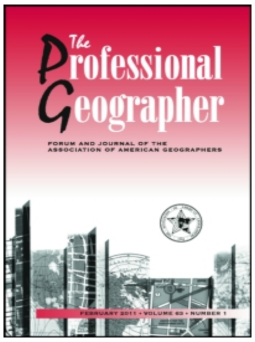

The Professional Geographer

ISSN: 0033-0124 (Print) 1467-9272 (Online) Journal homepage: https://www.tandfonline.com/loi/rtpg20

Comparing Measures of Accessibility to Urban Supermarkets for Transit and Auto Users

Michael J. Widener

To cite this article: Michael J. Widener (2017) Comparing Measures of Accessibility to Urban Supermarkets for Transit and Auto Users, The Professional Geographer, 69:3, 362-371, DOI: 10.1080/00330124.2016.1237293

To link to this article: https://doi.org/10.1080/00330124.2016.1237293

Published online: 07 Nov 2016.

Comparing Measures of Accessibility to Urban Supermarkets for Transit and Auto Users

Michael J. Widener
University of Toronto–St. George

Research on access to healthy foods often emphasizes the spatial proximity of residents to food stores like supermarkets as a way to gauge overall accessibility. Much of the literature has focused on locating the closest facility, assuming that access to one food store is sufficient. Given evidence that access to multiple healthy food stores can improve diets, however, this article examines how closest facility measures differ from cumulative opportunity accessibility measures across space in a medium-sized U.S. city. Differences in access between automobile and transit riders, using realistic travel time costs, are also considered. Results demonstrate that the two types of accessibility measures produce different accessibility geographies and that there are disparities in access for those dependent on transit. These findings indicate that researchers should carefully consider whether access to one supermarket opportunity is enough and pay special attention to the mode residents rely on to access food. **Key Words: accessibility, closest facility, cumulative opportunities, food environments, transit.**

有关取得健康食物之研究，经常强调居民之于诸如超市等粮食商店的空间邻近性，做为测量总体可及性的方法。此类文献多半聚焦于标定最近的设施，并假设单一粮食商店的获取管道是足够的。但有鉴于证据显示，多重的健康粮食取得管道能够增进饮食，本文因而检视一个中型美国城市中，最近的设施测量如何不同于空间中的累计机会之可及性测量。本文同时运用实际的交通时间成本，考量汽车和搭乘大众运输的管道差异。研究结果証实，两种类型的可及性测量，生产出不同的可及性地理，且对于依赖大众运输者而言，其取得管道具有悬殊差异。这些研究发现指出，研究者应审慎考量仅从单一超市获取粮食的机会是否足够，并特别关注居民赖以取得粮食的方式。 **关键词: 可及性, 最近的设施, 累计机会, 粮食环境, 运输**。

La investigación sobre el acceso a los alimentos saludables a menudo hace énfasis sobre la proximidad de los residentes a las tiendas de comida, supermercados, por ejemplo, como el modo de calibrar la accesibilidad en general. Gran parte de la literatura está enfocada en términos de la localización de la instalación más cercana, asumiendo que el acceso a solo una tienda de alimentos es suficiente. Dado que la evidencia del acceso a tiendas múltiples de alimentos saludables puede mejorar las dietas, sin embargo, este artículo examina cómo las medidas del acceso a la facilidad más cercana difieren de las mediciones de la oportunidad de accesibilidad acumulativa a través del espacio en una ciudad de tamaño mediano en los EE.UU. También se consideraron las diferencias en acceso entre los viajeros que conducen su automóvil y los del tránsito general, usando costos realistas del tiempo de viaje. Los resultados demuestran que los dos tipos de medidas de accesibilidad producen diferentes geografías de accesibilidad y que hay disparidades de acceso para quienes dependen del tránsito. Estos descubrimientos indican que los investigadores deben considerar cuidadosamente si el acceso a una sola oportunidad de supermercado es suficiente, y poner especial atención al modo del que los residentes dependen para acceder a los alimentos. **Palabras clave: accesibilidad, instalación más cercana, oportunidades acumulativas, entornos alimentarios, transporte público.**

Access to healthy food in cities has been a popular topic among researchers in fields like public health, health geography, and urban planning over the past few decades (Beaulac, Kristjansson, and Cummins 2009; Walker, Keane, and Burke 2010; Caspi et al. 2012). This focus is largely the result of an increase in obesity and related comorbidities in many urban regions in North America and parts of Western Europe beginning in the late twentieth century (Sobal and Stunkard 1989; Flegal et al. 2002). Some proposed that one reason for this upturn was a lack of both spatial and economic access in certain neighborhoods to stores that sell fresh and healthy foods, like fruits and vegetables (Cummins 2002). These neighborhoods came to be called *food deserts*, a term that has become increasingly popular in academic and policy spheres in the early twenty-first century.

An especially intriguing component of the food desert concept is that it lends itself to being mapped in various ways. Researchers often use readily available data from sources like the U.S. Census to characterize populations' economic statuses and locations via aggregated spatial units and then measure these units' distances to the nearest food store (generally a supermarket due to their relatively large selection, affordability, and daily operation). The U.S. Department of Agriculture (USDA) Economic Research Service's Food Accessibility Mapper is a popular example of this methodology (U.S. Department of Agriculture 2015a). Through explicitly labeling certain spaces as food deserts, policymakers and planners can generate place-specific interventions and researchers can compare differences in local health attributes for populations within and outside of areas lacking access.

The Professional Geographer, 69(3) 2017, pages 362–371 © 2017 by American Association of Geographers.
Initial submission, April 2016; revised submissions, June and August 2016; final acceptance, August 2016.
Published by Taylor & Francis Group, LLC.

The utility of the food desert concept has recently been brought into question, however. Contemporary work has not been able to consistently link worse health outcomes or lower nutrition diets with residing in food deserts (Cummins and Macintyre 2006; Lake and Townshend 2006; An and Sturm 2012; Cummins, Flint, and Matthews 2014). Although more exploratory research is necessary on the linkages among diet, health, and regions with fewer opportunities to acquire healthy foods, the current absence of a reliable relationship warrants further thought on what components contribute to improved access. Issues like flawed assumptions (Guthman 2013) and the discounting of temporal considerations (Widener, Metcalf, and Bar-Yam 2011; Widener and Shannon 2014) problematize the conventional methodologies for defining regions as without access to healthy food and the concept of the obesogenic environment more generally.

