Scientific Research Publishing

Journal of Human Resource and Sustainability Studies, 2020, 8, 219-248
https://www.scirp.org/journal/jhrss
ISSN Online: 2328-4870
ISSN Print: 2328-4862

Human Health and the Transportation Infrastructure

Drew Pavlick[1], Ardeshir Faghri[1], Samantha DeLucia[1], Saumabha Gayen[2]

[1]Department of Civil and Environmental Engineering, University of Delaware, Newark, DE, USA
[2]Lyles School of Civil Engineering, Purdue University, West Lafayette, IN, USA
Email: faghri@udel.edu

How to cite this paper: Pavlick, D., Faghri, A., DeLucia, S., & Gayen, S. (2020). Human Health and the Transportation Infrastructure. *Journal of Human Resource and Sustainability Studies, 8,* 219-249.
https://doi.org/10.4236/jhrss.2020.83013

Received: July 6, 2020
Accepted: August 7, 2020
Published: August 10, 2020

Abstract

Since the invention of the car, the built transportation environment is becoming increasingly more automobile focused. The creation of auto-oriented roadways and increased automobile usage is in direct contrast with the decrease of more active transportation modes, such as walking, biking, or public transit transportation. Although personal automobiles may save users' time in traveling, there is a growing concern, backed by numerous studies, regarding the health effects directly and indirectly caused by increased automobile dependence and the auto-oriented transportation environment. The present report explores the many health related problems that are correlated with the current transportation environment, including reduced physical activity, obesity, respiratory problems, and mental health issues, particularly in the United States. The findings indicate that the modern built transportation system indeed influences many aforementioned problems, and that there must be engineering and societal responses to both encourage and allow greater opportunities for active transportation. The report further discusses the responses that have already taken place and planning measures to foster more active transportation in the future. Finally, it focuses on the development of a land-use planning health index, which would force land-use planners to identify active transportation needs and create a standard for the accessibility of active transportation within communities.

Keywords

Built Transportation Environment, Health Effects, Active Transportation, Health Index

1. Introduction

We humans have the unique ability to rapidly change the environment that we

live in, enabling us to drastically change the world. However, we have nearly forgotten that our surroundings have just as great of an effect on us. The things we build, such as houses, cities, and roads, in addition to benefitting society, change our behaviors as well. These man-made structures and networks make up the built environment. A subfactor within the overall built environment is the built transportation environment, which consists of the roads and paths that connect destinations and allow travel. The transportation environment we have created shapes our behaviors and creates habits that eventually become culture.

Our immense focus on easy automobile transportation over the past several decades has created a culture that ignores and disincentivizes more physically active modes of transportation, such as walking and bicycling. As more people use cars, they become cheaper and more prolific. This affects infrastructure planning, focusing more on driving and parking, less on walking and transit. Distances between destinations increase, further devaluing active transportation. Today, due to increased traffic and congestion, roads must be widened and maintained, requiring even more funding. By now, in most communities, car travel is easy, available, and also necessary. This self-reinforcing cycle is shown in **Figure 1**.

All this congestion and traffic pollutes the environment, costing people money and time. Mobile source pollution from car engines directly causes respiratory problems such as asthma and lung damage. Solitary commutes in private vehicles also play a role in reducing human interaction, which can contribute to mental health problems. The most dangerous health effect of car travel results from the disappearance of regular travel-related physical activity, which plays a major role in the obesity epidemic that is sweeping the nation. The Director of the CDC's National Center for Environmental Health warns us:

The diseases of the 21*st century will be "chronic" diseases, those that steal vitality and productivity, and consume time and money. These diseases: heart disease, diabetes, obesity, asthma, and depression, are diseases that can be moderated by how we design and build our human environment* (Jackson & Kochtitzky, Creating a Healthy Environment: The Impact of the Built Environment on Public Health, 2010).

The engineering field is only recently recognizing and addressing this problem which was first identified by the medical field. Over the past several years, there has been increasing recognition that the transportation environment, and more importantly, the overarching built capital (also referred to as the built environment), lays the foundation for community health. The built capital as a whole, defined as the "physical infrastructure that enables network communication and access to service and markets", can ultimately facilitate or impede productive activities within communities, which determine the health of its residents (Flora, Flora, & Gasteyer, 2016). In fact, it is suggested that this built capital and its transportation infrastructure are more influential towards health effects than the other types of community capitals, including natural, social, and financial capital

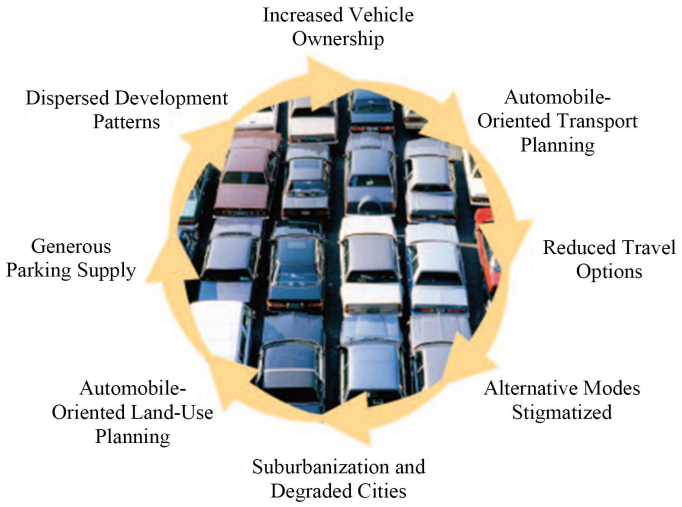

Figure 1. Cycle of automobile dependency (Scott, Beck, & Rabidou, 2011).

(Chi, Shapley, Yang, & Wang, 2019). It is time engineers and planners communicate with public health professionals to properly improve the built capital in communities to deal with the problems caused by the automobile-biased culture of the United States.

2. History

Urban planning and the deliberate design of population centers is an ancient practice, extending several thousands of years into the past. However, Hippodamus of Miletus, a Greek philosopher during the fifth century BC, is considered the "Father of Urban Planning." He is credited with the 451 BC work "Urban Planning Study for Peiraeus" and today, the grid city layout is known as Hippodamian planning. He went on to develop plans for Peiraeus, Thurii, and Rhodes with the main desired health effect of reducing disease through the removal of waste.

Some of these advancements in waste removal may have been forgotten during the Dark Ages, when terrible epidemics ravaged the world. These problems were compounded by the Industrial Revolution, which saw factories, mills, and chemical plants spring up in urban centers, spewing pollutants into the air while drawing impoverished workers into overpopulated communities. These filthy conditions led to outbreaks of diseases including yellow fever, cholera, typhoid fever, typhus, scarlet fever, and diphtheria. It wasn't until the late 1800s when sanitary system reform began. City residents also had to contend with deadly smog events caused by warm air trapping the cooler, dirtier air in the city. Notable events occurred in Donora, Pennsylvania, St. Louis, Missouri, and London, where a 1952 smog event lasted four days, killed an estimated 4000 people, and sickened 100,000 more. Events like these led to changes in zoning regulations in order to separate residential buildings from industrial pollution.

The proliferation of the automobile and New Deal era policies led to population thinning of American cities (**Figure 2**). Henry Ford's Model T and the af-

fordable, assembly-line car allowed the masses to leave the cities, yet retain the ability to commute back for work. The National Housing Act of 1934 and the creation of the Federal Housing Administration further assisted the exodus. Suburbs began to spring up all over the country, close enough to cities for drivable commute, but free of their pollution and disease. The American Dream fueled this culture change, and it was realistic; middle-class families could own their suburban home and drive to work in their own car. The next step to suburban America was the Interstate Highway System, championed by President Eisenhower in the late 1950s. These highways improved the regional connectivity and expanded suburban development. The reduced population densities, combined with medical advancements, seemingly brought an end to the epidemics of the past.

However, as funding poured into this auto-based transportation system, active modes like walking and biking were largely ignored. As previously mentioned, this contributed to the obesity epidemic. Transportation planners and engineers were focused on facilitating car travel by minimizing collisions, increasing speed and capacity, and improving driver comfort. Road layouts of residential areas became less connected and less grid-like in favor of quieter and more isolated cul-de-sacs (**Figure 3**), which concentrated traffic on the connecting roads, making them more dangerous. The zoning laws that separated land-uses led to increased distances from home to work, school, and shopping, further necessitating driving. This separation required larger stores and residential developments as well as more parking. It is estimated that the United States now has a total paved area roughly the size of Georgia (Jackson, The Impact of the Built Environment on Health: An Emerging Field, 2003).

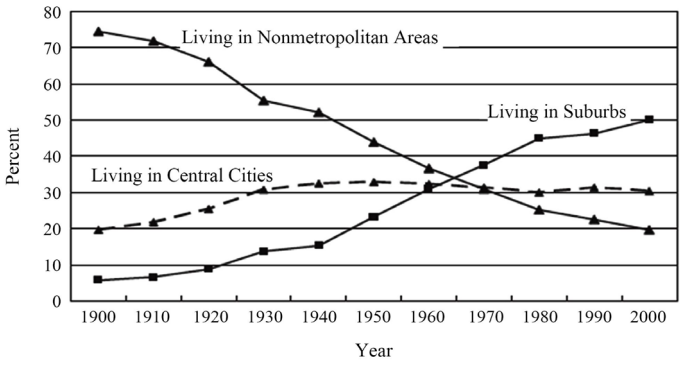

Figure 2. Suburbanization trends (US Bureau of the Census).

