New and fringe residential development and emergency medical services response times in the United States

Lambert, Thomas and Meyer, Peter

IU Southeast, University of Louisville

December 2008

State and Local Government Review
Vol. 40, No. 2 (2008): 115–24

Practitioner's Corner

New and Fringe Residential Development and Emergency Medical Services Response Times in the United States

Thomas E. Lambert and Peter B. Meyer

Delayed emergency medical services (EMS) response times in remote and new suburban or exurban settlements can cost many communities much more than in terms of increased expenditures for emergency technicians and medical equipment. According to the American Red Cross (1998), response time to medical emergencies can mean the difference between life and death. For example, 4 to 6 minutes after cardiac arrest, brain damage is possible. Six to 10 minutes later, brain damage is likely, and beyond 10 minutes, irreversible brain damage is certain (American Red Cross 1998).

In the debate between antisprawl groups on one side and developers and public choice advocates on the other, issues concerning the equity, cost, and quality of public services in suburban and exurban areas compared with urban areas often arise (Atkinson and Oleson 1996; Gordon and Richardson 1997; 1998; Katz and Bradley 2000). Questions are raised as to whether the delivery of public services costs more in new and fringe areas than in urban areas and whether these services are inferior in quantity and quality, holding costs constant. The aim of this study is to determine whether there is a difference between remote suburban and exurban areas and urban areas when it comes to how quickly emergency services respond to a crisis.

According to the public choice model (Tiebout 1956), many residents choose to live in fringe areas despite the possibility of having inadequate police, firefighting, and EMS provision. The Tiebout model assumes that residential location decisions are made after all costs and benefits are weighed and that home buyers are perfectly rational (Rosen 1992, 530). Others ague that decisions often are made under conditions of bounded rationality and that consumers often have less-than-perfect information regarding their choices and purchases (Simon 1957). Home buying and residential choice also could be included under bounded rationality. Surveys show that most new homebuyers consider area schools and crime rates but do not give much thought to local public transportation, access to roads, or retail locations (Lucy 2003, 1568). Bounded rationality is not the same as irrationality. Consumers make the best decisions possible with the information available, but having

This research was partially supported by a U.S. Environmental Protection Agency Region 4 Grant. The authors thank Babak Khorrami of the Fatal Accident Reporting System, who provided data, and Dr. Eric Schansberg of Indiana University Southeast, who provided useful insights in the preparation of the manuscript.

the best possible information does not guarantee optimal outcomes. Those who have imperfect information may be unaware of the risks of living in a remote area. Knowing whether there is a significant difference between average EMS times in the two types of residential areas therefore could help consumers and policymakers make more informed decisions.

The U.S. National Highway Traffic Safety Administration's Fatal Accident Reporting System (FARS) for many years has noted longer EMS response times to fatalities in rural areas compared with urban areas. The EMS response times to fatal accidents (in which victims are found dead at a site or die within 30 days of an accident) in rural areas typically have been nearly twice those in urban areas (U.S. National Highway Traffic Safety Administration 2005). Other than a case study of the Chicago area, which found that EMS delays were the result of large-lot housing and low-population-density development (Esseks, Schmidt, and Sullivan 1999), the degree to which residential settlement patterns within various urban areas contribute to EMS delays has not been examined until recently. In a study of the metro counties in eight southeastern states, Lambert and Meyer (2006) found that sparse population density in exurban areas exacerbates EMS delays.

In this expanded analysis, models are developed similar to those used by Lambert and Meyer (2006), Felder and Brinkmann (2002), Kvalseth and Deems (1979), and Ewing, Schieber, and Zeeger (2003) to assess the impact of settlement density and age on average EMS response times.[1] Two geographical areas are examined: (1) the core metro counties of the metropolitan statistical areas or consolidated metropolitan statistical areas of 42 states for which there are data and (2) the municipalities and unincorporated areas of all the counties (not just the core counties) in these metro areas. Core counties are those that contain the urban center(s) of metro areas (i.e., cities with populations of 50,000 or more).

