Urban Sprawl and Public Health

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When regular steam ferry service between Brooklyn and Manhattan began in 1814, the first commuter suburb became possible.[1] Suburbs continued to develop slowly but steadily during the 19th and early 20th centuries, thanks to transportation advances such as commuter trains and streetcars, the innovations of early real estate developers, and the urge to live in pastoral tranquility rather than in urban squalor. As automobile ownership became widespread starting in the 1920s, suburban growth continued, a trend that accelerated greatly during the second half of the 20th century. One in two Americans now lives in the suburbs.[2]

In recent years, the rapid expansion of metropolitan areas has been termed "urban sprawl"—referring to a complex pattern of land use, transportation, and social and economic development. As cities extend into rural areas, large tracts of land are developed in a "leapfrog," low-density pattern. Different land uses—housing, retail stores, offices, industry, recreational facilities, and public spaces such as parks—are kept separate from each other, with the separation enforced by both custom and zoning laws. Extensive roads need to be constructed; for suburban dwellers, most trips, even to buy a newspaper or a quart of milk, require driving a car. Newly built suburbs are relatively homogeneous in both human and architectural terms, compared with the diversity found in traditional urban or small town settings. With the expansion of suburbs, capital investment and economic opportunity shift from the center to the periphery. Regional planning and coordination are relatively weak.[1,3–7]

Clearly, the move to the suburbs reflects a lifestyle preference shared by many Americans. Such a major shift in the nation's de-

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mographics and in the form of our environment might also be expected to have health implications, both positive and negative. Some of these effects relate directly to heavy reliance on automobiles: air pollution, automobile crashes, and pedestrian injuries and fatalities. Other effects relate to land use patterns that typify sprawl: sedentary lifestyles, threats to water quantity and quality, and an expansion of the urban heat island effect. Finally, some mental health and social capital effects are mediated by the social dimensions of sprawl. Many of these health effects are individually recognized as environmental health issues, and certain aspects of sprawl, such as reliance on automobiles, have been analyzed as public health issues.[8,9] Yet the broad phenomenon of sprawl, a complex of issues related to land use, transportation, urban and regional design, and planning, has been the intellectual "property" of engineers and planners. Public health professionals have provided neither an intellectual framework nor policy guidance. This is a striking departure from the legacy of the 19th and early 20th centuries, when public health and urban design were overlapping and largely indistinguishable concerns.[10–12]

This article offers a public health framework for understanding the consequences of urban sprawl. For each of the health outcomes noted earlier, available evidence about the health effect and its connection with sprawl is presented, and issues that require further research are identified. Because the adverse impacts of sprawl do not fall equally across the population, the distribution of health impacts across the population and resulting equity concerns are addressed. Finally, some solutions are discussed.

DIRECT EFFECTS OF RELIANCE ON AUTOMOBILES

One of the cardinal features of sprawl is driving, reflecting a well-established, close relationship between lower density development and more automobile travel.[4,13–16] For example, in the Atlanta metropolitan area, one of the nation's leading examples of urban sprawl, the average person travels 34.1 miles in a car each day—an average that includes the entire population, both drivers and non-drivers.[17] More densely populated metropolitan areas have far lower per capita daily driving figures than Atlanta, e.g., 16.9 miles for Philadelphia, 19.9 for Chicago, and 21.2 for San Francisco.[17] On a neighborhood scale, the same pattern is observed. In the Los Angeles, San Francisco, and Chicago metropolitan areas, vehicle miles traveled increase as neighborhood density decreases (see Figure 1).[18]

Automobile use offers extraordinary personal mobility and independence. However, it is also associated with health hazards, including air pollution, motor vehicle crashes, and pedestrian injuries and fatalities.

Air pollution

Motor vehicles are a leading source of air pollution.[20] Even though automobile and truck engines have become far cleaner in recent decades, the sheer quantity of vehicle miles driven results in large releases of carbon monoxide, carbon dioxide, particulate matter, nitrogen oxides, and hydrocarbons into the air.[21] Nitrogen oxides and hydrocarbons, in the presence of sunlight, form ozone.

