**Smart Growth and The Transportation-Land Use Connection:**

**What Does the Research Tell Us?**

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## Abstract

The connection between transportation and land use lies at the center of efforts in the U.S. to combat sprawl through smart growth strategies. Proponents of smart growth commonly make several specific propositions about the relationships between transportation and land use: 1. building more highways will contribute to more sprawl; 2. building more highways will lead to more driving; 3. investing in light rail transit systems will increase densities; 4. adopting New Urbanism design strategies will reduce automobile use. This paper explores how well the available evidence supports these four propositions and provides an overview of the theory, research efforts, and current debates associated with each of these propositions. This overview shows that the four propositions have not yet been fully resolved: researchers have made more progress on some of these propositions than others, but even in the best cases, our ability to predict the impact of smart growth policies remains limited.

# Smart Growth and The Transportation-Land Use Connection: What Does the Research Tell Us?

## INTRODUCTION

Sprawl is a common label for the low-density, auto-oriented spread of metropolitan regions pervasive throughout the U.S. The Vermont Forum on Sprawl (2003), for example, defines sprawl as "dispersed, auto-dependent development outside of compact urban and village centers, along highways, and in rural countryside." Environmental groups and others voice concerns of the impacts of sprawl. For example, the Sierra Club (2003) asserts, "In communities across America 'sprawl' - scattered development that increases traffic, saps local resources and destroys open space - is taking a serious toll." Such concerns have contributed to the growing momentum of the smart growth movement. Closely related to the concept of sustainability, smart growth is seen as a way of combating sprawl and building better communities. Smart growth strategies aim to channel new development into existing urban areas and away from undeveloped areas and to improve the viability of alternatives to the car. According to the American Planning Association (2002), "Compact, transit accessible, pedestrian-oriented, mixed use development patterns and land reuse epitomize the application of the principles of smart growth" (pg. 2).

As these statements suggest, the connection between transportation and land use lies at the center of efforts in the U.S. to combat sprawl through smart growth strategies. Casual observation suggests that transportation and land use in are inextricably linked in at least two basic ways (Figure 1). First, transportation investments and policies influence development patterns: commercial development stretches out along highway corridors, new subdivisions pop up after the new freeway opens, shopping malls and gas stations congregate at interchanges. In this way, transportation investments contribute to sprawl, but they can also potentially be used as strategies to help fight sprawl. Second, development patterns shape travel patterns: the design of suburban areas makes transit and walking a challenge, the separation between land uses in low–density developments makes driving a necessity. In this way, sprawl contributes to automobile dependence, but policies designed to fight sprawl can potentially help to reduce automobile dependence.

While theory lends support to these apparent relationships, the empirical evidence is surprisingly mixed, at least with respect to the impact we can expect from smart growth policies that depend on these relationships. The mixed evidence leaves plenty of room for debate among researchers. Genevieve Guiliano, for example, says that "the precise relationship between transportation and land use continues to elude us" and points to "a cluster of unsubstantiated beliefs" about the land use – transportation connection (Guiliano 1995: 3). She has argued that the connection between transportation and land use has weakened, that commute distance, for example, no longer matters so much in the choice of where to live. In response, Robert Cervero and John Landis (1995) argued that the transportation – land use connection still greatly matters. They accept the premise "the connection is undoubtedly much weaker today than it was a century ago," but they argue that transportation investments "still strongly affect land use patterns, urban densities, and housing prices" in combination with other policies and that "there remains strong evidence that characteristics of built environments… significantly influence travel demand" (pg. 3).

Underlying these positions is some degree of consensus. First, highways have been a necessary but not sufficient condition for the scale of suburban growth we see today. Freeway construction enabled the explosive growth of U.S. suburbs in the latter half of the Twentieth Century, but the desire for suburban living was a more fundamental cause. Second, sprawl has been a sufficient but not necessary condition for automobile dependence. Although sprawling patterns of development make driving a practical necessity, it is possible to find high levels of automobile use in places that are not sprawling. Thus, most participants in the debate agree on the historic strength of the connection between transportation and land use, but diverge on the current and future strength of this connection. How much impact do new transportation investments have on development patterns? How much impact do changes in development patterns now have on travel patterns?

The answers to these questions are key to evaluating the potential effectiveness of smart growth strategies. Yet despite uncertainty over the answers to these questions, proponents of smart growth strategies make several specific propositions about the relationships between transportation and land use related to the causes of sprawl and to its solutions. These propositions include, but are not limited to, the following:

- Building more highways will contribute to more sprawl.
- Building more highways will lead to more driving.
- Investing in light rail transit systems will increase densities.
- Adopting New Urbanism design strategies will reduce automobile use.