The research presented here questions the common practice of establishing spatial access by locating the closest supermarket (e.g., Laraia et al. 2004). Given that there is evidence that many people choose to shop at a grocery store that is not the closest opportunity (Hillier et al. 2011), it is important to consider spatial accessibility to a range of supermarkets via a cumulative opportunity accessibility method, which counts the number of supermarkets available to a region within a certain travel cost threshold. In addition to providing this novel perspective to spatial food accessibility in a medium-sized U.S. metropolitan area (Hamilton County, Ohio, which contains the city of Cincinnati), a comparison between transit and automobile cumulative opportunity accessibility measures is presented. The inclusion of an analysis of transit access, using realistic travel times and routes (e.g., considering transfers and walk times), is an important addition to the literature, as this mode is often discounted due to difficulties computing travel costs.

The next section dives further into the food desert concept, considers its limitations, and specifically focuses on previous attempts to identify regions that might be spatially disadvantaged when it comes to accessing food stores. This is followed by a description of the methods and data and then a presentation of results. Finally, implications of the findings are discussed, alongside a consideration of limitations and future research directions.

Measuring Access to Food Retailers

As mentioned in the Introduction, there are myriad examples of research exploring the food desert concept. Two well-cited review articles (Beaulac, Kristjansson, and Cummins 2009; Walker, Keane, and Burke 2010) provide thorough overviews of the many relevant issues and are therefore only briefly noted here. Generally, interest in food deserts arose out of a desire to understand differences in food consumption across space (Wrigley 2002). Researchers hypothesized that spaces where less healthy food was consumed and residents were assumed to experience worse health outcomes could be due to the clustering of "disadvantaged consumers" who lacked the economic and transportation resources needed to acquire the staples of a healthy diet (Whelan et al. 2002). These disadvantages were exacerbated by systematic disinvestment in food retail, or "supermarket redlining," that occurred in many cities from the mid-to-late twentieth century to, arguably, present day (Eisenhauer 2001). The focus on these spatial patterns ultimately led to an explicitly spatial metaphor, the food desert—a space without (healthy) foods—which easily lent itself to analyses focusing on the spatial relationships of poverty, retail, and transportation (Widener and Shannon 2014).

Although there is a substantial amount of debate regarding the appropriateness of this spatial metaphor in trying to uncover the spatial disparities in nutritious diets (Cummins and Macintyre 2002; Widener, Metcalf, and Bar-Yam 2011; Guthman 2013; Cummins, Flint, and Matthews 2014; Widener et al. 2015), studies have consistently been published exploring the concept's various components, including, but not limited to, spatial dimensions of availability, accessibility, affordability, accommodation, and acceptability, to borrow from Penchansky and Thomas (1981; Caspi et al. 2012). Most relevant to this research are papers focusing on spatial accessibility to stores selling healthy food. As is made evident by the extensive analysis of this literature by three recent literature reviews, spatial accessibility is largely determined by distance to the nearest food store (Beaulac, Kristjansson, and Cummins 2009; Walker, Keane, and Burke 2010; Caspi et al. 2012).

Although distance to the nearest food store is a logical way of considering spatial accessibility, research points to the fact that people's shopping habits are not always so straightforward, as documented by Handy and Clifton's (2001) work showing that a person's regular food store is not always the closest one. Additionally, work by Morland, Wing, and Roux (2002) noted that there is a positive correlation between more than one supermarket near black Americans and their reported intake of fruits and vegetables. To account for this, considering the number of nearby healthy food store opportunities might provide a more complete picture of spatial access in food accessibility research. Previous researchers have used this cumulative methodology but often use a simplistic approach to account for nearby food stores. For example, Gustafson et al. (2011) counted the number of supermarkets within a census tract, and multiple papers count the number of food stores within a simple 1-km (or less) buffer (Block and Kouba 2006; Apparicio, Cloutier, and Shearmur 2007; Black et al. 2011). Finally, although select previous research has considered both the closest option and the cumulative number of food stores (e.g., Apparicio, Cloutier, and Shearmur 2007; Black et al. 2011), their use of simple distance-based buffers does not realistically depict the opportunity landscape. The transit- and auto-network methods used in this article provide a more accurate

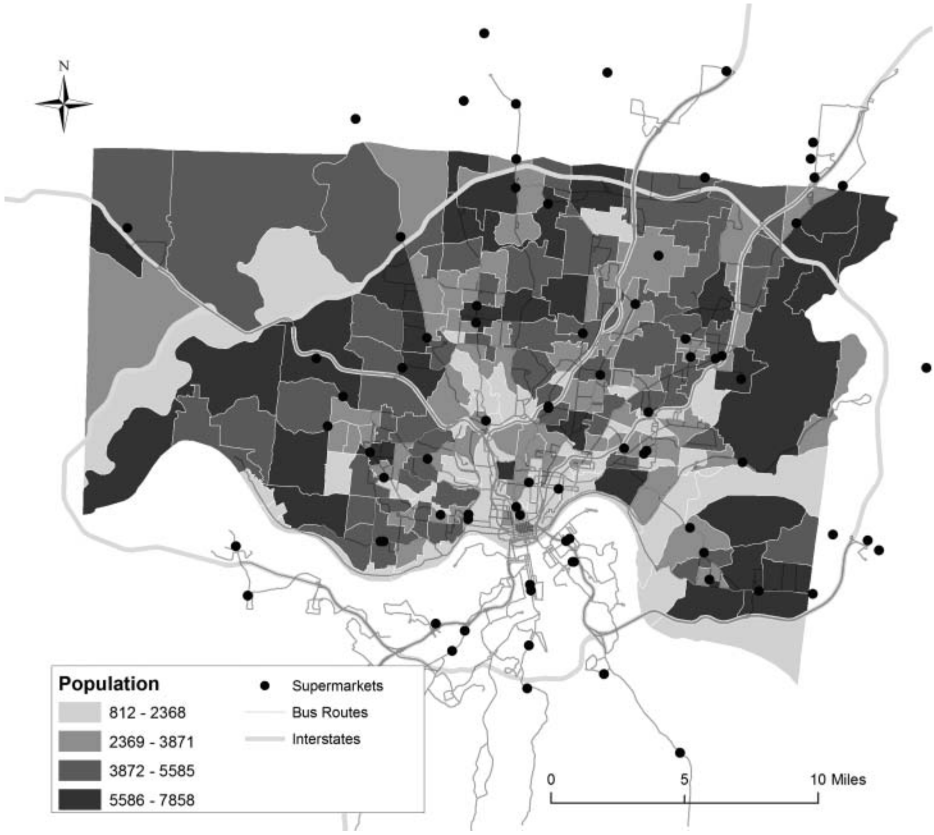

Figure 1 *Hamilton County, Ohio.*

characterization of the geography of food store opportunities when considering either the nearest store, or set of stores, accessible within an analytically derived travel-time threshold.