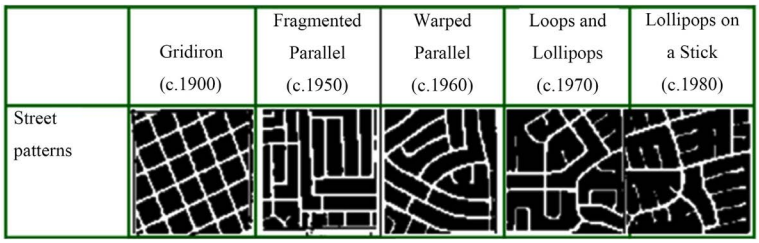

Figure 3. Evolution of residential street patterns (Southworth & Owens, 1993).

The 1940s saw the development of the field of ekistics, created by Greek planner and engineer Konstantinos Doxiadis. Ekistics is the science of human settlements and aims to understand how humans fit into the environment and reduce chaotic communities. The exploration of this field laid the groundwork for the New Urbanist movement of the late 1980s and 1990s. New Urbanist, or neo-traditional, communities aim to control suburban sprawl by mixing land-uses to increase density so that people can live, work, and play within the community. They promote active transportation over car travel by reducing the built environment to a more human level and decreasing distances between attractions. One of the motivations behind the New Urbanist movement was reducing obesity, among other beneficial effects. Today the effects of obesity are studied in great detail from the medical perspective, but more research centered on its relationship to the built environment needs to be completed.

3. Obesity

Obesity is defined as having a Body Mass Index of 30 or greater. Body Mass Index, or BMI, is a common statistic for analyzing body fat and can be calculated with the equation $\mathrm{BMI} = \frac{\mathrm{mass}(\mathrm{kg})}{[\mathrm{height}(\mathrm{m})]^2}$. The BMI classes are listed in **Figure 4**.

The CDC estimated in 2012 that 35.7 percent of American adults and 16.9 percent of children and adolescents are obese (US Department of Health and Human Services, 1996). These are only the percentages of the obese; over two-thirds of Americans are overweight. Since 1976, the rate of obesity in children has tripled (Rahman, Cushing, & Jackson, 2011). The effects of obesity are well-known and dangerous. These include increased risks of:

- Coronary heart disease
- Type 2 diabetes
- Cancers (endometrial, breast, and colon)
- Hypertension
- Dyslipidemia
- Stroke
- Liver and gallbladder disease
- Sleep apnea and respiratory problems
- Osteoarthritis
- Gynecological problems

Classification	BMI
Underweight	<18.5
Normal	18.5-25
Overweight	25-30
Obese	>30

Figure 4. BMI classes (Centers for Disease Control and Prevention, 2011a).

The obesity epidemic in the United States is the greatest health issue facing Americans today. Data collected by the Centers for Disease Control and Prevention show that in only 20 years, every state has seen dramatic increases in obesity rates (**Figure 5**). The average person in 2012 was 10 to 12 pounds heavier than they were in 1985 (Cutler, Glaeser, & Shapiro, 2003). More recent CDC data shows that the prevalence of obesity has increased from 30.5% to 42.4% between 2000 and 2018 (Centers for Disease Control and Prevention, 2020).

This problem is essentially an energy imbalance; people are taking in more energy than they expend. On the intake side, portions are larger and lower in nutritional value. As for expending, people are less active at home and at work due to modern inventions such as the elevator, dishwasher, automobile, and computer. Low activity white-collar jobs have increased at the expense of more labor-intensive jobs. The obesity epidemic has many causes, but this report will focus on the built environment's role.

The Surgeon General warns that obese individuals have a 50 to 100 percent higher chance of premature death than normal individuals. It is estimated that 300,000 deaths may be attributable to obesity each year (Office of the Surgeon General, 2007). Another estimate claims that the financial cost of obesity in the United States annually is in excess of $140 billion. This includes healthcare costs and lost wages due to illness, disability, and premature death (Urban Design 4 Health, Inc., 2010). Obesity is so prolific that a 2005 study warned that this may be the first time since data was collected that children have a shorter life expectancy than their parents (Olshansky, Passaro, Hershow, Layden, & Carnes, 2005). Obesity in the United States has been proven to be dangerous, with many causes and no single solution.

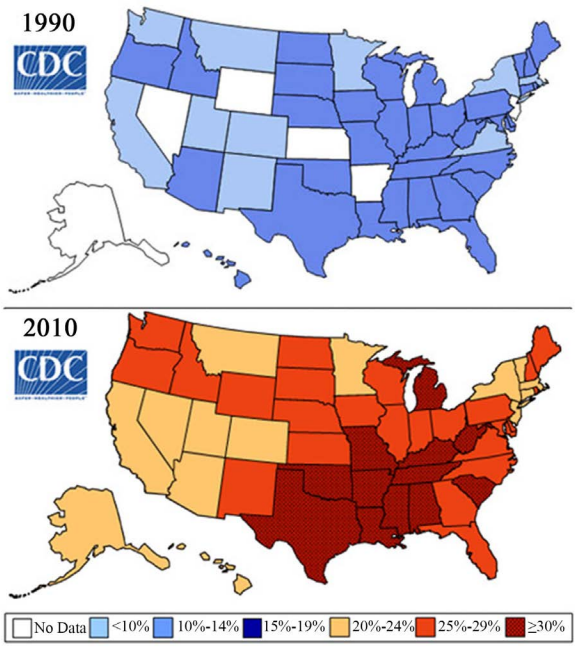

Figure 5. BMI > 30 in US adults (Centers for Disease Control and Prevention, 2012).

4. Physical Activity

The built transportation environment has a large influence on the physical activity levels and overall health of Americans. The auto bias of the current transportation network has reduced active transportation modes which were major sources of physical activity in the past. The effects of reduced physical activity are increasingly apparent in children, who generally no longer walk to school due to distance and danger to pedestrians.

Figure 6 shows two curves relating activity and health. Curve A shows the dose-response pattern currently used to recommend activity levels, while curve B approximates mortality rates to activity. According to the CDC's 2008 Physical Activity Guidelines for Americans, it is recommended that adults exercise moderately for 150 minutes per week or exercise vigorously for 75 minutes per week to receive important health benefits. Most important among these benefits are a reduced risk of dying prematurely, dying from heart disease, developing diabetes, and developing high blood pressure (US Department of Health and Human Services, 1996).

Health benefits of physical activity specific to children include strengthening of the skeletal structure and improved self-esteem and confidence (Bailey, McKay, Crocker, & Faulkner, 1999) (US Department of Health and Human Services, 1996). Studies have shown that active people have lower medical costs, fewer hospital stays, use fewer medications, miss fewer days of work, and are more productive at work than their inactive counterparts. Despite all of the evidence of benefits, Americans are not meeting the recommended levels of activity, and it appears to be getting worse. According to the 2000 Behavioral Risk Factor Surveillance System survey conducted by the CDC, only 26.2 percent of Americans reach the recommended levels. A quarter of Americans reported no physical activity whatsoever on this survey. The highest rates of physical inactivity are concentrated in the southeast states (**Figure 7**), the same location as the highest rates of obesity (**Figure 4**).

Both **Figure 4** and **Figure 7** indicate that the greatest physical inactivity rates and the greatest obesity rates occur in southern states, where communities tend to be mostly rural and have higher poverty as well. Recent studies concur with this correlation, identifying that people in rural dwellings have significantly less opportunities for active modes of transportation, as well as active leisure opportunities. One such study attributes the disproportionally lower physical activity among rural residents to a lower amount of built environment networks, most prominently sidewalks, parks, and trails (Park, Eyler, Tabak, Valko, & Brownson, 2017).

5. Travel

Travel is a simple way to add considerable physical activity to daily life. Based on demand theory, travelers base their behavior and mode choice on the value to the traveler. A person will drive to a destination if the cost of driving is less than

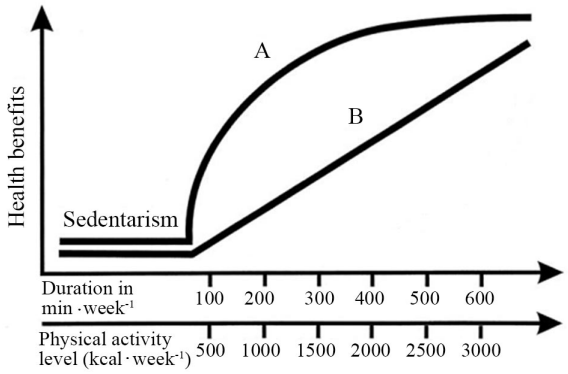

Figure 6. Physical activity vs. health (Bouchard, 2001).

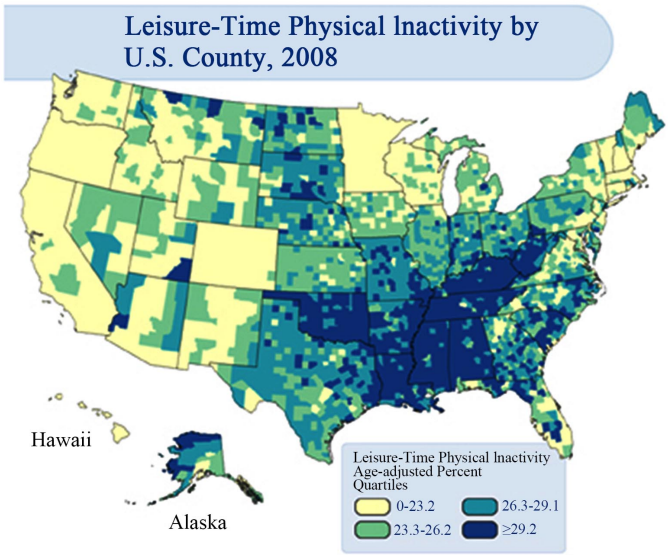

Figure 7. Physical inactivity in US (Centers for Disease Control and Prevention, 2011b).

the cost of other modes. Factors that make up this cost are time, distance, and comfort. For example, if a person wanted to travel to a store .25 direct miles away, walking would be less costly than driving if they were forced to take a circuitous, congested route by car. However, if the walk route was dangerous or unappealing, a car might be a less costly mode. The increased availability, accessibility, and capacity of roads, as well as relatively low prices of fuel, all reduce the cost of car travel. They also devalue active transportation modes by making them dangerous, unappealing, and more costly by comparison. This has reduced rates of walking and bicycling while dramatically increasing automobile use (**Figure 8**). The Future of Transportation National Survey conducted in 2010 found that 73% of Americans felt as if they had no choice but to drive as much as they do (Weigel & Metz, 2010).