Methodology

Core Counties

For the first part of the analysis, 2002 FARS urban and rural average EMS run times (from the time of notification to arrival of an EMS unit to an accident site) were matched for each county according to five variables developed from the 2000 census and the 1997 and 2002 *Census of Governments* (U.S. Census Bureau 1997; 2002; U.S. National Highway Traffic Safety Administration 2002a).[2] The variables are a density index (i.e., the sum of population per square mile and the number of housing units per square mile), land area in square miles, per capita income, the number of first responders per square mile, and the median age of homes.[3] Each variable was divided according to urban and rural-nonfarm categories for each county.

Since sprawl usually is defined at least in terms of the presence of large-lot homes and sparse population density, adding population density and housing density together is an appropriate overall measure of sprawl. Also, while not probable, an area could have moderate population density but high housing-unit density, which would not be indicative of sprawled development but might suggest outward migration and decline. Land area per square mile was used to control for and approximate the coverage that an urban- or fringe-area EMS unit would have to provide.

Per capita income within an area has been used in other research as a measure of a community's ability to dedicate resources to EMS provision and the demand of citizens in an area for health, well-being, and safety as a normal good (i.e., as income goes up, the greater the demand for better health, all other things held constant). Felder and Brinkmann (2002) employed the measure as a proxy variable for the resources that can be devoted to EMS.

The number of first responders per square mile was used as an approximation of local resources devoted to EMS provision, the rationale being that there is often a lag time between when a new and remote development is completed and when certain public services such as EMS are provided. The median age of homes in an area was used to gauge the newness of an area.

At the time this study was conducted, there were no FARS data for the core counties or any of the cities or counties in the metro areas in Alaska, Indiana, Illinois, Maryland, Nebraska, New Jersey, New Mexico, or Virginia. In the states for which there were data, in some cases, average EMS response time was reported for the urban part of the county but not for fringe areas. In other cases, times were reported as an average but actually were based on a single run time. Data for these types of core counties were excluded. Average run times in this study were based on two or more observations (most but not all areas reported 100 percent of the run times for the fatal accidents). A total of 196 counties were included in the analysis, yielding a sample size of 392 because each county was dichotomized as urban or rural-nonfarm (U.S. Census Bureau 2000a; 2000b; 2000c). The metro areas included 270 metropolitan statistical areas and 10 consolidated metropolitan statistical areas as defined by the U.S. Office of Management and Budget as of June 30, 1999 (U.S. Census Bureau 2002a).

"Urban" and "rural" were conceptualized based on FARS definitions of these concepts. FARS uses the Federal Highway Administration's definition of urban, which basically follows the U.S. Census Bureau's definition of urban but "allows responsible state and local officials in cooperation with each other, and subject to approval by the Secretary of Transportation, to adjust the Census boundaries outward, as long as they encompass, at a minimum, the entire Census designated area [of urban]" (U.S. Federal Highway Administration 2003). FARS defines all other areas as rural.

The U.S. Census Bureau classifies populations and land areas as urban, rural-nonfarm, and rural-farm according to population density. An urbanized area or urban cluster "consists of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile." The classification for rural "consists of all territory, population, and housing units located outside of urbanized areas and urban clusters," which means a population density of less than 500 people per square mile (U.S. Census Bureau 2000c).

All the counties had rural as well as urban EMS run times according to FARS. Only a handful of these counties had any rural-farm land area according the U.S. Census Bureau. Such data were not used in this analysis. All counties had rural-nonfarm land, labeled fringe areas in this study. The corresponding EMS times were 6.01 minutes for the urban run times and 10.59 minutes for the fringe area run times.

A caveat regarding estimations: FARS may have classified some EMS response times as urban rather than fringe because some state and local boundaries extend beyond those of urbanized areas or urbanized clusters as defined by the U.S. Census Bureau. The fringe EMS times therefore may have been underestimated. Thus, the estimates from the model developed for this study may have been somewhat biased in favor of showing a slightly faster response time in fringe areas than what would ordinarily be the case (if census boundaries had been used, the urban EMS times probably would have been shorter).