Data and Methods

This section documents the data and methods used to understand spatial access to supermarkets in Hamilton County, Ohio, which contains the city of Cincinnati, using a closest facility measure and a cumulative opportunity metric. Transportation infrastructure, supermarket location, and population distribution of the study area are displayed in Figure 1. The first subsection reviews data, and the second documents how the two accessibility measures are computed.

Data

The analysis is conducted at the census tract level, with population and demographic data acquired from the 2010 U.S. Census (U.S. Census Bureau 2010). Additionally, census tract–level data are acquired from the USDA's Food Access Mapper (U.S. Department of Agriculture 2015a) describing the tract as being "low income" or "low income, low access" (i.e., a food desert). The USDA defines a tract as low income when "the tract's poverty rate is 20 percent or greater; or the tract's median family income is less than or equal to 80 percent of the state-wide median family income; or the tract is in a metropolitan area and has a median family income less than or equal to 80 percent of the metropolitan area's median family income" (U.S. Department of Agriculture 2015a). The USDA defines a tract as low income, low access when it meets the criteria for being low income as described in the previous sentence and the tract's population live "far from a supermarket, where 1 mile was used in urban areas and 10 miles was used in rural areas" (U.S. Department of Agriculture 2015a). There are additional definitions of low access, but for the purposes of this study, only the one- and ten-mile thresholds are considered.

Data on the location of supermarkets within and around the county are compiled from the Orbis business directory (Orbis 2014), georeferenced to a 2009 streets file from Tele Atlas (ArcGIS, Version 10.3, Esri, Redlands, CA, USA), and cross-referenced with data from Google Maps (Google 2014). Supermarkets in surrounding counties are included to account for edge effects, as residents near the county border might have access to a store in an adjacent county. To compare automobile spatial access and transit spatial access, transportation network data are required. The same streets file used for geocoding contains speed limit information and is used for shortest path calculations (based on the amount of time it takes to traverse the path; i.e., time cost) between automobiles and supermarkets, as well as for pedestrians attempting to access transit stops (using a constant walking speed of 3 miles per hour). General transit feed specification (GTFS) data, which describe a transit network's schedule (i.e., arrivals and departures), geography (e.g., stop locations), and connectivity (e.g., transfer points), are used from two local transit agencies, Southwestern Ohio Regional Transit Authority and the Transit Authority of Northern Kentucky, to calculate shortest transit paths. Because Cincinnati's downtown is located on the Ohio River bordering the state of Kentucky and both transit agencies operate in both states, transit networks are fully accounted for to ensure that a number of supermarkets just across the river in Kentucky are considered.

Method

As previously alluded to in the background section, a cumulative opportunity and closest facility measure are both initially derived through computing the lowest cost path between an origin point (population) and destination point (supermarket). For this article, populations are generalized to the census tract centroid, and supermarkets are represented as a point at their address location. For spatial access to supermarkets via automobile, an origin–destination travel cost matrix is computed using ArcGIS's Network Analyst toolkit, where the set of origins (tracts) is represented by I and the set of destinations (supermarkets) is represented by $\mathcal{J}$.

The closest facility measure for a tract i is simply defined as the minimum road network travel time between tract i and any supermarket j in the set of all supermarkets $\mathcal{J}$. The cumulative facility access measure used in this article is calculated in the same manner as many previous studies (e.g., Horner et al. 2015) and is defined as

$$A_i^t = \sum\nolimits_{j \in Ni} O_j, \qquad (1)$$

where A_i^t is the count of supermarket opportunities at census tract i given a travel cost threshold of t, O_j equals one and represents a supermarket opportunity at location j, and $N_i = (j \mid C_{ij} \leq t)$ is the subset of supermarkets (from set $\mathcal{J}$) where the travel cost in minutes from census tract i is less than threshold t. Note that for this study, t is inclusive of the entire minute; for example, a supermarket j with a travel cost of 15.9 minutes to tract i will be included when $t = 15$.

For the analysis of transit access, multiple origin–destination travel cost matrices are constructed using a transit network analysis extension for ArcGIS 10.2. This extension allows users to calculate the scheduled time cost of trips using the network analyst toolkit and GTFS transit data (Morang 2015). The minimum time cost, inclusive of walk, transit vehicle, and transfer times, is captured for all census tract centroids in I to all supermarkets in $\mathcal{J}$, for multiple departure times. Specifically, travel cost matrices are constructed for departure times of 12:00 p.m., 12:05 p.m., 12:10 p.m., 12:15 p.m., 12:20 p.m., 12:25 p.m., 12:30 p.m., 12:35 p.m., 12:40 p.m., 12:45 p.m., 12:50 p.m., and 12:55 p.m. using generic Monday and Saturday schedules. This period represents a typical daytime schedule; Monday represents a typical weekday schedule, and Saturday represents a typical weekend schedule.

The consideration of these multiple departure times is important because the time cost between two points in the transit network can vary significantly depending on the frequency of scheduled service, making it difficult to generalize the geography of time cost. For example, consider a bus that leaves at 12:01 p.m. and 12:31 p.m. If a potential rider arrives at the stop at 12:00 p.m. and boards the 12:01 p.m. departure, their travel time will be approximately half an hour less than if they arrive at 12:02 p.m. and are forced to wait for the next bus. For more on the complexities of describing travel costs for transit trips, see work by Farber, Morang, and Widener (2014).

