Measuring Food Access in Urban Areas

Kathryn M. Neckerman
Michael Bader
Marnie Purciel
Paulette Yousefzadeh

Built Environment and Health
Columbia University
February 9, 2009

Motivated by concern about rising obesity rates, researchers have begun to map the neighborhood "food environment" and examine its association with the risk of overweight or obesity. Some argue that "food deserts" – areas with little or no provision of fresh produce and other healthy food – may contribute to disparities in obesity, diabetes, and related health problems. When access to healthy food is limited, households must expend more time and/or money in order to eat a nutritious diet; more resource-constrained households may be especially likely to respond by substituting unhealthy for healthy food, leading to elevated rates of overweight and obesity. Recent studies have sought to explain socioeconomic or race/ethnic disparities in diet and body size using measures of proximity to food outlets such as supermarkets, convenience stores, or fast food restaurants. This research takes advantage of geographic information systems (GIS) technology and more widely available spatially referenced data to develop precise and objective measures of the local food environment.

GIS measures have enabled a significant expansion of research on disparities in the food environment and their implications for health. More attention to conceptual and methodological issues would enhance the value of this research for science and public policy. This paper contributes to this broader agenda by examining the measurement of the food environment in urban areas. It opens with an overview of research on the food environment, drawing from epidemiology as well as urban planning and the social sciences. This discussion highlights two key categories of conceptual and methodological questions: how to define the relevant neighborhood and how to characterize the food environment within that neighborhood. Second, using an extensive collection of GIS data, we examine the spatial accessibility of healthy food in New York City. These analyses include fruit and vegetable markets and farmers' markets as well as supermarkets. As part of this empirical exercise, we conduct a series of sensitivity analyses to examine how adjustments for spatial variation in characteristics such as vehicle ownership, crime, and public transit access affect measured disparities in the accessibility of healthy food. Lastly, we review recent food access initiatives in New York City and discuss the extent to which they are responsive to the disparities identified in our empirical analysis.

Background

Recent attention to the food environment is motivated by the assumption that food access affects dietary intake and thus body size. “Food deserts,” or neighborhood environments in which access to healthy food is more limited, are believed to contribute to poor diets and an elevated prevalence of obesity and diabetes in disadvantaged populations. This idea has motivated two complementary streams of research: studies that describe disparities in the food environment and those relating food environment measures to dietary intake, weight status, and other health outcomes.

To measure the food environment, this research typically uses business listings obtained from public agencies (e.g. health departments) or proprietary sources (Dun & Bradstreet, InfoUSA) which identify the location and attributes of local restaurants and food stores. Detailed industry codes are used to classify food outlets as likely to offer healthy or unhealthy food. Supermarkets are assumed to provide a large selection of fresh produce as well as other healthy items such as whole-grain bread and low-fat milk, while fast food restaurants, convenience stores, and small grocery stores are assumed to offer little or no healthy food. Most food environment indicators are neighborhood-scale measures of the presence or density of food outlets within a Census tract, zip code area, or a half-mile to one-mile distance from a study subject’s residence, although a few rely on county- or even state-level measurement.

Most research on disparities in the food environment has documented variation in the accessibility of food outlets by area income and/or racial/composition. Findings have been relatively consistent. Neighborhoods with higher income levels and higher proportions of white residents tend to have greater access to supermarkets or large chain food stores, although poorer neighborhoods and those with higher proportions of black or Hispanic residents may have greater access to small grocery stores.[1-11] A few studies consider access to convenience stores, with most finding that low-income or predominantly minority neighborhoods are more likely to have access to such stores.[8] Research on the accessibility of fast food restaurants finds more mixed results. Low-income neighborhoods and schools tend to have more fast food restaurants nearby.[12-17] but a few studies find that middle-income areas are more likely to have access to fast food restaurants.[18,19] Some studies find that predominantly black neighborhoods have more access to fast food restaurants,[10,13,20,21] while others do not.[4,15]

Discrepancies in these results are not surprising given the cross-study variation in food environment measures, data sources, and study sites. Fast food restaurants, for instance, are operationalized variously as national chains such as McDonalds, limited-service restaurants, and restaurants selling hamburgers, hot dogs, and fried chicken. In addition, research includes some national studies as well as those for one or more cities or metropolitan areas, and even for selected neighborhoods within cities. In addition, some studies adjust access measures for demographic characteristics – reporting on racial disparities net of area poverty or income, for instance – while some do not. A few studies further adjust for built environment features, such as population density or zoning, likely to be associated with density of retail outlets; most do not. In part, this heterogeneity reflects a bona fide distinction in research aims. For some studies, in which the intent is to document disparities by income or race/ethnicity, unadjusted results are appropriate; for others, which seek to explain variation in the food environment, a multivariate approach is essential. Greater consistency of measures and analytic strategies would make it easier to derive generalizable conclusions from this literature.

In particular, the built environment is a critical but under-recognized driver of variation in the spatial accessibility of healthy food. Access to almost any type of food outlet tends to follow a general urbanicity gradient in which more highly urbanized areas – those with higher population density and more land zoned to permit commercial use – are more likely to have stores and restaurants. Because urbanized areas often have concentrations of minority and/or low-income populations, retail density may be higher in minority or low-income neighborhoods.[9] One way to control for the influence of the built environment is through sampling strategies that allow comparisons of similar neighborhoods. For example, Helling and Sawicki compare predominantly black and white suburban neighborhoods, and Horowitz and colleagues compare New York City's East Harlem and the Upper East Side neighborhoods .[10,15,22] Alternatively, some studies statistically control for built environment features.[9,20] Although explicit consideration of the built environment is not necessary to document disparities, doing so will aid both in interpretation of findings and in generalization of those findings from the literature overall.

Research relating the food environment to health outcomes posits that better access to supermarkets will be associated with a healthier diet, lower BMI, and lower risk of overweight or obesity, while access to outlets such as convenience stores, small grocery stores, and fast food restaurants will be associated with poor diets, higher BMI, and higher weight. Nearly all such studies are cross-sectional; they include analyses based on national samples as well as single- and multi-site studies. Covariates tend to include individual-level socio-demographic characteristics such as age, sex, race/ethnicity, marital status, and socioeconomic position; some analyses also include neighborhood economic or ethnic composition or, more rarely, built environment characteristics.

This research has yielded promising but not unmixed results. Supermarket access is positively associated with consumption of a healthy diet in some studies[23-26] but not all.[27-31] Access to convenience stores is associated with poorer diet.[28,30,31] Some studies find that access to fast food restaurants is associated with poorer diets[30-32] while others do not.[33,34] Although most studies use food outlet type as a proxy for availability of healthy food, one recent study directly measured shelf space devoted to fruits and vegetables in small grocery stores, and found that proximity to stores stocking more fresh produce was associated with vegetable consumption.[29]

Most studies find that supermarket access is associated with lower BMI and lower risk of overweight or obesity (for an exception, see work by Wang and colleagues[18]).[35-37] States and counties with higher density of fast food restaurants tend to have higher obesity rates,[37-39] but there is little evidence that neighborhood-scale variation in fast food access is associated with weight status.[32-35,40,41] Access to convenience stores is associated with poorer weight status,[37,42,43] but evidence about the effect of non-fast food restaurants is inconclusive.[33,34,39,44]

As with most studies of neighborhood effects, and most epidemiologic research more generally, this literature is subject to questions about causal inference.[45] Study designs are typically observational and cross-sectional, making it difficult to determine the extent to which the food environment influences diet and weight status, individuals select into food environments that reflect their dietary preferences, or retailers adapt menus and merchandise to local consumers. Only a few studies have taken advantage of natural experiments or other strategies for establishing causality.[46]

In addition, studies relating food environment characteristics to health outcomes may be affected by two kinds of confounding. First, the density of food outlets tends to be higher in "walkable" or pedestrian-oriented environments – in other words, environments associated with higher physical activity and lower BMI.[47,48] Most analyses of the health effects of food environments do not control for land use mix, population density, or other walkability indicators. Failure to control for neighborhood walkability may bias studies relating food outlet access to obesity or BMI. Inclusion of controls for neighborhood walkability should be routine in order to avoid confounding. Second, because different types of food outlets are likely to locate in the same neighborhoods for a number of reasons (e.g., commercial zoning, high pedestrian traffic, access to shipping/deliveries, etc.), measures of the density of the different food outlets, say, supermarkets, fruit and vegetable markets, and fast food restaurants will in many cases be correlated. Analysis of the effect on health of one type of food outlet risks confounding with the overall food environment, but the simultaneous inclusion of measures of many different types of food outlets is likely to induce multicollinearity. Rundle and colleagues addressed this problem by creating three food environment categories – "BMI-healthy" (supermarkets, fruit and vegetable markets, health food stores), "BMI-unhealthy" (e.g. fast food restaurants, bodegas, convenience stores), and "BMI-intermediate" (e.g. full-service restaurants, medium-sized grocery stores) outlets – and including all three in an analysis of BMI.[49]

Cutting across these two streams of research – studies of disparities in the food environment and of the association between food environment and health outcomes – are a series of conceptual and methodological issues concerning the measurement of food access. More careful consideration of these issues can improve the validity of food environment measures. Here we focus on two sets of questions. The first concerns the neighborhood definitions used to define which food outlets are deemed accessible. The second concerns the characterization of the food environment within those neighborhoods.

Defining the neighborhood

Spatial accessibility research has examined the advantages and disadvantages of common measurement strategies.[50,51] Many studies use the presence/absence, count, or density of food outlets within a neighborhood defined by administrative boundaries such as Census tracts or as a radial or network buffer around a study subject's residence.[36,49] These measures are straightforward to construct and interpret, but they have disadvantages.[50] A given neighborhood may be internally heterogeneous, so that residents located in different parts of the neighborhood experience significantly different environments. In addition, these measures arbitrarily omit readily accessible resources just outside the neighborhood boundary. This problem often appears with neighborhoods defined by administrative or Census units because the boundaries for these units typically follow major commercial thoroughfares; stores on one side of the street are treated as part of the neighborhood, while those stores on the other side are not. To address this problem, some researchers use the minimum distance to the nearest outlet of a given type or average distance to all outlets within a given distance.[3,23,41] Distance-based measures avoid the boundary problem; unlike density measures, however, distance-based measures do not indicate the presence of multiple facilities. Proximity to multiple outlets offers more selection and may lower prices through competition.[51] Another form of measurement, kernel densities, is just beginning to be used in studies of the food environment.[25] The kernel density approach constructs a continuous density surface in which the value of any point on the surface is determined by the number of food outlets within a given search radius (with greater weight given to outlets that are closer to a given point). Because kernel densities create a continuous surface over the entire study region and are created from all outlets within the search radius, this approach both addresses the boundary problem and measures multiple outlets.[51]

Choice of measurement determines how the neighborhood will be bounded, but leaves unanswered the question of neighborhood dimensions. Studies of the food environment make some assumptions – implicit or explicit – about which food outlets are “accessible” to a given household or neighborhood. Of course, most food outlets are not literally inaccessible. Instead, food outlets fall along a continuum of accessibility based on the travel burden involved in reaching them. The analyst’s classification of accessibility is based either on convenience or on judgments about the travel burden people will or should have to accept. For instance, when Helling and Sawicki chose their benchmarks for accessibility of 5 or 10 minutes travel time, they consulted previous studies of travel time and distance to grocery stores and other shopping locations among middle-class American families.[10]

Straight-line distance offers a simple approximation of travel burden, but spatial accessibility is affected by individual/ household and neighborhood characteristics beyond simple distance. Individual characteristics such as vehicle ownership or mobility impairments due to poor health or disability can have a profound impact on spatial accessibility. In addition, neighborhood features may affect the efficiency or safety of specific types of travel. For instance, infrequent bus service will increase average travel time, and unsafe traffic or crime hot spots might encourage pedestrians to use less direct routes or patronize more distant stores (or fail to patronize stores altogether, even those that are spatially proximal). Spatial variation in characteristics such as vehicle ownership, public transit infrastructure, crime, and safety is likely to have significant implications for the validity of food environment measures as well as for comparability of studies across contexts defined by urban form.

The remainder of this section considers two sets of characteristics that could affect the validity of food environment measures. The first considers individual or household characteristics that affect mobility. The second considers neighborhood characteristics that may affect the efficiency of travel.