By using the U.S. Census Bureau designations of urban and rural-nonfarm (or fringe), the built environment in two areas of each county could be matched approximately with the FARS data. The sprawl indices created by Ewing, Schieber, and Zeeger (2003) and Cutsinger et al. (2005) were not useful for this study because they give an overall measure of sprawl for an entire county or metropolitan statistical areas. The intent here was to characterize the built environment for two areas within each county since there were two measures of average EMS run time. Because the

Federal Highway Administration classifies the areas and roadways within a county as either urban or rural, there was no overall average EMS response time per county. A major reason for using the urban/rural dichotomy in FARS was that urban roadways typically have lower speed limits than their rural counterparts (even in heavily populated counties), and thus rural roadways have a higher number of fatal accidents as a proportion of all accidents (U.S. National Highway Traffic Safety Administration 2002b; 2003; 2005). Using a sprawl index would mean having to calculate an overall EMS run time for each county, which would blur the distinctions in the key differences between the urban and rural (or more precisely, fringe suburban or exurban) areas within each county.

A density index for each area within each county was used as an approximation of sprawl to assess the built environment. Additionally, the correspondence between population density figures from the U.S. Census Bureau and the sprawl index measurements compiled by Smart Growth America (McCann and Ewing 2003) for the 50 largest counties in the United States showed a correlation coefficient of 0.95, indicating that the concepts are similar. The U.S. Department of Agriculture's National Resources Inventory for metro regions was not used as a method of classification because each county was split into an urban/fringe dichotomy (providing two observations—not one—per county). Furthermore, these data do not lend themselves to application below the metro or regional level of analysis according to the U.S. Department of Agriculture (2001).

A log-log regression model was developed whereby the log of the average EMS time in each area of each county was the dependent variable (see Table 1). Scatterplots showed a better fit between the variables using a logarithmic rather than quadratic specification. A Chow test (F = 0.52) indicated that the two subsamples did not need to be split in this part of the analysis (Studenmund 1992, 174–75). Table 2 gives the descriptive statistics for these variables.

Table 1. Regression Analysis of Variations in EMS Times for Core Counties (Model 1)

Variable	Coefficient	*t*-statistic
LN density index	−0.061	(−3.569)**
LN land area	0.062	(3.175)*
LN per capita income	−0.173	(−2.775)*
LN first responder per square mile	−0.033	(−3.587)**
LN median age of home	−0.083	(−1.706)

Note: The dependent variable is the natural logarithm of average EMS response times from notification to arrival at the scene. Constant = 3.976. Adjusted R^2 = 0.518. N = 392.
$^*p < .01$ $^{**}p < .001$

Table 2. Descriptive Statistics for Core Counties

Variable	Urban areas[a]	Fringe areas[b]
EMS response time	6.01 (1.82)	10.59 (3.91)
Density index	3,131.75 (1,146.71)	98.33 (66.64)
Land area (square miles covered by EMS units)	158.91 (153.21)	1,008.86 (1,774.92)
Per capita income	$20,696.98 ($4,081.70)	$23,320.89 ($8,055.48)
First responder per square mile	2.37 (1.50)	0.11 (0.49)
Median age of homes	30.49 (9.05)	22.95 (7.03)

Note: Numbers are means. Standard deviations are in parentheses.
[a] n = 196
[b] n = 196

The six-minute period was used because this amount of time appears to be a critical threshold for EMS units to arrive at a scene, including fire emergencies (American Red Cross 1998; Davis 2004), and is the response time for all emergency services recommended by the National Fire Prevention Association (2004). A logistic regression model incorporating the same independent variables therefore was employed using a dummy variable (0 = an average run time of more than six minutes; 1 = an average run time of six minutes or less) (see Table 3).

Table 3. Regression Analysis of Variations in EMS Times for Core Counties (Model 2)

Variable	b	e^b	Wald statistic
Density index	0.000	1.000	(14.440)*
Land area	−0.003	0.997	(17.667)*
Per capita income	0.000	1.000	(0.042)
First responders per square mile	0.158	1.171	(1.885)
Median age of home	0.027	1.027	(2.717)

Note: The dependent variable is a dummy variable for average run time (0 = more than six minutes; 1 = six minutes or less).

Constant = −1.406 (*b*); 0.245 (e^b). Overall percentage correctly predicted = 78.1. Chi-square = 175.639. *N* = 392.

