PLANNING FOR HEALTHY, ACTIVE COMMUNITIES:

DOES TORONTO'S BUILT ENVIRONMENT PROMOTE HEALTHY, ACTIVE LIVING?

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Submitted: April 1, 2015

A Major Paper submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies, York University, Toronto, Ontario, Canada.

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ABSTRACT

The goal of this major research paper was to identify the built environment components of healthy, active communities and examine the spatial distribution of these components in the City of Toronto. Healthy, active communities were defined as communities that foster transportation or recreational physical activity, healthy eating, and a healthy body weight among residents. A review of existing planning and public health literature was conducted to identify characteristics of the built environment associated with these outcomes.

The literature review identified strong evidence for associations between transportation physical activity and variables capturing density, land use mix, street pattern, and walkability or urban sprawl. Evidence was also relatively strong for relationships between access to walking trails, parks and open spaces, street pattern, and recreational physical activity.

Evidence for associations between objectively quantifiable aspects of the food environment and dietary outcomes was less strong. The only measures that had somewhat consistent associations were proximity and density of more healthy and less healthy food sources. Additionally, the only two variables consistently associated with weight status were population density and land use mix. There was also some evidence of associations between less healthy food sources and weight status.

Geographic Information Systems were used to map the spatial distribution of these built environment components in Toronto, Ontario. Density measures were generally highest in downtown and adjacent Neighbourhoods, and lower in more suburban areas of the City. Patterns of proximity to and presence of utilitarian destinations followed a similar pattern, though the range of values in the results was much more constrained. Considerably more variation was observed with respect to the density of utilitarian destinations, which was over twenty times

higher in some downtown Neighbourhoods that in other Neighbourhoods. Availability of smaller parks and open spaces was generally highest in parts of downtown and adjacent areas. Some suburban areas also had access to smaller parks, while others did not. In comparison, access to larger parks within longer travel distances was almost uniformly high across the City.

More healthy and less healthy food sources had similar spatial distributions across the City. Neighbourhoods near downtown generally had the shortest travel distances to and higher densities of food sources in both categories. Conversely, some suburban Neighbourhoods consistently had longer travel times to and lower densities of both types of food sources. In some of these areas the travel distance to the nearest healthy food source was longer than 1 kilometre, which may present a barrier to purchasing healthy food.

These findings present an important first step toward understanding the spatial pattern of healthy built environment characteristics across Toronto. Though we were unable examine associations with specific health outcomes, future researchers with access to suitable data are encouraged to select independent variables for such analysis based on the results of this paper.

This paper also discussed the legal and policy framework governing land use planning and public health in Ontario. Reforms that would promote increased integration of health principles into the planning process were presented. These reforms included implementation of the Health Background Study framework in Toronto, adoption of a Health Impact Assessment tool, and amendments to related legislation and provincial plans. These reforms should prove of interest to researchers and professionals in both public health and planning, and if implemented will encourage further collaboration between these groups at all stages of the planning process.

FOREWORD

This major research paper helps fulfill several components of my area of concentration through examining the interrelationships between the built environment, public health, and related laws and policies. First, the literature review improved my understanding of urban planning and design "best practices" for developing a built environment that fosters physical activity and healthy living. This furthers learning objective two of component one of my area of concentration. The examination of ecological frameworks for assessing the built environment's influence on individuals' health and transportation behaviours also furthered objective one of component one, as it expanded my knowledge of fundamental urban planning discourses.

Second, this paper utilized Geographic Information Systems to examine the spatial distribution of healthy built environment characteristics in the City of Toronto. This analysis relates directly to both learning objectives under component three of my area of concentration, as it involved application of efficient network analysis protocols and the use of ArcMap and Adobe lllustrator software in the creation of built environment variables and maps thereof.

Third, this paper provided a comprehensive overview of the legal and policy frameworks that govern land use planning and public health in the Province of Ontario. This relates directly to objective one of component two of my area of concentration. This paper also presented several potential legal and policy reforms aimed at further integrating health principles within provincial and municipal land use planning processes. This research relates to objectives two, three, and four of component two of my area of concentration. I developed and applied critical legal and policy analysis skills to identify the reforms presented in this paper. I also identified specific legal and policy interventions that may further promote active transportation and chronic disease prevention as land use planning goals within the Province and the City of Toronto.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Mark Winfield, for his continued support and advice throughout my time in the MES/JD Joint Program. Thank you also to Stepan Wood and Dayna Scott for taking the time to discuss the role of this paper within my overall plan of study.

I would also like to thank Dr. Richard Glazier and Dr. Gillian Booth for first turning my mind to the complex connections between the built environment and health, and allowing me to conduct the analyses in this paper on their GIS network computer. Thank you also to Peter Gozdyra and Marisa Creatore for your continued insight into GIS and epidemiological methodologies over the last ten years. Jane Polsky, thank you for allowing me to use the food data that you so attentively cleaned for your own PhD research—this contribution was an invaluable time-saver.

Finally, thank you to my wife, Natasha Chatterjee, for your continued love and support over our many wonderful years together. This work truly would not have been possible without your advice, insight, and encouragement.

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1 Introduction and Background

1.1 Why the Built Environment?

There is a growing recognition among planning and public health professionals that the way in which communities are planned and designed can promote or discourage healthy lifestyle choices and engagement in physical activity among residents. In the past decade, an explosion of literature has considered the relationships between characteristics of the built environment and a variety of potentially dependent transportation and health outcomes. The built environment comprises all human-constructed or -modified aspects of the environment; it has been defined as:

> [A]ll buildings, spaces and products that are created, or modified, by people. It includes homes, schools, workplaces, parks/recreation areas, greenways, business areas and transportation systems. It extends overhead in the form of electric transmission lines, underground in the form of waste disposal sites and subway trains, and across the country in the form of highways. It includes land-use planning and policies that impact our communities in urban, rural and suburban areas.[1]

Built environment research has emerged predominantly from two fields: transportation, planning, and geographic research that has examined the influence of the built environment on travel behaviours;[2] and public health research that has examined the influence of the built environment

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[1] National Institutes of Health, *Obesity and the Built Environment - Grant Request for Applications*, 2004, accessed April 1, 2015, http://grants.nih.gov/grants/guide/rfa-files/rfa-es-04-003.html.

[2] See Simon D S Fraser and Karen Lock, "Cycling for Transport and Public Health: a Systematic Review of the Effect of the Environment on Cycling," *European Journal of Public Health*, October 6, 2010, http://eurpub.oxfordjournals.org/content/21/6/738.long; Reid Ewing, Rolf Pendall, and Don Chen, "Measuring Sprawl and Its Transportation Impacts," *Transportation Research Record* 1831 (2003): 175–83; R Ewing et al., "Identifying and Measuring Urban Design Qualities Related to Walkability," *Journal of Physical Activity & Health* 3, Suppl 1 (2006): S223-S240; Lawrence D Frank et al., "Stepping Towards Causation: Do Built Environments or Neighborhood and Travel Preferences Explain Physical Activity, Driving, and Obesity?," *Social Science & Medicine* 65, no. 9 (October 31, 2007): 1898–1914; Chanam Lee and Anne Vernez Moudon, "Physical Activity and Environment Research in the Health Field: Implications for Urban and Transportation Planning Practice and Research," *Journal of Planning Literature* 19, no. 2 (2004): 147–81; LD Frank and PO Engelke, "The Built Environment and Human Activity Patterns: Exploring the Impacts of Urban Form on Public Health," *Journal of Planning Literature* 16, no. 2 (2001): 202–18.

on physical activity, dietary intake, and related health outcomes such as obesity, diabetes, and cardiovascular disease.[3]

The rationale for this research is multiple, but arguably stems from long-term trends and current patterns in land use planning, transportation behaviours, physical activity, food production and consumption, and the pandemic of obesity.[4] During the Post-World War II economic boom, dramatic changes in land use planning and urban form began to take place in Canada and the United States. Urban planners, whose earlier professional work was largely focused on mitigating the health impacts of rapid industrialization and urbanization, shifted their focus toward large infrastructure and transportation projects that supported suburban economic development.[5] The rise in production and affordability of automobiles, combined with construction of large-scale highway systems in Canada and the United States, ushered in the

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[3] See Gerlinde Grasser et al., "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," *International Journal of Public Health* 58, no. 4 (2013): 615–25; James F Sallis et al., "Neighborhood Built Environment and Income: Examining Multiple Health Outcomes," *Social Science & Medicine* 68, no. 7 (2009): 1285–93; Christina Black, Graham Moon, and Janis Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?," *Health and Place* 27 (2014): 229–42; Louis Lebel et al., "Lifestyles and Consumption in Cities and the Links with Health and Well-Being: the Case of Obesity," *Current Opinion in Environmental Sustainability* 4, no. 4 (2012): 405–13; Richard H Glazier et al., "Density, Destinations or Both? a Comparison of Measures of Walkability in Relation to Transportation Behaviors, Obesity and Diabetes in Toronto, Canada," *PloS One* 9, no. 1 (2014): e85295.

[4] Ross C Brownson, Tegan K Boehmer, and Douglas A Luke, "Declining Rates of Physical Activity in the United States: What Are the Contributors?," *Annual Review of Public Health* 26 (2005): 421–43; Boyd A Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," *Lancet* 378, no. 9793 (2011): 804–14; Frida J Dangardt et al., "Exercise: Friend or Foe?," *Nature Reviews Cardiology* 10, no. 9 (2013): 495–507; Lawrence H Kushi, "Epidemiologic Research on the Obesity Epidemic: a Socioenvironmental Perspective," *Epidemiology* 17, no. 2 (2006): 131–33.

[5] Jason Corburn, "Confronting the Challenges in Reconnecting Urban Planning and Public Health," *American Journal of Public Health* 94, no. 4 (April 2004): 542.

"Freeway era."[6] For those living in the "suburban ring" surrounding major cities, automobiles were no longer a luxury but a necessity for daily commuting, shopping, and socializing.[7]

Fast-forwarding to the early 20th century, data demonstrates continued reliance on automobiles for transportation. According to the Census of Canada, 71.4% of persons aged 15 years and older living within the Toronto Census Metropolitan Area commuted to work or school by automobile in 2001.[8] In the United States in 2001, 92.4% of trips made to or from work, 91.2% of trips made for work-related business purposes, and 90.9% of trips made for family or personal business purposes were made using private vehicles.[9] The average number of daily vehicle miles traveled ("VMT") has also steadily increased across the United States since 1969.[10] Time trends in data from the Nationwide Personal Transportation Survey and National Household Travel Survey in the United States show that average daily VMT increased from 34.01 miles in 1969 to 58.05 miles in 2001, an increase of over 70%.[11] Average daily time spent in a private vehicle also increased by roughly 10% between 1995 and 2001 in the United States.[12]

Reliable data on physical activity rates dating back to the Post-World War II period is more difficult to obtain. However, Brownson et al.'s analysis of several national U.S. data

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[6] P O Muller, "Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis," in *The Geography of Urban Transportation*, ed. S Hanson, (New York: Guilford, 1995), 26–52.

[7] Brownson, Boehmer, and Luke, "Declining Rates of Physical Activity in the United States: What Are the Contributors?."

[8] *2001 Census of Canada: Community Highlights for Toronto Census Metropolitan Area*, (Statistics Canada, 2013), http://www12.statcan.ca/.

[9] Pat S Hu and Timothy R Reuscher, *Summary of Travel Trends: 2001 National Household Travel Survey*, *U.S. Department of Transportation, Federal Highway Administration*, (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, December 2004), 19.

[10] Brownson, Boehmer, and Luke, "Declining Rates of Physical Activity in the United States: What Are the Contributors?," 427.

[11] Hu and Reuscher, *Summary of Travel Trends: 2001 National Household Travel Survey*, 12.

[12] ibid., 28.

sources indicated that rates of transportation- and work-related physical activity have decreased since 1960 and 1950, respectively.[13] By comparison, average daily time spent in sedentary behaviours such as watching television has increased since 1950.[14] Interestingly, the proportion of the U.S. adult population that met physical activity recommendations slightly increased between 1990 and 2000, though a decrease was found among adults with fewer than twelve years of education, as well as children and youth, for the same time period.[15] Due to data limitations, Brownson et al. were not able to examine time trends in overall physical activity over a longer period, and it is possible that overall physical activity rates also declined between 1950 and 1990.

In recognition of these trends, transportation planners have become increasingly interested in the role the built environment and urban form may play in influencing travel behaviours.[16] Studies have examined whether built environment measures indicative of urban sprawl are associated with VMT, and whether indicia of compact, pedestrian-oriented built environments are associated with increased rates of walking and bicycling for transportation.[17]

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[13] Brownson, Boehmer, and Luke, "Declining Rates of Physical Activity in the United States: What Are the Contributors?," 427.

[14] ibid., 427.

[15] ibid., 427.

[16] See Lawrence Frank and Gary Pivo, "Impacts of Mixed Use and Density on Utilization of Three Modes of Travel: Single-Occupant Vehicle, Transit, and Walking," *Transportation Research Record* 1466 (1995): 44–52; R Crane, "The Influence of Urban Form on Travel: an Interpretive Review," *Journal of Planning Literature* 15, no. 1 (August 1, 2000): 3–23; Ewing: 2001uj; Ewing, Pendall, and Chen, "Measuring Sprawl and Its Transportation Impacts;" Reid Ewing and Robert Cervero, "Travel and the Built Environment: a Meta-Analysis," *Journal of the American Planning Association* 76, no. 3 (2010): 265–94.

[17] Reid Ewing and Robert Cervero, "Travel and the Built Environment," *Transportation Research Record* 1780 (2001): 87–114; Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis;" Fraser and Lock, "Cycling for Transport and Public Health: a Systematic Review of the Effect of the Environment on Cycling;" Reid Ewing, "Can the Physical Environment Determine Physical Activity Levels?," *Exercise and Sport Sciences Reviews* 33, no. 2 (March 31, 2005): 69–75; E Leck, "The Impact of Urban Form on Travel Behavior: a Meta-Analysis," *Berkeley Planning Journal* 19, no. 1 (2006).

The simplified hypothesis is that factors such as higher density, greater land-use diversity or "mix," and pedestrian-oriented designs encourage active transportation and reduce auto trips and VMT.[18] While the notion that the way in which communities are designed influences travel behaviour appears intuitive, and professional transportation planners and engineers regularly engage in travel behaviour modeling when evaluating alternative development patterns,[19] evidence of a causal relationship is relatively limited.[20] Thus one focus of this research paper is to examine the current evidence base and identify components of the built environment consistently related to active transportation, while highlighting methodological issues future studies should address.

Another driver of the explosion in built environment research over recent years is the change in food production and consumption during the latter half of the 20th century. During this period agriculture in North America shifted away from "diversified farms" that raised multiple crops and livestock to an industrial food production model characterized by specialization, standardization, mechanization, consolidation, and commodification.[21] Crop production moved toward monocultures and livestock production was separated into many distinct stages in an effort to boost economies of scale. As a result of increased production, between 1950 and 2000

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[18] Robert Cervero and Kara Kockelman, "Travel Demand and the 3Ds: Density, Diversity, and Design," *Transportation Research Part D: Transport and Environment* 2, no. 3 (1997): 199–219.

[19] Crane, "The Influence of Urban Form on Travel: an Interpretive Review."

[20] See Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis;" Frank et al., "Stepping Towards Causation: Do Built Environments or Neighborhood and Travel Preferences Explain Physical Activity, Driving, and Obesity?;" Susan Handy, Xinyu Cao, and Patricia Mokhtarian, "Correlation or Causality Between the Built Environment and Travel Behavior? Evidence From Northern California," *Transportation Research Part D: Transport and Environment* 10, no. 6 (2005): 427–44; Xinyu Jason Cao, "Exploring Causal Effects of Neighborhood Type on Walking Behavior Using Stratification on the Propensity Score," *Environment and Planning A* 42, no. 2 (2010): 487–504.

[21] John Hopkins Centre for a Livable Future, *Teaching the Food System*, *Jhsph.Edu*, (Baltimore, MD: John Hopkins Bloomberg School of Public Health, 2010), 4; Brewster Kneen, "Industrial Food," in *From Land to Mouth: Understanding the Food System*, (Toronto: NC Press Limited, 1995), 48-49.

the amount of food calories available for consumption, per capita, per day, in the United States food supply increased by approximately 30%.[22] Along with the marked increase in food supply during this period came a plethora of convenient, energy-dense prepared foods, effective and pervasive food industry advertising, and a reduction in the time-cost of food preparation and consumption.[23]

There is a substantial literature that has examined the impacts of these systemic and environmental drivers on diet, energy intake, and obesity. One branch of this research has considered the role that environmental factors, such as physical access to or availability of healthy and less healthy food sources, may play in promoting or discouraging a healthy diet.[24] Common measures include assessment of food store density or proximity using Geographic Information Systems ("GIS"), store audits that estimate the per cent of shelf-space certain foods occupy in food stores, and survey methods that assess participants' perceived access to food stores and other food sources. The first systematic review of this literature identified consistent significant associations between measures of *perceived* food availability and dietary outcomes, as well as significant associations between GIS measures of food availability and dietary outcomes in a majority of studies.[25] However a more recent review of reviews suggested that, despite a trend toward identifying statistically significant relationships, the majority of studies

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[22] USDA Centre for Nutrition Policy and Promotion, "Nutrient Content of the U.S. Food Supply, 1909-2010," (Washington, D.C.: United States Department of Agriculture, 2010), accessed April 1, 2015, http://www.cnpp.usda.gov/USFoodSupply-1909-2010.

[23] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 807; David M Cutler, Edward L Glaeser, and Jesse M Shapiro, "Why Have Americans Become More Obese?," *Journal of Economic Perspectives* 17, no. 3 (September 2003): 93–118, doi:10.1257/089533003769204371; Anthony Winson, "Bringing Political Economy Into the Debate on the Obesity Epidemic," *Agriculture and Human Values* 21 (2004): 301.

[24] Caitlin E Caspi, Glorian Sorensen, S V Subramanian, and Ichiro Kawachi, "The Local Food Environment and Diet: a Systematic Review," *Health and Place* 18, no. 5 (2012): 1172, doi:10.1016/j.healthplace.2012.05.006.

[25] ibid., 1175.

that have examined food store density or proximity did not find significant associations with dietary outcomes.[26] It is nonetheless possible that these or other environmental factors may influence dietary outcomes, particularly among low income or ethnic minority communities that research indicates have poorer access to stores selling healthier foods and better access to stores selling less healthy foods, compared with more affluent communities.[27]

A final factor leading to the recent interest in built environment research is the global obesity pandemic. Obesity rates in high-income countries first began to rise in the 1970s and 1980s, followed similarly by most middle-income and many lower-income countries.[28] Worldwide prevalence of obesity has more than doubled since 1980. In 2008, 1.5 billion adults worldwide were overweight and of these 500 million—representing 11% of the world's adult population—were obese.[29] Both overweight and obesity are measures of weight status. They are defined as "abnormal or excessive fat accumulation that may impair health," and are leading risks for development of chronic diseases such as diabetes and ischaemic heart disease, as well as morbidity.[30]

Overweight and obesity are fundamentally the result of an imbalance in individuals' energy intake (calories consumed) and energy expenditure (calories expended).[31] While genetic

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[26] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?," 235-236.
[27] ibid., 231-232.
[28] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 805.
[29] World Health Organization, "Obesity and Overweight," (2014), accessed April 1, 2015, http://www.who.int/mediacentre/factsheets/fs311/en/.
[30] ibid.
[31] ibid.; W P T James, "The Epidemiology of Obesity: the Size of the Problem," *Journal of Internal Medicine* 263, no. 4 (2008): 336–52; Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments."

factors are generally considered an underlying cause of obesity,[32] the rapid rise in prevalence over recent decades has also prompted researchers to consider social and environmental factors.[33] This line of research suggests that key determinants and moderators of obesity may lie in "obesogenic" environmental factors linked to excess caloric intake and decreased physical activity.[34] Various ecological frameworks have been proposed in an effort to theorize the relationships between systemic, environmental, and individual drivers and moderators of obesity. For example, Swinburn et al.[35] suggest that the food environment may act as a driver promoting high energy intake while the transport, recreation, socioeconomic, and sociocultural environments may act as environmental moderators that amplify or attenuate both energy intake and physical activity. Studies have rarely been able to capture or evaluate all of the complex interactions in such models, however a number of studies have examined potential built environment characteristics that may influence obesity through their links to physical activity behaviours and dietary intake.[36] One aim of this research paper is to review and summarize this branch of the built environment-obesity literature in an effort to identify built environment characteristics consistently associated with overweight and obesity, and methodological issues for consideration in future research.

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[32] Anthony G Comuzzie and David B Allison, "The Search for Human Obesity Genes," *Science* 280 (May 29, 1998): 1374–77; I S Farooqi and S O Rahilly, "Genetic Factors in Human Obesity," *Obesity Reviews* 8, no. 1 (2007): 37–40.

[33] Joreintje D Mackenbach, Harry Rutter, Sofie Compernolle, Ketevan Glonti, Jean-Michel Oppert, Helene Charreire, Ilse de Bourdeaudhuij, Johannes Brug, Giel Nijpels, and Jeroen Lakerveld, "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and Adult Weight Status, the SPOTLIGHT Project," *BMC Public Health* 14, no. 1 (2014): 233.

[34] ibid.; Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments;" James, "The Epidemiology of Obesity: the Size of the Problem."

[35] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 808.

[36] Mackenbach et al., "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and Adult Weight Status, the SPOTLIGHT Project."

Systemic drivers of obesity are another important component of Swinburn et al.'s obesity framework. These drivers are the policy and economic systems that both enable and promote excess energy intake.[37] Many of the changes witnessed in the North American built environment since World War II are the direct or indirect result of legal, policy, and economic systems that promote or discourage certain types of development and land use.[38] Shifts in North American food systems during the same period were similarly influenced through legal, policy, and economic mechanisms that promoted increased productivity, specialization, and commodification.[39] Thus interventions aimed at reducing or reversing environmental drivers and moderators of obesity are typically based in law or policy.[40] Examples include: municipal efforts to incorporate a healthy development index as part of the development review process in the Region of Peel, an upper-tier municipality in the Greater Toronto Area;[41] enactment of childhood obesity prevention legislation in several states throughout the U.S.;[42] and, more broadly, the use

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[37] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 808.

[38] William W Buzbee, "Urban Form, Health, and the Law's Limits," *American Journal of Public Health* 93, no. 9 (September 1, 2003): 1395; Wendy Collins Perdue, Lesley A. Stone, and Lawrence O. Gostin, "The Built Environment and Its Relationship to the Public's Health: the Legal Framework," *American Journal of Public Health* 93, no. 9 (September 2003): 1390–94.

[39] See Harriet Friedmann and Philip McMichael, "Agriculture and the State System," *Sociologia Ruralis* 29, no. 2 (1989): 105-110.

[40] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 810.

[41] James Dunn et al., *Final Report - Peel Healthy Development Index*, (Brampton, ON: Peel Public Health, July 8, 2010), accessed April 1, 2015, http://www.peelregion.ca/health/resources/healthbydesign/pdf/HDI-report.pdf; Jonathan T Weyman et al., "Planning Health-Promoting Development: Creation and Assessment of an Evidence-Based Index in the Region of Peel, Canada," *Environment and Planning B: Planning and Design* 40, no. 4 (2013): 707–22.

[42] Elizabeth A Dodson et al., "Preventing Childhood Obesity Through State Policy: Qualitative Assessment of Enablers and Barriers," *Journal of Public Health Policy* 30 (2009): S161–76.

of health impact assessments to evaluate the potential health consequences (positive and negative) of decision-makers actions.[43]

It is perhaps not surprising that such legal and policy interventions have received relatively minimal research attention in comparison with research focused on identifying relationships between built environment characteristics, physical activity behaviours, diet, and obesity. After all, a sufficient evidence base is arguably required upon which to base legal and policy interventions. Researchers have suggested, however, that sufficient evidence does exist to support policy-based interventions,[44] which could provide further opportunity for study of pre- and post-intervention outcomes—the type of research needed to better demonstrate causality. Thus, in addition to reviewing the evidence for characteristics of the built environment associated with physical activity, dietary intake, and obesity and examining these characteristics in the City of Toronto, Canada, this study also aims to identify policy-based interventions that may reduce or reverse environmental drivers or moderators of these outcomes in the same setting.

1.2 Research Questions and Scope

The brief outline of built environment research presented above demonstrates the considerable breadth of interests and perspectives in this field. This paper is focused on a more narrow sub-set of the field, sitting at the intersection of planning and health. The aim of this

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[43] Wilhelmine D Miller, Craig E Pollack, and David R Williams, "Healthy Homes and Communities - Putting the Pieces Together," *American Journal of Preventive Medicine* 40, no. 1 (January 2011): S48–S57; Mary E Northridge and Elliott Sclar, "A Joint Urban Planning and Public Health Framework: Contributions to Health Impact Assessment," *American Journal of Public Health* 93, no. 1 (January 1, 2003): 118; N Krieger, "Assessing Health Impact Assessment: Multidisciplinary and International Perspectives," *Journal of Epidemiology and Community Health* 57, no. 9 (September 1, 2003).

[44] Brian E Saelens and Susan L Handy, "Built Environment Correlates of Walking: a Review," *Medicine and Science in Sports and Exercise* 40, no. 7 (July 2008): S550–66.

research is to identify components of "healthy, active communities" and examine the presence of these components in various communities throughout the City of Toronto, Ontario, Canada. Our goal is to determine which components of the built environment are most strongly associated with positive health behaviours and health outcomes, and determine whether and to what extent these components exist in Toronto communities.