Recent studies have shown that the casual pedestrian will walk distances up to one kilometer (.62 miles). People more conditioned will go further; in Europe, where walking is more accepted as a legitimate transportation mode and part of

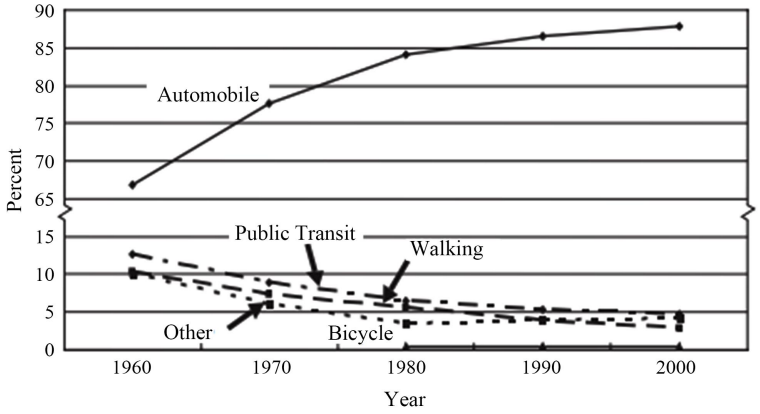

Figure 8. US work trips by mode (Pucher & Renne, 2003).

the culture, pedestrian journeys go up to about 3 km (1.86 mi) (O'Flaherty, et al., 1996). According to the 2009 National Household Travel Survey, 28 percent of all trips are one mile or less and 50 percent are less than three miles. Of the trips under one mile, 60 percent are driven (Federal Highway Administration Office of Policy). These short distances should be walkable or bikeable instead.

Having useful services and destinations nearby is important in minimizing auto use. However, not everything can be incorporated into a residential area. An older (1992) study looked at the travel patterns of residents of four communities with varying degrees of local and regional accessibility. It found that the two communities with grid street layouts and high local accessibility had significantly higher utilitarian walking trips than their low local accessibility counterparts, regardless of their regional accessibility.

However, the number of regional trips was similar throughout the sample, implying that some local trips are in addition to regional trips, rather than replacing them (Handy S. L., 1992). A more recent study in 2005 used a matched pair of communities in North Carolina to examine travel. It found that the two communities, one neo-traditional and one conventional, had similar numbers of total trips. However, it also found each household in the neo-traditional community had:

- 1.6 fewer auto trips per day
- Lower automobile trip rate (78.4 percent vs. 89.9 percent)
- 14.7 fewer vehicle miles travelled (VMT) daily
- 1.8 fewer daily external trips
- Higher internal trip capture (21.4 percent vs. 5.3 percent) (Khattak & Rodriguez).

A 2011 study echoed these results, finding only 33.6 percent of internal trips in neo-traditional developments were by car, compared to 83 percent in conventional developments (Green, et al., 2011). A 1994 study examining travel records from Palm Beach, Florida and found sprawling suburban households generate almost 67 percent more vehicle hours of travel per person than a city household. It recommends internalizing commercial and industrial land-uses rather than

improving the pedestrian or transit infrastructure to minimize time spent in cars (Ewing, Haliyur, & Page, 1994). Another 2011 study looked into walking rates for residents moving into a mixed-use development near Atlanta. The mostly young, educated, female respondents reported 46 to 50 percent increases in walking for recreation and fitness and 44 to 84 percent increases in walking for transportation as well as reduced auto travel (Mumford, Contant, Weissman, Wolf, & Glanz, 2011).

Children are a unique group as they must get to school almost every day, a location typically closer to home than a parent's workplace. In recent years, more and more children are being driven to school by private vehicle or school bus rather than walking. This is partially because newer schools are likely to be larger and at the edge of communities, rather than inside them. These "edge" schools are either too far for children to walk to or too far for parents to allow walking permission, causing more driven trips. In some places, up to 21 percent of morning traffic is from parents driving their children to school (National Safe Routes to School Task Force, 2008).

In 1969, 48 percent of children ages 5 to 14 walked or biked to school regularly, but by 2009, this number was only 13 percent. Additionally, in 1969, 89 percent of children who lived within one mile of their school walked or biked, but in 2009 only 35 percent did so (National Center for Safe Routes to Schools, 2011). In South Carolina, students are four times as likely to walk to a school built before 1983 than a newer building (**Figure 9**) (Kouri, 1999). A 2007 study in the Atlanta region found that commercial and recreational areas within one kilometer of home and residential density were predictors of walk rates in children. Residential density, recreation space, and number of cars were the strongest predictors. Older children ages 12 to 15 were more likely to walk than younger children and were more affected by the factors measured (Frank, Kerr, Chapman, & Sallis, 2007). Reduced active transportation rates have been compensated for by increased busing, an expensive alternative. Sometimes this requires a cut in other programs, and physical education programs are usually among the first to go, which reduces physical activity rates even further.

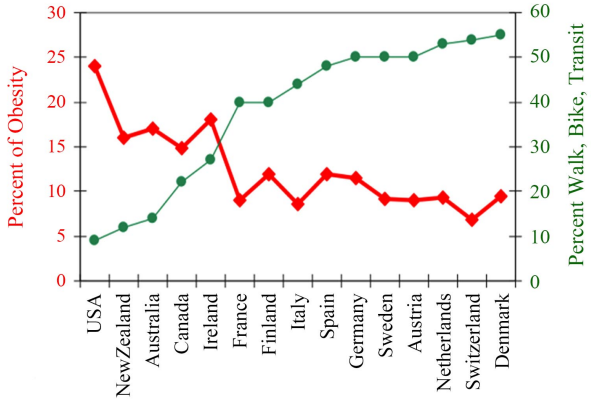

Figure 9. Worldwide obesity vs. travel mode (Pucher, 2009).

Bicycling is another active travel mode that can be harnessed for distances too great to walk; however, little research exists relating cycling rates to the built environment. A 2010 study in Vancouver attempted to find which built environment factors encourage bicycle trips rather than auto trips. It found that even terrain, high intersection density, fewer arterials and highways, more bicycle signage, more traffic calming measures, cyclist-activated signals, greater land-use mix, higher population density, and more local commercial, educational, and industrial land uses all enhanced rates of bicycle travel (Winters, Brauer, Setton, & Teschke, 2010).

It has been shown that transit travel and active modes are synergistic, each increasing as the other does. One study found that using public transportation rather than a personal automobile increased energy expenditure 124 Calories per day, enough to lose one pound of body fat in six weeks (Morabai, et al., 2010). Transit travel is much more prevalent in dense urban areas than in areas of lesser density, but is an important mode to consider when travelling. While it does not match the health benefits of purely active travel, active travel is usually involved with public transit, whether it be walking to a bus stop or cycling to a train station.

Americans tend to rely on the automobile almost exclusively for travel, virtually cutting out active transportation modes from their lives. Active transportation like walking and cycling are not sedentary, like driving, and allow physical activity in daily life. This physical activity gives numerous health benefits, including prevention of obesity and the health problems that go along with it. When compared to nations that have higher rates of active transportation, the link to obesity is easily seen (**Figure 9**).

6. Built Environment Correlations

There have been several recent studies linking measures of the built environment to physical activity. A 2005 study used objective measures of both the built environment (land-use mix, residential density, and street connectivity) and physical activity (using accelerometers). It determined that people in the highest quartile of their "walkability index" were 2.4 times more likely to meet the CDC recommendations for physical activity than those in the lowest quartile (Frank, Schmid, Sallis, Chapman, & Saelens, 2005). A study that compared a neo-traditional community to a similar conventional one found that the number of active transportation trips was 2.4 times higher in the neo-traditional community (Rodriguez, Khattak, & Evenson, 2006). The 1992 study of four developments found that while the high local accessibility area had more utilitarian walking trips, the leisure walking trips remained similar throughout the population (Handy S. L., 1992). The Neighborhood Quality of Life Study, run by esteemed doctors in several fields, found a significant correlation between walkability index and both BMI and active transportation (Frank, et al., 2006).

Other studies were able to directly link built environment factors to obesity

and health. A 2004 study of the Atlanta region found land-use mix to be the strongest contributor to obesity. Each quartile increase in land-use mix showed a 12.2 percent drop in obesity rates. It also found that each extra hour in a car daily resulted in a six percent increase in likelihood of obesity. Every extra kilometer travelled by foot showed a decrease of 4.8 percent in obesity rates (Frank, Andresen, & Schmid, Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars, 2004). A 2003 study compared sprawl measures to health status data obtained through the CDC's annual Behavioral Risk Factor Surveillance System (BRFSS) survey at the county level. It found that people living in sprawling counties walked less for leisure, weighed more, and had higher rates of hypertension.

