ARTICLE

Can the Physical Environment Determine Physical Activity Levels?

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EWING, R. Can the physical environment determine physical activity levels? *Exerc. Sport Sci. Rev.*, Vol. 33, No. 2, pp. 69–75, 2005. *Does your place of residence affect your level of physical activity and ultimately your weight and health? There is relatively strong evidence of association between compact development patterns and use of active travel modes such as walking and transit. There is weaker evidence of linkage between compact development, overall physical activity, and downstream weight and health effects.* **Key Words:** physical environment, built environment, urban sprawl, neighborhood design, physical activity, active travel, obesity

INTRODUCTION

There is a long-running debate in urban planning about the degree to which the physical environment determines human behavior. The theory of environmental or architectural determinism ascribes great importance to the physical environment as a shaper of behavior. The counter view is that social and economic factors are the main or even exclusive determinants of behavior. The hypothesis of this article is decidedly environmental and deterministic in its outlook.

To outsiders, this debate may seem simplistic. Any extreme view would be. Yet we all bring paradigms to the study of physical activity, paradigms that affect our interpretation of the facts. For example, nearly all evidence of associations between the physical environment and physical activity is based on cross-sectional data. Depending on your point of view, the documented relationship between walking and the built environment might as well be caused by 1) individuals who want to be physically active selecting pedestrian-friendly environments (self-selection) as it is caused by 2) pedestrian-friendly environments making individuals more physically active than they would be otherwise (environmental determinism).

So, with this paradigm-related caveat, I (who lean toward environmental determinism) will review what is known about the built environment and its relationship to physical activity.

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DEFINING SPRAWL AND THE BUILT ENVIRONMENT

Qualitative Notions of Urban Sprawl

Urban planners apply the term "built environment" to elements of the physical environment that are man-made; this is in contrast to the natural environment. The built environment includes everything from metropolitan land-use patterns to urban transportation systems to individual buildings and the spaces around them (10).

Urban sprawl (also called suburban sprawl) has become the predominant metropolitan development pattern in the United States. Examples of compact development, the antithesis of sprawl, are so few and far between that they seem almost quaint these days. For every New York metropolitan area, there are dozens of Atlantas and Detroits. For every Manhattan, there are hundreds of Walton and Lapeer counties (counties located on the peripheries of the Atlanta and Detroit metropolitan areas).

Because the costs of sprawl have become more apparent, the term urban sprawl has gone from urban planning construct to public concern. But what exactly is urban sprawl? In the early 1990s, I worked on a definition of sprawl for purposes of growth management in Florida. The definition ultimately adopted by the state encompassed the following urban forms (Fig. 1): 1) leapfrog or scattered development; 2) commercial strip development; 3) expanses of low-density development; or 4) expanses of single-use development (as in

Figure 1. Sprawl prototypes (leapfrog, commercial strip, low-density/single use).

sprawling bedroom communities). Because these forms are prototypical, and a matter of degree, we supplemented the Florida definition with "primary indicators" of sprawl that could be measured and made subject to regulation. The two indicators I proposed, which became part of the law, were any development pattern characterized by poor accessibility and lack of functional open space (4).

All four prototypical patterns (leapfrog, etc.) are characterized by poor accessibility and lack of functional open space. The potential link to physical activity is clear. In sprawl, poor accessibility of land uses to one another may leave residents with no alternative to automobile travel. And lack of public open spaces (both natural and man-made) may leave residents with few opportunities for outdoor recreation.

Operationalizing Metropolitan Sprawl

Even the specificity of Florida's regulatory definitions falls short of an operational definition of sprawl. Before something can be studied quantitatively, it must be measured. So it is with sprawl.

In approximately 2000, researchers began to measure sprawl. Initial attempts were crude (*e.g.*, *USA Today*'s of February 22, 2001). Based on this index, *USA Today* declared: "Los Angeles, whose legendary traffic congestion and spread-out development have epitomized suburban sprawl for decades, isn't so sprawling after all. In fact, Portland, OR, the metropolitan area that enacted the nation's toughest anti-growth laws, sprawls more." According to *USA Today's* index, even the New York metropolitan area sprawls more than Los Angeles.