Kent and Thompson propose three domains through which urban planning and the built environment support health: physical activity, healthy eating, and community interaction.[45] This paper is focused on the first two, as the literature on community interaction and its associated mental and social health benefits is sufficiently broad to render it a distinct field. Thus, for the purposes of this paper, "healthy, active communities" are defined as communities in which the built environment promotes healthy, active living through active transportation, recreational physical activity, and equitable access to healthy food. This paper also considers the built environment's role in promoting or discouraging a healthy weight status among community residents through environmental drivers that influence physical activity and diet. The terms "healthy, active communities" and "healthy built environment" are used interchangeably throughout.

The research consists primarily of a literature review and GIS analyses. The literature review is focused on identifying quantifiable components of the built environment that have been significantly associated with outcomes that measure active transportation, physical activity, access to or consumption of healthy or unhealthy foods, and weight status. This entails review of built environment studies in two general fields, the "physical activity environment" and the "food environment." The aim is to produce a comprehensive list of quantifiable built

[45] J L Kent and S Thompson, "The Three Domains of Urban Planning for Health and Well-Being," *Journal of Planning Literature* 29, no. 3 (June 29, 2014): 240.

environment factors that together represent the components of a healthy, active community. GIS analyses are then utilized to generate and map, for communities across Toronto, all built environment factors identified in the literature review for which suitable data are available. Results are depicted on maps to examine the presence and extent of healthy, active communities in Toronto and allow for comparison of results to the health-promoting built environment factors identified in the literature review.

This paper also considers the extent to which the legal and policy framework governing land use planning and public health in the City of Toronto enables or discourages development of healthy, active communities. Consideration of this framework is a critical (and occasionally overlooked) aspect of built environment research because national, provincial (or state), and municipal laws and policies heavily influence development patterns in Toronto and other North American cities. In Ontario, land use planning is primarily a matter of provincial jurisdiction[46] and is heavily regulated through provincial legislation and policies and municipal bylaws and plans. This paper provides an overview of the relevant frameworks in the City of Toronto. The discussion section also considers potential legal and policy reforms aimed at encouraging development of healthier built environments, fostering greater collaboration between planning and public health professionals, and incorporating substantive health goals into planning policies.

The rationale for this research is threefold. Firstly, the results will provide a comprehensive assessment of healthy built environment components in communities across Toronto that indicates whether the current state of the built environment across the city fosters healthy, active living. The majority of research to date in this field has focused on cities or

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[46] *Constitution Act, 1867* (UK), 30 & 31 Vict, C 3, ss 92(8), 92(13), 92(16), Reprinted in RSC 1985, App II, No 5.

regions in the United States, and relatively little research has been conducted in Canada.[47]) Additionally, few researchers have examined built environment components related to multiple built environment domains (i.e., the food environment and the physical activity environment) in Toronto.

Secondly, this paper aims to bridge the gap between existing research from the health and planning fields. Health researchers' in the field generally have a strong understanding of the ways in which the built environment may influence various health outcomes, while planning researchers generally have a strong understanding of built environment influences on transportation patterns and travel behaviours. Professionals in both fields may share the theoretical and practical experiences of implementing this research within the confines of legal and policy frameworks that govern land use planning decisions, though health professionals may be less familiar with the legal context. This research reviews and integrates the theoretical models and strength of the evidence from both fields, summarizing known influences of the built environment on transportation and recreation physical activity, diet, and weight status from both fields. Additionally, through identifying legal and policy reforms that may foster greater collaboration and integration between planning and health professionals, this research may help rekindle the historical relationship between the fields.

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[47] But see Glazier et al., "Density, Destinations or Both? a Comparison of Measures of Walkability in Relation to Transportation Behaviors, Obesity and Diabetes in Toronto, Canada;" Lisa Oliver et al., "Assessing the Influence of the Built Environment on Physical Activity for Utility and Recreation in Suburban Metro Vancouver," *BMC Public Health* 11, no. 1 (2011): 959; Meghan Winters et al., "Built Environment Influences on Healthy Transportation Choices: Bicycling Versus Driving," *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 87, no. 6 (December 2010): 969–93; Gillian L Booth et al., "Neighbourhood Infrastructure and Health," in *Neighbourhood Environments and Resources for Healthy Living — a Focus on Diabetes in Toronto*, ed. Richard H Glazier et al., (Toronto: Institute for Clinical Evaluative Sciences, 2007), 119–50, accessed April 1, 2015, http://www.ices.on.ca/.

Finally, it is expected that the combination of increasingly sedentary lifestyles and an aging Canadian population will place a growing burden on Canada's health-care system in coming years. Planning for communities that promote, rather than discourage, opportunities for healthy living is an increasingly important aspect of health promotion that, while not inexpensive, may prove less costly than treating the implications of inactive lifestyles in years to come.

This paper proceeds as follows. The remainder of section one provides additional introductory and background information regarding economic and societal trends that have influenced built environment research. In light of the rise in research from multiple disciplines on active transportation, physical activity, food, diet, and weight status highlighted above, the rest of this section discusses the potential for built environment research to revitalize the historic relationship between planning and health. A brief history of the interaction between the two professions is presented below. A contextual overview of the legal and policy framework governing land use planning and public health in Toronto is also provided.

Section two turns to the literature review. This section sets out the aims and parameters of the review in greater detail. Models of built environment-health relationships, modes of measurement, and units of analysis are discussed. Results of the literature review are presented in four categories: components of the transportation physical activity environment; components of the recreation physical activity environment; components of the food environment related to dietary intake; and components of the physical activity and food environments related to weight status.

Section three of this paper describes the GIS methodology used to map the components of healthy, active communities in the City of Toronto. The analytical methodologies for

calculation of the various built environment components as well as data and software requirements are discussed.

Section four contains the results of the GIS analyses. Maps depicting the presence of and patterns in quantifiable components of healthy, active communities are presented and compared with the health-promoting built environment components identified in the literature review.

Section five discusses these results and presents potential options for legal and policy reform aimed at encouraging development of healthy built environments, furthering collaboration between planning and public health professionals, and incorporating substantive health goals into planning policies. The discussion also presents any limitations of this research and highlights areas for future research.

1.3 Revitalizing the Historic Relationship Between Planning and Health

Urban planning and public health both trace their origins to Progressive reform efforts to combat the harmful effects of rapid industrialization and urbanization during the late nineteenth century.[48] Reformers viewed poor sanitation systems, slum housing, pollution, and dangerous working conditions as sources of sickness and transmittable diseases such as cholera and typhoid.[49] Planning and public health departments regularly collaborated on efforts to reduce the spread of infectious disease during this time, and became increasingly involved in the development of provincial and national regulatory structures to improve housing and sanitation

[48] M Greenberg et al., "Linking City Planning and Public Health in the United States," *Journal of Planning Literature* 8, no. 3 (February 1, 1994): 235; Corburn, "Confronting the Challenges in Reconnecting Urban Planning and Public Health," 541.

[49] Gerald Hodge and David L.A. Gordon, *Planning Canadian Communities: an Introduction to the Principles, Practice, and Participants*, 5 ed., (Toronto, ON: Nelson Education, 2008), 89; Corburn, "Confronting the Challenges in Reconnecting Urban Planning and Public Health," 541.

conditions in growing cities.[50] Many of the these urban policies viewed public health and urban planning issues as "nearly identical."[51]

Health, safety, and welfare concerns associated with urbanization and land use also informed legislative and case law developments in the late nineteenth and early twentieth centuries. In Ontario, prior to the year 1904, provincial legislation provided municipalities with only minimal powers to regulate urban development.[52] The 1897 *Municipal Act*[53] provided municipalities with a limited authority to regulate the way in which buildings were constructed[54] and the power to define areas in which specified public nuisances such as tanneries and slaughterhouses could not carry on their activities.[55]. The other form of municipal authority to regulate land use at the time was found in the 1897 *Public Health Act*, which provided for municipal regulation, restriction, and inspection of industries that had a potential for public health nuisance.[56]. Under section 72 of the Act, municipalities could also prohibit any "noxious or offensive trade, business, manufacture, or such as may become offensive."[57] Municipal services such as water, sewage, fire, and police, and bylaws that regulated public health matters in the City of Toronto at this time were similarly focused on mitigating health and safety concerns associated with urban development.[58]

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[50] Hodge and Gordon, *Planning Canadian Communities: an Introduction to the Principles, Practice, and Participants*, 89.
[51] Greenberg et al., "Linking City Planning and Public Health in the United States," 236.
[52] David J. Hulchanski, *The Evolution of Ontario's Early Urban Land Use Planning Regulations, 1900-1920*, *Canadian-American Comparative Urban History Conference, University of Guelph*, (Toronto, ON: Centre for Urban and Community Studies, University of Toronto, 1983), 3-4.
[53] *Municipal Act*, RSO 1897.
[54] ibid., s553(1).
[55] ibid., ss 586(3), 586(5).
[56] *Public Health Act*, RSO 1897, s 65.
[57] ibid.
[58] Hulchanski, *The Evolution of Ontario's Early Urban Land Use Planning Regulations, 1900-1920*, 4.

In the United States, prior to enactment of more formal enabling legislation, some municipalities nonetheless adopted early forms of zoning bylaws. One such bylaw was challenged in the case of *Village of Euclid v. Ambler Realty Co*.[59] The U.S. Supreme Court's landmark decision in this case recognized that a municipality's adoption of a zoning bylaw that restricted the use of private land was a valid exercise of the municipality's constitutional authority. The bylaw at issue restricted the plaintiff's use of private land within the Village of Euclid, Ohio, effectively preventing development of the land for industrial purposes. The court reasoned that the bylaw's purpose was to mitigate public health, safety, and general welfare concerns associated with rapid expansion of industrial development into the municipality, and the bylaw was thus a valid exercise of the municipality's police powers notwithstanding its impact on the plaintiff's use of private land.[60]

Development of standard state planning and zoning enabling legislation was also underway in the United States during the 1920s. The motivation for such legislation was to provide a stronger legal foundation for the rapid municipal adoption of zoning bylaws that targeted urban issues such as industrial pollution, sanitation, and poor living conditions.[61] Between 1921 and 1928, the U.S. Department of Commerce's advisory committee on zoning drafted and published two standard zoning enabling acts, *A Standard State Zoning Enabling Act*

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[59] *Village of Euclid v Ambler Realty Co*, 272 US 365 (1926).
[60] ibid., 395.
[61] Stuart Meck, "Model Planning and Zoning Enabling Legislation: a Short History," in *Modernizing State Planning Statutes: the Growing Smart Working Papers,* Volume 1, ed. American Planning Association, (Chicago: American Planning Association, Planning Advisory Service Report Number 462/463, 1996), 1-2; United States Department of Commerce Advisory Committee on Zoning, *A Standard State Zoning Enabling Act*, Revised edition, (Washington, D.C.: U.S. Government Printing Office, 1926), accessed April 1, https://www.planning.org/growingsmart/pdf/SZEnablingAct1926.pdf.

("*SZEA*") and *A Standard City Planning Enabling Act* ("*SCPEA*").[62] *SZEA* was eventually adopted by 50 states, and as of 1996 it remained in effect, in modified form, in 47 states.[63] It is notable that section 1 of the *SZEA* granted municipalities the power to enact zoning ordinances "[f]or the purpose of promoting health, safety, morals, or the general welfare of the community."[64] This indicates the drafters' recognition of health promotion as one of the substantive purposes underlying enactment of zoning legislation.[65]

In Ontario, the Provincial Legislature did not confer on municipalities the general authority to enact comprehensive zoning bylaws until the mid-1940s.[66] Before this, municipalities that sought to regulate the location of various land uses resorted to petitioning the Provincial Legislature with requests for amendments to the *Municipal Act* that provided specific authority to enact targeted zoning bylaws.[67] For example, in the early 1900s residents of Toronto's Moss Park neighbourhood were opposed to the location of a factory within their neighbourhood and discovered the City did not have authority to pass a bylaw restricting this use of private land. The City petitioned the Provincial Legislature requesting an amendment to the *Municipal Act* that would allow municipalities to "enact a Bylaw regulating the location of

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[62] ibid.; United States Department of Commerce Advisory Committee on Zoning, *A Standard City Planning Enabling Act*, (Washington, D.C.: U.S. Government Printing Office, 1928), accessed April 1, 2015, https://www.planning.org/growingsmart/pdf/CPEnabling%20Act1928.pdf.

[63] Meck, "Model Planning and Zoning Enabling Legislation: a Short History," 3.

[64] United States Department of Commerce Advisory Committee on Zoning, *A Standard State Zoning Enabling Act*.

[65] These purposes were also likely included because they are consistent with recognized State jurisdiction under the Police power. See *Lochner v New York*, 198 US 45 (1904). Compare also Meck, "Model Planning and Zoning Enabling Legislation: a Short History." Meck notes that planning scholars have critiqued the *SZEA* for its overt focus on setting out the process for enactment of zoning ordinances rather than the substantive planning policies that should inform such ordinances.

[66] Hulchanski, *The Evolution of Ontario's Early Urban Land Use Planning Regulations, 1900-1920*, 11.

[67] *Municipal Act*; Hulchanski, *The Evolution of Ontario's Early Urban Land Use Planning Regulations, 1900-1920*, 9-10.

factories and generally the location of industries and business enterprises of every kind… ."[68] Eleven days after the requested amendment was enacted, Toronto City Council passed a bylaw restricting non-residential uses in the affected area of Moss Park.[69] Regulation of land use in the City of Toronto evolved in this piecemeal fashion until the City passed its first comprehensive zoning bylaw in 1954.[70]

As time progressed, much of the close collaboration between planning and public health that characterized the late 19th and early 20th century Progressive reform efforts described above was lost in the post-world war II period.[71] Corburn explains that throughout the first half of the 20th century public health researchers shifted their focus toward germ theory, the notion that "there are specific agents of infectious disease, in particular microbes, and these agents relate in a one-to-one manner to specific diseases."[72] Physicians became the new public health professionals as laboratory research targeted specific microbes and immunization plans. Meanwhile, the post-word war II economic boom in North America witnessed a change in the role of planners as well. Previously concerned with regulating the harmful activities of unrestrained industrial economic development, planning became concerned with promoting suburban economic development through large infrastructure and transportation projects.[73] As a result of these ideological and economic shifts, most planning and public health professionals in

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[68] ibid., 10.
[69] ibid.
[70] ibid., 10; Peter W Moore, "Zoning and Neighbourhood Change: the Annex in Toronto, 1900–1970," *Canadian Geographer*, 1982, 25-2.
[71] Mary E Northridge, Elliott D Sclar, and Padmini Biswas, "Sorting Out the Connections Between the Built Environment and Health: a Conceptual Framework for Navigating Pathways and Planning Healthy Cities," *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 80, no. 4 (December 2003): 557.
[72] Corburn, "Confronting the Challenges in Reconnecting Urban Planning and Public Health," 542.
[73] ibid.

the late 20th century were largely disconnected from the common health and social welfare orientations that typified these professions' formative years.

Over the last twenty years, however, there has been a gradual re-convergence of interests as groups on both sides recognized some of the problems associated with sprawling suburban development patterns.[74] Increases in obesity rates and lower levels of physical activity initially prompted public health professionals to consider the role of built environment and socioeconomic characteristics in influencing health behaviours and health outcomes. In light of increased congestion, auto-reliance, and decreased quality of life, planners examined alternative land use and development patterns that could foster more compact, mixed-use growth. A considerable body of literature authored from a variety of fields and perspectives has developed as a result. Public health has examined the links between various aspects of the built environment and physical activity, weight status, healthy eating, and diabetes and the role of potential socioeconomic and ethnic moderators in these relationships. Planners have examined the concepts of "walkability" and "bikability," asking whether residents of compact, mixed-use, pedestrian- and bicycle-oriented communities are more likely to walk or bike for transportation purposes than residents of suburban communities.

These are vast generalizations, and there are studies in both fields authored by members of both professions. Yet Silver notes that increased collaboration in public health and planning research has not translated fully into the professional realm.[75] It is still relatively uncommon for planning departments to collaborate or consult with public health during development of city plans, and many plans do not contain public health goals. An American Planning Association

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[74] Mitchell Silver, "Planners and Public Health Professionals Need to Partner...Again," *North Carolina Medical Journal* 73, no. 4 (July 2012): 292-295.
[75] ibid., 292.

survey conducted in 2011 found that only 31% of comprehensive plans in American cities contained explicit goals, objectives or policies that addressed public health.[76] Similar data is unavailable for Ontario, though the Ontario Professional Planners Institute ("OPPI") has published several policy papers and "calls to action" encouraging planners and other stakeholders to plan for healthy and sustainable communities in the province.[77] The OPPI recognizes that planning for healthy living and active transportation is not the sole domain of planners and mentions the need for collaboration with a multi-disciplinary team including public health professionals.[78] Efforts such as the Region of Peel's Healthy Development Index and Healthy Canada by Design Coalitions Linking Action and Science for Prevention are strong steps toward greater collaboration and are discussed further in section five of this paper. Opportunities for greater integration of planning and public health through legal and policy mechanisms such as Health Impact Assessments and the provision of substantive public health goals in Toronto's planning policies are also considered in section five. Notwithstanding substantial efforts to date, there remains considerable room for increased collaboration between planning and public health given their shared background and common interests in the health, transportation, and economic issues facing modern society.

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[76] American Planning Association, *Comprehensive Planning for Public Health*, *U.S. Government Printing Office*, (American Planning Association, March 2011), accessed April 1, 2015 https://www.planning.org/research/publichealth/pdf/surveyreport.pdf.

[77] See Ontario Professional Planners Institute, *Healthy Communities and Planning for Active Transportation* (Ontario Professional Planners Institute, June 21, 2012), accessed April 1, 2015, http://ontarioplanners.ca/PDF/Healthy-Communities/2012/Planning-and-Implementing-Active-Transportation-in.aspx.

[78] ibid., 3.

1.4 The Legal and Policy Framework Governing Land Use Planning and Public Health in Toronto and Ontario

1.4.1 Land Use Planning and the *Planning Act*

In Ontario, land use planning is primarily a matter of provincial jurisdiction pursuant to sections 92(8), 92(13), and 92(16) of the *Constitution Act, 1867*.[79] These sections provide Provincial Legislatures with exclusive jurisdiction to make laws in relation to: municipal institutions in the Province; property and civil rights in the Province; and matters of a merely local or private nature in the Province, respectively. Municipalities do not have constitutional status in Canada but are instead "creatures of provincial statutes."[80] A municipality only has the powers and authority conferred upon it by the province or territory in which it is located.[81] Thus, while municipalities play a critical role in land use planning, the system of land use planning in the Province of Ontario is a hierarchical provincial policy-led one.

The core statute that governs land use planning in Ontario is the *Planning Act*.[82] Two of the key purposes of this Act are to "provide for a land use planning system led by provincial policy" and to "integrate matters of provincial interest in provincial and municipal planning decisions."[83] The *Planning Act* sets out examples of matters of provincial interest and provides the Minister of Municipal Affairs and Housing (the "Minister of MAH") with the authority to issue provincial policy statements on matters of land use planning that, in the opinion of the Minister, are of provincial interest.[84] The *Provincial Policy Statement* ("*PPS*") issued pursuant to section 3(1) of the *Planning Act* creates the provincial policy framework that is the basis for all

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[79] *Constitution Act, 1867* (UK).
[80] *R v Greenbaum*, [1993] 1 SCR 674, 14 MPLR (2d) 1 at para 22.
[81] John Mascarin and Christopher J Williams, *Ontario Municipal Act & Commentary*, 2013 ed., (Markham, ON: LexisNexis Canada, 2012), 3.
[82] *Planning Act*, RSO 1990, c P.13.
[83] ibid., ss 1.1(b), 1.1(c).
[84] ibid., ss 2, 3(1).

planning decision-making in Ontario.[85] All planning decisions made under the *Planning Act*, including those made by municipal councils, must be consistent with the policies set out in the *PPS*.[86] These policies are focused primarily on land use management, infrastructure development, natural resource management, and protecting the public's health and safety from natural and human-made environmental hazards.

Section 3(5)(b) of the *Planning Act* also requires that all planning decisisions made under the Act conform with (or not conflict with, as the case may be) provincial plans. The Province of Ontario has established a number of plans that fall within the definition of "provincial plan" under section 1(1) of the *Planning Act*, including the *Greenbelt Plan* and the *Growth Plan for the Greater Golden Horseshoe* ("*GPGGH*").[87] Provincial plans are enacted pursuant to plan-specific enabling legislation and set out policies regarding environmental protection, growth management, infrastructure development, resource management, and economic development in specific geographic areas of the province. Because of section 3(5)(b) of the *Planning Act*, these provincial plans provide another mechanism for provincial policy oversight of municipal planning decisions.

The *Planning Act* provides a variety of powers to municipalities in relation to land use planning decisions, subject to the *PPS* and provincial plan conformance standards described above. Two of the key municipal powers are in relation to the adoption and approval of municipal official plans and the authority to enact zoning bylaws.

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[85] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement*, (Queen's Printer for Ontario, 2014).

[86] *Planning Act*, s 3(5)(a).

[87] ibid; Ministry of Municipal Affairs and Housing, *Greenbelt Plan*, (Toronto, ON: Queen's Printer for Ontario, February 28, 2005); Ministry of Infrastructure, *Growth Plan for the Greater Golden Horseshoe, 2006*, (Toronto, ON: Queen's Printer for Ontario, 2013).

An official plan is a municipality's overarching planning policy document. The *Planning Act* specifies that an official plan shall contain "goals, objectives and policies established primarily to manage and direct physical change and the effects on the social, economic and natural environment of the municipality or part of it."[88] An official plan may also contain measures and procedures proposed to attain the plan's objectives. This is a relatively broad grant of powers that the Ontario Court of Appeal has stated should be given a broad and generous interpretation absent express statutory language to the contrary.[89] Official plans typically contain policies regarding growth management, land use designations, urban form, transportation, and community services. In Ontario, only a list of prescribed municipalities are required to prepare and adopt an official plan, though many municipalities in southern Ontario, including the City of Toronto, are listed in the relevant regulation.[90]

When a municipality adopts an official plan in accordance with its authority under the *Planning Act*, the official plan must be consistent with policies in the *PPS* and conform with (or not conflict with, as the case may be) applicable provincial plans.[91] The Minister of MAH is also the approval authority for official plans adopted by upper- and single-tier municipalities, unless otherwise provided under the *Planning Act*.[92] An upper-tier municipality is the approval authority for official plans adopted by lower-tier municipalities, and a lower-tier municipality's official plan must conform with the applicable upper-tier municipality's official plan.[93] There are various provisions under the *Planning Act* that allow the minister to remove an upper-tier

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[88] *Planning Act*, s 16(1)(a).
[89] *Croplife Canada v Toronto (City)*, (2005), 75 OR (3d) 357, 10 MPLR (4th) 1 (application for leave to appeal to the SCC dismissed).
[90] *Planning Act*, s 17(13); *Mandatory Adoption of Official Plans*, O Reg 352/02.
[91] *Planning Act*, s 3(5).
[92] ibid., s 17(1).
[93] ibid., ss 17(2), 27(1).

municipality's approval authority.[94] The Minister may also exempt an official plan from the approval requirement altogether.[95] Subject to this exemption, a municipal council's adoption of an official plan is not final and the plan does not come into effect until it receives approval from the approval authority.[96] These statutory requirements are aimed at ensuring that the high-level planning policies put in place by the Province are reflected in municipal official plans across the province.

Zoning bylaws are the technical mechanism for implementation of a municipality's official plan. Their purpose is twofold. First, zoning bylaws classify and segregate lands within a municipality into districts or zones according to the uses of lands and buildings permitted and prohibited in the bylaw. Secondly, zoning bylaws regulate "the permitted uses in varying degrees depending upon attendant circumstances."[97] Zoning bylaws often specify minimum and maximum lots sizes, parking requirements, and building heights and setbacks.

Under the *Planning Act*, only a lower-tier or single-tire municipality can adopt a zoning bylaw.[98] Regardless of whether the municipal structure is single- or dual-tier, however, a zoning by-law must conform with all applicable official plans. For example, where a zoning bylaw is passed by a lower-tier municipality it must conform with both the lower-tier and the upper-tier municipality's official plans.[99] Where a single-tier municipality enacts a zoning bylaw, the bylaw must conform with the municipality's official plan.[100] These conformance requirements ensure that the provincial policies embodied in each municipality's official plan are given full effect

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[94] ibid., ss 17(6), 17(7).
[95] ibid., s 17(9), 17(10).
[96] ibid., s 17(38).
[97] J B Milner, "An Introduction to Zoning Enabling Legislation," *The Canadian Bar Review* 60 (March 1962): 2.
[98] *Planning Act*, s 34(1).
[99] ibid., s 24(1).
[100] ibid., s 26(9).

through the lower-level technical bylaws that implement them. The validity of a zoning bylaw that does not meet these conformance requirements may be challenged in court on the grounds that its enactment was *ultra vires* the powers of the municipality. Alternately, a municipality's enactment (or failure to enact) a zoning bylaw, or the provisions of a zoning bylaw itself, may be appealed to the Ontario Municipal Board ("OMB") on land use planning grounds. [101]

Moving down the hierarchy of land use planning tools, the *Planning Act* provides increasingly focused mechanisms such as plans of subdivision, severances, and site plan control. Plans of subdivision and severances are both mechanisms for controlling the division or fragmentation of land. Subsection 50(3)(a) of the *Planning Act* places a general prohibition on the sale or conveyance of land unless the land is "described in accordance with and is within a registered plan of subdivision." The purpose of these subdivision controls is to prevent the unrestricted subdivision of land through any form of of conveyance.[102]

The *Planning Act* creates a procedural mechanism through which an owner of land that is not already part of a registered plan of subdivision can apply to the municipality for approval of a draft plan of subdivision.[103] The Act sets out the required contents of a submitted draft plan of subdivision and the criteria and matters against which the draft plan of subdivision will be evaluated.[104] These criteria include the effects of the draft plan of subdivision on matters of provincial interest and conformity of the draft plan with the municipality's official plan. In approving a draft or final plan of subdivision the approval authority (the lower-, upper- or single-tier municipality or the Minister as specified, prescribed, or delegated in accordance with the

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[101] ibid., ss 34(11), 34(19).
[102] *Re Forfar and Township of East Gwillimbury et al*, [1971] 3 OR 337; 20 DLR (3d) 377.
[103] *Planning Act*, s 51(16).
[104] ibid., s 51(24).