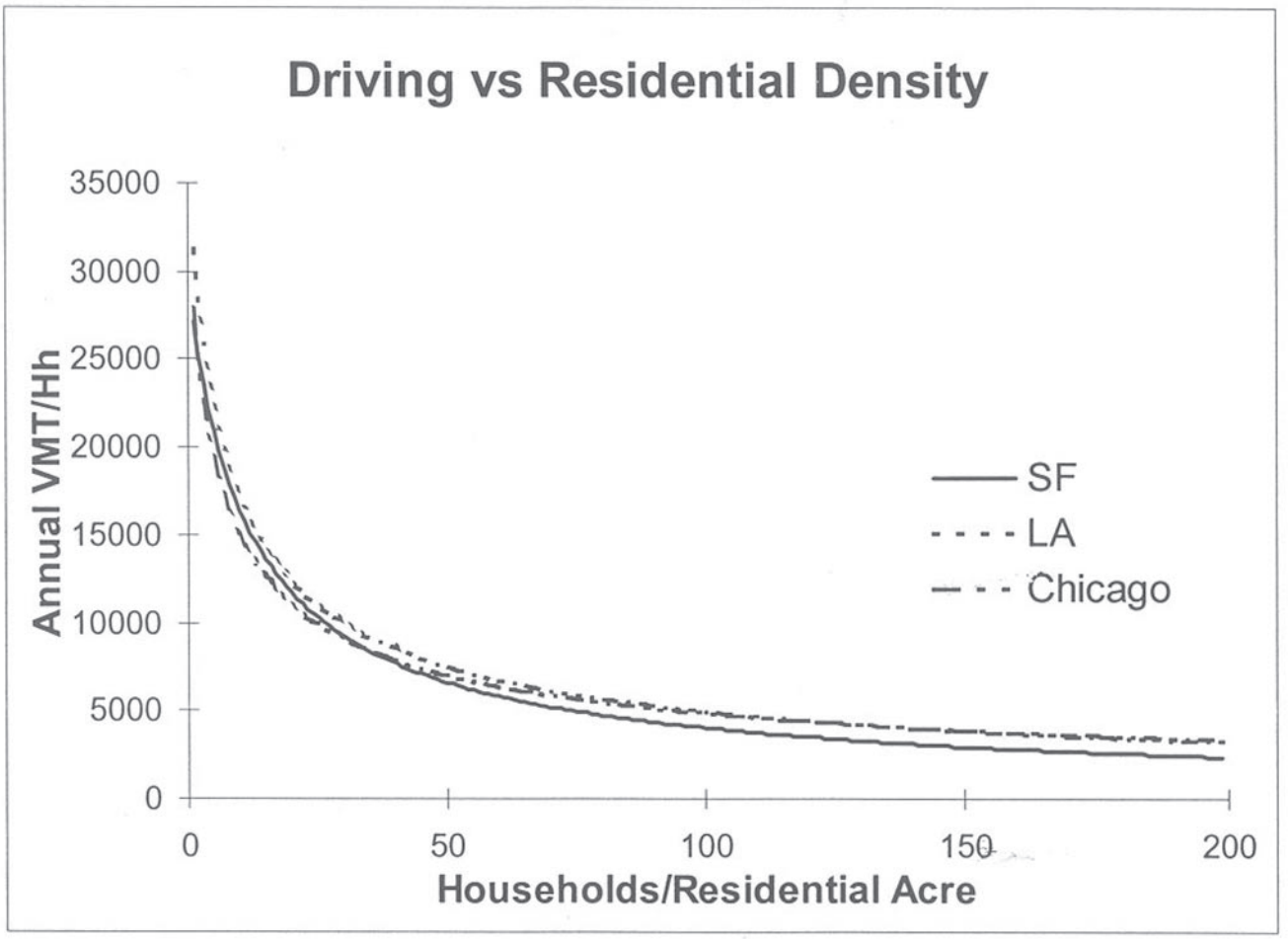
Nationwide, "mobile sources" (mostly cars and trucks) account for approximately 30% of emissions of oxides of nitrogen and 30% of hydrocarbon emissions.[22] However, in automobile-dependent metropolitan areas, the proportion may be substantially higher. In the 10-county metropolitan Atlanta area, for example, on-road cars and trucks account for 58% of emissions of nitrogen oxides and 47% of hydrocarbon emissions, figures that underestimate the full impact of vehicle traffic because they exclude emissions from related sources, such as fuel storage facilities and filling stations.[23]

In various combinations, the pollutants that originate from cars and trucks, especially nitrogen oxides, hydrocarbons, ozone, and particulate matter, account for a substantial part of the air pollution burden of American cities. Of note, the highest air pollution levels in a metropolitan area may occur not at the point of formation but downwind, due to regional transport. Thus, air pollution is a problem not only alongside roadways (or in close proximity to other sources) but also on the scale of entire regions.

The health hazards of air pollution are well known.[24] Ozone is an airways irritant. Higher ozone levels are associated with higher incidence and severity of respiratory symptoms, worse lung function, more emergency room visits and hospitalizations, more medication use, and more absenteeism from school and work.[24] Although healthy people may demonstrate these effects, people with asthma and other respiratory diseases are especially susceptible. Particulate matter is associated with many of the same respiratory effects and, in addition, with elevated mortality.[25–27] People who are especially susceptible to the effects of air pollution include the elderly, the very young, and those with underlying cardiopulmonary disease.

An additional driving-related emission is carbon dioxide, the end product of burning fossil fuels such as gasoline. Carbon dioxide is the major greenhouse gas, accounting for approximately 80% of emissions

Figure 1. Annual vehicle miles traveled per household, by neighborhood residential density



SOURCE: Reference 18.

with global warming potential.[28] Motor vehicles are also a major source of other greenhouse gases, including methane, nitrogen oxides, and volatile organic compounds. As a result, automobile traffic is a major contributor to global climate change, accounting for approximately 26% of U.S. greenhouse gas emissions.[28] During the decade of the 1990s, greenhouse gases from mobile sources increased 18%, primarily a reflection of more vehicle miles traveled.[28] In turn, global climate change threatens human health in a number of ways, including the direct effects of heat, enhanced formation of some air pollutants, and increased prevalence of some infectious diseases.[29–32]

Thus, the link between sprawl and respiratory health is as follows: Sprawl is associated with high levels of driving, driving contributes to air pollution, and air pollution causes morbidity and mortality. In heavily automobile-dependent cities, air pollution can rise to hazardous levels, and driving can account for a majority of the emissions. Although ongoing research is exploring the pathophysiology of air pollution exposure and related issues, there are also important research questions that revolve around prevention. Technical issues include such challenges as the development of low-emission vehicles and other clean technologies. Policy research needs to identify approaches to land use and transportation that would reduce the need for motor vehicle travel. Behavioral research needs to identify factors that motivate people to choose less-polluting travel behaviors, such as walking, carpooling, or use of more efficient vehicles.

