effect of transportation access on prices (real estate values, land values, and so on), and a sizable number of studies that examine the effect of transportation on land use directly – some of which are reviewed in this essay. But there are very few studies that examine both steps – the effect on prices and the effect of prices on land use. One reason for this lack of studies is the fact that effects on prices can, most probably, be seen rather quickly. The effects on land use, if any, probably take several years to emerge. This timing issue is discussed by Bollinger and Ihlanfeldt (1997), but not resolved. McMillen and McDonald (2004) have studied the timing of the effects of a new rapid transit line in Chicago on single-family house prices. The time pattern is shown to be complex, and includes price increases in anticipation of the opening of the transit line as well as additional adjustments after the line opened in 1993. The implications of these results for changes in land use have not been explored.

Recent research has concentrated on the effects of new mass transit facilities on land use. More work is needed on the effects of access to highways and highway interchanges. Research is also needed on the impacts of airports on land use. Airports do not provide transportation within the urban area, of course, but they are central points for interurban transportation that have largely replaced the railroad stations of an earlier era.
Bibliography