Peak Oil, Urban Form, and Public Health: Exploring the Connections

We assessed the relationships between peak oil and urban form, travel behavior, and public health.

Peak oil will affect the general economy, travel behavior, and urban form through income and substitution effects; however, because of the wide range of substitution possibilities, the impacts are likely to be gradual and relatively small. Furthermore, we suggest that changes in travel behavior and increases in urban density will have both favorable and unfavorable effects on public health.

To mitigate the adverse impacts and to maximize the positive effects of peak oil, we recommend that careful attention should be paid to urban design and public health responses for a range of urbanization patterns. (*Am J Public Health.* 2011;101:1598–1606. doi:10.2105/AJPH.2011.300192)

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URBAN PLANNING AND PUBLIC health arose in the age of coal, when soot filled the air, raw sewage overwhelmed rivers and streams, and infectious diseases spread rapidly in overcrowded tenements. Over time, such urban pestilence diminished dramatically, but the age of oil rendered a more immediate solution to the health risks of crowded cities: spread the city out, separate jobs from households, and build highways to facilitate driving between central city jobs, commercial uses, and low-density suburbs. This solution, of course, brought its own set of health consequences. As people spent more time in cars, they became less physically active and gained weight, spent less time with others, and became socially isolated.[1] As the age of oil comes to an end, therefore, many planners and health officials see a potential silver lining. Frumkin et al., for example, stated:

> Shifting transport from motor vehicles to other modes of travel—mass transit, bicycling, and walking—could yield substantial health benefits apart from reduced petroleum reliance. More physical activity, reduced air pollution, and reduced traffic-related injuries and fatalities are all beneficial to the public's health.[2(p16)]

But the anticipated changes in urban form—particularly increases in density—that make walking, biking, and other forms of physical activity more attractive, also come with health consequences and challenges. We address how peak oil might affect public health through changes in travel behavior and urban form. We present an economic framework for considering how peak oil might affect individual consumption, transportation, and residential location decisions. We then simulate the effects of rising oil prices on development patterns in the Baltimore–Washington region. Finally, we discuss how changes in urban form might affect public health through changes in travel behavior and urban density.

On the basis of economic theory, results from a simulation exercise, and a review of the literature, we suggest that peak oil is likely to result in changes in consumption patterns, travel behavior, and increases in urban densities, although these effects are likely to be gradual and small. Increases in density could in turn foster more physical activity, more social capital, and subsequent improvements in public health. However, increases in density could also have adverse effects, such as more exposure to pollution and communicable diseases and higher risks of injuries and crime. The net effect on public health is difficult to assess, but it is clear that such changes will present new challenges to both planners and public health professionals.

We conclude that urban areas in the foreseeable future will look much like they do today—regardless of when the production of oil peaks. Large swaths of low-density residential and employment development will remain, but the number and size of disparate pockets of mixed-use, high-density, and pedestrian-oriented development will increase. Which end of the intensity of development spectrum, or where along this spectrum of development patterns is optimal is probably less important than having appropriate design and public health responses for the entire development spectrum.

PEAK OIL, TRAVEL BEHAVIOR, AND URBAN FORM

According to the Association for the Study of Peak Oil and Gas,

> peak oil refers to the maximum rate of the production of oil in any area under consideration, recognizing that it is a finite natural resource subject to depletion.[3]

The concept of peak oil was first introduced by M. King Hubbert in 1956, who suggested that peak oil would occur sometime in the 1960s or early 1970s.[4] Although the date when oil extraction will peak remains the subject of debate, the fact that oil production will peak is now a generally accepted fact.

The potential far-reaching effects of peak oil on public health are subtle in some cases and dramatic in others. Frumkin et al. focused on 4 areas: medical supplies and equipment, transportation, energy generation, and food production.[2] Hanlon and McCartney suggested that peak oil would have sweeping implications for the creation of wealth, economic globalization, and geopolitics.[5] We agree that peak oil could have such far-reaching effects, but our focus is more narrow. Specifically, we focused on the effects of peak oil on public health issues that could stem from changes in travel behavior and urban form. We do not argue that changes in travel behavior and urban form will have the largest or most immediate effects on public heath, but we limited our focus to our areas of expertise. The structure of our argument is illustrated in Figure 1.

Peak oil will have significant impacts on the US and world economies primarily by changing incomes and relative prices. Among the economic effects are changes in travel behavior and urban form. Changes in travel behavior and urban form—as a result of the rising cost of automobile travel and urban land—will have distinct effects on public health. Here we focus on 4 aspects of public health: chronic disease, communicable disease, intentional injuries, and unintentional injuries. We recognize that by narrowing our focus we add many more caveats to our conclusions.

