Characteristics, Causes, and Effects of Sprawl: A Literature Review

Reid H. Ewing

Keywords: costs · public services · urban sprawl · pattern of development · Florida · open space · subsidies · policy · farmland

Editor's Note: This literature review was prepared for the Florida Department of Community Affairs (DCA) as background to the amendment of Florida's local comprehensive planning rule, Rule 9J-5. On October 2, 1992, DCA published a proposed amendment that, among other things, included criteria for the review of plans to ensure that they discourage urban sprawl. The proposed rule was challenged by the Florida Association of Realtors, Florida Home Builders Association, Florida Farm Bureau Federation, and other parties. DCA settled with most parties, but not all, and the matter went to administrative hearing on September 13, 1993. The hearing officer's order is to be issued momentarily, and if favorable to DCA, will allow DCA to adopt a final rule by early 1994.

The physical characteristics, causes, and effects of sprawl must be understood before sprawl can be effectively regulated. Relying on the literature in the field, this paper provides a conceptual framework against which DCA's proposed sprawl rule can be judged and upon which the final rule can rest.

Classic Sprawl Patterns

Sprawl has been equated to the natural expansion of metropolitan areas as population grows (Sinclair, 1967; Brueckner and Fansler, 1983; Lowry, 1988) and to "haphazard" or unplanned growth, whatever form it may take (Peiser, 1984; Koenig, 1989). More often, though, sprawl is defined in terms of "undesirable" land-use patterns—whether scattered development, leapfrog development (a type of scattered development that assumes a monocentric city), strip or ribbon development, or continuous low-density development. Table 1 indicates which patterns have been labeled sprawl in the technical literature of the past three decades. Scattered development is probably the most common archetype, but any "non-compact" development pattern qualifies.

Using archetypes to define sprawl still leaves us short of a working definition. Like obscenity, the experts may know sprawl when they see it, but that is not good enough for rulemaking. There are two problems with the archetypes.

R.H. Ewing
National Center for Smart Growth, Preinkert Field House, University of Maryland, College Park, MD 20742 USA
e-mail: rewing1@umd.edu

Originally Published in 1994 in Environmental and Urban Studies vol 21(2):1–15
J.M. Marzluff et al., *Urban Ecology,*

Table 1 Sprawl Archetypes

	Low-Density Development	Strip Development	Scattered Development	Leapfrog Development
Whyte (1957)			x	x
Clawson (1962)			x	
Lessinger (1962)	x		x	
Boyce (1963)	x		x	
Harvey and Clark (1965)	x	x		x
Bahl (1968)				x
McKee and Smith (1972)	x	x	x	x
Archer (1973)			x	x
Real Estate Research Corporation (1974)			x	x
Ottensmann (1977)			x	
Popenoe (1979)	x	x	x	
Mills (1981)			x	x
Gordon and Wong (1985)			x	
Fischel (1991)	x			
Heikkila and Peiser (1992)			x	

First, sprawl is a matter of degree. The line between scattered development and so-called polycentric or multinucleated development is a fine one. "At what number of centers polycentrism ceases and sprawl begins is not clear" (Gordon and Wong, 1985, p. 662). Scattered development is classic sprawl; it is inefficient from the standpoints of infrastructure and public service provision, personal travel requirements, and the like. Polycentric development, on the other hand, is more efficient than even compact, centralized development when metropolitan areas grow beyond a certain size threshold (Haines, 1986). A polycentric development pattern permits clustering of land uses to reduce trip lengths without producing the degree of congestion extant in a compact, centralized pattern (Gordon et al., 1989).

Likewise, the line between leapfrog development and economically efficient "discontinuous development" is not always clear. Leapfrogging occurs naturally due to variations in terrain (Harvey and Clark, 1965). New communities nearly always start up just beyond the urban fringe, where large tracts of land are available at moderate cost (Ewing, 1991). Some sites are necessarily bypassed in the course of development, awaiting commercial or higher-density residential uses that will become viable after the surrounding area matures (Ohls and Pines, 1975). "The sprawl of the 1950s is frequently the greatly admired compact urban area of the early 1960s. An important question on sprawl may be, 'How long is required for compaction?' as opposed to whether or not compaction occurs at all" (Harvey and Clark, 1965, p. 6). Whether leapfrog development is inefficient will depend on how much land is bypassed, how long it is withheld, how it is ultimately used, and the nature of leapfrog development (Breslaw, 1990).

Nuances arise with other sprawl archetypes as well. The difference between strip development and other linear patterns (e.g., Mainstreet USA or transit corridor development) is a matter of degree. So, too, the difference between low-density urban development, exurban development and rural residential development. Wherever one draws the line between sprawl and related forms of development will be subject to challenge unless based on an analysis of impacts. It is the impacts of development that render development patterns undesirable, not the patterns themselves.

The second problem with the archetypes is that sprawl has multiple dimensions, which are glossed over in the simple constructs. It is sometimes said that growth management has three dimensions—density, land use, and time. The same is true of sprawl. Leapfrog development is a problem only in the time dimension; in terms of ultimate density and land use, leapfrog development may be relatively efficient. It is known, for example, that infill parcels tend to be developed at higher densities than the land surrounding them (Peiser, 1989; Peiser, 1990). Keep the time frame short and leapfrog development ceases to be inefficient.

Similarly, low-density development is problematic in the density dimension, and strip development in the land-use dimension (since it consists only of commercial uses). If development is clustered at low gross densities, or land uses are mixed in a transportation corridor, these patterns become relatively efficient. Again, it is the impacts of development that render development patterns desirable or undesirable, not the patterns themselves.

Dimensions of Sprawl

Studies analyzing the costs of alternative development patterns have, by necessity, defined alternatives in multiple dimensions, rather than limiting themselves to simple sprawl archetypes. One cannot analyze the costs of "leapfrog development," for example, without specifying densities and land uses. Even the classic anti-sprawl study, *The Costs of Sprawl*, depicts multidimensional community prototypes such as "Sprawl Mix Community," "Low Density Planned Community," and "Low Density Sprawl Community."

Table 2 lists alternative development patterns analyzed in several recent studies. While tailored to their respective regions, all alternatives may be characteriz in two dimensions, density and land use (a third dimension, time, is never considered in these static analyse. Relative to the base case (suburban sprawl), most alternatives involve greater concentration of development and/or greater mixing of uses. Some alternatives stri for a "balanced" mix of jobs and housing by subare others simply for a degree of mixing that does not occur regularly in suburbia. Some concentrate development the urban core(s) of the region, others in a few major suburban centers, and still others in a multitude of small centers.

Poor Accessibility

Ultimately, what distinguishes sprawl from alternative development patterns is poor accessibility of related land uses to one another. The concept of "accessibility is central to urban economics (in simple models of urban form) and travel demand modeling (in gravity-type models of trip distribution). But for some reason, accessibility is hardly ever mentioned in the literature on spraw even though poor accessibility is the "common denominator" among sprawl archetypes.

In scattered or leapfrog development, travelers and service providers must pass vacant land on their way from one developed use to another. In classic strip development, the consumer must pass other commercial uses (usually on crowded arterials) on the way to the desired destination. Of course, in low-density development, everything is far apart due to large private land holdings.