Vehicle ownership – Whether people travel by automobile, public transit, or walking has a very large effect on travel burden. For pedestrians, a 10-15 minute trip may extend a half mile, while for drivers a trip of the same duration – even in a congested urban setting – may reach destinations 3-5 miles away. Most food environment studies use neighborhood measures that approximate a walking distance, such as a Census tract, zip code area, or half-mile buffer. Food shopping trips may extend over longer distances, however. Individuals in the Multiethnic Study of Atherosclerosis (MESA) sample, located in New York City, New York, Baltimore, Maryland, and Forsyth County, North Carolina, reported traveling a median distance of 3.5 miles to shop for food.[52] Given this heterogeneity, small-area food environment measures are a better approximation of opportunities to buy healthy food among less mobile populations and, perhaps, those in more densely settled environments. Using the MESA data, Auchincloss et al. found that the food environment within a mile of the home had a much stronger association with insulin resistance for study subjects who did not own cars and for residents of New York City (a more densely settled context with lower rates of car ownership than the other two sites).[52]

Spatial accessibility studies, including studies of the food environment, rarely take explicit account of travel mode, although there are exceptions. Rose and Richards develop a composite index of supermarket accessibility which includes car ownership as well as travel time and supermarket use; in a comparison of supermarket accessibility in low- and higher-income neighborhoods, Block and Kouba identify areas with relatively low proximity to supermarkets and relatively high rates of car ownership.[7,24] Studies using Census tracts or zip code measures do reflect a crude de facto adjustment, because these Census/administrative units typically are larger in lower-density environments where vehicle ownership tends to be higher. However, more systematic adjustment for vehicle ownership would make measures of spatial accessibility more comparable across areas.

Mobility impairment – For individuals who are disabled or in poor health, the built environment is more difficult to navigate. Shorter walking distances – for instance a quarter mile rather than a half mile – may be indicated, and other environmental features such as short crossing times at intersections, steep hills, or a broken sidewalk path may constitute barriers to travel for this population.[53] For persons using wheelchairs, built features of the store itself are also critical. Mojtahedi et al. audited 82 food stores in low-income urban and suburban neighborhoods in Chicago to evaluate their accessibility to persons with mobility impairment. Only 12 percent of these stores met even minimal accessibility standards (ramp or level access at the store entrance) and offered at least some healthy food items.[54]

Residential vs. "daytime" neighborhoods – For people who spend a significant part of the day outside their neighborhood of residence, the stores and restaurants near their school or place of work, or on the route between home and school/workplace, are also part of their food environment. Public health researchers are just beginning to consider the implications of time spent outside the residential neighborhood.[55] The food environment surrounding schools – in particular, the proximity of fast food outlets or other sources of energy-dense food – has recently received attention.[15,19] A few studies have included measures of food outlets near the school or workplace in studies of food intake or body size,[33,44] but datasets rarely include information on both residential and nonresidential neighborhoods.

In addition to adjustments for individual or household characteristics, features of the neighborhood environment may affect the efficiency of travel.

Street connectivity – For any distance, travel is more efficient in an environment with high street connectivity. Distance or buffer measures may be based either on Euclidean (straight-line) or network distance. Network-based measures are more accurate representations of travel time because they follow the street network – particularly important in contexts with winding or discontinuous street patterns. In more urbanized environments, in which streets tended to follow a more regular, gridded pattern, network-based measures may be less important.[56] A recent analysis using data from New York City compared effects of neighborhood walkability on BMI using radial and network buffers of the same radius and found no significant difference in their results.[57] In lower-density environments, however, use of network buffers or distances may significantly alter results.[58]

Public transit network – Particularly for those who lack a private automobile, the extent and frequency of public transit service may be pivotal for accessing services. Researchers have included measures of public transit in studies of neighborhood walkability[59] and of physical activity and weight status.[48,60,61] Larsen and Gilliland incorporate public transit into spatial accessibility measures; points within a 500-meter walk and a 10 minute (3 km) bus ride of a supermarket were classified as having accessibility by bus. Among residents of the most urbanized part of London, Ontario, 35.1 percent lived within 1 km of a supermarket, and 86.5 percent had accessibility by bus.[62] As these results indicate, public transit can substantially expand access to retail services including grocery stores. In locations with infrequent or unreliable transit service, however, use of transit is likely to be time-consuming and inefficient.[53,63]

Crime and traffic hazards as barriers to travel – There is evidence that fear of crime and other safety-related concerns discourage neighborhood walking or other forms of outdoor physical activity.[64,65] Concern about safety may deter use of local food outlets, especially for people traveling on foot or by public transit because these travel modes involve greater exposure to conditions in the neighborhood immediately surrounding the food outlet.[53] Concerns about safety could prompt shoppers to take a less direct route or seek out more distant stores. High crime rates near a supermarket could also lead to a vicious cycle in which lower usage of an outlet by consumers reduces sales revenues, making it more difficult to stock a variety of foods, especially perishable foods such as fresh produce, and also reduces pedestrian traffic near the food outlet, weakening informal social controls that might otherwise curb street crime. Although issues of crime and traffic safety are widely noted in studies of neighborhood influences on physical activity, to our knowledge no research has considered the implications of crime or traffic hazards for use of the local retail environment.

In sum, both individual and environmental characteristics may modify decisions about neighborhood boundaries in spatial accessibility studies. These boundaries may be contingent on characteristics of the study population. For instance, some individuals have wider mobility either because they travel by car or because their daily schedules take them far from home, while others have more restricted mobility because of poor health or disability. In addition, environmental conditions may facilitate or represent barriers to travel. As crime and residents' concern for their safety increases stores in high-crime neighborhoods may in effect be excluded from the relevant neighborhood; for non-drivers, stores that are too distant from public transit lines may similarly drop out of consideration.

Characterizing the food environment

Once the relevant neighborhood is defined, researchers must decide how to characterize the food environment. Most food environment measures are constructed using business listings from public agencies, proprietary business databases (usually Dun & Bradsteet or InfoUSA), or other databases such as telephone books. Attempts to "ground-truth" business databases by comparing individual records to stores and restaurants observed through fieldwork or by comparing one database to another typically find a number of discrepancies.[66] These discrepancies may occur for a number of reasons: there may be a time lag in adding newly opened businesses or deleting closed ones, a business is given an incorrect or incomplete industry code, there are discrepancies in name or address fields, a legal or administrative address is mistaken for a retail location, a business is re-branded or changes ownership, the name given refers to the owner or company name rather than the store name.[67,68] More research on the accuracy of business listings would be helpful. In particular, while spatial inaccuracy is easiest to assess and has received the most attention, we know little about the accuracy of the industry classifications in business databases; because food outlets are classified as offering healthy or unhealthy food primarily on the basis of detailed industry classifications, the accuracy of this information is critical.

In addition, this section discusses three questions about the validity of food outlet-based measures. First, how valid is food outlet type (e.g. supermarket, fast food restaurant) as an indicator of the availability of healthy food? Second, how does the omission of information on food price and quality affect food environment measures? Finally, how should researchers conceptualize the effect of unhealthy food?

Food outlets as proxies for food availability – In studies using objective data on food outlets, the presence or proximity of a specific type of food outlet is taken as a proxy for the availability of specific types of food. For instance, supermarkets are assumed to sell a wider range of produce and other healthy foods than smaller food outlets; convenience stores and fast food restaurants are assumed to sell mostly energy-dense food.

Stores in low-income or predominantly minority neighborhoods are widely assumed to offer fewer healthy foods such as fresh produce, low-fat milk, or whole wheat bread and pasta. Audit studies have compared stores in low-income or predominantly minority neighborhoods with those in more affluent or white neighborhoods, and most find that stores in disadvantaged neighborhoods are indeed less likely to sell healthy foods.[6,22,69-74] For our purposes, however, what matters is whether food availability varies within store type. Substantial within-type variation would make store categories such as supermarkets or convenience stores less valid indicators of food access.

Franco and colleagues adapted a recently developed audit tool to measure the food availability in Baltimore-area stores.[74] Consistent with other studies, they found lower availability of healthy foods in stores in predominantly black neighborhoods and in low-income neighborhoods. Most of this variation is accounted for by differences between – not within – store category. For instance, their healthy food availability index (HFAI) averaged 5.48 in black neighborhoods and 13.04 in white neighborhoods. Supermarkets in black neighborhoods had an average HFAI of 20.34, compared with 24.00 among supermarkets in white neighborhoods; smaller grocery stores in black neighborhoods had an average score of 3.85, while those in white neighborhoods averaged 6.17. Similar patterns were obtained for comparisons across low- and high-income neighborhoods. The results of other studies are mixed. Studies set in Chicago and Albany found no within-store-type difference in food availability.[7,75] Three studies based in New York City neighborhoods reported differences in healthy food availability among bodegas[22,76] or supermarkets[6] in neighborhoods of differing income or race/ethnic composition. Distinctive features of the local retail environment – for instance, the predominance of chain versus independent groceries or the organization of food distribution networks – may help explain differences across cities in the implications of neighborhood composition for food availability.

In contrast to food stores, for which industry categories such as supermarket, small grocery store, and convenience store provide reasonably good proxies for food pricing and availability, restaurants are more difficult to characterize. Researchers have commonly distinguished between full-service and limited-service or “fast food” restaurants. Eating at fast food restaurants is associated with poor dietary intake and increased weight, while eating at other or full-service restaurants is not; thus the distinction between full-service and limited-service restaurants has some predictive validity.

However, identifying restaurant characteristics that promote or discourage good nutrition may not be straightforward. The Nutrition Environment Measures Study in Restaurants (NEMS-R) is a recently developed audit tool that assesses the availability of healthy menu items, such as healthy entrees, baked chips, and low-fat milk, as well as food pricing, provision of nutritional information, and signage highlighting healthy or unhealthy food choices. This protocol was tested in samples of “sit down” and “fast food” restaurants in Atlanta: fast food restaurants were more likely to offer healthy entrees and main-dish salads, and more likely to post nutritional information, but fast food pricing encouraged over-eating through pricing strategies that encouraged the purchase of larger portions or combinations of items.[77] This study raises questions about the utility of the full-service versus limited-service (fast food) distinction for identifying healthy food outlets.

A few audit studies have compared healthy food availability in restaurants in more and less advantaged neighborhoods. These studies tend to find fewer healthy food items in low-income and predominantly minority neighborhoods.[21] More research is needed, however, to understand whether and how categories of restaurants can be used to map accessibility of healthy foods in restaurants.

Omission of food price and quality information – Spatial accessibility measures are sometimes criticized for excluding aspatial aspects of access such as the cost and quality of food. Food prices are obviously an important aspect of food access. Consumers tend to buy fewer fruits and vegetables in contexts in which fresh produce is more costly relative to more energy-dense food such as fast food, and lower relative prices of fruits and vegetables are associated with slower weight gain.[34,44,78] Longitudinal research suggests that the growing price gap between healthy and unhealthy food may have contributed to the rise in obesity, and price differences between a high- and low-energy-dense diet may contribute to poor nutrition and high obesity rates among low-income consumers, who are assumed to be more price sensitive.[79,80] For low-income households, purchasing the recommended market basket of fruits and vegetables is estimated to cost between 43 and 70 percent of the food budget – figures likely to put a healthy diet out of reach for many.[81]

If food prices vary by type of neighborhood, then spatial measures of food accessibility would omit an important dimension of access. Both anecdotal reports and some more systematic studies have suggested that "the poor pay more" – that residents of low-income neighborhoods pay higher prices for food. However, the evidence on this point is inconclusive.[82] In fact, a number of recent studies have found that food prices in low-income neighborhoods are no higher – and sometimes even lower – than in more affluent neighborhoods.[7,11,22,69,71,81-83] There is more consistent evidence that store type is associated with price; with supermarkets, larger chain stores, or discount stores tending to offer lower prices.[11,81,82] Given this evidence, it seems likely that food access measures that differentiate by store type are likely to capture much of the variation in food pricing.

Store audits have less frequently examined food quality, which is more difficult to measure reliably. The few available studies suggest that food outlets in low-income neighborhoods may sacrifice quality in order to provide goods at prices affordable to their clientele. Poor-quality fruits and vegetables are more often observed in stores in low-income neighborhoods, in part because stores in more affluent areas may stock better and more costly grades of produce, and in part because produce in lower-income areas may not sell as quickly and thus becomes spoiled or over-ripe.[7,71,82,84] In addition, Jetter and Cassady observed that small grocery stores in low-income areas tended to stock discount brands of food with poorer nutritional quality, such as bread with less dietary fiber.[85] To date, however, we do not know whether quality is associated systematically with food outlet type.