Act) may impose conditions of subdivision approval.[105] These include requiring the owner to enter into a subdivision agreement dealing with matters the approval authority considers necessary, including the provision of municipal or other services. A subdivision agreement shall be registered on title and bind future owners of the land, thus ensuring that the conditions of the agreement are enforceable against future owners of the land.[106]

Severances are generally used for the minor division of a parcel of land into a small number of lots. The process is very similar to that of applying for a plan of subdivision, except that a severance may be granted for lands already within a registered plan of subdivision. An application for a provisional consent to sever is determined in accordance with the same criteria as an application for a draft plan of subdivision.[107] The approval authority may grant an application for a consent to sever if it is "satisfied that a plan of subdivision of the land is not necessary for the proper and orderly development of the municipality."[108]

Moving down the hierarchy of planning tools, the purpose of site plan control is "to ensure that detailed site specific matters with respect to the development of a particular parcel of land and its impact on and relationship to the surrounding existing or proposed land uses are addressed."[109] Only local (i.e. not upper-tier) municipalities may exercise site plan control powers.[110] Additionally, the use of site plan control is not required under the *Planning Act*. In order to utilize site plan control a municipality must enact a by-law establishing one or more site

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[105] ibid., s 51(25).
[106] ibid., s 51(26).
[107] ibid., s 53(12).
[108] ibid., s 53(1).
[109] John Mascarin, "Five Things You Should Know About Site Plan Agreements," in Law Society of Upper Canada, "Six Minute Real Estate Lawyer," Professional Development Materials (November 18, 2014): 505-516, 505 (citing *120562 Ontario Inc v Richmond Hill (Town) (1998)*, 36 OMBR 215 (OMB)).
[110] *Planning Act*, ss 41(2), 41(8).

plan controls areas within the municipality, and the municipality's official plan must contain provisions describing a proposed site plan area.[111]

The *Planning Act* sets out a prohibition on development or redevelopment (as defined in subsection 41(1) of the Act) within a site plan control area unless the council of the municipality (or the delegated person or committee), or the OMB on appeal, has approved the site plans or drawings in respect of the development or redevelopment.[112] The Act sets out criteria regarding the mandatory contents of submitted site plans, including the massing, design, and location of all proposed building, structures, facilities, and works proposed to be erected or provided.[113] Council may also exempt certain classes of development from site plan control requirements, and may impose conditions for site plan control approval.[114] Such conditions may include requiring the owner of the subject lands to enter into or more site plan agreements that may be registered on title and enforced against the current owner and all future owners of the land. As opposed to the conditions that may be imposed at the plan of subdivision stage, however, the conditions that may be imposed on approval of a site plan are limited to those enumerated in the Act.[115]

The *Planning Act* also provides authority to municipalities to adopt a Development Permit System ("DPS") that would act as an alternative to the current zoning bylaw and site plan approval system.[116] The Regulation that established the DPS and permitted all local municipalities to enact a bylaw adopting the DPS came into effect on January 1, 2007. The City of Toronto is one of the few municipalities that is currently exploring the use and adoption of this alternative mechanism for implementation of the city's official plan. The DPS would

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[111] ibid., ss 41(2), 41(3).
[112] ibid., s 41(1).
[113] ibid., s 41(4).
[114] ibid., ss 41(13)(a), 41(7), 41(8).
[115] ibid., ss 41(13)(a), 41(7), 41(8).
[116] ibid., s 70.2.

essentially replace the current site-by-site approval mechanisms with area-based plans and rules that "reflect local character and distinctiveness." The City of Toronto's aim in adopting a DPS is to develop "a more comprehensive planning process in which outcomes are predictable and align with the expectations of the community."[117] The City of Toronto is currently conducting a community consultation process to identify the planning vision for each area to which the DPS will apply.

The *Development Permits* regulation requires that a municipality's official plan contain policies regarding proposed developmit permit areas before a municipality may pass a bylaw establishing its DPS.[118] The required official plan policies include specification of the geographic extent of the development permit areas, the proposed goals, objectives, and policies for the development permit system, and the types of criteria that will be used for determining the classes of development and land uses that may be permitted through issuance of a development permit. The City of Toronto's council adopted Official Plan Amendment ("OPA") 258 on July 28, 2014. OPA 258 endorsed the implementation of a city-wide DPS and an amendment of the official plan to include the required DPS-related policies.[119] Thirteen parties have appealed OPA 258 to the OMB and as of March 25, 2015 these hearings were not yet scheduled.[120] Because the *Development Permits* regulation requires that a municipality's official plan contain DPS-related policies, the City of Toronto cannot proceed with implementation of its proposed DPS until these appeals are resolved.

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[117] City of Toronto, "Reset TO - Towards Neighbourhood Planning," *City of Toronto*, 2015, accessed April 1, 2015 http://www1.toronto.ca/.
[118] *Development Permits*, O Reg 608/06, s 3(1).
[119] City of Toronto, *To Adopt Amendment No. 258 to the Official Plan for the City of Toronto with Respect to the Policies for the Implementation of a Development Permit System*, City of Toronto Bylaw 726-2014.
[120] City of Toronto, "Reset TO - Towards Neighbourhood Planning."

1.4.2 Public Health and the *Health Protection and Promotion Act*

The *Constitution Act, 1867* does not provide either the federal or provincial governments with explicit jurisdiction over the matter of "health."[121] As a result, jurisdiction over health matters in Canada is somewhat divided. The federal government's largest influence on matters related to healthcare is through its "spending power," inferred from its taxation power and power to legislate in relation to "public property."[122] Through the development of federally-funded public health insurance in Canada, and enactment of the *Canada Health Act* and its predecessor legislation, the federal government has retained some limited oversight over Canada's healthcare system. This is primarily through the establishment of five key criteria in the *Canada Health Act* that a provincial healthcare system must meet in order to receive federal transfer payments.[123]

By comparison, provincial governments have the majority of jurisdictional responsibility regarding healthcare in Canada. This is due to their express constitutional authority over hospitals, property and civil rights in the province, and matters of a merely local or private nature.[124] In *Schneider v The Queen*, the decision of the majority of the Supreme Court of Canada ("SCC") confirmed that section 92(16) of the *Constitution Act, 1867* provides provincial legislatures with "general jurisdiction over public health."[125] Thus the majority of legislation respecting both healthcare and public health in Canada is provincial.

In Ontario, the *Health Protection and Promotion Act* ("*HPPA*") is the primary statute respecting public health.[126] Section 48 of the *HPPA* requires the creation of a board of health for each "health unit," which is the geographic area over which a board of health has jurisdiction.

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[121] *Constitution Act, 1867* (UK).
[122] ibid., ss 91(3), 91(1A).
[123] *Canada Health Act*, RSC 1985, c C-6, s 5.
[124] *Constitution Act, 1867* (UK), ss 92(7), 92(13), 92(16).
[125] *Schneider v The Queen*, [1982] 2 SCR 112.
[126] *Health Protection and Promotion Act*, RSO 1990, c H.7.

Under the *HPPA*, most regional and single-tier municipalities in the Greater Toronto Area, including the City of Toronto, must have a board of health.

Every board of health has a number of duties, roles, and responsibilities as set out in the *HPPA*. The chief duty of each board of health is to superintend, provide for, or ensure the provision of health programs and services required by the *HPPA* and regulations pursuant to persons residing in the board's health unit.[127] The mandatory health programs and services set out in the Act include community sanitation, provision of safe drinking water, control of infectious diseases, health promotion, health protection, disease and injury prevention, family health, and collection and anlysis of epidemiological data.[128]

Each board of health is also required to superintendent and ensure the carrying out of Parts II, III, and IV of the *HPPA* and applicable regulations within its respective health unit.[129] These Parts of the *HPPA* set out in further detail the powers, duties, and responsibilities of the boards of health, medical officers of health, Chief Medical Officer of Health, and the Minister of Health and Long-Term Care ("Minister of HLTC") in respect of health programs and services, community health protection, and communicable diseases, respectively. A board of health also has the power to provide "any other health program or service" in any area of the health unit so long as the board of health is of the opinion that the program or service is necessary or desirable and the municipal council in the area approves.[130] Each board of health therefore oversees the provision of a number of mandatory health services and programs and also has the discretion to implement a broad range of optional health programs or services within its health unit.

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[127] ibid., s4(a).
[128] ibid., s 5.
[129] ibid., s 61.
[130] ibid., s 9.

Each board of health is composed of members appointed pursuant to provisions in the *HPPA* and its regulations. The *City of Toronto Act, 2006* provides certain exceptions to the appointment protocol with respect to the board of health in the City of Toronto, however. In particular, all members of the City of Toronto's board of health shall be appointed by the City, rather than by the Lieutenant Governor in Council as provided in the *HPPA*.[131] The City of Toronto's board of health is comprised of six city councillors, six citizen representatives, and a school board nominee.[132]

In accordance with its statutory roles, duties, and responsibilities, the City of Toronto's board of health determines and establishes public health policies for the City and advises city council on a range of public health matters.[133] These policies are implemented primarily through Toronto Public Health, a division of the City that is responsible for protecting and promoting the health of the City's residents through implementation of policies adopted by the board of health. Under the *City of Toronto Act, 2006*, the City also has the duty to provide employees, including public health nurses, that the City considers necessary to carry out the board of health's functions, including its responsibilities for mandatory health program and service delivery.[134] The provision of Toronto Public Health staff and public health nurses is therefore the responsibility of the City of Toronto.

The Minister of HLTC has a number of powers and duties under the *HPPA* that are too numerous to summarize here. Of particular importance, however, is the Minister's power to publish guidelines that specify the minimum standards of mandatory health programs and

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[131] *City of Toronto Act, 2006*, SO 2006, c 11, Sch A, s405(3).
[132] City of Toronto, "Toronto City Council and Committees Meetings Agendas, and Minutes - Board of Health (2010-2014)," accessed April 1, 2015, http://app.toronto.ca/.
[133] City of Toronto, "About Toronto Public Health," *City of Toronto*, accessed April 1, 2015, http://www1.toronto.ca/.
[134] *City of Toronto Act, 2006*, s405(5).

services with which every board of health must comply.[135] These guidelines are the *Ontario Public Health Standards*.[136] The guidelines set out four foundational principles—need, impact, capacity, and partnership and collaboration—and related goals, outcomes, standards, and requirements.[137] The foundational standards in respect of population health assessment, surveillance, research and knowledge exchange, and program evaluation establish standards and requirements that underlie and support each of the specific program standards.[138] The program standards are grouped in five areas: chronic disease and injuries; family health; infectious diseases; environmental health; and emergency preparedness. Each of these program standards set out program goals, outcomes, and mandatory program and service requirements with which every board of health must comply.

Through publication of the *Ontario Public Health Standards* the Minister retains considerable control over local implementation of provincial public health policy. In this sense, the level of provincial oversight accorded to the Minister under the *HPPA* bears some resemblance to the provincial hierarchical model for land use planning discussed previously. In particular, the *Ontario Public Health Standards* operate in a manner somewhat similar to the *PPS*.[139] Boards of health must provide for or ensure the provision of the minimum health program and service standards established by the Minister in the *Ontario Public Health Standards*.[140] Similarly, all planning decisions of municipal councils must be consistent with matters of provincial interest set out in the *PPS* and conform with (or not conflict with, as the

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[135] *Health Protection and Promotion Act*, s7(1).
[136] Ministry of Health and Long-Term Care, *Ontario Public Health Standards*, 1st ed., (Ministry of Health and Long-Term Care, January 1, 2009), accessed April 1, 2015, http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/default.aspx.
[137] ibid.
[138] ibid.
[139] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement*.
[140] *Health Protection and Promotion Act*, s 7(1).

case may be) applicable provincial plans.[141] Both the *HPPA* and the *Planning Act* therefore establish the statutory frameworks for hierarchical provincial policy-led approaches to the provision of public health programs and services and land use planning at the municipal level.

There is also a level of overlap between these legislative schemes. In particular, the conformance requirements in sections 3(5) and 3(6) of the *Planning Act* apply not only to municipal councils, but also to "local boards." Under the *Planning Act*, a "local board" expressly includes a "board of health."[142] Therefore, a decision of a board of health "in respect of the exercise of any authority that affects a planning matter" must be consistent with the *PPS* and conform with (or not conflict with, as the case may be) applicable provincial plans.[143] Similarly, "[c]omments, submissions or advice affecting a planning matter" that are provided by a board of health must meet the same conformance requirements.[144]

It is arguable that many decisions or comments made by a board of health will affect a "planning matter." For example, decisions regarding disease and injury prevention, community sanitation, and health promotion may affect planning matters such as transportation and infrastructure, separation of land uses, and the provision of community services. Therefore, in addition to their broad duties and responsibilities under the *HPPA*, boards of health also bear the responsibility of ensuring that their decisions, comments and advice are in conformance with provincial land use planning policies.

It is notable that the reverse is not true for municipal councils: there is no requirement that the decisions of a municipal council that affect a "health matter" conform with the *Ontario Public Health Standards* or *HPPA*. Toronto's municipal council must ensure the provision of

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[141] *Planning Act*, s 3(5).
[142] ibid., s 1(1).
[143] ibid., s 3(5).
[144] ibid., s 3(6).

various resources necessary to carry out the board of health's functions, roles, and responsibilities under the *HPPA*. But this is not the same as a statutory requirement that all decisions and advice affecting a "health matter" be consistent with public health policies and standards established under the *HPPA* and *Ontario Public Health Standards*. It is possible, for example, that a much broader set of decisions than those made only by the board of health with respect to health programs and services would relate to health matters. Municipal council decisions that affect a health matter could include those made in respect of land use planning and development applications that may influence the physical activity levels or weight status of area residents. Given this potential gap in the legislative and policy framework, a related reform that would better integrate health principles within the land use planning process is presented in the discussion section of this paper.

This review of the legal and policy frameworks respecting land use planning and public health in Ontario has also highlighted gaps within the policy goals in the *Provincial Policy Statement* and the *Ontario Public Health Standards*. The *PPS* contains some policies related to health, with a particular focus on protection of the public from natural and human-made environmental health hazards. The *PPS* also contains some policies focused on facilitating active transportation, natural spaces for outdoor recreation, and fostering compact development through residential intensification. The *PPS* also makes reference to promoting development of "liveable, healthy, and resilient communities,"[145] yet contains relatively few policies that place a specific focus on relationships between the built environment and population health. In general, health policies in the *PPS* are more reflective of the historic intersections between land use planning and public health in relation to environmental hazards, sanitation, and contamination, than more

[145] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement*, Policy 1.0.

recent population health concerns. Thus, future revisions to the *PPS* could include additional population health-related planning goals and requirements in an effort to foster healthy, active communities across the province.

By comparison, the *Ontario Public Health Standards* contain a number of goals and requirements focused on health, with some specific requirements related to prevention of chronic diseases associated with poor diets and obesity. Boards of health are required to conduct epidemiologic analysis of data regarding healthy eating, healthy weights, and physical activity, and to "support environmental changes through [collaborative] policy development related to healthy eating."[146] Boards of health are also required to "work with municipalities to support healthy public policies and the creation or enhancement of supportive environments in recreational settings and the built environment" in relation to healthy eating, healthy weights, and physical activity.[147] This latter requirement provides a strong basis for the involvement of boards of health in development of municipal planning policies aimed at fostering healthy, active communities. Unfortunately this examination of related laws and policies did not indicate that municipalities or municipal employees are required to participate in collaborative healthy public policy development efforts. Thus, the success of a board of health's efforts to develop policies in collaboration with municipal planning departments may ultimately depend on how willing members of the planning department are to engage in such efforts. Both planning and public health professionals have a number of statutory duties and responsibilities, and it is possible that these competing demands may hinder rather than promote collaboration between them. Reforms that may encourage greater collaboration between these two groups with respect to planning policies and processes are therefore presented in the discussion section of this paper.

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[146] Ministry of Health and Long-Term Care, *Ontario Public Health Standards*, 29.
[147] ibid.

2 Literature Review: How Can the Built Environment Promote Healthy, Active Living?

This section contains a description of the aims and parameters, search methodology, and results of the literature review conducted for this major research paper. The section begins with a description of the literature review's goals, scope, and search methodology. Following this various models of relationships between the built environment and health are summarized. The variety of measurement methodologies and units of analysis employed in the literature are also discussed. Lastly, the results of the literature review are presented in four built environment categories based on the health outcomes examined in the literature review: transportation physical activity; recreation physical activity; dietary intake; and weight status.

2.1 Aims and Parameters

The aim of the literature review was to identify components of the built environment that represent healthy, active communities. For the purposes of this review healthy, active communities are defined as those that promote physical activity, equitable access to healthy food and a healthy diet, and a healthy weight status among residents. This is consistent with two of Kent's three "domains" of planning and health: physical activity, and food. The definition also incorporates weight status, however, given that built environment determinants of physical activity and dietary intake may be implicated in the global obesity pandemic.[148] Thus, the primary goal of this review was to identify components of the built environment that are associated with one or more of the following health outcome categories:

- transportation or "utilitarian" physical activity (e.g., walking or biking for transportation purposes);

[148] Kent and Thompson, "The Three Domains of Urban Planning for Health and Well-Being;" Mackenbach et al., "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and Adult Weight Status, the SPOTLIGHT Project."

- recreation or "leisure" physical activity (e.g., walking, biking, running or playing sports for recreational purposes)
- dietary intake (e.g., overall daily energy intake; daily consumption of fruits and vegetables); and
- weight status (e.g., prevalence of overweight or obesity)

The first two categories fall under the broad label of the physical activity environment, while the third category represents one aspect of the food environment. The fourth category is focused on built environment components from either the physical activity or food environments that relate to indicators of weight status such as overweight, obesity, body mass index and waist circumference. Independent literature searches were conducted for each of these four categories using the methodology described below.

A secondary focus in the review was also placed on identifying methodologies for measurement of built environment components related to health and any associated methodological discrepancies in the literature. This focus was particularly relevant for the identification of suitable methodologies for GIS calculation of built environment components of healthy, active communities in the City of Toronto discussed in sections 3 and 4 of this paper.

Given the volume of literature in this area, it was also necessary to specify certain parameters in an effort to guide and contain the literature review. The focus of the review was on adult populations, not on children, youth, or seniors despite the existence of considerable research focused on both of these age groups. Studies with a mean population age of less than 18 or older than 65 were therefore excluded. The review was concerned with identifying objectively measurable components of urban, suburban, and regional environments related to healthy, active communities and did not examine rural environments. Studies in languages other than English were not included. Articles that met the search criteria outlined below were sorted into categories based on the health outcome examined rather than the built environment components measured.

Thus, articles that examined health outcomes not falling into the four categories set out above were excluded. Lastly, articles whose geographic focus fell outside North America, Europe and Australia were excluded from the review.

2.2 Search Methodology

The following search methodology was developed to capture articles that met the above inclusion parameters and examined relationships between the built environment and one or more of the following categories of health outcomes: transportation physical activity; recreational physical activity; dietary intake; and weight status. In an effort to capture articles published in both planning and health/medical journals multiple search engines were used, including: Scopus; PubMed; Web of Knowledge; Science Direct; and Urban Studies Abstracts. Keywords representing the built environment and its various components were searched in combination with keywords representing each of the four health outcome categories. Individual searches were conducted to capture all potential articles eligible for inclusion in each of the four health outcome categories, using combinations of keywords representing the built environment and each individual health outcome category. These keywords are included as Appendix A to this paper.

Initial searches of titles, abstracts, and keywords based on combinations of these keywords retrieved more than 1,000 articles for each health outcome category. Accordingly, a decision was made to limit initial searches to review articles only. Subsequent searches returned 141 articles on the built environment and transportation physical activity, 57 articles on the built environment and recreational physical activity, 43 articles on the built environment and dietary intake, and 83 articles on the built environment and weight status. These searches were not exclusive, as some articles met the inclusion criteria for multiple health outcome categories.

Articles identified based on these queries were downloaded and imported into the reference management software Mendeley Desktop, with separate folders created for each of the health outcome categories.[149] Duplicates entries were removed as the software permits cross-referencing of one article in multiple folders. Articles within each category were then screened based on title and abstract, and obviously irrelevant or duplicate articles were excluded. The remaining articles were read fully to determine their inclusion in each of the review categories based on the aims and parameters specified above, and final coding of articles into the four health outcome categories was performed. Many of the physical activity articles did not distinguish between transportation and recreational physical activity, and a separate category was created for these articles.

Additional articles were also identified for inclusion in the review based on the author's existing reference library and the "snowball" methodology. The latter refers to inclusion of relevant articles identified through examination of works cited in articles obtained through the initial search process. In some instances search engines, such as Science Direct, also suggested "recommended articles" which were included in the review if they met its aims and parameters. This "snowball" process was not limited to review articles, and therefore a small number of more recent cross-sectional and longitudinal studies were also included in the review.

The final number of articles included in each non-exclusive review category was as follows: 50 articles on the built environment and overall physical activity (including articles that examined both transportation and recreational physical activity as individual dependent variables); 15 articles that examined the built environment and transportation physical activity only; 2 articles that examined the built environment and recreational physical activity only; 18

[149] "Mendeley Desktop," version 1.12.4 (Mendeley Limited, 2014).

articles that examined the built environment and dietary intake; and 31 articles that examined the built environment and weight status. For each article, the study aim, design, methodology, built environment components, outcomes, and associations were recorded along with notes regarding relevance and study strengths or weaknesses. The results of this literature review are presented below, after an overview of the various models of relationships between the built environment and health and a discussion of the modes of measurement and units of analysis employed in these studies.

2.3 Models of Relationships between the Built Environment and Health

A number of theoretical models and frameworks have been proposed to capture the relationships between the built environment and health behaviours (such as physical activity), transportation behaviours (such as walking and bicycling), food choices and eating patterns, and weight status. Various ecological models of health have been used to examine the influence of multiple individual- and population-level factors on physical activity and healthy eating behaviours, and weight status.[150] The transportation planning literature has also generated frameworks such as the behavioural model of environment ("BME") and the 3D model of travel demand, focused on capturing with greater detail the specific physical environmental factors associated with travel behaviours such as walking and bicycling.[151] Other studies have examined five dimensions of access within the food environment and physical activity environment, using

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[150] James F Sallis, Neville Owen, and Edwin B Fisher, "Ecological Models of Health Behaviour," in *Health Behaviour and Health Education: Theory, Research, and Practice*, ed. Karen Glanz, Barbara K Rimer, and K Viswanath, 4 ed., (Hoboken, NJ: John Wiley & Sons, 2008), 465–85; Jennifer L Black and James Macinko, "Neighborhoods and Obesity," *Nutrition Reviews* 66, no. 1 (2008): 2–20.

[151] Cervero and Kockelman, "Travel Demand and the 3Ds: Density, Diversity, and Design;" Anne Vernez Moudon and Chanam Lee, "Walking and Bicycling: an Evaluation of Environmental Audit Instruments," *Am J Health Promot* 18, no. 1 (2003): 21–37.

an adapted version of the model Penchansky and Thomas first proposed for theorizing access to the health system more broadly.[152] A brief summary of these frameworks provides insight into the various theories connecting the built environment to a number of different health behaviours and outcomes. A basic understanding of these theories is critical to understanding how the literature has developed over time and interpreting the results of the literature review.

2.3.1 Ecological Models of Health Behaviour

Ecological models of health were first conceptualized to capture multiple levels of influence on health behaviours and health promotion generally. The basic thesis underlying these models is that healthy behaviours are maximized when "environments and policies support healthful choices, and individuals are motivated and educated to make those choices."[153] In 1988, McLeroy et al. proposed five levels of determinants: intrapersonal; interpersonal; institutional; community; and public policy factors that influence health behaviours.[154] Sallis et al. adopted this model for examination of environmental and policy interventions focused on promoting physical activity behaviours, but noted that McLeroy's model did not explicitly address the influence of physical environmental factors on health behaviours.[155] Accordingly, Sallis et al. proposed the addition of "behaviour settings"—the "physical and social contexts in which

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[152] Roy Penchansky and J William Thomas, "The Concept of Access: Definition and Relationship to Consumer Satisfaction," *Medical Care* 19, no. 2 (1981): 127–40; Ebonee N Butler, Anita M H Ambs, Jill Reedy, and Heather R Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature," *Journal of Physical Activity & Health* 8 (January 2011): S91–S97; Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review."

[153] Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour," 467.