This suggests that sprawl might be characterized generically as any development pattern with poor accessibility among related land uses. Poor accessibility may result from a failure to concentrate development and/or to mix land uses.

The beauty of equating sprawl to poor accessibility is twofold. First, unlike the simple archetypes, the definition recognizes that real-world development patterns are a matter of degree and are multidimensional (a discussed above). No real-world pattern will exactly match an archetype. By defining sprawl generically, we need not debate whether a given pattern is sufficiently similar to an archetype to constitute sprawl.

Second, this generic definition is readily operationalized. Many different accessibility measures are found in the literature (Hansen, 1959; Ingram, 1971 Vickerman, 1974; Burns and Golob, 1976; Dalvi and Martin, 1976; Weibull, 1976; Morris et al., 1979; Pirie 1979; Wachs and Koenig, 1979; Koenig, 1980; Leake and Huzayyin, 1980; Richardson and Young, 1982; Hanson

Table 2 Travel Impacts of Alternative Development Patterns

	Concentrated Jobs	Clustered Housing	Mixed Land-Use	VMT (% change)	Speed (% change)
Washington, D.C.[1]					
– Balanced		○	●	−9	+1
– Concentrated	●	○	●	−9	+2
Seattle, WA[2]					
– Major Centers	●	●		−4	−7
– Multiple Centers	○	○	●	−1	0
– Dispersed Growth			○	+3	0
– Preferred Alternative	●	●	●	−3	+7
Baltimore, MD[3]					
– Centralized Residential	●	○		−1	0
– Decentralized Residential	●			+2	−2
– Transit-Accessible Residential	●	○		−1	−5
Middlesex, NJ[4]					
– Scenario 1	●	●	●	−12	+21
– Scenario 2	○	○	○	−9	+11
Dallas-Fort Worth, TX[5]					
– Rail Corridors	●	●	○	−1	−2
– Activity Centers	●			−1	−1
– Uncongested Areas			○	−4	+2
San Diego, CA[6]					
– Move Jobs			●	−6	NA
– Move Housing			●	−8	NA
– Move Jobs (transit access)			●	−5	NA
– Move Housing (transit access)		○	●	−9	NA
– Job Concentration	●			+11	NA

Key

Jobs	Housing	Land Use
● Large Concentrations	● Highly Clustered	● Balanced Jobs-Housing
○ Small Concentrations	○ Slightly Clustered	○ Mixed Jobs-Housing

[1] Metropolitan Washington Council of Governments (1991)
[2] Puget Sound Council of Governments (1990)
[3] Baltimore Regional Council of Governments (1992)
[4] Middlesex Somerset Mercer Regional Council (1991)
[5] North Central Texas Council of Governments (1990)
[6] San Diego Association of Governments (1991b)

and Schwab, 1987). Simple measures of accessibility, such as average trip length or average travel time can be obtained from travel surveys. More sophisticated measures, such as vehicle miles or vehicle hours of travel (VMT or VHT) per capita, can be estimated with any standard four-step travel modeling system such as FSUTMS (Florida Standard Urban Transportation Model Structure). FSUTMS will even calculate and report "accessibility indexes" for individual traffic zones, using travel time, cost, or distance between zones as the measure of accessibility.

Lack of Functional Open Space

Another characteristic common to all sprawl archetypes is a paucity of functional open space. Strip development presents a solid wall of commercial uses. Low-density suburban development subdivides land until every developable parcel is spoken for; while there is abundant open space, if you count people's yards, it is all in private hands or in holdings too small for community uses. Even leapfrog development, which leaves large areas undeveloped, fails to provide functional open space. The leftover lands are no longer farmed and yet, being in private hands, are unavailable for community uses. Land in suburbia, not actually used for urban purposes, typically is not used at all. It was once estimated that there is about as much idled land in and around cities as there is land used (in any meaningful sense) for urban purposes (Clawson, 1962, p. 107).

As Schneider (1970, p. 69) notes: "It is physically impossible to preserve large open spaces in reasonable proximity to people when millions of people are spread out in uniform low densities. The barrack-like development of land leaves people with the monotony of urban space and form at the scale of the street and private yard." He argues instead for well-designed nodal developments, a complete range of urban spaces (from the most compact to the most open and spacious), and high net densities coupled with low gross densities. The resulting urban form is the antithesis of urban sprawl. Functional open space can be used, then, to define sprawl in much the same way as accessibility. It can be readily operationalized and treated as a matter of degree.

Causes of Sprawl

Low-density suburban development is a "natural" consequence of rising incomes, technological changes, and low travel costs and high travel speeds (for a thorough discussion of the economic forces at work, see Boyce, 1963; Giuliano, 1989). Rising personal income has allowed households to spend more money on travel and on residential space. Industry has shifted from vertical to horizontal production processes, and agglomeration economies have become less important. Increased auto ownership and the construction of high-speed highways have improved the accessibility of outlying sites, causing the urban boundary to shift outwards and flattening land rent and density gradients. Growth and decentralization of population have led to the decentralization of other activities, as market thresholds have been reached at outlying locations.

Leapfrog and scattered development are also a product of market forces (see Clawson, 1962; Bahl, 1968). Expectations of land appreciation at the urban fringe cause some landowners to withhold land from the market. Expectations vary, however, from landowner to landowner, as does the suitability of land for development. The result is a discontinuous pattern of development. The higher the rate of growth in a metropolitan area, the greater the expectations of land appreciation, and the more land will be withheld for future development (Lessinger, 1962; Ottensmann, 1977).

Even strip development results from market forces, albeit forces powerfully shaped by public policy favoring the automobile (Garrison et al., 1959; Boal and Johnson, 1968; Achimore, 1993). "The packaging of 50,000 daily vehicles (and therefore, a total daily population of 60,000 to 70,000 drivers plus passengers) into a single arterial street leads to the irresistible urge to sell things to this population, and creates a sellscape along the street. . .. Once in place, almost no power on earth will stop its march toward strip commercial" (Kulash, 1990).

While a product of market forces, sprawl development patterns are not economically efficient. "[W]e may accept urban sprawl and speculation in raw suburban land as the natural consequences of the economic and social processes we have described, and at the same time we may seek to change one or more stages or bases of those processes because we dislike their final outcome" (Clawson, 1962). In economic theory, a perfectly functioning market requires many buyers and sellers, good information about prices and quality, and no external costs or benefits. The land market meets none of these requirements. The number of buyers and sellers of raw land is limited at any point in time. The rate of land appreciation is speculative. Suburban development is subsidized directly and through the tax code. The land market is rife with externalities. And government regulation of development introduces additional market distortions. See Lee (1979) for an overview of land market imperfections.

In effect, market imperfections define sprawl and provide the justification for public intervention to discourage sprawl.

Subsidies

Raup (1975) lists all manner of subsidies for suburban development. Owner-occupied housing is heavily subsidized through the income tax code. “Although owner-occupied housing is available in central city locations, it seems likely that the net effect of these (tax) provisions has encouraged suburban housing and so contributed to an urban-rural border farther from the center than that which would have obtained in the absence of such a subsidy” (Fischel, 1982).