Two methodological limitations warrant early and explicit comment. First, we formulated our analysis and grounded our models in economic theory. Criticism of economic analysis abounds, especially of its underlying assumptions of rationality and perfect information, but few would argue that an analysis of the effects of peak oil based on standard economic theory offers no insights. Second, we focused our analysis of urban form primarily on density (and not other measures of urban form, such as diversity of uses and urban design). We did so for 3 reasons: (1) it is impossible to address the health impacts of every characteristic of urban form in a short journal article; (2) density, diversity, and design do not covary in strict proportions,[6] and if health impact assessments are to be used to evaluate urban form, it is important to isolate the effects of each; and (3) most importantly, economic theory suggests changes in oil prices will logically lead to increases in densities, not necessarily increases in diversity or improvements in design.

ECONOMIC EFFECTS OF PEAK OIL

It is difficult to overestimate the importance of oil to the US economy. According to the US Department of Energy, "Oil is the lifeblood of America's economy."[7] It supplies more than 40% of total US energy demands and more than 99% of the fuel use in US cars and trucks. The notion that oil supplies are limited is not new but has caused significant concern. But economic theory suggests that the effects of peak oil are governed by prices set in competitive markets and, thus, are likely to be less dramatic than many noneconomists anticipate.

Oil Prices

Many tend to think we will consume oil products at a constant or accelerating rate until they are gone. However, if supplies are limited and sold in competitive markets, prices will rise over time as oil supplies are depleted. This trend will encourage oil producers to look for more oil and develop substitute fuels on the supply side, and will encourage consumers to consume less, use alternative fuels, choose alternative modes of travel, or move to locations with greater accessibility on the demand side. If the supply is absolutely fixed, as in the case of oil, oil prices will rise continually over time, until supplies are gradually but eventually exhausted. As stated by Campbell and Laherrère:

> From an economic perspective, when the world runs completely out of oil is thus not directly relevant: what matters is when production begins to taper off. Beyond that point, prices will rise unless demand declines commensurately.[8(p78)]

The logic of steadily rising prices is unassailable in a world of perfect information and rational behavior. But recent bubbles in the technology, real estate, and financial markets make clear that we do not live in such a perfect world. The likely consequences will be continuing short-run fluctuations that reflect changing expectations and herd behavior. Recent experiences with other bubbles, however, also suggest that short-run bubbles eventually converge to long-term trends, and these trends are fairly predictable through standard economic theory.

General Consumption Patterns and Incomes

Oil is a major source of US energy consumption, and energy is an input into nearly every economic activity. Rising oil prices, therefore, are likely to have sweeping implications that reverberate throughout the economy. In economic theory, a rise in the price of a commodity can be analyzed in terms of income and substitution effects. Substitution effects stem from changes in the relative costs of goods, and cause the relatively more expensive good to be exchanged for the less expensive good; income effects stem from the general loss of purchasing power, which causes the demand for some goods to rise and some to fall. Both income and substitution effects for oil are potentially large.

The most direct response to rising oil prices will be reductions in the consumption of products derived from oil, such as gasoline. How much depends on its price elasticity: the ratio of relative

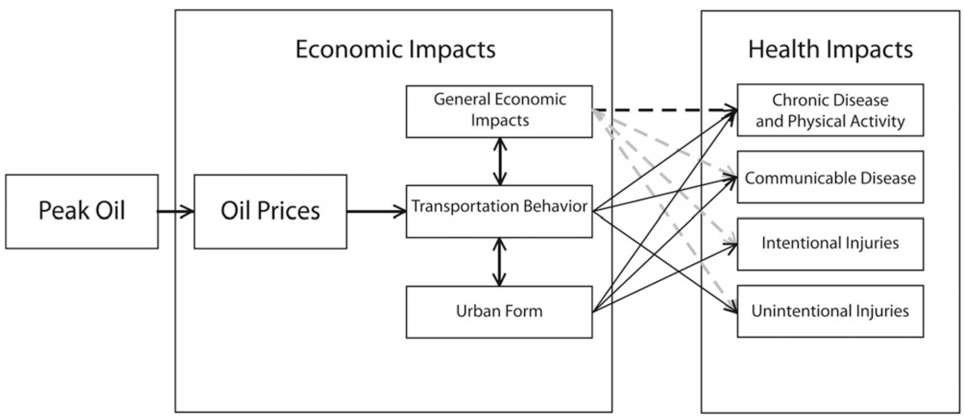

FIGURE 1—Selected linkages from peak oil to economic and health impacts.