The effect of unhealthy food – In urban areas, especially in densely settled cities, unhealthy food is everywhere. It is sold not only by traditional food outlets but also by chain drug stores, liquor stores, variety and discount stores, and sidewalk vending carts. From an economic perspective, for a consumer who intends to purchase healthy foods the availability of unhealthy food is simply irrelevant; someone who passes five fast food restaurants on the way to the supermarket still comes home with salad greens and whole grain bread. In a social psychological framework, however, branded architecture, point-of-purchase advertising, and other sensory cues (the McDonald's golden arches, the ice cream truck jingle) may promote buying of unhealthy food even when healthy food is readily available.

The implications of the availability of unhealthy food are not well theorized in public health research on the food environment: as a result, it has been unclear how to specify the effects of unhealthy food in empirical analyses. “Food deserts” are usually discussed in terms of the absence of healthy food without respect to the availability of unhealthy food. The empirical literature provides little guidance: some studies consider the effects of unhealthy food in isolation while a few measure the proportion of food outlets that are unhealthy, and overall the pattern of findings is too mixed to support conclusions about the conditions under which the availability of unhealthy food influences diet and weight. Because unhealthy food is so widely available, neighborhood variation in its density may have little impact. Further conceptual development and hypothesis generation, drawing on theory and evidence from social psychology and marketing research, is needed to understand when and for whom the availability of unhealthy food contributes to poor diet and obesity.

Spatial Accessibility of Healthy Food in New York City

Our analysis of food access in New York City draws on an extensive spatial database assembled for research on the built environment and health. Given the research reviewed above, which finds much more consistent results for proximity to “healthy” outlets such as supermarkets than to “unhealthy” outlets such as fast food restaurants, our analyses focused on access to healthy food.[26,86] Using a kernel density approach, we constructed density measures for a “healthy food retail” category that includes supermarkets, fruit and vegetable markets, and farmers’ markets. We also considered proximity to emergency food outlets. Using Census tract-level characteristics, we examined differences in the food environment by neighborhood poverty level, race/ethnic composition, and immigrant composition.

In addition to a general description of variation in spatial accessibility, our empirical work had three aims. First, we examined the contribution of smaller retailers - fruit and vegetable markets and farmers’ markets – in the food environment overall and in low-income and minority neighborhoods. Second, motivated by the discussion above, we examined the sensitivity of food environment measures to adjustments for neighborhood conditions such as rates of vehicle ownership, public transit access, crime, and traffic safety. Third, we examined variation in healthy food accessibility in a multivariate context to show how these measures vary by built environment characteristics including population density and land use zoning. These analyses inform discussion of disparities in food access by showing that differential residential location by race/ethnicity, poverty, and immigrant status is likely to influence food access.

Our basic measure of the spatial accessibility of healthy food outlets is a kernel density measure that represents the density of supermarkets, fruit and vegetable markets, and farmers' markets within a half mile of the population-weighted centroid of the Census tract (see Figure 1). (The appendix provides more detailed information about variable construction and analysis.) Across all tracts, the mean density of healthy food outlets per square kilometer is 2.87. Healthy food density varies by neighborhood racial composition, with predominantly black tracts having lower access to healthy food than tracts in which other ethnic groups predominate (Table 1). Neighborhoods with a large foreign-born population tend to have higher access to healthy food, as do poorer neighborhoods. The distribution of healthy food outlets is skewed. The city's most affluent and densely populated neighborhoods – the residential areas to the east and west of Central Park in Manhattan – have a very high density of supermarkets and other healthy food outlets, while more than a quarter of the city's Census tracts have a density of less than 1 store/km^2.

The description of the food environment above is entirely ecological, meaning that we measure accessibility for the average spatial unit (i.e., Census tract) in New York City. Another way to conceptualize accessibility is to ascertain how accessible healthy food stores are to the average resident in New York City. Methodologically, this means that we weight the healthy food accessibility of each Census tract by the number of residents living in that tract. Calculating accessibility figures this way results in higher levels of accessibility to healthy food: the density of healthy food is 3.473 stores/km^2. However, racial disparities remain, with the average black resident having a density of 2.612 healthy food outlets per km^2, compared with 3.732 for whites, 3.435 for Latinos, and 4.487 for Asians (Table 2).

<u>Types of healthy food outlets</u>

In addition to supermarkets, healthy food outlets include fruit and vegetable markets and farmers' markets. Small outlets like these may be particularly important in densely-settled urban neighborhoods because it may be costly and difficult to assemble the land required for a supermarket. Table 3 disaggregates the availability to each of these three outlet types for a) all Census tracts and b) by tract composition. For each outlet type, the first column displays the mean density; the second column displays the proportion of the total density that is accounted for by this outlet type; and the third column displays the median density of this outlet type.

Smaller retailers clearly play an important role in healthy food access in New York City. Across all tracts, only 36.1 percent of the accessible healthy food outlets were supermarkets, while 57.3 percent were fruit and vegetable markets and 6.6 percent were farmers' markets. Supermarkets are relatively more important in neighborhoods with a high proportion of white residents, low proportions of foreign-born residents, and low poverty rates. Fruit and vegetable markets are especially important in poor neighborhoods and in those with high proportions of Latinos and foreign-born residents. Interestingly, although use of farmers' markets is often associated with middle or upper-income consumers, these markets play a more important role in the food environment of high-poverty neighborhoods, where they represent 10 percent of the accessible healthy food outlets.

Sensitivity analyses

We conducted a series of sensitivity analyses to illustrate the impact of adjustments related to neighborhood definitions, including a simple change in the geographic scale of neighborhood accessibility, as well as adjustments for vehicle ownership, public transit, crime, and traffic safety. In addition, we examined the spatial distribution of supermarkets and farmers' markets that accepted food stamps and of emergency food outlets.

Scale effects – The results reported above were based on a half-mile search radius meaning that this measure represents the food environment within a half mile of the tract centroid, with outlets closer to the centroid weighted more heavily in the density calculations. (It is important to keep in mind that food outlets outside the half-mile radius are reflected in the density surface.) As Table 4 shows, increasing the search radius to a mile tends to "smooth out" inter-neighborhood variation in food environment characteristics, while reducing the radius makes the measure more sensitive to small-scale variation in neighborhood characteristics. The difference between the 75^{th} and 25^{th} percentile is largest for the quarter-mile radius and smallest for the mile radius measures. Disparities in the food environment by race/ethnicity or foreign born population tended to be larger when smaller neighborhood definitions are used; however, we did not find that disparities by income were sensitive to the scale at which we measured accessibility.

The sensitivity of measured disparities to adjustment of the neighborhood scale is likely to depend on the spatial or geographic scale of race/ethnic and income segregation, as Reardon and colleagues have discussed.[87] Where levels of segregation drop quickly with increasing scale, a larger search radius around the tract centroid is likely to encompass an area that is more demographically diverse, and the retail environment is likely to be more similar to the city as a whole. In New York City, by contrast, segregation remains high at a relatively large spatial scale; if the retail environment is responsive to characteristics of the resident population, increasing the search radius is likely to produce relatively little change in the retail environment. The implications of changing neighborhood scale for measured disparities are also likely to depend on a city's ecological features. For instance, changing the neighborhood scale is likely to have a more substantial effect in instances where residential and commercial land uses are highly segregated. In general, however, kernel density measures are relatively insensitive to changes in scale. Changing the neighborhood scale can have more implications for other types of accessibility measures, such as measures of the presence/absence or count of food outlets.

Vehicle ownership – As discussed above, access to a vehicle has significant implications for the number of food outlets that a household can access. Households without vehicles are disproportionately low-income or headed by elderly or disabled individuals; food environment measures that don't adjust for this difference are likely to understate disparities in the ability to access healthy food outlets. To illustrate the effect of adjusting for cross-neighborhood variation in vehicle ownership, we weighted measures of healthy food accessibility by the rate of vehicle ownership in each tract. We assumed that households without a vehicle used food stores within a half-mile radius while households with vehicles used food stores within a mile radius. Because kernel density measures are relatively insensitive to changes in neighborhood scale, we present an alternative measure – the count of supermarkets within the relevant neighborhood.

The first column in Table 5 shows the unadjusted measure; all tracts are assigned the count of supermarkets within half a mile of the population-weighted centroid. The second column displays the mean proportion of households with at least one vehicle. The third and fourth columns show unadjusted and adjusted measures, respectively. As expected, the mean number of accessible supermarkets increases, from 2.05 to 2.763. In addition, where vehicle ownership rates are higher – tracts with lower proportions of minority and poor residents – the mean number of accessible supermarkets increases. Also, importantly, racial/ethnic and income disparities are higher for the adjusted than the unadjusted measure.

Public transit – Consumers without vehicle access may use public transit to reach supermarkets that are not within walking distance. Because of its extensive public transit network, New York City should provide unusually good transit access to food outlets. We evaluated transit access to supermarkets through a several-step procedure. We classified each supermarket as bus- and/or subway-accessible by examining whether it had a bus or subway stop within one-quarter mile. Similarly, we classified each tract centroid as bus- or subway-accessible by examining whether it had a bus or subway stop within a quarter mile. A tract was deemed to have bus accessibility to a supermarket if the tract centroid was bus-accessible and there was at least one bus-accessible supermarket within a mile of the centroid. Subway-accessible tracts had a subway stop a quarter mile from the centroid and at least one subway-accessible supermarket within a mile. Each tract was classified into the first category for which it met the criteria: in order, walking-accessible (at least one supermarket within a quarter mile), subway-accessible, bus-accessible, or inaccessible by both walking and public transit. We use this method as opposed to determining access using actual bus and subway routes because of the increases in computational requirements to measure network distance on the public transportation network and because, as we mention above, New York City has a very dense public transportation network. In areas with a less dense public transportation network, measuring the network travel distance along bus and/or subway routes might be more important.

Overall, 24.9 percent of tracts had walking access to a supermarket, 25.6 percent had a subway-accessible supermarket, 45.6 percent had only a bus-accessible supermarket, and 3.9 percent had neither walking- nor transit-accessible supermarkets (see Table 6). Tracts that were majority-white, low-poverty, or had small foreign-born populations had slightly higher proportions of tracts with no walking- or transit-accessible supermarkets, but no more than 10 percent of tracts fell into this category.

Of greater concern are the tracts with bus-only access (i.e. no walking or subway access to supermarkets). Although consumers are able to travel to and from grocery stores by bus, these trips may be lengthy. Assuming a 3 mph walking speed, a quarter-mile walk to and from the bus stop, a bus speed of 7.5 mph, and a wait time of 5 minutes, the estimated time required to take a bus to a supermarket a mile away is about 23 minutes, slightly longer than it would take to walk the same distance. These assumptions are optimistic. With slower travel speeds or longer wait times for buses, a one-way trip could easily take longer than half an hour. Travel by public transit becomes more efficient for longer distances; for a supermarket 2 miles away, for instance, the most optimistic speed and bus frequency assumptions imply a transit trip of 31 minutes compared to a walking trip of 40 minutes. (The subway is faster, but the reduction in overall travel time is modest over short distances because of the fixed time costs of walking to and from subway stops and waiting for the train.) More than half of all majority-black tracts have bus-only access to supermarkets; low-poverty tracts are also likely to have bus-only access. Tracts with predominantly Latino, Asian, or foreign-born residents, on the other hand, fare relatively well; fewer than half of their residents have bus-only access to supermarkets.

Crime – High crime in the neighborhood adjacent to food outlets may deter consumers, especially for people traveling on foot or by public transit because these travel modes involve greater exposure to conditions in the neighborhood immediately surrounding the food outlet. High crime rates near the supermarket could lead to a vicious cycle in which lower usage of an outlet by consumers reduces sales revenues, making it more difficult to stock a variety of foods, especially perishable foods such as fresh produce. Fear of victimization might also reduce pedestrian traffic near the food outlet which could weaken informal social controls that might otherwise curb street crime. To our knowledge, no studies have examined the influence of fear of crime on use of retail outlets.