Motor vehicle crashes

Automobiles now claim more than 40,000 lives each year in the United States, a number that has slowly declined from about 50,000 per year in the 1960s.[33]

Rates of automobile fatalities and injuries per driver and per mile driven have fallen thanks to safer cars and roads, seat belt use, laws that discourage drunk driving, and other measures, but the absolute toll of automobile crashes remains high. Automobile crashes are the leading cause of death among people 1–24 years old, account for 3.4 million nonfatal injuries annually, and cost an estimated $200 billion annually.[34]

The relationship between sprawl and motor vehicle crashes is complex. At the simplest level, more driving means greater exposure to the dangers of the road, translating to a higher probability of a motor vehicle crash.[35] Suburban roads may be a particular hazard, especially major commercial thoroughfares and "feeder" roads that combine high speed, high traffic volume, and frequent "curb cuts" for drivers to use in entering and exiting stores and other destinations.[36] However, available data from the National Highway Traffic Safety Administration (NHTSA) show fatal crashes aggregated into only two categories of roads: urban (accounting for approximately 60% of fatalities) and rural (approximately 40%).[33]

The NHTSA data do permit comparison of automobile fatality rates by city.[33] In general, denser cities with more extensive public transportation systems have lower automobile fatality rates (including drivers and passengers, but excluding pedestrians) than more sprawling cities: 2.45 per 100,000 population in San Francisco, 2.30 in New York, 3.21 in Portland, 6.67 in Chicago, and 5.26 in Philadelphia, compared with 10.08 in Houston, 16.15 in Tampa, 12.72 in Atlanta, 11.35 in Dallas, and 9.85 in Phoenix.[33] (There are notable exceptions to this pattern, such as 5.79 per 100,000 population in Los Angeles and 10.93 per 100,000 in Detroit.[33])

According to the American College of Emergency Physicians, "Traffic crashes are predictable and preventable, and therefore are not 'accidents.'"[37] In fact, the determinants of motor vehicle injuries and fatalities are well recognized. For some of these, public health interventions, from seat belts to traffic signals, have achieved dramatic reductions in injury and fatality rates in the three-quarters of a century since automobile use became widespread. A relatively overlooked risk factor, however, is the simple fact of driving and the number of miles driven. Primary prevention would consist of decreasing exposure, an approach that is currently impractical in many metropolitan areas.

Pedestrian injuries and fatalities

On December 14, 1995, 17-year-old Cynthia Wiggins rode the public bus to her job at the Walden Galleria in suburban Cheektowaga, New York, outside of Buffalo. The bus did not stop at the mall itself, so Cynthia had to cross a seven-lane highway on foot to complete her trip to work. On that day, she had made it across six lanes when a dump truck crushed her.[38] Her death received national media attention; it was seen as exemplifying inadequate mass transportation links, pedestrian-hostile roadways, and the disproportionate impact of these factors on members of minority groups.

Each year, automobiles cause about 6,000 fatalities and 110,000 injuries among pedestrians nationwide. Pedestrians account for about one in eight automobile-related fatalities.[39,40] Data from Atlanta show that as the city sprawled in recent years, the pedestrian fatality rate increased even as the national rate declined slightly.[41] The most dangerous stretches of road were those built in the style that typifies sprawl: multiple lanes, high speeds, no sidewalks, long distances between intersections or crosswalks, and roadways lined with large commercial establishments and apartments blocks.[41] Across the country, the pattern seen for driver and passenger fatalities is repeated for pedestrian fatalities, with lower annual rates in denser cities: 1.89 per 100,000 population in Portland, 2.22 in New York, 2.52 in Chicago, and 2.57 in Philadelphia, compared with 3.03 in Dallas, 3.61 in Atlanta, 4.08 in Phoenix, and 6.60 in Tampa. However, this pattern is not as consistent as for driver and passenger fatalities, and there are exceptions, e.g., 2.60 per 100,000 population in Los Angeles, 2.61 in Houston, 3.86 in San Francisco, and 4.73 per 100,000 in Detroit.[33]

While many factors contribute to the high toll of pedestrian fatalities, including alcohol abuse, inadequate lighting, and pedestrian behavior, the proliferation of high-speed, pedestrian-hostile roads in expanding metropolitan areas likely plays an important part. Walking offers important public health benefits, but safe and attractive sidewalks and footpaths are needed to attract walkers and assure their safety. Much of the knowledge needed to make progress is available, but further research might help clarify the best and most cost-efficient ways to build walkways and the most successful approaches to zoning, financing, and other incentives.

EFFECTS OF LAND USE DECISIONS

Land use and travel patterns are closely linked. If distinct land uses are separated, if the distances between them are great, and if roads are more available than sidewalks and paths, then people shift from walking and bicycling to driving. Accordingly, the U.S. is a nation of drivers, in which only 1% of trips are on bicycles and 9% are on foot.[42] For comparison, in the

Netherlands 30% of all trips are on bicycles and 18% are on foot, and in England the corresponding figures are 8% and 12%.[42] Approximately 25% of all trips in the U.S. are shorter than one mile; of these, 75% are by car.[43]

Physical activity

A considerable body of research establishes that sprawl—as measured by low residential density, low employment density, low "connectivity," and other indicators—is associated with less walking and bicycling and with more automobile travel than denser communities.[13,44–48]