change in quantity consumed to the relative change in prices or income. Most estimates of the price elasticity of demand for gas are relatively low—in the −0.25 range (consumption of oil falls by 2.5% for 10% rise in prices) in the short run and in the −0.6 range in the long run, although the variance in the estimates of both is large.[9] These estimates suggest that it will take large increases in the price of gas to reduce the consumption of gas. Furthermore, because the price elasticity of demand is low consumers will reduce their consumption of other commodities when gas prices rise.[10] Reductions in the consumption of these commodities reflect less on the extent to which they are complements or substitutes for gasoline than whether they are the kinds of commodities that are forsaken when real incomes fall. For some households, the choice of goods to forgo could be dinner and a movie; for others, it could be visits to the doctor, healthy foods, or prescription drugs. Although it is not the focus of this paper, we believe that the loss of household purchasing power, the loss of economic productivity, and the redistribution of wealth are probably the most important means by which peak oil could affect public health.[5]

Travel Behavior

Rising oil prices will unquestionably impact the transportation sector even if the price elasticity of demand for gasoline is low. An area of extensive research focuses on the "rebound effect" (i.e., increases in fuel efficiencies that partially or fully offset increases in fuel prices). This effect occurs when rising fuel prices stimulate the replacement of less-fuel-efficient cars by more-fuel-efficient cars or other improvements in fuel efficiency. Evidence from recent increases in fuel prices has shown that consumers fairly rapidly trade their heavy wagons, trucks, and sport utility vehicles for smaller, more-fuel-efficient sedans.[11] The long-run elasticity of fuel efficiency with respect to fuel price is estimated at 0.38 and the response to fuel prices has become increasingly dominated by changes in fuel efficiency rather than changes in travel.[12]

Another change in the transportation sector will be the substitution of fuel from oil to alternative fuel sources. Given current technologies, it is unlikely that alternative fuel vehicles will completely replace oil-based vehicles in the near future[2]; however, partial substitution is inevitable. How much consumers will be able to substitute alternative fuels for oil-based fuels is difficult to predict, but experience from countries such as Brazil, which generates about 30% of its transportation energy from biofuels, suggests that significant substitution is possible, even if not every nation has that option. In the United States, between 1995 and 2008 alternative fuel vehicles (not including gasoline hybrids) rose from 7000 to 1.2 million.[13] However, because alternative fuel vehicles are relatively new, little is known about their cross-price elasticities of demand.

Other responses to rising oil prices in the transportation sector include changes in travel behavior that may come with or without changes in the built environment. Travel behavior is usually expressed as a combination of trips taken, trip length, and mode choice. Experience during the spike in the price of oil in 2006 suggests that almost immediately residents will ride more transit, carpool more often, and telecommute more,[14] which represent changes in mode and reductions in trips. Once again, however, the elasticity of alternative modes with respect to fuel prices is quite low. The cross-price elasticity of transit ridership with respect to fuel prices is 0.22, with higher values for high-quality transit and longer-distance travel and lower values for basic bus service and shorter-distance trips.[15,16] More optimistic estimates suggest that higher parking fees or a road toll in urban areas generally cause 20% to 60% of automobile trips to shift to transit, whereas other trips will shift to nonmotorized modes, ridesharing, or be avoided altogether when travelers consolidate errands or shift destinations through trip chaining.[17]

Changes in transportation costs will also likely lead to other changes in consumption patterns. Consumption of locally produced goods, for example, could rise, whereas the consumption of imported goods could fall. This represents the substitution of commodities that require high transportation costs for commodities that involve low transportation costs. On the one hand, this may lead to increases in the consumption of fresh, organically produced local foods (petroleum being an important factor of production in fertilizers); on the other hand, it may lead to less consumption of fruits and vegetables that cannot be locally produced, if transportation costs outweigh economies of scale and competitive advantages of specialization.[18] Furthermore, substitution of agricultural land for biofuel production from food production is likely to occur.[19] Subsequent increases in food prices will result in disproportionate health impacts on low-income households and primarily on children.

Urban Form

Urban form takes many dimensions, including density, diversity, and design. How rising oil prices might affect all the various dimensions of urban form simultaneously is difficult to assess. However, economic theory suggests that rising oil prices will raise the cost of mobility and, thus, increase the value of accessibility. Therefore, as oil prices rise, households and firms have greater incentives to locate near the city center and to use less land. As a result, rising oil prices are likely to lead to more compact development and higher employment, population, and household densities. The effects of rising oil prices on other dimensions of urban form are far more difficult to analyze. Although other theories may provide clues, urban economic theory is largely silent about the causal mechanisms between rising prices and changes in design and diversity.