Infrastructure is also subsidized. While less true today, federal funding of waste treatment systems (and related regulations that led to excess capacity) contributed to the sprawl of the 1960s, 1970s, and early 1980s. “Several important aspects of the current EPA design, review, and funding process raise serious questions concerning the role of EPA-sponsored interceptors in furthering suburban sprawl. In the initial physical design phase of interceptor projects, it appears that current regulations and procedures encourage—or at least permit—the design of unnecessarily large and extensive sewerage systems” (Binkley et al., 1975, p. 2).

Transportation remains heavily subsidized. The magnitude of subsidies for the private automobile is estimated by Renner (1988), Cameron (1991), Voorhees (1991), Hanson (1992a and 1992b), and MacKenzie (1994). Hanson concludes: “The result (of subsidies) is the over-provision of transportation infrastructure relative to what it would be if user fees existed to capture more or all of the direct costs—not to mention externalities—of transportation infrastructure use.... Sprawl and discontiguous urban growth are logical outcomes. The glue holding the compact city together has been lost” (Hanson, 1992a, p. 62).

To illustrate, Archer (1973) analyzed a case of leapfrog development in Lexington, Kentucky. By bypassing five tracts of land well-suited for residential development, developers drove up private and public costs by $272,534 per year. Some of these costs were incurred by residents of the outlying development in the form of higher travel costs; they presumably paid less for land and housing than they would have at a more accessible site, in keeping with efficient resource allocation. The remaining costs, however, were defrayed by other consumers and taxpayers in the area, who ended up subsidizing outlying development (see Table 3). Furthermore, the social costs of auto use were

Table 3 Additional Costs of a 200-acre ‘Leapfrog’ Residential Development Near Lexington, Kentucky

Item	Total Additional Costs per Annum ($)	Who Paid These Additional Costs
Water	8,766	Consumers, Lexington area
Gas	1,013	Consumers, Lexington area
Telephone	13,931	Consumers, statewide
Electricity	937	Consumers, statewide
Sanitary Sewage	9,016	City taxpayers
Refuse Collection	638	City taxpayers
Fire Protection	208	City taxpayers
Police Protection	7,425	City taxpayers
Mail Service	374	Federal taxpayers
School Bus Service	737	County taxpayers
Commercial Delivery Services	54,677	Consumers, Lexington area
Automobile Commuting	172,207	Development’s residents
Bus Commuting	2,483	60% by consumers, Lexington area 40% by development’s residents
Road and Street Maintenance	122	County taxpayers
Total	272,534	

Source: Archer (1973)

Table 4 Social Costs of Urban Travel (Cents per VMT)

Accidents	4.1–12.5
Air Pollution	1.5–2.5
Water Pollution	0.2
Noise	0.1–0.4
Public Services	0.7–1.1
Congestion	12.5–20.0

Source: DeCorla-Souza (1991)

not even factored into the calculation, though such costs are comparable in magnitude to the direct costs of auto use (see Table 4).

As Archer notes, "[T]he land market will only ensure the efficient use of urban-fringe land if the landowner, developer and homebuyer participants are confronted with the costs and benefits of their respective decisions." They are not so confronted generally in the suburban land market. The result is faster decentralization, lower densities, and more bypassed land than optimal from an economic standpoint.

Externalities

"The use and value of a tract or parcel of land within a metropolis (city center and suburbs) is affected more by the use and value of other tracts or parcels of land than it is by what takes place on the tract itself" (Clawson, 1971, p. 166). Clawson reviews the various externalities and interdependencies that cause suburban land markets to fail.

Particularly relevant to the discussion of sprawl are the external benefits associated with open space. A large body of empirical work shows that buyers are willing to pay more for land if it is close to public open space, whether waterbodies, parks, orpublicly owned greenbelts (Hendon, 1971; Darling, 1973; Weicher and Zerbst, 1973; Hammer et al., 1974; Correll et al., 1978; Pollard, 1982; McLeod, 1984; Didato, 1990; Larsen, 1992). Yet, as a public or quasi-public good, open space tends to be undersupplied by the private sector (Gardner, 1977).

Government Regulation

Local governments have elaborate regulatory systems composed of zoning ordinances, subdivision regulations, and building codes. The common rationale for such regulation is that land markets fail because developers do not take into account the costs (negative externalities) they impose on others in their decisions concerning land use. However, the effect of regulation may be to compound market failure (Richardson and Gordon, 1993). Suburban land-use regulation encourages low-density development and the strict separation of land uses. The result is sprawl (see Moss, 1977).

Costs of Sprawl

A recent assessment of two development plans for the State of New Jersey, one a continuation of current sprawl and the other a more compact pattern, estimated that sprawl would cost an additional $740 million for roads and $440 million for water and sewer, would destroy an additional 90,000 acres of prime farmland and almost 30,000 acres of environmental lands; would produce an additional 4,560 tons of water pollutants; and so forth (Center for Urban Policy Research, 1992). The savings with compact development were typically 30 percent or more of the base amounts.

Table 5 Costs of Sprawl

	Psychic Costs	Excess Travel/ Congestion	Energy Costs	Environmental Costs	Inflated Costs of Infrastructure/ Services	Loss of Agriculture Land/Open Space	Downtown Decay
Whyte (1957)					x	x	
Clawson (1962)	x				x	x	
Boyce (1963)							x
Harvey and Clark (1965)		x			x	x	x
Sinclair (1967)						x	
McKee and Smith (1972)		x			x		
Archer (1973)		x			x		
Real Estate Research Corporation (1974)	x	x	x	x	x		
Ottensmann (1977)	x	x	x	x	x	x	
Popenoe (1979)	x						x
Hainca (1986)			x				
Lowry (1988)	x	x					
Neuman (1991)	x				x		

One can quibble with these estimates, but there is no doubt that sprawl carries a large price tag, and not just in monetary terms. Table 5 itemizes the costs of sprawl, as posited in the literature. Several are highlighted below.

Psychic Costs

In the article, "Urban Sprawl: Some Neglected Sociological Considerations," Popenoe (1979) identifies sprawl with two types of psychic costs: environmental deprivation and deprivation of access. The former he defines as a deficiency of elements that provide activity and stimulation. The visual uniformity, the lack of identifiable community, and other unaesthetic qualities of sprawl may all contribute to environmental deprivation.

While it may appear self-evident that sprawl is unaesthetic, the reaction of the American public is less clear. Surveys reveal that people, when shown images of both sprawl and traditional communities, favor the latter by wide margins (Neuman, 1991). Yet, some of the hallmarks of sprawl are apparently to the public's liking. By a margin of 66 to 34 percent, people favor "homogeneous neighborhoods" over "mixed neighborhoods where different types and sizes of houses are in the same general area and where small stores and other commercial activities are nearby" (Bookout, 1992). Survey research in Florida demonstrates a distinct preference for low-density suburban or exurban living (Audirac et al., 1989).

The other psychic cost of sprawl, deprivation of access, is much clearer. In a sprawl development pattern, nearly half of the American public, those who cannot drive, are deprived of good access to community facilities and services. "[I]t is hard to escape the conclusion that urban sprawl is an urban development pattern designed by and for men, especially middle class men. . .. Fewer women than men are able, or wish, to drive a car, and if a family has just one car, that car traditionally is used by the man. No teenager can legally drive a car until a certain minimum age, usually sixteen or seventeen. And automobile driving is often impossible or economically difficult for the elderly, the poor, and the handicapped" (Popenoe, 1979, pp. 262–263). The impacts of poor accessibility on these groups have been well-documented (Schaeffer and Sclar, 1975; Popenoe, 1977; Berg and Medrich, 1980; Carp, 1980; Millas, 1980; Carp, 1988).