Low levels of physical activity threaten health both directly and indirectly. A sedentary lifestyle is a well-established risk factor for cardiovascular disease, stroke, and all-cause mortality,[49–53] whereas physical activity prolongs life.[54,55] Men in the lowest quintile of physical fitness have two to three times the risk of dying overall, and three to five times the risk of dying of cardiovascular disease, compared with men who are more fit.[56] Among women, walking 10 blocks per day or more is associated with a 33% lower risk of cardiovascular disease.[57] The risk associated with poor physical fitness is comparable to, and in some studies greater than, the risk associated with hypertension, high cholesterol, diabetes, and even smoking.[56,58] Among diabetic patients, the higher the blood sugar, the more protective is physical fitness.[59] Physical activity also appears to be protective against cancer.[60–63]

In addition to its direct effects on health, lack of physical activity is also a risk factor for being overweight. Sedentary lifestyles may help explain the rapid increase in the prevalence of overweight in recent years. In 1960, 24% of Americans were overweight (defined as a Body Mass Index $\geq$25 kg/m^2), and by 1990 that proportion had increased to 33%.[64] During the same interval, the prevalence of obesity (defined as a Body Mass Index $\geq$30 kg/m^2) nearly doubled.[65] According to data from the Behavioral Risk Factor Surveillance System, this trend continued during the 1990s, with the prevalence of obesity rising from 12.0% in 1991 to 17.9% in 1998.[66,67]

Being overweight is itself a well-established risk factor for a number of diseases: ischemic heart disease (overweight increases the risk up to fourfold in the 30–44 age group, less at older ages[68]), hypertension, stroke, dyslipidemia, osteoarthritis, gall bladder disease, and some cancers. Overweight people die at as much as 2.5 times the rate of non-obese people.[51,68–71] Being overweight increases the risk of Type 2 diabetes up to fivefold, and the current epidemic of Type 2 diabetes tracks closely with the increase in being overweight.[72]

Sprawl does not fully account for Americans' increasingly sedentary lives, and physical inactivity does not tell the entire story of the national epidemic of being overweight. However, by contributing to physical inactivity and therefore to overweight and associated health problems, sprawl has negative health consequences. Further research will help provide a more complete understanding of the association between sprawl and physical inactivity.[73] In theory, a randomized trial might assign some people to live in walkable neighborhoods and others to live in subdivisions without sidewalks or nearby schools, stores, or workplaces. Then, the two groups might be followed for physical activity patterns and related health outcomes. Such residential randomization is, of course, impossible. Observational studies are underway to characterize the relationships among land use, travel patterns, and physical activity.[74] However, such research is challenging. People living in walkable neighborhoods may have chosen to live there because of better health and a greater inclination to walk. Because children do not choose their neighborhoods, an alternative might be to study adult physical activity and travel patterns according to the type of neighborhood of origin to test the hypothesis that childhood access to walkable neighborhoods predicts lifelong travel preferences and activity patterns. Research is also needed on design issues (how to build more walkable communities), policy issues (how to put incentives in place to encourage needed environmental and behavioral changes), and behavior issues (how to motivate more physical activity, including walking).

Water quantity and quality

Americans take for granted the availability of clean, plentiful, and cheap water. Indeed, the development of an excellent water supply—the result of social policy, civil engineering, and health advocacy over more than a century—is credited with a central role in improving public health during the first half of the 20th century.[12,75]

Sprawl may threaten both the quantity and quality of the water supply. As forest cover is cleared and impervious surfaces built over large areas, rainfall is less effectively absorbed and returned to groundwater aquifers.[76] Instead, relatively more stormwater flows to streams and rivers and is carried downstream. One study found that about 4% of rainfall on undeveloped grassland, compared with 15% of rainfall on suburban land, was lost as runoff.[77] The same is true for snowmelt, especially early in the melting process.[78] Modeling shows that higher density development patterns can reduce peak flows and total runoff volumes.[79] With less groundwater recharge, communities that depend

on groundwater for their drinking water—about one-third of U.S. communities[80]—may face shortages.

Water quality may be affected in several ways. With better control of "point sources" of water pollution—factories, sewage treatment plants, and similar facilities—"non–point source" water pollution has emerged as the major threat to water supplies. Non–point source water pollution occurs when rainfall or snowmelt moves over and through the ground, picking up contaminants and depositing them into surface water (lakes, rivers, wetlands, and coastal waters) and groundwater. Much of this problem is specific to agricultural land, the primary source of contamination by fertilizers, herbicides, and insecticides. However, growing forms of non–point source pollution include oil, grease, and toxic chemicals from roadways, parking lots, and other surfaces, and sediment from improperly managed construction sites, other areas from which foliage has been cleared, or eroding stream banks. Studies of the movement of polycyclic aromatic hydrocarbons,[81] zinc,[82] and organic waste[83] suggest that suburban development is associated with high loading of these contaminants in nearby surface water.