In our sensitivity analysis, we looked only at supermarkets, using counts of stores within a half-mile radial buffer drawn around the tract centroid. To indicate the immediate neighborhood of the supermarket, we used a quarter-mile buffer around each supermarket; this measure defines the neighborhood within about a five-minute walk. Using recent homicide data, we constructed a kernel density surface for New York City, and intersected this density surface with the supermarket buffers, using the mean kernel density value to assign a homicide rate to each supermarket. Supermarkets with homicide rates in the top quintile were categorized as "high crime." For this analysis, we assumed that "high crime" supermarkets simply became unavailable for use. Table 7 displays average counts of supermarkets including (unadjusted) and excluding (adjusted) high-crime stores. The last column presents the difference between adjusted and unadjusted measures.

Across all tracts, excluding high-crime stores reduces the mean number of supermarkets within half a mile from 2.05 to 1.643. Not surprisingly, the impact is concentrated in the poorest neighborhoods. Excluding high-crime stores reduces the mean count of supermarkets by 0.989 in the highest-poverty tracts, compared with only 0.1 in the lowest-poverty tracts. Excluding high-crime stores also has a relatively large impact on neighborhoods with higher proportions of black or Latino residents. Overall, not surprisingly, adjustment for crime rates widens income and race/ethnic disparities in food environment measures.

Pedestrian traffic safety – Hazardous traffic conditions may make food outlets unattractive to pedestrians. We constructed two indicators of pedestrian safety within the quarter-mile buffer around supermarkets. The first indicator measures the density of expressways, which typically have high traffic speeds and limited sidewalks and other features to support safe travel by walking. The second is a density measure of pedestrian-automobile accidents, providing a direct measure of hazardous traffic. For both expressways and pedestrian-automobile accidents, we constructed kernel density surfaces and intersected them with quarter-mile radial buffers around supermarkets. As in the analyses using homicide rates, we computed adjusted spatial accessibility measures in which supermarkets in the top quintile of expressway density or accident density were excluded.

Table 8 displays the results using each of these adjustments. Column 2 shows the same unadjusted average supermarket counts displayed in previous tables. The third column reports mean supermarket counts in which stores with the highest expressway density were removed; the fourth column shows the difference between these adjusted measures and the unadjusted figures in column 2. The fifth column shows mean supermarket counts in which stores with the highest accident density were removed, and the sixth column reports the difference between these adjusted figures and the unadjusted measures in column 2.

Excluding supermarkets with high expressway densities reduces the number of accessible supermarkets most in predominantly white and Latino neighborhoods and in low-poverty neighborhoods. The white neighborhoods adjacent to expressways tend to be in Manhattan; those in predominantly Hispanic neighborhoods are concentrated in the Bronx, a major conduit to the city’s island boroughs, which has a very high density of expressways. In general, adjusting supermarket accessibility for expressway density reduces disparities in access between white and nonwhite neighborhoods, and between high-poverty and low-poverty neighborhoods.

Supermarkets with high densities of traffic accidents tend to be located in neighborhoods that are majority-white and majority-Asian, those with low poverty rates, and those with a relatively low proportion of foreign-born residents. They are also located in high-density neighborhoods, particularly in Manhattan. Adjusting for the density of accidents tends to reduce disparities in supermarket access by race/ethnicity and poverty.

Food assistance programs – To examine the food environment from the perspective of households receiving public assistance, we identified authorized food stamp retailers among supermarkets as well as farmers' markets at which one or more vendors accepted food stamps via electronic benefits transfer (EBT). The second and third columns of Table 9 show the average proportions of spatially accessible supermarkets and farmers' markets that accept food stamps/EBT. Even in low-poverty neighborhoods, four out of five supermarkets accept food stamps; in high-poverty neighborhoods, 87.9 percent do so. By contrast, an average of only 17 percent of farmers' markets accepted EBT. High-poverty and majority-Latino neighborhoods were more likely to have farmers' markets that accepted EBT, but even in these neighborhoods, most markets did not.

The last column in Table 9 reports the density of emergency food outlets by tract composition. We have no information on the availability of healthy food at these food pantries and soup kitchens, but for families facing financial hardship, use of emergency food outlets could ease pressure on the family food budget, making purchase of healthy food more feasible. Not surprisingly, emergency food sources are concentrated in low-income neighborhoods, and in neighborhoods with relatively high proportions of black or Latino residents, which also tend to have elevated rates of poverty.

The built environment and healthy food access

Healthy food access varies by built environment features, with more healthy food outlets located in neighborhoods with higher population density, more commercially zoned land, and more transit stops. All else equal, higher population density increases local consumer demand; a higher fraction of commercially zoned land allows more retail development; and transit stops are associated with pedestrian traffic. Race/ethnic and income differences in the spatial distribution of population across these built environment features may account for some differences in the accessibility of healthy food.

To explore this possibility, we ran a series of simple regressions predicting the logged (kernel) density of healthy food outlets as well as the logged density of supermarkets, fruit and vegetable markets, and farmers' markets (Table 10). The first set of models includes only tract population composition measures – the proportions of residents who are black, Latino, Asian, or foreign-born, as well as poverty rates. Unlike the measures presented earlier, these models indicate the association between neighborhood composition and healthy food accessibility net of other composition measures. These figures show that tract poverty rates and proportion of foreign-born population tend to be positively associated with healthy food availability while the proportions of black and Latino residents are both negatively associated.

The second set of models includes four built environment characteristics: population density, proportion of commercial building area, presence of a subway stop, and proportion of buildings constructed prior to 1940 (older neighborhoods tend to facilitate mix of residential and commercial land use). In almost all instances, these characteristics are positively associated with the density of healthy food outlets. After controlling for these built environment measures, the estimated effects for some neighborhood composition variables shift. While the effects of neighborhood percent black change little, the coefficients for the proportions of Latino, foreign-born, and poor residents become slightly more negative, indicating that the apparent advantage of these neighborhoods in spatial accessibility is in part due to built environment factors. This pattern of effects is interpretable in terms of the concentration of Latino, immigrant, and low-income New York City residents in high-density neighborhoods in Manhattan and the Bronx.

Food Access Policy in New York City

In response to the disparities highlighted above, New York City has pursued a variety of food access initiatives that affect both the supply and demand of healthy foods and address geographical as well as financial barriers. Our selection of policy initiatives reflects the variety of the approaches that have been recently used in facilitating better access to healthy foods in high-need communities. We will focus on the Healthy Bodegas Initiative, the Health Bucks initiative, and the NYC Green Carts Program. We describe these initiatives, review the practical and policy barriers they faced, and consider how well these initiatives address food access problems previously identified in New York City. We will also discuss a new policy initiative, currently in its early stages, which would promote the opening of supermarkets in high-need areas across New York State.

Healthy Bodegas Initiative

The Healthy Bodegas, in addition to the "Health Bucks" programs, are administered by New York City's three District Public Health Offices (DPHOs). The DPHOs represent an effort by the New York City Department of Health and Mental Hygiene (DOHMH) to address health disparities by devoting resources and programs to specific high-need areas: the South Bronx, East and Central Harlem, and North and Central Brooklyn. The Healthy Bodegas initiative is an effort to enhance the food available in existing food outlets, specifically the small grocery stores that are so numerous in the city's low-income neighborhoods. For example, bodegas, or small grocery stores, represent more than 80 percent of food outlets in Central Brooklyn (the situation is similar in the other DPHO areas) and these stores generally stock few healthy foods. Given their prevalence, improving healthy food availability in bodegas could be an effective way to improve the food environment in low-income communities. This initiative aimed to make fresh produce and low-fat milk more accessible. The target number of bodegas to be reached by December 2008 was 1,000. The campaign was not penalty-oriented; enforcement is accomplished by follow-up visits to the bodegas from health department officials and through a questionnaire.[88]

In January 2006 bodega owners in Central Brooklyn, South Bronx, and Harlem began working with DOHMH to offer 1% milk to their customers. Participating bodega owners agreed to stock 1% milk, offer discounts, display DOHMH educational posters, and distribute health information to customers. In addition to providing bilingual posters and educational postcards on the health benefits of 1% milk, educational materials were made available at the DPHOs and offices of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) in the three pilot neighborhoods. Information distribution was coordinated through the DOHMH's three District Public Health Offices (DPHOs), which serve these communities. The pilot project began with approximately fifteen bodegas.

The DOHMH began a similar fruit and vegetable campaign in December 2007 at 60 locations. For this campaign, the DOHMH worked with the New York State Department of Agriculture and Markets and the Bodega Association of the United States to bring New York

State produce to the bodegas in the form of snack packages with ready-to-eat (cut and peeled) carrots and apples. As part of the pilot program, each of the 60 bodegas received a free shipment of fresh, ready-to-eat local carrots and apples and participating bodegas sold the packets for 50 cents each while offering a "buy one get one free" incentive to customers. Bodegas also received toolkits containing promotional posters and postcards in English and Spanish, decals, and display containers for the snack packages. The DOHMH conducted outreach and education in local schools, daycare centers, and Women Infants and Children (WIC) Centers to raise awareness about the campaign and encourage healthy eating.

The fruit and vegetable program is considered less successful than the 1% milk campaign, as participation has proved difficult for many bodegas.[88,89] Some of the barriers to carrying fresh produce cited by bodega owners include: a lack of adequate space for fresh produce and a reluctance to risk carrying products that have a relatively short shelf life. Furthermore, price also acts as a deterrent to purchasing fruits and vegetables, which are more expensive than other foods more typically sold in the bodegas.[88] Because this program was less successful, the next stage of the initiative will include fewer stores than initially anticipated. A health department official said about 450 bodegas will participate, all of whom already sell some fruits or vegetables.

The Healthy Bodegas initiative has several advantages: its cost is low (less than $300,000 per annum), it can be implemented quickly, the "Move to 1% Milk" campaign enjoyed a fair amount of success, and the initiative employed a two-pronged strategy by influencing both the demand side (in encouraging bodegas to advertise their healthy foods and in disseminating information at the DPHO and WIC offices) as well as the supply side. However, the initiative is not without disadvantages. First of all, it does little to address the issue of price. Nor does it address the structural reasons that selling fresh produce is not a profitable venture for small grocers, making it difficult to make the program sustainable. To address this problem, health department officials plan to explore ways to help bodegas obtain loans so that they could afford to either purchase fresh produce or revamp their stores to make more room for it.[88]

<u>"Health Bucks" Program</u>

In addition to the Healthy Bodegas initiative, the DPHOs administer Health Bucks, a program that offers financial incentives to lower-income community members to patronize farmers' markets. Health Bucks, worth $2 each, are distributed by the DPHOs in partnership with local community groups in the South Bronx, North and Central Brooklyn, and East and Central Harlem, and can be used to purchase fresh fruits and vegetables at participating farmers' markets in New York City. At the farmers' markets that accept Electronic Benefit cards, one Health Buck coupon is offered to customers for every $5 they spend using food stamps. The initiative primarily addresses financial access and seeks to increase demand for fresh fruits and vegetables, but is also part of an effort to get more farmers' markets to accept food stamps and Electronic Benefit cards.

Of the 9,000 Health Bucks coupons distributed in 2006, 40 percent were redeemed, and the program was expanded, with 15,000 Health Bucks slated for distribution in 2008. Approximately 30 markets in the city participate in the program, and about half of them have EBT capability for customers who wish to pay using food stamps. Local partners in the Health Bucks program reported that this initiative has proved especially popular among Bronx residents.

Like the Healthy Bodega initiative, the Health Bucks program uses existing food sources to improve access to healthier foods, this time by reducing price as a barrier. The program also supports the local farmers and urban gardeners. However, the program is not without limitations. First, the program is limited in size and spatial coverage; coupons are distributed primarily to residents of the DPHO neighborhoods, ignoring high-need populations in other neighborhoods. In particular, according to Joel Berg, executive director of the New York City Coalition Against Hunger, Queens has been largely neglected in city-funded food assistance programs because of the misconception of Queens as a middle-class borough.[90] Second, as discussed earlier, only a small minority of farmers' markets accept Electronic Benefits Cards. Third, as discussed above, farmers' markets are a limited solution to food access problems because of their limited hours and seasonal operation. Fourth, even with the vouchers, farmers' market produce may still be too costly for low-income residents.