Excess Travel and Congestion

Sprawl has an impact on travel demand and traffic congestion. These two performance criteria are not equivalent. All else being equal, more travel will translate into more congestion. But all else is not equal with alternative development patterns; the level of roadway congestion depends on where travel occurs as well as how much occurs.

The extensive literature relating travel and traffic to urban form is reviewed by Gilbert and Dajani (1974), U.S. Department of Transportation (1976), Neels et al. (1977), Giuliano (1989), Holtzclaw (1991), Cervero (1991a), Downs (1992), and Steiner (1994). High densities generate fewer vehicle miles of travel (VMT) per capita than do low densities (as in Figure 1). Trips become shorter as densities rise, and a growing percentage of trips are made by walking ortransit (Levinson and Wynn, 1963; Bellomo et al., 1970; Guest and Cluett, 1976; Pushkarev and Zupan, 1977; Smith, 1986; Newman and Kenworthy, 1989; Spillar and Rutherford, 1990; Prevedouros, 1991; Dunphy and Fisher, 1994). At the same time, high densities are associated with high levels of traffic congestion (Neels et al., 1977; Newman and Kenworthy, 1988). The net effect of shorter trips and heightened congestion on travel times and travel costs is unclear *a priori*, but recent empirical evidence suggests that the former overwhelms the latter (Prevedouros, 1991; Ewing, 1994).

The picture is further complicated by the multiple dimensions of development. Urban and suburban centers may be large or small and may have single or mixed uses. These variables may have more impact on travel and traffic than do densities per se.

Mixing complementary land uses reduces trip lengths and encourages alternatives to the automobile. Indeed, since dense urban environments tend to be mixed-use environments, the positive impacts attributed to density in the literature may result as much from mixed uses. Cities with the highest rates of walking/bicycling are those with a balance of jobs and residents in their central cities (like Boston); high employment densities alone do not foster alternatives to the automobile (Newman and Kenworthy, 1989, p. 47). Jobs/housing balance is the best predictor of trip length in the San Diego region; trip lengths average 8.8 miles for commuters living in balanced areas,

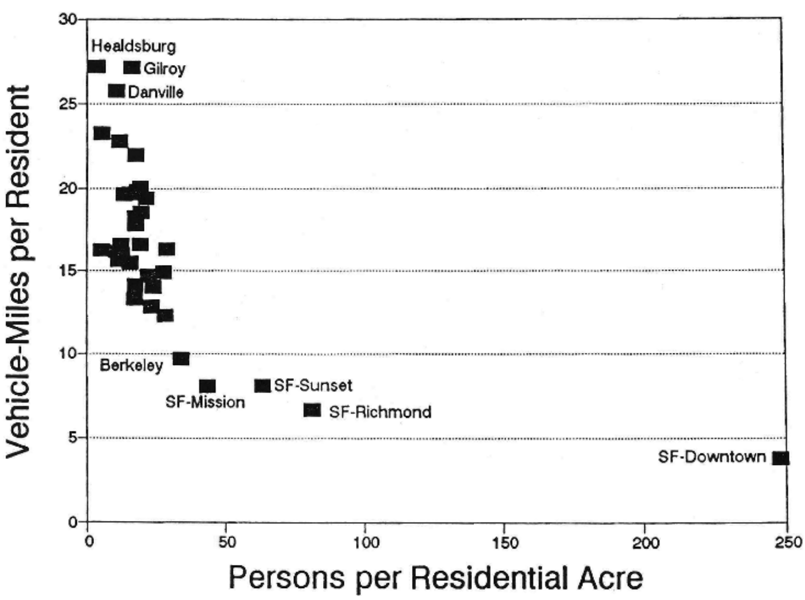

Fig. 1 Residential Density Versus VMT Per Resident
Source: Harvey and Deakin (1991)

two miles less than the regional average and four miles less than areas with an excess of housing over jobs (San Diego Association of Governments, 1991a and 1991b). Transit and walking account for bigger shares of Seattle's work and shopping trips in census tracts with mixed uses; this is true even controlling for densities and demographic factors (Frank, 1994). A balance of jobs and housing increases the amount of walking and biking to suburban centers, and reduces the level of congestion on nearby freeways (Cervero, 1989). The addition of retail uses to office-oriented centers also increases the amount of walking, biking, ridesharing, and transit uses (Cervero, 1988; Cervero, 1991b).

How to break out the effects of different development variables on travel and traffic? Alternative development patterns have been analyzed for their travel and traffic impacts in many computer simulation studies (for a review of studies, see Gilbert and Dajani, 1974; Giuliano, 1989; DeCorla-Souza, 1992). We focus here on recent simulation studies because they have achieved greater realism in the depiction of alternative development patterns.

For each of six recent studies, Table 2 compares alternative development patterns to a "base case." The base case is a continuation of current sprawl patterns. The alternatives are typically more concentrated in their development patterns and/or more mixed in their land uses than is the base case. For each alternative, percentage changes in VMT (reflecting travel demand) and average peak-period travel speed (reflecting traffic congestion) are shown relative to the base case. The alternatives that perform well in both dimensions are those with mixed land uses. Simply concentrating development, without mixing uses, reduces VMT in some cases at the expense of travel speed. (Note, though, that none of the simulations allowed for significant mode shifts to transit as densities rose.)

Energy Inefficiency and Air Pollution

Higher densities mean shorter trips and more travel by energy-conserving modes. They also mean more congestion. In a paper entitled, "The Transport Energy Trade-Off: Fuel-Efficient Traffic versus Fuel-Efficient Cities," Newman and Kenworthy (1988) find that the former effect overwhelms the latter. Even though vehicles are not as fuel-efficient in dense areas due to traffic congestion, fuel consumption per capita is still substantially less because people drive so much less. On balance, fuel consumption per capita declines by one-half to two-thirds as city densities rise from four to 12 persons per acre (or roughly, 10 to 30 persons per hectare) (see Figure 2).

As with travel, the relationship of fuel consumption to urban form is complicated by the multiple dimensions of development. Studies comparing centralized development to low-density sprawl consistently find the former to be more energy-efficient. But when polycentric development is included in the comparison, that pattern emerges as the preferred alternative from an energy-efficiency standpoint (see Table 6).

Air pollution from mobile sources is less affected by urban form than is energy consumption. As with energy consumption, vehicle emissions are directly related to VMT and inversely related to vehicle speed (up to about 40 mph). But the emissions associated with "cold starts" and "hot soaks" add another element. In an early simulation study, extreme changes in development patterns within the Denver region were found to have "little or no effect on ambient air quality" (Scheuemstuhl and May, 1979). A recent study found that while balancing jobs and housing in the San Diego region would reduce VMT by 5 to 9 percent, and reduce congested miles of freeway by 31 to 41 percent, it would cut vehicle emissions by less than 2 percent. "[B]alancing jobs and housing does not cause a significant change in vehicle trips. A major part of auto pollution comes from cold starts which are directly related to vehicle trips (as opposed to VMT or congestion)" (San Diego Association of Governments, 1991b).