The most notable feature of studies at that time was their failure to define sprawl in all its complexity. Population density is relatively easy to measure, and hence served as the sole indicator of sprawl in several studies. If all you are measuring is average population density, Los Angeles looks compact; it is the endless, uniform character of Los Angeles's density that makes it seem so sprawling. Another notable feature of these studies was the wildly different sprawl ratings given to different metros by different analysts. With the exception of Atlanta, which always seems to rank as one of the worst, the different variables used to operationalize sprawl led to very different results. In one study, Portland was ranked as the most compact, and Los Angeles was way down the list. In another, their rankings were essentially reversed. A third notable feature of the studies was how little attention was paid to the impacts of sprawl. With the exception of a few studies focusing on individual outcomes, sprawl was presumed to have negative impacts, or presumed to be free of them, depending on the ideological bent of the author.

Meanwhile, we were working on a more comprehensive assessment of sprawl, funded initially by the U.S. Environmental Protection Agency, and later by Smart Growth America, a nonprofit advocacy group. We considered sprawl to be any environment characterized by: 1) a population widely dispersed in low-density residential development; 2) a rigid separation of homes, shops, and workplaces; 3) a lack of distinct, thriving activity centers, such as strong downtowns or suburban town centers; and 4) a network of roads marked by very large block size and poor access from one place to another (6). Principal components analysis was used to reduce 22 land-use and street network variables to four factors representing these four dimensions of sprawl, with each factor being a linear combination of the underlying operational variables. The four were combined into an overall metropolitan sprawl index.

A simpler county sprawl index was developed to measure the built environment at a finer geographic scale, the individual county. It is a linear combination of six variables from the larger set, these six being available for counties, whereas many of the larger set are available only for metropolitan areas.

Both sprawl indices were standardized, with mean values of 100 and standard deviations of 25. The way the indices were constructed, the bigger the value of the index, the more compact the metropolitan area or county. The smaller the value, the more sprawling the metropolitan area or county. Thus, in the year 2000, the New York metropolitan statistical area had an index value of 178, whereas Atlanta has a value of 58, and Detroit a value of 80. Manhattan had an index value of 352, whereas Walton County has a value of 70, and Lapeer County a value of 72.

Operationalizing Neighborhood Design

The concept of sprawl seems particularly tailored to large areas, such as metros and their component counties. The degree to which employment is concentrated in central business districts or suburban centers, for example, is a characteristic of an entire metropolitan area, not of smaller subareas. Yet there are analogous measures for subareas as small as neighborhoods. And these analogous measures have been studied in depth for their relationships to transit use, walking, and bicycling.

The term "3 Ds" was coined to describe the built environment at the neighborhood level. The 3 Ds are density, diversity, and design. Density is usually measured in terms of persons, jobs, or housing units per unit area. Diversity refers to land-use mix. It is often related to the number of different land uses in an area, and the degree to which they are "balanced" in land area, floor area, or employment. Design includes street network characteristics within a neighborhood. Street networks vary from dense urban grids of highly interconnected, straight streets to sparse suburban networks of curving streets forming "loops and lollypops."

Starting in approximately 1990, researchers began to rigorously study the relationships of the 3 Ds to travel behavior. The focus initially was on density and its impact on travel, but each successive study became more sophisticated in its characterization of the built environment. Thus, a lot was known about these relationships by 2000, when the Environmental Protection Agency released its "Smart Growth Index" model for predicting travel behavior. For this model, we measured density in terms of residents plus jobs per square mile, diversity was measured by the ratio of jobs to residents relative to the regional average, and design was measured in terms of street network density, sidewalk coverage, and route directness (two of three measures relating to street network design) (15). These are just a few of the many ways in which the 3 Ds have been operationalized at the neighborhood level (see literature review in (5)).

BUILT ENVIRONMENT AND ACTIVE TRAVEL

What is of ultimate interest to urban planners is not development patterns *per se*, but the costs and benefits of one pattern versus another. That is, there are no inherently good or bad patterns, only good or bad in terms of outcomes. The loaded term "sprawl" has come to be applied to certain development patterns because of their documented negative outcomes (2).

Impact of Metropolitan Sprawl

The study for Smart Growth America analyzed relationships between sprawl and various travel outcomes, including some related to physical activity (6). The percentages of workers walking and taking public transportation to work proved significantly related to the metropolitan sprawl index. Walk trips to work involve significant amounts of physical activity, because work trips tend to be longer than trips for other purposes. Public transportation trips are less obviously related to physical activity, but are still classified as active travel, because they almost always require a walk at one or both ends of the trip. So, *ipso facto*, the more sprawling the area, the less physical activity residents get through active travel.

