The Impact of Community Design and Land-Use Choices on Public Health: A Scientific Research Agenda

Andrew L. Dannenberg, MD, MPH, Richard J. Jackson, MD, MPH, Howard Frumkin, MD, DrPH, Richard A. Schieber, MD, MPH, Michael Pratt, MD, MS, MPH, Chris Kochtitzky, MSP, and Hugh H. Tilson, MD, DrPH

The design of a community's built environment influences the physical and mental health of its residents. Because few studies have investigated this relationship, the Centers for Disease Control and Prevention hosted a workshop in May 2002 to help develop a scientific research agenda on these issues.

Workshop participants' areas of expertise included physical activity, injury prevention, air pollution, water quality, urban planning, transportation, architecture, epidemiology, land use, mental health, social capital, housing, and social marketing. This report describes the 37 questions in the resulting research agenda.

The next steps are to define priorities and obtain resources. The proposed research will help identify the best practices for designing new communities and revitalizing old ones in ways that promote physical and mental health. (*Am J Public Health.* 2003;93:1500–1508)

The design choices we make in our homes, schools, workplaces, communities, and transportation systems can have major effects on health,[1] which is defined by the World Health Organization as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."[2] A healthy community protects and improves the quality of life for its citizens, promotes healthy behaviors and minimizes hazards for its residents, and preserves the natural environment.

Increasing evidence suggests that land-use and transportation decisions can facilitate or obstruct the creation and maintenance of healthy communities. The design of cities, neighborhoods, and individual buildings can affect levels of physical activity,[3] which is an important factor in the prevention of obesity and its associated adverse health consequences.[4] Community design influences the amount to which its residents are dependent on automobiles, whose use contributes to air pollution, motor vehicle crashes, and pedestrian injuries.[5] The design of the built environment affects the ability of persons with disabilities to be physically active and to be socially integrated into their community.[6] The mental health of individuals[7] and a community's social capital[8] may be influenced by the design of the built environment. Environmental justice is also a concern because persons with low socioeconomic status may suffer disproportionately from the adverse consequences of transportation and land-use decisions in their communities.[9]

Although some research has been done to document the specific interactions between the built environment and health, it is often conducted within one discipline, and results are typically not widely shared across disciplines. Community leaders and public health officials need to know more about which community design and land-use choices are most effective in improving the physical, mental, and social well-being of the public. The Centers for Disease Control and Prevention (CDC) has collaborated with an interdisciplinary group of academic researchers, public health practitioners, and professional organizations to create a scientific research agenda that highlights areas in which further investigations are needed to improve our understanding of these issues.

METHODS

To help develop a research agenda, the CDC invited external experts to a 1-day workshop held in May 2002 in Atlanta. The workshop participants represented a wide range of disciplines, including physical activity, injury prevention, air pollution, water quality, urban planning, transportation, architecture, epidemiology, land use, mental health, social capital, health policy, housing, and social marketing.

Before the workshop, participants were asked to provide, from their areas of expertise, 2 scientific research questions "that if answered would further our knowledge of the relation of public health to community design and land-use choices." During the workshop, these draft research questions were refined and edited by small groups, and the full workshop panel then discussed them further and made additions. After the workshop, a summary of these discussions was circulated for further input to other individuals and organizations from various public health and other professional backgrounds. Although not representing a full consensus of all persons involved, the current report includes ideas from dozens of individuals, all of whom were offered the opportunity to comment on the document as it was nearing completion.

RESULTS

The workshop participants and subsequent contributors generated 37 research questions designed to extend scientific knowledge of the relationship between public health and community design and land-use choices. The questions were grouped into themes including research methods, physical activity and transportation choices, schools and children, unintentional and intentional injuries, impact on persons with disabilities, air and water quality, mental health, social capital, environmental justice, and cross-cutting issues. Although no formal priority-setting process was conducted, this report's authors selected 18 questions for further elaboration (discussed below), considering factors such as utility, feasibility, generalizability, and affordability. The remaining questions are summarized in Table 1. For all questions, some possible re-

TABLE 1—Additional Research Questions Regarding the Impact of Community Design and Land Use Choices on Public Health[a]