*$p < .001$

Cities and Unincorporated County Areas of All Metro Counties

For the next part of the study, the same variables were used in log-log regression and logistic regression models, but the units of analysis were changed. The average run times of all the cities were compared with those of the rural-nonfarm (or fringe) areas within all the metro counties (not just the core counties) for which there were FARS data. Whereas in the first part of this study, the focus was on the urban run times within the core counties (consisting of a weighted average of the municipal run times within a county), here it was on whether there were any jurisdictional effects on EMS run times and whether run times were shorter in more densely settled cities than in more sparsely settled cities (all else held constant).

Because of the strong possibility that there were small, incorporated cities in the exurban areas, a city versus noncity analysis was incorporated into the regression analysis of urban versus exurban. The total sample size was 1,092 (514 cities and 578 fringe areas) and included large cities such as Los Angeles and Houston. The descriptive statistics are shown in Table 4. A Chow test ($F = 3.69$) indicated that the data for the city and fringe areas should be split in the log-log regression model, so dummy variables were created for each area (Darnell 1994, 49–54; Studenmund 1992). The results of this model and the logistic regression model are shown in Tables 5 and 6.

Results

Table 1 shows that the variables explain approximately 51 percent of the variation in EMS run times in the core counties, with all but home age being statistically significant ($\alpha < 5$ percent). EMS run times are affected by the square-mile area that units must cover as well as the density of the built environment. Model 1 shows that there is a potential "risk" associated with fringe settlement patterns because of longer EMS run times in these areas. For every 10 percent increase in density, there is an average 0.61 percent decrease in average EMS run time; for every 10 percent increase in the land area covered, EMS run times go up by 0.62 percent on average. The logistic regression model for the core counties (Model 2) correctly predicts approximately 78 percent of the dummy EMS run time values and shows an area's density and land area to be important factors in predicting whether an average run time takes six minutes or less. When the density index increases by 1, the odds in favor of an EMS run time taking six minutes or less go up to 1.0001:1 whereas

Table 4. Descriptive Statistics for Cities and Fringe Areas

Variable	City areas[a]	Fringe areas[b]
EMS response time	5.89 (3.50)	10.97 (4.48)
Density index	4,378.26 (3,331.72)	99.13 (60.89)
Land area (square miles covered by EMS units)	48.74 (75.67)	804.09 (1,471.02)
Per capita income	$21,269.96 ($5,651.64)	$21,615.10 ($6,219.20)
First responder per square mile	4.77 (5.34)	0.12 (0.65)
Median age of homes	32.02 (13.47)	23.27 (7.69)

Note: Numbers are means. Standard deviations are in parentheses.

[a] *n* = 514

[b] *n* = 578

Table 5. Regression Analysis of Variations in EMS Times for Cities and Fringe Areas (Model 3)

Variable	Coefficient	*t*-statistic
LN city density index	−0.088	(−2.456)*
LN fringe density index	−0.027	(−0.964)
LN city land area	0.125	(5.821)***
LN fringe land area	0.086	(2.896)**
LN city per capita income	−0.165	(−2.909)**
LN fringe per capita income	−0.175	(−3.091)**
LN city first responder per square mile	−0.023	(−1.638)
LN fringe first responder per square mile	−0.040	(−3.836)***
LN median age of city home	−0.127	(−2.999)**
LN median age of fringe home	−0.200	(−3.889)***

Note: The dependent variable is the natural logarithm of average EMS response times from notification to arrival at the scene.
Constant = 4.032. Adjusted R^2 = 0.473. N = 1,092.
*p < .05 **p < .01 ***p < .001

Table 6. Regression Analysis of Variations in EMS Times for Cities and Fringe Areas (Model 4)

Variable	*b*	e^b	Wald statistic
Density index	0.000	1.000	(6.515)*
Land area	−0.006	0.994	(90.635)**
Per capita income	0.000	1.000	(0.047)
First responders per square mile	0.014	1.014	(0.145)
Median age of home	0.020	1.020	(6.194)*

Note: The dependent variable is a dummy variable for average run time (0 = more than six minutes; 1 = six minutes or less).
Constant = –0.437 (b); 0.646 (e^b). Overall percentage correctly predicted = 81.3. Chi-square = 511.373. N = 1,092.
*p < .05 **p < .001

when land area increases by a square mile, the odds decrease to 0.997:1.