NYC Green Carts Program

One initiative recently spearheaded by DOHMH and key actors in the municipal government is the NYC Green Carts Program, which allows vendors with mobile carts to sell fresh fruits and vegetables in low-income communities with little access to healthy food options. Prior to this program, most of the city's 4,100 existing food carts sold less healthy foods such as pretzels, hot dogs, kabobs, and soft drinks; only about 10 percent offered fruits and vegetables. The new Green Carts vendors are permitted to sell only raw produce; frozen, processed, or cut fruits and vegetables are not allowed. The Green Carts are restricted to specific underserved neighborhoods, with compliance to be monitored by health inspectors and the police.[91] Neighborhoods selected were those in which 15 percent or more of the population reported having consumed zero servings of fruits or vegetables in the previous 24 hours, according to the annual Community Health Survey fielded by the DOHMH. Despite licensing costs and administrative and inspection requirements, including a food safety course, the program proved very popular with aspiring vendors, 2,500 of whom applied to participate. ACCION, a non-profit microfinance organization, partnered with the City to help aspiring vendors with the associated start-up costs. The DOHMH recently closed the waiting list for permits.

The initiative proved to be somewhat controversial. It had the strong backing of the Mayor, speaker of the City Council, and DOHMH as well as local public health and anti-poverty organizations. It was opposed, however, by supermarket and grocery store owners and by some borough officials and City Council members, who raised concerns about whether the new Green Carts would crowd already-congested sidewalks or unfairly increase competition for local grocers. Some argued that consumer demand for produce was inadequate to support new suppliers. Opponents of the Green Carts suggested alternatives such as providing tax incentives or allowing stores to set up their own fresh fruit and vegetable stands outside their premises. On the other hand, an advocacy group for street vendors, Vamos Unidos, contended that the proposal for an additional 1,500 permits was too limited. Ultimately the City Council passed a scaled-back version of the original proposal, the Mayor signed it on March 13, 2008, and implementation began the following summer. The total number of Green Cart permits was reduced to 1,000 (350 the Bronx, 350 for Brooklyn, 150 for Manhattan, 100 for Queens, and 50 for Staten Island) and the number of precincts where vendors could operate was also reduced.

Although it is too early to evaluate the Green Carts program, some advantages and disadvantages are evident at this point. Its advantages are primarily its flexibility, low cost, and relative ease of administration. Compared with building a new supermarket, food carts are a much simpler and faster way to improve the food environment, and can readily be “redeployed” as neighborhood retail environments change. The primary limitation of the program is its failure to address pricing and payment issues. The Green Carts program solves the spatial accessibility problem without addressing the higher cost of fresh produce relative to less healthy, energy-dense foods. Compounding the problem, so far the Green Carts do not accept Electronic Benefits Cards (food stamps); EBT capability may not be cost-effective given the low sales volume for individual carts. Anecdotal evidence suggests that fruit and vegetable vendors may face insufficient demand.[92] In addition, because the program had to be reduced in scope in order to placate opponents, future attempts to expand it may prove difficult.

Future Policy Initiative: Statewide Supermarket Commission

While the Healthy Bodegas, Health Bucks, and Green Carts initiatives can make relatively quick and low-cost improvements to the local food environment in underserved areas, all three have limitations. Store audit research suggests that supermarkets are the most effective way to supply communities with a wide selection of fresh and relatively affordable healthy food; they are typically also open year-round for more convenient hours and generally have EBT capability. In New York City, supermarkets are reported to be struggling financially because of rising real estate and energy costs, and there is widespread concern that more stores will close. A new initiative has begun to help establish new supermarkets or assist existing stores in high-need areas in New York. The Statewide Supermarket Commission is led by the Food Trust (a Philadelphia-based nonprofit) and the Food Bank for New York City as well as United Way of New York City, in partnership with the City's Food Policy Coordinator and the Food Industry Alliance. The Commission, supported by both City Council and foundation funding, seeks to identify state and local policy measures that would encourage new supermarket development and prevent supermarkets in high-need areas from shutting down. The Commission includes representatives from City and State government agencies (including the Council), as well as advocates, industry leaders, and labor organizations.

A similar campaign has been already been executed in Pennsylvania, where the Food Trust helped attract 32 new supermarkets to underserved areas across the state. The Pennsylvania Fresh Food Financing Initiative (FFFI) is a public-private program with the goal of increasing the number of supermarkets and other grocery stores in underserved communities. The initiative offers financial backing to supermarket operators that plan to operate in these high-need areas where conventional financial institutions alone cannot fill the infrastructure costs and credit needs of these operators. FFFI offers grants and loans to qualified food retailers for predevelopment costs such as land acquisition, financing, equipment financing, capital grants for project funding gaps, construction and permanent finance, and workforce development. The Food Trust, the Greater Philadelphia Urban Affairs Coalition (GPUAC), and The Reinvestment Fund (TRF) partnered with the state government on the FFFI. The state government appropriated $30 million for this initiative, and TRF leveraged this funding with an additional $90 million to form a $120 million pool to finance food retailers in under-served areas. In a well-publicized report which has now been replicated for New York, the Food Trust used GIS analysis to identify high-need areas and highlight the burden of diet-related disease.

Conclusion

Research using GIS measures of the food environment has greatly enhanced our understanding of environmental constraints on healthy eating, and has motivated and informed a number of new food access initiatives. To maximize the contribution of this approach, however, it is important to address a number of conceptual and methodological issues. As this paper has highlights, one set of issues concerns strategies for defining the relevant neighborhood that bounds food outlets to which households have (spatial) access. Defining the neighborhood is not solely a matter of physical distance. For any given distance, accessibility is also affected by parameters having to do with personal mobility (vehicle ownership, disability) as well as environment facilitators and barriers to travel (public transit service, poor safety). These parameters may be particularly important in urban environments. Adjusting for differences in crime and vehicle ownership tends to widen measured disparities in the food environment, while adjusting for traffic safety may have the opposite effect. More research in other locations will be important for understanding the extent to which these patterns are specific to New York City.

A second set of issues involves the characterization of food outlets within the relevant neighborhood. Analysts typically use detailed industry category to classify food outlets types as offering healthy or unhealthy foods. Store audit studies suggest that this strategy is reasonably valid for food stores, but there is less evidence to inform classification of restaurants as healthy or unhealthy. Further work with new audit tools such as the NEMS-R will be important to identify restaurant characteristics that promote healthy eating. Spatial variation in price may be approximated reasonably well by store outlet type, but spatial variation in quality may not be.

Lastly, further theoretical and conceptual development is needed to inform modeling of access to unhealthy food and its implications for diet and health.

Our analysis of the spatial accessibility of healthy food outlets in New York City highlights racial disparities: predominantly black neighborhoods have lower access to supermarkets and other healthy food outlets, and more than half of the city's predominantly black neighborhoods have bus-only access to supermarkets. Although densely-settled areas of concentrated poverty have received justifiable policy attention, lower-density neighborhoods may also be underserved, particularly where low incomes, limited mobility, and limited public transit service are impediments. Our analysis also highlighted the critical role of smaller retailers and farmers' markets in providing fresh produce, especially in low-income and minority neighborhoods.

Recent food policy initiatives in New York City have made efficient use of existing food outlets and distribution systems – bodegas, farmers' markets, and vending carts – to enhance the food environment in low-income neighborhoods. While these initiatives are limited in scale and geographic scope, they are important first steps. However, it is unclear how effective these measures will be without doing more to address the non-spatial aspects of food access, particularly issues of cost.

APPENDIX: DATA SOURCES AND GIS METHODS

The analyses presented here use data on the locations of food retail outlets where fresh fruits and vegetables are more widely available and their food stamp acceptance status, neighborhood economic and demographic characteristics, and neighborhood social and built environment indicators. Specific data sources and variable definitions are provided.

Food environment measures

Food environment measures were constructed from several databases that include the locations of supermarkets, fruit and vegetable markets, farmers' markets, and supermarkets and farmers' markets that accept food stamps.

Supermarket and fruit and vegetable market measures were derived from 2005 data purchased from Dun & Bradstreet. Data include the location of the establishment, the business name, number of employees, annual sales, and the Standard Industrial Classification (SIC) code. Supermarkets were identified through SIC code and a query of annual sales and the number of employees. Supermarkets are coded with SIC code '5411' and have an annual sales of $2,000,000 or higher. Where annual sales data were missing, greater than 17 employees indicated a supermarket. Establishments with the SIC code 5431 indicated the presence of a fruit and vegetable market.

Farmers' market measures were constructed from data downloaded from the New York City Coalition Against Hunger (NYCCAH) who collected the data from the Council on the Environment of New York City and the New York State Department of Agriculture and Markets. Data included the names and addresses of all known farmers' markets in New York City as of 2006. Addresses were geocoded.

Food environment measures were expressed as density values. The kernel density function in ArcGIS was used to estimate raster grid surfaces of establishments per square kilometer. Kernel density estimation involves the following: distances are measured from each grid cell to each establishment point that falls within a predefined distance or bandwidth of the cell (0.25, 0.50 and 1 mile search radii were used here). The contribution of each establishment point to the local density value of a given grid cell is based on that cell's distance from the establishment. Nearby establishments are given more weight in the density calculation than those that are farther away and weights given to establishments near the boundary defined by the bandwidth approach zero. The final measures are the average establishment density of the grid cells in a Census tract.

Neighborhood measures

The neighborhood was defined as a Census tract for the analyses of differences in food accessibility by neighborhood economic, race/ethnic, social and built characteristics. The analyses included the proportion of residents in the tract below the federal poverty line; the proportion of white, Black or African American, Latino or Hispanic and Asian residents; the proportion of residents that were foreign born; the proportion of households receiving public assistance income; the proportion of households with at least one vehicle available and the tract population using data from the 2000 U.S. Census summary file 3.

Other social and built environment characteristics included indicators of walkability, crime and urban form. Non-pedestrian roadways served as markers of areas not conducive to walking, as did areas with higher levels of pedestrian injuries and fatalities due to automobile accidents and areas with higher levels of homicides. Non-pedestrian roadways were represented using data from the New York City Department of City Planning's (DCP) LION streets database. A non-pedestrian indicator in the database was used to pull out the expressways, on/off ramps, and other roadways designated by the Department of Education as non-pedestrian in determining walking routes from a pupil's home to his or her school. A kernel density grid was estimated for non-pedestrian roadway locations and the average density per quarter mile buffer around supermarkets was obtained and used as the final measure.

Locations of automobile accidents that resulted in pedestrian injuries or fatalities also served as indicators of less walkable neighborhoods. These data were obtained for 2002 to 2005 through a freedom of information letter submitted to the New York City Department of Transportation by a partner organization, Transportation Alternatives. A kernel density grid was estimated for accident point locations and the average density per quarter mile buffer around supermarkets was obtained and used as the final measure.

Criminal activity, a potential deterrent to walking, was measured with homicides. Data are based on the point locations of homicides occurring in 2003 to 2005 (averaged across the three years) that were obtained from a public New York Times web site (http://www.nytimes.com/packages/html/nyregion/20060428_HOMICIDE_MAP.html). A kernel density grid was estimated for homicide point locations and the average density per quarter mile buffer around supermarkets was obtained and used as the final measure.

Food retail outlets located near bus and/or subway stops may be considered more accessible than others. Public transit access may also serve as a confounder for higher density food retail. Therefore we incorporated 2004 bus and subway stop locations obtained from the Metropolitan Transit Authority through Community Cartography into our analyses. A kernel density grid was estimated for point locations of subway and bus stops. In addition, the count of subway and bus stops that intersected a quarter mile buffer around supermarkets and a quarter mile buffer around tracts was obtained.

We also assessed the potentially confounding effects of more dense and commercial development using measures of population density and commercial land use. Population density from the 2000 U.S. Census was expressed by tract in population per kilometer squared. Commercial land use data was derived from the New York City DCP's Primary Land Use Tax Output (PLUTO) database. The final measure was the proportion of commercial building area of the tract land area.

Food stamp program participation

In order to evaluate the extent to which low income households face a more restricted food environment, supermarkets and farmers' markets that are authorized to accept food stamps were compared with neighborhoods with higher proportions of residents in poverty and households receiving public assistance income. Food retailers that accept food stamps were measured with 2008 data from the United States Department of Agriculture. These establishments were matched with more recent (2007) supermarket data from Trade Dimensions to identify supermarkets that do and do not accept food stamps. Records from the two datasets were matched on street address and establishment name. The locations of unmatched Trade Dimensions supermarkets were also visually inspected to identify additional name matches in the food stamp data. An indicator was added to the Trade Dimensions dataset to mark a food stamp accepting establishment. A kernel density grid was estimated for the point locations of all Trade Dimensions supermarkets and separately for just those that accept food stamps. Farmers' market address and food stamp acceptance status was also obtained for 2008 from the New York State Department of Agriculture and Markets and the Farmers' Market Federation of New York. Similarly, density grids were estimated for all farmers' markets and separately for just those that accept food stamps, or that have EBT capacity. The average density values were calculated by Census tract for the density grids and the proportion of supermarkets or farmers' markets that accept food stamps was calculated from the two tract averages.