This paper explores how well the available evidence supports these four propositions. The review that follows provides an overview of the theory, research efforts, and current debates associated with each of these propositions. Rather than providing an exhaustive review of existing research for each proposition, I focus on widely cited studies that have played a central role in shaping the debates within the planning field, comprehensive reviews by others that attempt to summarize the strength of the empirical evidence related to the propositions, and recent studies that add interesting new dimensions to efforts to resolve these propositions. Although the connections between transportation and land use at first brush seem both obvious and simple, our appreciation of the complexities of these connections increases as the research on these connections progresses: the more we know, the less we seem to know. Researchers have made more progress on some of these propositions than others, but even in the best cases, our ability to predict the impact of different policies remains limited.

## PROPOSITION 1: BUILDING MORE HIGHWAYS WILL CONTRIBUTE TO MORE SPRAWL

The unprecedented construction of freeways that got underway in the 1950s has often been blamed for the explosive expansion of suburban areas that got underway at the same time. Although freeway building has slowed considerably since then, many metropolitan areas are still planning new facilities that will serve relatively undeveloped areas. In the Austin, TX region, for example, at least three major new freeways are planned in the next decade or so, all serving areas that are expected to grow rapidly in the near future. Such plans seem clearly to conflict with the tenets of smart growth because of their potential to increase sprawl. In a campaign flyer for a bond election in Austin in

2001, the Austin Neighborhoods Together Political Action Committee (PAC) argued that "The $185 million Travis County Bond Package will cause pollution by… extending roads into far-flung areas outside the city that will increase sprawl and air pollution."

Economic theory explains the connection between highway construction and both expanding boundaries and decreasing densities in metropolitan areas. Commuters make trade-offs between land costs and commute costs, so that they are willing to pay more for housing that minimizes their commute and can afford to pay less for housing the farther they commute (Alonso 1960). Where commuters live depends on their household budgets, their preferences for space, and competition with other commuters for different locations. In this model, a decline in transportation costs means that commuters can live farther from work or buy a larger house at the same location without an increase in budget. Both options tend to increase sprawl. An increase in income has the same effect, enabling commuters to afford more house and/or more commute. This model, despite simplifications, provides a convincing explanation of the expansion of metropolitan areas in the U.S. over the Twentieth Century as travel costs declined and incomes rose. The question for today is the degree to which new investments reduce transportation costs.

Economic theory also suggests that the amount of development a particular location will attract depends on the accessibility of that location relative to others (Hansen 1959). Transportation facilities play an important role in this model by determining the relative accessibility of different locations and thus the relative transportation costs associated with locating there. Historically, roads and transit services converged on the center of the city, which was the most accessible location to the most people. The first freeways continued this pattern. But the growing web of freeways soon created locations of relatively high accessibility in the suburbs, and development then concentrated at these nodes as well. The value of highway accessibility is reflected in both the price of land and the intensity of development (Mohring 1961). Theory suggests that the increases in price and intensity associated with an increase in accessibility might occur both in total, or what has been called a "generative" impact, and as a result of shifts in development from one location to another, or what has been called a "redistributive" impact (TCRP 1998). The question for today is whether new investments significantly change the relative accessibility of different locations in the region.

The historic contribution of freeway building to suburbanization, at least as an enabling force rather than a causal force, is generally supported by the empirical evidence. In one of the first studies of the impact of highways on development patterns, Garrison, et al. in 1959 found significant changes in the locational patterns of retail business and residential land use in response to highway improvements, including the prevailing tendency for certain types of businesses to locate along highways in the now-pervasive commercial strip. Studies that followed looked at the impact of highways in a variety of different ways. Some studies focused on the impact of highways on overall economic growth, while others explored the distribution of development, usually as measured by property values or population and employment densities. Some studies looked for evidence of impacts at the scale of census tracts or other small areas, while others analyzed the impacts at the scale of counties or metropolitan regions. Much of the research on the impacts of highways on development has focused on non-metropolitan areas, either the impact for communities of being on the interstate system (e.g. Chandra and Thompson 2000) or the impact of the construction of a highway bypass around the community (e.g. TRB 1996).

The debate today is over the degree to which additional freeway building continues to shape development patterns and, in particular, promote sprawl by reducing transportation costs and changing relative accessibilities. Most relevant to this debate are studies of the impact of beltways on development patterns. The widely-cited Payne-Maxie study from 1980 looked at the impact of beltways – "limited access highways partially or completely circling cities" – on development patterns in metropolitan areas. The researchers found no statistically significant impact on economic growth for regions with beltways, but they did find an impact on development patterns. They concluded that a beltway can "increase development opportunities in its corridor, reinforce prevailing urbanization patterns, and facilitate compact development" at least in areas around interchanges, but that a beltway cannot create a market for development where none would otherwise exist. More recently, Hartgen and Curley (1999) studied the relationships between beltway construction, sprawl, and traffic congestion. They concluded that urbanized areas without beltways or with just partial beltways actually grew faster in area, population and employment than areas with full beltways, contrary to the proposition that highway building increases sprawl. But population densities declined faster in cities with full or partial beltways than cities without beltways, supporting the proposition that highway building increases sprawl. The evidence from this study is thus mixed.