[154] K R McLeroy et al., "An Ecological Perspective on Health Promotion Programs," *Health Education Quarterly* 15 (1988): 351–77; J F Sallis, A Bauman, and M Pratt, "Environmental and Policy Interventions to Promote Physical Activity," *American Journal of Preventive Medicine* 15, no. 4 (October 31, 1998): 379–97.

[155] ibid., 380.

behaviour occurs"—as an additional determinant of physical activity behaviour.[156] Because some behaviour settings are specifically designed to encourage physical activity (e.g., parks, gyms, sports fields, and trails) while others are designed to discourage it (e.g., highways), the environment may restrict behaviours through promoting or in some contexts requiring certain actions and discouraging or prohibiting others.

Common to all ecological models is the notion that there are multiple influences on specific behaviours that interact across different levels to determine behavioural outcomes.[157] The environment may restrict or promote certain behaviours, but it is the interaction between intrapersonal, interpersonal, cultural, policy, and physical environment factors that ultimately influences health behaviours.[158] This is consistent with Bandura's social cognitive theory that the influence personal and environmental factors exert on behaviours varies in different circumstances, for different individuals and activities.[159] Bandura suggested that in certain circumstances, environmental constraints may exercise sufficiently powerful restraints on behaviour that they become overriding determinants of it.[160] In the context of physical activity behaviours, environmental determinants such as behaviour settings that restrict physical activity may be especially influential.[161]

Given the broad range of health behaviours that ecological models may be theorized to capture, researchers have suggested the need for more behaviour- and context-specific ecological

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[156] ibid.
[157] Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour," 466.
[158] Sallis, Bauman, and Pratt, "Environmental and Policy Interventions to Promote Physical Activity," 380.
[159] Albert Bandura, *Social Foundations of Thought and Action: a Social Cognitive Theory*, (Englewood Cliffs, NJ: Prentice-Hall, 1986).
[160] ibid.
[161] Nancy Humpel, Neville Owen, and Eva Leslie, "Environmental Factors Associated with Adults' Participation in Physical Activity: a Review," *American Journal of Preventive Medicine* 22, no. 3 (April 2002): 188.

models.[162] The primary use of ecological models in built environment and health research has been to theorize the interaction between multiple individual, social, cultural, policy, and physical environmental factors that influence physical activity behaviours.[163] But individuals engage in physical activity behaviours for different purposes in different contexts, and the interaction between these influences and the outcomes may differ accordingly. Thus Giles-Corti et al. and Sallis et al. both suggest the need to define a "context-specific behaviour outcome measure" and examine environmental determinants of behaviour hypothesized to have a specific relationship with that measure.[164] Researchers should attempt to break down the behaviour of interest into its specific components, including the type of physical activity (e.g., walking), the purpose of the behaviour (e.g., transportation), the time frame of the behaviour, and the context of the behaviour (i.e., where it takes place). The capacity of the model to predict a behaviour is greatly increased when a specific behaviour outcome measure is matched to specific physical environmental, social environmental, and individual determinants hypothesized to influence that behaviour.[165]

Ecological models of health have been utilized to examine the influence of multiple factors on physical activity for transportation[166] or recreation purposes,[167] on healthy eating

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[162] B Giles-Corti and Anna Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models," *Exercise and Sport Sciences Reviews* 33, no. 4 (2005): 175–81; Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour."

[163] Giles-Corti and Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models."

[164] ibid., 176; Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour," 466.

[165] Giles-Corti and Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models," 176.

[166] Terri Pikora, Billie Giles-Corti, Fiona Bull, Konrad Jamrozik, and Rob Donovan, "Developing a Framework for Assessment of the Environmental Determinants of Walking and Cycling," *Social Science & Medicine* 56, no. 8 (2003): 1693–1703.

[167] Andrew T Kaczynski and Karla A Henderson, "Environmental Correlates of Physical Activity: a Review of Evidence About Parks and Recreation," *Leisure Sciences* 29, no. 4 (2007): 315–54.

behaviours,[168] and the way in which these outcomes may interact to influence weight status and obesity.[169] The work of Pikora et al. is a good example of defining behaviour and context-specific outcomes. The authors divide the physical or built environment factors hypothesized to influence walking and bicycling for two different purposes (transportation and recreation) into four "features" of the built environment: functional, safety, aesthetic and destination.[170] Functional features include the physical attributes of the street or path between origins and destinations of trips. Safety refers to factors that support personal safety and safety from traffic. Aesthetic features are those that create a visually and mentally pleasing environment. Destination features capture the availability of commercial (e.g., retail) and community (e.g., school, community centre) facilities within a neighbourhood. Pikora et al. hypothesized that different aspects of the built environment within these four classes of features may influence more strongly the different physical activity behaviours and purposes examined. Their results were consistent with this hypothesis, indicating that the built environment may exert a stronger influence on walking and bicycling for transportation purposes than for recreation.[171]

The majority of research that has employed ecological models of health has focused on physical activity, however Glanz et al. also adapted ecological models of health behaviour to develop a model of healthy nutrition environments.[172] This model is aimed at determining the

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[168] Karen Glanz, James F Sallis, Brian E Saelens, and Lawrence D Frank, "Healthy Nutrition Environments: Concepts and Measures," *American Journal of Health Promotion* 19, no. 5 (2005): 330–33.

[169] Mia A Papas, Anthony J Alberg, Reid Ewing, Kathy J Helzlsouer, Tiffany L Gary, and Ann C Klassen, "The Built Environment and Obesity," *Epidemiologic Reviews* 29, no. 1 (2007): 129–43; Black and Macinko, "Neighborhoods and Obesity."

[170] Pikora, Giles-Corti, Bull, Jamrozik, and Donovan, "Developing a Framework for Assessment of the Environmental Determinants of Walking and Cycling," 1696.

[171] ibid., 1700.

[172] Glanz, Sallis, Saelens, and Frank, "Healthy Nutrition Environments: Concepts and Measures," 330-331.

complex influence of social and built environments on individuals' access to healthy, affordable food and the interaction between these factors and sociodemographic variables in influencing individuals' eating patterns. The model incorporates government and industry policies, which are hypothesized to influence four different environmental variables, which in turn influence individual-level factors and eating patterns. Environmental variables are divided into the community nutrition environment, the organizational nutrition environment, and the consumer nutrition environment. These food environments are hypothesized as having two pathways of influence on eating patterns. First, "[e]nvironmental, social, and individual factors [may directly] influence eating patterns, which in turn affect risk of many chronic diseases." Second, "[e]nvironmental effects can be moderated or mediated by demographic, psychosocial, or perceived environment variables."[173]

The community food environment includes factors such as the number, type, location, and accessibility of food outlets (e.g., food retail stores and restaurants). Building on Zipf's principle of least effort, Glanz et al. suggest that the relative spatial proximity of healthy versus unhealthy food products influences the odds of individuals' eating a healthy versus an unhealthy diet.[174] By comparison, the consumer food environment includes factors that capture what consumers experience within a food retail store or restaurant. This includes the nutritional qualities of available food, price, sales promotions, product placement, choice and freshness of foods, and availability of nutritional information.[175] Research on the consumer food environment generally requires in-person assessment using a tool such as the Nutrition Environment Measures Survey, which is focused on assessing the availability and cost of healthy food options in retail

[173] ibid., 331.
[174] ibid., 331-332.
[175] ibid., 332.

food stores. Such research is relatively time-consuming and perhaps less commonly undertaken than research on aspects of the community food environment. Thus greater focus was placed on the latter in this literature review.

Though not explicitly ecological in design, Swinburn et al.'s model of food environments and the factors that attenuate or accentuate their impact on individuals' dietary patterns, quality and quantity of food consumed bears some resemblance to ecological models. This model defines "food environments" as the "collective physical, economic, policy and sociocultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status."[176] Thus food environments have four dimensions: physical factors such as the availability, promotion, and quality of food; economic factors such as the cost of different foods; policy factors that represent the "rules" of the food environment; and sociocultural factors such as group norms and beliefs regarding food. Swinburn et al. hypothesize that there are four "components" of food environments that interact with these "dimensions" to attenuate or accentuate the influence of the dimensions on individuals' dietary patterns and food choices. These components consist of the private food industry, government, society, and individual factors.[177]

The private food industry is the primary creator of food supply, and generally determines the availability, quality and price of food. The food industry also promotes consumption of the food products it generates through marketing and product placement within stores.[178] Government, through regulations, laws, fiscal policies, and health promotion influences various

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[176] B Swinburn et al., "INFORMAS (International Network for Food and Obesity/Non-Communicable Diseases Research, Monitoring and Action Support): Overview and Key Principles," *Obesity Reviews: an Official Journal of the International Association for the Study of Obesity* 14, no. 2012 (2013): 2.

[177] ibid., 3.

[178] ibid., 3.

aspects of the food environment. For example, fiscal policies may subsidize or reduce taxation of certain food products and thereby influence their cost. Society holds cultural and religious values and practices that influence consumption of various food products and establish the cultural norms for various foods and cuisines. Government health promotion and marketing efforts may also influence sociocultural norms regarding food. Finally, individual level factors such as income, preferences for certain foods, and habits of consumption interact with food environments to influence individuals' dietary behaviours and eating patterns.[179] Swinburn et al. therefore characterize a "healthy food environment" as an environment in which "the foods, beverages and meals that contribute to a population diet meeting national dietary guidelines are widely available, affordably priced and widely promoted."[180]

Unhealthy diets and overconsumption are one of the primary drivers of population-level obesity.[181] Because the root cause of obesity is an imbalance in energy intake and energy expenditure,[182] researchers have hypothesized that the built environment may play a key role in influencing obesity through creation of settings that promote reduced energy intake and increased energy expenditure.[183] Prior to the rise in built environment research, most of the research on obesity and related interventions focused on modifying individual-level risk factors, with a focus on improving physical activity or diet through lifestyle modifications, or reducing weight through pharmaceutical or surgical interventions.[184] But these approaches generally failed to impact population-level increases in obesity prevalence. Researchers thus became more

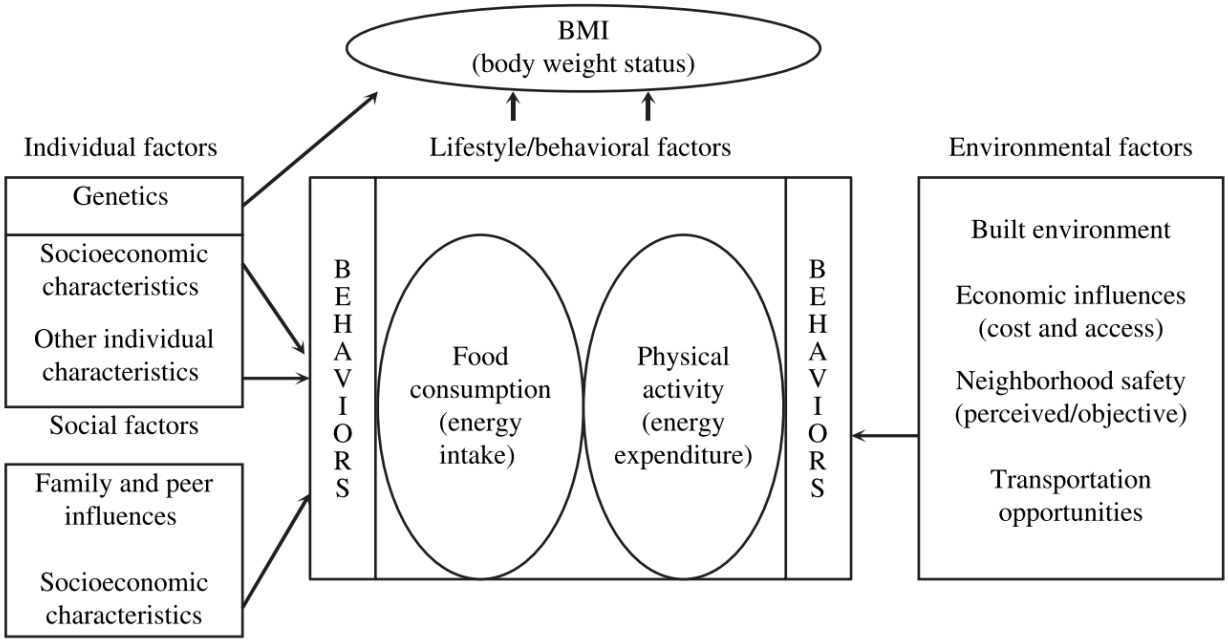
[179] ibid., 3.
[180] ibid., 2.
[181] ibid., 2.
[182] World Health Organization, "Obesity and Overweight;" James, "The Epidemiology of Obesity: the Size of the Problem;" Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments."
[183] Papas et al., "The Built Environment and Obesity."
[184] Black and Macinko, "Neighborhoods and Obesity," 2.

interested in the social and contextual determinants of body weight, which may offer more "upstream" population-level preventive strategies that could complement "downstream" individual-level interventions.[185] Much of this research has focused on the areas in which individuals live, based on the notion that neighbourhood social and environmental factors can either promote or discourage physical activity and healthy eating, and some neighbourhoods are thus more "obesogenic" than others.

Various frameworks have been proposed to capture these interactions. Papas et al. proposed an ecological model that relates individual, social, and environmental factors to physical activity, diet, and body weight status.[186] Individual factors include socioeconomic characteristics, behaviour preferences, and genetics. Social factors include family and peer influences, as well as group socioeconomic characteristics. Environmental factors include the built environment, as well as perceptions of neighbourhood safety and economic influences such as cost of and access to various resources. This framework is based on the notion that "it is the interaction of the individual with his or her environment that influences health" and appropriate measures, concepts and relationships may therefore differ based on individual-, behaviour-, and context-specific factors.[187] A graphical depiction of this framework is presented as Figure 1, below.

[185] ibid., 3.
[186] Papas et al., "The Built Environment and Obesity."
[187] ibid., 130.

Figure 1. An ecological model of the relationships between individual, social, and built environment factors and physical activity, food consumption, and body weight status. (Source: *Ibid*).



Black et al. also developed a conceptual framework aimed at capturing the influence of neighbourhood factors on body weight and obesity.[188] This framework incorporates macro-, meso-, and individual-level factors that interact to influence behaviours (dietary intake and physical activity) related to body weight and obesity.[189] Macro-level factors include social, historical, and political factors such as economic, cultural, legislative and policy influences that affect how neighbourhoods develop over time, as well as group-level social factors. Meso-level factors are the contextual features of a neighbourhood that "directly and indirectly shape health behaviours."[190] These include the physical features of neighbourhoods (e.g. land use, road networks), its aesthetics, the availability and quality of food and other amenities, and the social capital of a neighbourhood.

[188] Black and Macinko, "Neighborhoods and Obesity."
[189] ibid., 12-13.
[190] ibid., 13.

This framework is based on the theory that "neighbourhoods can influence obesity through long-term processes that help shape individuals and their norms and behavioural intentions over time, through indirect effect modification, or as direct mediators of an individual's ability to carry out desired health behaviours."[191] For example, an individual may intend to consume healthy foods but if no sources of fruits and vegetables are readily available, fresh, affordable, or culturally appropriate her desired behaviour may be impeded. Neighbourhood factors may also directly support or constrain behaviours. For example, an individual may intend to increase her engagement in physical activity, but a lack of parks or greens spaces, or perceptions of crime and poor safety may impede this behaviour.[192] This model therefore shares similarities with the framework of Papas et al. in recognizing that certain environmental features may restrict or inhibit physical activity behaviours, [193] healthy eating, and ultimately influence weight status and development of obesity.

A third ecological model of obesity was first presented in the introduction to this paper. This is the framework that Swinburn et al. developed to categorize population-level determinants of obesity and related solutions and interventions. It includes categories of environments, behaviours, and physiology related to obesity.[194] Environmental factors include systemic drivers such as policy and economic systems that promote growth and consumption, as well as environmental drivers such as the food marketing and supply environments that promote high energy intake. Environmental moderators include the socioeconomic, sociocultural, transportation and recreation environments that may attenuate or accentuate the influence of

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[191] ibid., 14.
[192] ibid., 13.
[193] Papas et al., "The Built Environment and Obesity."
[194] Swinburn et al., "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments," 806-808.

systemic and environmental drivers. All of these factors are hypothesized to have some influence on dietary and physical activity behaviour patterns that can produce an energy imbalance and influence body weight status.[195]

Most of the ecological models discussed above share the four "key aspects" of ecological models that Sallis et al. proposed. These models are premised on the notion that multiple influences on specific behaviours interact across different levels to determine behavioural outcomes. The models and related research also recognize the importance of developing behaviour-specific frameworks that link a context-specific behaviour outcome to specific factors hypothesized to influence that outcome.[196] Lastly, the research suggests that interventions targeting multiple levels of influence are likely to be most effective in modifying population-level behaviours. For example, it is likely that a combined intervention targeted at creating environments that are more supportive of physical activity and educating populations to increase motivation, physical activity skills, and knowledge of how to use such environments for physical activity would be more effective than either intervention on its own. Individuals who lack the motivation or skills to engage in or maintain physical activity may be more likely to engage in it if both a supportive environment and education on how and why to use it for physical activity are provided.

2.3.2 Five Dimensions of Access

A second type of framework that has been used to theorize relationships between individuals, environments, and health is Penchansky and Thomas' "five dimensions of access:"

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[195] ibid., 808.

[196] Giles-Corti and Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models," 176; Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour," 466.

[197] This framework defines access as "the degree of fit between the characteristics and expectations of users and the characteristics of a system," and was first proposed for categorizing the fit between patients and health care systems generally.[198] More recently the framework has been adopted for use in capturing various aspects of the physical activity environment and the food environment.[199]

Penchansky and Thomas suggested that users' access to a system consists of five dimensions: availability, accessibility, affordability, acceptability, and accommodation. In adapting this framework for examining relationships between the environment and physical activity, Butler et al. suggest that the "users" are individuals within a community, and the "system" is the community's built and social environment.[200] In this context availability refers to the supply of resources within the community for engagement in physical activity, and proximity to common destinations (e.g., parks and retail stores that can be accessed using active transportation). Accessibility refers to features of the built environment, such as roads, sidewalks, and paths, that enable travel to available destinations. Accommodation refers to factors such as safety, aesthetics, and sidewalk conditions; these are objectively measured ancillary features of the built environment that can promote or discourage physical activity engagement. Affordability refers to population-level socioeconomic status or related proxy measures. Acceptability refers to whether the built environment is "perceived as suitable to the

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[197] Penchansky and Thomas, "The Concept of Access: Definition and Relationship to Consumer Satisfaction."

[198] Butler, Ambs, Reedy, and Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature," 92-93.

[199] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review;" Butler, Ambs, Reedy, and Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature."

[200] ibid., 93.

needs of individuals for physical activity engagement," and may be measured using surveys of individuals' perception of the built environment.[201]

Caspi et al. have also adapted the five dimensions of access framework to conceptualize food environments in a more subtle manner than the useful distinction between "community food environments" and "consumer food environments" that Glanz et al. previously developed.[202] In conducting a literature review focused on quantitative methods for assessment of the food environment and its relationship to dietary outcomes, Caspi et al. categorize the food environment based on categories of availability, accessibility, affordability, acceptability, and accommodation. In the context of the food environment, availability refers to how adequate the supply of healthy food is, capturing factors such as the presence of certain food stores or restaurants near an individual's home or workplace.[203] Accessibility refers to the physical location of food retail stores or restaurants, and the ease with which an individual can travel to these locations. Affordability refers both to the cost of food as well as individuals' perceptions of cost relative to the worth of various food products. Acceptability refers to individual- and population-level attitudes and standards about aspects of the food environment, and whether or not the supply of certain products meets these standards. Accommodation is a relatively underexamined aspect of the food environment, and refers to "how well local food sources accept and adapt to local residents' needs." This could include, for example, hours of operation and accepted methods of payment at local food stores.[204]

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[201] ibid., 93.
[202] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review," 1172-173; Glanz, Sallis, Saelens, and Frank, "Healthy Nutrition Environments: Concepts and Measures."
[203] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review," 1173.
[204] ibid.

Though the five dimensions of access frameworks discussed above are not explicitly ecological, they do recognize the importance of interactions between individuals and their environment in categorizing their engagement in certain types of behaviour. Ecological models are similarly focused on the multiple levels of interaction between individuals and the social, physical, and policy aspects of their environments that influence specific health behaviours. By comparison, other frameworks developed primarily in the transportation planning literature place less focus on the individual and greater emphasis on categorizing specific built environment features that may influence travel demand and engagement in transport-related physical activity. These frameworks, discussed below, are useful for understanding in greater detail the theories underlying relationships identified between various built environment factors and transportation behaviours such as walking and bicycling. They are perhaps not as effective as the ecological and five dimensions frameworks in capturing the role that individual- and population-level socioeconomic and cultural factors may play in influencing these outcomes and should be considered with these caveats in mind.

2.3.3 Models of Travel Demand (3D, BME)

One of the foundational models of travel demand utilized in built environment research is Cervero and Kockelman's "3D" model. This model is based on the New Urbanist theory that changing three dimensions of the built environment—density, diversity, and design—is necessary to achieve the transportation planning objectives of reducing motorized trips, increasing non-motorized trips, and reducing travel distances.[205] Cervero and Kockelman explored the relative influences of each of the built environment dimensions on travel demand,

[205] Cervero and Kockelman, "Travel Demand and the 3Ds: Density, Diversity, and Design," 199.

building on utility-based theories under which travel is a "derived" demand and individuals' trips are made based on a desire to reach certain places.

In this framework density is thought to influence travel demand through bringing trip origins and destinations closer together, making it easier to travel on foot or bicycle.[206] Diversity primarily refers to having a mix of land uses within neighbourhoods. Higher diversity is hypothesized to influence travel demand through generating shorter trip distances and encouraging commuters to link work and shopping trips on foot.[207] For example, if an individual's home and workplace are both located near public transit, and grocery and retail stores are similarly located near those public transit stops, this diversity may encourage commuters to link work and shop trips on foot rather than by car. The first dimension, density, also supports and is often found in combination with increased public transit service and a greater mix of land uses. The third dimension, design, refers to factors such as walking and cycling amenities (e.g., sidewalks and trails), the location of parking lots in relation to stores and streetfronts, and the presence of street trees and benches. Such features may make accessing destinations by foot or bicycle both more convenient (as compared with driving) as well as more pleasurable.[208]

Results of Cervero and Kockelman's early work in this field indicated that quantifiable measures of density, diversity, and design may offer some additional explanatory power in understanding the influence of the built environment on travel behaviours beyond that captured by control variables such as annual household income, the number of workers and vehicles in a

[206] ibid., 200.
[207] ibid., 201.
[208] ibid., 201.

household, and transit service levels.[209] A large body of research in this area has emerged since, and is further summarized within the results of this paper's review of the transportation physical activity environment literature.

Other transportation planning researchers have also developed frameworks aimed at categorizing the various built environment dimensions that may influence transport-related physical activity. Moudon and Lee proposed a behavioural model of environments ("BME") focused primarily on identifying with greater detail the physical environmental determinants of walking and bicycling for transportation purposes. This model aims to capture the spatiophysical, spatiobehavioural, and spatiopsychosocial aspects of the environment-behaviour interaction, and does not place the same emphasis on intra- or inter-personal determinants of activity behaviours as ecological models of health behaviour do.[210]

The BME categorizes the environment into three components: the origin and destination of the walk or bike trip; the characteristics of the route traveled; and the characteristics of the area in which the trip takes place. Each of these components includes certain spatiophysical, spatiobehavioural, and spatiopsychosocial aspects.[211] For example, aspects of the origin and destination define the purpose of the trip—whether it is for transportation, recreation, or exercise purposes. The route characteristics component captures the distance between the origin and destination of the trip, the design of the roadway, and the related perceptions of safety and comfort for bicyclists and pedestrians traveling the route. The characteristics of the area include spatiophysical characteristics such as land use mix and density, which can affect the volume of

[209] ibid., 216-219.
[210] Moudon and Lee, "Walking and Bicycling: an Evaluation of Environmental Audit Instruments," 22.
[211] ibid., 22-23.

bicyclists and pedestrians and support the viability of bicycling, walking, and public transportation infrastructure.[212]

Moudon and Lee stressed the importance of examining built environment factors from all three BME components in order to comprehensively measure the influence of the environment on walking and bicycling for transportation purposes:

> For example, sidewalks as characteristics of the route traveled are a welcome support for pedestrians only if they link the pedestrian trip origin with a destination. Furthermore, they will support a substantial number of pedestrians only if they link origin and destination points that have a substantial number of people around them. Hence, although the presence of origin and destination points, the quality of the route, and the number of people and activities in an area are, individually, necessary, they are not sufficient conditions for travel.[213]

Cervero and Kockelman similarly recognized theoretical justifications for examining the relevance of each built environment dimension's combined influence on travel behaviours.[214] The theory appears sound. Factors such as greater land use mix, higher population and employment densities, and pedestrian-friendly design often co-exist and their combined capacity to influence travel behaviour may be stronger than the influence of any one built environment dimension on its own. The ability of subsequent research to examine and capture these subtle interactions is explored further in discussion of the literature review results.