While these differences were small, they were statistically significant (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003). Another study used the same sprawl index to examine its relationship to chronic health problems in metropolitan areas. It found an increase of 96 chronic medical problems per 1000 residents from one standard deviation below the average to one above. This is roughly equivalent to the population aging four years (Sturm & Cohen, 2004). A 2004 study used a different urban sprawl index and found that an increase of one in the urban sprawl index (1 - 100 scale) resulted in a 0.5 percent increase in obesity rates, and a 0.2 percent increase in overweight rates (Lopez, 2004). Another study of the Chicago metropolitan area showed that people living closer to the city have slightly lower BMIs than people in further suburbs (Metaxatos, 2011).

Perhaps the most exhaustive study regarding the built environment and its effects on human health was done in 2005 in King County, Washington. The LUTAQH (Land Use, Transportation, Air Quality, and Health) was based on a similar study done in Atlanta, the SMARTRAQ program. Important findings include:

- Compact, varied, connected land uses reduce auto use, improve efficiency and air quality.
- Walking rates increased with higher connectivity and more varied retail.
- Transit and walking are synergistic.
- Vehicle miles traveled are 26 percent lower in connected areas than sprawling ones.
- Compact, varied, connected land uses have lower emissions.
- The most walkable areas have lower obesity and higher activity.

It found that each quartile increases in intersection density results in a 14 percent increase in non-work walking trips. These trips increase 19 percent when the number of retail establishments increases one quartile and increase 23 percent when residential density increases the same. Perhaps the most valuable finding from this study is the principle that more attractions are better than large ones as far was health and reducing auto use are concerned. The "bigger is better" design that creates fewer, larger attractions contributes to the travel behaviors that affect health and should be avoided when possible.

Communities that are more walkable and less auto-oriented allow residents more opportunities for physical activity. These communities tend to have better street connectivity, higher residential density, and a greater mix of land-use, fostering active transportation modes, which contribute to more active transportation. This increase in physical activity can help reduce obesity in the United States, which may improve quality of life, save lives, and offer large financial returns. However, these communities are rare amidst the sprawling auto-focused suburban developments, all connected by large, dangerous highways. This has contributed to the obesity epidemic that is ravaging the health of American citizens.

7. Respiratory Health & Air Quality

Increased vehicle usage stemming from the built environment degrades the air quality of the United States, leading to respiratory health problems. Combustion engines in automobiles are an enormous source of air pollution. When fossil fuels and petrochemicals are burned, dangerous pollutants are released into the air including carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter, which contributes to ozone formation and global warming. Advancements have been made in both emission control and engine efficiency, but more people are using automobiles, continuing to release large amounts of contaminants. The Environmental Protection Agency estimates that motor vehicles emissions contribute 51 percent of CO_2, 34 percent of NO_x, and 10 percent of fine particulate matter (Office of Air Quality Planning and Standards, 2001). These chemicals cause a multitude of health problems in the large populations that are exposed to them. While it takes extremely heavy pollution like the London smog events to cause death in otherwise healthy people, more at-risk populations, such as children, the elderly, and those with preexisting respiratory conditions, are more susceptible at lower levels.

Asthma is the most prolific respiratory condition in the United States. Additionally, the CDC estimates that asthma rates have increased from 7.3 percent in 2001 to 8.2 percent in 2009 (Hendrick, n.d.). The number of Americans diagnosed with asthma doubled from 1980 to 1994 (Petersmarck & Wilkerson, 2003). Ground-level ozone is closely tied to asthma. A landmark CDC study was conducted in Atlanta during the 1996 Olympics. In order to control congestion, the city-imposed regulations limiting vehicle usage in the downtown area. These led to a 22.5 percent decrease in traffic counts and a 27.9 percent decrease in ozone concentrations. During the seventeen-day analysis period, asthma-related hospitalizations were reduced by 41.6 percent (Friedman, Powell, Hutwagner, Graham, & Teague, 2001).

The LUTAQH study found that in order for a location to receive significant air quality improvement, 150,000 square feet of retail is required within one kilometer. Another study of the Puget Sound region found significant relationships between built environment measures household density, work tract em-

ployment density, and street connectivity and vehicle emissions (Frank, Stone Jr., & Bachman, Linking Land Use with Household Vehicle Emissions in the Central Puget Sound: Methodological Framework and Findings, 2000). Several other studies have been able to significantly link greater mixing of land use, higher residential density, and greater street connectivity to lower per capita emissions of VOCs and NOx (Frank & Engelke, Multiple Impacts of the Built Environment on Public Health: Walkable Places and the Exposure to Air Pollution, 2005) (Frumpkin, Frank, & Jackson, 2004).

The built transportation environment forces people to drive more to get to desired destinations. More driving and use of combustion engines raise levels of ozone, carbon monoxide, nitrogen oxides, volatile organic chemicals, and particulate matter. These pollutants are inhaled by those exposed, inflicting damage on their lungs and respiratory systems, leading to chronic pulmonary problems like asthma.

8. Social Capital & Mental Health

Mental health and social capital are harder to study than obesity and physical health. Proponents of New Urbanism argue that car travel is an anti-social activity that reduces the number of interactions between members of a community, which would otherwise occur during walking. The isolation can also lead to mental health issues. Stress, a common factor in many mental health problems, has been linked to commuting time, which is significantly higher in suburbs. Stress during commuting can lead to road rage, which has been linked to suburban sprawl, higher in areas with limited transit opportunities and lower in areas with sidewalks, grid street layouts, and less time spent driving (Handy, Boarnet, Ewing, & Killingsworth, 2002). These mental issues can manifest themselves physically and do further damage. In his 2000 publication, Harvard professor Robert Putnam says:

The more integrated we are with our community, the less likely we are to experience colds, heart attacks, strokes, cancer, depression, and premature death of all sorts … Over the last 20 *years more than a dozen studies … have shown that people who are socially disconnected are between* 2 *and* 5 *times more likely to die from all causes, compared with matched individuals who have close ties with family, friends, and community* (Putnam, 2000).

The Director of the CDC's National Center for Environmental Health even says, "for treatment of relatively mild cases of anxiety and depression, physical activity is as effective as the most commonly prescribed medications" (Jackson & Kochtitzky, Creating a Healthy Environment: The Impact of the Built Environment on Public Health, 2010).

Social capital is generally defined as the value and strength of the interpersonal relationships and social networks within a community. A neighborhood with little social capital is not connected, trusting, or involved politically, and is more prone to crime and vandalism. A Dutch study found that social capital was re-

sponsible for 10 percent of variance in crime (Akcomak & ter Weel, 2008). Increased social capital encourages residents to take more ownership and involvement in the community. This can be achieved by beautifying the environment and improving social networks and interactions. One example is the Paterno Trivium, a small "pocket park" in the Hudson Heights part of New York City. Built in a dangerous intersection to increase pedestrian safety it has since become a social gathering place. When troublesome teenage skateboarders started to use the park, its protectors enlisted their help to keep it clean rather than involving the police. The skateboarders became more attached to the park and worked to keep it maintained (Mikkelsen, 2004).

Several studies have tried to quantify the social capital based on certain measurable factors. In the previously mentioned publication by Dr. Robert Putnam, he identifies the trend in national social capital through measures of civic engagement. This includes data on voter turnout, attendance at parent-teacher association meetings, and attendance at religious or professional organizations. From the 1960s to the 1990s, the US has seen a drastic 10 - 20 percent decrease in participation and involvement in the activities listed above, suggesting a significant decline in community networks that contribute to social capital (Putnam, 2000).

A 2002 report by Robert Sampson compiled information from over 40 reputable studies conducted over the period from the mid 1990s to 2001 in order to find various indicators of what at the time was called "neighborhood effects". These measures mostly included quantifiable crime, violence, poverty, and health problems (Sampson, Morenoff, & Gannon-Rowley, Assessing "Neighborhood Effects": Social Processes and New Directions in Research, 2002). However, the more important finding underlined by all these studies was the geographical concentration of these problems, which results in concentrated poverty, and subsequently, concentrated affluence (Sampson, Morenoff, & Earls, 1999; Wilson, 1987). This contributes to the socioeconomic and racial segregation that has been studied in great detail, culminating in huge disparities in social capital.

To find the connection between residential layout (the transportation environment) and social capital at the neighborhood level, many studies compared matched pairs of residential developments (neo-traditional and conventional). A 2009 study of Orenco Station, a neo-traditional community in Portland, Oregon, revealed data supporting New Urbanist claims. Residents of Orenco Station and three nearby conventional communities were asked to compare their current neighborhood to places they have lived in the past in terms of friendliness, sense of community, and group participation. The Orenco Station residents had the highest rates of people that responded more friendly, more community, and more group participation than previous homes (Podobnik, 2009). A 2003 study in Galway, Ireland, also supported New Urbanist ideas. The author categorized eight neighborhoods as City Center/Near City Neighborhoods, Older/Mixed Use

Suburbs, or Modern/Automobile Dependent Suburbs and surveyed residents to measure familiarity with neighbors, political participation, trust, and social participation. He states:

The results are clear and consistent: *the more places respondents report being able to walk to in their neighborhood*, *the higher level of social capital. This relation suggests that walkable*, *mixed-use neighborhoods are better generators of social capital than are modern*, *car dependent suburbs … residents living in walkable*, *mixed-use neighborhoods are more likely to know their neighbors*, *to participate politically*, *to trust others*, *and to be involved socially* (Leyden, 2003).