Household vehicle ownership

To adjust our food access measures to neighborhoods where residents may travel more by car than on foot; people for whom a quarter or half mile distance is too small, we modified our supermarket accessibility measure by weighting travel distance to supermarkets by the proportion of vehicle ownership in the tract. Two methods were employed. In the first, the tract average supermarket density for a *one* mile search radius was multiplied by the proportion of households with at least one vehicle available and this was added to 1 – the proportion of households with at least one vehicle multiplied by the tract average supermarket density value for a *half* mile search radius. The second method followed the same formula, but substituted counts of supermarkets within a one mile and a half mile street network buffer for the density values. Using these alternative measures allowed us to assess the impact travel distance and household vehicle ownership can have on food access in low-density urban environments.

Walkability and crime

Non-pedestrian roadway, pedestrian automobile accident and homicide indicators were constructed using similar methodologies. We were interested in determining if accessibility would decrease for poor and/or minority neighborhoods when we took these factors that might negatively impact walking into account? We measured the indicators for areas around supermarkets and assessed supermarket accessibility for tracts as supermarkets surrounded by higher densities of the walkability variables were removed. Kernel density raster grids were created for non-pedestrian roadways, pedestrian injuries or fatalities due to automobile accidents, and homicides using a half-mile search radius or bandwidth. To associate the density values with supermarkets the average density of each of the three indicators was calculated for a quarter mile bird-fly buffer around all supermarkets. Supermarkets were then associated with Census tract neighborhoods by intersecting the supermarket points with a half mile buffer around the population-weighted tract center points. The final measure represented a tract-level count of supermarkets located within a half mile of the tract by quintiles of expressway, pedestrian auto accident and homicide density.

Slightly different methods were used to measure public transit access and its impact on supermarket accessibility. Supermarkets with a bus or a subway stop within a quarter mile were first identified. These supermarkets with a transit stop nearby were then intersected with a one mile bird-fly-buffer to obtain a tract-specific count of the transit accessible supermarkets. A count of the number of subway or bus stops was also obtained for each tract. A supermarket-transit-accessible tract would be one with supermarkets with subway or bus stops nearby and that also included a subway or bus stop itself.

References

1. Powell LM, Slater S, Mirtcheva D, Bao YJ, Chaloupka FJ. Food store availability and neighborhood characteristics in the United States. Preventive Medicine 2007;44(3):189-195.
2. Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the location and type of food stores. American Journal of Public Health 2006;96(2):325-331.
3. Zenk S, N. , Schulz A, J. , Israel B, A. , James S, A. , et al. Neighborhood Racial Composition, Neighborhood Poverty, and the Spatial Accessibility of Supermarkets in Metropolitan Detroit. American Journal of Public Health 2005;95(4):660.
4. Morland K, Wing S, Diez Roux AV, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. American Journal of Preventive Medicine 2002;22(1):23-29.
5. Alwitt LF, Donley TD. Retail stores in poor urban neighborhoods. Journal of Consumer Affairs 1997;31(1):139-164.
6. Morland K, Filomena S. Disparities in the availability of fruits and vegetables between racially segregated urban neighborhoods. Public Health Nutrition 2007.
7. Block D, Kouba J. A comparison of the availability and affordability of a market basket in two communities in the Chicago area. Public Health Nutrition 2006;9(7):837-845.
8. Sloane DC, Diamant AL, Lewis LB, Yancey AK, Flynn G, Nascimento LM, McCarthy WJ, Guinyard JJ, Cousineau MR. Improving the nutritional resource environment for healthy living through community-based participatory research. Journal of General Internal Medicine 2003;18(7):568-575.
9. Small ML, McDermott M. The presence of organizational resources in poor urban neighborhoods: An analysis of average and contextual effects. Social Forces 2006;84:1697-1724.
10. Helling A, Sawicki DS. Race and residential accessibility to shopping and services. Housing Policy Debate 2003;14(1-2):69-101.
11. Chung CJ, Myers SL. Do the poor pay more for food? An analysis of grocery store availability and food price disparities. Journal of Consumer Affairs 1999;33(2):276-296.
12. Powell LM, Chaloupka FJ, Bao Y. The Availability of Fast-Food and Full-Service Restaurants in the United States: Associations with Neighborhood Characteristics. American Journal of Preventive Medicine 2007;33(4, Supplement 1):S240-S245.
13. Block JP, Scribner RA, DeSalvo KB. Fast food, race/ethnicity, and income - A geographic analysis. American Journal of Preventive Medicine 2004;27(3):211-217.
14. Reidpath DD, Burns C, Garrard J, Mahoney M, Townsend M. An ecological study of the relationship between social and environmental determinants of obesity. Health & Place 2002;8(2):141-145.
15. Zenk SN, Powell LM. US secondary schools and food outlets. Health & Place 2008;14(2):336-346.
16. Sturm R. Disparities in the food environment surrounding US middle and high schools. Public Health 2008;122(7):681-690.
17. Simon PA, Kwan D, Angelescu A, Shih M, Fielding JE. Proximity of fast food restaurants to schools: Do neighborhood income and type of school matter? Preventive Medicine;In Press, Corrected Proof.

18. Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. J Epidemiol Community Health 2007;61(6):491-8.
19. Austin SB, Melly SJ, Sanchez BN, Patel A, Buka S, Gortmaker SL. Clustering of fast-food restaurants around schools: A novel application of spatial statistics to the study of food environments. American Journal of Public Health 2005;95(9):1575-1581.
20. Kwate NOA, Yau C-Y, Loh J-M, Williams D. Inequality in obesigenic environments: Fast food density in New York City. Health & Place 2009;15(1):364-373.
21. Lewis LB, Sloane DC, Nascimento LM, Diamant AL. African Americans' Access to Healthy Food Options in South Los Angeles Restaurants. American Journal of Public Health 2005;95(4):668.
22. Horowitz CR, Colson KA, Hebert PL, Lancaster K. Barriers to buying healthy foods for people with diabetes: Evidence of environmental disparities. American Journal of Public Health 2004;94(9):1549-1554.
23. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Preventive Medicine 2004;39(5):869-875.
24. Rose D, Richards R. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. Public Health Nutrition 2004;7(8):1081-1088.
25. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR, Jr. Associations of the Local Food Environment with Diet Quality--A Comparison of Assessments based on Surveys and Geographic Information Systems: The Multi-Ethnic Study of Atherosclerosis. American Journal of Epidemiology 2008:kwm394.
26. Morland K, Wing S, Diez Roux AV. The contextual effect of the local food environment on residents' diets: The atherosclerosis risk in communities study. American Journal of Public Health 2002;92(11):1761-1767.
27. Pearson T, Russell J, Campbell MJ, Barker ME. Do [`]food deserts' influence fruit and vegetable consumption?--a cross-sectional study. Appetite 2005;45(2):195-197.
28. Pearce J, Hiscock R, Blakely T, Witten K. The contextual effects of neighbourhood access to supermarkets and convenience stores on individual fruit and vegetable consumption. J Epidemiol Community Health 2008;62(3):198-201.
29. Bodor JN, Rose D, Farley TA, Swalm C, Scott SK. Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. Public Health Nutrition 2008.;11:413-420.
30. Jago R, Baranowski T, Baranowski J, Cullen K, Thompson D. Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. International Journal of Behavioral Nutrition and Physical Activity 2007;4(1):35.
31. Timperio A, Ball K, Roberts R, Campbell K, Andrianopoulos N, Crawford D. Children's fruit and vegetable intake: Associations with the neighbourhood food environment. Preventive Medicine 2008;46(4):331-335.
32. Pearce J, Hiscock R, Blakely T, Witten K. A national study of the association between neighbourhood access to fast-food outlets and the diet and weight of local residents. Health & Place 2009;15(1):193-197.

33. Jeffery R, Baxter J, McGuire M, Linde J. Are fast food restaurants an environmental risk factor for obesity? International Journal of Behavioral Nutrition and Physical Activity 2006;3(1):2.
34. Powell LM, Christopher Auld M, Chaloupka FJ, O'Malley PM, Johnston LD, Kristian Bolin and John C. Access to Fast Food and Food Prices: Relationship with Fruit and Vegetable Consumption and Overweight among Adolescents. Advances in Health Economics and Health Services Research. Vol. Volume 17 JAI, 2006;23-48.
35. Lopez RP. Neighborhood Risk Factors for Obesity. Obesity 2007;15(8):2111-2119.
36. Morland K, Diez Roux AV, Wing S. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. Am J Prev Med 2006;30(4):333-9.
37. Morland KB, Evenson KR. Obesity prevalence and the local food environment. Health & Place;In Press, Accepted Manuscript.
38. Maddock J. The relationship between obesity and the prevalence of fast food restaurants: State-level analysis. American Journal of Health Promotion 2004;19(2):137-143.
39. Mehta NK, Chang VW. Weight status and restaurant availability: A multilevel analysis. American Journal of Preventive Medicine 2008;34(2):127-33.
40. Burdette HL, Whitaker RC. Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. Preventive Medicine 2004;38(1):57-63.
41. Liu GC, Wilson JS, Qi R, Ying J. Green neighborhoods, food retail and childhood overweight: Differences by population density. American Journal of Health Promotion 2007;21(4):317-325.
42. Morland K, Diez Roux AV, Wing S. Supermarkets, other food stores, and obesity - The atherosclerosis risk in communities study. American Journal of Preventive Medicine 2006;30(4):333-339.
43. Grafova IB. Overweight children: Assessing the contribution of the built environment. Preventive Medicine 2008;47(3):304-308.
44. Sturm R, Datar A. Body mass index in elementary school children, metropolitan area food prices and food outlet density. Public Health 2005;119(12):1059-1068.
45. Oakes JM. The (mis)estimation of neighborhood effects: causal inference for a practicable social epidemiology. Social Science & Medicine 2004;58(10):1929-1952.
46. Cummins S, Petticrew M, Higgins C, Findlay A, Sparks L. Large scale food retailing as an intervention for diet and health: quasi-experimental evaluation of a natural experiment. Journal of Epidemiology and Community Health 2005;59(12):1035-1040.
47. Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. American Journal of Preventive Medicine 2004;27(2):87-96.
48. Rundle A, Diez Roux AV, Freeman LM, Miller D, Neckerman KM, Weiss CC. The urban built environment and obesity in New York City: a multilevel analysis. Am J Health Promot 2007;21(4 Suppl):326-34.
49. Rundle A, Neckerman K, Freeman L, Lovasi G, Purciel M, Quinn J, Richards C, Sircar N, Weiss C. Neighborhood food environment and walkability predict obesity in New York City. Environmental Health Perspectives Accepted.
50. Talen E, Anselin L. Assessing spatial equity: An evaluation of measures of accessibility of public playgrounds. Environment and Planning 1998;30:595-613.