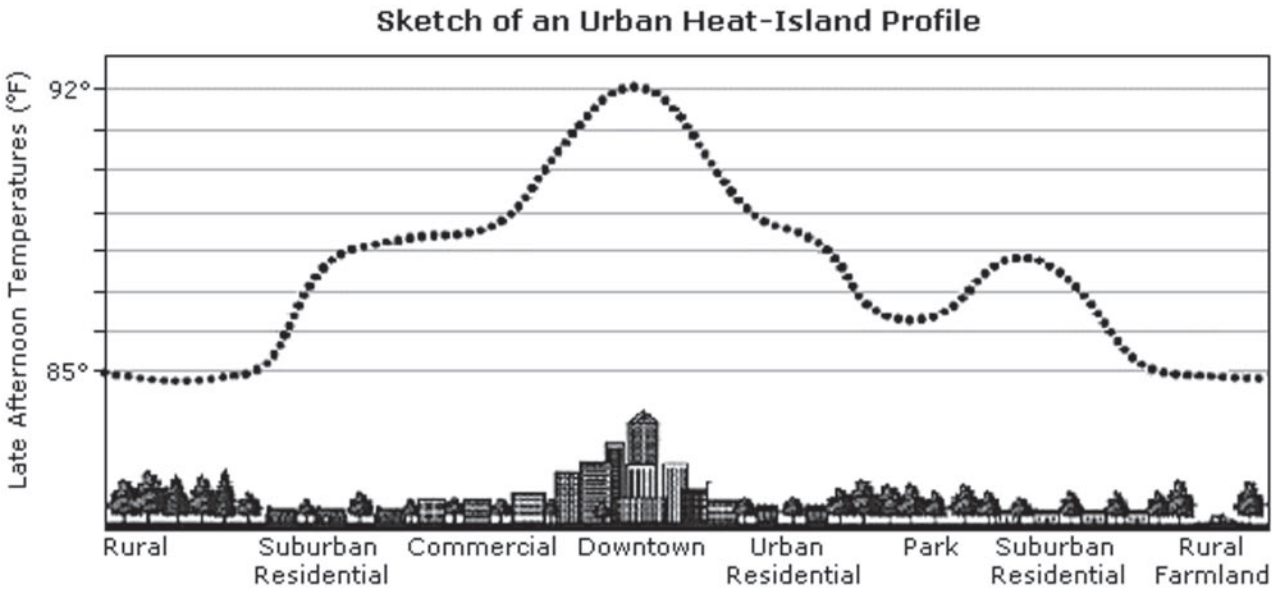
Both water quantity and water quality are directly affected by land use and development patterns, and evidence suggests that sprawl contributes to these problems in specific ways. Further evidence is needed to identify the precise features of land use that best predict non–point source pollution, the impact of this pollution on drinking water quality, and the optimal control methods.

The heat island effect

On warm days, urban areas can be 6°–8° F warmer than surrounding areas, an effect known as an urban heat island (see Figure 2). The heat island effect is caused by two factors. First, dark surfaces such as roadways and rooftops efficiently absorb heat from sunlight and reradiate it as thermal infrared radiation; these surfaces can reach temperatures of 50°–70° F higher than surrounding air. Second, urban areas are relatively devoid of vegetation, especially trees, that would provide shade and cool the air through "evapotranspiration." As cities sprawl outward, the heat island effect expands, both in geographic extent and in intensity. This is especially true if the pattern of development features extensive tree cutting and road construction.[84,85] NASA satellite imagery, available for public viewing on the Web, documents the heat island effect for several cities.[86]

Metropolitan expansion involves a positive feedback loop that may aggravate the heat island effect. Sprawling metropolitan areas, with greater travel distances, generate a large amount of automobile travel. This, in turn, results in more fuel combustion, with more production of carbon dioxide, and consequent contributions to global climate change.[87] Global climate change, in turn, may intensify the heat island effect in metro-

Figure 2. An urban heat island profile



SOURCE: Reference 93.

politan areas. Thus, not only does the morphology of metropolitan areas contribute to warming, but so may the greenhouse gas production that results from increased driving.

The magnitude of the contribution of sprawl to urban heat episodes is unclear. Data from the last half century show a clear increasing trend in extreme heat events in U.S. cities.[88] While global warming may contribute to this trend, the rate of the increase far exceeds the rate of global warming, suggesting that urban growth patterns may be a primary determinant.[89] Further research on this phenomenon is required.

Heat is of concern because it is a health hazard.[90] Relatively benign disorders include heat syncope, or fainting; heat edema, or swelling, usually of dependent parts such as the legs; and heat tetany, a result of heat-induced hyperventilation. Heat cramps are painful muscle spasms that occur after strenuous exertion in a hot environment. Heat exhaustion is a more severe acute illness that may feature nausea, vomiting, weakness, and mental status changes. The most serious of the acute heat-related conditions is heat stroke, which represents the body's failure to dissipate heat. The core body temperature may exceed 104°F, muscle breakdown occurs, and renal failure and other profound physiologic derangements may follow. The fatality rate is high.

There are several well-known risk factors for developing heat stroke or dying during a heat wave, including being elderly, bedridden, homebound, or socially isolated, having certain diseases or using certain medications, and living on an upper floor.[91,92] Poverty and minority race or ethnicity are also risk markers.[93]

Heat also has indirect effects on health, mediated through air pollution. As the temperature rises, so does the demand for energy to power air conditioners, requiring power plants to increase their output. The majority of U.S. power plants burn fossil fuels, so increased summer demand results in higher emissions of the pollutants they generate, including carbon dioxide, particulate matter, sulfur oxides, nitrogen oxides, and air toxics. Ozone formation from its precursors, nitrogen oxides and hydrocarbons, is enhanced by heat. In summary, through both the direct and indirect effects of heat, sprawl has potential adverse health consequences.

SOCIAL ASPECTS OF SPRAWL

Mental health

One of the original motivations for migration to the suburbs was access to nature.[1] People like trees, birds, and flowers, and these are more accessible in the suburbs than in denser urban areas. Moreover, contact with nature may offer benefits beyond the purely aesthetic; it may benefit both mental health and physical health.[94] In addition, the sense of escaping from the turmoil of urban life to the suburbs, the feeling of peaceful refuge, may be soothing and restorative to some people. In these respects, there may be health benefits to suburban lifestyles.