A handful of recent studies examined the impact of freeway expansion on land development in metropolitan areas. Hansen, Gillen, and Puvathingal (1998) looked at building activity in eight corridors in California where freeway capacity had been expanded in the previous two decades and found different effects for different types of land uses and different impacts at different points in time. They conclude: “While we acknowledge uncertainty over these details, our results offer strong support for one overriding conclusion: highway capacity expansion stimulates development activity, both residential and non-residential, in the corridors served by the expanded facilities” (pg. 10). Ten Siethoff and Kockelman (2002) looked at the link between property values and highway expansion in a single corridor in Austin, TX in which the highway had been upgraded from an unlimited-access to a wider, limited-access facility with frontage roads. They conclude: “the timing of this freeways project’s construction and completion were significant events for property valuations” and that “dramatic valuations also accrued to those properties most proximate to the freeway corridor” (pg. 200). Finally, as a part of a study of induced traffic, a topic discussed in the next section, Cervero (2003) looked at the connection between freeway expansions and development activity for a sample of expansion projects in California. His analysis showed a significant link, with a lag of 2 to 3 years, between freeway expansion and both residential and nonresidential development within a four-mile buffer of the freeway.

Although all three of these studies demonstrate a significant impact of highway expansion on development in the highway corridor, they did not evaluate changes in other parts of the region to determine if the impacts were generative or redistributive. Using data for California counties, Boarnet (1998) addressed this question and found evidence of “negative output spillovers,” which occur when street and highway investments in one county lead to a reduction in economic output in adjacent counties.

He concludes that "the evidence supports the idea that street-and-highway capital influences output in California counties, and that such infrastructure creates negative output spillovers across counties of similar urban character" (pg. 396).

These studies and others together suggest that beltways or urban highways more generally do not increase the overall rate of growth but may influence where growth occurs and at what densities. In other words, the available research provides no evidence of generative impacts but does provide evidence of redistributive impacts. Boarnet and Haughwot (2000), in a review of the research on the influence of highways on development for the Brookings Institute, conclude: "In sum, the evidence suggests that highways influence land prices, population, and employment changes near the project, and that the land use effects are likely at the expense of losses elsewhere" (pg. 12). They go on to say that the evidence does not support the belief that highways cause suburbanization, which is driven by a wide range of forces, but that highways clearly influence development patterns: "Yet given that metropolitan areas are decentralizing for reasons that might be unrelated to transportation, highways certainly have the potential to influence the geographic character of that decentralization" (pg. 13). Highway building thus appears to contribute to sprawl not by increasing the rate of growth but by influencing where in the region development occurs and by influencing the character of the development that occurs.

Based on these findings, it is reasonable to conclude that new highway building will enable or encourage additional sprawl to some degree, although to exactly what degree is uncertain and depends on local conditions. However, the converse of this proposition is probably not true: not building more highways will probably not slow the rate of sprawl, at least not much. If other factors are more fundamental causes of sprawl than new highways, then sprawl may continue even in the absence of new highways. It is possible, for example, that the hope for or expectation of a new highway sometime in the future is sufficient to encourage new development at the fringe.

## PROPOSITION 2: BUILDING MORE HIGHWAYS WILL LEAD TO MORE DRIVING

Proponents of smart growth often argue that building more highways will simply lead to more driving, that new capacity will generate new travel and thereby offset any reductions in congestion. Roy Kienitz, for example, while executive director of the Surface Transportation Policy Project, argued in a widely circulated essay, "evidence shows new roads fuel the already explosive growth in the amount we drive. New and wider roads bring short-term relief, at great expense" (Kienitz 1999). The phrase "build it and they will come" has become a shorthand way of talking about this phenomenon, and references to new freeways or newly expanded freeways that were as congested as the original are common. This growth in traffic occurs in the short run and independently of the growth in traffic that might occur because of the impact of highway building on development.