This overview of frameworks linking the built environment and health indicates that each framework offers advantages and disadvantages with respect to capturing specific environment-behaviour influences. In general, the literature presents a strong rationale for the use of behaviour-specific ecological models to provide greater insight into the influence of specific environmental factors on health behaviours. But research has not always followed this advice

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[212] ibid.
[213] ibid.
[214] Cervero and Kockelman, "Travel Demand and the 3Ds: Density, Diversity, and Design," 217.

and where it has the result has arguably been considerable heterogeneity in methods used to calculate dependent and independent variables across studies.[215] By comparison, the "five dimensions of access" model, and other models of travel demand generated in the transportation planning literature, may provide greater specificity in the classification of input variables and better capture relationships between specific built environment factors and health outcomes. However, these frameworks also do not place the same focus on how the interaction between individual, social, policy, and environmental factors together influence specific behaviours. The transportation planning models in particular are useful for categorizing how various built environment factors influence travel demand and use of different transportation modes, but do not capture to the same extent the role that individual- and population-level socioeconomic and cultural factors may play in influencing these outcomes. Given the advantages and disadvantages associated with the use of these frameworks, this literature review was not limited to studies conducted using any one framework.

2.4 Measurement and Units of Analysis

In order to comprehend with greater clarity the results of the literature review, it is necessary to briefly review the principal methods for defining both the units of analysis typically used in built environment and health studies, and the methods used for measuring various built environment factors (or "metrics") within the models researchers have utilized. Studies are generally conducted at either the population (i.e., ecological) or individual level. The former generally rely on "neighbourhoods" as a unit of analysis for built environment metrics, socioeconomic data, population-level health or transportation outcomes, and examination of

[215] Jing Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence," *Health and Place* 16 (2010): 175–90.

associations between these variables. Studies conducted at the individual level also generally rely on neighbourhoods as a unit of analysis for built environment metrics, and possibly socioeconomic data, but utilize individual-level measurements of health or transportation outcomes as hypothesized dependent variables. Various conceptions of what constitutes a "neighbourhood" are explored below, followed by a discussion of common metrics utilized in measuring various dimensions of the built environment.

2.4.1 Defining Neighbourhoods

Models and conceptualizations of the "neighbourhood unit" have been utilized in planning communities since the early days of professional planning. Many of these models were based on the concept of people living within a walkable distance of schools, services, and community centres. For example, Clarence Perry's early conceptions of the "neighbourhood unit" were based in part on Ebenezer Howard's Garden City theory. Common to both of these models was the conception of new communities as relatively small groups of residents living within walking distance of schools, community centres and services, and in the case of Howard's Garden Cities, linked together by rail transit.[216] More recently, New Urbanists have advocated for a return to "traditional neighbourhood design" and "transit-oriented development," modern conceptions of walkable neighbourhoods based on pre-suburban community designs.[217] The concept of neighbourhood is not limited to the planning profession either. Public health has also utilized neighbourhoods to examine the influence of where people live on their health; for

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[216] Anne Vernez Moudon, Chanam Lee, Allen D Cheadle, Cheza Garvin, Donna Johnson, Thomas L Schmid, Robert D Weathers, and Lin Lin, "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights," *Journal of Physical Activity & Health* 3, no. 1 (2006): 100; Ebenezer Howard, *Garden Cities of to-Morrow*, (Cambridge: MIT Press, 1965), 50-55.

[217] Moudon et al., "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights," 100.

example, using multi-level analysis to examine the influence of neighbourhood-level determinants of health on residents' health outcomes.[218] It is perhaps not surprising then that the neighbourhood has become the dominant unit of analysis in built environment and health research, given the shared origins of this field from both planning and public health.

Moudon et al. propose a synthesized definition of the neighbourhood based on the theoretical perspectives of Perry, Howard, and Galster:

> [N]eighborhood [is] a geographical construct of place, defined around home and everyday activities, centered on schools, community centers, parks, or retail services. Neighborhood evokes socio-physical homogeneity, a shared sense of place, connection, and access. It has multiple cognitive, economic, geographic, behavioral, cultural, and temporal dimensions. The concept is dynamic, individually defined, and changing over the short and long terms, including multiple levels of influence and geographic extents. [219]

This definition indicates that neighbourhoods have multiple aspects and dimensions, the definition of which may differ for various individuals and change over time. It also recognizes that both objective and subjective measurements may capture different characteristics of neighbourhoods. Moudon et al. suggest that synthesizing the theoretical constructs of what constitutes a neighbourhood is relatively straightforward.[220] A much more complex task has been the development of empirical approaches for measuring specific characteristics or features of neighbourhoods as they relate to health and transportation behaviours.

One of the primary difficulties has been defining the geographic extent of the neighbourhood as it relates to both dependent and independent variables in built environment research. For example, a researcher may hypothesize that independent variables such as

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[218] Ana V Diez Roux, "Invited Commentary: Places, People, and Health," *American Journal of Epidemiology* 155, no. 6 (March 15, 2002): 516–19.
[219] Moudon et al., "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights," 102.
[220] ibid., 102.

population density, land use mix, presence of retail stores and services, and length of sidewalks within a neighbourhood influence the dependent variable of walking for transportation purposes within a neighbourhood after controlling for neighbourhood-level socioeconomic status. This leaves the difficult decision of how to define the neighbourhood's area? Depending on whether a study is conducted at the population- or individual-level and utilizes objective or perceived measures, there are numerous possible definitions.

Many population-level studies have defined neighbourhoods based on administrative units such as census tracts.[221] This definition is advantageous in that socioeconomic, population, and employment data are often readily available for census tracts. But census tracts are defined based on a target population range, and can thus vary in geographic extent based on the density or location of a given tract.[222] The boundaries of a census tract are also strict and may fail to capture the conceptual neighbourhood of individuals who live closer to the edges of the tract boundary than those living in the middle of it. The use of census tracts also confines the definition of neighbourhood to the same spatial extent for all variables examined. This may simplify analysis, but is also not consistent with theories regarding the multiple behavioural, contextual, and geographic dimensions of neighbourhoods that may influence dependent variables in different ways depending on how they are defined.

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[221] See Ross C Brownson, Christine M Hoehner, Kristen Day, Ann Forsyth, and James F Sallis, "Measuring the Built Environment for Physical Activity: State of the Science," *American Journal of Preventive Medicine* 36, no. 4 (April 2009): S99–123; Helene Charreire, Romain Casey, Paul Salze, Chantal Simon, Basile Chaix, Arnaud Banos, Dominique Badariotti, Christiane Weber, and Jean-Michel Oppert, "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review," *Public Health Nutrition* 13, no. 11 (November 2010): 1773–85.

[222] Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence," 186.

Given the potential drawbacks of relying solely on administrative units in neighbourhood analyses, other studies have defined neighbourhoods based on geographic buffers surrounding the locations of study participants' homes.[223] For example, an analyst using GIS may geocode the home address or postal code of each study participant to a point located along the appropriate city block face, or to a point representing the geographic centre ("centroid") of an administrative unit that contains the participants' home. Geographic buffers of various extents are then generated around this point to define each participant's individual neighbourhood for purposes of calculating independent built environment variables. For example, a researcher may measure the presence of retail and service destinations within an 800 m, 1 km, 1.5 km, or 1.6 km buffer distance of each participant's geocoded location. The study may then examine associations between these independent variables and dependent health outcomes collected using participant survey or monitoring methods.

Because this method focuses on the geographic extent of a neighbourhood surrounding an individual or group of individuals it arguably provides greater validity than the use of administrative units. Standardized buffers may better reflect an individual's immediate neighbourhood and thus reduce errors attributable to the modifiable areal unit problem. This is a problem where artificial spatial patterning can result from the use of artificial geographic units "of varying sizes and aggregation levels" (e.g., census tracts) to measure a continuous geographic phenomenon (e.g., population density or land use mix).[224]

The definition of neighbourhoods based on buffers is not without its own drawbacks, however. There is little between-study agreement in the buffer distances used to define

[223] See Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science;" Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review."

[224] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 117.

neighbourhoods and the methodology used to generate the buffers (which can be defined using straight-line or road network-based methodologies). This presents difficulties for meta-analysis or comparison of results across studies and remains a considerable limitation in identifying strong associations between the built environment and health.[225] The relevant buffer size may differ based on the age group, setting, behaviour, and built environment characteristics examined.[226] For example, larger buffer sizes may be appropriate for examination of measures associated with bicycling as compared with walking. Yet few studies have examined these differences to empirically define buffer sizes most relevant to specific activities or built environment characteristics.[227] Furthermore, in studies that utilize both objective and perceived measures of built environment and/or health outcomes, the definition of neighbourhood employed in measuring respondent perceptions may differ from that used in defining neighbourhoods objectively. Such differences in specificity can weaken correlations between objective and perceived measures, as behaviours may not be matched to the context in which they are undertaken.[228]

Given these drawbacks researchers have argued for the need to define the spatial scale of analyses based on the specific behaviours examined and the neighbourhood contexts hypothesized to influence them.[229] Yet relatively few studies have questioned participants regarding the distances they are willing to travel to engage in certain behaviours (such as

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[225] Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence," 185.
[226] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 117-118.
[227] ibid., 118.
[228] Giles-Corti and Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models," 178.
[229] Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence," 187.

purchasing healthy food, or playing a specific sport).[230] Accordingly there remains little consensus in the literature regarding the most appropriate way in which to define the size of neighbourhoods in relation to their environments' influence on specific behavioural outcomes.

2.4.2 Modes of Measuring the Built Environment

Having discussed the various theories and definitions of neighbourhoods as they apply to built environment and health research, this paper moves to consider in more detail the various methodologies used to measure neighbourhood built environment factors proposed to influence health behaviours. Studies have typically employed methods from one or more of three general categories. Some studies have examined individuals' perceptions of the neighbourhood built environment using, for example, self-reported answers to survey questionnaires.[231] Other studies have relied on researchers' objective observational assessment of environmental factors in the field, using systematic "community audit" tools.[232]. The third methodological category encompasses the wide variety of objective GIS methods used to measure characteristics of the built environment.

Appendix B contains a more details discussion of these measures and their respective advantages and disadvantages. Because this literature review was focused on identifying objectively measurable built environment components of healthy, active communities, our discussion does not focus on methods that rely on individuals' perceptions of the built environment. Instead, the type of objective measures derived using either observational

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[230] Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review," 1782.

[231] See Nancy Humpel et al., "Changes in Neighborhood Walking Are Related to Changes in Perceptions of Environmental Attributes," *Annals of Behavioral Medicine* 27, no. 1 (February 2004): 60–67.

[232] See Ewing et al., "Identifying and Measuring Urban Design Qualities Related to Walkability;" Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

assessments or GIS methodologies are discussed further in Appendix B. The broad advantages and disadvantages of these measures are also considered. Much of this discussion is drawn from the work of Brownson et al. and Charreire et al. in characterizing measures of the physical activity and food environments, respectively.[233]

The discussion demonstrates that objective GIS measures of the built environment are the only feasible method for capturing detailed variations in built environment characteristics across a large study area. The most commonly assessed GIS measures include population density, land use mix, access to recreational facilities, street pattern, sidewalk coverage, vehicular traffic, crime, other (e.g. public transit, greenness, slope/hilliness), and composite indices.[234]Variables within these categories are often calculated in different ways, using measures of density, accessibility (or proximity), intensity, or pattern. There are a large variety of buffer sizes, variable definitions, and analytical methodologies employed in the literature, which has posed difficulties in comparing results across studies.[235] Additionally, there are some aspects of the built environment, such as visual aesthetics, landscape maintenance, and architectural quality that are not easily captured using GIS measures. Thus some studies continue to employ objective observational measures such as community audits either alone or in combination with GIS methods.

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[233] ibid.; Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review."

[234] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

[235] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?;" Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence."

2.5 The Components of a Healthy Built Environment

With the establishment of a basic understanding of models and metrics for measurement of relationships between characteristics of the built environment and health outcomes completed, this paper turns to the results of the literature review. The results are presented based on the different categories of built environment characteristics examined. The first section presents characteristics of the physical activity environment hypothesized to influence transportation and recreational physical activity. The second section presents characteristics of the food environment hypothesized to influence various measures of dietary intake. The third section presents characteristics of either the physical activity or food environments hypothesized to influence weight status, including measures of overweight, obesity, or waist circumference. A more detailed discussion of each of these fields of research in presented in Appendix C.

2.5.1 The Physical Activity Environment

A total of 50 articles that focused on overall physical activity or examined both transportation and recreational physical activity outcomes were identified. An additional 15 articles focused only on transportation physical activity and 2 articles focused only on recreational physical activity were also identified. Some of the reviews in the first group differentiated between various types and purposes of physical activity in reporting their results, while others did not. The specificity and grouping of the outcomes examined in the different reviews varied considerably. For example, Fraser & Lock focused only on reviewing studies that examined bicycling prevalence for either commuting or leisure purposes, yet did not differentiate between the two purposes in reporting their findings.[236] By comparison, Sugiyama et al.

[236] Fraser and Lock, "Cycling for Transport and Public Health: a Systematic Review of the Effect of the Environment on Cycling."

examined only transportation and recreational walking, but distinguished between the two categories of outcomes in reporting their findings.[237] Similarly, Van Holle et al. grouped their review and findings based on several outcome categories, including total physical activity, leisure physical activity, total walking and bicycling, recreational walking and bicycling, total active transportation, walking for transportation, and bicycling for transportation.[238]

Because of the theoretical importance of linking specific environmental measures to context-specific behaviour outcomes,[239] reviews that organize and report their results based on the different types and purposes of physical activity examined provide a much more useful summary of the state of the literature. Accordingly this paper did not place much weight on reviews that did not differentiate between transportation and recreation physical activity in their results. Instead, the results of relevant physical activity reviews and studies are summarized below based on these two physical activity purposes.

2.5.1.1 Transportation Physical Activity

Characteristics of the built environment significantly associated with measures of transportation physical activity in the literature reviewed are presented in Table 1. Potential data sources for use in calculating these variables using GIS analysis for the City of Toronto are also noted. A total of 15 articles focused exclusively on transportation physical activity and an additional 17 articles in the general physical activity category that reported results separately for

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[237] Takemi Sugiyama, Maike Neuhaus, Rachel Cole, Billie Giles-Corti, and Neville Owen, "Destination and Route Attributes Associated with Adults' Walking: a Review," *Medicine and Science in Sports and Exercise* 44, no. 7 (2012): 1275-1286.

[238] Veerle van Holle, Benedicte Deforche, Jelle Van Cauwenberg, Liesbet Goubert, Lea Maes, Nico Van de Weghe, and Ilse de Bourdeaudhuij, "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," *BMC Public Health* 12, no. 1 (2012): 807.

[239] Giles-Corti and Timperio, "Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models," 176; Sallis, Owen, and Fisher, "Ecological Models of Health Behaviour," 466.

transportation physical activity were reviewed. Within these reviews and studies there was considerable variation in the specific transportation outcomes examined, though most studies focused on walking and/or bicycling to work, school, or for errands. There was also variation in the built environment measures examined, but in general measures fell within the broad categories identified by Brownson et al. and discussed in the previous section of this paper.[240] The more detailed discussion of environmental determinants of transportation physical activity contained in Appendix C is therefore organized based on these categories.

Table 1. Built Environment Variables Significantly Associated with Measures of Transportation Physical Activity*.

Variable	Example of Variable Definition	Relevant Reviews and Studies
Density		
Gross Population Density	Persons per square km	Grasser et al., 2013; de Nazelle et al., 2011; Brownson et al., 2009; Saelens and Handy, 2008; Leck, 2006
Net Residential Density	Dwellings per square km of residential land use	Grasser et al., 2013; McCormack and Shiell, 2011; de Nazelle et al., 2011; de Nazelle et al., 2011; Brownson et al., 2009; Lee and Moudon, 2006
Gross Employment Density	Jobs per square km	de Nazelle et al., 2011; Saelens and Handy, 2008; Leck, 2006
Jobs-Housing Balance	Ratio of Jobs to Dwellings	Ewing and Cervero, 2010
Land Use Mix		
Land Use Mix Entropy	$-\frac{\sum_k (p_k \ln p_k)}{\ln N}$ where: • k is the category of land use • p is the proportion of land area within a neighbourhood devoted to a category of land use • N is the number of land use categories in the study area	de Nazelle et al., 2011; McCormack and Shiell, 2011; Butler et al., 2011; Ewing and Cervero, 2010; Saelens and Handy, 2008; Leck, 2006

[240] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

Presence of Utilitarian Destinations	Whether categories of utilitarian destinations (e.g. grocery store, supermarket, restaurant, post office, bank, or public transit stop) exist within a defined neighbourhood	Sugiyama et al., 2012
Proximity of Utilitarian Destinations	Network or euclidean distance from home to nearest grocery store, supermarket, restaurant, post office, bank, or public transit stop	Sugiyama et al., 2012; Butler et al., 2011; Ewing and Cervero, 2010; Saelens and Handy, 2008; Lee and Moudon, 2006; Van Holle et al., 201
Density of Utilitarian Destinations	Number of utilitarian destinations (e.g. grocery store, supermarket, restaurant, post office, bank, or public transit stop) within a defined neighbourhood or per square km	Glazier et al., 2014; Lee and Moudon, 2006
Street Pattern		
Intersection Density	Number of 3-way or greater intersections per square km	Grasser et al., 2013; Sugiyama et al., 2012; McCormack and Shiell, 2011; Butler et al., 2011; Ewing and Cervero, 2010
Indices		
Walkability Index	Comprised of weighted z-scores of: residential density; intersection density; land use mix entropy; and retail floor area ratio	Grasser et al., 2013; Van Holle et al., 2012; Frank et al., 2010; Sallis et al., 2009
Sprawl Index	Comprised of 22 land use and street network variables reduced to four factors: residential density; land use mix; degree of centering; and street accessibility	Ewing, 2005; Ewing et al., 2003
Other		
Slope/Hilliness	Standard deviation of slope (average change in elevation) in degrees within a defined neighbourhood	Sarkar et al., 2013; van Holle et al., 2012; Butler et al., 2011; Lee and Moudon, 2006

*Examples of dependent variables include:

- Daily or weekly frequency of walking for transportation purposes
- Daily or weekly frequency of bicycling for transportation purposes
- Daily or weekly frequency of walking or bicycling for transportation purposes
- Total daily or weekly minutes of walking for transportation purposes
- Total daily or weekly minutes of bicycling for transportation purposes
- Total daily or weekly minutes of walking or bicycling for transportation purposes

The literature review identified measures of density, land use mix, and street pattern as consistent significant positive correlates of transportation physical activity. Higher levels of population or employment density, land use mix, intersection density, and proximity to utilitarian

destinations are most commonly identified as significant positive correlates of walking or bicycling for transportation purposes. Composite walkability indices that combine these measures are also consistently associated with walking for transportation purposes and total physical activity. The slope or hilliness of the built environment may also influence transportation physical activity, but in different directions for different purposes. Relatively few studies have examined this last measure and additional research is required to confirm its validity. Nonetheless, when these results are compared with the below results for recreation physical activity, the food environment, and weight status, it is clear that the evidence is strongest for relationships between certain characteristics of the physical activity environment and transportation physical activity.

2.5.1.2 Recreational Physical Activity

With a few exceptions, most of the factors identified above as significant built environment correlates of transportation physical activity are generally unrelated to recreational or leisure-time physical activity. This is consistent with the theoretical notion that different environmental influences may act differently on different types of behaviours in different contexts. For example, access to a walking trail or a park may have a much stronger influence on walking or running for recreational purposes, than on transportation physical activity related to commuting or running errands. Other than intersection density, most of the reviews identified quite different correlates of recreational physical activity compared with transportation physical activity. These variables are listed in Table 2 and include the *quality* but not *proximity* of recreational facilities, the presence of certain types and sizes of parks and green spaces, access to walking trails, sidewalk length, intersection density, and safety. Each of these variables is discussed in further detail in Appendix C.

Table 2. Built Environment Variables Significantly Associated with Measures of Recreation Physical Activity*.

Variable	Example of Variable Definition	Relevant Reviews and Studies
Access to Parks and Recreational Facilities		
Quality of Recreational Facilities	Attractiveness of or satisfaction with recreational facilities	Thompson, 2013; Sugiyama et al., 2012; Lee and Maheswaran, 2011
Availability of Parks, Green and Open Space	Presence of specific sizes of parks, green and open space within specific network or euclidean distances of residents' homes	Butler et al., 2011; Lachowycz and Jones, 2011; Kaczynski and Henderson, 2007; Ward Thompson, 2013; Lee and Maheswaran, 2011; Sugiyama et al., 2010; Sugiyama et al., 2012
Access to Walking Trails	Presence of walking trail within a defined neighbourhood	Sugiyama et al., 2014
Street Pattern		
Intersection Density	Number of 3-way or greater intersections per square km	Sugiyama et al., 2014; Butler et al., 2011
Sidewalk Length	Metres of sidewalk within a defined neighbourhood	Lee and Moudon, 2006
Other		
Safety	Number of crimes per year in a defined neighbourhood; also commonly assessed based on participant perceptions of safety from crime.	Kent et al., 2011; Butler et al., 2011; Foster and Giles-Corti, 2008

*Examples of dependent variables include:

- minutes or frequency of walking and/or bicycling for recreation or leisure purposes
- minutes or frequency of moderate to vigorous physical activity for recreation or leisure purposes

Overall, the literature review indicated that measures of the availability of specific sizes or types of parks, green spaces, and open spaces, as well as the quality of available recreational facilities, are relatively consistent significant positive correlates of recreational physically activity. Fewer studies identified sidewalk length, intersection density, access to walking trails, and safety as significant correlates of recreational physical activity and more research is required regarding these measures.

Some of the more notable results include the finding that proximity to or density of recreational facilities was identified as having no significant association with recreational

physical activity in a majority of studies that examined that relationship.[241] The evidence did indicate, however, that the quality or attractiveness of recreational facilities, as well as the presence of certain sizes or types of parks within specific travel distances are most likely to influence recreational physical activity. Access to walking trails may also play a stronger role in influencing recreational *walking* than the presence or proximity of a public open space does. Intersection density also appears to have a relatively strong influence on *walking* for recreation purposes, but not on other forms of recreational physical activity. Intersection density also has strong associations with transportation walking, and it is therefore possible that this characteristic may exert an influence on walking generally rather than on other types of physical activity, regardless of the purpose of the activity.

2.5.2 The Food Environment

Having summarized the evidence regarding associations between the built environment and different forms of physical activity, this paper now turns to discuss evidence regarding the food environment and dietary intake. Overall, evidence of relationships between measures of the food environment and dietary intake is mixed and inconsistent. Several trends were identified. First, older reviews generally reported a majority of significant associations between the proximity or density of healthy food stores (e.g. supermarkets and grocery stores) and healthy dietary outcomes.[242] But more recent reviews that have attempted to categorize independent and dependent variables with greater specificity indicate that a majority of studies have reported null

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[241] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," 8.

[242] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review;" Nicole I Larson, Mary T Story, and Melissa C Nelson, "Neighborhood Environments: Disparities in Access to Healthy Foods in the U.S," *American Journal of Preventive Medicine* 36, no. 1 (2009): 74–81; Black and Macinko, "Neighborhoods and Obesity."

associations.[243] Nonetheless, the considerable heterogeneity in both independent and dependent variables examined remains a barrier to meaningful comparison of results across studies.

Secondly, fruit and vegetable consumption is the most commonly examined dependent variable in the literature.[244] There is relatively strong evidence that greater proximity to or density of stores hypothesized to sell fruits and vegetables (e.g., supermarkets, grocery stores, and green grocers) is linked to increased fruit and vegetable consumption.[245] But most reviews indicate that, while there is a trend toward identifying significant relationships, the majority of studies that have examined this relationship reported null associations.[246] Reviews that have focused on fast food consumption have also generally reported mixed associations between proximity or density of fast food outlets and fast food consumption.[247]

Thirdly, perceived measures of the food environment assessed through participant survey are generally more consistently associated with dietary intake outcomes than objective measures of the food environment calculated using GIS.[248] For example, Caspi et al. found that six out of seven studies which examined measures of perceived food availability reported significant

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[243] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?."

[244] Elham Rahmanian, Danijela Gasevic, Ina Vukmirovich, and Scott a Lear, "The Association Between the Built Environment and Dietary Intake - a Systematic Review," *Asia Pacific Journal of Clinical Nutrition* 23, no. 2 (2014): 183–96.

[245] Larson, Story, and Nelson, "Neighborhood Environments: Disparities in Access to Healthy Foods in the U.S."

[246] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?;" Rahmanian, Gasevic, Vukmirovich, and Lear, "The Association Between the Built Environment and Dietary Intake - a Systematic Review."

[247] See Lorna K Fraser et al., "The Geography of Fast Food Outlets: a Review," *International Journal of Environmental Research and Public Health* 7, no. 5 (2010): 2290–2308; S E Fleischhacker et al., "A Systematic Review of Fast Food Access Studies," *Obesity Reviews: an Official Journal of the International Association for the Study of Obesity* 12, no. 5 (2011): e460–71.

[248] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review."

relationships with dietary outcomes.[249] By comparison, only thirteen out of twenty studies that examined the presence or availability of food stores within a neighbourhood or buffer reported significant associations with dietary outcomes.[250] It is therefore possible that individuals' perceptions of availability and accessibility of healthy or unhealthy foods within the food environment may play a substantial role in influencing their dietary behaviours. Unfortunately, calculation of such measures for the City of Toronto was outside the scope of the analysis conducted in this paper.