Thus, although the effects of rising oil prices on some elements of urban form are difficult to predict, the effects on density are unambiguous: rising oil prices will lead to more compact cities and increases in urban population and employment densities. However, these changes tend to occur very slowly. Urban form changes occur slowly over time for 2 distinct reasons: building stock durability and regulatory inertia. First, the built form is durable; only about 0.10% of the housing stock is added in each year.[20,21] Second, increases in density are constrained by local land use controls. Even when there is economic pressure for infill and higher-density development, higher densities are resisted by local opposition manifest in local zoning and subdivision regulations. However, this resistance is less common in the central city than it is in the suburbs.

EFFECTS OF RISING OIL PRICES ON DEVELOPMENT PATTERNS

To explore the potential effects of peak oil on urban form, we examined the effects of rising gas prices on development patterns by using advanced economic, land use, and transportation models we developed for the Baltimore–Washington area. This modeling system uses estimated relationships between economic, land use, and transportation variables to forecast future development patterns. Simulations are conducted by entering "exogenous" parameters (such as oil prices) into a computable general equilibrium model, which then produces estimates of impacts on the state and national economy.[22] The outputs of the econometric model are then fed into the land use and transportation models. The land use model is based on accessibility differentials of jobs and households whereas the transportation model is a traditional 4-step model albeit at a much larger geographical scale than is usually the case. These models subsequently produce forecasts of where people will live and work and how they will travel from home to work. More information on the modeling system is available at http://www.leam.illinois.edu/maryland.

In this exercise we used our modeling system to produce 2 scenarios: a business-as-usual scenario and a high-energy-price scenario. These scenarios were generated by entering 2 different time paths of energy prices into the economic model and following their impacts though the modeling system. The 2 fuel price paths are illustrated in Figure 2. The business-as-usual scenario assumes the time path of energy prices follows the Energy Information Administration's forecast of fuel prices and extends it to 2040. The high-energy-price scenario is predicated on fuel prices rising 1% faster than inflation (2%), reaching about $135 per barrel (2008 USD). The output of the econometric model is then fed into the land use and transportation models. The transportation model estimates travel times between various locations throughout the metropolitan area; the land use model uses travel times to compute employment accessibility that then determines household location choices.

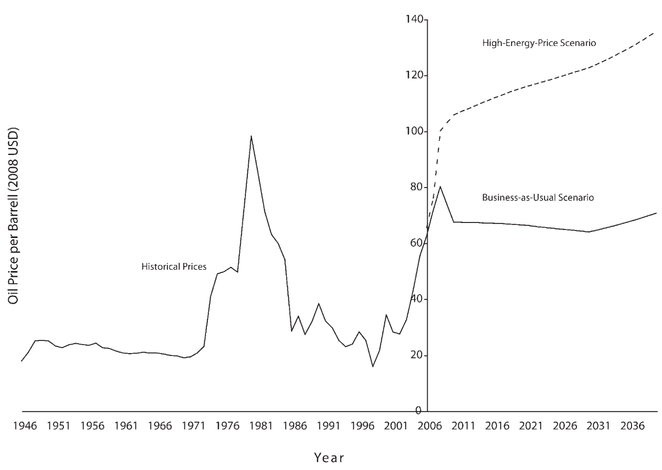

FIGURE 2—Historical and projected oil price paths, adjusted for inflation (2008 USD).

Figure 3 presents the difference in population densities in the Baltimore–Washington area between 2 alternative paths of fuel prices. High energy prices lead to changes in gross domestic product and industry mix at the national and state levels. When these changes are fed into the land use model, they lead to increases in population densities in the central parts of the region (i.e., in the central cities and inner suburbs of Baltimore and Washington), and decreases in densities in the outer parts of the region compared with business as usual.

To further illustrate differences between the 2 scenarios, we present in Figure 4 links in the road network that are congested in the 2 scenarios. Figure 4a highlights those links that are congested under the business-as-usual scenario but not the high-energy-price scenario. Figure 4b highlights those links that are congested under the high-energy-price scenario but not the business-as-usual scenario. As shown, and consistent with differences in development patterns illustrated in Figure 3, the congested links under the high-energy-price scenario are generally located in the inner parts of the Baltimore and Washington metropolitan areas, whereas the congested links under the business-as-usual scenario are located in the periphery of the metropolitan areas. Both of these figures illustrate the point that rising oil prices will lead to increases in densities and congestion in the inner parts of metropolitan areas, but decreases in the outer rings. A public health response must be responsive to both effects.