Sometimes referred to as "induced demand," this phenomenon is more accurately labeled "induced travel." In theory, new capacity reduces the price of travel by reducing travel times and, in economic terms, shifts the supply curve. As the price of travel goes down, the consumption of travel goes up; the supply curve intersects a new point on the demand curve (as illustrated in Figure 2). This effect should occur even without an increase in population, as existing residents choose to make more trips, longer trips, and more trips by car as a result of the decline in price. But it is important to note that only capacity increases that reduce travel times will have this effect. Definitions of these concepts and explanations of this theory are provided by Downs (1992), Litman (2001), Noland and Lem (2002), Mokhtarian, et al. (2002), Cervero (2002), among others. Documenting the extent or even existence of this effect has been a significant challenge for researchers, however. Following a string of studies showing a strong connection, two recent studies failed to find a statistical link between increases in capacity and increases in driving (Choo, et al. 2001; Mokhtarian, et al. 2002) and a third found a much weaker link (Cervero 2003).

A series of studies showing a statistically significant connection between highway capacity and travel seemed to have put the debate to rest by the late 1990s. In a 1995 report published by the Transportation Research Board (TRB), an expert panel reviewed the available evidence on the relationships between highway capacity additions, emissions, air quality, and energy consumption and concluded that "major highway capacity additions are likely to have larger effects on travel and to increase emission in the affected transportation corridors in the long run unless some mitigating strategy is implemented in conjunction with the capacity addition" (pg. 8). A 1998 Transportation Research Circular noted that "the range of disagreement between highway proponents and opponents on the subject of induced travel has narrowed considerably" (pg. 6), a trend attributed to a recognition on the part of highway proponents that new capacity induces a variety of changes in land use and travel behavior and on the part of highway opponents that the induced travel effect is a result of time savings rather than capacity increases per se.

Noland and Lem (2002) reviewed nine studies of induced travel and their estimates of the elasticity of vehicle miles traveled (VMT) with either travel time or lane miles. The studies reviewed in this paper had consistently estimated elasticities from at least 0.3 to as much as 1.1 for lane miles: a 10 percent increase in lane miles is associated with at least a 3 percent increase in VMT and as much as an 11 percent increase. The elasticities for travel time ranged from –0.3 to –1.0: a 10 percent decrease in travel time could lead to a 3 percent to 10 percent increase in VMT. These results do not take into account additional travel that might be generated by new development that occurs in response to the new highway capacity. The authors conclude: "The research evidence on induced travel effects clearly shows that behavioural responses are real and can have significant impacts on the congestion reduction benefits of capacity expansion projects" (pg. 23).

However, new research appears to refute the earlier studies. Choo, Mokhtarian, and Salomon (2001) developed a national-level model of VMT growth as a function of a variety of factors but found that the coefficient for highway capacity was not statistically significant. A study by Mokhtarian, et al. (2002) took a more disaggregate approach that matched 18 highway segments in California whose capacities had been expanded with similar segments whose capacities had not been expanded. Three different statistical approaches used to test for a difference in average daily traffic (ADT) between expanded and unexpanded segments consistently showed no statistically significant difference and thus "no evidence of induced demand." Cervero (2003), using a path model that sorted out the causal links between freeway investments and traffic increases, found that a 10% increase in speed was associated with a 2.4% increase in traffic and that a 10% increase in lane miles was associated with a 1% increase in traffic. This result is considerably lower than those found in previous studies, and Cervero concludes that "past estimates of induced demand derived from lane-mile elasticities has overstated near-term impacts" (pg. 153).

The debate will most likely continue as new data sets and more sophisticated statistical techniques are used to sort out the complex relationships that link the expansion of highway capacity to increases in the amount of driving. As Cervero concludes, "There is no question that road improvements prompt traffic increases… To what degree and under what circumstances, however, remains a matter of debate" (Cervero 2002: 17). The degree to which increases in highway capacity have themselves contributed to the growth in VMT or simply helped to accommodate the relentless growth in VMT driven by rising incomes, changing lifestyle patterns, or other factors has yet to be determined. What is beyond doubt is that VMT has grown faster than highway capacity, population, the economy, or just about any other possible causal factor. Thus, the converse of this proposition is almost certainly not true: not building new highways will not appreciably slow the growth in vehicle travel, at least not until congestion levels increase significantly.

## PROPOSITION 3: INVESTING IN LIGHT RAIL TRANSIT SYSTEMS WILL INCREASE DENSITIES

Investments in transit and especially in light rail transit (LRT) systems play an important role in smart growth strategies. Not only will such investments increase the use of transit and encourage a shift from driving to transit, they will help to increase the density of development and thus serve as a counterforce to continued sprawl, according to proponents. A pro-light rail group in Austin, TX argues that "…LRT strengthens existing neighborhoods while attracting clusters of development around transit stations in more lightly developed areas… LRT is a powerful tool to deal with urban sprawl" (Light Rail Now 2002). Transit agencies throughout the US are working to promote transit-oriented development (TOD) in station areas, and the Federal Transit Administration gives credit for policies to encourage transit-supportive development in its assessment of funding requests for new rail systems (FTA 2002). Most proponents recognize that LRT on its own won't promote TOD, but believe that it can be a powerful force for shaping land development patterns in metropolitan areas when combined with appropriate policies and some public assistance.