Further examination of the complex relationships between the food environment, dietary intake, income, race, and sex is necessary to advance the literature, but is also outside the scope of this paper. While this review was focused on adults and not on population sub-groups, a majority of research does support the proposition that access to fast food outlets (which sell less healthy foods) is higher in neighbourhoods that have a higher proportion of low income and visible minority populations. These results support the need for interventions targeted at improving access to affordable, healthy foods in low-income communities. Accordingly, despite the somewhat mixed results identified in this review, it remains pertinent to further examine the patterns of proximity to and density of stores selling more healthy and less healthy foods in the City of Toronto. The variables selected for further analysis are presented in Table 3. Though the evidence regarding associations between these objective food environment measures and dietary intake is mixed, the majority of the literature has focused on the United States and only one known study has previously examined these variables in the City of Toronto.

Table 3. Built Environment Variables Significantly Associated with Measures of Dietary Intake*.

Variable	Example of Variable Definition	Relevant Reviews and Studies

[249] ibid., 1175.
[250] ibid.

More Healthy Food		
Proximity of More Healthy Food Sources	Network or euclidean distance from home to the nearest supermarket, grocery store, or green grocer.	Black et al., 2014; Caspi et al., 2012; Larson et al., 2009; Black and Macinko, 2008
Density of More Healthy Food Sources	Number of supermarkets, grocery stores, and green grocers within a neighbourhood divided by the total area of a neighbourhood in sq km	Black et al., 2014; Caspi et al., 2012; Black and Macinko, 2008
Less Healthy Food		
Proximity of Less Healthy Food Sources	Network or euclidean distance from home to the nearest fast food outlet or convenience store.	Fleischhacker et al., 2011; Fraser et al., 2010
Density of Less Healthy Food Sources	Number of fast food outlets and convenience stores within a neighbourhood divided by the total area of a neighbourhood in sq km	Fleischhacker et al., 2011; Fraser et al., 2010

*Examples of dependent variables include:

- daily fruit and vegetable consumption
- daily fast food consumption
- overall daily energy intake
- daily intake of specific nutrients
- measures of food purchasing behaviour

2.5.3 Physical Activity Environment and Food Environment Correlates of Weight Status

A total of 31 studies were identified that reviewed or examined the relationship between various measures of the physical activity environment and/or the food environment and various indicators of weight status (e.g., BMI, overweight, obesity, waist circumference). Together these studies indicated that very few of the independent variables examined in the literature demonstrate consistent significant associations with weight status. The evidence is mixed and inconsistent for a number of physical activity environment variables, including measures of street pattern, access to parks, green spaces and recreational facilities, and composite walkability indices. Several recent reviews concluded that the only two measures of the physical activity environment consistently associated with weight status outcomes were density and land use mix,

and even among these reviews there was some disagreement.[251] With respect to the food environment, the only objective measure that has emerged as a potential correlate of weight status is proximity to or density of fast food outlets.[252] The evidence regarding this measure is still relatively equivocal,[253] though one of the few longitudinal studies identified in this review reported significant increases in weight and waist circumference among participants living in areas with higher densities of fast food outlets.[254]

This lack of positive findings may be attirubted in part to the great heterogeneity in measures of the environment and definitions of "neighbourhoods" used in different studies, which has made it consistently difficult for reviews to draw conclusions based on existing evidence.[255] The models discussed previously suggest that relationships between the built environment, physical activity, diet, and weight status are complex and there are many potential individual and environmental drivers and modifiers. Thus, research that targets specific population sub-groups (rather than adults generally) and specific environmental influences may prove more effective in identifying associations. For example, there is relatively strong support for the notion that neighbourhoods with lower-income and higher visible minority populations have worse access to healthy food stores and better access to unhealthy food stores, as well as a

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[251] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review;" Mackenbach et al., "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and Adult Weight Status, the SPOTLIGHT Project;" Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence."

[252] Fleischhacker et al., "A Systematic Review of Fast Food Access Studies;" Fuzhong Li et al., "Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults: Portland Neighborhood Environment and Health Study," *American Journal of Epidemiology* 169, no. 4 (February 14, 2009): 401–8.

[253] Fraser et al., "The Geography of Fast Food Outlets: a Review."

[254] Li et al., "Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults: Portland Neighborhood Environment and Health Study."

[255] Joanna E Holsten, "Obesity and the Community Food Environment: a Systematic Review," *Public Health Nutrition* 12, no. 3 (2009): 397–405.

higher risk of obesity, especially among women.[256] A further difficulty is that most studies to date are ecological, and therefore even those with significant positive results cannot be interpreted as demonstrating causality. Therefore future research should utilize longitudinal study designs to examine the influence of specific environment-behaviour relationships on weight status and waist circumference in specific population sub-groups over time.

Table 4 presents the physical activity environment and food environment variables selected for further analysis in this paper. Density, land use mix, and the sprawl index were the only measures of the physical activity environment that had clear associations with body weight. The only food environment variable consistently associated with body weight was proximity to or density of fast food outlets. Despite these findings, it is nonetheless possible that other built environment factors (either individually or in combination with each other) may influence weight status through complex pathways in specific population sub-groups. More detailed evidence regarding the relationships between these variables and weight status outcomes is further discussed in Appendix C.

Table 4. Built Environment Variables Significantly Associated with Measures of Weight Status*.

Variable	Example of Variable Definition	Relevant Reviews and Studies
Density		
Gross Population Density	Persons per square km	Grasser et al., 2013; Zick et al., 2009
Land Use Mix		
Land Use Mix Entropy	$-\frac{\sum_k (p_k \ln p_k)}{\ln N}$ where: • k is the category of land use • p is the proportion of land area within a neighbourhood devoted to a category of land use	Mackenbach et al., 2014; Sallis et al., 2009; Feng et al., 2010; Brown et al., 2009

[256] Tim Townshend and Amelia A. Lake, "Obesogenic Urban Form: Theory, Policy and Practice," *Health and Place* 15 (2009): 909–16; Black and Macinko, "Neighborhoods and Obesity."

	• *N* is the number of land use categories in the study area	
Indices		
Sprawl Index	Comprised of 22 land use and street network variables reduced to four factors: residential density; land use mix; degree of centering; and street accessibility	Mackenbach et al., 2014; Feng et al., 2010
Fast Food		
Proximity of Less Healthy Food Sources	Network or euclidean distance from home to the nearest fast food outlet or convenience store.	Fleischhacker et al., 2011
Density of Less Healthy Food Sources	Number of fast food outlets and convenience stores within a neighbourhood divided by the total area of a neighbourhood in sq km	Li et al., 2009

*Examples of dependent variables include:

- Body Mass Index (calculated as body mass in kg divided by height squared in m^2)
- Waist circumference (in inches or centimeters)
- Overweight (e.g., BMI >=25)
- Obesity (e.g., BMI >= 30)

3 Geographic Information Systems Methodology

Upon conclusion of the literature review, this paper now turns to the methodology used for calculation of the identified components of healthy, active communities in the City of Toronto. Table 5 presents the components of the physical activity environment and food environment that are associated with transportation or physical activity, dietary intake, and/or weight status, as identified in the literature review. This section describes the data requirements and GIS methodology used to calculate each of these variables for Toronto.

The aim of these analyses was to generate and map for the City of Toronto each of the built environment variables identified in the literature review. The goal was to conduct an exploratory, rather than a confirmatory, analysis of the existing state of the built environment with respect to healthy, active communities in the study area. This focus was driven both through the need for a flexible approach in examining spatial variability of the built environment across

Toronto, as well as a lack of data with which to analyze and validate relationships between built environment variables and potential dependent variables in the study area. Accordingly, these analyses are a first step towards understanding the built environment as it may relate to physical activity, diet, and obesity in Toronto.

Table 5. Built Environment Components of Healthy, Active Communities and Variable Definitions for Analysis.

Variable	Analysis Definition	Data Sources	Relevant Outcomes
Density			
Gross Population Density	Total census population within a neighbourhood divided by the total area of a neighbourhood in sq km	Census of Canada, 2006 ("Census")	Transportation Physical Activity; Weight Status
Net Residential Density	Total number of census dwellings within a neighbourhood divided by the total residential area of a neighbourhood in sq km	Census; DMTI Spatial Inc.	Transportation Physical Activity
Gross Employment Density	Total number of jobs at places of employment located within a neighbourhood divided by the total area of a neighbourhood in sq km	Toronto Employment Survey, 2008 ("TES")	Transportation Physical Activity
Jobs-Housing Balance	Total number of jobs at places of employment located within a neighbourhood divided by the total number of census dwelling within a neighbourhood	Census; TES	Transportation Physical Activity
Land Use Mix			
Land Use Mix Entropy	$-\frac{\sum_k (p_k \ln p_k)}{\ln N}$ where: k is the category of land use p is the proportion of land area within a neighbourhood devoted to a category of land use N is the number of land use categories in the study area	Insufficient data	Transportation Physical Activity; Weight Status
Presence of Utilitarian Destinations	Per cent of neighbourhood population having access to a utilitarian destination* within an 800 metre network distance	City of Toronto; DMTI Spatial Inc.	Transportation Physical Activity
Proximity of Utilitarian Destinations	Population-weighted average network distance to the nearest utilitarian destination*	City of Toronto; DMTI Spatial Inc.	Transportation Physical Activity

Density of Utilitarian Destinations	Number of utilitarian destinations* within a 100 metre buffer of a neighbourhood, divided by the total area of the neighbourhood (including the 100 metre buffer) in sq km	City of Toronto; DMTI Spatial Inc.	Transportation Physical Activity
Street Pattern			
Intersection Density	Number of 3-way or greater intersections within a neighbourhood divided by the total area of a neighbourhood in sq km.	City of Toronto; DMTI Spatial Inc.	Transportation Physical Activity; Recreational Physical Activity
Sidewalk Length	Population-weighted average length of sidewalk within a 1km network distance of residential centroids	City of Toronto; DMTI Spatial Inc.	Recreational Physical Activity
Access to Parks and Recreational Facilities			
Quality of Recreational Facilities	Attractiveness of or satisfaction with recreational facilities	Insufficient data	Recreational Physical Activity
Availability of Parks, Green and Open Space	Per cent of neighbourhood population having access to a park, green or open space of a specified size within a specified network travel distance. The following size and distance combinations were examined: 0.01-0.49 ha within 400m 0.5-2.9 ha within 800m 3.0-4.9 ha within 1200m 5.0-14.9 ha within 3km 15.0+ ha within 5km	City of Toronto; DMTI Spatial Inc.	Recreational Physical Activity
Access to Walking Trails	Per cent of neighbourhood population having access to a multi-use trail within an 800 metre km network distance	City of Toronto; DMTI Spatial Inc.	Recreational Physical Activity
More Healthy Food			
Proximity of More Healthy Food Sources	Population-weighted average network distance from home to the nearest grocery store, fruit and vegetable store, or health food store	City of Toronto Healthy Environments Information System (THEIS)	Dietary Intake
Density of More Healthy Food Sources	Number of grocery stores, fruit and vegetable stores, and health food stores within a neighbourhood divided by the total area of a neighbourhood in sq km	THEIS	Dietary Intake
Less Healthy Food			
Proximity of Less Healthy Food Sources	Population-weighted average network distance to the nearest fast food restaurant, convenience store, or pizza restaurant.	THEIS	Dietary Intake; Weight Status

Density of Less Healthy Food Sources	Number of fast food restaurants, convenience stores, and pizza restaurants within a neighbourhood divided by the total area of a neighbourhood in sq km	THEIS	Dietary Intake; Weight Status
Indices			
Walkability Index	Comprised of weighted z-scores of: residential density; intersection density; land use mix entropy; and retail floor area ratio	Insufficient data	Transportation Physical Activity
Sprawl Index	Comprised of 22 land use and street network variables reduced to four factors: residential density; land use mix; degree of centering; and street accessibility	Insufficient data	Transportation Physical Activity; Weight Status
Other			
Safety	Number of crimes per year in a defined neighbourhood; also commonly assessed based on participant perceptions of safety from crime.	Insufficient data	Recreational Physical Activity
Slope/Hilliness	Standard deviation of slope (average change in elevation) in degrees within a defined neighbourhood	Insufficient data	Transportation Physical Activity

*See Appendix B, *infra* for the definition of utilitarian destinations.

3.1 Data and Software Requirements and Limitations

Creation of the built environment variables presented in Table 5 required specialized GIS software and a variety of data. All analyses presented in this paper were conducted using ArcGIS version 10.2, and MapInfo Professional version 7.0.[257] All variables were derived using data from the Census of Canada; DMTI Spatial Inc.; City of Toronto Open Data; City of Toronto Employment Survey; and the City of Toronto Healthy Environments Information System. The specific data sources used for calculating each built environment variable are listed in Table 5.

[257] "ArcGIS," version 10.2.0.3348 (ESRI Inc., 2013); "MapInfo Professional," version 7.0 (MapInfo Corporation, 2002).

Unfortunately, data limitations removed the possibility of calculating certain key variables identified in the literature review. These variables were land use mix entropy, quality of recreational facilities, composite walkability index, sprawl index, safety, and slope/hilliness. Land use mix entropy requires detailed parcel-level data regarding square footage devoted to each category of land use within a study area. Such data for urban areas in Ontario is available for purchase from the Municipal Property Assessment Corporation, but the cost was prohibitive against acquisition for use in this paper. DMTI Spatial Inc. also publishes generalized land use data that was available for analysis, but this data lacked the parcel-level detail required to calculate land use mix entropy. Because both the composite walkability index and the sprawl index include the land use mix variable, it was also not possible to calculate these indices.

Assessment of the quality of recreational facilities typically relies on some form of subjective or objective survey data.[258] Toronto Open Data does provide information regarding the different types of facilities available at public recreation centres (e.g., swimming pools, ice rinks), but it was not feasible to derive a measure of attractiveness or satisfaction with recreational facilities using this data.

Variables representing "safety" are calculated either objectively using location-based crime data or subjectively through participant survey regarding perceptions of crime. Limited location-based crime data is available from the Toronto Police Service, however this data is aggregated to the spatial unit of police divisions, which are larger than the neighbourhood units selected for the analysis in this paper. To avoid disaggregation of data, it was decided not to examine safety in this analysis.

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[258] See Sugiyama et al., "Destination and Route Attributes Associated with Adults' Walking: a Review," 1280.

Finally, calculation of variables representing slope or hilliness requires digital elevation model (DEM) data for the study area. This is raster-based data, with each raster cell representing the ground level elevation at its location. DEM data for all of Canada is available from Natural Resources Canada's GeoGratis service. However, the GIS skills required to work with this data were beyond those of this author, and a decision was made to not examine this variable further.

Despite these limitations, data was available for calculation of the majority of built environment variables identified in the literature review. The methodologies used in calculating these variables are discussed below.

3.2 Analyses

This section describes the methodologies used in calculating the built environment variables that comprise a healthy, active community, as listed in Table 5 above. The basic variable definition and data source(s) used to calculate each variable are listed in Table 5, along with the outcomes of relevance to each variable as identified in the literature review. The literature review also indicated that there are a wide variety of potentially relevant built environment variable definitions, and there is a need for increased consistency in variable definitions and reporting of research methodologies.[259] Our analysis therefore adopted, where feasible, existing analysis protocols published in Forsyth et al.'s Environment and Physical Activity GIS Protocols Manual.[260] It was necessary to modify these protocols in some instances, however, given data availability, and accordingly the detailed methodologies used in defining

[259] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 118-119.

[260] Ann Forsyth et al., "Neighborhood Environment for Active Transport--Geographic Information Systems Protocols," *Design for Health*, accessed April 1, 2015, http://designforhealth.net/wp-content/uploads/2012/12/NEAT_GIS_V5_1_Jan2012.pdf.

and cleaning the units of analysis, and generating each of the built environment variables listed in Table 5, are discussed below.

3.2.1 Study Area and Units of Analysis

The study area for all analyses was the City of Toronto (n = 2,503,281). Two units of analysis were utilized in generating and mapping the built environment variables, the Dissemination Block ("DB") and the Neighbourhood. Both of these units, and all population and dwelling data used in these analyses, were derived from the 2006 Statistics of Canada Census. A decision was made to use the 2006 Census as opposed to the 2011 Census due to the improved reliability and availability of the 2006 Census data at the time the analyses were initiated.

Dissemination Blocks are the smallest areal units for which Statistics Canada disseminates population and dwelling count data in the Census of Canada. The boundaries of DBs are defined based on the Census road network and based on Dissemination Area (DA) boundaries. DBs are at least as small as city blocks defined based on the Census road network. They are also at least as small as DAs, which in some instances comprise only half a city block due to high population and dwelling densities in urban areas. Thus, DBs are at least as small as DAs (where one or multiple DAs exist within a city block), and in some instances are smaller than DAs (where one DA covers multiple city blocks). After data cleaning and removal of non-residential DBs, there were a total of n = 10,409 DBs within the study area, ranging in size and population from 0.00067 to 5.63 km^2 and 5 to 7,333 people, respectively.

DBs were selected as the initial unit of analysis for built environment variables that were generated based on road network travel distances. This is consistent with the trend toward utilizing buffers around study participants' places of residence when measuring the presence or

proximity of various destinations within the built environment.[261] Our analysis used a centroid point representing the geometric centre of a city block as the "origin" point in road network-based analyses, a method that is similar to the use of address- or postal-code based origin points in other studies.

Toronto Neighbourhoods were selected as the unit of analysis for calculation of density-based built environment variables and as the administrative unit for mapping of all analysis results. The City of Toronto's Social Policy Analysis and Research Unit defined Neighbourhood boundaries by aggregating Statistics Canada Census Tract units selected based on a variety of social planning criteria. These criteria included maintaining a target population of between 7,000 to 10,000 people in each Neighbourhood, aggregating component census tracts based on similarities in income levels, and respecting natural boundaries between neighbourhoods in the City. There were a total of 140 Neighbourhoods within the study area, ranging in size and population from 0.424 to 37.5 km^2 and 6,526 to 52,461 people, respectively.

The data cleaning procedures used to clean these units of analysis are described in further detail in Appendix D.

3.2.2 Road Network Creation

Several of the built environment variables included in this analysis required creation of a road network file for spatial analysis in the ArcGIS Network Analyst extension. These variables included the presence and proximity of utilitarian destinations, availability of parks and green spaces, and proximity of more and less healthy food sources. In this type of analysis, the distance along the road network from each residentially-weighted DB centroid ("origin" point) to each

[261] See Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science;" Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review."

location of a given resource (e.g., utilitarian destination) within a specific distance cutoff is calculated. These results are then queried to determine, for each DB centroid, the proximity (i.e. distance) to the nearest location of a given resource or the presence of a given resource within a defined network travel distance. The road network files used in this analysis were created based on data for the year 2009 from DMTI Spatial Inc., available through the York University Map Library. For all analyses other than the food environment variables, the road network was limited to "walkable" streets and paths; expressways and highways onramps were excluded from potential routes between origins and destinations because these analyses were focused on capturing walking routes and distances only.

3.2.3 Density Variables

A total of four density variables were included in the analyses: gross population density; net residential density; gross employment density; and jobs-housing balance. Population and residential dwelling data from the 2006 Census of Canada, and residential land use data from DMTI Spatial Inc., 2009, were used to calculate gross population density and net residential density for each Toronto Neighbourhood as defined in Table 5. Employment data from the Toronto Employment Survey, 2008, available through the Wellbeing Toronto mapping service, was used to calculate gross employment density for each Neighbourhood. The same employment data was used in combination with residential dwelling data from the 2006 Census of Canada to calculate the jobs to housing ratio for each Neighbourhood.

3.2.4 Land Use Mix Variables

A total of three land use mix variables were examined. These were the presence, proximity, and density of utilitarian destinations. Utilitarian destinations are neighbourhood resources such as grocery stores, supermarkets, restaurants, post offices, banks, or schools that

present opportunities for daily transportation physical activity. For the purpose of these analyses, utilitarian destinations were defined based on categories of "diverse uses" in the LEED for Neighbourhood Development rating system.[262] Further detail regarding the creation of the Utilitarian destinations data set using DMTI Spatial Inc. Enhanced Points of Interest data for the year 2009 is presented in Appendix D.

Using this dataset the presence, proximity, and density of utilitarian destinations were calculated as follows. Network analysis was used to calculate the road network distance in metres from each DB centroid to the nearest utilitarian destination. Results were then aggregated to the Neighbourhood level in order to map the proximity and presence of utilitarian destinations within each Neighbourhood. The presence measure was calculated as the per cent of a given Neighbourhood's population that had access to a utilitarian destination within an 800 metre road network distance. The proximity measure was calculated as the population-weighted average road network distance, in metres, from each DB centroid within a given neighbourhood to the nearest utilitarian destination.

The density measures were calculated using Neighbourhood boundaries. A 100 metre buffer of each Neighbourhood boundary was created in order to capture residents' ability to access utilitarian destinations that may exist on the opposite side of a street that defines a given Neighbourhood's boundary. The density of utilitarian destinations per square kilometre of gross neighbourhood area (including the additional buffer area) was then calculated using the Spatial Join function in ArcGIS. This function counted all utilitarian destinations within each buffered

[262] Congress for New Urbanism et al., *LEED 2009 for Neighbourhood Development Rating System with Canadian Alternative Compliance Paths*, 2011 ed., (Washington, DC: US Green Building Council, 2011), 145.

Neighbourhood. The resulting count was divided by the gross neighbourhood area in square kilometres to calculate the density of utilitarian destinations within each Neighbourhood.

3.2.5 Street Pattern Variables

Two measures of street pattern were calculated: intersection density and sidewalk length. Intersection density was calculated as the total number of three-way or greater intersections within a Neighbourhood divided by the gross area of the Neighbourhood in square kilometres. In order to capture intersections that existed on roadways bordering a given Neighbourhood, the file containing 100 metre buffers of Neighbourhoods was used in calculating both the numerator and denominator for this variable. The intersection file was generated using the 2009 road network data obtained from DMTI Spatial Inc. through the York University Map Library. Small five metre buffers of each intersection point were created and were spatially joined to the road network file to calculate the number of arcs (road and path segments) that met at each intersection. Only those intersections with three or more intersecting arcs were included in this calculation in order to exclude cul de sacs, which provide minimal connectivity.

Sidewalk length was calculated using 2011 sidewalk data obtained from the City of Toronto Open Data catalogue. The data obtained consisted of the road and multi-use trail network across Toronto, with fields indicating road classifications and sidewalk presence on both, one, or neither sides of the street. A measure of sidewalk length was initially derived for each DB based on the total length of sidewalk, in kilometres, within a 1 kilometre road network buffer of each DB centroid. To create this measure, a road network file based on the sidewalk data was created in ArcGIS Network Analyst. Each road and path segment was assigned a "sidewalk multiplier" field with a value of 2, 1, or 0 based on the presence of sidewalks on both,

one, or neither sides of the street, respectively. Walking paths and multi-use trails were assigned a multiplier value of 1.

A service area buffer analysis was then performed in ArcGIS Network Analyst to generate lines corresponding with each road segment or portion thereof that fell within a 1 kilometre road network buffer of each DB centroid. The sidewalk length associated with each of these line segments was then calculated as the length of each line segment multiplied by its corresponding sidewalk multiplier value. The total length of sidewalk for all line segments captured for each DB centroid within the 1km buffer was then calculated using the summary statistics tool in ArcGIS. For mapping purposes, these results were transferred to Neighbourhood units. The average sidewalk length for all DBs located within a given Neighbourhood was calculated, weighted based on the population associated with each DB.

3.2.6 Parks and Recreational Facilities Variables

Two parks and recreational facilities variables were calculated: availability of parks, green and open space; and access to walking trails. As identified in the literature review, both the size and proximity of parks, green and open spaces can influence recreational walking and physical activity. This finding is also reflected in urban planning guidelines for park availability within the City of Toronto and in other cities in the United States.[263] Based on these guidelines and the literature review, the availability of five categories of parks and open spaces within specific road network distance cutoffs was calculated. These park and open space categories and their corresponding distance cutoffs used are presented in Table 6. Further details regarding the

[263] City of Toronto, "Parks Plan 2013-2017," *City of Toronto*, (Toronto, 2013), accessed April 1, 2015, http://www.toronto.ca/legdocs/mmis/2013/pe/bgrd/backgroundfile-57282.pdf; J D Mertes and J R Hall, *Park, Recreation, Open Space and Greenway Guidelines*, (Arlington, VA: National Recreation and Park Association, 1996).

calculation of the park and green space availability variables using DMTI Spatial Inc. 2009 land use data are presented in Appendix D.

Table 6. Categories of Parks and Open Spaces and Corresponding Travel Distances.

Category	Size	Travel Distance
Parkette	0.01-0.49 Ha	400m
Neighbourhood Park	0.5-2.9 Ha	800m
Community Park	3.0-4.9 Ha	1200m
District Park	5.0-14.9 Ha	3km
City Park	15.0+ Ha	5km

In order to calculate access to walking trails, data containing entry points for access to multi-use trails for the year 2011 was obtained from the City of Toronto Open Data catalogue. This data contained the point locations of entrances to multi-use (e.g. walking and bicycling) trails within the study area. Network analysis was conducted using the Network Analyst extension to calculate the distance from each DB centroid to the nearest trail entrance point. This data was queried to calculate, for each DB, whether or not a trail entrance point was located within an 800 metre road network distance of the DB's centroid. For mapping purposes, this data was attributed to Neighbourhood units. The per cent of each Neighbourhood's population that had access to a trail entrance point within the 800 metre cutoff distance was calculated, based on the population of each DB located within a given Neighbourhood.