DENSITY AND PUBLIC HEALTH

The discussion thus far explores the relationship between peak oil and travel behavior and urban form—specifically urban density. The relationship between urban density and public health remains underexplored. The growing conventional wisdom in the public health and planning communities is that higher density development combined with greater mixes of uses and more pedestrian-friendly urban designs will have favorable health effects.[1,23] These favorable effects occur as people become less dependent on automobile travel, exercise more, become more physically fit, and are less subject to automobile-related consequences such as traffic accidents and exposure to air pollution. But the evidence on many of these relationships remains relatively weak, and increases in urban density—whether a result of peak oil, changing preferences, or public policy—could have other, heretofore underexplored, effects. We discuss the effects of rising population density on chronic disease, unintentional and intentional injuries, and communicable diseases.

Chronic Disease

Heart disease is among the leading causes of death in the United States and a contributing cause of heart disease is obesity caused in part by a lack of physical activity. For this reason, planners and public health officials have looked closely at the relationship between travel behavior and urban form. The finding that physical activity increases in dense, mixed-use, and pedestrian-friendly environments is the basis for the argument that peak oil

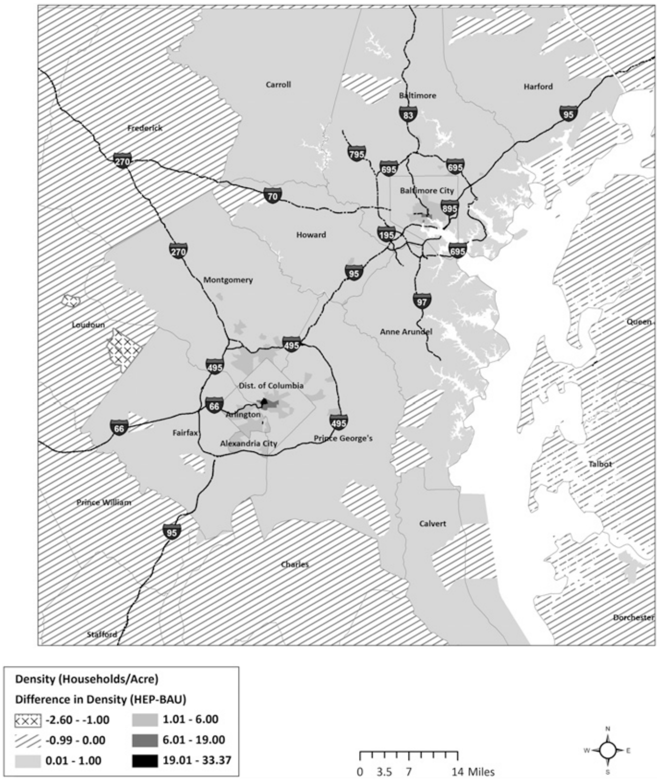

FIGURE 3—Differences in density between the high-energy-price (HEP) and business as usual (BAU) scenarios in the Baltimore–Washington region.

might have a silver lining.[24,25] But the debate on this issue is far from over. For example, after a meta-analysis of more than 63 studies, Feng et al. concluded that

> existing evidence does not identify a clear and strong role for built environmental risk factors with the possible exception of the county sprawl index and land use mix.[26(p6)]

Eid et al. suggested that the entire observed relationship between obesity and urban sprawl reflects the self-selection of the physically active into dense, mixed-use neighborhoods.[27] Furthermore, the overall level of physical activity is not necessarily greater in dense and diverse new urbanist neighborhoods than in conventional suburbs, though more outdoor physical activity is observed in the former.[28,29]

Peak oil could also affect the incidence of respiratory disease. If peak oil causes decreases in the consumption of oil-based fuels, then it might also increase air quality and decrease risks of respiratory disease.[30] This could occur both because of changes in fuel mix and because of reductions in vehicle miles traveled (VMT). But if we posit that substitution of fuels is likely in a rising fuel price scenario, we must be cognizant of the effects of alternative fuels relative to conventional ones. For example, switching from gasoline to E85 (85% ethanol) increases ozone-related adverse health effects by 4% in the United States.[31] On the other hand, many biofuel vehicles emit less carbon dioxide and carbon monoxide but have significantly higher nitrous oxide emissions.[32,33] Substitution of more-fuel-efficient vehicles for less-efficient vehicles, however, will likely reduce airborne pollutants.