Transit systems potentially impact development in two ways, just as highways do: by reducing transportation costs and by changing relative accessibilities. First, if a transit system reduces travel times, it may enable residents to live farther out, thereby increasing rather than decreasing sprawl. In addition, by reducing transportation costs, a transit system might increase overall development in the region, leading to a net gain for the region (though probably at the expense of some other region) – a "generative" impact. However, most new light rail systems are designed to serve areas of existing development and may have little impact on travel times. Second, through its impact on accessibility, a transit system might influence where in the region development occurs, focusing development in particular corridors and around station areas, for example; this effect means a redistribution of development rather than a net gain. This effect can help to increase ridership and may serve as a catalyst for redevelopment in selected areas. Theory thus suggests that transit systems may have conflicting effects on development patterns, encouraging sprawl in some ways and acting as a counterforce to sprawl in others. In determining the net effect of transit, it is difficult to separate out the effect of transit from the other forces influencing the amount and location of development in a region. Despite this challenge, the impacts on development of transit systems, particularly rail rapid transit systems and light rail systems, have been evaluated and summarized by a number of researchers.

On the first point, the available research provides no support for the proposition that transit will lead to a net gain in development for a region. A widely cited 1977 study by Knight and Trygg concluded that transit systems do not generate "inter-regional transfers," thereby increasing the overall development within the region, although the evidence on this issue was scant (Knight and Trygg 1977). In other words, there was no evidence that regions that invest in new transit systems grow faster than they would have had they not invested in the transit system. This finding was echoed in a 1995 report from the Transit Cooperative Research Program (TCRP), which concluded that "urban rail transit investments rarely 'create' new growth, but more typically redistribute growth that would have taken place without the investment" (pg. 3).

On the second point, the evidence shows that transit can and often does influence where in the region growth occurs, but only given the right conditions and policies. The Knight and Trygg study explored the importance of four different factors in influencing the impact of transit on land use: local government land use policies, regional development trends and forces, availability of developable land, and the physical characteristics of the area (Knight and Trygg 1977). They concluded that all of these factors influence the likelihood of development. Another important issue raised in this study is the timing of land use impacts: "substantial land use impacts do not occur until several years after inauguration of transit service" (Knight and Trygg 1977: 245). The report concluded on the sobering note that transit operators cannot always count on station-area development ever happening: "It seems from the evidence available that rapid transit improvements can provide an impetus toward generation of new nearby development. However, transit alone seems no longer enough to insure such development, in this day of very high accessibility often only marginally improved by the transit system" (pg. 245).

Many studies since then have pointed to necessary conditions for development to occur. A widely cited study by Cervero in 1984 concluded that "a strong and growing regional economy is an important prerequisite" for station area development (pg. 146). A more recent review concluded that "almost exclusively, transit system's impacts on land use are limited to rapidly growing regions with a healthy underlying demand for high-density development" (Vesalli 1996). The alignment of the light rail system also matters, in that "the developability of land and a suitable physical setting around LRT stations are important conditions for positive land use changes" (Cervero1984: 146), an issue that arises when alignments were chosen to minimize construction costs rather than maximize development potential. Because most transit systems have the greatest impact on accessibility to downtown, rather than to other areas of the region, the greatest impacts on development have been seen in downtown areas: "within downtowns, rail transit investments have stimulated redevelopment and brought life to once moribund commercial districts," concluded a 1995 report from the Transit Cooperative Research Program (TCRP) (pg. 15). Vesalli (1996) found that public sector involvement, including land assembly, high-density zoning allowances, restrictions on parking, and financial incentives, played an important role in most successful examples of development around transit stations.

The message that emerges from these studies is clear: transit will not influence development unless these conditions are in place. Cervero concluded that "LRT can be an important, though unlikely a sufficient, factor in changing land use" (Cervero 1984: 146). The 1995 TCRP report comes to a similar conclusion: "transit investments and services are incapable by themselves of bringing about significant and lasting land-use and urban form changes without public policies that leverage these investments and the pressure of such forces as a rapidly expanding regional economy" (pg. 5). This point was echoed by Vesalli: "these land use impacts of transit are not accidental, nor automatic… the only substantial impacts of transit on land use are those that have been planned, and this planning entails a substantial investment of public sector resources and coordination" (Vesalli 1996: 99).