3.2.7 Food Environment Variables

Four food environment variables related to the availability and accessibility of more and less healthy sources of food were calculated. These variables were the proximity and density of "more healthy" sources of food and "less healthy" sources of food. Data was obtained from the

City of Toronto Healthy Environments Information System for the year 2009. This data is based on food inspector visits to each store or restaurant that sells food in the city. Extensive verification, cleaning, and categorization of this data was performed by Jane Polsky as part of her PhD thesis research. The cleaned data was used with her permission and the original (uncleaned) dataset is publicly available from the City of Toronto.

The cleaned dataset was originally categorized into six categories: fast food; convenience stores; pizza; supermarkets and grocery stores; fruit and vegetable stores; and health food stores. For the purposes of this analysis, two categories representing "more healthy" and "less healthy" food stores and restaurants were created. The more healthy food dataset contained grocery stores, fruit and vegetable stores, and health food stores, while the less healthy food dataset contained fast food restaurants, convenience stores, and pizza restaurants.

The ArcGIS Network Analyst extension was used to calculate the road network distance from each DB centroid to the location of the nearest food store or restaurant in each food dataset. The result was two fields for each DB, representing the distance to the nearest more healthy food store and to the nearest less healthy food store or restaurant, respectively. For mapping purposes, these results were attributed to Neighbourhoods. The average travel distance to the nearest location of a store or restaurant in each food category was calculated, weighted based on the population of each DB located within a Neighbourhood.

The density of more healthy and less healthy food stores and restaurants was calculated using 100 metre buffers of Neighbourhood units, in order to capture stores and restaurants located on the opposite side of a street that defined the boundary of a given Neighbourhood. For each Neighbourhood, all food stores and restaurants within a given food category that intersected the buffered Neighbourhood area were counted using a spatial join. These counts were then

divided by the buffered Neighbourhood area (in kilometers) to calculate the density of more healthy and less healthy food stores within a given Neighbourhood.

3.2.8 Mapping of Built Environment Variables

A choropleth map of each built environment variable displayed at the Neighbourhood level was created using using ArcGIS ArcMap version 10.2 and Adobe Illustrator CS2.[264] Data was classified using the Natural Breaks (Jenks) algorithm, which identifies clusters of data through minimizing the variance between data values within a class and maximizing the variance between data classes. On certain maps with a small number of outlier data values, the classifications were modified to enlarge the outlier data group. This was performed to avoid having a very small number of neighbourhoods (e.g. one to three) displayed in one class on a map. The map results are presented in Section 4, below.

4 Results

This section presents the findings of GIS analyses examining the spatial distribution in Toronto of built environment variables associated with physical activity, diet, and body weight. Each of the variables identified in Table 5, above, is depicted spatially in Figures 2 through 21, below. Following these figures is a discussion of the key findings identified in this analysis.

[264] "ArcGIS;" "Illustrator CS2," version 12.0.1 (Adobe Systems Inc., 2005).

Figure 2. Neighbourhoods of the City of Toronto, 2014

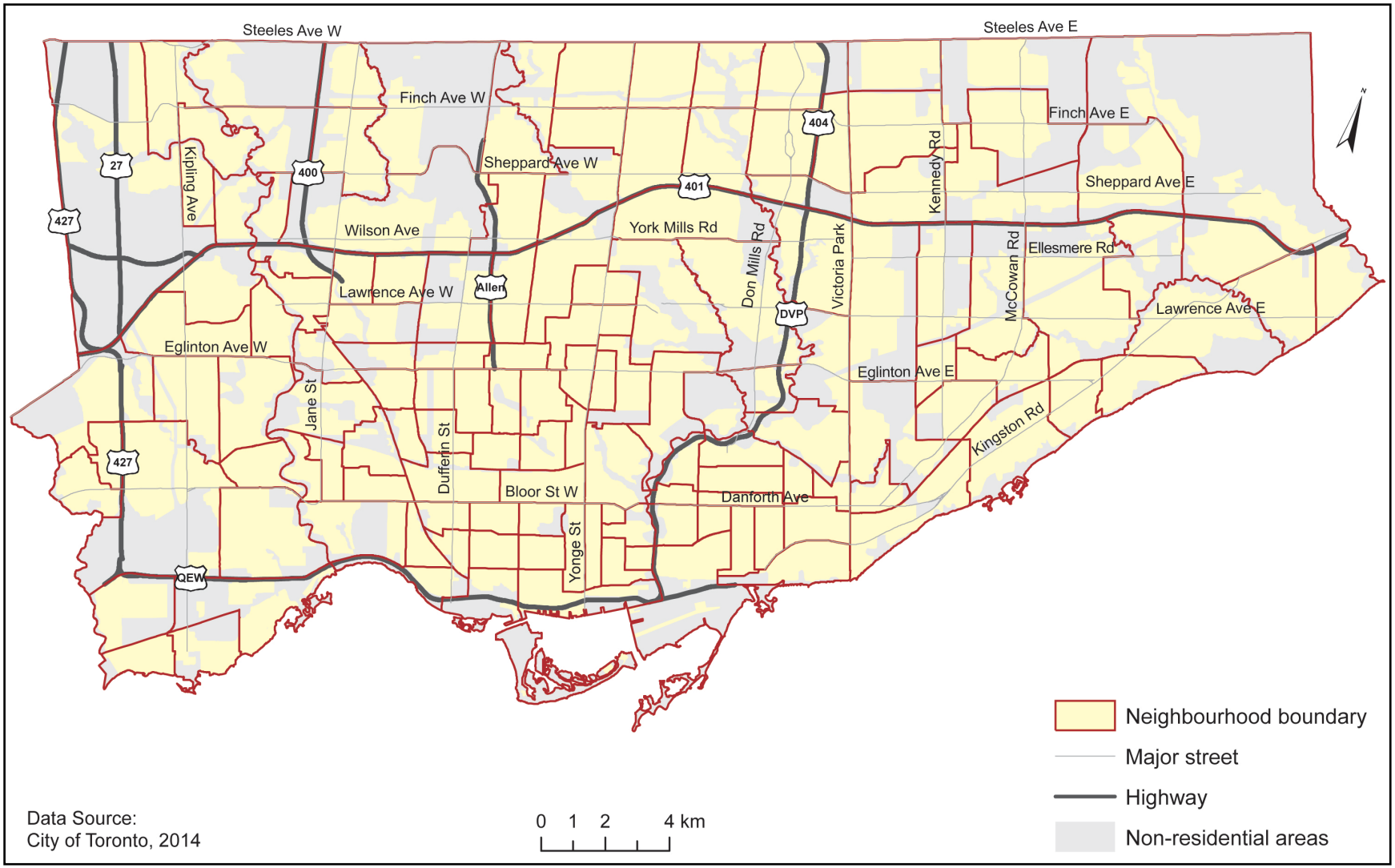

Figure 3. Gross Population Density in Toronto Neighbourhoods, 2006

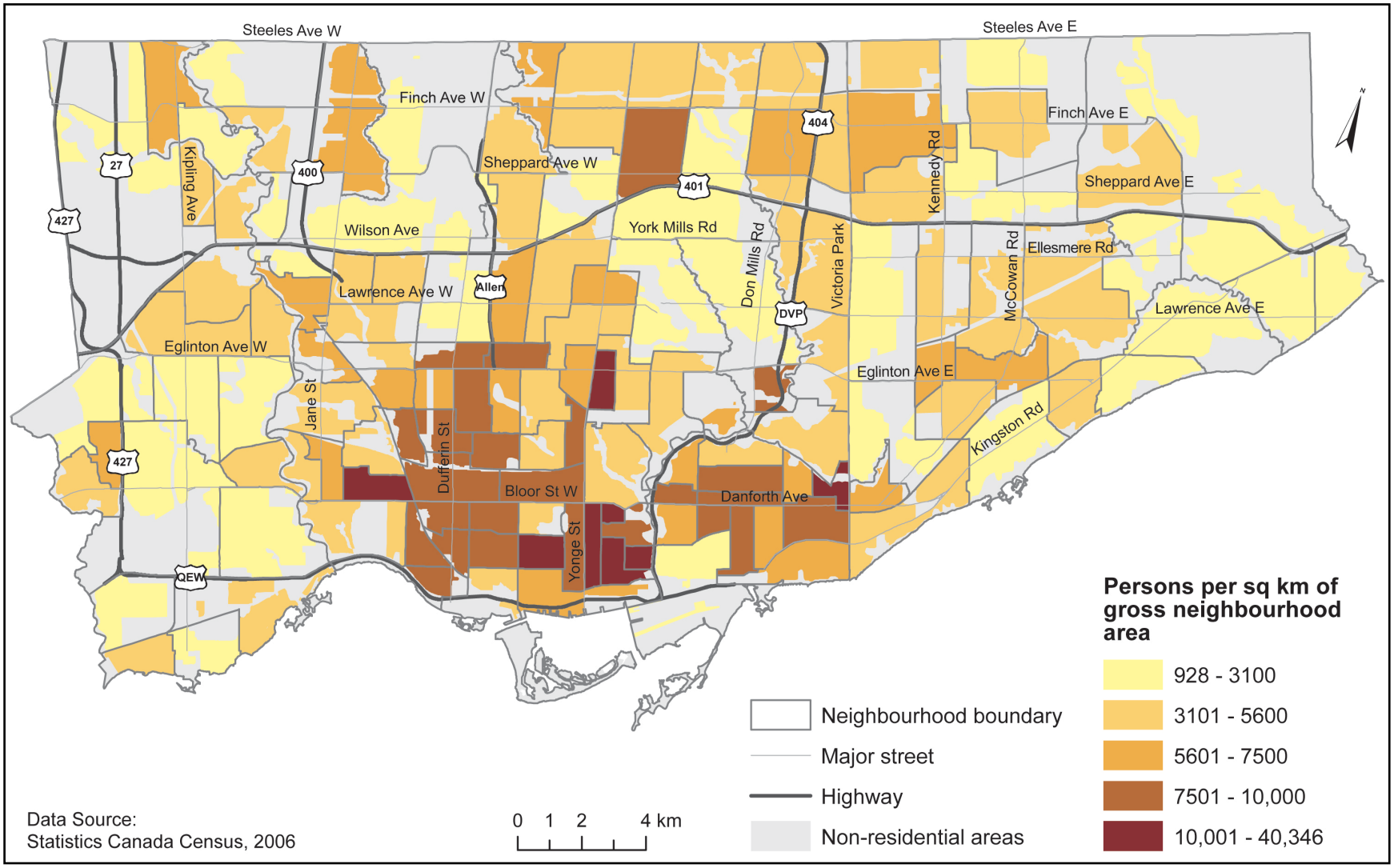

Figure 4. Net Residential Density in Toronto Neighbourhoods, 2006

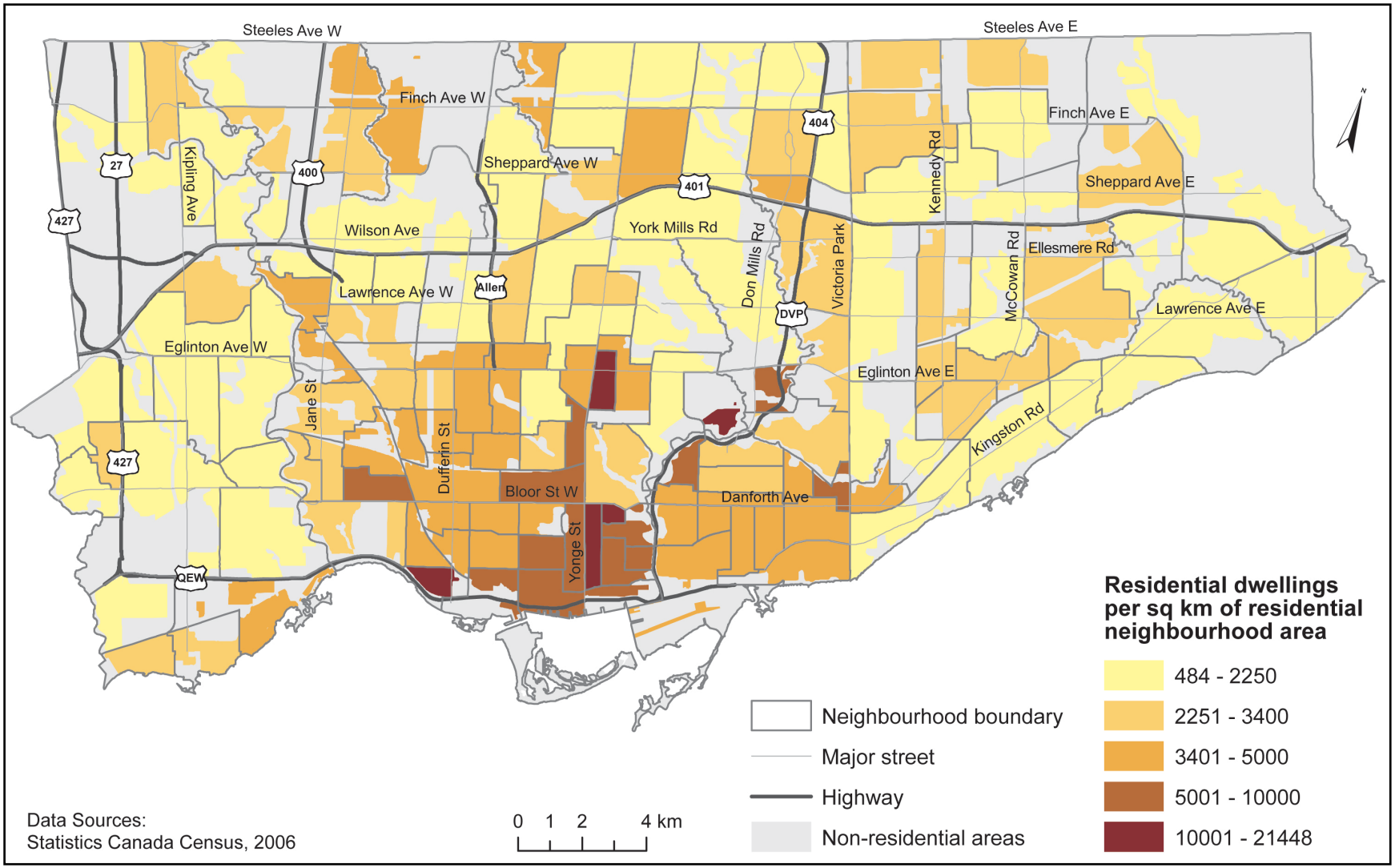

Figure 5. Gross Employment Density in Toronto Neighbourhoods, 2008

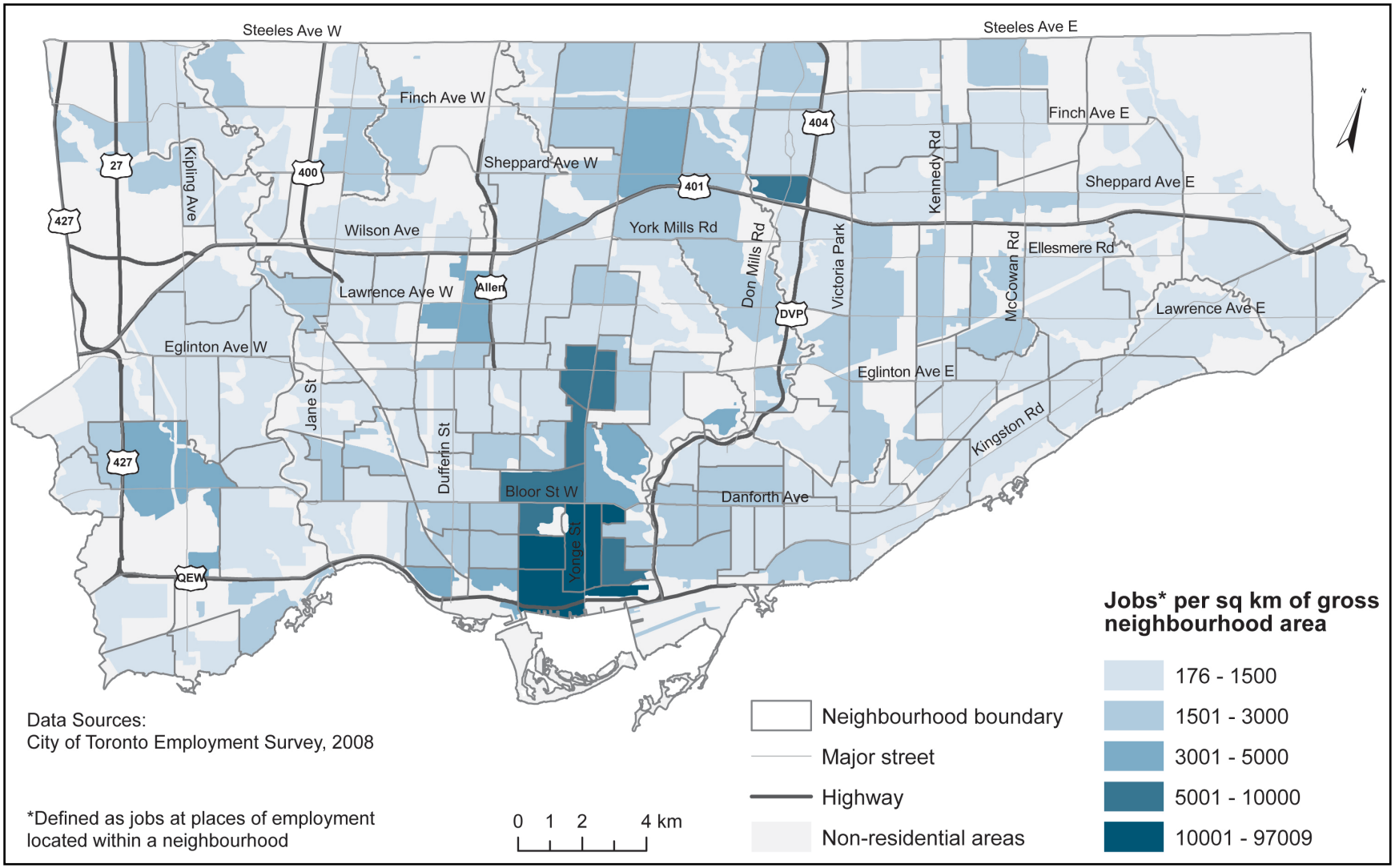

Figure 6. Ratio of Jobs (2008) to Residential Dwellings (2006) in Toronto Neighbourhoods

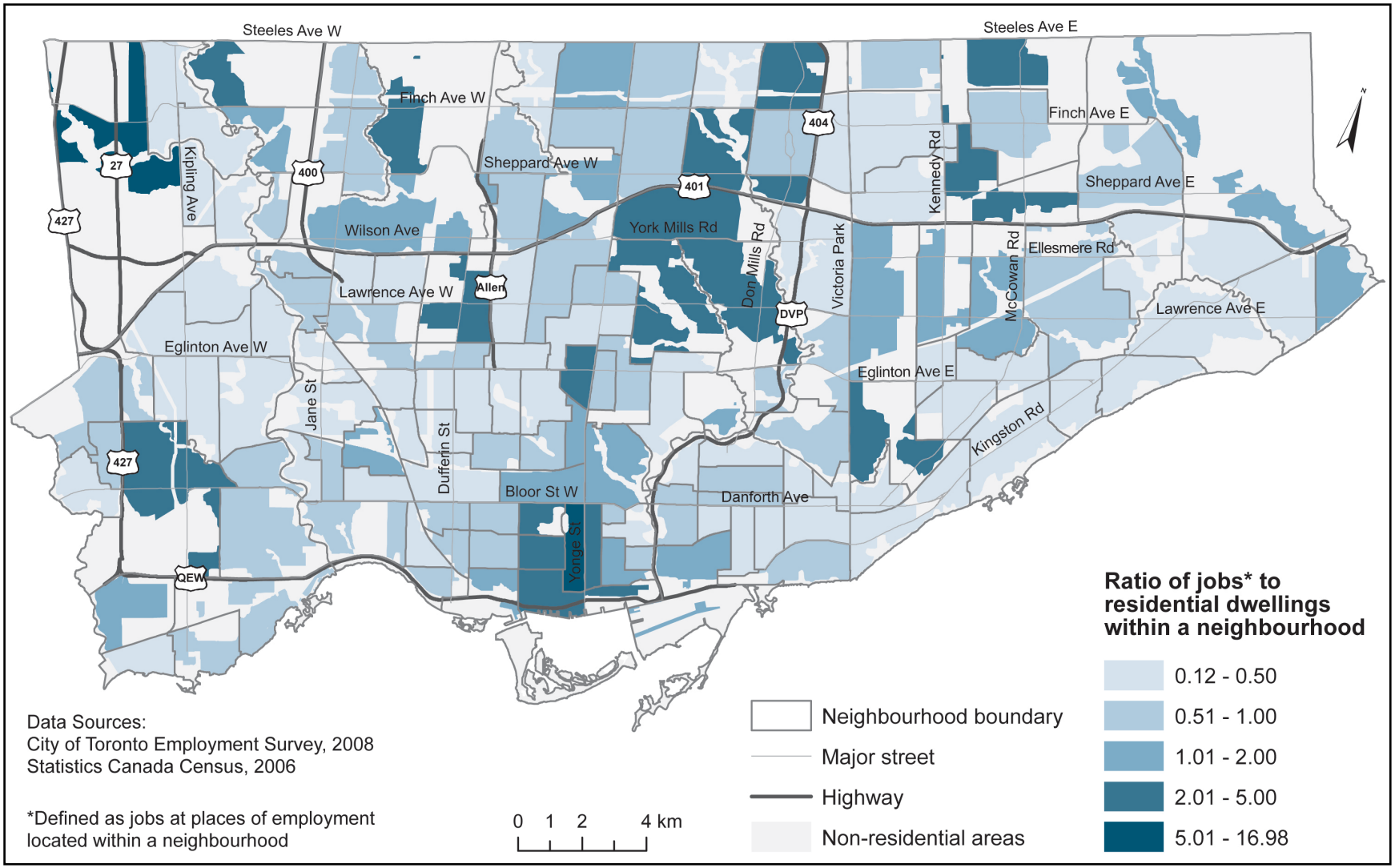

Figure 2 depicts Toronto's 140 Neighbourhoods, the unit of analysis used for display of all GIS analysis results. This map also highlights the non-residential areas of the city, which are overlaid on all other maps as well, to indicate the portions of the city in which people reside. The non-residential areas of Toronto include parks, ravines, employment and industrial areas. In particular, there are sizeable portions of the northwest and northeast of the city that are comprised of non-residential uses. In the northeast, there is an industrial area adjacent to Lester B. Pearson International Airport. In the northwest, a portion of the city is protected for agricultural and park uses under the *Greenbelt Plan*.[265]

The gross population density in Toronto Neighbourhoods is shown in Figure 3. Neighbourhoods with the highest number of persons per square kilometre (10,000 to 40,346) were found primarily in downtown Toronto, and in two midtown Neighbourhoods, one Neighbourhood in the west end, and one Neighbourhood in the east end of the city. A number of Neighbourhoods with the second-highest number of persons per square kilometre (7,501 to 10,000) were also found in these same areas, as well as some parts of Scarborough, Etobicoke, and North York. Neighbourhoods with the lowest number of persons per square kilometre (928 to 3,100) were found almost exclusively in Scarborough, Etobicoke, and North York.

The pattern of net residential density depicted in Figure 4 is generally similar to the pattern of gross population density shown in Figure 3. Neighbourhoods with the highest and second-highest number of residential dwellings per residential square kilometre (5,001 to 21,448) were located in downtown Toronto, the west end, east end, and midtown. There were no Neighbourhoods in Scarborough, Etobicoke, or North York that had the highest or second-highest number of dwellings per residential square kilometre. In comparison, a number of

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[265] Ministry of Municipal Affairs and Housing, *Greenbelt Plan*.

Neighbourhoods in Scarborough, Etobicoke, and North York had the lowest number of residential dwellings per square kilometre (484 to 2,250). Parts of uptown also had Neighbourhoods in the lowest category of net residential density.

Figure 5 displays gross employment density in Toronto Neighbourhoods, calculated based on the number of jobs at places of employment located within a given Neighbourhood. All Neighbourhoods with the highest number of jobs per square kilometre (10,0001 to 97,009) were located in downtown Toronto. This is not surprising given the concentration of high-density employment towers in Toronto's downtown financial district. Most of the other areas of the city had Neighbourhoods with the lowest- and second-lowest levels of gross employment density (176 to 3,000 jobs per square kilometre).

The ratio of jobs to residential dwellings in Toronto's neighbourhoods is presented in Figure 6. Neighbourhoods with the highest and second-highest ratios of jobs to residential dwellings (2.01 to 16.98) were found scattered across the city, in downtown, midtown, Etobicoke, North York, and Scarborough. Similarly, neighbourhoods with the lowest ratio of jobs to residential dwellings (0.12 to 0.50) were also found scattered throughout Toronto. These results indicate that, in addition to downtown Toronto, there are other areas of employment located throughout the city that provide jobs in excess of the number of dwellings in a given Neighbourhood.