The closest facility measure for a tract i for Monday is the minimum average travel cost to a supermarket j, where the average travel cost between a tract i and j is the sum of travel costs between 12:00 p.m. and 12:55 p.m. on Monday, in five-minute intervals, divided by twelve. This is repeated for the travel costs from Saturday to provide a comparison between a generic weekday and weekend schedule. Finally, the cumulative facility access measure is computed, as described earlier in Equation 1, for both Monday and Saturday using average travel costs.

After noting minimal differences in access between Monday and Saturday, we decided to focus solely on Monday scores. For more on this, refer to Figure 2, which shows cumulative opportunity access measures for transit users at three example time points for both Monday and Saturday. Although there are slight differences, the overall patterns and magnitudes of access are consistent across the hour time span on both days.

Results

In this section, the results from the closest facility and cumulative opportunity accessibility measures are presented for both auto and transit users.

Closest Facility Accessibility Measure

Unsurprisingly, automobile users have lower travel costs to their closest supermarket, when compared to the average midday Monday travel cost experienced by transit users in Hamilton County (Figure 3). All automobile users have access to a supermarket in 15 minutes or less, with the maximum cost of 15.9 minutes, a minimum cost of less than 0.5 minute, and a mean travel time of approximately 4 minutes. Generally, the lower travel costs are in the center of Hamilton County, corresponding to the locations of two major interstates that

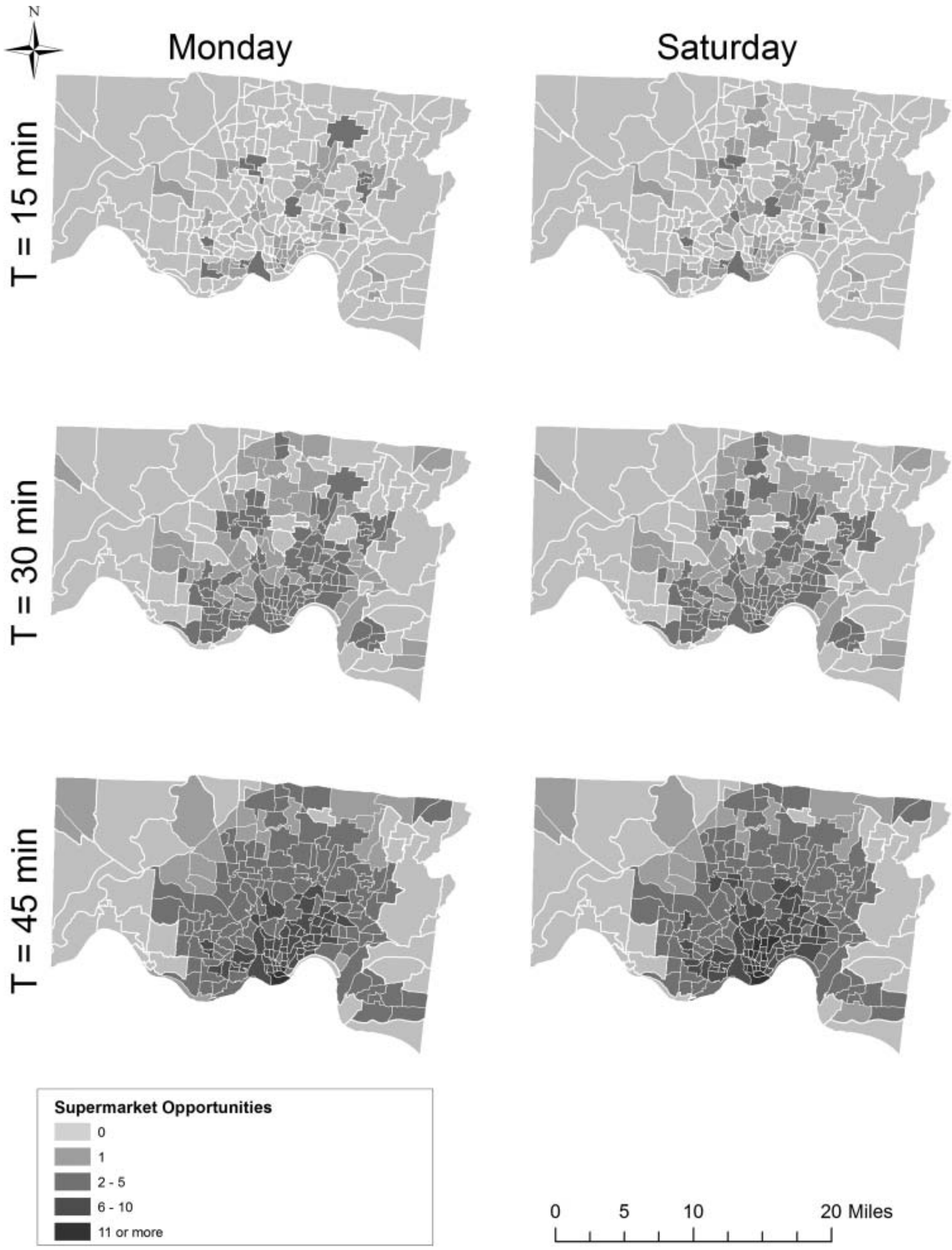

Figure 2 *Comparison of cumulative opportunity access measure for transit riders across three different time thresholds (t) for Monday and Saturday service.*

facilitate quick passage from the southern portion of the county to the north-northeastern part of the county.

The average travel cost to the nearest supermarket for transit users, on the other hand, ranges from approximately 3 minutes to a maximum of approximately 145 minutes, with a mean travel time of 28 minutes. Here, the tracts with the highest accessibility are dispersed across the county, generally corresponding with supermarket sites, and reflect the ability of residents to quickly walk to and from the supermarket. Tracts surrounding these supermarket sites on transit corridors tend to have moderate levels of access, and more peripheral tracts have the lowest levels of access.