The relationship between urban form and exposure to airborne pollutants is more complicated. Frank and Engelke provided a thorough overview of the relationship between urban form and respiratory and cardiovascular health.[34] Virtually undisputed are 2 facts: (1) more driving produces higher emissions of carbon monoxide, particulate matter, nitrogen oxides, and volatile organic compounds that combine to form ozone; and (2) higher levels of exposure to these chemicals adversely affect public health, especially for populations with chronic diseases such as asthma or other respiratory diseases. If higher urban densities decrease VMT, increases in density might increase exposure to vehicle-related air pollution for 2 reasons: (1) pollution emissions are not linearly related to VMT, and (2) increases in densities could expose more people to polluted air, which depends on the density–emission elasticity.[35]

The relationship between VMT and air emissions is complicated by the fact that cars emit more effluents at the start and the end of a trip than when they travel at constant speeds.[36] Therefore, although total VMT by car may diminish, emissions may increase because trips are shorter and made in more congested conditions. As shown in Figure 4, however, most of the links congested exclusively in the business-as-usual scenario are in the low-density periphery whereas the links congested exclusively in the high-energy-price scenario are in high-density areas, perhaps increasing human exposure.[37] However, as technology in catalytic convertors improves over time, these stop-and-go emissions may become less of a concern.

Furthermore, a growing body of research has identified the health trade-offs of mode choice within cities. Simulation exercises and empirical analysis suggest that walking and biking in cities provide measureable health benefits but also increase exposure to environmental pollutants, especially particulate matter.[38–41] In some cases, the physical activity benefits outweigh exposure risks. But air quality impacts are heterogeneous across income groups within cities. Lower-income neighborhoods, even with high walkability, have higher nitric oxide concentrations but lower ozone concentrations, and neighborhoods that are better off in terms of air quality are almost exclusively composed of higher-income households.[42,43]

The age of peak oil can bring with it stresses that affect subgroups of people differently, especially marginalized and low-income groups. Residential relocation closer to the employment centers could renew the housing stock thereby reducing the prevalence of asthma.[44] However, in the vulnerable populations, the loss of income because of rising fuel prices could force people into substandard housing exacerbating health disparities. On the other hand, the provision of social and public health services is likely to be easier in denser environments. This relationship suggests that we need to think carefully about the effects of physical, social environments and the provision of public health and social services in dense urban contexts.[45]