51. Guagliardo MF, Ronzio CR, Cheung I, Chacko E, Joseph JG. Physician accessibility: an urban case study of pediatric providers. Health & Place 2004;10(3):273-283.
52. Auchincloss AH, Diez Roux AV, Brown DG, Erdmann CA, Bertoni AG. Neighborhood Resources for Physical Activity and Healthy Foods and Their Association With Insulin Resistance. Epidemiology 2008;19(1):146-157.
53. Hillary JS. Food Deserts: Towards the Development of a Classification. Geografiska Annaler: Series B, Human Geography 2006;88(2):231-247.
54. Mojtahedi MC, Boblick P, Rimmer JH, Rowland JL, Jones RA, Braunschweig CL. Environmental Barriers to and Availability of Healthy Foods for People With Mobility Disabilities Living in Urban and Suburban Neighborhoods. Archives of Physical Medicine and Rehabilitation 2008;89(11):2174-2179.
55. Inagami S, Cohen DA, Finch BK. Non-residential neighborhood exposures suppress neighborhood effects on self-rated health. Social Science & Medicine 2007;65(8):1779-1791.
56. Apparicio P, Shearmur R, Brochu M, Dussault G. The Measure of Distance in a Social Science Policy Context: Advantages and Costs of using Network Distances in Eight Canadian Metropolitan Areas. Journal of Geographic Information and Decision Analysis 2003;7(2):105-131.
57. Neckerman KM, Lovasi GS, Diez Roux AV, Quinn JW, Simon Thomas J, Weiss C, Rundle A. Body mass index and indices of neighborhood walkability: Heterogeneity of associations across different definitions of neighborhood. New York, NY: Columbia University, 2008.
58. Oliver LN, Schuurman N, Hall AW. Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. International Journal of Health Geographics 2007;6.
59. Hoehner CM, Ramirez LKB, Elliott MB, Handy SL, Brownson RC. Perceived and objective environmental measures and physical activity among urban adults. American Journal of Preventive Medicine 2005;28(2):105-116.
60. Wener RE, Evans GW. A Morning Stroll: Levels of Physical Activity in Car and Mass Transit Commuting. Environment and Behavior 2007;39(1):62-74.
61. Li F, Harmer PA, Cardinal BJ, Bosworth M, Acock A, Johnson-Shelton D, Moore JM. Built Environment, Adiposity, and Physical Activity in Adults Aged 50-75. American Journal of Preventive Medicine 2008;35(1):38-46.
62. Larsen K, Gilliland J. Mapping the evolution of 'food deserts' in a Canadian city: Supermarket accessibility in London, Ontario, 1961-2005. International Journal of Health Geographics 2008;7:16.
63. Clifton KJ. Mobility strategies and food shopping for low-income families - A case study. Journal of Planning Education and Research 2004;23(4):402-413.
64. Foster S, Giles-Corti B. The built environment, neighborhood crime and constrained physical activity: An exploration of inconsistent findings. Preventive Medicine 2008;47(3):241-51.
65. Harrison RA, Gemmell I, Heller RF. The population effect of crime and neighbourhood on physical activity: an analysis of 15 461 adults. Journal of Epidemiology and Community Health 2007;61(1):34-39.

66. Boone JE, Gordon-Larsen P, Stewart JD, Popkin BM. Validation of a GIS Facilities Database: Quantification and Implications of Error. Annals of Epidemiology 2008;18(5):371-377.
67. Schwartz A. Dun and Bradstreet's market identifiers and economic geography. Professional Geographer 1987;39:166-172.
68. Carlson VL. Identifying neighborhood businesses: A comparison of business listings. Economic Development Quarterly 1995;9(1):50-59.
69. Ball K, Timperio A, Crawford D. Neighbourhood socioeconomic inequalities in food access and affordability. Health & Place 2009;15(2):578-85.
70. Fisher BD, Strogatz DS. Community measures of low-fat milk consumption: comparing store shelves with households. American Journal of Public Health 1999;89(2):235-237.
71. Glanz K, Sallis JF, Saelens BE, Frank LD. Nutrition Environment Measures Survey in Stores (NEMS-S): Development and Evaluation. American Journal of Preventive Medicine 2007;32(4):282-289.
72. Hosler A, Varadarajulu D, Ronsani A, Fredrick B, Fisher B. Low-fat milk and high-fiber bread availability in food stores in urban and rural communities. J Public Health Manag Pract 2006;12(6):556-62.
73. Baker EA, Schootman M, Barnidge E, Kelly C. The role of race and poverty in access to foods that enable individuals to adhere to dietary guidelines. Prev Chronic Dis 2006;3(3):A76.
74. Franco M, Diez Roux AV, Glass TA, Caballero B, Brancati FL. Neighborhood Characteristics and Availability of Healthy Foods in Baltimore. American Journal of Preventive Medicine 2008;35(6):561-7.
75. Lane SD, Keefe RH, Rubinstein R, Levandowski BA, Webster N, Cibula DA, Boahene AK, Dele-Michael O, Carter D, Jones T, Wojtowycz M, Brill J. Structural violence, urban retail food markets, and low birth weight. Health & Place 2008;14(3):415-423.
76. Wechsler H, Basch CE, Zybert P, Lantigua R, Shea S. The availability of low-fat milk in an inner-city Latino community: implications for nutrition education. American Journal of Public Health 1995;85(12):1690-1692.
77. Saelens BE, Glanz K, Sallis JF, Frank LD. Nutrition Environment Measures Study in Restaurants (NEMS-R): Development and Evaluation. American Journal of Preventive Medicine 2007;32(4):273-281.
78. Ard JD, Fitzpatrick S, Desmond RA, Sutton BS, Pisu M, Allison DB, Franklin F, Baskin ML. The impact of cost on the availability of fruits and vegetables in the homes of schoolchildren in Birmingham, Alabama. American Journal of Public Health 2007;97(2):367-372.
79. Drewnowski A. Obesity and the food environment: Dietary energy density and diet costs. American Journal of Preventive Medicine 2004;27(3, Supplement 1):154-162.
80. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. American Journal of Clinical Nutrition 2004;79(1):6-16.
81. Cassady D, Jetter KM, Culp J. Is Price a Barrier to Eating More Fruits and Vegetables for Low-Income Families? Journal of the American Dietetic Association 2007;107(11):1909-1915.
82. Latham J, Moffat T. Determinants of variation in food cost and availability in two socioeconomically contrasting neighbourhoods of Hamilton, Ontario, Canada. Health & Place 2007;13(1):273-287.

83. Winkler E, Turrell G, Patterson C. Does living in a disadvantaged area entail limited opportunities to purchase fresh fruit and vegetables in terms of price, availability, and variety? Findings from the Brisbane Food Study. Health & Place 2006;12(4):741-748.
84. Topolski R, Boyd-Bowman KA, Ferguson H. Grapes of Wrath: Discrimination in the Produce Aisle. Analyses of Social Issues and Public Policy 2003;3(1):111-119.
85. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. American Journal of Preventive Medicine 2006;30(1):38-44.
86. Rundle A, Neckerman K, Freeman L, Lovasi G, Purciel M, Quinn J, Richards C, Sircar N, Weiss C. Food Environment Predicts Obesity In New York City. New York, 2007.
87. Reardon SF, Matthews SA, O'Sullivan D, Lee BA, Firebaugh G, Farrell CR. The segregation profile: Investigating how metropolitan racial segregation varies by spatial scale. Working Paper 06-01 2006.
88. Gross C. Creating Healthy Bodegas. Gotham Gazette New York City News and Policy. New York: Citizens Union Foundation, 2008.
89. Mindlin A. The Battle over the Greens. The New York Times. New York, 2008.
90. Nasongkhla D, Scott N. Food Stamps Not Accepted at Many Queens Greenmarkets. Daily News. New York, 2008.
91. Lombardi F. Cynics Jam Wheels of 'Green Carts' Proposal. Daily News (New York). New York: Daily News, 2008.
92. Sederstrom J. Wilted Biz at Fruit Carts, She Sez. Daily News. New York, 2008.

Table 1: Summary of tract healthy food density by tract racial/ethnic, immigrant, and poverty composition

				Percentiles	
	Tracts	Mean	Median	25th	75th
All NYC Tracts					
All NYC tracts	2173	2.873	2.157	0.870	4.074
By Percent White					
<10%	803	2.692	2.242	0.983	3.804
10% - 49.9%	556	2.669	1.904	0.845	3.684
50%+	814	3.192	2.210	0.797	4.896
By Percent Black					
<10%	1122	3.297	2.382	0.946	4.836
10% - 49.9%	524	2.899	2.519	1.053	4.051
50%+	527	1.946	1.449	0.512	2.813
By Percent Latino					
<10%	780	2.870	1.750	0.564	4.104
10% - 49.9%	1004	2.752	2.025	0.870	3.906
50%+	388	3.195	2.972	1.612	4.245
By Percent Asian					
<10%	1479	2.658	1.966	0.706	3.823
10%+	693	3.333	2.563	1.209	4.580
By Percent Foreign Born					
<25%	703	2.721	1.653	0.555	3.875
25%-49.9%	1038	2.561	1.989	0.823	3.672
50%+	431	3.876	3.049	1.894	5.247
By Percent Poverty					
First Quartile	543	2.356	1.025	0.366	2.884
Second Quartile	543	2.619	1.989	0.870	3.598
Third Quartile	543	3.278	2.667	1.333	4.588
Fourth Quartile	543	3.240	2.820	1.416	4.322

Table 2: Density and proportion of healthy food establishments available by type for New York City residents

	N	Healthy Food Density
Average NYC resident	8,008,278	3.473
Average white resident	2,749,885	3.732
Average black resident	1,930,036	2.612
Average Latino resident	2,161,530	3.435
Average Asian resident	792,980	4.487
Average foreign-born resident	2,871,032	3.724
Average U.S.-born resident	1,700,799	3.599
Average poor resident	6,307,479	3.439

Table 3: Density of supermarkets, fruit and vegetable markets, and farmers' markets by tract composition

		Supermarkets			Fruit and Vegetable Markets			Farmers' Markets		
	Tracts	Mean Density	Avg. Proportion	Median Density	Mean Density	Avg. Proportion	Median Density	Mean Density	Avg. Proportion	Median Density
All NYC Tracts										
All NYC Tracts	2173	1.038	0.361	0.610	1.647	0.573	1.121	0.188	0.066	0.000
By Percent White										
<10%	803	0.807	0.300	0.564	1.635	0.608	1.144	0.250	0.093	0.001
10% - 49.9%	556	0.974	0.365	0.669	1.572	0.589	1.049	0.122	0.046	0.000
50%+	814	1.309	0.410	0.646	1.709	0.536	1.126	0.173	0.054	0.000
By Percent Black										
<10%	1122	1.291	0.391	0.756	1.849	0.561	1.280	0.157	0.048	0.000
10% - 49.9%	524	0.928	0.320	0.650	1.698	0.586	1.270	0.273	0.094	0.001
50%+	527	0.609	0.313	0.368	1.166	0.599	0.642	0.171	0.088	0.000
By Percent Latino										
<10%	780	1.132	0.394	0.442	1.587	0.553	0.918	0.151	0.053	0.000
10% - 49.9%	1004	1.015	0.369	0.656	1.567	0.569	1.082	0.170	0.062	0.000
50%+	388	0.911	0.285	0.743	1.974	0.618	1.637	0.310	0.097	0.019
By Percent Asian										
<10%	1479	0.921	0.346	0.479	1.525	0.574	0.997	0.213	0.080	0.000
10%+	693	1.289	0.387	0.883	1.907	0.572	1.343	0.137	0.041	0.000
By Percent Foreign Born										
<25%	703	1.178	0.433	0.488	1.254	0.461	0.699	0.289	0.106	0.002
25%-49.9%	1038	0.857	0.335	0.550	1.549	0.605	1.102	0.155	0.060	0.000
50%+	431	1.246	0.322	0.999	2.524	0.651	2.022	0.105	0.027	0.000
By Percent Poverty										
First Quartile	543	1.164	0.494	0.367	1.041	0.442	0.499	0.151	0.064	0.000
Second Quartile	543	1.067	0.407	0.692	1.433	0.547	1.094	0.119	0.046	0.000
Third Quartile	543	1.019	0.311	0.725	2.112	0.644	1.538	0.147	0.045	0.000
Fourth Quartile	543	0.902	0.278	0.666	2.002	0.618	1.486	0.336	0.104	0.064

Table 4: Summary of tract healthy food density at quarter, half, and one mile distances by tract composition