Figure 4 displays the relative levels of closest facility access across Hamilton County by computing the standard scores from the minimum travel times. Interestingly, the geographic pattern of relative access for auto users is very similar to that experienced by transit users (Pearson's correlation coefficient of 0.952). Downtown tracts and a number of nearby peripheral tracts experience relatively

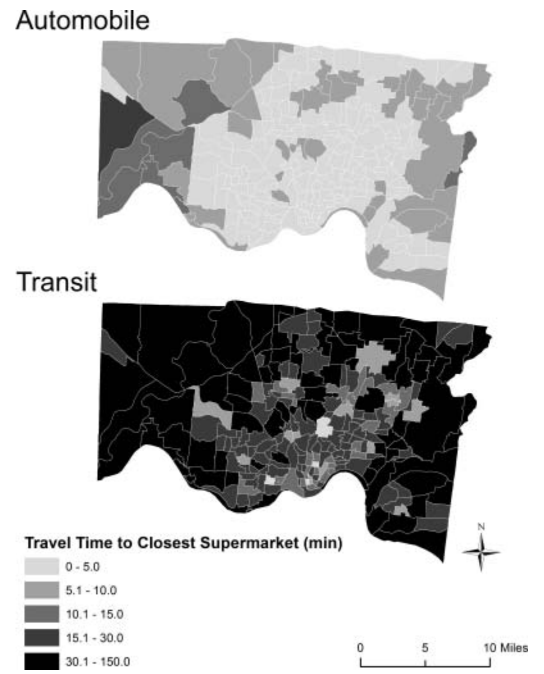

Figure 3 *Closest facility accessibility measure results for Hamilton County, Ohio, in minutes.*

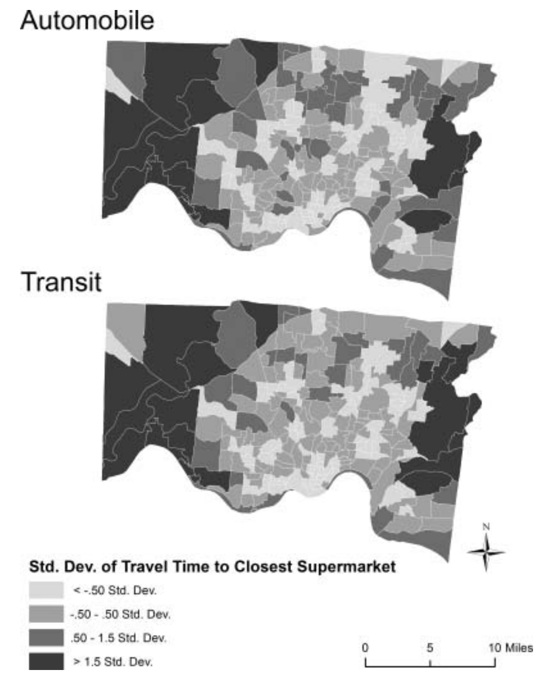

Figure 4 *Standardized closest facility accessibility measure scores for Hamilton County, Ohio.*

low travel costs, whereas the most western and eastern tracts experience relatively high travel costs.

Despite the geographic similarities in relative travel cost, transit users are at a clear disadvantage when considering the absolute time costs associated with accessing the nearest supermarket. In other words, although the geography of "good" and "bad" access is consistent across modes, the population of transit riders is acutely affected by the slower nature of public transportation.

Cumulative Facility Accessibility Measure

Unlike the closest facility accessibility measure results discussed in the previous subsection, the additional parameter of time cost threshold must be considered, adding a third dimension to the cumulative facility accessibility measure results. In other words, for each census tract there are multiple accessibility scores that vary based on the travel cost threshold t discussed earlier. Generally, as this threshold increases, there will be a corresponding increase in the number of opportunities afforded to residents in a tract, as there will be more travel time available to reach additional supermarkets.

Figure 5 shows the cumulative facility accessibility measure results for $t = 15$ minutes for both automobile and transit users, with darker shades indicating more opportunities. Again, what is immediately evident is the advantage car drivers have when it comes to having choices in where they shop for food. The vast majority of tracts have more than eleven supermarket choices within 15 minutes, whereas only two tracts have a single option. Examining the cumulative opportunity accessibility measure for transit users reveals a very different picture. In this case, a vast majority of tracts have no access to supermarkets within 15 minutes (on average during the examined time period), and only fifteen tracts have a choice of two to five supermarkets within the same time threshold. This by itself is an interesting finding, as it provides further and clear evidence that spatial access to supermarkets is limited for those dependent on public transportation.

As in the previous subsection, standard scores are computed to display the spatial distribution of relatively good access for the two modes (Figure 6). For automobile users, the geography of good versus bad access is very similar to the closest facility accessibility measure map, with the best access occurring in downtown Cincinnati (the south-central part of Hamilton County). The geography of relatively good access for transit users is rather different than what is seen using the closest facility accessibility measure in Figure 4, however. Here, the most choice, when $t = 15$ minutes, is found in a few pockets of tracts that happen to be both on major transit lines and near many supermarkets. The gradient of improved access radiating from the city center seen in Figure 4 is no longer present, due to many tracts being categorized as having "0" opportunity. The difference between the auto and transit cumulative opportunity accessibility landscapes is confirmed by a low Pearson's correlation coefficient of 0.370 (compared to the 0.952 coefficient for the closest facility measure). This indicates a weak positive relationship between tracts' automobile cumulative opportunity access and transit cumulative opportunity access scores.

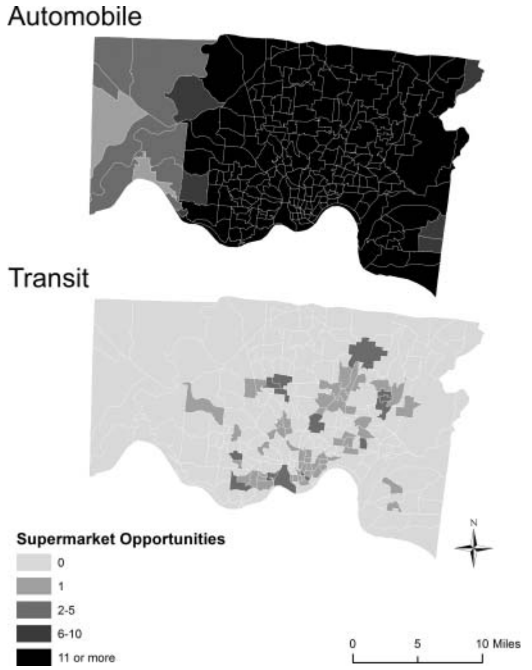

Figure 5 *Cumulative opportunity accessibility measure results where t = 15 for Hamilton County, Ohio, in number of supermarkets.*