Elasticity Estimates

For purposes of this survey article, we returned to the metropolitan sprawl database to compute elasticities of walk- and transit-mode shares with respect to the metropolitan sprawl index. Elasticities are widely used in urban planning to summarize relationships between variables. An elasticity is a percentage change in one variable with respect to a one percent change in another variable. Elasticities are often assumed to be constant over a wide range of values of independent variables.

In this case, the elasticity of walk-mode share with respect to the sprawl index was computed to be 0.93, whereas the elasticity of transit-mode share with respect to the sprawl index was an even higher 1.78. These elasticities suggest that for every 1% increase of the index, the percentage of commute trips made on foot increases by 0.93%, and the percentage made by public transportation increases by 1.78%. The way the index was constructed, lower values correspond to more sprawling areas, and higher values to more compact areas. So, this relationship is in the expected direction.

Outliers and Threshold Effects

In the Smart Growth America study, two metropolitan areas were excluded from the analysis because they appeared as outliers. The two were the most compact of the 83 metro areas in the sample, New York and Jersey City. Their walk- and transit-mode shares were much higher than even their outlying sprawl index values would predict.

The existence of such areas suggests that active travel may be subject to thresholds or critical levels of "compactness," beyond which mode shares increase exponentially. Perhaps active travel is best represented as a logarithmic or other nonlinear function of built environmental variables. To compute travel elasticities for this article, we used a log–log function. Subsequent research will have to explore threshold effects and alternative functional forms.

Impact of Neighborhood Design

At the neighborhood level, approximately 50 studies conducted during the 1990s related the travel behavior of individuals, including their choice of active travel modes, to aspects of the built environment (5). These studies were more sophisticated than earlier ones in that they used disaggregate travel data for individuals or households, made some effort to control for other influences on travel behavior (particularly socioeconomic status of travelers), and tested a wider variety of local land-use, transportation, and site-design variables than had earlier studies. None, however, moved beyond utilitarian travel to overall physical activity analysis, or beyond cross-sectional analysis to research designs that supported causal inference.

From these studies, transit use varies primarily with local densities, and secondarily with the degree of land-use mixing. Walking varies as much with the degree of land-use mixing as with local densities. An unresolved issue is whether the relationship of density to travel behavior is due to density itself or to other variables with which density co-varies (central location, good transit service, etc.).

The third D—design—has a more ambiguous relationship to travel behavior than do the first two Ds (5). Gridlike street networks improve walk and transit access by offering relatively direct routes and alternatives to travel along high-volume, high-speed roads. At the same time, gridlike street networks improve auto access by dispersing vehicular traffic and providing multiple routes to any destination. Thus, *a priori*, it is difficult to say which modes gain relative advantage as networks become more gridlike, let alone predict the impacts this may have on travel decisions. The evidence regarding the impact of street network design on travel behavior is correspondingly mixed.

Other elements of design, such as sidewalk coverage, building orientation, landscaping, pedestrian amenities, and other streetscape features also have ambiguous relationships to travel. Any effect is likely to be a collective effect involving multiple design features. It may also be an interactive effect involving land-use and transportation variables. This is the idea behind composite measures such as Portland, Oregon's "pedestrian environment factor," and Montgomery County, Maryland's "transit serviceability index."

Elasticity Estimates

The final contribution of the literature survey (5) was to conduct a meta-analysis of travel elasticities with respect to the 3 Ds. Travel elasticity estimates were extracted from a subset of the studies reviewed, in which necessary data were provided by the authors. The elasticities so derived suggest that for every 1% increase of measures of density or design, the percentage of trips made on foot rises by approximately 0.45%. The same applies to transit-mode share. Diversity (land-use mix) may have a slightly smaller effect on transit-mode share. These effects are independent and cumulative. Thus, any percentage increase in all 3Ds is associated with an even greater percentage increase in active travel. These results are consistent with the preceding estimated elasticities of walk- and transit-mode share with respect to sprawl.