That said, recent studies have examined the impact of light rail on land values and have found a significant connection. Because higher land values are associated with higher density of development, these studies lend support to the proposition that light rail can increase densities around stations. For example, Cervero and Duncan (2002) found that a location within one quarter mile of a light rail station increased land values by $4 per square foot, and a location within one quarter mile of a commuter rail station increased values by $25 per square foot. This study thus lends support to the proposition that light rail can increase densities, at least over time. Other studies have looked at the impact of light rail plans on land values in proposed station areas. For example, Knapp, et al. (2001) found that land values within half a mile of a proposed station were 71 percent higher than elsewhere in the year after the announcement of station location. Their findings suggest that at least in areas with an established light rail system, an expansion to the system can begin to have an impact on station area development as early as the planning stages.

The evidence thus supports the proposition that investments in light rail transit will increase densities – but only under the right conditions. These studies point to several important lessons about the conditions under which the proposition will hold: a region that is experiencing significant growth, a system that adds significantly to the accessibility of the locations it serves, station locations in areas where the surrounding land uses are conducive to development, and public sector involvement in the form of supportive land use policies and capital investments. Without these conditions, increased densities are unlikely. With these conditions, increased densities are not assured but they are possible.

## PROPOSITION 4: ADOPTING NEW URBANISM DESIGN STRATEGIES WILL REDUCE AUTOMOBILE USE

Another proposition of the smart growth movement is that land use and design strategies, such as those proffered by the Congress for the New Urbanism (CNU), will reduce automobile use and create more livable communities. Authors identified with the New Urbanism have articulated specific design characteristics to achieve this goal and claim that by putting the activities of daily living within walking distance and providing an interconnected network of streets, sidewalks, and paths, walking will increase and driving will decrease (e.g. Duany and Plater-Zyberk 1991; Calthorpe 1993; Katz 1994). One of the primary tenets of the New Urbanism is the idea that "communities should be designed for the pedestrian and transit as well as the car" (CNU 2002). The Charter of the New Urbanism states that "Many activities of daily living should occur within walking distance.... Interconnected networks of streets should be designed to encourage walking, reduce the number and length of automobile trips, and conserve energy" (CNU 2002).

Mitchell and Rapkin are often given credit for first articulating the connection between land use patterns and travel behavior in their 1954 book *Urban Traffic: A Function of Land Use*. This connection was built into travel demand forecasting models, first developed in the 1950s and designed to predict travel demand as a function of the distribution of population and employment. The theoretical basis for studying this connection has evolved considerably since then. The application of a discrete choice framework for understanding of travel behavior was first articulated by Domencich and McFadden (1975) and later by Ben-Akiva and Lerman (1985) and Train (1986). In this framework, the travel choices made, such as the choice of mode or destination, are determined by the characteristics of the choices available. Each possible choice offers a certain "utility" or value to the individual, who seeks to maximize her utility. Maximizing utility generally means minimizing travel time, but other factors can outweigh time. For example, the greater attractiveness of a more distant destination can lure travelers there, or the value of the exercise one gets while walking can compensate for the longer time it takes. Theory thus points to mixed effects on travel for new urbanism strategies: these strategies may increase the utility of alternatives to driving, but they also tend to increase the utility of making trips, so that savings from a shift in travel modes may be offset by increases in the frequency of trips.

The idea that land use and design policies could be used to influence travel behavior was not widely explored until the 1980s. Early interest focused on the connection between density and transit use. The 1977 study by Pushkarev and Zupan is often taken to suggest that transit use can be increased through polices that increase densities. A heated debated ensued in the early 1990s over analysis by Newman and Kenworthy's of the correlation between densities and gasoline consumption for a sample of international cities (Newman and Kenworthy 1989; Newman and Kenworthy 1999). In response to the emergence of the new urbanism movement, more recent studies have taken on the broader question of the link between travel behavior and characteristics of the built environment more generally and have set out to test the hypothesis that policies that shape the built environment can be used to reduce automobile travel. Since the early 1990s, studies of the link between the built environment and travel behavior have appeared in the literature with increasing frequency. Recent literature reviews document over 70 studies published during the 1990s that have explored and quantified these relationships (e.g. Handy 1996; Boarnet and Crane 2001a; Ewing and Cervero 2001).

One of the challenges in these studies has been to sort out the relative importance of socio-economic characteristics and characteristics of the built environment in explaining travel behavior. Ewing and Cervero (2001), after one of the most thorough reviews of these studies, come to several important conclusions:

- Trip frequencies appear to be primarily a function of the socio-economic characteristics of travelers and secondarily a function of the built environment.

- Trip lengths are primarily a function of the built environment and secondarily a function of socioeconomic characteristics.