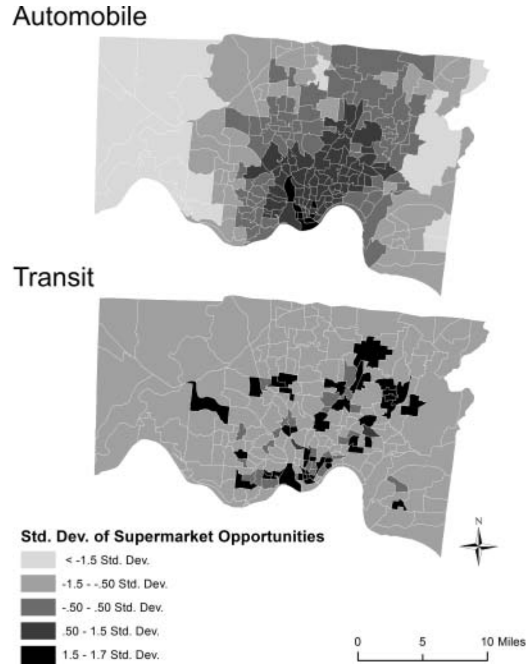

Figure 6 *Standardized cumulative opportunity accessibility measure scores for Hamilton County, Ohio.*

Further examination of the cumulative accessibility metric is necessary, though, given its sensitivity to the value of t, to understand the magnitude of the issue in the study area. Returning to Figure 2, it is possible to see that when $t = 45$ minutes on Monday, the number of tracts with access to multiple supermarket opportunities via public transportation increases markedly in the central core of Hamilton County, where the transit network is the most accessible.

To illustrate the variation in supermarket opportunities via automobile and transit, an aspatial approach is used in Figure 7. In Figure 7, there are eight plots that display the average, minimum, and maximum number of supermarkets that can be accessed within a time of t for a subset of tracts in the study area. For comparison, the following groups of tracts are included for both auto and transit riders: the set of all tracts in Hamilton County, the set of tracts considered to be food deserts (i.e., designated as low income, low access by the USDA), the set of tracts classified as low income by the USDA, and the set of tracts not classified as low income by the USDA.

First concentrating on Figure 7A, which displays the cumulative opportunity accessibility metric results for automobile users, it is notable that at $t = 5$ minutes the average number of opportunities for all tracts is 2.62. Additionally, the minimum number of supermarket opportunities rapidly increases to more than thirty opportunities when $t = 30$ minutes. Focusing only on those tracts designated as food deserts, it is evident that the minimum and average number of opportunities are equal to or greater than those available to all tracts. Finally, the plot of the set of tracts classified as only low income displays that beginning at $t = 15$ minutes, there are at least three supermarket options available.

Turning to Figure 7B, which displays the cumulative opportunity accessibility metric results for transit users, the levels of access are, as previously discussed, relatively worse. In particular, it is worth noting that the maximum number of supermarket opportunities a tract can reach via transit with $t = 45$ minutes is eighteen, compared to more than eighty via automobile. Additionally, the rate of increase in the average number of opportunities as t goes up is lower than the automobile case. Again, this is not surprising given the flexibility of automobility and the constraints associated with transit. These findings explicitly demonstrate, though, the extent to which transit riders are disadvantaged when it comes to having a choice of where to shop for groceries.

Examining particular cases from Figure 7B it is possible to see that the minimum and maximum numbers of supermarket opportunities for low-income, low-access tracts closely resemble all tracts in the study area, as well as those tracts designated as low income. Also noteworthy is the fact that low-income, low-access tracts have higher average numbers of supermarket opportunities when compared to all tracts, especially at $t = 30$ minutes or greater. Finally, it is important to point out that the two subsets of tracts that would be considered the most disadvantaged (low income, low access and low income) each have better average access to supermarket opportunities than the

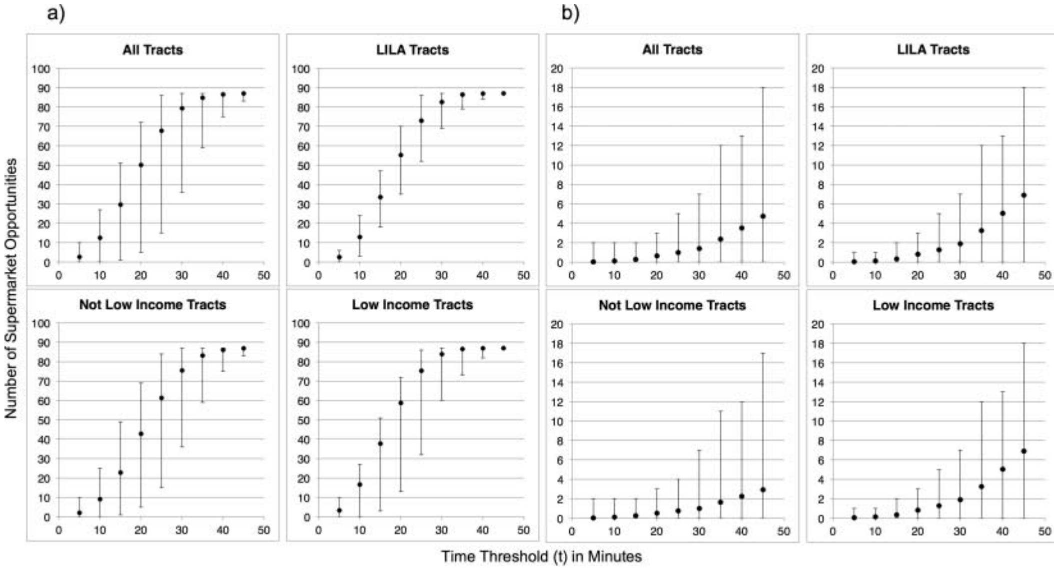

Figure 7 *Maximum (upper dash), minimum (lower dash), and average (dot) cumulative supermarket opportunities for t = 5 minutes to t = 45 minutes for (A) automobile users and (B) transit users. LILA = low income, low access.*

set of all tracts in Hamilton County and those tracts not designated as low income. This implies that those tracts that would be considered most at risk of not having access, generally speaking, to supermarket opportunities in fact have better spatial access via transit than those tracts that would be considered less at risk.