A 2004 study compared Kentlands, a neo-traditional community in Maryland, to a similar conventional neighborhood to determine differences in sense of community. Its authors concluded, "Kentlands respondents more strongly identify with their community, find its distinctive physical character more satisfying, feel more attached to the community, and have greater appreciation for local services and natural features in their walkable vicinity" (Kim & Kaplan, 2004). However, there is not a consensus on the success of New Urbanism with regards to social capital. A 2006 study of a Portland area New Urbanist development found no significant improvement in social capital over two conventional developments in the area (Dill, 2006). A more comprehensive 2011 study of 17 matched pairs discovered a 4 percent higher social cohesion and trust scores in neo-traditional developments than conventional ones, but this difference disappeared when demographic differences were controlled for (Green, et al., 2011).

The link between mental health and the built environment is less clear. A 2004 study done by metropolitan area found no significant association between sprawl index and depression and anxiety (Sturm & Cohen, 2004). However, in a 2003 literature review, the author found that major built environment factors that contribute to mental health are house type, floor level, housing quality, neighborhood quality, crowding, noise, indoor air quality, and light, mostly indoor factors not related to the transportation environment (Evans, 2003). Neighborhood quality is strongly related to crime and violence. A suggestion to combat these activities is to keep "eyes on the street" by increasing pedestrian activity and reducing front yard setbacks, which creates a sense of accountability and closeness in the neighborhood. This paper additionally mentions social support as an indirect mental health effect of the built environment. It states, "physical proximity increases unplanned social interaction. Functional opportunities for interaction (e.g., doorway opening, proximity to pedestrian pathway) also afford greater social interaction" (Evans, 2003). It appears that the link between the built transportation environment and mental health is dependent on the social capital created by the built environment and the stress induced by commuting distance and time.

9. Engineering Response

The engineering community has begun responding to these alarming health

problems, but further work is needed to reverse these trends. The New Urbanist movement was the first major development in combating the damaging effects of the auto-based society. This movement began in the late 1980s aiming to reduce urban sprawl and its negative impact on the environment, health, and equity and to allow residents to live, work, and play in the community. This is accomplished through mixing land uses, increasing residential density and diversity, and encouraging active transportation modes and transit use. Typical neo-traditional towns have a community center that is within walking distance (quarter mile or five-minute walk) of most residents. There are a variety of dwellings, mixed land uses, narrow roads, and parking lots and garage doors that are hidden from view. These developments have been proven to have fewer total auto trips, a lower share of auto trips, fewer vehicle miles travelled, fewer external trips, and higher internal trip capture. The second major response was the complete streets movement, which gained prominence in the early 2000s. Complete streets are roadways that treat all modes of transportation equally, enabling safe access for all users (**Figure 10**). Many states and municipalities have adopted complete street policies. This strategy is especially useful because converting existing roads into complete streets is much easier than creating whole new developments.

Both complete streets and New Urbanism use many engineering techniques to achieve their goals of fostering active transportation over car travel. One important concept is reducing the built environment to the human scale. The human brain processes things differently at different speeds. Drivers are more comfortable with gradual curves, large signs, and simple geography because of their high speeds, while pedestrians prefer a more complex, interesting, beautiful environment. Engineers and architects use this principle to incentivize active transportation in numerous ways. Adding street trees and street furniture like benches helps to beautify the environment for a pedestrian, making it more appealing to them. Smaller block lengths, recommended to be kept between 250 to 500 feet, provide variety to a pedestrian while also slowing traffic (Wilkerson, 2007) (Institute for Public Administration, 2004).

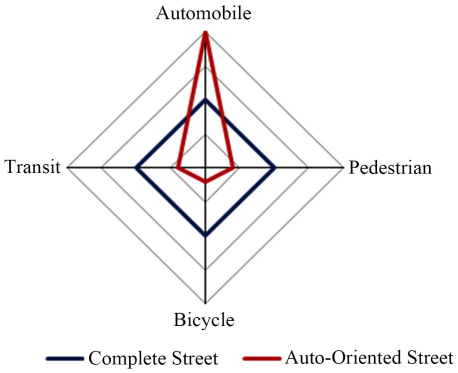

Figure 10. Complete street LOS profile (Kingsbury, Lowry, & Dixon, 2011).

Pedestrian safety is critical to increasing active transportation, as dangerous routes strongly discourage walking and bicycling. Reducing the speed limit has been proven to be effective. For existing roads it is recommended that speed limits be reduced to 25 mph on residential streets and 35 mph on larger collector roads (Institute for Public Administration, 2004). In addition to decreasing speed limits, traffic calming measures, detailed in the US Traffic Calming Manual, must be used to control the speed and behavior of drivers. Reducing the width of the travel lanes, even just by adjusting the striping, makes drivers less comfortable at high speeds and more alert. One study found that each two-foot increase in lane width resulted in a 35 to 50 percent increase in injuries to pedestrians. Other traffic calming measures include:

- Speed bumps and speed tables to force drivers to slow to avoid damage.
- Smaller curb radii to reduce the speed of cars going around curves.
- Medians to reduce the drivable roadway.
- Raised and textured crosswalks to increase visibility.
- Curb extensions to narrow travel lanes at points.
- Overhanging street trees to create a "tunnel" effect.

A California consultant company studied the speed, volume, and safety impacts of several of these measures and found that each measure was effective in reducing the 85th percentile speed up to 23 percent, in reducing volume between 20 and 44 percent, and in reducing collisions between 11 and 73 percent (Fehr & Peers Transportation Consultants, n.d.). Crossing the travel lanes, especially on larger roads, is another safety concern for pedestrians. Crossings and intersections should be designed so that pedestrians only have to cross two lanes at once. Refuges built into roadway medians can be provided for large roads with more than two lanes of travel.

Sidewalks are a pedestrian's major avenue for travel and should be provided for all roads. Unfortunately, developers have marginalized sidewalks to focus on roads for automobiles. A travel survey found 25 percent of walking trips took place on roads without sidewalks or shoulders (Bureau of Transportation Statistics, 2002). Having such a large share of pedestrians walking on travel lanes is very dangerous should be provided on both sides of a street and separated from travel lanes. This separation can be distance, where a four to five-foot buffer is ideal, or a physical barrier such as a tree or parked car. These sidewalks should be a minimum of five feet, larger than the four feet typically provided today and enough for two people to walk side by side comfortably. It is recommended that this minimum be increased to eight feet at storefronts and ten feet at transit stops (Wilkerson, 2007). The sidewalk network must be continuous and well-connected to popular destinations like retail shops and recreation facilities. Benches and pedestrian lighting along these sidewalks help to keep the environment at the human scale, rather than vehicle-scale long expanses and large streetlights.

The other major route system that should be prioritized is bicycle lane networks, since this provides active transportation opportunities for intermediate

distances that may be too long for walking. A case study of Seville conducted in 2016 analyzed the effects of the implementation of their cycling promotion policy which began in 2006. Local governments transformed urban Seville by creating a 140 km bicycle lane network and introduced the bike-share system SEVici, which provided many bicycles, docking stations, and bike racks. This study conducted a cost benefit analysis over a 25-year period from 2006 to 2030 using real and projected data, ultimately estimating a net annual monetary saving over 44 million euros (2006 value) from 2011 onwards (Brey, 2017). The US is now starting to adopt this strategy which has been very successful in many European cities. US bicycle systems are still very underdeveloped, but new initiatives set by the DOT include adding protected bike lanes, adding storage and parking facilities, lane separation, and bicycle signage, should slowly encourage more travelers to use bicycles (U.S. Department of Transportation, 2019).

When designing new developments, it is important to consider the street layout. A grid-like street layout gives more accessibility by providing more options to a traveler and reducing distances between destinations. If a person wanted to walk from point A to point B in **Figure 11**, he would have a much more direct route in the grid layout. Additionally, the use of cul-de-sacs concentrates traffic on the major roads, making them more dangerous to pedestrians due to their higher speeds, wider lanes, and larger volumes.

10. Planning Measures

The development of sound city plans that facilitate and encourage active transportation is important in fighting both the obesity epidemic and the respiratory problems caused by vehicle exhaust. Planners can help reduce the built environment to the human level by regulating city codes. Building setbacks should be decreased and entrances should be on sidewalks and close to the access road, not distanced from travel routes by expansive parking lots.

Easily available parking makes automobile use more valuable while decreasing its value to pedestrians. Large parking lots increase distances pedestrians must walk while increasing the scale of the built environment. During most hours, these lots are empty and simply taking up space. When necessary, large lots should be placed behind retail outlets to bring the entrances closer to the street and sidewalk. Parking should be managed as a system, not as individual lots for individual buildings. Lots can be shared for attractions with different usage peaks. For example, a typical movie theater is most crowded during nights and weekends while an office building sees most usage during morning hours of the work week. Also, limited availability of parking will increase the value of a bike or walk trip. The creation of small parking fees is another way to encourage more active trips. To reduce the land consumed by parking, underground and multi-level garages should be encouraged.

When planning a town or development, pedestrians, bicyclists, and transit should be prioritized over automobiles. Sidewalk, trails, and shared-use paths

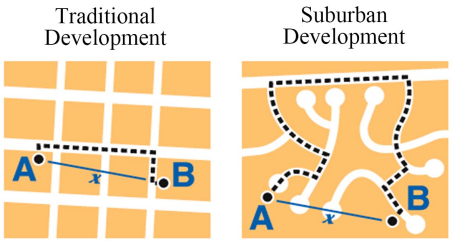

Figure 11. Street accessibility (Scott, Beck, & Rabidou, 2011).

should be displayed on all maps and properly signed to assist navigation. Facilities that encourage active modes, such as bike racks, pedestrian lighting, benches, and shade trees should be required for roads. Community centers and major attractions should be zoned for higher densities. These community centers should be mixed-use, not simply strip malls.