The coefficients for the two subsamples indicate that all variables are statistically significant except for the density index for the fringe areas (perhaps because it is strongly and inversely correlated with the index for the city areas) and the number of first responders per square mile for the cities (Model 3). Although there was some multicollinearity among some of the independent variables, the adjusted R-square is not an inflated amount (explaining only about 47 percent of the variance), and even severe multicollinearity can be tolerated in models to avoid "specification bias" or "omitted variable bias" (Studenmund 1992, 277–88). If the subsamples are not split, the correlation coefficients are much like those for the independent variables in Model 1, which showed no signs of multicollinearity. The median age of homes in each area is statistically significant: newer homes are associated with longer EMS run times in either area (more so in the fringe areas). Greater land area and higher per capita income make a difference as well: greater land coverage is associated with longer run times and higher income is associated with shorter run times. The Model 4 results parallel those for Model 2 except that the median home age variable is significant. A one-year increase in the age of a home increases the odds in favor of the average EMS run being six minutes or less to 1.02:1.

There are several limitations to the models used in this exploratory analysis. Mobile units and standby stationary units can provide EMS (Steele 1993), and the extent of deployment can vary according to the specific resources devoted to it (e.g., number of emergency technicians for an area, expenditures on equipment and training). These factors may account for variation in response times that cannot be captured in these models. To the authors' knowledge, no national census or survey of local governments has a standardized database that would yield such data. In the case of Kentucky, the state has records of where registered and certified emergency medical technicians live but not where they work (interview with Brian Bishop, Kentucky Board of Emergency Medical Services, May 12, 2007). Moreover, jurisdictions vary in their EMS-delivery planning efforts: some use advanced GIS modeling and linear programming models whereas others rely upon rules of thumb (Steele 1993). Those that use advanced modeling consider area population and housing characteristics as well as neighborhood configurations, although residential population density is probably the most important factor (Ball and Lin 1993; Pirkul and Schilling 1988; Schilling 1982). Variations in EMS run times due to these factors are not entirely captured in the models, although the density index represents an attempt to incorporate them. According to Monosky (2003), 99 percent of EMS units surveyed by the *Journal of Emergency Medical Services* reported having either a basic or enhanced 911 system for EMS access, but it is possible that some of the areas examined in this study for which there were data did not have a 911 system.

Conclusion

As the results of this study suggest, there is a connection between the built environment and delays in EMS. Obviously, delays in EMS response times can have harmful if not fatal consequences. EMS helps the critically ill and injured and can save lives. For example, studies have shown that the decline in the murder rate since the 1960s has been partially due to better and more widespread emergency care in the United States. Improvements in emergency services from 1960 to 1999 helped lower the murder rate by 70 percent (Harris et al. 2002). By the early 1990s, the decline in the homicide rate as a result of improved EMS provision had been noted in Memphis and other communities (Giacopassi, Sparger, and Stein 1992).

From a public finance perspective, it is established in the literature that up to a certain population maximum, large economies of scale exist in the provision of public services due to the compactness of many cities. Despite having a large number of residents to serve, a city's average costs for providing police, firefighting, and sanitation go down over a densely settled geographic area (Carruthers and Ulfarsson 2003; O'Sullivan 2003, 512; Rosen 1992, 535). The regression results of this study showing that shorter EMS run times correspond to older, densely settled, urbanized areas support this assertion. Although the data come from EMS response times to traffic accidents, the response times likely would not be that different for other emergencies such as heart attack or injuries resulting from home accidents.

Some new and fringe areas with greater income and wealth levels may be spending more for emergency services on a per household basis, *ceteris paribus*, in order to compensate for the vast, sparely settled areas that need to be covered by these services. One way these areas can realize savings is to form their own fire and rescue districts. The fact that many wealthy and high-income areas have lower EMS run times is supported by the findings of Felder and Brinkmann (2002) and supports the concept of health as a normal good as put forth by Jones-Lee (1976) and Johannson (1995). Lambert and Meyer (2006) find a negative albeit statistically insignificant relationship between per capita income and average EMS response times for the metro counties of eight southeastern states.