Research Question	Research Design
Physical activity and transportation mode choice	
a. What are the physical and social barriers to walking and biking for transportation and for recreation?	Conduct a cross-sectional survey of adults and children in urban, suburban, and rural settings.
b. Does improved design to encourage walking/biking lead to a decline in per capita automobile use?	Examine before and after person-hours of walking and biking and per capita vehicle miles traveled in redesigned or revitalized neighborhoods.
c. For decreasing automobile dependence and increasing physical activity, is it more important to improve the design of residential areas, of commercial areas, or of the transportation links between them?	Examine before and after per capita miles traveled riding in vehicles, walking, and bicycling, and overall physical activity in redesigned or revitalized residential and commercial areas.
Injury prevention	
a. Compared with areas with a narrow range of housing values, what are the impacts of mixed-income neighborhoods on public safety and public health, such as crime rates, rates of chronic disease, and social cohesion?	Examine before and after crime victimization rates, health measures, and social capital in communities where urban redesign and revitalization is planned, controlling for confounders. Also conduct a survey of residents' fears and perceived risk compared with true risk.
b. How do features of the built environment affect risk of unintentional injury in vulnerable populations such as children, the elderly, and persons with disabilities?	Examine injury rates in vulnerable persons in traditional neighborhoods and in newer automobile-dependent neighborhoods. Examine before and after community injury rates as urban redesign and renovation occurs.
c. What is the relationship between the health of neighborhood residents and local crime rates, in that fear of potential victimization may discourage physical activity and social interactions even in pedestrian-friendly communities?	Conduct a cross-sectional survey of health, physical activity, and characteristics of the built environment in neighborhoods with high and low crime rates. Conduct surveys of residents' perceived risks of victimization compared with true risks in the same communities.
d. What is the relationship between characteristics of the built environment and vulnerability to natural disasters and to terrorism?	Conduct computer simulations of the impact of various natural disaster and terrorism scenarios on different types of neighborhoods. For example, the time required for emergency response and community evacuation can be tested for various street patterns.
Air quality and climate change	
a. What is the relationship between the age and maintenance of houses, schools, and other buildings and the incidence of asthma attacks, especially in urban areas, and are such adverse health events improved when communities are renovated?	Conduct a longitudinal study of frequency of asthma attacks compared with neighborhood building conditions, including age, maintenance, ventilation, infestation, and other factors that may contribute to asthma, before and after community renovations.
b. How do factors contributing to climate change differ between areas with and without strong regional planning processes?	Compare greenhouse gas emissions levels and loss of farmland and green space in communities with and without good regional planning.
Public policy and other crosscutting issues	
a. What are the political, economic, and psychological barriers to building pedestrian-oriented mixed-use communities?	Interview decisionmakers and conduct focus groups in new communities to examine the political, economic, and psychological factors that led to desirable and undesirable designs in those communities.
b. What are the barriers, such as lack of knowledge or personal rationalizations, that (1) prevent planners from considering public health impacts in their decisions and (2) prevent public health officials from becoming more involved in the planning process?	Conduct focus groups with planners and public health practitioners to identify these barriers, and then develop partnerships to work on addressing these barriers.
c. What factors, such as differences in education, funding, and politically active citizenry, contribute to the disparities in desirable design elements between lower and upper socioeconomic communities?	Conduct interviews and cross-sectional surveys with planners and builders of new communities designed for persons with low and high income levels.
d. What are the effects on health of design and policy decisions that affect urban housing quality, including housing construction, rehabilitation, and management?	Conduct cross-sectional surveys with builders, repairers, and managers of urban housing units and periodic interviews with residents of those units.
e. What interventions to improve housing, particularly low-income housing, will lead to better health in children and adults, especially in relation to asthma, mold-induced illness, lead poisoning, carbon monoxide poisoning, and unintentional injuries?	Assess the health status of children and adults living in low-income housing before and after implementation of selected housing interventions.
f. How can incentives (e.g., location efficient mortgages) and disincentives (e.g., impact fees) be used to encourage community designs that promote health for the diversity of groups (e.g., race/ethnicity, class, life stage, citizenship, disability status) who live in the United States?	Conduct interviews and cross-sectional surveys with policymakers, regional planners, developers, and bankers in a variety of communities.

Continued

TABLE 1—*Continued*

g. What strategies are used in successful well-designed communities to maintain public policies favorable to health and quality of life?	Conduct interviews with policymakers and managers in existing well-designed communities.
h. As part of including community residents in the planning process, what is the perceived value in terms of health, safety, and desirability that communities place on specific design elements such as sidewalks, green spaces, and community centers?	Conduct focus groups and cross-sectional surveys with random samples of citizens in existing well-designed and poorly designed communities.
i. What analytic techniques from fields other than public health, such as urban planning, transportation engineering, and architecture, might be useful for examining health and community design issues?	Conduct a literature review of fields related to community design to identify potentially useful analytic techniques from other disciplines.
j. How are urban, suburban, and rural built environments changing over time in terms of density, connectivity, walkability, travel patterns, and health outcomes?	Use existing surveillance systems of environmental characteristics and health outcomes and develop new tracking systems where needed.

[a]This table describes research questions suggested by participants at the May 2002 workshop described in the "Methods" section of the text but excludes research questions described in the "Results" section.

search designs are suggested, although we recognize that investigators may design valuable studies using methods other than those considered in this report.

Research Methods and Data Sources

Much research relevant to the relationship between health and community design has been conducted by professionals in other fields, including transportation engineering, urban and regional planning, architecture, atmospheric chemistry, psychology, sociology, and political science. Identifying relevant data sources, measures, and research methods in these fields is important; new methods and measures can be developed as needed.

Identifying exposure measurements. Research question: What are the best measures of the physical environment that may be relevant to health? How do these measures relate to the health of populations in specific urban and suburban environments? Neighborhood-level examples might include the presence of front porches, sidewalks, traffic calming, and green space; community-level examples might include residential density, housing features, land-use mix, quantity and quality of public space, connectivity, and transportation systems.[10] High levels of noise, graffiti, broken windows, and liquor stores may reflect poor community health.

Research design: Potential measures might be identified by a literature review of research in related fields such as urban and regional planning, land use, transportation design, sustainable development, and healthy cities, especially focusing on indicators. Longitudinal and quasi-experimental studies would be useful for documenting which of these measures are associated with health outcomes, in what ways the measures cluster, and what new measures might be useful.

Defining guidelines. Research question: Analogous to ideal body weight, what are desirable levels of health-related parameters of the physical environment, such as land-use mix, walkability, indoor environmental quality, or proximity to green space? The Leadership in Energy and Environmental Design guidelines[11] may serve as a model for developing health-related community design guidelines. New guidelines should be consistent with standards for accessibility for persons with disabilities.[12]

Research design: Analytic studies are needed to define the levels of the parameters associated with quantifiable health benefits or adverse outcomes. Natural experiments may provide useful data for some parameters. As with other public health interventions, proposed guidelines should be assessed for safety, efficacy, costs, and unintended consequences. For example, narrow streets designed to encourage walking could interfere with response time for emergency vehicles. Data on proposed guidelines should be systematically reviewed through a formal meta-analytic approach or other structured review process, such as that used to create the Guide to Community Preventive Services.[13] Further research would be valuable in areas where insufficient evidence is available.