Discussion

This work set out to examine how the geography of spatial access to supermarkets differed when comparing nearest facility and cumulative opportunity approaches, as there is a need for more nuanced thought on how spatial access is measured in this arena. Additionally, realistic time costs via public transportation are considered in the analysis, providing further information about how urban residents' mobility can affect their ability to access one or more supermarket opportunities. Whereas the previous section presented and described the results from the analysis, this section discusses the findings. First, a comparison is made between the two accessibility measures. Next, a discussion on the need to compare accessibility across modes is presented. Finally, limitations of this study are reviewed.

Cumulative Opportunities versus Closest Facility Accessibility Measures

The results from the two accessibility measures presented in the last section demonstrate that the geography of access to supermarkets is highly dependent on the tool being used to measure accessibility, especially when considering transit travel costs. Relative levels of access for automobile users exhibit a similar geographic pattern in both cumulative opportunity and closest facility measures, whereas the geography of relatively good levels of access for transit users differ.

The question remains as to which of these accessibility measures might be more appropriate to the topic at hand. It could be argued that access to a single supermarket is sufficient, as these stores typically offer a large number of items at prices that tend to be lower than alternative food markets. In this case, the closest facility measures provide a clear way to evaluate what regions are within an acceptable travel cost threshold from a supermarket. The importance of choice has been documented by work previously discussed in the background section, however (Handy and Clifton 2001; Morland, Wing, and Roux 2002). Having more opportunities could relate to an increase in exposure and increased competition between supermarkets. Here, the cumulative opportunity accessibility measurement might be more appropriate.

The research presented in this article demonstrates that it is very important for researchers of food access, and accessibility more generally, to carefully consider the usage of these different types of measures, especially given the differences in relative accessibility seen for transit riders. The fact that food desert tracts tend to have equal or better spatial access could point to a need for more refined, and potentially aspatial, approaches for identifying populations with limited access to healthy foods. In particular, a focus on economic access, time pressure, or reliance on public transit might provide a better representation of those with accessibility issues.

Differences in Automobile and Transit Mobility

As previously mentioned, it is not unexpected that automobile users will have lower travel costs and more supermarket opportunities. Given the mode's flexibility and speed, people with access to cars tend to have an advantage in cities like Cincinnati, with autocentric infrastructures. When considering access via automobile, the spatial distribution of relatively good access for both measures was concentrated in the denser city center, with relatively worse access scores on the periphery. Despite this, the worse access seen in the periphery was consistently better than levels seen for transit riders.

For access via transit, the same pattern appears for the closest facility accessibility measure, but the relatively good access scores for the cumulative opportunity accessibility measures were concentrated around supermarkets and along transit corridors. This makes intuitive sense, as riders are dependent on the transit network's topology and constrained by the speed at which they walk.

It is likely that a person's ability to access a region via one mode or another will actually influence his or her choice to use that mode, given that he or she has the financial means. So, although transit access to supermarkets is lower for both accessibility measures in the periphery of Hamilton County, much of the population in this area might rely on automobiles to conduct their grocery shopping. What should be of concern to researchers and policymakers in this arena are those people who cannot afford an automobile and live in an area poorly connected by transit. Therefore, although the analysis presented in this article shows broad trends present in access across the study area for automobile and transit users, it is important to consider individual contexts.

Limitations

It is important to note that the results of this study are dependent on the geography of the road and transit networks, as well as the supermarkets, in and around Hamilton County, Ohio. Other regions will exhibit different patterns of access based on their unique transportation network and supermarket geographies. Despite this, the geography of Hamilton County and Cincinnati is representative of many midsized urban areas in North America, with a dense core consisting of residents with lower incomes and a sprawling, car-dependent periphery.

Another limitation to consider includes the choice made to average travel cost on transit over the course of one hour. Given the increase in location-aware technology, an individual could now use a device like a mobile phone to receive up-to-the-second information on transit vehicles and plan trips accordingly. Accounting for this in a macrolevel accessibility analysis is not feasible, however. Finally, as mentioned in the previous subsection, the presented accessibility analyses are conducted at an aggregate level, which results in accessibility calculations being subject to aggregation errors (Hewko, Smoyer-Tomic, and Hodgson 2002; Apparicio et al. 2008) and discounts the many individual constraints experienced by the population in the study area. It is necessary to link these aggregate-level analyses to individual-level studies to understand how well these high-level approaches capture the on-the-ground reality. Future research must tackle this by comparing observed dietary outcomes with aggregate-level measures, like those examined in this article.

Conclusions

This research provides a thorough comparison of closest facility accessibility and cumulative opportunity accessibility measures in the context of access to supermarkets. Given the plethora of research on healthy food accessibility, this article demonstrates that the type of accessibility measure used can reveal different geographic patterns in access, especially for transit users. Additionally, this article provides a novel analysis of access to supermarkets via transit using a cumulative opportunity accessibility measure, which to the author's knowledge, has not yet been presented in the literature.

Together, these findings help to steer researchers and policymakers conducting research on healthy food toward more appropriate methodologies. Additionally, it demonstrates that transit travel costs are consistently higher than automobile travel costs and come with different accessibility geographies.

As mentioned in the Introduction, given the complex nature of people's grocery shopping habits, it is important to think carefully about how researchers measure spatial access. Ultimately, these findings help move the research community toward more thorough understandings of access to healthy foods by demonstrating the differences that can emerge when defining spatial access using two common accessibility measures. Future work should note these differences, as well as the sensitivity of spatial access measures to transportation mode. ■

Literature Cited

An, R., and R. Sturm. 2012. School and residential neighborhood food environment and diet among California youth. *American Journal of Preventive Medicine* 42 (2): 129–35.

Apparicio, P., M. Abdelmajid, M. Riva, and R. Shearmur. 2008. Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. *International Journal of Health Geographics* 7 (7): 1–14.

Apparicio, P., M.-S. Cloutier, and R. Shearmur. 2007. The case of Montreal's missing food deserts: Evaluation of accessibility to food supermarkets. *International Journal of Health Geographics* 6 (1): 4. http://ij-healthgeographics.biomedcentral.com/articles/10.1186/1476-072X-6-4 (last accessed 14 October 2016).

Beaulac, J., E. Kristjansson, and S. Cummins. 2009. A systematic review of food deserts, 1966–2007. *Preventing Chronic Disease* 6 (3): A105.