New strip malls should be discouraged, and existing ones gradually converted into urban villages. Rather than adding large supermarkets, neighborhood markets should be added at intersections of collector roads, adding more, smaller destinations. The same can be done for recreational areas. Rather than enormous complexes, smaller "pocket parks" should be added within residential areas and linked to the bike path and sidewalk networks. These will serve the dual purpose of adding more walking trips and more activity as well as strengthening the social capital of the community through increased interaction.

In rural communities, where physical activity and active travel opportunities are especially low, planners should prioritize adding trails to connect homes with amenities, and invest in more recreational facilities within walkable distances. The 2017 study referenced earlier surveyed residents from eight different towns in rural southeast Missouri, finding that those who had access to and used trails saw a tripling in physical activity time (Park, Eyler, Tabak, Valko, & Brownson, 2017). The study suggests a multilevel intervention to create accessible trails and encourage their use to improve active transportation and physical activity in these rural areas.

Safe Routes to School is a program advocated by the Federal Highway Administration that attempts to increase student walking rates in school areas. This program targets both children and parents and represents an opportunity to affect travel culture. It includes traffic calming, traffic enforcement, and safety education elements and offers resources and funding to achieve its goals. Funding for Safe Routes to Schools has increased from $51 million in 2005 to almost $202 million in 2011 (Federal Highway Administration, 2011). Elementary and secondary schools should be encouraged to pursue funding to raise the percentage of students walking to school. This could save money in busing and free up budget room to improve physical education.

Additionally, a 2012 study in Tehran, Iran found commute distance to have the greatest influence on school trip transportation mode. It also observed that addressing parents' safety concerns could increase active transportation to

school by up to 60% (Ermagun & Samimi, 2015). Similarly, a 2011 study in California also found that distance affected transportation mode to school much more than school quality or residential environment (He, 2011). Gradually transitioning to smaller school districts and investing in pedestrian infrastructure near schools can greatly impact student walking/biking rates.

More recently, Congress is attempting to invest more on active transportation methods in accordance with the CDC's goal of making 27 million people more physically active by 2027 (Brooks, 2020). The new congressional bill will use up to $500 million from the Highway Trust Fund to create connected sidewalks, trails, and bike routes between communities in order to allow greater active transportation opportunities (Connecting America's Active Transportation System Act, H.R. 5696, 2020). Successful implementation of this bill will require immense measures in transportation engineering and infrastructure planning, but the financial returns alone, not to mention the health benefits discussed previously, make a strong case for active transportation investment. A 2019 report conducted by reputable researchers of the Rails-to-Trails Conservancy nonprofit organization considered a modest improvement, defined by all states achieving active transportation percentages equal to the average of the current top 25 states for trips under three miles. Their statistical methods calculated a potential annual return on investment of $73 billion from fostering active transportation (Bhattacharya, Mills, & Mulally, 2019).

Health Impact Assessments (HIAs) are a very useful, yet underutilized tool in analyzing a project or policy. The World Health Organization's definition of a HIA is "a combination of procedures, methods, and tools by which a policy, program, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population" (Heath Impact Assessment (HIA), 1999). An HIA opens the lines of communication between designers like planners, engineers, and architects, and health professionals like doctors. This communication can go a long way in reducing the negative health impacts of new policies and developments. HIAs should be performed for all major projects and the results publicized to improve public understanding of the built environment's effect on human health. These assessments are becoming more and more common, mostly advocated by the medical field. It is time the engineering and planning fields understand their effect and role in health by collaborating with medical professionals.

11. Health Index

In addition to the engineering responses and planning measures discussed, a land-use planning health index could significantly improve the feasibility of active transportation within communities. Land-use planning projects are not required to consider the impacts they will have on human physical activity. This does not protect or hold to standard any changes that could decrease the safety or accessibility to modes that promote physical activity such as walking, biking,

and transit.

A health index that assesses the safety and ease of non-motorized or transit travel would help reverse this change into a fully automobile travel culture. It would score an area based on its ability to promote physical activity as a means of travel, thus creating a standard which will be expected from newly created neighborhoods, towns, and metropolitan areas. Preliminary efforts for such an index have already been established, and further research and investigation into this idea could help it become a reality.

There are four factors that are impacted by land-use and effect human health through physical activity: walking, biking, transit, and green space. The benefits of walking, specifically with regards to obesity and cardiovascular problems, as well as the methods and strategies to create more walkable communities, has already been discussed in detail. Biking has also been mentioned, but there are not as many well-developed ideas on how to integrate biking on a larger scale into the transportation system in the US, and this can be attributed to the very poor existing biking infrastructure in the country. However, making transportation more bike-friendly can drastically improve health conditions. Denmark, a country that has invested heavily in bicycle infrastructure, has the highest percent of physically engaging transportation modes and one of the lowest rates of obesity (seen earlier in **Figure 10**). In Copenhagen, 45% of residents who work in the city commute by bike (World Health Organization, 2015).

Transit also plays a role in human physical activity. Since transit stops are located in centralized areas, most passengers can walk to a stop from their homes and then to their destination creating a further walking distance than just to one's driveway. Lastly, green space has been proven to promote physical activity just through invoking people to go outside. A study conducted in England showed a direct correlation between the amount of physical activity and the abundance of green space (Mytton, Townsend, Rutter, & Foster, 2012). It specified that the use of green space for physical activity did not change, but that the existence of greenspace alone encouraged more physical activity.

Currently the only existing assessment in the US for protecting human health is the HIA, mentioned earlier, which is only used as an optional planning resource. However, there are other assessment tools that land-use planners can use to score the walkability, bikeability, transit accessibility, and green space prevalence to help understand the ease of physical activity in an area. One such tool is The Walk Score, which produces three scores from 0 - 100 for walking, biking, and transit (one for each mode) based on how accessible these modes are for traveling to nearby amenities. The scores for walking, biking, and transit travel utilize compilation methods and decay functions based on important factors such as distance, safety, infrastructure availability (for biking), and service levels (for transit) (The Walk Score, 2020).

The last factor of green space was best measured by the Building Neighborhood Green Index (BNGI) created by Yuqin Liu, Qingyan Meng, Jiahui Zhang,

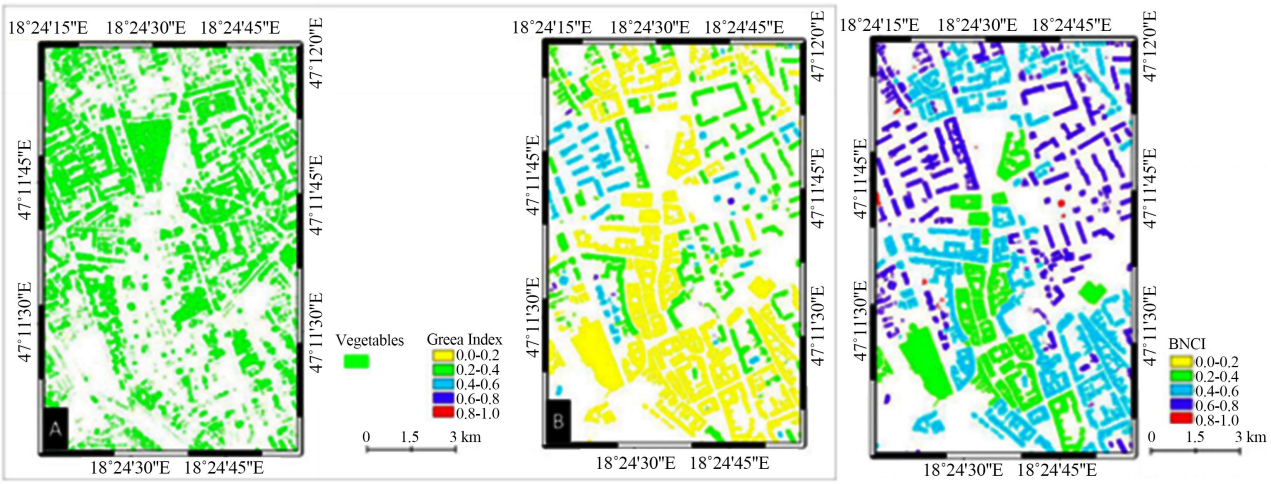

Figure 12. Vegetation, GI, and BNGI on study area.

Health Index	(Grade) Description
60-100	(A) Promotes a healthy lifestyle
40-59	(B) Requires some effort to live a healthy lifestyle
20-39	(C) Requires a lot of effort to live a healthy lifestyle
0-19	(D) Does not promote a healthy lifestyle

Figure 13. Health index details.

Linlin Zhang, Tamas Jancso & Rumiana Vatseva. They took the existing Green Index (GI) which used the area of the green divided by the area of the buffer zone each around a single building and enhanced it with factors such as green type, proximity to green, building sparsity, and high-rise sparsity using LiDAR technology (Liu, et al., 2016). Each calculation was normalized into a result ranging from 0 - 1 for each building within the study area. The enhancement of the original GI can be seen in Figure 12 showing a higher BNGI representing good green space compared to the low GI scores representing poor green space.

The overall Heath Index calculates the Walk Score, Bike Score, Transit Score, and BNGI and compiles them all into one score ranging from 0 - 100 and then assigns that number to a letter grade to indicate a passing grade or failing grade based on the ability to promote physical activity in an area (Figure 13). As a preliminary measure, the following assumptions for a fundamental execution of the Health Index along with the evaluation in:

- Walk Score - 60%
- Bike Score or Transit Score (larger of the two) - 20%
- Building Neighborhood Green Index - 20%

Using this methodology is a good foundation for analyzing the area's ability to promote physical activity but it does have some major flaws. It works well in city areas but some suburbs that are spread out and hilly, have a tough time achieving a passing score. Also, the BNGI is not easily accessible as it is purely in the research stage; there is no widget or program to output a BNGI value for a specific address or city. This forces the Health Index to use an estimated average

BNGI for each type of area such as rural, suburb, and city developments not accurately capturing the green space for a specific area.