On the other hand, certain aspects of sprawl, such as commuting, may exact a mental health toll. For some time, automobile commuting has been of interest to psychologists as a source of stress, stress-related health problems, and even physical ailments. Evidence links commuting to back pain, cardiovascular disease, and self-reported stress.[95] As people spend more time on more crowded roads, an increase in these health outcomes might be expected.

One possible indicator of such problems is road rage, defined as "events in which an angry or impatient driver tries to kill or injure another driver after a traffic dispute."[96] Even lawmakers may be involved; one press account described a prominent attorney and former Maryland state legislator who knocked the glasses off a pregnant woman after she had the temerity to ask him why he had bumped her Jeep with his.[97]

Available data do not make clear whether road rage is on the rise. The only longitudinal study available in the U.S., published by the AAA Foundation for Traffic Safety in 1997, reported a 51% increase in reported annual incidents of road rage during the interval from 1990 to 1996.[98] The Foundation documented 10,000 reports of such incidents, resulting in 12,610 injuries and 218 deaths. A variety of weapons was used, including guns, knives, clubs, fists, or feet, and in many cases the vehicle itself. However, since the data sources included police reports and newspaper accounts, it is possible that the apparent increase reflected growing public awareness and media attention rather than a true increase in the number or rate of road rage incidents.

Road rage is not well understood, and there is a multiplicity of reasons for its occurrence. Stress at home or work may combine with stress while driving to elicit anger.[99,100] Data from Australia[101] and Europe[102] suggest that both traffic volume and travel distance are risk factors. Long delays on crowded roads are likely to be a contributing factor.

Episodes of road rage may reflect a reservoir of frustration and anger on the roads. In national telephone surveys conducted by Mississippi State University in 1999 and 2001,[103,104] large numbers of respondents reported both engaging in aggressive behaviors while driving and being the objects of such behavior

(see Table). The surveys did not identify respondents who lived in suburban locations, although the responses differed in several respects across the geographic categories used (rural, small town, small city, and large city), suggesting an influence of density and other "built environment" factors on aggressive driving behavior. A similar survey, conducted for NHTSA in 1998, found somewhat lower but comparable numbers.[105] In the NHTSA survey, the two leading reasons cited for aggressive driving were (*a*) being rushed or being behind schedule (23% of respondents), and (*b*) increased traffic or congestion (22%)—common experiences on the crowded roadways of sprawling cities. Moreover, 30% of the NHTSA respondents perceived that aggressive driving—their own and others'—was increasing over time, and only 4% thought it was decreasing. More recently, Curbow and Griffin[106] surveyed 218 women employed by a telecommunications company. This was a stable, professional population; 67% of the respondents had more than a high school education, 76% were parents, and the average job seniority was 18 years. Among these women, 56% reported driving aggressively, 41% reported yelling or gesturing at other drivers while commuting, and 25% reported taking out their frustrations from behind the wheel of their cars. Aggressive driving behavior appears to be a widespread problem.

It seems reasonable to hypothesize that anger and frustration among drivers are not restricted to their cars. When angry people arrive at work or at home, what are the implications for work and family relations? If the phenomenon known as commuting stress affects well-being and social relationships both on the roads and off, and if this set of problems is aggravated by increasingly long and difficult commutes on crowded roads, then sprawl may in this manner threaten mental health.

Social capital

Since World War II, social commentators have ascribed to suburban living a sense of social isolation and loneliness,[107–114] although some of these claims have re-

Table. Prevalence of self-reported driving behaviors, 1999 and 2000 National Highway Safety Surveys

	Percent of respondents by response choice			
How often do you . . . (1999)	*Never*	*Rarely*	*Sometimes*	*Often*
Say bad things to yourself about other drivers	15.3	22.9	39.5	22.1
Complain or yell about other drivers to a passenger in your vehicle	25.5	22.2	39.0	13.1
Give another driver a dirty look	41.8	17.6	32.7	7.7
Honk or yell at someone through the window to express displeasure	61.1	17.9	17.9	2.9
Keep someone from entering your lane because you are angry	80.2	12.9	5.9	0.8
Make obscene gestures to another driver	83.7	9.2	6.1	0.8
Think about physically hurting another driver	89.0	5.4	4.4	1.1
Make sudden or threatening moves to intimidate another driver	94.6	4.0	1.1	0.1
Follow or chase another driver in anger	96.5	3.2	0.3	0.0

	Percent of respondents by place of residence				
Within the last year, another driver . . . (2001)	*Rural*	*Small town*	*Small city*	*Large city*	*Total*
Made an obscene gesture at you	39.7	37.1	44.9	44.3	41.8
Made a threatening move with car	25.4	23.5	30.0	25.9	26.4
Tailgated you	69.1	61.3	70.3	69.8	66.8
Followed or chased you in anger	9.9	6.4	9.9	11.5	9.4
Got out of car to argue with you	5.8	5.8	4.2	8.3	5.9
Cut you off	32.0	33.7	38.6	48.0	38.1

SOURCE: Adapted from references 103 and 104.

cently been challenged.[115] "It is no coincidence," observes Yale architecture professor Philip Langdon, "that at the moment when the United States has become a predominantly suburban nation, the country has suffered a bitter harvest of individual trauma, family distress, and civic decay." [116] Indeed, a perceived erosion of civic engagement and mutual trust—a loss of what is called "social capital"—has been widely noted and discussed in recent years.[117,118] Some authors have attributed this decline, in part, to suburbanization and sprawl.[119,120]