		Quarter Mile				Half Mile				One Mile			
	Tracts	Mean	Median	25th%	75th%	Mean	Median	25th%	75th%	Mean	Median	25th%	75th%
All NYC Tracts													
All NYC Tracts	2173	3.003	1.744	0.257	4.276	2.873	2.157	0.870	4.074	2.605	2.299	1.147	3.562
By Percent White													
<10%	803	2.770	1.744	0.225	4.005	2.692	2.242	0.983	3.804	2.488	2.456	1.431	3.379
10% - 49.9%	556	2.834	1.505	0.266	3.887	2.669	1.904	0.845	3.684	2.461	2.131	1.132	3.417
50%+	814	3.350	1.874	0.302	4.892	3.192	2.210	0.797	4.896	2.819	2.203	0.943	4.161
By Percent Black													
<10%	1122	3.490	2.006	0.404	5.131	3.297	2.382	0.946	4.836	2.907	2.429	1.226	4.056
10% - 49.9%	524	3.086	2.150	0.450	4.554	2.899	2.519	1.053	4.051	2.577	2.553	1.409	3.504
50%+	527	1.887	0.769	0.029	2.696	1.946	1.449	0.512	2.813	1.990	1.830	0.830	2.882
By Percent Latino													
<10%	780	2.939	1.157	0.135	3.985	2.870	1.750	0.564	4.104	2.629	2.031	0.783	3.786
10% - 49.9%	1004	2.906	1.749	0.256	4.098	2.752	2.025	0.870	3.906	2.508	2.176	1.198	3.491
50%+	388	3.386	2.625	0.614	5.259	3.195	2.972	1.612	4.245	2.806	2.762	2.010	3.488
By Percent Asian													
<10%	1479	2.774	1.409	0.159	3.973	2.658	1.966	0.706	3.823	2.418	2.148	1.021	3.370
10%+	693	3.493	2.217	0.611	4.825	3.333	2.563	1.209	4.580	3.003	2.639	1.465	4.074
By Percent Foreign Born													
<25%	703	2.794	1.096	0.137	3.916	2.721	1.653	0.555	3.875	2.489	1.991	0.746	3.426
25%-49.9%	1038	2.616	1.607	0.182	3.778	2.561	1.989	0.823	3.672	2.384	2.070	1.107	3.313
50%+	431	4.277	3.140	0.990	5.953	3.876	3.049	1.894	5.247	3.325	3.095	2.091	4.234
By Percent Poverty													
First Quartile	543	2.502	0.768	0.043	3.146	2.356	1.025	0.366	2.884	2.099	1.129	0.620	2.763
Second Quartile	543	2.638	1.548	0.275	3.750	2.619	1.989	0.870	3.598	2.419	2.092	1.071	3.155
Third Quartile	543	3.504	2.315	0.444	5.055	3.278	2.667	1.333	4.588	2.953	2.870	1.782	3.986
Fourth Quartile	543	3.370	2.323	0.582	4.950	3.240	2.820	1.416	4.322	2.948	2.828	1.932	3.694

Table 5: Count of accessible supermarkets weighted by rate of vehicle ownership, by tract composition

	Tracts	% with Vehicle	Unadjusted	Adjusted	Difference
All NYC Tracts					
All NYC Tracts	2173	0.496	2.05	2.763	0.713
By Percent White					
<10%	803	0.395	1.581	2.052	0.471
10% - 49.9%	556	0.517	1.982	2.937	0.955
50%+	814	0.581	2.558	3.345	0.787
By Percent Black					
<10%	1122	0.549	2.517	3.412	0.895
10% - 49.9%	524	0.393	1.861	2.302	0.441
50%+	527	0.485	1.243	1.842	0.599
By Percent Latino					
<10%	780	0.589	2.247	2.983	0.736
10% - 49.9%	1004	0.496	1.998	2.834	0.836
50%+	388	0.309	1.786	2.137	0.351
By Percent Asian					
<10%	1479	0.468	1.805	2.356	0.551
10%+	693	0.556	2.571	3.632	1.061
By Percent Foreign Born					
<25%	703	0.469	2.314	2.691	0.377
25%-49.9%	1038	0.5	1.712	2.481	0.769
50%+	431	0.486	2.432	3.559	1.127
By Percent Poverty					
First Quartile	543	0.679	2.284	3.129	0.845
Second Quartile	543	0.587	2.11	3.067	0.957
Third Quartile	543	0.441	2.017	2.856	0.839
Fourth Quartile	543	0.277	1.788	2.001	0.213

Note: Densities calculated for non-vehicle owners at half mile and for vehicle owners at one mile

Table 6: Proportion of tracts with accessible supermarket by travel mode and tract composition

	Tracts	Not Accessible	Bus Accessible	Bus or Subway Accessible	Walking Accessible
All NYC Tracts					
All NYC Tracts	2173	0.040	0.456	0.256	0.249
By Percent White					
<10%	803	0.019	0.453	0.321	0.207
10% - 49.9%	556	0.022	0.460	0.264	0.254
50%+	814	0.072	0.455	0.187	0.286
By Percent Black					
<10%	1122	0.053	0.421	0.234	0.292
10% - 49.9%	524	0.029	0.414	0.311	0.246
50%+	527	0.023	0.571	0.249	0.157
By Percent Latino					
<10%	780	0.065	0.545	0.149	0.241
10% - 49.9%	1004	0.031	0.441	0.274	0.254
50%+	388	0.008	0.314	0.428	0.250
By Percent Asian					
<10%	1479	0.044	0.473	0.254	0.229
10%+	693	0.029	0.420	0.261	0.290
By Percent Foreign Born					
<25%	703	0.081	0.461	0.185	0.273
25%-49.9%	1038	0.023	0.482	0.289	0.206
50%+	431	0.009	0.385	0.295	0.311
By Percent Poverty					
First Quartile	543	0.098	0.589	0.070	0.243
Second Quartile	543	0.024	0.529	0.182	0.265
Third Quartile	543	0.026	0.355	0.361	0.258
Fourth Quartile	543	0.009	0.350	0.413	0.228

Table 7: Count of accessible supermarkets adjusted for homicide rates, by tract composition

	Tracts	Unadjusted	Adjusted	Difference
All NYC Tracts				
All NYC Tracts	2173	2.05	1.643	-0.407
By Percent White				
<10%	803	1.581	0.738	-0.843
10% - 49.9%	556	1.982	1.804	-0.178
50%+	814	2.558	2.425	-0.133
By Percent Black				
<10%	1122	2.517	2.337	-0.180
10% - 49.9%	524	1.861	1.197	-0.664
50%+	527	1.243	0.611	-0.632
By Percent Latino				
<10%	780	2.247	2.012	-0.235
10% - 49.9%	1004	1.998	1.608	-0.390
50%+	388	1.786	0.995	-0.791
By Percent Asian				
<10%	1479	1.805	1.311	-0.494
10%+	693	2.571	2.352	-0.219
By Percent Foreign Born				
<25%	703	2.314	1.791	-0.523
25%-49.9%	1038	1.712	1.332	-0.380
50%+	431	2.432	2.151	-0.281
By Percent Poverty				
First Quartile	543	2.284	2.184	-0.100
Second Quartile	543	2.11	1.941	-0.169
Third Quartile	543	2.017	1.648	-0.369
Fourth Quartile	543	1.788	0.799	-0.989

Table 8: Count of accessible supermarkets adjusted for expressway density and accident density, by tract composition

			Expressway density		Accident density	
	Tracts	Unadjusted	Adjusted	Difference	Adjusted	Difference
All NYC Tracts						
All NYC Tracts	2173	2.05	1.645	-0.405	1.644	-0.406
By Percent White						
<10%	803	1.581	1.294	-0.287	1.499	-0.082
10% - 49.9%	556	1.982	1.599	-0.383	1.818	-0.164
50%+	814	2.558	2.021	-0.537	1.668	-0.890
By Percent Black						
<10%	1122	2.517	2.012	-0.505	1.816	-0.701
10% - 49.9%	524	1.861	1.397	-0.464	1.681	-0.180
50%+	527	1.243	1.108	-0.135	1.241	-0.002
By Percent Latino						
<10%	780	2.247	1.818	-0.429	1.451	-0.796
10% - 49.9%	1004	1.998	1.647	-0.351	1.768	-0.230
50%+	388	1.786	1.289	-0.497	1.711	-0.075
By Percent Asian						
<10%	1479	1.805	1.431	-0.374	1.462	-0.343
10%+	693	2.571	2.101	-0.470	2.032	-0.539
By Percent Foreign Born						
<25%	703	2.314	1.828	-0.486	1.603	-0.711
25%-49.9%	1038	1.712	1.340	-0.372	1.427	-0.285
50%+	431	2.432	2.079	-0.353	2.245	-0.187
By Percent Poverty						
First Quartile	543	2.284	1.772	-0.512	1.348	-0.936
Second Quartile	543	2.11	1.744	-0.366	1.738	-0.372
Third Quartile	543	2.017	1.648	-0.369	1.849	-0.168
Fourth Quartile	543	1.788	1.414	-0.374	1.641	-0.147

Table 9: Proportion of supermarkets accepting food stamps and farmers' markets accepting EBT in half mile radius by tract composition

	Tracts	Supermarkets Mean Proportion	Farmers' Markets Mean Proportion	Emergency food outlets Density
All NYC Tracts				
All Tracts	2173	0.828	0.167	2.634
By Percent White				
<10%	803	0.855	0.305	4.417
10% - 49.9%	556	0.805	0.134	1.814
50%+	814	0.817	0.054	1.439
By Percent Black				
<10%	1122	0.805	0.078	1.480
10% - 49.9%	524	0.861	0.280	3.672
50%+	527	0.845	0.244	4.060
By Percent Latino				
<10%	780	0.831	0.093	2.099
10% - 49.9%	1004	0.804	0.144	2.514
50%+	388	0.884	0.375	4.021
By Percent Asian				
<10%	1479	0.853	0.212	3.139
10%+	693	0.775	0.07	1.558
By Percent Foreign Born				
<25%	703	0.825	0.222	3.351
25%-49.9%	1038	0.836	0.146	2.460
50%+	431	0.815	0.128	1.885
By Percent Poverty				
First Quartile	543	0.806	0.066	1.161
Second Quartile	543	0.801	0.084	1.522
Third Quartile	543	0.826	0.154	2.802
Fourth Quartile	543	0.879	0.364	5.053
By Percent Receiving Public Assistance				
<10%	1556	0.807	0.095	1.766
10%+	616	0.880	0.349	4.829

Table 10: Regression of healthy food establishment density on tract composition and built environment characteristics

	All healthy food	Supermarkets	Fruit & veg. markets	Farmers' markets
	Model 1	Model 1	Model 1	Model 1
Percent black	-0.010 ***	-0.005 ***	-0.012 ***	0.000
	0.001	0.001	0.001	0.001
percent Latino	-0.005 ***	0.001	-0.009 ***	0.004 ***
	0.001	0.001	0.001	0.001
Percent Asian/Pacific Islander	-0.005	0.012 ***	-0.013 ***	0.003
	0.003	0.003	0.003	0.002
Percent foreign born	0.019 ***	0.003	0.028 ***	-0.011 ***
	0.002	0.002	0.002	0.001
Percent in poverty	0.027 ***	0.007 ***	0.032 ***	0.011 ***
	0.002	0.002	0.002	0.002
Constant	-0.195 **	-0.777 ***	-1.009 ***	-1.742 ***
	0.066	0.074	0.071	0.053
r^2	0.167	0.057	0.197	0.099
Tracts	2172	2172	2172	2172
	Model 2	Model 2	Model 2	Model 2
Percent black	-0.008 ***	-0.004 ***	-0.010 ***	0.002 *
	0.001	0.001	0.001	0.001
percent Latino	-0.008 ***	-0.002	-0.011 ***	0.002
	0.001	0.001	0.001	0.001
Percent Asian/Pacific Islander	-0.002	0.012 ***	-0.010 ***	0.003
	0.002	0.003	0.003	0.002
Percent foreign born	0.011 ***	-0.004 *	0.020 ***	-0.015 ***
	0.001	0.002	0.002	0.001
Percent in poverty	0.019 ***	-0.001	0.026 ***	0.007 ***
	0.002	0.002	0.002	0.002
Population density (logged)	0.543 ***	0.513 ***	0.443 ***	0.292 ***
	0.021	0.025	0.024	0.019
Percent commercial	0.014 ***	0.013 ***	0.011 ***	0.011 ***
	0.001	0.001	0.001	0.001
Subway stop present	0.228 ***	0.269 ***	0.142 *	0.120 **
	0.051	0.061	0.059	0.045
Percent of buildings built before 1940	0.007 ***	0.000	0.008 ***	0.002 **
	0.001	0.001	0.001	0.001
Constant	-5.404 ***	-5.460 ***	-5.379 ***	-4.544 ***
	0.194	0.232	0.224	0.173
r^2	0.412	0.234	0.347	0.222
Tracts	2163	2163	2163	2163

Note: Outcome is the logged density of Healthy Food Establishments
* p<0.05, ** p<0.01, *** p<0.001

Figure 1: Density of Healthy Food Retail Outlets by Census Tract