Physical Activity, Obesity, and Transportation Choices

Despite the proven benefits of a physically active lifestyle, over 60% of American adults are insufficiently active to achieve these benefits and over 25% are not active at all in their leisure time.[14,15] Activity decreases with age and is less common among women than men and among those with lower income and less education. Data suggest that such community characteristics as proximity of recreation facilities; street design; housing density; and accommodation for safe pedestrian, bicycle, and wheelchair use play a significant role in promoting or discouraging physical activity.[16,17] A number of instruments have been developed to assess physical activity, such as the International Physical Activity Questionnaire,[18] although accurate measurement of physical activity levels in children is difficult. The National Center for Chronic Disease Prevention and Health Promotion at the CDC is currently developing a detailed research agenda on scientific and policy issues associated with promoting physical activity.

Measuring physical activity levels and contributory factors. Research question: What are the best objective measures of physical activity levels and how do they compare with self-reported measures in adults and in children? How do individuals perceive whether or not their environment encourages physical activity and how do those perceptions correlate with objective measures of the environment (such as percentage of

streets with sidewalks)? Do perceived or objective measures better predict physical activity behavior? What are the best measures of pedestrian and bicycling infrastructure and other environmental characteristics that facilitate physical activity? What community policies are best correlated with physical activity?

Research design: One could compare self-reported physical activity levels with those measured by the use of global positioning satellite and geographic information systems, as is being done in the SMARTRAQ project.[19] Environmental assessments could include gathering self-reported perceptions and measuring prevalence, quality, and use of recreational and transportation facilities such as walking trails, sidewalks, and bicycle paths.[20] Current projects supported by the Robert Wood Johnson Foundation on environmental factors and policies that influence physical activity may provide useful information on these research areas.[21]

Walking as an indicator of community health. Research question: Can observed levels of walking be used as an indicator of the physical and mental health of a community? After socioeconomic status and other factors are controlled for, do communities with high observed levels of walking have less obesity than those with low levels of walking? Can walking be used as a unifying theme for other realms of public health such as physical activity, safety, air pollution, and social capital?

Research design: In multiple neighborhoods or communities, one could measure walking, walkability,[22] overall physical activity levels, obesity, neighborhood satisfaction, social engagement, and other health measures to assess their associations while controlling for self-selection and other confounders.

Schools and Children

Recent reports have documented a substantial increase over the past decade in the proportion of US children and adolescents who are overweight.[23] These changes most likely result from decreased physical activity and increased dietary fat and calories, causes that are in turn influenced by the physical, social, and economic environment. Physical activity and nutrition habits established in childhood are likely to influence lifelong habits. The design of the built environment, especially distance and traffic hazards, influences whether a child will walk, bicycle, or be driven to school.[24]

Older urban community schools, rather than being renovated, are often abandoned in favor of larger new suburban schools located farther from community centers, further hindering children's ability to walk or bike.[25] Hazardous routes that prevent children from walking and bicycling to school can be improved when there are the resources and political will to make changes, such as those promoted by the Safe Routes to School initiative.[26]

The term "hazard busing" describes the use of school buses to transport children short distances from home to school to avoid unsafe road crossings and absent sidewalks. While the prevalence of hazard busing nationally is unknown, a South Carolina study found that students attending schools built after 1971 were 3 times more likely than those attending older schools to receive hazard busing.[27]

Types and determinants of travel to school. Research questions: What factors promote or hinder children's ability to walk or bicycle to school? What design characteristics of schools facilitate walking and biking? What policies, such as magnet schools, may lead to longer commutes to school? When did those policies go into effect and what was their impact on the prevalence of children walking and biking to school? Are there social benefits for children who are able to walk or bicycle to school? How prevalent is hazard busing and how do planners decide where it is needed? Is the prevalence of walking and bicycling among persons of all ages higher in communities with high rates of children walking and bicycling to school?

Research design: One could conduct cross-sectional surveys of schools to assess the relationships among walking and bicycling to school, obesity prevalence, hazard busing, school design, and environmental factors. Longitudinal studies would also be valuable; for example, Safe Routes to School programs and policy interventions could be evaluated in intervention and control communities by a multiple time series design.

Unintentional Injuries

Motor vehicle and pedestrian injury rates are associated with numerous environmental factors (including road design and traffic congestion) and with driver and pedestrian behaviors that result from these and other factors. A recent study reported an average annual traffic death rate that was over 50% higher in the nation's 10 most sprawling metropolitan areas than in the 10 least sprawling metropolitan areas.[5] Environments designed to encourage walking and bicycling contribute to lower pedestrian and bicyclist injury rates in Holland and Germany than in the United States.[28] Traffic-calming measures[29] and other improved road and trail designs that take into account potential conflicts between pedestrians, bicyclists, and motorists may lead to reductions in motor vehicle collisions and injuries.

Influence of community design on risk of injury. Research question: How do motor vehicle, pedestrian, and bicyclist injury rates differ between traditional suburbs and newer automobile-dependent suburbs, controlling for socioeconomic factors? How can community design elements predictive of lower injury rates in a neighborhood be identified and measured? How do these design features affect mobility and transportation choices for children and the elderly?