In lieu of creating special fire and rescue districts, existing local governments could extend emergency services to fringe suburban and exurban areas, or residents in these areas could accept delays in services as a consequence of their choice about where to live. To manage residential growth, local governments could enact urban growth boundaries, impose impact fees on new development, or raise the rates on existing impact fees. These governments may want to create or factor into their existing impact fees the costs of extending more police, firefighting, and emergency services. Currently, most of these fees or taxes only consider public services such as sewers, roads, and bridges (Nelson and Moody 2003; O'Sullivan 2003, 240–41). These fees usually have flat structures based on average costs of service rather than graduated structures based on marginal costs of serving difficult areas, such as remote suburban locations or developments on hillsides. Although Gordon and Richardson (1997; 1998) doubt that urban growth boundaries and other "smart-growth" policies increase the efficiency of public expenditures with regard to infrastructure costs, they argue that if such costs of suburban and exurban living are shown to be higher than those in the central city, then impact fees are a better policy choice than the banning of suburban and exurban growth or the enactment of strict growth controls. With many local governments reluctant to increase property taxes, this approach might be a way either to pay for the extension of certain services or to manage new development.

Another alternative suggested by Katz and Bradley (2000) and Atkinson and Oleson (1996) among others is for states to allow, encourage, and enhance some type of regional planning among their counties and to create more incentives for such regional planning so as to minimize sprawl and regional fiscal and public services disparities. Such smart growth or regionalist policies see major urban cities, surrounding smaller suburban cities, and unincorporated suburban and exurban areas within a metropolitan region as interconnected entities that should have as their mutual goals more rational land-use planning, better transportation planning, more revenue sharing, higher population density, and more equitable provision of public services, which would include EMS. Under these policies, spending on roads and infrastructure would be targeted toward older urban and suburban areas, and any new residential development would have smaller lot sizes and be in closer proximity to existing infrastructure and public services. Several states have enacted legislation encouraging and promoting regional planning among different local government entities to promote these goals.

Carruthers (2002; 2003) and Carruthers and Ulfarsson (2002) point out that less regional political fragmentation and more regional planning may be promising if regional planning is done on a consistent basis. Regional planning seems to make a difference in curbing uneven residential development. Since regional planning tends to promote higher population density, it also promotes more cost efficiencies and perhaps is another method by which to remedy the disparities that exist in EMS run times.

Thomas E. Lambert *was a visiting assistant professor in the political science department at the University of Louisville in 2007–8 and has taught economics and statistics for the College of Business at the University of Louisville, the School of Business at Indiana University Southeast, and the Department of Public Administration at Kentucky State University. His research interests include the environmental and economic consequences of development and the efficiency and effectiveness of public services. His work has appeared in the* Journal of Economic Issues, Journal of Transportation Management, Economic Development Quarterly, Population Research and Policy Review, Social Science Quarterly, *and* Transportation Journal.

Peter B. Meyer *is professor emeritus of urban policy and economics and former director of the Center for Environmental Policy and Management at the University of Louisville. He is also president of The E. P. Systems Group Inc., an environment and economic planning firm. A specialist in community and local economic development and public policy evaluation, he has been engaged in brownfield redevelopment research and practice and sustainable development planning. His work has appeared in the* Journal of the American Planning Association, Journal of Economic Issues, *and* Economic Development Quarterly, *among other publications.*

Notes

1. Although Ewing, Schieber, and Zeeger (2003) predicted fatal crashes per capita in metro counties rather than EMS times, some of the independent variables in their models are useful for conceptualizing the built environment of a geographic area.
2. The averages are calculated for an entire year and for accidents that occur at all times of day and night, thereby controlling for variations in weather and traffic congestion. Although there are more total fatalities per year in urban areas than in fringe areas,

on a per capita basis, fatalities are much higher in exurban and fringe areas than in urban areas (Ewing, Schieber, and Zeeger 2003; Lambert and Meyer 2006). Thus, given the per capita rate of fatalities, it could be argued that EMS units in fringe areas should be as prepared as urban EMS units.