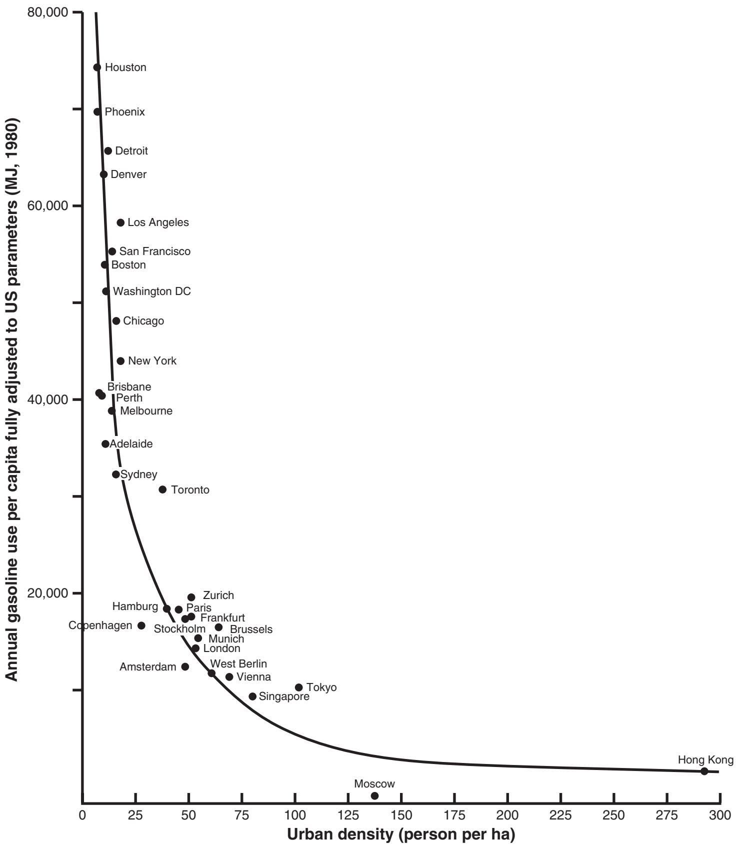

Fig. 2 Urban Density Versus Gasoline Use per Capita Adjusted for Vehicle Efficiency
Source: Newman and Kenworthy (1989)

Inflated Infrastructure and Public Service Costs

The Costs of Sprawl and other studies have shown that neighborhood infrastructure becomes less costly on a per-unit basis as density rises (for a review of literature, see Priest et al., 1977; Frank, 1989). Just how much costs decline with density has been debated, with some arguing that cost differences largely evaporate when one adjusts for dwelling unit size. Also debated has been the shape of the cost curve, with some contending that costs rise at very high densities (due to the special needs of high-rise structures) and fall at very low densities (due to the feasibility of septic systems, natural drainage, and rural street cross sections). But the basic inverse relationship between density and neighborhood infrastructure costs is well-established.

Having said this, it turns out that neighborhood infrastructure costs are not particularly relevant to the issue of sprawl. As long as developers are responsible for the full costs of neighborhood infrastructure, and pass such costs on to homebuyers and other end-users of land, lower-density development patterns will meet the test of economic efficiency (at least with respect to infrastructure costs).

Table 6 Conclusions of Land Use Studies Concerning the Most Energy-Efficient Urban Form

Bacon (1973)	centralization	
Franklin (1974)	centralization	
Real Estate Research Corporation (1974)	centralization	
Council on Envirn. Quality (1975)	centralization	
Hoben (1975)	centralization	
Nadler (1975)	centralization	
Kydes et al. (1976)		multinucleation
Slayton (1976)		multinucleation
Cornehls (1977)	centralization	
Burby and Bell (1978)		multinucleation
Carroll (1978)	centralization	
Edwards (1978)		multinucleation
Roberts (1978)	centralization	
Romanos (1978)		multinucleation
Soot and Sen (1979)		multinucleation
Windsor (1979)		multinucleation
Small (1980)		multinucleation
Van Til (1980, 1982)		multinucleation
Keyes (1981)		multinucleation

Source: Haines (1986); full citations for these studies can be found in Haines.

Where inefficiency is more likely to arise is in the provision of community-level infrastructure. Inefficiency may also arise in the operation and maintenance of infrastructure, and in the provision of police and other public services. These tend to be financed with local taxes or user fees that are independent of location, causing remote development to be subsidized.

"[C]osts beyond the neighborhood level are not fully passed onto the consumer as part of buying a house. . .. The costs associated with distance from central facilities, although potentially larger than many of the other costs at distances of 20 miles, are almost completely ignored in pricing schemes like impact fees. The inevitable results of both of these factors are to stimulate overconsumption of housing in costly-to-serve circumstances and to subsidize the more costly locations with the less costly ones" (Frank, 1989, p. 42).

From the standpoint of community-level infrastructure, costs vary not so much with residential density but with the degree of clustering and/or proximity to existing development (Howard County Planning Commission, 1967; Stone, 1973; Real Estate Research Corporation, 1974; Barton-Aschman Associates, 1975; Downing and Gustely, 1977; Peiser, 1984). So, too, the costs of public services (Archer, 1973; Real Estate Research Corporation, 1974; Downing and Gustely, 1977; Peiser, 1984). See, for example, Table 7.

Table 7 Annual Cost of Providing Public Services per Mile Distance from Public Facility Site: 1973

	Capital* or Operating** Costs per Mile ($)
Police	438*
Fire	216*
Sanitation	3,360***
Schools	19,845***
Water supply	21,560**
Storm drainage	6,187**
Sanitary sewers	12,179**
Total Cost	68,498

* Includes only operating costs
** Includes only capital costs
*** Includes both capital and operating costs
Source: Downing and Gustely (1977)

Loss of Farmland

Urbanization generally, and sprawl in particular, contribute to loss of farmlands and open spaces. Because lands most suitable for growing crops also tend to be most suitable for "growing houses" (being flat and historically near human settlements), a disproportionate amount of prime farmland is lost to urbanization. For estimates of losses, see Berry and Plaut, 1978; Fischel, 1982; Nelson, 1990.

Having acknowledged the relationship between urbanization and loss of farmland, we must still ask whether (1) the loss is in some sense peculiar to sprawl-type development, and (2) the loss is a result of some market failure demanding public intervention.

Insofar as sprawl consumes more land in toto than does compact development, sprawl may cause the loss of more agricultural lands and open spaces. In *The Costs of Sprawl*, a community prototype representing low-density sprawl leaves no land in its natural (unimproved) state (Real Estate Research Corporation, 1974, Table 43). In contrast, planned prototypes leave anywhere from 18 to 57 percent unimproved land by means of clustered, contiguous and/or higher-density development.

The literature offers differing views on the extent to which rural/urban land conversion results from market imperfections, and on the concomitant need for public intervention to preserve farmlands. Arguing that the problem is illusory or at least overstated are Gardner (1977) and Fischel (1982). On the other side of the issue are Raup (1975) and Nelson (1990).

There is evidence of market failure in three areas:

(1) Urban "spillover effects" (externalities) that make nearby farming operations less profitable and cause farmers to disinvest; such effects may extend up to three miles from urban development (Nelson, 1986).
(2) The "impermanence syndrome" that causes farmers to abandon operations prematurely in anticipation of urban development; perhaps as much as one acre is idled for every acre converted to urban uses in the Northeastern United States (Plaut, 1976; also see Sinclair, 1967).
(3) Misjudgment of the value of farmland to future generations (Peterson and Yampolsky, 1975).