Nuanced Understanding

Nearly all research on the 3 Ds and their relationship to active travel has involved adults. In a recent study for Environmental Protection Agency, we modeled mode choice on the journey to school as a function of socioeconomic, school, and built environmental variables (8). Students with shorter walk and bike times to school proved significantly more likely to walk or bike, a finding that argues for neighborhood schools serving nearby residential areas. Students traveling through areas with sidewalks on main roads were also more likely to walk, which argues for "safe routes to school" sidewalk improvements. Consistent with these findings, a U.S. Centers for Disease Control (CDC) survey of parents disclosed that long distances were the foremost barrier to children walking or biking to school, and that danger from traffic was second (3).

Interestingly, in our study, the standard 3 D variables—density, land-use mix, and street connectivity—bore no relationship to mode choice on the journey to school. The travel-behavior literature emphasizes the importance of such variables in travel decision-making. Apparently, school trips are different. They tend to be unlinked to other activities, thus reducing the need for proximity to other land uses. They are mandatory, which may render the walking environment less important than with discretionary travel. And they involve children, whose parents may be making travel decisions based on considerations unrelated to the built environment. In the CDC survey, adverse weather conditions, danger from crime, and adverse school policy were the third, fourth, and fifth more important barriers to children walking or biking to school (3). This is a case in which the social and natural environments may trump the built environment.

Our study suggests that the built environment may have differential effects on the physical activity of different sociodemographic groups. We need to move beyond the simple 3 D travel paradigm to a more nuanced understanding of these relationships.

BUILT ENVIRONMENT AND LEISURE-TIME ACTIVITY

Distinct from the impact of the built environment on travel is its impact on leisure-time physical activity. Historically, urban planners have dealt strictly with travel, whereas physical activity researchers have focused on leisure-time activity. Only now are the two beginning to intersect, as the urban planning and public health fields increasingly interact.

Urban planning researchers are expanding their horizons, giving increased attention to how their fields affect human behavior and health (10). Travel modeling is slowly being superseded by activity modeling, in which travel is represented as an outgrowth of daily activity patterns. Planners are beginning to ask about nontravel-related physical activity as part of their travel diary–based surveys (routinely conducted to calibrate the travel demand models used in regional transportation planning).

Likewise, public health researchers are expanding their horizons, moving beyond individual models of behavior to more inclusive ecological models that recognize the importance of physical as well as social environments as determinants of health (11). The emerging literature has been summarized this way: "Both cross-sectional and longitudinal studies have shown that access to facilities (*e.g.*, walking trails, swimming pools, gyms) has a positive correlation with physical activity behavior patterns in adults" (1).

Public health researchers are also beginning to recognize the health benefits of active travel, and to include development patterns in their assessment of the physical environment. Recognizing the need to monitor more than just leisure-time physical activity, the 2001 Behavioral Risk Factor Surveillance System (BRFSS) questions were modified to include transportation-, household-, and work-related physical activity.

This author has conducted only one study relating the built environment to leisure-time physical activity (7). This study found that residents of sprawling and compact counties were equally likely to engage in leisure-time physical activity, and equally likely to engage in recommended levels of physical activity. The one physical activity measure that differed significantly across counties was the number of minutes of leisure-time walking by residents, with residents of compact counties having an edge in this regard. Interestingly, however, the difference in leisure-time walking between the most sprawling and most compact counties was only 79 min·month^{-1}, hardly significant in a practical sense. The elasticity of leisure-time walk minutes with respect to the county sprawl index came in at a modest 0.11.

Again, Nuance

We will return to this last finding as we discuss the effects of the built environment on obesity and overall health. For now, we simply suggest that the way we measured sprawl has far more relevance to active travel than leisure-time physical activity. People engage in travel to participate in activities at destinations, whereas people engage in leisure-time physical activity for its own sake. Hence, elements of the built environment are likely to affect the two differently. In particular, travel will depend on land-use patterns because land use accommodates specific activities, whereas leisure-time physical activity will depend on proximity to and quality of recreational facilities.

BUILT ENVIRONMENT, OBESITY, AND MORBIDITY

The next wave of built environment–physical activity studies will explore downstream impacts of the built environment on obesity and morbidity. In these analyses, physical activity will be treated as a mediating variable, one of many intervening to produce weight and, ultimately, health effects (Fig. 2). Several such studies are currently underway, and a few have been completed.