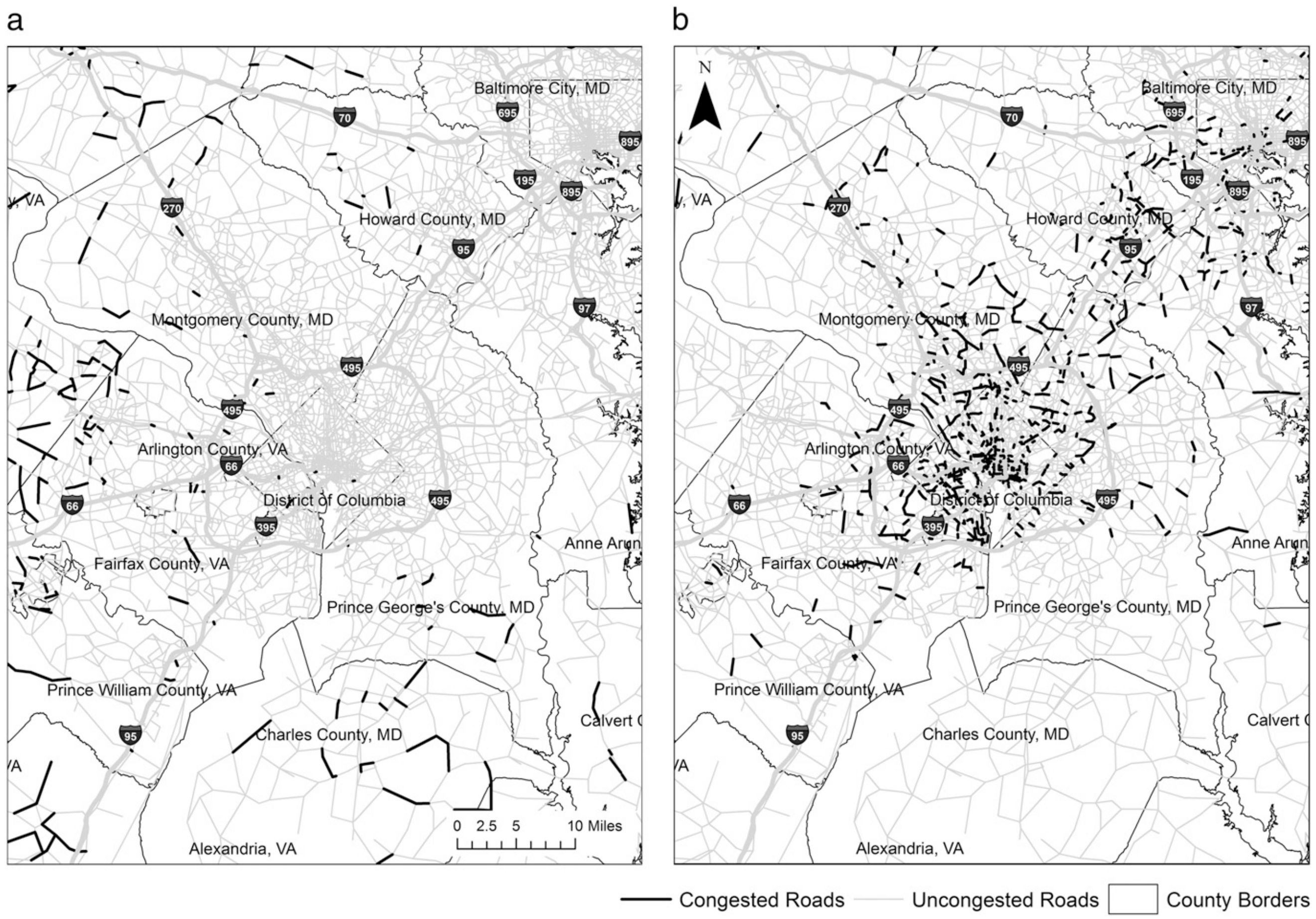

FIGURE 4—Differences in congested links between the (a) business-as-usual and (b) high-energy-price scenarios.

Unintentional and Intentional Injuries

Unintentional injuries come in many forms but a large share of unintentional injuries occurs in automobile accidents, which generally increase with VMT. For this reason, a considerable body of research has focused on the relationship between VMT and urban form. Vehicle miles traveled in total and per person have risen steadily in the United States until the recent spike in oil prices. When VMT decreased during the recent fuel price hike, substantial decreases in road fatalities were also observed, although this finding was partly a result of changing driving patterns (such as decreases in rural and leisure driving) rather than decreases in total driving.[46] In a recent review of studies on the effects of urban form on the rate of accidents and injuries, Ewing and Kreutzer concluded that density, design, and land use diversity (3 Ds) all can lower VMT per capita and, thus, potentially reduce travel-related injuries.[47] However, according to a recent National Academy of Science report, the effects of urban form on travel behavior are likely to be small,[28] and a more recent review by Ewing and Cervero suggests that density alone is the least likely of the 3 Ds to change travel behavior.[48]

Although perhaps small, changes in travel behavior are likely to include reductions in trips, changes in travel mode, and changes in travel routes. The net effect of these changes on accidents and injuries is difficult to predict. A reduction in trips is likely to reduce collisions of all kinds. Increasing density and mixing land uses are also associated with shifts in modes from automobiles to pedestrian, bicycle, and transit travel that have both positive and negative effects. Greater use of transit in place of cars is certain to reduce accident rates. But the substitution of motorcycles for cars is estimated to cause an additional 1500 fatalities per dollar increase in fuel prices,[49] even if accident rates remain stable.[50] Pedestrian accidents will almost certainly increase as pedestrian trips increase. Whether unintentional injuries will increase or decrease as oil prices rise is difficult to predict, but we can be certain that it will depend on where and how we design the intersections within and among modes of travel, the separation and design of facilities for particular modes of travel, and the behavior of travelers in each mode.[51]

Intentional injuries such as homicide and physical assault may also be affected by changes in urban form. The relationship between population density and crime is a longstanding but unsettled topic of research. Although positive relationships between crime and population density have been reported, some of these effects could reflect covariation in socioeconomic status. Rates of crime within cities have been declining since the 1970s, albeit nonuniformly.[52,53] In dense urban areas, crimes such as burglary, larceny without contact, and even rape tend to be lower because of more "eyes on the street,"[54] but robberies, larceny with contact, and motor vehicle theft tend to be higher in urban areas than in suburbs. Again, many of these effects may be attributable to changes in design and behavior patterns rather than increases in density.

In sum, the literature on the effects of increases in urban density on intentional and unintentional injury is inconclusive. Claims that peak oil will reduce transportation-related injuries are based on a weak association between density and VMT. Although the effects are small and tenuous, it seems reasonable to conclude that the combination of rising fuel prices and population densities in urban areas should produce less automobile travel. Slower travel speeds and better street design could also reduce both the incidence and severity of automobile, bicycle, and pedestrian crashes. On the other hand, higher rates of travel on motorcycles, bicycles, and foot introduce new risks. The relationship between density and crime is also inconclusive. Some crimes are more common in dense environments, although perhaps they can be mitigated through changes in behavior and improvements in urban design.