Black, J. L., R. M. Carpiano, S. Fleming, and N. Lauster. 2011. Exploring the distribution of food stores in British Columbia: Associations with neighbourhood socio-demographic factors and urban form. *Health & Place* 17 (4): 961–70.

Block, D., and J. Kouba. 2006. A comparison of the availability and affordability of a market basket in two communities in the Chicago area. *Public Health Nutrition* 9 (7): 837–45.

Caspi, C. E., G. Sorensen, S. V. Subramanian, and I. Kawachi. 2012. The local food environment and diet: A systematic review. *Health & Place* 18 (5): 1172–87.

Cummins, S. 2002. Food deserts. In *The Wiley Blackwell encyclopedia of health, illness, behavior, and society*, ed. W. C. Cockerham, R. Dingwall, S. R. Quah, 562–64. Hoboken, NJ: John Wiley & Sons.

Cummins, S., E. Flint, and S. A. Matthews. 2014. New neighborhood grocery store increased awareness of food access but did not alter dietary habits or obesity. *Health Affairs* 33 (2): 283–91.

Cummins, S., and S. Macintyre. 2002. "Food deserts"—Evidence and assumption in health policy making. *BMJ: British Medical Journal* 325 (7361): 436–38.

———. 2006. Food environments and obesity—Neighbourhood or nation? *International Journal of Epidemiology* 35 (1): 100–104.

Eisenhauer, E. 2001. In poor health: Supermarket redlining and urban nutrition. *GeoJournal* 53 (2): 125–33.

Farber, S., M. Morang, and M. J. Widener. 2014. Temporal variability in transit-based accessibilty to supermarkets. *Applied Geography* 53:149–59.

Flegal, K. M., M. D. Carroll, C. L. Ogden, and C. L. Johnson. 2002. Prevalence and trends in obesity among US adults, 1999–2000. *Journal of the American Medical Association* 288 (14): 1723–27.

Google. 2014. Google Maps directory 2014. http://www.google.com/maps (last accessed 1 November 2014).

Gustafson, A. A., J. Sharkey, C. D. Samuel-Hodge, J. Jones-Smith, M. C. Folds, J. Cai, and A. S. Ammerman. 2011. Perceived and objective measures of the food store environment and the association with weight and diet among low-income women in North Carolina. *Public Health Nutrition* 14 (6): 1032–38.

Guthman, J. 2013. Too much food and too little sidewalk? Problematizing the obesogenic environment thesis. *Environment and Planning A* 45 (1): 142–58.

Handy, S. L., and K. J. Clifton. 2001. Local shopping as a strategy for reducing automobile travel. *Transportation* 28 (4): 317–46.

Hewko, J., K. E. Smoyer-Tomic, M. J. Hodgson. 2002. Measuring neighbourhood spatial accessibility to urban amenities: Does aggregation error matter? *Environment and Planning A* 34 (7): 1185–1206.

Hillier, A., C. C. Cannuscio, A. Karpyn, J. McLaughlin, M. Chilton, and K. Glanz. 2011. How far do low-income parents travel to shop for food? Empirical evidence from two urban neighborhoods. *Urban Geography* 32 (5): 712–29.

Horner, M. W., M. D. Duncan, B. S. Wood, Y. Valdez-Torres, and C. Stansbury. 2015. Do aging populations have differential accessibility to activities? Analyzing the spatial structure of social, professional, and business opportunities. *Travel Behaviour and Society* 2 (3): 182–91.

Lake, A., and T. Townshend. 2006. Obesogenic environments: Exploring the built and food environments. *The Journal of the Royal Society for the Promotion of Health* 126 (6): 262–67.

Laraia, B. A., A. M. Siega-Riz, J. S. Kaufman, and S. J. Jones. 2004. Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Preventive Medicine* 39 (5): 869–75.

Morang, M. 2015. *Add GTFS to a network dataset*. http://www.arcgis.com/home/item.html?id=0fa52a75d9ba4abcad6b88bb6285fae1 (last accessed 15 December 2015).

Morland, K., S. Wing, and A. Diez Roux. 2002. The contextual effect of the local food environment on residents' diets: The Atherosclerosis Risk in Communities Study. *American Journal of Public Health* 92 (11): 1761–68.

Orbis, Bureau Van Dijk. 2014. Company information from across the globe. https://orbis.bvdinfo.com/ (last accessed 1 November 2014).

Penchansky, R., and J. W. Thomas. 1981. The concept of access: Definition and relationship to consumer satisfaction. *Medical Care* 19 (2): 127–40.

Sobal, J., and A. J. Stunkard. 1989. Socioeconomic status and obesity: A review of the literature. *Psychological Bulletin* 105 (2): 260–75.

U.S. Census Bureau. 2010. 2010 Census data. http://www.census.gov/ (last accessed 17 January 2015).

U.S. Department of Agriculture. 2015a. *Food access research atlas*. http://www.ers.usda.gov/data/fooddesert/ (last accessed 17 January 2015).

———. 2015b. *Food access research atlas documentation*. http://www.ers.usda.gov/data-products/food-access-research-atlas/documentation.aspx (last accessed 30 January 2015).

Walker, R. E., C. R. Keane, and J. G. Burke. 2010. Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place* 16 (5): 876–84.

Whelan, A., N. Wrigley, D. Warm, and E. Cannings. 2002. Life in a "food desert." *Urban Studies* 39 (11): 2083–2100.

Widener, M. J., S. Farber, T. Neutens, and M. Horner. 2015. Spatiotemporal accessibility to supermarkets using public transit: An interaction potential approach in Cincinnati, Ohio. *Journal of Transport Geography* 42:72–83.

Widener, M. J., S. S. Metcalf, and Y. Bar-Yam. 2011. Dynamic urban food environments: A temporal analysis of access to healthy foods. *American Journal of Preventive Medicine* 41 (4): 439–41.

Widener, M. J., and J. Shannon. 2014. When are food deserts? Integrating time into research on food accessibility. *Health & Place* 30:1–3.

Wrigley, N. 2002. "Food deserts" in British cities: Policy context and research priorities. *Urban Studies* 39 (11): 2029–40.

MICHAEL J. WIDENER is an Assistant Professor in the Department of Geography and Planning at the University of Toronto–St. George, Toronto, ON M5S 3G3, Canada. E-mail: michael.widener@utoronto.ca. He is interested in pursuing research projects that examine the complex links between health and transportation systems.