Implementation of such an index at this time is not feasible due to the elementary methodology for compiling the four evaluation systems, but with further analysis and modeling this Index could be required for all land-use projects. Using such an index would raise the standard for active transportation requirements, fostering a change to a culture that incentivizes physically active travel modes.

12. Conclusion

The built environment plays a major role in public health trends. For the past century, the evolution of this environment has made American lifestyles more and more sedentary by promoting use of automobiles as the primary, almost exclusive, form of transportation. Increasing auto use has all but removed the active transportation modes, which were formerly a large source of physical activity. Reduced physical activity is a major factor in the obesity epidemic that is sweeping the nation and increased vehicle usage spews dangerous pollutants into the atmosphere that further damage human health. In addition to negatively affecting physical and respiratory health, increased auto usage has isolated people from their communities which damages mental health.

Excessive auto usage is necessitated by the infrastructure we build, which in turn leads to these health problems. Separated land uses and large distances make driving the only option for most Americans. It is important that we address these problems before future generations are forced to adopt this automobile culture and the health problems it entails. Though this is just one factor causing these health problems, it has a large effect. Cooperation between medical, engineering, and planning professionals, as well as more research into a more health-friendly environment is required. Programs like Safe Routes to Schools and National Walk to Workday help to raise awareness regarding this issue, but a more walk-friendly built environment is the best way to change the nation's drive first culture.

Going forward, it will become easier to quantify exactly how the built transportation environment affects public health as the link is better understood. More research is needed to further this understanding and develop countermeasures. As neo-traditional and New Urbanist communities age and mature, the culture is more ingrained into the inhabitants and the true effects on health are better represented. They should be continuously studied to better understand these effects, such as walk and bike share, and how the communities perform relative to more sprawling developments. Much more research is needed regarding parking availability. The effect of easily available parking has on trip share is poorly understood and should be analyzed. A better understanding will give planners another weapon to reduce auto trips.

Another area that is need of serious improvement is transportation networks

in rural areas. This report mostly focuses on urban and suburban environments since many of the engineering responses and planning measures can be implemented fairly easily to these environments, as their road networks can be modified or adapted to achieve more active transportation. However, for rural communities, new infrastructure must be created to promote and foster active travel. This is an area that needs more exploration and investment, as rural residents are much more likely to experience physical inactivity as a result of the limited transportation infrastructure available to them.

More quantifiable research on how the scale of the built environment affects travel would also be very beneficial. A human scale-built environment increasing active transportation modes is logical in theory, but little scientific evidence supports this concept. Finally, a land-use planning health index must be developed in order to assess and set a standard for the accessibility of active travel modes. The academic branches of engineering and planning should use this opportunity to help develop measures that reduce the harmful health effects of the automobile-centered transportation environment.

Acknowledgements

Partial funding for this study was provided by the State of Delaware Department of Transportation (DelDOT). The authors express their gratitude for financial and advisory assistance received from all the professional staff at DelDOT.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

(2020). *Connecting America's Active Transportation System Act*, *H.R.* 5696. 116th Congress.

Akcomak, I. S., & ter Weel, B. (2008). *The Impact of Social Capital on Crime*: *Evidence from the Netherlands*. The Hague: Institute for the Study of Labor.

Bailey, D., McKay, H., Crocker, P., & Faulkner, R. (1999). A Six-Year Longitudinal Study of the Relationship of Physical Activity to Bone Mineral Accrual in Growing Children. *Journal of Bone and Mineral Research, 14,* 1672-1679. https://doi.org/10.1359/jbmr.1999.14.10.1672

Bhattacharya, T., Mills, K., & Mulally, T. (2019). *Active Transportation Transforms America*: *The Case for Increased Public Investment in Walking and Biking Connectivity*. Washington DC: Rails-to-Trails Conservancy.

Bouchard, C. (2001). Physical Activity and Health: Introduction to the Dose-Response Symposium. *Medicine & Science in Sports & Exercise, 33,* S347-S350. https://doi.org/10.1097/00005768-200106001-00002

Brey, R. (2017). Is the Widespread Use of Urban Land for Cycling Promotion Policies Cost Effective? A Cost-Benefit Analysis of the Case of Seville. *Land Use Policy, 63,* 130-139. https://doi.org/10.1016/j.landusepol.2017.01.007

Brooks, P. (2020). *About Active People*, *Healthy Nation*. Centers for Disease Control and

Prevention. https://www.cdc.gov/physicalactivity/activepeoplehealthynation/about-active-people-healthy-nation.html

Bureau of Transportation Statistics (2002). *National Survey of Pedestrian and Bicyclist Attitudes and Behaviors*. National Highway Traffic Safety Administration.

Centers for Disease Control and Prevention (2011a). *About BMI for Adults*. http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Centers for Disease Control and Prevention (2011b). *Facts about County-Level Estimates of Leisure-Time Physical Activity*. http://www.cdc.gov/diabetes/pubs/factsheets/county_inactivity_estimates.htm

Centers for Disease Control and Prevention (2012). *Adult Obesity Facts*. http://www.cdc.gov/obesity/data/adult.html

Centers for Disease Control and Prevention (2020). *Adult Obesity Facts*. https://www.cdc.gov/obesity/data/adult.html

Chi, G., Shapley, D., Yang, T.-C., & Wang, D. (2019). Lost in the Black Belt South: Health Outcomes and Transportation Infrastructure. *Environmental Monitoring and Assessment, 191,* 297. https://doi.org/10.1007/s10661-019-7416-1

Cutler, D., Glaeser, E., & Shapiro, J. (2003). Why Have Americans Become More Obese? *Journal of Economic Perspectives, 17,* 93-118. https://doi.org/10.1257/089533003769204371

Dill, J. (2006). Evaluating a New Urbanist Neighborhood. *Berkeley Planning Journal, 19,* 59-78. https://doi.org/10.5070/BP319111489

Ermagun, A., & Samimi, A. (2015). Promoting Active Transportation Modes in School Trips. *Transport Policy, 37,* 203-211. https://doi.org/10.1016/j.tranpol.2014.10.013

Evans, G. W. (2003). The Built Environment and Mental Health. *Journal of Urban Health, 80,* 536-555. https://doi.org/10.1093/jurban/jtg063

Ewing, R., Haliyur, P., & Page, G. (1994). Getting around a Traditional City, a Suburban Planned Unit (PUD), and Everything in Between. *Transportation Research Record, 1466,* 53-62.

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., & Raudenbush, S. (2003). Relationship between Urban Sprawl and Physical Activity, Obesity, and Morbidity. *American Journal of Health Promotion, 18,* 47-57. https://doi.org/10.4278/0890-1171-18.1.47

Federal Highway Administration (2011). *State Routes to Schools Funding*. Washington DC: US Department of Transportation.

Federal Highway Administration Office of Policy (n.d.). *National Household Travel Survey 2009*.

Fehr & Peers Transportation Consultants (n.d.). *Effectiveness*. http://trafficcalming.org/effectiveness

Flora, C., Flora, J., & Gasteyer, S. (2016). *Rural Communities: Legacy and Change* (4th ed.). Boulder, CO: Westview Press.

Frank, L. D., & Engelke, P. (2005). Multiple Impacts of the Built Environment on Public Health: Walkable Places and the Exposure to Air Pollution. *International Regional Science Review, 28,* 193-216. https://doi.org/10.1177/0160017604273853

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many Pathways from Land Use to Health. *Journal of the American Planning Association, 72,* 75-87. https://doi.org/10.1080/01944360608976725

Frank, L. D., Stone Jr., B., & Bachman, W. (2000). Linking Land Use with Household Ve-

hicle Emissions in the Central Puget Sound: Methodological Framework and Findings. *Transportation Research Part D Transport and Environment, 5,* 173-196. https://doi.org/10.1016/S1361-9209(99)00032-2

Frank, L., Andresen, M., & Schmid, T. (2004). Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars. *American Journal of Preventive Medicine, 27,* 87-96. https://doi.org/10.1016/j.amepre.2004.04.011

Frank, L., Kerr, J., Chapman, J., & Sallis, J. (2007). Urban Form Relationships with Walk Trip Frequency and Distance among Youth. *American Journal of Health Promotion, 21,* 305-311. https://doi.org/10.4278/0890-1171-21.4s.305

Frank, L., Schmid, T., Sallis, J., Chapman, J., & Saelens, B. (2005). Linking Objectively Measured Physical Activity with Objectively Measured Urban Form: Findings from SMARTRAQ. *American Journal of Preventive Medicine, 28,* 117-125. https://doi.org/10.1016/j.amepre.2004.11.001

Friedman, M., Powell, K., Hutwagner, L., Graham, L., & Teague, W. (2001). Impact of Changes in Transportation and Commuting Behaviors during the 1996 Summer Olympic Games in Atlanta on Air Quality and Childhood Asthma. *JAMA, 285,* 897-905. https://doi.org/10.1001/jama.285.7.897

Frumpkin, H., Frank, L., & Jackson, R. (2004). *The Public Health Impacts of Sprawl*. Washington DC: Island Press.

Green, J., Larco, N., Yang, Y., Schlosberg, M., Rodriguez, D., McDonald, N., & Combs, T. (2011). *Travel Behavior, Residential Preference, and Urban Design: A Multi-Disciplinary National Analysis*. Oregon Transportation Research and Education Consortium. https://doi.org/10.15760/trec.35

Handy, S. L. (1992). Regional versus Local Accessibility: Neo-Traditional Development and Its Implications for Non-Work Travel. *Built Environment, 18,* 253-267.