The first study linking the built environment to health outcomes appeared in late 2003 (7). Health data for more than 200,000 American adults were extracted from BRFSS. These data were matched to Smart Growth America's county sprawl index (described above) using county geocodes from BRFSS. Obesity, body mass index (BMI), hypertension, diabetes, and coronary heart disease (CHD) were modeled in terms of individual characteristics and the county sprawl index. After controlling for age, education, fruit and vegetable consumption, and other sociodemographic and behavioral covariates, residents of sprawling counties weighed more, were more likely to be obese, and were more likely to have high blood pressure than were their counterparts living in compact counties.

The difference in weight between the least and most sprawling counties was 6.3 lb for the average adult. This is not large, but it is equivalent to the effects of certain sociodemographic (gender) and behavioral (smoking) covariates. And it is large enough to raise concerns for public health specialists, who note that even small shifts in distribution at the population level can have important public health implications for individuals.

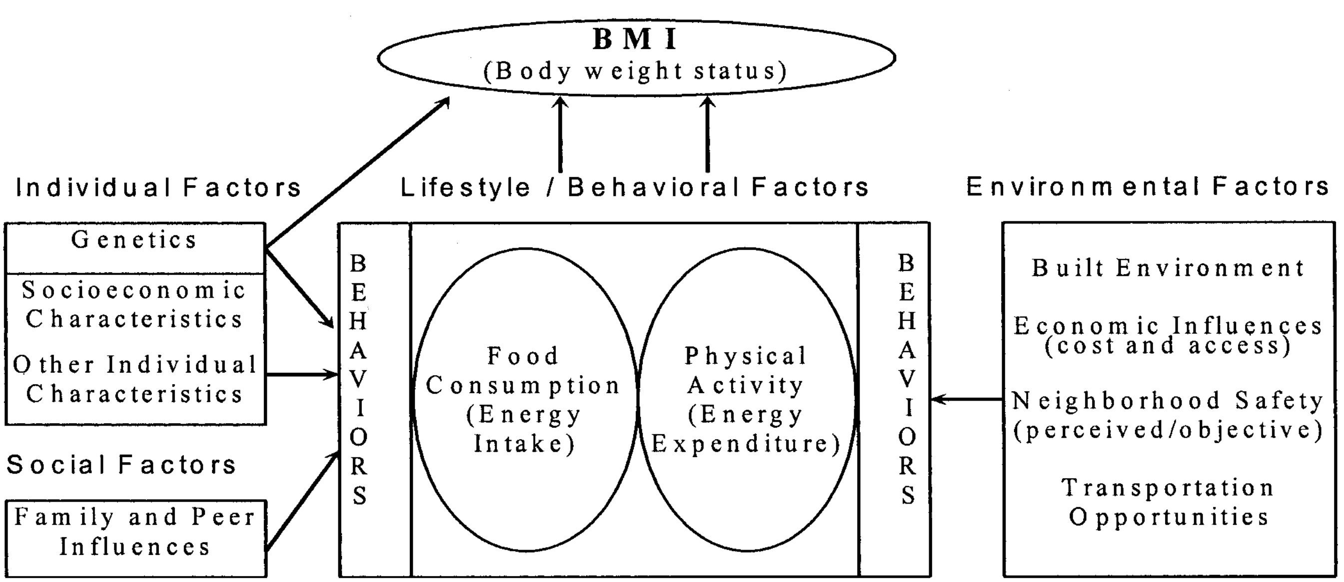

Figure 2. Ecological model relating the built environment to physical activity and body weight. (Reprinted from: Powell, L., S. Slater, F. Chaloupka. *A Multi-Causal Model of Eating, Physical Activity and Obesity*. www.impacteen.org/. Used with permission.)

By Way of Explanation

Additional analyses were conducted, which included the amount of leisure-time walking as an independent variable in both BMI and obesity equations. We wanted to explore the mechanisms by which sprawl affects BMI and obesity—to see if living in compact counties was independently related to weight, after controlling for the amount of reported leisure-time walking. Both variables—minutes walked, and county sprawl index—proved significantly (and independently) associated with BMI and obesity.