A full discussion of the complex sociology of suburban life is beyond the scope of this article. Several facts bear mention, however. First, as Robert Putnam argues in *Bowling Alone*, the simple fact of more driving time means less time with family or friends, and less time to devote to community activities, from neighborhood barbecues to PTA meetings.[118] Putnam estimates that each additional 10 minutes of driving time predicts a 10% decline in civic involvement.[118] Second, suburban development patterns often feature considerable economic stratification. Many housing developments are built to specific price ranges, so that buyers of $250,000 homes are effectively segregated from buyers of $500,000 homes (and those at the bottom of the economic ladders are excluded altogether).[121] This pattern creates income homogeneity within neighborhoods but may intensify income inequality across metropolitan areas. Third, both polling data and voting records have demonstrated that suburban residents prefer more individualized, less collective solutions to social problems relative to rural, small town, and urban voters, with the possible exception of schools.[122–125] Finally, suburban neighborhoods with capacious houses and lawns offer few options for older adults once their children have grown up and moved from the home. These "empty nesters" typically have to change neighborhoods if they wish to find smaller, lower maintenance homes. The inability to remain in a single neighborhood through the life cycle may also undermine community cohesiveness. Collectively, these trends suggest that certain features of sprawl tend toward greater social stratification and less social capital.

A large literature has explored the relationship between social relationships and health, focusing both on the individual level (one's own relationships) and on the societal level (social capital).[126] In general, a higher quantity and quality of social relationships is associated with health benefits. Conversely, social stratification, in particular income inequality, is associated with higher all-cause mortality, higher infant mortality, and higher mortality from a variety of specific causes, independent of income and poverty, according to data from the United States[127–130] and Great Britain.[131,132] There is evidence that this effect is mediated, at least in part, through effects on social capital.[133,134] Therefore, to the extent that sprawl is associated with social stratification and loss of social capital and these phenomena are in turn associated with increased morbidity and mortality, sprawl may have a negative health impact on this broad scale.

ENVIRONMENTAL JUSTICE CONSIDERATIONS

Research over the last 15 years has suggested that poor people and members of minority groups are disproportionately exposed to environmental hazards.[135–137] Could any adverse health consequences of sprawl disproportionately affect these same populations?

In general, the pattern of urban development of which sprawl is a part may deprive the poor of economic opportunity. When jobs, stores, good schools, and other resources migrate outward from the core city, poverty is concentrated in the neighborhoods that are left behind.[138–142] A full discussion of the impact of urban poverty on health is beyond the scope of this article, but a large literature explores this relationship.[143–147] To the extent that sprawl aggravates poverty, at least for selected groups of people, it may contribute to the burden of disease and mortality.

More specifically, there is evidence that several of the specific health threats related to sprawl affect minority populations disproportionately. Air pollution is one example. Poor people and people of color are disproportionately impacted by air pollution for at least two reasons: disproportionate exposure, and higher prevalence of underlying diseases that increase susceptibility. Members of minority groups are relatively more exposed to air pollutants than whites, independent of income and urbanization.[148,149] Environmental Protection Agency data show that black people and Hispanics are more likely than white people to live in areas that violate air quality standards.[150] As asthma continues to increase, asthma prevalence and mortality remain higher in minority group members than in white people.[151] The cumulative prevalence of asthma is 122 per 1,000 in black people and 104 per 1,000 in white people, and asthma mortality is approximately three times as high in black people as in white people.[152] Similarly, asthma prevalence is more than three times as high among Puerto Rican children as among non-Hispanic children.[153] Among Medicaid patients, black children are 93% more likely, and Latino children 34% more likely, than white children to have multiple hospitalizations for asthma.[154] Although some

of this excess is related to poverty, the excess persists in analyses controlled for income.[155] Asthma prevalence and mortality are especially high, and rising, in inner cities, where minority populations are concentrated.[156,157] Both exposure to air pollution and susceptibility to its effects appear to be concentrated disproportionately among the poor and people of color. As sprawl contributes to air pollution in metropolitan areas, these populations may be disproportionately affected.

Heat-related morbidity and mortality also disproportionately affect poor people and members of minority groups. In the 1995 Chicago heat wave, black residents had a 50% higher heat-related mortality rate than white residents.[158] Similar findings have emerged following heat waves in Texas,[159] Memphis,[160] St. Louis,[161] and Kansas City[161] and are reflected in nationwide statistics.[162] Of special interest in the context of urban sprawl, one heat wave study considered transportation as a risk factor and found that poor access to transportation—a correlate of poverty and non-white race[163]—was associated with a 70% higher rate of heat-related death.[92]

There are significant racial/ethnic differences in motor vehicle fatality rates. Results from the National Health Interview Survey revealed motor vehicle fatality rates of 32.5 per 100,000 person-years among black men, 10.2 among Hispanic men, 19.5 among white men, 11.6 among black women, 9.1 among Hispanic women, and 8.5 among white women.[164] Much of the disparity was associated with social class.[164] However, differences in neighborhood design, road quality, automobile quality, and behavioral factors may be important, and need to be better understood.

Pedestrian fatalities disproportionately affect members of minority groups and those at the bottom of the economic ladder.[164] In Atlanta, for instance, pedestrian fatality rates during 1994–1998 were 9.74 per 100,000 for Hispanics, 3.85 for black people, and 1.64 for white people.[41] In suburban Orange County, California, Latinos represent 28% of the population but account for 43% of pedestrian fatalities.[165] In the Virginia suburbs of Washington, Hispanics represent 8% of the population but account for 21% of pedestrian fatalities.[166] The reasons for this disproportionate impact are complex and may involve the probability of being a pedestrian (perhaps related to low access to automobiles and public transportation), road design in areas where members of minority groups walk, and behavioral and cultural factors (such as being unaccustomed to high speed traffic).