Handy, S., Boarnet, M., Ewing, R., & Killingsworth, R. (2002). How the Built Environment Affects Physical Activity: Views from Urban Planning. *American Journal of Preventive Medicine, 23,* 64-73. https://doi.org/10.1016/S0749-3797(02)00475-0

He, S. (2011). Effect of School Quality and Residential Environment on Mode Choice of School Trips. *Transportation Research Record: Journal of the Transportation Research Board, 2213,* 96-104. https://doi.org/10.3141/2213-13

Heath Impact Assessment (HIA) (1999). http://www.who.int/hia/about/defin/en/index.html

Hendrick, B. (n.d.). *CDC Study Shows 24.6 Million Americans Have Asthma*. http://www.webmd.com/asthma/news/20110503/asthma-rates-on-the-rise-in-the-us

Institute for Public Administration (2004). *Mobility Friendly Design Standards: A Framework for Delaware*. Newark, DE: University of Delaware.

Jackson, R. (2003). The Impact of the Built Environment on Health: An Emerging Field. *Journal of Public Health, 93,* 1382-1384. https://doi.org/10.2105/AJPH.93.9.1382

Jackson, R., & Kochtitzky, C. (2010). *Creating a Healthy Environment: The Impact of the Built Environment on Public Health*.

Khattak, A. J., & Rodriguez, D. (n.d.). Travel Behavior in Neo-Traditional Neighborhood Developments: A Case Study in USA. *Transportation Research Part A Policy and Practice, 39,* 481-500. https://doi.org/10.1016/j.tra.2005.02.009

Kim, J., & Kaplan, R. (2004). Physical and Psychological Factors in Sense of Community: New Urbanist Kentlands and Nearby Orchard Village. *Environment and Behavior, 36,* 313-340. https://doi.org/10.1177/0013916503260236

Kingsbury, K., Lowry, M., & Dixon, M. (2011). *What Makes a "Complete Street" Com-*

plete? https://doi.org/10.3141/2245-13

Kouri, C. (1999). *Wait for the Bus*: *How Low Country School Site Selection and Design Deter Walking to School and Contribute to Urban Sprawl*. Durham, NC: Duke University.

Leyden, K. M. (2003). Social Capital and the Built Environment: The Importance of Walkable Neighborhoods. *American Journal of Public Health, 93,* 1546-1551. https://doi.org/10.2105/AJPH.93.9.1546

Liu, Y., Meng, Q., Zhang, J., Zhang, L., Jancso, T., & Vatseva, R. (2016). An Effective Building Neighborhood Green Index Model for Measuring Urban Green Space. *International Journal of Digital Earth, 9,* 387-409. https://doi.org/10.1080/17538947.2015.1037870

Lopez, R. (2004). Urban Sprawl and Risk for Being Overweight or Obese. *American Journal of Public Health, 94,* 1574-1579. https://doi.org/10.2105/AJPH.94.9.1574

Metaxatos, P. (2011). Built Environment, Individual Attributes, and Variability of Body Mass Index in the Chicago, Illinois, Metropolitan Area: Empirical Analysis. *Transportation Research Record: Journal of the Transportation Research Board, 2231,* 93-101. https://doi.org/10.3141/2231-12

Mikkelsen, M. J. (2004). *The Built Environment and Health: 11 Profiles of Neighborhood Transformation*. Oakland, CA: Prevention Institute.

Morabai, A., Mirer, F., Amstislavski, T., Eisl, H., Werbe-Fuentes, J., Gorczynski, J., Markowitz, S. et al. (2010). Potential Health Impact of Switching from Car to Public Transportation When Commuting to Work. *American Journal of Public Health, 100,* 2388-2391. https://doi.org/10.2105/AJPH.2009.190132

Mumford, K., Contant, C., Weissman, J., Wolf, J., & Glanz, K. (2011). Changes in Physical Activity and Travel Behaviors in Residents of a Mixed-Use Development. *American Journal of Preventive Medicine, 41,* 504-507. https://doi.org/10.1016/j.amepre.2011.07.016

Mytton, O. T., Townsend, N., Rutter, H., & Foster, C. (2012). Green Space and Physical Activity: An Observational Study Using Health Survey for England Data. *Health & Place, 18,* 1034-1041. https://doi.org/10.1016/j.healthplace.2012.06.003

National Center for Safe Routes to Schools (2011). *How Children Get to School: School Travel Patterns from 1969 to 2009*.

National Safe Routes to School Task Force (2008). *Safe Routes to School: A Transportation Legacy*. Washington DC: US Department of Transportation.

O'Flaherty, C., Bell, M., May, A., Nash, C., Leake, G., & Bonsall, P. (1996). *Transport Planning and Traffic Engineering*. Oxford: Butterworth-Heinemann.

Office of Air Quality Planning and Standards (2001). *National Air Quality and Emissions Trends Report 1999*. Washington DC: US Environmental Protection Agency.

Office of the Surgeon General (2007). *The Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity*. Washington DC: US Department of Health & Human Services.

Olshansky, S. J., Passaro, D. J., Hershow, R. C., Layden, J., & Carnes, B. A. (2005). A Potential Decline in Life Expectancy in the United States in the 21st Century. *New England Journal of Medicine, 352,* 1138-1145. https://doi.org/10.1056/NEJMsr043743

Park, T., Eyler, A., Tabak, R., Valko, C., & Brownson, R. (2017). Opportunities for Promoting Physical Activity in Rural Communities by Understanding the Interests and Values of Community Members. *Journal of Environmental and Public Health, 2017,* Article ID: 8608432. https://doi.org/10.1155/2017/8608432

Petersmarck, K., & Wilkerson, R. (2003). *Land Use Affects Public Health*. Michigan Governor's Council on Physical Fitness, Health, and Sports.

Podobnik, B. (2009). Assessing the Social and Environmental Achievements of New Urbanism. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 4,* 105-126. https://doi.org/10.1080/17549175.2011.596271

Pucher, J. (2009). *Cycling and Walking for All New Yorkers: Path to Improved Public Health*. New York: Fit City Conference.

Pucher, J., & Renne, J. (2003). Socioeconomics of Urban Travel: Evidence from the 2001 NHTS. *Transportation Quarterly, 57,* 49-77.

Putnam, R. (2000). *Bowling Alone*: *The Collapse and Revival of American Community*. New York: Simon & Schuster. https://doi.org/10.1145/358916.361990

Rahman, T., Cushing, R. A., & Jackson, R. J. (2011). Contributions of Built Environment to Childhood Obesity. *Journal of Translational and Personalized Medicine, 78,* 49-57. https://doi.org/10.1002/msj.20235

Rodriguez, A. D., Khattak, J. A., & Evenson, R. K. (2006). Can New Urbanism Encourage Physical Activity? Comparing a New Urbanist Neighborhood with Conventional Suburbs. *Journal of the American Planning Association, 72,* 43-54. https://doi.org/10.1080/01944360608976723

Sampson, R., Morenoff, J., & Earls, F. (1999). Beyond Social Capital: Spatial Dynamics of Collective Efficacy for Children. *American Sociological Review, 64,* 633-660. https://doi.org/10.2307/2657367

Sampson, R., Morenoff, J., & Gannon-Rowley, T. (2002). Assessing "Neighborhood Effects": Social Processes and New Directions in Research. *Annual Review of Sociology, 28,* 443-478. https://doi.org/10.1146/annurev.soc.28.110601.141114

Scott, M., Beck, C., & Rabidou, B. (2011). *Complete Streets in Delaware*: *A Guide for Local Governments*. Newark, DE: University of Delaware Institute for Public Administration.

Southworth, M., & Owens, P. (1993). The Evolving Metropolis: Studies of Community, Neighborhood, and Street Form at the Urban Edge. *Journal of the American Planning Association, 59,* 271-287. https://doi.org/10.1080/01944369308975880

Sturm, R., & Cohen, D. (2004). Suburban Sprawl and Physical and Mental Health. *Public Health, 118,* 488-496. https://doi.org/10.1016/j.puhe.2004.02.007

The Walk Score (2020). *Walk Score Methodology*. https://www.walkscore.com/methodology.shtml

U.S. Department of Transportation (2019). *Expand and Improve Bicycle and Pedestrian Infrastructure*.

Urban Design 4 Health, Inc. (2010). *The Hidden Health Costs of Transportation*. Washington DC: American Public Health Association.

US Bureau of the Census (n.d.). *Decennial Census of Population*. Washington DC: US Department of Commerce.

US Department of Health and Human Services (1996). *Physical Activity and Health: A Report of the Surgeon General*. Washington DC.

Weigel, L., & Metz, D. (2010). *Future of Transportation National Survey*. http://t4america.org/resources/2010survey

Wilkerson, J. (2007). *Example Comprehensive Plan Policies to Support Physically Active Communities*. Washington DC: Department of Community, Trade, and Economic Development.

Wilson, W. J. (1987). *The Truly Disadvantaged*: *The Inner City*, *the Underclass*, *and Public Policy*. Chicago, IL: University of Chicago Press.

Winters, M., Brauer, M., Setton, E. M., & Teschke, K. (2010). Built Environment Influences on Healthy Transportation Choices: Bicycling versus Driving. *Journal of Urban Health, 87,* 969-993. https://doi.org/10.1007/s11524-010-9509-6

World Health Organization (2015). *Denmark Physical Activity Fact Sheet*. https://www.euro.who.int/__data/assets/pdf_file/0004/288103/DENMARK-Physical-Activity-Factsheet.pdf?ua=1