3. The *Census of Governments* (U.S. Census Bureau 1997; 2002) classifies EMS personnel along with firefighters as being municipal- and county-level employees. These personnel are not listed separately, and volunteer personnel are not included. According to Monosky (2003, 50), about 97 percent of emergency services are provided by fire departments. Hospitals per county according to the U.S. Census Bureau's *County Business Patterns* (2002b) could be used as a proxy for EMS resources to determine countywide EMS run times. However, because each county is divided into two parts (i.e., urban and fringe areas) and numbers of hospitals and personnel are available at the county level only in the aggregate, these data are not useful. Likewise, *County Business Patterns* does not give hospital data for municipalities and the unincorporated parts of counties.

References

American Red Cross. 1998. *Community CPR*. St. Louis: Mosby Lifeline.

Atkinson, Glen, and Ted Oleson. 1996. Urban sprawl as a path dependent process. *Journal of Economic Issues* 30:609–14.

Ball, Michael O., and Feng L. Lin. 1993. A reliability model applied to emergency service vehicle location. *Operations Research* 41:18–36.

Carruthers, John I. 2002. The impacts of state growth management programs: A comparative analysis. *Urban Studies* 39:1959–82.

————. 2003. Growth at the fringe: The influence of political fragmentation in United States metropolitan areas. *Papers in Regional Science* 82:475–99.

Carruthers, John I., and Gudmundur F. Ulfarsson. 2003. Urban sprawl and the cost of public services. *Environment & Planning B: Planning & Design* 30:503–22.

Cutsinger, Jackie, George Galster, Harold Wolman, Royce Hanson, and Douglas Towns. 2005. Verifying the multi-dimensional nature of metropolitan land use: Advancing the understanding and measurement of sprawl. *Journal of Urban Affairs* 27:235–59.

Darnell, Adrian C. 1994. *A dictionary of econometrics*. Aldershot, England: E. Elgar.

Davis, Robert. 2004. Six minutes to live or die. *USA Today*, February 24, A1. www.usatoday.com/news/nation/ems-day1-dc.htm. Accessed February 7, 2008.

Esseks, J. Dixon, Harvey E. Schmidt, and Kimberly L. Sullivan. 1999. *Fiscal costs and public safety risks of low-density residential development on farmland: Findings from three diverse locations on the urban fringe of the Chicago metro area*. American Farmland Trust, Center for Agriculture in the Environment Working Paper 98-1. www.farmlandinfo.org/documents/29027/wp98-1.pdf. Accessed July 8, 2008.

Ewing, Reid, Richard A. Schieber, and Charles V. Zeeger. 2003. Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. *American Journal of Public Health* 93:1541–45.

Felder, Stefan, and Henrik Brinkmann. 2002. Spatial allocation of emergency medical services: Minimizing the death rate or providing equal access? *Regional Science and Urban Economics* 32:27–45.

Giacopassi, David J., Jerry R. Sparger, and Preston M. Stein. 1992. The effects of emergency medical care on the homicide rate: Some additional evidence. *Journal of Criminal Justice* 20:249–52.

Gordon, Peter, and Harry W. Richardson. 1997. Are compact cities a desirable planning goal? *Journal of the American Planning Association* 63:95–106.

————. 1998. Prove it: The costs and benefits of sprawl. *Brookings Review* (fall): 23–26.

Harris, Anthony, Stephen H. Thomas, Gene A. Fisher, and David J. Hirsch. 2002. Murder and medicine: The lethality of criminal assault 1960–1999. *Homicide Studies* 6:128–66.

Johannson, Per Olav. 1995. *Evaluating health risks: An economic approach*. Cambridge: Cambridge University Press.

Jones-Lee, Michael Whittaker. 1976. *The value of life: An economic analysis*. Chicago: University of Chicago Press.

Katz, Bruce, and Jennifer Bradley. 2000. Divided we sprawl. *Atlantic Monthly* (July): 24. www.brookings.edu/articles/1999/12metropolitanpolicy_katz.aspx. Accessed February 7, 2008.

Kvalseth, Tarald O., and John M. Deems. 1979. Statistical models of the demand for emergency medical services in an urban area. *American Journal of Public Health* 69:250–55.