Research design: Ecological studies of injury rates in traditional neighborhoods, recently gentrified urban neighborhoods, and newer automobile-dependent suburbs with similar socioeconomic characteristics would be useful. Geographic information systems could be used to compare pedestrian, bicycle, and motor vehicle crashes in different neighborhoods or census tracts. Case–control studies could be used to identify specific community design factors associated with the occurrence of injuries. A cross-sectional survey of teenagers and elderly persons could be used to examine risk exposures and factors influencing their transportation choices.

Crime and Violence

Rates of crime and fear of crime are associated with features of the physical environment within neighborhoods.[30] Such features range from housing configurations that facilitate "eyes on the street" to abandoned buildings

that suggest vulnerability to crime. Little is known about how these factors interact with each other and with the larger social environment within neighborhoods to affect property crimes, violent crimes, and other social and health-related outcomes. In the 1970s, the strategy of Crime Prevention Through Environmental Design (CPTED), including design recommendations for housing layout, land use, territoriality, and physical maintenance, was developed to improve public safety.[31,32] Reductions in crime have been documented in communities that have followed CPTED recommendations.[33] Implementation of CPTED recommendations may have consequences on the health of a community beyond crime prevention, such as improvements in physical activity, mental health, and social capital.

Public health consequences of public safety design choices. Research question: Do specific CPTED design elements focused on public safety have secondary public health consequences? These consequences may be positive, such as fewer unintentional injuries, more physical activity, greater social capital, and lower rates of substance abuse, or negative, such as increased nonresidential land use, loss of community identity, and higher property values leading to less affordable housing. As a related question, how do walking patterns differ in communities with and without security gates?

Research design: A first step would be to collect qualitative data on public health consequences from focus groups of residents and service providers in communities where CPTED-related interventions have occurred. Next, quantitative research could be conducted to examine the prevalence of these consequences, the specific types of CPTED-related changes that contribute to them, and the subgroups of the population most affected. This research could include before-and-after data on a range of indicators from communities in which CPTED interventions have been implemented and similar comparison communities without such interventions.

Impact of Community Design on Persons With Disabilities

The design of the built environment has a substantial impact on the ability of persons with disabilities to be physically active, to use transportation systems, and to be socially integrated into their community.[6] Communities that have user-friendly transportation systems and are compact and walkable are more accessible for persons with disabilities, allowing them to participate more fully in the community by working, shopping, and living within the integrated setting. Persons who use wheelchairs and other mobility devices generally benefit whenever a community is made more walkable, as long as appropriate accommodations (such as curb cuts) are included in such community improvements. Elderly persons without disabilities may receive similar benefits in improved quality of life from community designs that aid persons with disabilities.[34]

Physical activity, mobility, and social integration in persons with disabilities. Research questions: What characteristics of community design facilitate or discourage physical activity (such as curb cuts and benches for resting) in persons with disabilities? What accommodations (such as bus wheelchair lifts) are needed to provide access to community transportation systems and better mobility for persons with disabilities and for the elderly? What characteristics of community design (such as broken sidewalks and poor street lighting) lead to fear of injury and vulnerability to crime and thereby limit mobility in persons with disabilities and in the elderly? What characteristics of community design encourage the social integration of persons with disabilities into community activities? What are the barriers to providing design features that improve physical activity, mobility, and social integration for persons with disabilities? What are the health consequences of isolation in persons with disabilities and in the elderly if they cannot drive?

Research design: A first step would be to collect, from the literature and from focus groups of persons with disabilities, qualitative information on community designs that help and hinder physical activity, mobility, and social integration for persons with disabilities, and collect qualitative information on barriers to implementing favorable designs.[35] A case–control study, involving active persons with disabilities as cases and inactive persons with disabilities as controls, may be useful to help identify design factors that facilitate physical activity. A quasi-experimental design could be used to document improvements in quality of life for persons with disabilities in communities with and without the favorable community designs, while considering self-selection biases.

Health Effects of Air and Water Pollution

Environmental pollution is a well-documented cause of human illness.[36,37] Sprawling developments are associated with increased automobile use and accompanying air pollution.[5,38,39] Poor air quality exacerbates[40] and may even cause asthma[41] and other respiratory diseases. Disruption of farmlands and forests and paving for new roads and parking reduce the ground's natural filtering capacity, causing increased siltation, runoff of pollutants from impervious surfaces, and reduced water quality. Bacterial, chemical, and sediment contamination of water supplies increases the cost of providing potable water to communities and may cause gastrointestinal and other diseases.

Influence of community design on emissions of overall and specific pollutants. Research questions: What tradeoffs in terms of criteria air pollutants, particulate matter, and airborne toxics are involved with land-use policies that promote increased density, walkability, and connectivity? For example, although higher density may reduce per capita vehicle emissions on a regional basis, it may create more traffic congestion and higher levels of different pollutants in the dense areas. How can these consequences be mitigated? How can environmental regulations be revised to encourage community designs that have lower air and water pollution levels? Does the opening or expansion of a mass transit system lead to a measurable change in air pollution levels?

Research design: Detailed data from urban planning and air monitoring could be used with geographic information system techniques to compare selected design characteristics with health outcomes in a group of older traditional suburbs and newer automobile-dependent suburbs. In addition, many metropolitan areas that have measured levels of air pollutants could be compared to determine which design characteristics (such as density) are associated with

lower levels of each air pollutant. In suburban and rural areas not served by public water systems, one could compare well water quality to land-use features such as lot size, road design, and separation of residential areas from agricultural and industrial areas.