Other market imperfections that accelerate farmland conversion are discussed in Nelson (1992).

Conclusion

With a few refinements, the list of "sprawl indicators" in DCA's proposed rule can be brought into harmony with the technical literature on sprawl of the past three decades. DCA's basic approach is sound. It has defined a variety of sprawl indicators, some relating to *characteristics* of sprawl, others to *effects* of sprawl, and still others to *causes* of sprawl. In essence, the rule calls for policies to avoid the characteristics of sprawl, remove the causes, and mitigate the effects.

It might seem like overkill to attack sprawl on three fronts; certainly, it makes the rule lengthier and more cumbersome to apply than some might wish. Yet, market forces and public-policy biases favoring sprawl are strong and pervasive. The three-pronged approach in the proposed rule may be more successful than, for example, simply asking new development to pay 100 percent of the costs of public facilities and services it requires or, alternatively, drawing an urban service boundary on the future land use map in the hope that development within the boundary will be at reasonable density and entail a mix of uses.

References

Achimore, A. (1993) "Putting the Community Back into Community Retail," *Urban Land* 52(8), pp. 33–38.
Archer, R.W. (1973) "Land Speculation and Scattered Development: Failures in the Urban-Fringe Market," *Urban Studies* 10, pp. 367–372.

Audirac, I. and M. Zifou (1989) "Urban Development Issues: What is Controversial in Urban Sprawl? An Annotated Bibliography of Often-Overlooked Sources," *Council of Planning Librarians Bibliography No. 247*. Chicago, III.

Audirac, I., A.H. Shoemyen and M.T. Smith (1989) "Consumer Preference and the Compact Development Debate," paper presented at the National Planning Conference of the American Planning Association, Atlanta, Ga., Apr. 29-May 3, 1989.

Bahl, R.W. (1968) "A Land Speculation Model: The Role of the Property Tax as a Constraint to Urban Sprawl," *Journal of Regional Science* 8(2), pp. 199–208.

Baltimore Regional Council of Governments (1992) *Impact of Land Use Alternatives on Transportation Demand*. Baltimore, Md.

Barton-Aschman Associates, Inc. (1975) *Comparative Evaluation of New Community Growth versus Trend Development Growth*. Charles County, Md.

Bellomo, S.J., R.B. Dial and A.M. Voorhees (1970) "Factors, Trends, and Guidelines Related to Trip Length," *National Cooperative Highway Research Program Report 89*. Transportation Research Board, Washington, D.C.

Berg, M. and E.A. Medrich (1980) "Children in Four Neighborhoods: The Physical Environment and Its Effect on Play and Play Patterns," *Environment and Behavior* 12(3), pp. 320–348.

Berry, D. and T. Plaut (1978) "Retaining Agricultural Activities under Urban Pressures: A Review of Land Use Conflicts and Policies," *Policy Sciences 9*, pp. 153–178.

Binkley, C. et al. (1975) *Interceptor Sewers and Urban Sprawl*. Lexington Books, Lexington, Mass.

Boal, F.W. and D.B. Johnson (1968) "Nondescript Streets," *Traffic Quarterly* 22(3), pp. 329–344.

Bookout, L.W. (1992) "Neotraditional Town Planning: The Test of the Marketplace," *Urban Land* 51(6), pp. 12–17.

Boyce, R.R. (1963) "Myth versus Reality in Urban Planning," *Land Economics* 39(3), pp. 241–251.

Breslaw, J.A. (1990) "Density and Urban Sprawl: Comment," *Land Economics* 66(4), pp. 464–468.

Brueckner, J.K. and D.A. Fansler (1983) "The Economics of Urban Sprawl: Theory and Evidence on the Spatial Size of Cities," *Review of Economics and Statistics* 65(3), pp. 479–482.

Burns, L.D. and T.F. Golob (1976) "The Role of Accessibility in Basic Transportation Choice Behavior," *Transportation* 5, pp. 175–198.

Cameron, M. (1991) *Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion*. Environmental Defense Fund, Oakland, Cal.

Carp, F.M. (1980) "Environmental Effects Upon the Mobility of Older People," *Environment and Behavior* 12(2), pp. 139–156.

Carp, F.M. (1988) "Significance of Mobility for the Well-Being of the Elderly," *Transportation Research Board Special Report 218*, pp. 1–20.

Center for Urban Policy Research (1992) *Impact Assessment of the New Jersey Interim State Development Plan—Executive Summary*. New Jersey Office of State Planning, Trenton, N.J.

Cervero, R. (1988) "Land Use Mixing and Suburban Mobility," *Transportation Quarterly* 42, pp. 429–446.

Cervero, R. (1989) "Jobs-Housing Balancing and Regional Mobility," *Journal of the American Planning Association* 55(2), pp. 136–150.

Cervero, R. (1991a) "Congestion Relief: The Land Use Alternative," *Journal of Planning Education and Research* 10, pp. 119–129.

Cervero, R. (1991b) "Land Uses and Travel at Suburban Activity Centers," *Transportation Quarterly* 45(4), pp. 479–491.

Clawson, M. (1962) "Urban Sprawl and Speculation in Suburban Land," *Land Economics* 38(2), pp. 99–111.

Clawson, M. (1971) *Suburban Land Conversion in the United States: An Economic and Governmental Process*. The Johns Hopkins Press, Baltimore, Md.

Correll, M.R., J.H. Lillydahl and L.D. Singell (1978) "The Effects of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space," *Land Economics* 54, pp. 207–217.

Dalvi, M.Q. and K.M. Martin (1976) "The Measurement of Accessibility: Some Preliminary Results," *Transportation* 5, pp. 17–42.

Darling, A.H. (1973) "Measuring Benefits Generated by Urban Water Parks," *Land Economics* 49, pp. 22–34.

DeCorla-Souza, P. (1991) "Peak Period Tolls: One Cure for Urban Congestion," *ITE 1991 Compendium of Technical Papers*. Institute of Transportation Engineers, Washington, D.C.

DeCorla-Souza, P. (1992) "The Impacts of Alternative Urban Development Patterns on Highway System Performance," issue papers for the 1992 ITE International Conference. Institute of Transportation Engineers, Washington, D.C.

Didato, B. (Jan. 1990), "The Paths Less Traveled—A Wrapup on the Nation's Greenways," *Planning* 56, pp. 6–10.

Downing, P.B. and R.D. Gustely (1977) "The Public Service Costs of Alternative Development Patterns: A Review of the Evidence," in P.B. Downing (ed.), *Local Service Pricing Policies and Their Effect on Urban Spatial Structure*. University of British Columbia Press, Vancouver, B.C.

Downs, A. (1992) *Stuck in Traffic—Coping with Peak-Hour Traffic Congestion*. The Brookings Institution, Washington, D.C., pp. 79–120.

Dunphy, R.T. and K.M. Fisher (1994) "Transportation, Congestion, and Density: New Insights," paper presented at the 73rd Annual Meeting, Transportation Research Board, Washington, D.C.