- Mode choices depend on both socio-economic characteristics and characteristics of the built environment, though probably more the former.

- Characteristics of the built environment are much more significant predictors of VMT, which is the outcome of the combination of trip lengths, trip frequencies, and mode split.

In a form of meta-analysis, Ewing and Cervero (2002) estimated elasticities for VMT and vehicle trips based on the results of all available studies as well as original data analysis for available data sets. Four measures of the built environment were used:

“density,” measured as population plus jobs divided by land area, “diversity,” a measure of jobs-population balance; “design”, a combination of sidewalk completeness, route directness and street network density; and “regional accessibility,” an index derived with a gravity model. These estimates were both point elasticities, calculated at the average value of the variable, and partial elasticities, which control for the effects of other variables. The results showed a statistically significant but rather limited link between characteristics of the built environment and travel behavior (Table 1). A 10% increase in local density, for example, is associated with only a 0.5% decline in vehicle trips and VMT. The highest elasticity was for regional accessibility (a 10% increase in regional accessibility was associated with a 2% decline in VMT), but regional accessibility is also arguably the most difficult characteristic to modify.

The debate associated with this proposition now centers on the issue of causality. Almost all of the available studies have used a cross-sectional design that compares travel behavior for different people or places at one point in time. These studies thus reveal correlations between the built environment and travel behavior but do not prove causality. In other words, it is not possible to say that a 10% increase in local density in a particular neighborhood will lead to a 0.5% decline in vehicle trips and VMT. This issue is often discussed by researchers in terms of “self-selection,” the possibility that individuals who would rather walk or take transit than drive choose to live in neighborhoods conducive to walking and taking transit. In other words, the characteristics of the built environment did not cause them to drive less, rather their desire to drive less caused them to select a neighborhood with those characteristics – the reverse of the presumed causality. As a result, it is not possible to predict the impact on travel of either increasing the density in a particular neighborhood or of moving residents from one kind of neighborhood to another.

A few researchers have made some effort to address the self-selection issue. Handy and Clifton (2001) found both quantitative and qualitative evidence that residents of an Austin neighborhood where the average frequency of walking to the store is significantly higher than in other neighborhoods did in fact choose that neighborhood because they like to walk to the store. Bagley and Mokhtarian (2002) undertook a more sophisticated analysis of the relationships between attitudes, residential location choice, and travel behavior. They concluded that attitudinal variables had the greatest impact on travel behavior among all of the explanatory variables and that residential location type had little impact on travel behavior, suggesting that "the association commonly observed between land use configuration and travel patterns is not one of direct causality, but due primarily to correlations of each of those variables with others." In other words, observed associations between travel behavior and neighborhood type are largely explained by the self-selection of residents with certain attitudes into certain kinds of neighborhoods. Several studies underway at this writing attempt to address the self-selection issue more directly.

Based on the results of these studies, it is safe to conclude that land use and design strategies such as those proposed by the new urbanists may reduce automobile use a small amount, at least to the degree that these strategies help to address an unmet demand for neighborhoods conducive to driving less. Indeed, Levine,et al. (2002) found evidence of unmet demand in the form of a mismatch between preferences for neighborhood environments and the neighborhood environments in which residents live. An intriguing though unexamined question is whether land use and design strategies can fundamentally change attitudes towards transportation and thereby change desired behavior rather than simply enabling it. Further progress in determining the degree to which land use and design strategies impact travel behavior and determining which strategies are most effective will require significant improvements in data on travel behavior and characteristics of the built environment as well as research design (Handy, et al. 2002).

## CONCLUSIONS

Here's what we can reasonably conclude from the available research about these four common propositions about the transportation – land use connection and its role in smart growth efforts:

- New highway capacity will influence where growth occurs.
- New highway capacity might increase travel a little.
- Light-rail transit can encourage higher densities under certain conditions.
- New urbanism strategies make it easier for those who want to drive less to do so.

The propositions have not been fully resolved by the research to date for a variety of reasons. For one thing, the connections between transportation and land use are much more complicated than they at first seem (Figure 3). Rather than a simple linear relationship between transportation investments, land development patterns, and travel patterns, we face a system of endogenous relationships between transportation and land use: the influence of land use patterns on decisions about transportation investments, the impact of traffic on location decisions and highway investments, and so on. In addition, countless exogenous factors also come into play: attitudes and socio-demographic characteristics influence travel patterns, land development patterns are influenced by land use policies, transportation investments may reflect political forces. Accounting for these complexities requires more sophisticated research designs, particularly experimental designs and longitudinal studies (Handy, et al. 2002), and analysis techniques, including path analysis, structural equations modeling, and multilevel modeling (Masse 2002).