These examples illustrate that the health effects of sprawl may have disparate impacts on different sub-

populations. In other cases, there is less evidence of disparities in the health outcomes associated with sprawl, or when such disparities exist, they are likely to relate to factors other than land use and transportation. Examples include physical activity, water-related health outcomes, and mental health outcomes.

Physical activity and overweight vary by ethnic and racial group. People of color are more likely to be overweight[64,167] and more likely to lead sedentary lifestyles[168,169] than white people.[170–173] In the Third National Health and Nutrition Examination Survey (NHANES-III), for example, 40% of Mexican Americans and 35% of blacks reported no leisure time physical activity, compared with 18% of white people.[174] In this same survey, the mean Body Mass Index was 29.2 among black people, 28.6 among Mexican Americans, and 26.3 among white people.[170] The relationships among race/ethnicity, genetic factors, social class, the environment, diet, physical activity, and body weight are complex. There is no evidence that sprawl disproportionately affects people of color with regard to physical activity. In fact, poorer people may be less likely to own cars and therefore more likely to walk than wealthier people. Given the public health importance of overweight, obesity, and related health conditions, and the fact that relatively little research has addressed disparities in environmental contributors such as sprawl, further data on these relationships are needed.

In contrast, there is no evidence that sprawl-related threats to the water supply disproportionately affect poor people or members of minority groups. Similarly, there is no evidence that the mental health consequences of sprawl, such as road rage, affect various racial/ethnic groups differently. In the driving behavior survey data cited previously, no racial/ethnic differences were found in self-reported aggressive behavior. Although black people were slightly less likely to be the victims of aggression than white people or members of other racial/ethnic groups, this difference was not statistically significant.[103,104]

In summary, some of the health consequences of sprawl appear disproportionately to affect vulnerable subpopulations, while others do not demonstrate this pattern. In many cases we do not have sufficient data to reach firm conclusions. Given the significance of the health outcomes involved, the moral imperative of eliminating racial and ethnic health disparities, and the steady increase in sprawl, these associations deserve continued public health attention.

SOLUTIONS

As discussed above, further research is needed to clarify the complex relationships among land use, transportation, and health. What approaches to urban planning, design, and construction are most likely to reduce air pollution, reduce urban heat, encourage physical activity, reduce automobile-related morbidity and mortality, and promote mental health and a sense of community? Although this article has focused on the health consequences of sprawl, other forms of built environment—dense cities, remote rural areas, and small towns—all have advantages and disadvantages that need to be assessed. It is likely that many different kinds of built environments can promote health, and that optimal approaches will borrow elements of cities, suburbs, and small towns.

Some interventions may be relatively simple, such as planting more trees or providing more sidewalks. Others are more complex and expensive to implement, such as mass transit and mixed-use zoning. For each of these, standard health research methods—ranging from clinical trials to observational epidemiology—may offer insights. This research will require innovative partnerships with other professionals, such as urban planners, architects, and real estate developers.

It is especially important for health researchers to recognize and study "natural experiments." Patterns of urban land use are changing, with migration back into inner cities, urban growth boundaries that restrict development to certain areas, development of mixed-use projects, innovations in mass transportation, green space programs, and related initiatives. Such efforts offer opportunities for health researchers who can examine their effects on relevant health endpoints.

As we recognize and understand the health costs of urban sprawl, we can begin to design solutions. Many potential solutions are found in an urban planning approach that has come to be known as "smart growth," characterized by higher density; more contiguous development; preserved green spaces; mixed land uses with walkable neighborhoods; limited road construction balanced by transportation alternatives; architectural heterogeneity; economic and racial/ethnic heterogeneity; a balance of development and capital investment between central city and periphery; and effective, coordinated regional planning.[116,175–178] Importantly, many of the health-related benefits that could flow from this approach—less air pollution, more physical activity, lower temperatures, fewer motor vehicle crashes—would also yield collateral benefits, such as a cleaner environment and more livable neighborhoods.

If the health consequences of sprawl represent a "syndemic"[179]—a combination of synergistic epidemics that contributes to the population burden of disease—then solutions may also operate synergistically, ameliorating several health problems.

Health professionals can play an important role in designing and implementing transportation and land use decisions. Similarly, those who have traditionally managed these issues—urban planners, architects, engineers, developers, and others—should recognize the important health implications of their decisions and seek collaboration with health professionals.

CONCLUSIONS

Urban sprawl is a longstanding phenomenon. It began with the expansion of cities into rural areas and accelerated greatly during the last half of the 20th century. As the 21st century begins, approximately half of Americans live in suburbs,[2] and the features of sprawl—low-density land use, heavy reliance on automobiles for transportation, segregation of land uses, and loss of opportunity for some groups, especially those in inner cities—are widespread and familiar.

This article has discussed the relationship between sprawl and health based on eight considerations: air pollution, heat, physical activity patterns, motor vehicle crashes, pedestrian injuries and fatalities, water quality and quantity, mental health, and social capital. The data show both health benefits and health costs. As is true for most public health hazards, the adverse impacts of sprawl do not fall equally across the population, and those who are most affected deserve special attention.

As we address sprawl on a variety of levels, from personal transportation decisions to local zoning ordinances, from regional mass transit and land use decisions to federal regulations, it is essential to incorporate health considerations into policy making. Because the health effects of sprawl are unevenly distributed across the population, it is equally essential to incorporate considerations of social justice and equity.

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