Ewing, R. (1991) *Developing Successful New Communities*. Urban Land Institute, Washington, D.C.

Ewing, R. (1994) "Getting Around a Traditional City, a Suburban PUD, and Everything In-Between," paper presented at the 73rd Annual Meeting, Transportation Research Board, Washington, D.C.

Fischel, W.A. (1982) "The Urbanization of Agricultural Land: A Review of the National Agricultural Lands Study," *Land Economics* 58(2), pp. 236–259.

Fischel, W.A. (1991) "Good for the Town, Bad for the Nation? A Comment," *Journal of the American Planning Association* 57(3), pp. 341–344.

Frank, J.E. (1989) *The Costs of Alternative Development Patterns: A Review of the Literature*. Urban Land Institute, Washington, D.C.

Frank, L. (1994) "The Impacts of Mixed Use and Density on the Utilization of Three Modes of Travel: The Single Occupant Vehicle, Transit, and Walking," paper presented at the 73rd Annual Meeting, Transportation Research Board, Washington, D.C.

Gardner, B.D. (1977) "The Economics of Agricultural Land Preservation," *American Journal of Agricultural Economics* 59 (Dec.), pp. 1026–1036.

Garrison, W.L. et al. (1959) *Studies of Highway Development and Geographic Change*. University of Washington Press, Seattle, Wash.

Gilbert, G. and J.S. Dajani (1974) "Energy, Urban Form and Transportation Policy," *Transportation Research* 8, pp. 267–276.

Giuliano, G. (1989) "Literature Synthesis: Transportation and Urban Form," report prepared for the Federal Highway Administration under Contract DTFH61-89-P-00531.

Gordon, P. and H.L. Wong (1985) "The Costs of Urban Sprawl—Some New Evidence," *Environment and Planning A* 17(5), pp. 661–666.

Gordon, P., A. Kumar and H.W. Richardson (1989) "The Influence of Metropolitan Spatial Structure on Commuting Time," *Journal of Urban Economics* 26, pp. 138–151.

Gordon, P., H.W. Richardson, and M.J. Jun (1991) "The Commuting Paradox—Evidence from the Top Twenty," *Journal of the American Planning Association* 57(4), pp. 416–420.

Guest, A.M. and C. Cluett (1976) "Analysis of Mass Transit Ridership Using 1970 Census Data," *Traffic Quarterly* 30(1), pp. 143–161.

Haines, V. (1986) "Energy and Urban Form: A Human Ecological Critique," *Urban Affairs Quarterly* 21(3), pp. 337–353.

Hammer, T.R., R.E. Coughlin and E.T. Horn (1974) "The Effect of a Large Urban Park on Real Estate Value," *Journal of the American Institute of Planners* 40, pp. 274–277.

Hansen, W.G. (1959) "How Accessibility Shapes Land Use," *Journal of the American Institute of Planners* 25, pp. 73–76.

Hanson, M.E. (1992a) "Automobile Subsidies and Land Use: Estimates and Policy Responses," *Journal of the American Planning Association* 58(1), pp. 60–71.

Hanson, M.E. (1992b) *Results of a Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use*. U.S. Department of Transportation, Washington, D.C.

Hanson, S. and M. Schwab (1987) "Accessibility and Intraurban Travel," *Environment and Planning A* 19, pp. 735–748.

Harvey, G. and E. Deakin (1991) "Toward Improved Regional Transportation Modeling Practice," paper prepared for the National Association of Regional Councils, Washington, D.C.

Harvey, R.O. and W.A.V. Clark (1965) "The Nature and Economics of Urban Sprawl," *Land Economics* 41(1), pp. 1–9.

Hendon, W.S. (1971) "The Park as a Determinant of Property Values," *American Journal of Economics and Sociology* 30, pp. 289–296.

Hekkila, E.J. and R.B. Peiser (1992) "Urban Spawl, Density, and Accessibility," *Papers in Regional Science* 71(2), pp. 127–138.

Holtzclaw, J. (1991) *Explaining Urban Density and Transit Impacts on Auto Use*. Sierra Club, San Francisco, Cal.

Howard County Planning Commission (1967) *Howard County 1985*. Howard County, Md.

Ingram, D.R. (1971) "The Concept of Accessibility: A Search for an Operational Form," *Regional Studies* 5(2), pp. 101–107.

Koenig, J.G. (1980) "Indicators of Urban Accessibility: Theory and Application," *Transportation* 9, pp. 145–172.

Koenig, J. (1989) "Should We Halt Urban Sprawl?" *Florida Trend* 31(12), pp. 28–31.

Kulash, W. (1990) "Traditional Neighborhood Development—Will the Traffic Work?" paper presented at the Eleventh Annual Pedestrian Conference, Bellevue, Wash.