Lambert, Thomas E., and Peter B. Meyer. 2006. Exurban sprawl as a factor in traffic fatalities and EMS response times in the southeastern United States. *Journal of Economic Issues* 40:941–53.

Lucy, William H. 2003. Mortality risk associated with leaving home: Recognizing the relevance of the built environment. *American Journal of Public Health* 93:1564–69.

McCann, Barbara A., and Reid Ewing. 2003. *Measuring the health effects of sprawl*. Washington, DC: Smart Growth America. www.smartgrowthamerica.org/report/HealthSprawl8.03.pdf. Accessed February 7, 2008.

Monosky, Keith A. 2003. 200 city survey, 2002. *Journal of Emergency Medical Services* (February). www.jems.com/resources/surveys. Accessed February 7, 2008.

National Fire Prevention Association. 2004. *NFPA 450: Guide for emergency medical services and systems*. Quincy, MA: NFPA.

Nelson, Arthur C., and Mitch Moody. 2003. *Paying for prosperity: Impact fees and job growth*. Washington, DC: Brookings Institution Center on Urban and Metropolitan Policy. www.brookings.edu/es/urban. Accessed February 7, 2008.

O'Sullivan, Arthur. 2003. *Urban economics*. 5th ed. New York: McGraw-Hill.

Pirkul, Hasan, and David A. Schilling. 1988. The siting of emergency service facilities with workload capacities and backup service. *Management Science* 34:896–908.

Rosen, Harvey. 1992. *Public finance*. 3rd ed. Boston: Irwin Publishers.

Schilling, David A. 1982. Strategic facility planning: The analysis of options. *Decision Sciences* 13:1–14.

Simon, Herbert. 1957. A behavioral model of rational choice. In *Models of man, social and rational: Mathematical essays on rational human behavior in a social setting*. New York: Wiley.

Steele, Susi B. 1993. *Emergency dispatching: A medical communicator's guide*. Englewood Cliffs, NJ: Prentice Hall.

Studenmund, A. H. 1992. *Using econometrics: A practical guide*. 2nd ed. New York: Harper-Collins.

Tiebout, C. M. 1956. A pure theory of local expenditure. *Journal of Political Economy* 64:416–24.

U.S. Census Bureau. 1997. 2002. *Census of governments*. www.census.gov/govs/www/index.html. Accessed February 7, 2008.

————. 2000a. *Census of population and housing*. factfinder.census.gov/home/saff/main.html?_lang=en. Accessed February 7, 2008.

————. 2000b. *County and city data book: 2000*. www.census.gov/statab/www/ccdb.html. Accessed February 7, 2008.

————. 2000c. *Census 2000 urban and rural classification.* www.census.gov/geo/www/ua/ua_2k.html. Accessed February 7, 2008.

————. 2002a. *Metropolitan areas and components, 1999.* www.census.gov/population/estimates/metrocity/99 mfips.txt. Accessed February 7, 2008.

————. 2002b. *County business patterns, 2002.* www.census.gov/epcd/cbp/view/intro.html. Accessed February 7, 2008.

U.S. Department of Agriculture. 2001. *National resources inventory technical resources, 2001.* www.nrcs.usda.gov/technical/land/nri01/nri01dev.html. Accessed February 7, 2008.

U.S. Federal Highway Administration. 2003. Frequently asked questions: Applying 2000 census data to urbanized and urban areas. www.fhwa.dot.gov/planning/census/faqa2cdt.htm. Accessed February 7, 2008.

U.S. National Highway Traffic Safety Administration. 2002a. Fatal accident reporting system. Data from Web site sent electronically via e-mail from www-fars.nhtsa.dot.gov on April 2004.

————. 2002b. *Traffic safety facts 2002: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system (early edition).* Washington, DC: U.S. Government Printing Office. www-nrd.nhtsa.dot.gov/Pubs/TSF2002.PDF. Accessed February 7, 2008.

————. 2003. *Traffic safety facts 2001: Rural/urban comparison*. www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2001/2001rural.pdf. Accessed February 7, 2008

————. 2005. *Traffic safety facts 2005: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system.* Washington, DC: U.S. Government Printing Office. www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFANN/TSF2005.pdf. Accessed February 7, 2008.