Mental Health

The natural and built environment in which individuals or groups live can directly affect their mental health.[7] Positive effects of different types of natural environments such as green space include improved social and cognitive functioning and decreased violence.[42,43] Long commutes and traffic congestion may contribute to "road rage."[44]

Influence of physical setting characteristics on mental health. Research question: How do particular characteristics of a physical setting, such as noise level, crowding, crime, lighting, traffic, and green space, affect the mental health and social functioning of adults and children? How do these characteristics affect health in various physical settings, such as work, school, home, and during commuting? How do these characteristics affect health in persons at different life stages and in different social groups?

Research design: Cross-sectional surveys could be conducted in multiple communities to assess cognitive, social, and physical health in physical settings that have differing characteristics. In addition, a quasi-experimental design could be used to compare mental health in communities that have similar population characteristics but different physical settings. Investigators may be able to identify natural experiments in which they can assess the impact on mental health of some physical factors such as noise from roads and daylighting in buildings.

Social Capital

Social capital is defined as the social, political, and economic networks and interactions that inspire trust and reciprocity among citizens.[8] Social capital may be affected by the design of the physical environment; for example, persons with long commutes may have less time for civic engagement.[8] Persons with low social capital may be at increased risk for poor physical and mental health.[45,46]

Influence of built environment on social capital and health. Research question: What features of the built environment, such as front porches, sidewalks, parks, churches, community centers, and transportation alternatives, affect social capital in ways that in turn affect health?

Research design: Existing literature on the relationship of the built environment, social capital, and health could be reviewed, and cross-sectional, longitudinal, and quasi-experimental studies could be conducted in a variety of communities to further examine these issues. For example, after controlling for appropriate confounders, one could examine the differences in both community involvement and mental health among persons who spend the same amount of time in their commute to work but differ in whether their commute is made by walking, bicycling, using transit, carpooling, or driving alone.

Environmental Justice and Social Equity

Current patterns of urban development do not affect all populations equally. Persons with low incomes, minorities, children, the elderly, and persons with disabilities may suffer disproportionately from the adverse consequences of transportation and land-use decisions.[9] Many new communities, including some that incorporate many features of good design, do not accommodate these populations.

Characterizing social equity and health outcomes in relation to community design. Research questions: What is the impact of segregating people by life stage, income, ethnicity, disability status, or other demographic subgroup on health, well-being, and social capital? Does increased demand for well-designed urban housing lead to gentrification of older neighborhoods and decreased affordability of adequate housing[47] for low-income persons? What policies can protect low-income persons who are at risk of being displaced by urban renewal projects? Do the benefits of Smart Growth[48] accrue mainly to persons of high socioeconomic status?

Research design: Qualitative and quantitative case studies may be used to identify the impact on health of segregating persons by income and other characteristics. One could conduct a before-and-after study to assess whether an improved transportation system provided better access to jobs, medical care, and other necessities for low-income persons. Examples of mixed-income communities that have successfully incorporated Smart Growth principles may be valuable as best practices that could be replicated elsewhere.

Crosscutting Issues

Many design choices available to community planners and policymakers have the potential to improve the public's health in multiple ways. For example, changes in transportation policy can simultaneously improve air quality, increase physical activity, limit injury risks, facilitate mobility for persons with disabilities, and reduce social inequities.

Identifying useful case studies. Research question: What best practices about health and the built environment, including policies and environmental factors, can be identified from in-depth case studies of selected well-planned communities and of selected poorly designed communities? How do physical activity levels, transportation choices, air pollution levels, and health outcomes in conventional urban and suburban communities compare with those built in accordance with the principles of Smart Growth? What are the demographic characteristics, such as age, household structure, income, and race/ethnicity, of persons living in communities built in accord with Smart Growth principles compared with those living in other residential areas?

Research design: Case studies are valuable for describing processes and assessing the positive and negative impacts of design choices and policy interventions in individual communities[49]; results of such studies can help inform other communities that are facing similar decisions. Qualitative and longitudinal quasi-experimental studies could examine the health and behavior characteristics of residents in existing neighborhoods or communities before and after their renovation, as well as in selected neighborhoods or communities that represent good and poor design. Longitudinal studies can help overcome limitations associated with self-selection and financial considerations that influence where individuals choose to live.

Model codes and best practices in zoning and building requirements. Research question:

What types of enforceable building codes, zoning codes, parking regulations, and incentive/disincentive programs can be used to promote health and prevent disease and injury? What types of codes are more likely to lead to adverse health outcomes? For example, zoning codes that require a minimum number of parking spaces per housing unit but do not require sidewalks encourage automobile dependency and discourage walking. Zoning codes that restrict the use, storage, and transportation of hazardous materials near schools and residential areas may reduce the risk of toxic exposures. What model codes (such as the Smart Code[50]) already exist and how can one analyze model codes to assess their impacts on health?

Research design: The planning literature could be reviewed to identify model codes that promote healthy activities as well as codes that may serve as barriers to such activities. Selected health outcomes in communities that have adopted model codes and incentive programs could be compared with outcomes in communities that have less progressive codes. The social and political circumstances that lead a community to update its codes and to adopt or not adopt a model code also could be examined.

Health impact assessment of community design choices. A health impact assessment is an estimate of the effects of a specified action on the health of a defined population in order to improve the quality of public policy decisionmaking from a health perspective. Modeled in part on the concept of an environmental impact statement,[51] a health impact assessment could provide guidance to decisionmakers on the impact of a proposed project on physical activity, air and water pollution, mobility for persons with disabilities, mental health, social capital, and environmental justice. A health impact assessment may be more acceptable to the development community if it is created as a set of guidelines rather than as regulations. Research question: How could health impact assessments be incorporated into community design processes?

Research design: A pilot health impact assessment process could be developed from a literature review and with advice from a group of experts from relevant disciplines. One could then create and evaluate demonstration projects in several communities in which there are cooperative planning and public health staff. The health impact assessment processes used in the United Kingdom[52] could help guide such demonstration projects.