Communicable Disease

Empirical research on the effects of density on the spread of communicable disease in the United States is surprisingly sparse. There has been considerable research on whether high-density, mixed-use, and pedestrian-friendly forms of development engender social capital formation through, for example, increased social contacts via membership in religious organizations, civic engagement, and neighborhood interaction.[55] Also, many theoretical and computational models suggest that communicable diseases spread more rapidly with increases in social contacts.[56,57] However, little research has been done on whether the increases in density that facilitate the formation of social capital could also facilitate the spread of communicable diseases.

An early study that used simple correlation analysis found a close association between population densities in Honolulu and several measures of mortality and morbidity, especially rates of sexually transmitted disease.[58] In United States, as in developing countries, HIV is concentrated in inner cities where people have more sexual partners and intravenous drug use is high.[59] A significant association has been found between tuberculosis and housing density in Canadian First Nation communities[60] and in South Africa.[61] Fan and Song reported that mortality rates were higher in urban areas than they were in nonurban areas, and the "urban health penalty" for infectious diseases was higher for communicable disease than it was for other causes of death.[62] Urbanization results in increased groupings of susceptible populations (such as child care and hospice care), resulting in faster spread of infectious diseases.[63] These trends are likely to be amplified in a high-fuel-price scenario.

Communicable disease also spread via public transportation. Severe acute respiratory syndrome (SARS) and the avian flu, for example, were transmitted from Asia around the world via travel on airplanes.[64] If we posit that peak oil may result in mode shifts from single-occupancy vehicles to others such as public transportation, we have to be cognizant of increases in spreading risks.[65]

There is no doubt that improvements in the built environment, including advanced sewer and water systems, reductions in household size, and advancements in medicine would prevent a return to the conditions that were prevalent in cities during the industrial era. But increases in densities would also increase social contacts and perhaps spread infectious diseases. However, densification has attendant benefits. Targeted vaccinations coupled with surveillance are usually the right strategy to contain the spread of infectious disease.[56] These strategies are likely to be much more effective in dense urban environments than in rural areas.

CONCLUSIONS

The coming of peak oil is inevitable; it may have occurred already. But economic theory suggests that the depletion of oil will occur gradually as rising prices discourage the consumption of oil and encourage the production and consumption of alternatives. Because the price elasticity of demand for oil products is low, rising oil prices will likely lead to substantial reductions in purchasing power and the consumption of other goods.

Economic theory suggests that increases in the cost of transportation will lead to more compact urban development patterns and increases in urban densities. Simulation models of urban form corroborate these conclusions. However, because of the wide range of substitution possibilities and the resistance imposed by land use controls, the effects on urban densities—of rising oil prices alone—are also likely to be small.

Whereas increases in urban population densities will almost certainly reduce the destruction of sensitive environments and lower the consumption of energy, the effects of increases in density on public health are likely to be mixed. There are clear health benefits to more physical activity from walking and biking, and increased densities might make these forms of nonmotorized transportation more common. But increases in densities are also likely to bring new public health challenges with respect to intentional and unintentional injuries as well as chronic and communicable disease. Thus, improving or maintaining public health will require both public health and planning responses.

From a planning perspective, increased densities create even greater pressures to improve urban design. At the metropolitan scale this improvement will require channeling growth into transit-oriented, mixed-use centers that are pedestrian friendly and separated from automobile traffic. At the neighborhood level, it means designing neighborhoods to maintain "eyes on the street," thus minimizing exposure to crime. At the street level it means using context-sensitive design to minimize conflicts among pedestrian, bicycle, and vehicular movement.

From a public health perspective, increased densities also increase the need to change health behaviors. This change means even greater emphasis on behaviors such as washing hands, using condoms, and avoiding public places when contagious to minimize the spread of disease; eating healthy foods and keeping physically active to decrease the incidence of chronic disease; and taking appropriate cautions to avoid exposure to crime. Perhaps most importantly, it means recognizing that although increases in density could have some favorable behavioral effects, they will also bring about new public health challenges. These contraindications suggest that caution should be exercised before prescribing density as a treatment of the ailments of metropolitan America.

In short, even the silver lining that peak oil could foster more physical activity will not come without cost. As the price of oil rises, the price system will transmit this trend into falling real incomes, changes in travel behaviors, and increases in development densities. The effects on public health will depend on how successfully planners and public health officials respond with improvements in urban design and healthy behaviors. ■

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Contributors

N. Kaza completed the scenario analysis and wrote much of the economics section. G. Knaap supervised and organized the study and contributed to writing. I. Knaap contributed to the literature review relating to public health. R. Lewis contributed to the research and literature review relating to planning and density and created maps and graphics.

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Human Participant Protection

Institutional review board approval was not needed to complete this study because the data used were derived from secondary sources and were unidentifiable.

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