We found that a small portion of the overall sprawl–weight relationship was accounted for by the time people spend walking for leisure. The direct effect of sprawl was approximately 85 times stronger than the indirect effect through leisure-time walking. By way of explanation, we speculated that the big difference between sprawling and compact areas is not the amount of leisure-time physical activity residents get, but rather the amount of physical activity they get incidentally as they travel from place to place as part of their normal daily routines. In sprawling areas, people use their cars to go everywhere. In compact areas, they walk to lunch, walk to the bus stop, walk from the public parking garage, and have stairs to climb. Obviously, this is a working hypothesis that needs to be tested via more sophisticated research designs that support causal inference.

Elasticity Estimate

For purposes of this survey article, we returned to the sprawl–obesity database to compute the elasticity of BMI with respect to the county sprawl index. The elasticity value is minuscule, approximately −0.013. Recall that the way the index was constructed, lower values correspond to more sprawling areas, and higher values to more compact areas. So, this relationship is in the expected direction.

The relationship is also of plausible magnitude. We would not expect the built environment to overwhelm the many genetic, demographic, behavioral, and other environmental influences that contribute to overweight and obesity.

And More Nuance Still

Several independent studies are following up on our sprawl and obesity study, and getting slightly different results. In a study to be published in the *Journal of Planning Education and Research*, Kelly-Schwartz *et al.* (12) used our metropolitan sprawl index (6), and health data from National Health and Nutrition Examination Survey (NHANES), to test for relationships along the entire "sprawl–health causal chain." NHANES data have the advantage of being gathered through face-to-face interviews and medical examinations rather than a phone survey, as with our data source, BRFSS. The weight data are thus objective rather than self-reported and biased downward. They have the disadvantage of involving much smaller samples of both individuals and places than does BRFSS. Kelly-Schwartz *et al.* replicated our findings that after controlling for individual characteristics, adults living in sprawling counties walk less and weigh more than those living in compact counties. They could not replicate our finding that sprawl dwellers have higher blood pressure.

Kelly-Schwarz *et al.* also found that adults living in metro areas with high street accessibility (one of our four metropolitan sprawl factors) have better overall health than others, whereas those living in metro areas with high densities (another of our four factors) have worse overall health. They hypothesized that once environments are theoretically equal in terms of "walkability," as measured by street accessibility, a denser environment may be less inviting and more stressful.

Similarly nuanced findings are reported by Lopez (13) and Sturm and Cohen (14). Using our metropolitan sprawl index (6), and health data from Healthcare for Communities (a national U.S. household phone survey), Sturm and Cohen found that an increase in sprawl is associated with a significant increase in chronic medical conditions and a decline in health-related quality of life, but is unrelated to mental health disorders. Using a metropolitan sprawl index of his own creation and health data from BRFSS, Lopez reported that sprawl is directly related to overweight and obesity. We found no such relationship between sprawl at the metropolitan level and individual weight or obesity; significant relationships showed up only when we zeroed in on smaller geographic areas, namely counties.

Our original study and its progeny represent the built environment with county-wide or metropolitan-wide sprawl indices. Counties and metropolitan areas are large areas compared to the living and working environments of most residents, particularly compared to their walking environments. To the extent that intraarea differences in the built environment get averaged out over large areas, a major source of variance in physical activity levels may get washed out of the analysis.

In a study published in the *American Journal of Preventive Medicine*, Frank *et al.* (9) explored neighborhood effects on health. Using data from a travel survey in the Atlanta metropolitan area, and capturing the immediate neighborhood environment of each respondent with a geographic information system (GIS), they found links between built environment and obesity that are as strong as those in our original study. In their study, each quartile increase in the degree of land-use mixing was associated with a 12.2% reduction in the odds of being obese across gender and ethnicity classes. In our study, a quartile increase in compactness (indicated by the county sprawl index) was associated with a 14.2% reduction in the odds of being obese.

As these and other studies are published, the evidentiary base will grow, and may confirm or refute our original study. They almost certainly will add nuance to our findings. I expect it will take years before the preponderance of evidence points clearly in one direction or another.

CONCLUSIONS

This article began with a question: Can the physical environment determine physical activity levels? The literature offers extreme views—one according no importance to the physical environment, and the other viewing it as critically important. Existing evidence suggests a more moderate view. There is relatively strong evidence of association between metropolitan development patterns and use of active travel modes such as walking and transit, and between neighborhood design and active travel choices. Whether the environment is actually determining travel choices, how the environment relates to overall physical activity, and how the environment affects downstream weight and health remain issues for future research.

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