Effective communications strategies to distill research results into a practical form. Research question: What are the most effective strategies to communicate research findings about the health effects of community design processes to specific audiences such as policymakers, planners, bankers, community residents, and children?

Research design: For each target audience, appropriate communication strategies could be developed and tested with assistance from behavioral scientists and social marketers.

Market research to better understand how to motivate change. Research question: What are the perceived benefits and barriers to choosing healthier community designs from the perspective of the general public, planners, developers, and public officials? How can a better understanding of these perceptions be used to develop design recommendations that appeal to these target groups?

Research design: One could conduct market research with the target groups on the perceived benefits and barriers to choosing healthier community designs. The results could be used to stimulate market demand for such designs.[53]

Catalysts to increase likelihood that design changes have desired health impact. Research question: For specific physical design interventions to have the desired health outcomes, what catalysts or other conditions, such as active neighborhood groups, cohesiveness, high social capital, or health promotion services, must exist simultaneously? For example, building a sidewalk may or may not lead to increased physical activity, depending on other neighborhood characteristics such as perceived safety and proximity and connectedness to desirable destinations.

Research design: The implementation of selected interventions, such as building sidewalks or installing a new transit system, could be compared in multiple communities to assess other factors that influence the health impact of those interventions. From such studies, one could better understand the barriers to obtaining benefits from such changes and make recommendations on how to optimize the health benefits of such interventions.

DISCUSSION

While some background research has been done on almost all topics described in this report, further investigation of these questions would contribute to a fuller understanding of the relationship between health and the built environment. It is likely that there are other important research topics not considered here that should be added in future years.

As a next step, a process should be established to set priorities among the many topics described earlier and in Table 1. Setting such priorities requires balancing issues such as technical feasibility, availability of funding, and potential health impact.

Research on health and the built environment requires the collaboration of investigators from a variety of professional disciplines, including some who have not previously interacted with the public health community. Interdisciplinary conferences[54,55] are valuable for building ties among potential collaborators. Support for research may come from many sources, including federal government agencies (e.g., the CDC, National Institutes of Health, Environmental Protection Agency), private foundations (e.g., Robert Wood Johnson Foundation), professional associations (e.g., American Planning Association, Urban Land Institute), and industry groups (e.g., National Association of Home Builders). In addition, interested community groups may conduct local studies that have national implications.

A wide range of types of quantitative and qualitative studies[49,56] would be useful to help answer the questions raised in this research agenda. The choice of study design will depend on many factors, including the questions being asked, the ability to measure relevant variables, the availability of data and resources, and even the creativity of the investigators. For example, valuable information was obtained from a natural experiment in which investigators observed that pediatric asthma emergency events decreased significantly when motor vehicle traffic and air pollution levels declined during the 1996 Summer Olympics.[40]

Although it may be easier to design and conduct small studies on the specific topics included in this report, consideration should also be given to the development of a few large integrated studies that would examine multiple outcomes simultaneously in a number of types of urban and suburban communities. After assessing community characteristics such as sidewalks, transportation mode options, automobile usage, air pollution levels, connectivity, school accessibility, housing quality, and mixed-use design, investigators could measure corresponding health outcomes, including rates of physical activity, obesity, asthma, injury, and crime, as well as indicators of mental health, social capital, and social equity. Such large integrated studies would be valuable for documenting for policymakers the influence of good community design features on multiple health outcomes.

Two limitations should be considered in reviewing the topics presented in this research agenda. First, as in any process of expert decisionmaking, the ideas generated depended on the individuals invited to and participating in the workshop. A different group of participants may have generated a different list of research topics. We hope the publication of these results will stimulate other colleagues to identify and circulate other research topics and methods; this will result in a more robust research agenda and ultimately in more useful information on the association between health and the built environment.

Second, in a process such as the one described here, participants provide research ideas that are generally focused in their fields of expertise. This is appropriate as a means of launching specific research projects; however, such ideas may be disconnected and lack a unifying theoretical basis or empirical cross-linkages. In a complex area such as the interface of health and the built environment, theoretical approaches such as ecological models[57,58] and syndemic analysis[59] may help synthesize and systematize research data from different lines of research.

Results of the research described in this report may help identify best practices and help communities to avoid making design decisions that have unintended negative consequences. Research results are important both for the design of new communities and for the revitalization of existing communities. Overall, it is hoped that such research will help guide local community design decisions and favorably influence the health of the public. ■

About the Authors

Andrew L. Dannenberg and Richard J. Jackson are with the National Center for Environmental Health, Centers for Disease Control and Prevention (CDC), Atlanta, Ga. Howard Frumkin is with the Department of Environmental and Occupational Health, Emory University Rollins School of Public Health, Atlanta, Ga. Richard A. Schieber is with the National Center for Injury Prevention and Control, Michael Pratt is with the National Center for Chronic Disease Prevention and Health Promotion, and Chris Kochtitzky is with the National Center on Birth Defects and Developmental Disabilities, CDC. Hugh H. Tilson is with the University of North Carolina at Chapel Hill School of Public Health, Chapel Hill.

Requests for reprints should be sent to Andrew L. Dannenberg, MD, MPH, Division of Emergency and Environmental Health Services, National Center for Environmental Health, CDC, 4770 Buford Hwy, Mail Stop F-30, Atlanta, GA 30341 (e-mail: acd7@cdc.gov).

This article was accepted April 30, 2003.

Contributors

All authors contributed to the conception, writing, and revising of the article.