Larsen, P. (Spring-Summer 1992) "Open Space That Sells," *Land Development* 5, pp. 22–25.
Leake, G.R. and A.S. Huzayyin (1980) "The Impact of Accessibility on Trip Production and Trip Attraction Models," *Engineering and Traffic Control* 21(10), pp. 469–471.
Lee, D.B. Jr. (1979) "Land Use Planning as a Response to Market Failure," in J.I. de Neufville (ed.), *The Land Use Policy Debate in the United States*. Plenum Press, New York, N.Y.
Lessinger, J. (1962) "The Case for Scatterization," *Journal of the American Institute of Planners* 28(3), pp. 159–169.
Levinson, H.S. and F.H. Wynn (1963) "Effects of Density on Urban Transportation Requirements," *Highway Research Record No. 2*, pp. 38–64.
Lowry, I.S. (1988) "Planning for Urban Sprawl," *Transportation Research Board Special Report No. 220*, pp. 275–312.
MacKenzie, J.J. (1994) "The Going Rate: What It Really Costs to Drive," paper presented at the 73rd Annual Meeting, Transportation Research Board, Washington, D.C.
McKee, D.L. and G.H. Smith (1972) "Environmental Diseconomies in Suburban Expansion," *American Journal of Economics and Sociology* 31(2), pp. 181–188.
McLeod, P.B. (1984) "The Demand for Local Amenity: An Hedonic Price Analysis," *Environment and Planning A* 16, pp. 389–400.
Metropolitan Washington Council of Governments (1991) *Transportation Demand Impacts of Alternative Land Use Scenarios, Final Report*. Washington, D.C.
Middlesex Somerset Mercer Regional Council (1991) *The Impact of Various Land Use Strategies on Suburban Mobility, Final Report*. Princeton, N.J.
Millas, A.J. (1980) "Planning for the Elderly within the Context of a Neighborhood," *Ekistics* 283, pp. 264–273.
Mills, D.E. (1981) "Growth, Speculation, and Sprawl in a Monocentric City," *Journal of Urban Economics* 10, pp. 201–226.
Morris, J.M., P.L. Dumble and M.R. Wigan (1979) "Accessibility Indicators for Transport Planning," *Transportation Research* 13A, pp. 91–109.
Moss, W.G. (1977) "Large Lot Zoning, Property Taxes, and Metropolitan Area," *Journal of Urban Economics* 4(4), pp. 408–427.
Neels, K. et al. (1977) "An Empirical Investigation of the Effects of Land Use on Urban Travel," *Working Paper 5049–17–1*. The Urban Institute, Washington, D.C.
Nelson, A.C. (1986) "Towards a Theory of the American Rural Residential Land Market," *Journal of Rural Studies* 2, pp. 309–319.
Nelson, A.C. (1990) "Economic Critique of Prime Farmland Preservation Policies in the United States," *Journal of Rural Studies* 6(2), pp. 119–142.
Nelson, A.C. (1992) "Preserving Prime Farmland in the Face of Urbanization—Lessons from Oregon," *Journal of the American Planning Association* 58(4), pp. 467–488.
Neuman, M. (1991) "Utopia, Dystopia, and Diaspora," *Journal of the American Planning Association* 57(3), pp. 344–347.
Newman, P.W.G. and J.R. Kenworthy (1988) "The Transport Energy Trade-Off: Fuel-Efficient Traffic versus Fuel-Efficient Cities," *Transportation Research A* 22A(3), pp. 163–174.
Newman, P.W.G. and J.R. Kenworthy (1989) *Cities and Automobile Dependence*. Gower Technical, Aldershot, Eng.
North Central Texas Council of Governments (1990) *Urban Form/Transportation System Options for the Future: Dallas/Fort Worth Case Study*. Arlington, Tex.
Ohls, J.C. and D. Pines (1975) "Discontinuous Urban Development and Economic Efficiency," *Land Economics* 51(3), pp. 224–234.
Ottensmann, J.R. (1977) "Urban Sprawl, Land Values, and the Density of Development," *Land Economics* 53(4), pp. 389–400.
Peiser, R.B. (1984) "Does It Pay to Plan Suburban Growth?" *Journal of the American Planning Association* 50(4), pp. 419–433.
Peiser, R.B. (1989) "Density and Urban Sprawl," *Land Economics* 65(3), pp. 193–204.
Peiser, R.B. (1990) "Density and Urban Sprawl—Reply," *Land Economics* 66(4), pp. 469–472.
Peterson, G.E. and H. Yampolsky (1975) *Urban Development and the Protection of Metropolitan Farmland*. The Urban Institute, Washington, D.C.
Pirie, G.H. (1979) "Measuring Accessibility: A Review and Proposal," *Environment and Planning A* 11, pp. 299–312.
Plaut, T. (1976) "The Effects of Urbanization on the Loss of Farmland at the Rural-Urban Fringe: A National and Regional Perspective," *Regional Science Research Institute Discussion Paper Series No. 94*. University of Massachusetts, Amherst, Mass.
Pollard, R. (1982) "View Amenities, Building Heights, and Housing Supply," in D.B. Diamond and G.S. Tolley (eds.), *The Economics of Urban Amenities*. Academic Press, New York, N.Y., pp. 105–123.
Popenoe, D. (1977) *The Suburban Environment*. University of Chicago Press, Chicago, III.

Popenoe, D. (1979) "Urban Sprawl—Some Neglected Sociological Considerations," *Sociology and Social Research* 63(2), pp. 255–268.

Prevedouros, P.D. (1991) "Trip Generation: Different Rates for Different Densities," paper presented at the 71st Annual Meeting of the Transportation Research Board, Washington, D.C.

Priest, D. et al. (1977) *Large-Scale Development: Benefits, Constraints, and State and Local Policy Incentives*. Urban Land Institute, Washington, D.C., pp. 37–45.

Puget Sound Council of Governments (1990) *Summary and Comparison Between Alternatives*. Vision 2020, Seattle, Wash.

Pushkarev, B.S. and J.M. Zupan (1977) *Public Transportation and Land Use Policy*. Indiana University Press, Bloomington, Ind., pp. 24–63.

Raup, P.M. (1975) "Urban Threats to Rural Lands," *Journal of the American Institute of Planners* 41(Nov.), pp. 371–378.

Real Estate Research Corporation (1974) *The Costs of Sprawl, Detailed Cost Analysis*. U.S. Government Printing Office, Washington, D.C.

Renner, M. (1988) *Rethinking the Role of the Automobile*. Worldwatch Institute, Washington, D.C.

Richardson, A.J. and W. Young (1982) "A Measure of Linked-Trip Accessibility," *Transportation Planning and Technology* 7, pp. 73–82.

Richardson, H.W. and P. Gordon (1993) "Market Planning—Oxymoron or Common Sense?" *Journal of the American Planning Association* 59(3), pp. 347–349.

San Diego Association of Governments (1991a) "The Relationship Between Jobs/Housing Balance and Travel Patterns in the San Diego Region," *Regional Growth Management Strategy, Appendix 2*. San Diego, Cal.

San Diego Association of Governments (1991b) "Jobs/Housing Balance and Transportation Corridor Densities," *Regional Growth Management Strategy, Appendix 3*. San Diego, Cal.

Schaeffer, K.H. and E. Sclar (1975) *Access for All*. Penguin Books, Baltimore, Md., pp. 103–120.

Scheuernstuhl, G.J. and J. May (1979) "Analysis of Air Quality Sensitivity to Development Pattern Changes and Growth Levels," *Transportation Research Record* 714, pp. 12–17.

Schneider, K.R. (1970) "The Destruction of Urban Space," *Traffic Quarterly* 24, pp. 59–76.

Sinclair, R. (1967) "Von Thunen and Urban Sprawl," *Annuals of the Association of American Geographers* 57, pp. 72–87.

Smith, W.S. (1986) "Interactions Between Transportation and High-Rise, High-Density Living," *Ekistics* 320/321, pp. 336–344.

Spillar, R.J. and G.S. Rutherford (1990) "The Effects of Population Density and Income on Per Capita Transit Ridership in Western American Cities," *ITE 1991 Compendium of Technical Papers*. Institute of Transportation Engineers, Washington, D.C.

Steiner, R.L. (1994) "Residential Density and Travel Patterns: A Review of the Literature and Methodological Approach," paper presented at the 73rd Annual Meeting, Transportation Research Board, Washington, D.C.

Stone, P.A. (1973) *The Structure, Size, and Costs of Urban Settlements*. Cambridge University Press, London, Eng.

U.S. Department of Transportation (1976) *Urban Transportation and Land Use*. Washington, D.C., pp. 55–78.

Vickerman, R.W. (1974) "Accessibility, Attraction, and Potential: A Review of Some Concepts and Their Use in Determining Mobility," *Environment and Planning A* 6(6), pp. 675–691.

Voorhees, M.T. (1991) "The True Costs of the Automobile: A Basis for Comparison," *Grass Roots to Green Modes*. Proceedings of the 12th International Pedestrian Conference, Boulder, Colo., pp. 231–236.

Wachs, M. and J.G. Koenig (1979) "Behavioral Modelling, Accessibility, Mobility and Travel Need," in D.A. Hensher and P.R. Stopher (eds.), *Behavioral Travel Modeling*. Croom Helm, London, Eng., pp. 698–710.

Weibull, J.W. (1976) "An Axiomatic Approach to the Measurement of Accessibility," *Regional Science and Urban Economics* 6, pp. 357–379.

Weicher, J.C. and R.H. Zerbst (1973) "The Externalities of Neighborhood Parks: An Empirical Investigation," *Land Economics* 49, pp. 99–105.

Whyte, W.H. Jr. (1957) "Urban Sprawl" in *The Exploding Metropolis*. Doubleday & Company, Garden City, N.Y., pp. 115–139.