For another thing, the data available to sort out these complex relationships are simply not up to the challenge, although they are getting better. The development of adequate land use data has been especially challenging. Geographic information systems (GIS) offer promising capabilities for generating more detailed measures of the built environment and spatially matching these measures to data on travel behavior at the household level (Handy, et al. 2002). Standardized protocols, tested for validity and reliability, for objectively measuring characteristics of the built environment will also help by ensuring consistency across studies (Bauman, et al. 2002). Researchers are increasingly employing sophisticated statistical techniques to compensate for the poor data, and undoubtedly their efforts will lead to progress.

In the meantime, questions remain for all of these propositions about the degree of the connection and the direction of causality. As long as these questions remain, reliable predictions of the impacts of new transportation investments on land development patterns or of land use and design strategies on travel behavior will themselves remain elusive. The lack of reliable predictions does not necessarily mean that communities should not proceed with smart growth efforts, however. First, these efforts may have benefits other than those discussed here. For example, concerns over decreasing levels of physical activity and its contribution to an epidemic of obesity in the U.S. have led to calls for policies that will improve the quality of the environment for modes other than the automobile (e.g. Active Living by Design 2003). Second, the potential pay off of these efforts depends both on the likelihood of their impact and on the magnitude of the problems they seek to address. A large enough problem might justify strategies with uncertain rewards, as long as a reasonable possibility of positive impacts that exceed any negative impacts has been established. Whether the available evidence establishes a reasonable possibility of net positive impacts and whether the problems of sprawl and automobile dependence are sufficiently large relative to that possibility to justify smart growth efforts are questions that communities themselves must ultimately resolve.

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**Table 1. Typical Elasticities of Travel with Respect to the Built Environment**

| | Vehicle Trips | VMT |
|---|---|---|
| Local Density | -0.05 | -0.05 |
| Local Diversity | -0.03 | -0.05 |
| Local Design | -0.05 | -0.03 |
| Regional Accessibility | -- | -0.20 |

Source: Ewing and Cervero 2002

Figure 1.  Basic Links Between Transportation and Land Use

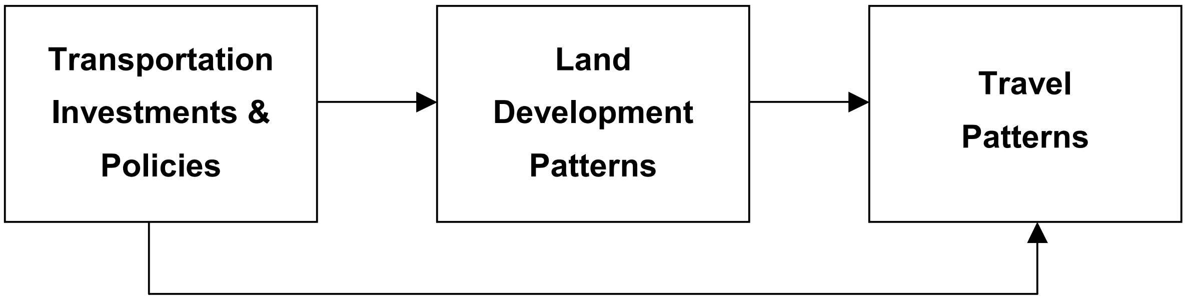

Figure 2. Illustration of How Shifts in Supply Impact Traffic Volumes

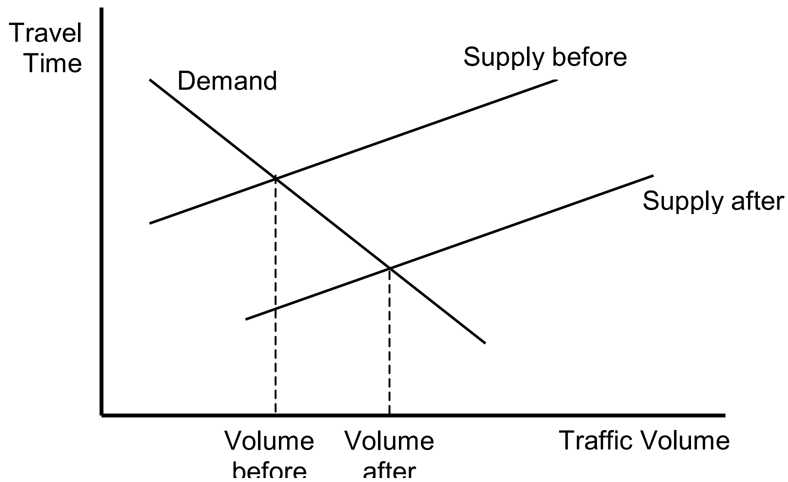

Figure 3. Complex Links between Transportation and Land Use