Acknowledgments

The authors gratefully acknowledge the contributions of the participants in the May 28, 2002, research agenda workshop. The participants included Hugh Tilson, MD, DrPH, University of North Carolina, Chapel Hill, workshop moderator (epidemiology); Robert Cervero, PhD, University of California Berkeley, Berkeley (transportation); Lawrence Frank, PhD, Georgia Institute of Technology, Atlanta (transportation); Steve Gaffield, PhD, Environmental Protection Agency, Washington, DC (water quality); Donna Higgins, PhD, Urban Research Center, Seattle, Wash (housing); Ed Jackson, Jr, ArchD, American Institute of Architects, Washington, DC (architecture); David Jacobs, PhD, CIH, Department of Housing and Urban Development, Washington, DC (urban development); Richard Killingsworth, MPH, University of North Carolina, Chapel Hill (physical activity); William Klein, AICP, American Planning Association, Chicago, Ill (planning); Frances Kuo, PhD, University of Illinois Urbana, Urbana (mental health); Kevin Leyden, PhD, West Virginia University, Morgantown (social capital); Edward Maibach, PhD, MPH, Porter Novelli, Washington, DC (social marketing); Rebecca Miles, PhD, Florida State University, Tallahassee (land use); Mary Northridge, PhD, MPH, Columbia University, New York, NY (environmental epidemiology); Richard Retting, PE, Insurance Institute for Highway Safety, Arlington, Va (injury); Ted Russell, PhD, Georgia Institute of Technology, Atlanta (air pollution); Tim Torma, Environmental Protection Agency, Washington, DC (Smart Growth); and Al Zelinka, AICP, CMSM, Consultant, RBF Consulting, Irvine, Calif (violence prevention). We also thank John Crews, Don Lollar, James Sallis, and Catherine Staunton for their contributions to the research agenda.

References

1. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002;117:201–217.

2. World Health Organization. WHO Definition of Health. New York, NY: World Health Organization; 1948. Available at: http://www.who.int/about/definition/en. Accessed April 22, 2003.

3. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002; 23(2 suppl):64–73.

4. National Task Force on the Prevention and Treatment of Obesity. Overweight, obesity, and health risk. *Arch Intern Med.* 2000;160:898–904.

5. Ewing R, Pendall R, Chen D. Measuring sprawl and its impact. Smart Growth America. 2002. Available at: http://www.smartgrowthamerica.org/sprawlindex/sprawlindex.html. Accessed April 22, 2003.

6. World Health Organization. International classification of functioning, disability, and health. Available at: http://www3.who.int/icf/icftemplate.cfm. Accessed April 22, 2003.

7. Evans GW. The built environment and mental health. *J Urban Health.* In press.

8. Putnam RD. *Bowling Alone: The Collapse and Revival of American Community.* New York, NY: Simon and Schuster; 2000.

9. Bullard RD, Johnson GS, eds. *Just Transportation: Dismantling Race and Class Barriers to Mobility.* Gabriola Island, British Columbia: New Society Publishers; 1997.

10. Lopez R, Hynes HP. Sprawl in the 1990s: measurement, distribution, and trends. *Urban Aff Rev.* 2003;38:325–355.

11. Leadership in Energy and Environmental Design Green Building Rating System for New Construction and Major Renovations. Version 2.1. Washington, DC: US Green Building Council; 2003. Available at: http://www.usgbc.org/LEED/LEED_main.asp. Accessed June 24, 2003.

12. 28 CFR Part 36: ADA Standards for Accessible Design. Washington, DC: US Dept of Justice; 1994. Available at: http://www.usdoj.gov/crt/ada/stdspdf.htm. Accessed June 24, 2003.

13. Briss PA, Zaza S, Pappaioanou M, et al. Developing an evidence-based guide to community preventive services—methods. *Am J Prev Med.* 2000;18(1 suppl): 35–43. Available at: http://www.thecommunityguide.org. Accessed April 22, 2003.

14. *Physical Activity and Health: A Report of the Surgeon General.* Washington, DC: Dept of Health and Human Services; 1996.

15. Centers for Disease Control and Prevention. Physical activity trends—United States, 1990–1998. *MMWR Morb Mortal Wkly Rep.* 2001;50:166–169.

16. Frank LD, Engelke PD. The built environment and human activity patterns: exploring the impacts of urban form on public health. *J Plann Lit.* 2001;16: 202–218.

17. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity: a systematic review. *Am J Prev Med.* 2002;22(4 suppl):73–107.

18. International Physical Activity Questionnaire Committee. International Physical Activity Questionnaire. 2002. Available at: http://www.ipaq.ki.se. Accessed April 22, 2003.

19. Georgia Institute of Technology. Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality (SMARTRAQ). Available at: http://www.smartraq.net/about.htm. Accessed April 22, 2003.

20. Pikora TJ, Bull FCL, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable audit instrument to measure the physical environment for physical activity. *Am J Prev Med.* 2002;23:187–194.

21. Robert Wood Johnson Foundation. Active Living Policy and Environmental Studies. Available at: http://www.alpes.ws. Accessed April 22, 2003.

22. Safe Routes to School Sacramento. Walkability checklist. Available at: http://www.saferoutessac.org/walk.pdf. Accessed April 22, 2003.

23. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA.* 2002;288:1728–1732.

24. Centers for Disease Control and Prevention. Barriers to children walking and biking to school—United States, 1999. *MMWR Morb Mortal Wkly Rep.* 2002;51:701–704.

25. National Trust for Historic Preservation. Historic neighborhood schools in the age of sprawl: why Johnny can't walk to school. 2000. Available at: http://www.nthp.org/issues/historic_schools.html. Accessed April 22, 2003.

26. Marin County Bicycle Coalition. Safe Routes to School. Available at: http://www.saferoutestoschools.org. Accessed April 22, 2003.

27. Kouri C. *Wait for the Bus: How Lowcountry School Site Selection and Design Deter Walking to School and Contribute to Urban Sprawl.* Charleston: South Carolina Coastal Conservation League; November 1999.

28. Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: lessons from The Netherlands and Germany. *Am J Public Health.* 2003;93:1509–1516.

29. Elvik R. Area-wide urban traffic calming schemes: a meta-analysis of safety effects. *Accid Anal Prev.* 2001;33:327–336.

30. Taylor RB, Harrell AV. Physical environment and crime. National Institute of Justice Research Report; May 1996. Available at: www.ncjrs.org/txtfiles/physenv.txt. Accessed April 22, 2003.

31. Michael S. International clearinghouse on crime prevention through environmental design. Available at: http://www.thecptedpage.wsu.edu. Accessed April 22, 2003.

32. Mair JS, Mair M. Violence prevention and control through environmental modifications. *Annu Rev Public Health.* 2003;24:209–225.

33. Carter SP, Carter SL, Dannenberg AL. Zoning out crime and improving community health in Sarasota, Florida: "crime prevention through environmental design." *Am J Public Health.* 2003;93:1442–1445.

34. Pollak PB. Liveable communities: an evaluation guide. 1999. Available at: http://research.aarp.org/consume/d16905_communities.html. Accessed April 22, 2003.

35. Center for Outcome Measurement in Brain Injury. Craig Hospital Inventory of Environmental Factors (CHIEF). Englewood, Colo. 2001. Available at: http://www.tbims.org/combi/chief. Accessed April 22, 2003.

36. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution. *Am J Respir Crit Care Med.* 1996;153:3–50.

37. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution: part 2. *Am J Respir Crit Care Med.* 1996;153:477–498.

38. Frank LD, Stone B Jr, Bachman W. Linking land use with household vehicle emissions in the central Puget Sound: methodological framework and findings. *Transportation Res Part D.* 2000;5:173–196.

39. Holtzclaw J, Clear R, Dittmar H, Goldstein D, Haas P. Location efficiency: neighborhood and socioeconomic characteristics determine auto ownership and use—studies in Chicago, Los Angeles and San Francisco. *Transportation Plann Technol.* 2002;25:1–27.

40. Friedman MS, Powell KE, Hutwagner L, Graham LM, Teague WG. Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma. *JAMA.* 2001;285:897–905.

41. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet.* 2002;359:386–391.

42. Kuo FE, Sullivan WC. Environment and crime in the inner city: does vegetation reduce crime? *Environ Behav.* 2001;33:343–367.

43. Taylor AF, Kuo FE, Sullivan WC. Coping with ADD: the surprising connection to green play settings. *Environ Behav.* 2001;33:54–77.

44. National Highway Traffic Safety Administration. National survey of speeding and other unsafe driving actions. Volume II: driver attitudes and behavior. Available at: http://www.nhtsa.dot.gov/people/injury/aggressive/unsafe/att-beh/Chapt1-2.html. Accessed April 22, 2003.

45. Kawachi I. Social capital and community effects on population and individual health. *Ann N Y Acad Sci.* 1999;896:120–130.

46. Hawe P, Shiell A. Social capital and health promotion: a review. *Soc Sci Med.* 2000;51:871–885.

47. Matte TD, Jacobs DE. Housing and health—current issues and implications for research and programs. *J Urban Health.* 2000;77:7–25.

48. Smart Growth Network. About smart growth. 2002. Available at: http://www.smartgrowth.org/about/default.asp. Accessed April 22, 2003.

49. Yin RK. *Case Study Research: Design and Methods.* 2nd ed. Thousand Oaks, Calif: Sage Publications; 1994.

50. Duany Plater-Zyberk & Company. Smart code. Available at: http://www.smartcode.org. Accessed April 22, 2003.

51. Norfolk International Airport new runway environmental impact statement. Available at: http://www.norfolkairport.com/eis. Accessed April 22, 2003.

52. International Health Impact Assessment Consortium. What is health impact assessment? Available at: http://www.ihia.org.uk/abouthia.html. Accessed April 22, 2003.

53. Maibach EW. Recreating communities to support active living: a new role for social marketing. *Am J Health Promot.* 2003;18(1):114–119.

54. Local Government Commission. 2nd Annual New Partners for Smart Growth: Building Safe, Healthy, and Livable Communities Conference. New Orleans, 2003. Available at: http://www.outreach.psu.edu/C&I/SmartGrowth. Accessed April 22, 2003.

55. Robert Wood Johnson Foundation. Active Living Network Conference. Boulder Colo, 2002. Available at: http://www.activeliving.org/network_conference.htm. Accessed April 22, 2003.

56. Brownson RC, Petitti DB, eds. *Applied Epidemiology: Theory to Practice.* New York, NY: Oxford University Press; 1998.

57. Sallis JF, Owen N. Ecological models. In: Glanz K, Lewis FM, Rimer BK, eds. *Health Behavior and Health Education.* 2nd ed. San Francisco, Calif: Jossey-Bass Publishers; 1997:403–424.

58. Institute of Medicine, Board on Health Promotion and Disease Prevention. *Who Will Keep the Public Healthy? Educating Public Health Professionals for the 21st Century.* Washington, DC: National Academies Press; 2003.

59. Centers for Disease Control and Prevention. Spotlight on syndemics. Available at: http://www.cdc.gov/syndemics. Accessed April 22, 2003.