Figure 7. Presence of Utilitarian Destinations* in Toronto Neighbourhoods, 2009

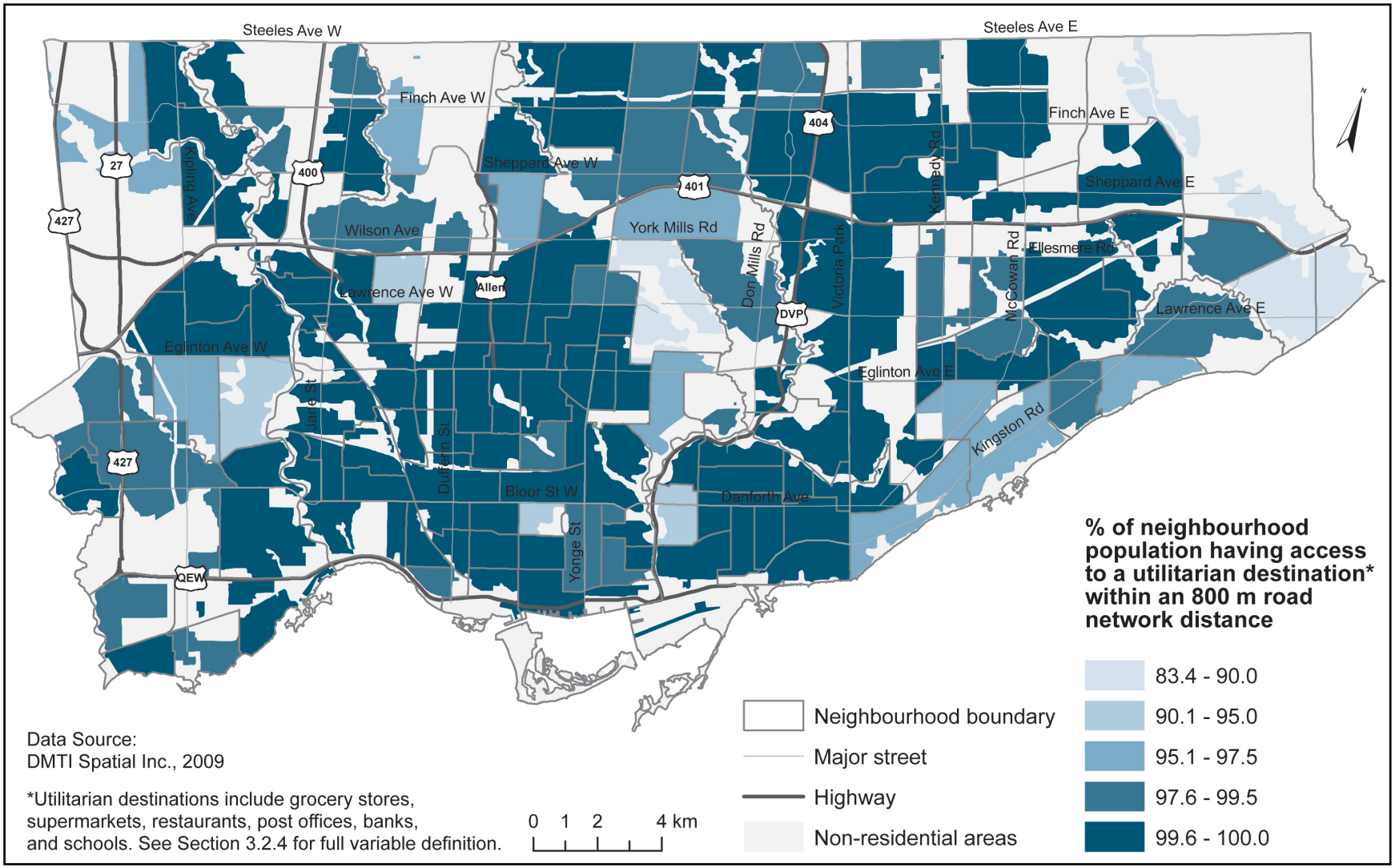


Figure 8. Proximity of Utilitarian Destinations* to Dissemination Block (DB) Centroids in Toronto Neighbourhoods, 2009

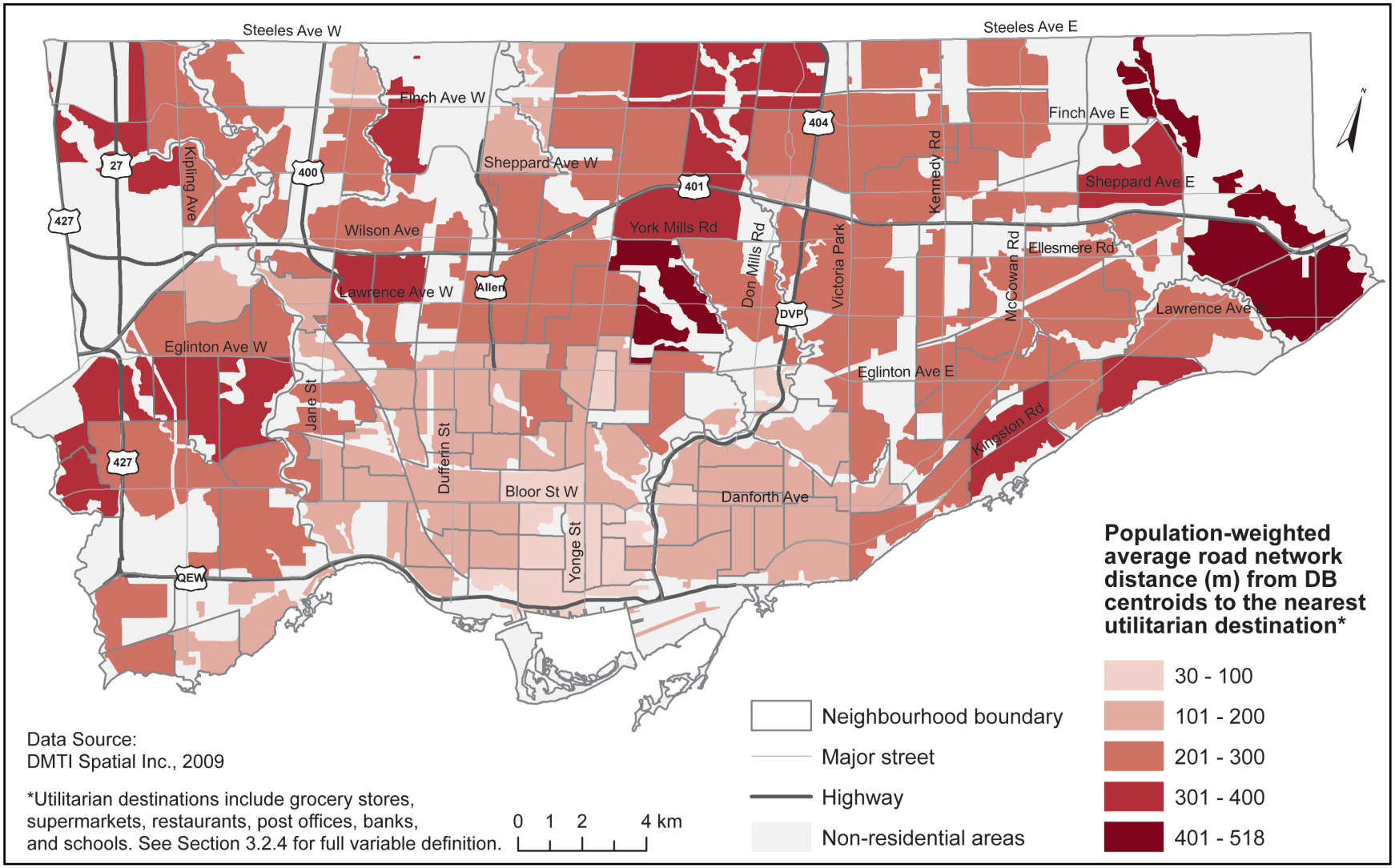
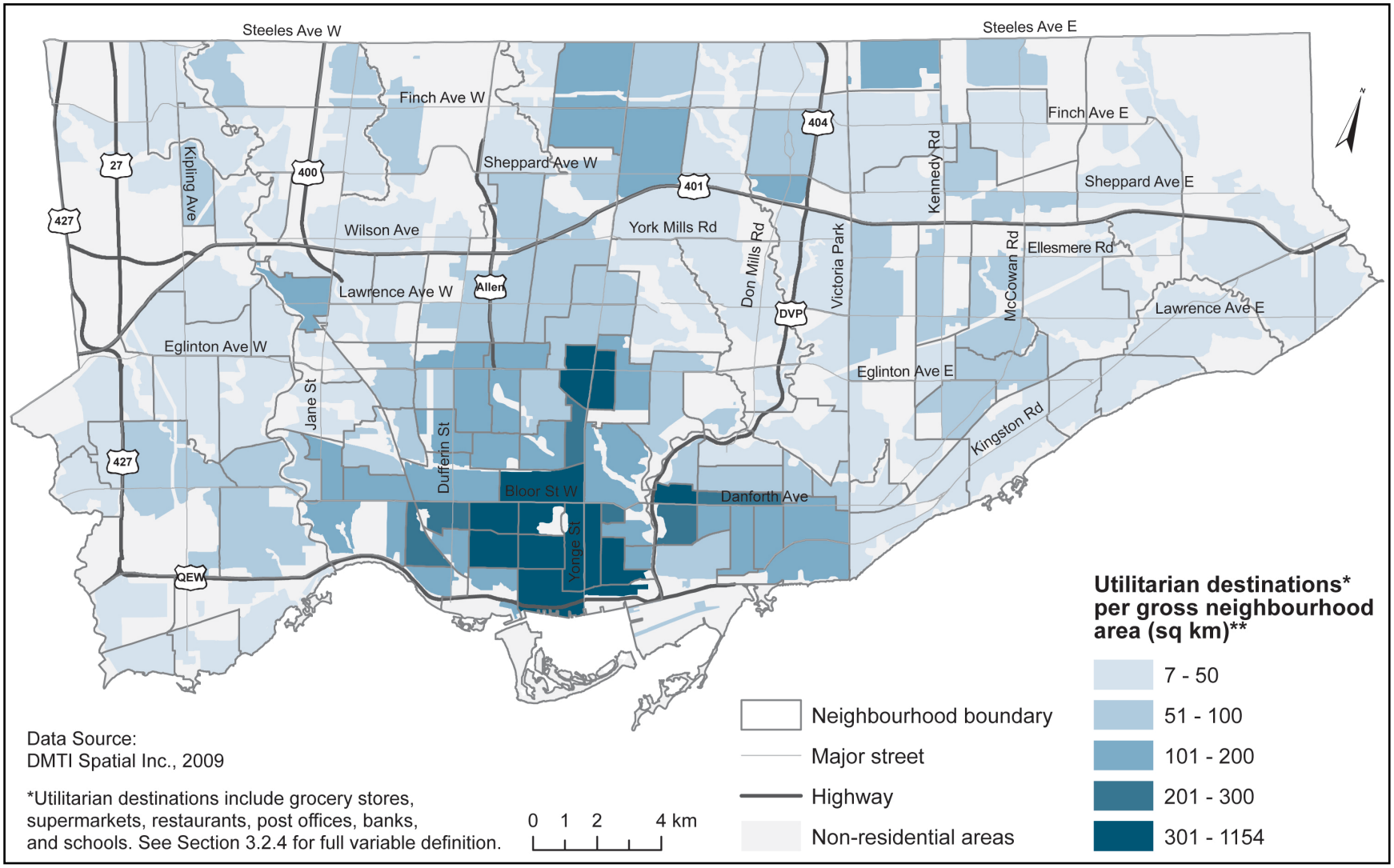


Figure 9. Density of Utilitarian Destinations* in Toronto Neighbourhoods, 2009



Maps depicting the presence, proximity, and density of utilitarian destinations such as grocery stores, restaurants, banks, post offices, and schools are presented in Figures 7, 8, and 9, respectively. Figure 7 examines the presence of utilitarian destinations, calculated as the per cent of a given Neighbourhood's population that had access to a utilitarian destination within an 800 metre road network distance. In general, all Neighbourhoods had a high proportion of residents that had access to a utilitarian destination within 800 metres. Even in those Neighbourhoods with the lowest level of access, 83.4 to 90.0 per cent of residents were able to access a utilitarian destination within 800 metres. These Neighbourhoods were found in eastern Scarborough and uptown. Most Neighbourhoods had even higher levels of access, with greater than 95 per cent of residents having access to a utilitarian destination within 800 metres in most Neighbourhoods across the City.

Figure 8 depicts the population-weighted average road network distance from residentially-weighted DB centroids within Neighbourhoods to the nearest utilitarian destination. In general, all Neighbourhoods had short average travel distances to the nearest utilitarian destination. Neighbourhoods with the longest travel distances in the city were located in east Scarborough and uptown, but even in these areas the average travel distance was 401 to 518 metres, equivalent to less than a 10 minute walk. Neighbourhoods with even shorter travel distances (30 to 200 metres) were located in downtown Toronto, most of the west end and east end, and a few areas of Etobicoke and North York.

Despite the relatively uniform results presented in Figures 7 and 8, the density of utilitarian destinations across Toronto, depicted in Figure 9, varied considerably. Neighbourhoods in downtown and some parts of midtown had the highest number of destinations per square kilometre (301 to 1,154). There were many Neighbourhoods in almost all other areas of Toronto that had the lowest density of utilitarian destinations (7 to 50 per sq km).

Figure 10. Intersection Density in Toronto Neighbourhoods, 2009

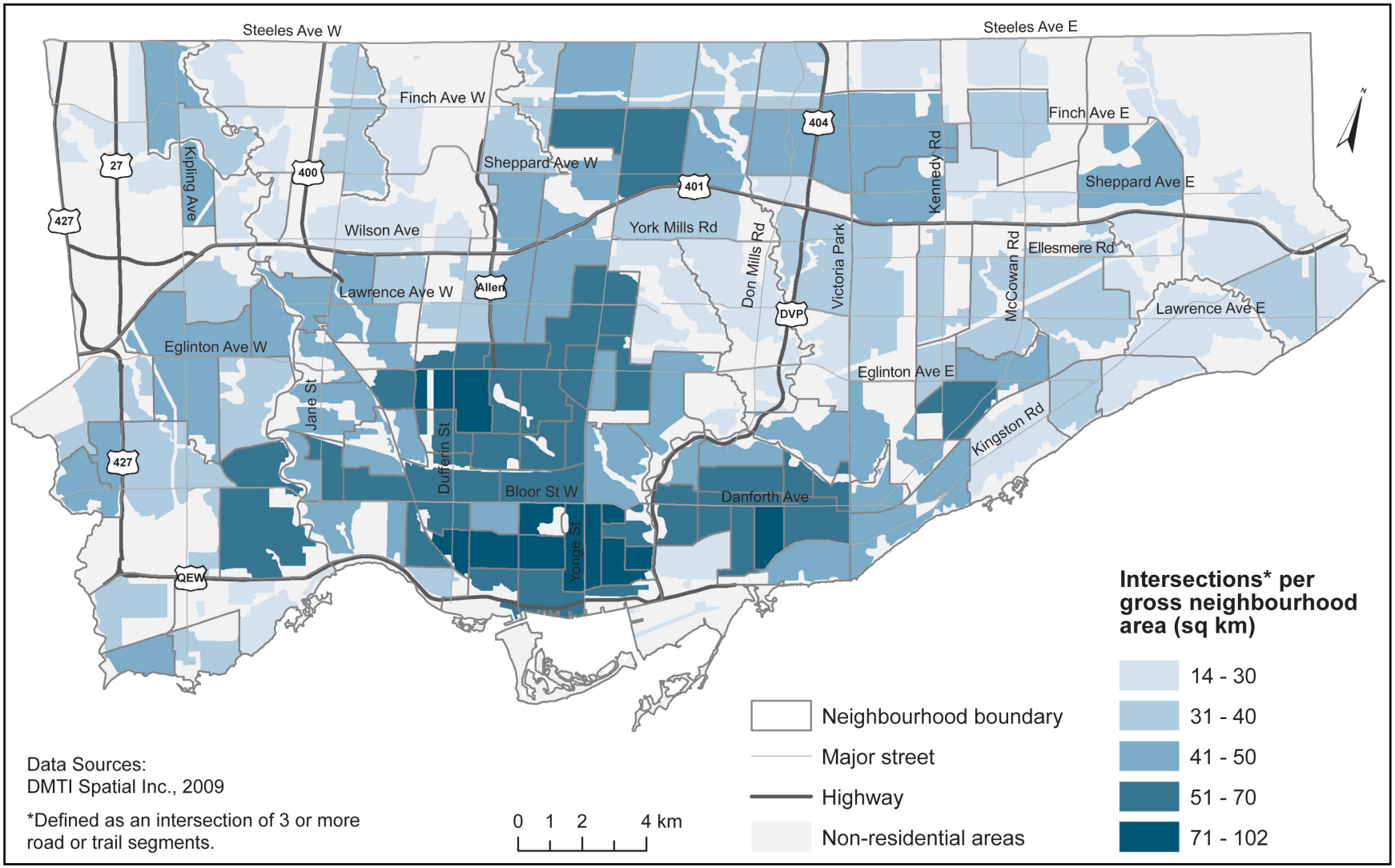
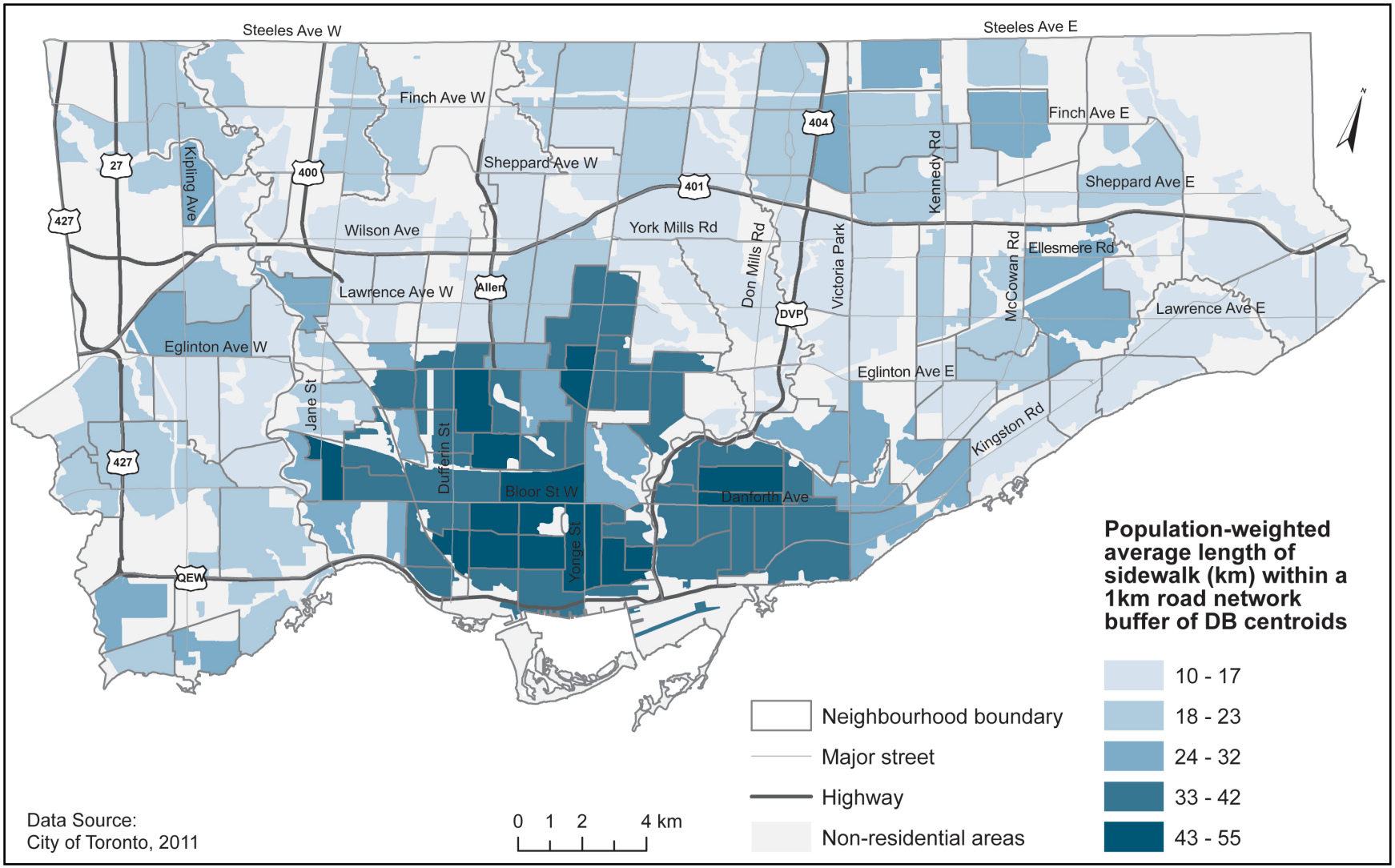


Figure 11. Average Sidewalk Length Within a 1 km Buffer of Dissemination Block (DB) Centroids in Toronto Neighbourhoods, 2011



The number of intersections per gross neighbourhood area in square kilometers is depicted in Figure 10. Neighbourhoods with the highest density of intersections (71 to 102 per sq km) were located in downtown Toronto, the northern west end, and the east end. The lowest density of intersections (14 to 30 per sq km) was found in Neighbourhoods located in Etobicoke, North York, Scarborough, and parts of uptown and midtown. There were also a small number of Neighbourhoods with medium and higher intersection density scattered throughout Etobicoke, Scarobourgh, and North York.

Figure 11 displays each Neighbourhood's population-weighted average sidewalk length, in kilometres, within a 1 kilometre road network buffer of DB centroids located within a given Neighbourhood. Neighbourhoods with the highest level of sidewalk length (an average of 43 to 55 km within a 1 km buffer) were located in downtown Toronto, midtown, and the west end and east end. Neighbourhoods with the lowest level of sidewalk length (an average of 10 to 17 km within a 1 km buffer) were located in a ring around these areas, and in parts of Scarborough, North York, and Etobicoke.

Figure 12. Per Cent of Neighbourhood Population Having Access to a Parkette* Within a 400 m Road Network Distance, 2009

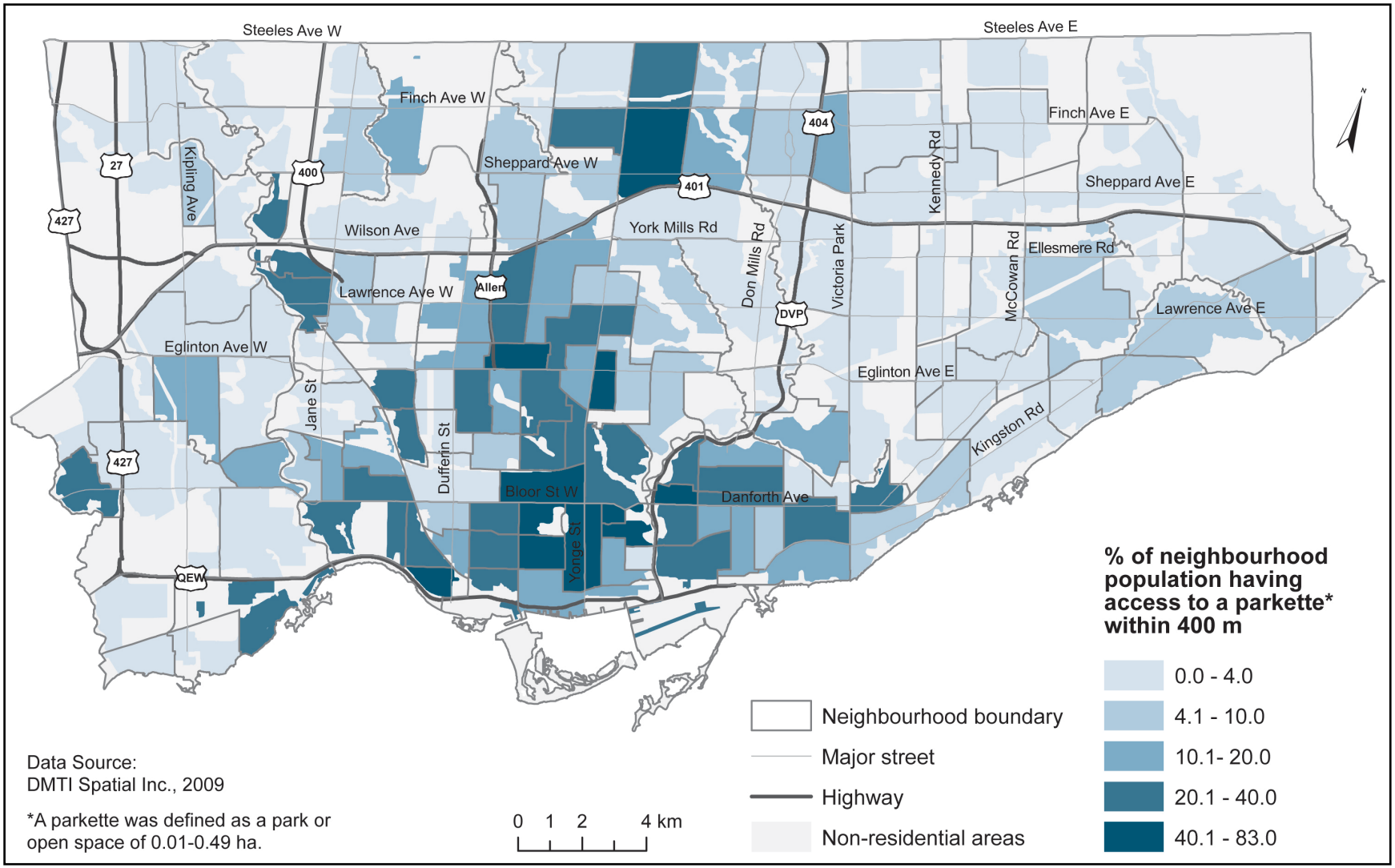


Figure 13. Per Cent of Neighbourhood Population Having Access to a Neighbourhood Park* Within a 800 m Road Network Distance, 2009

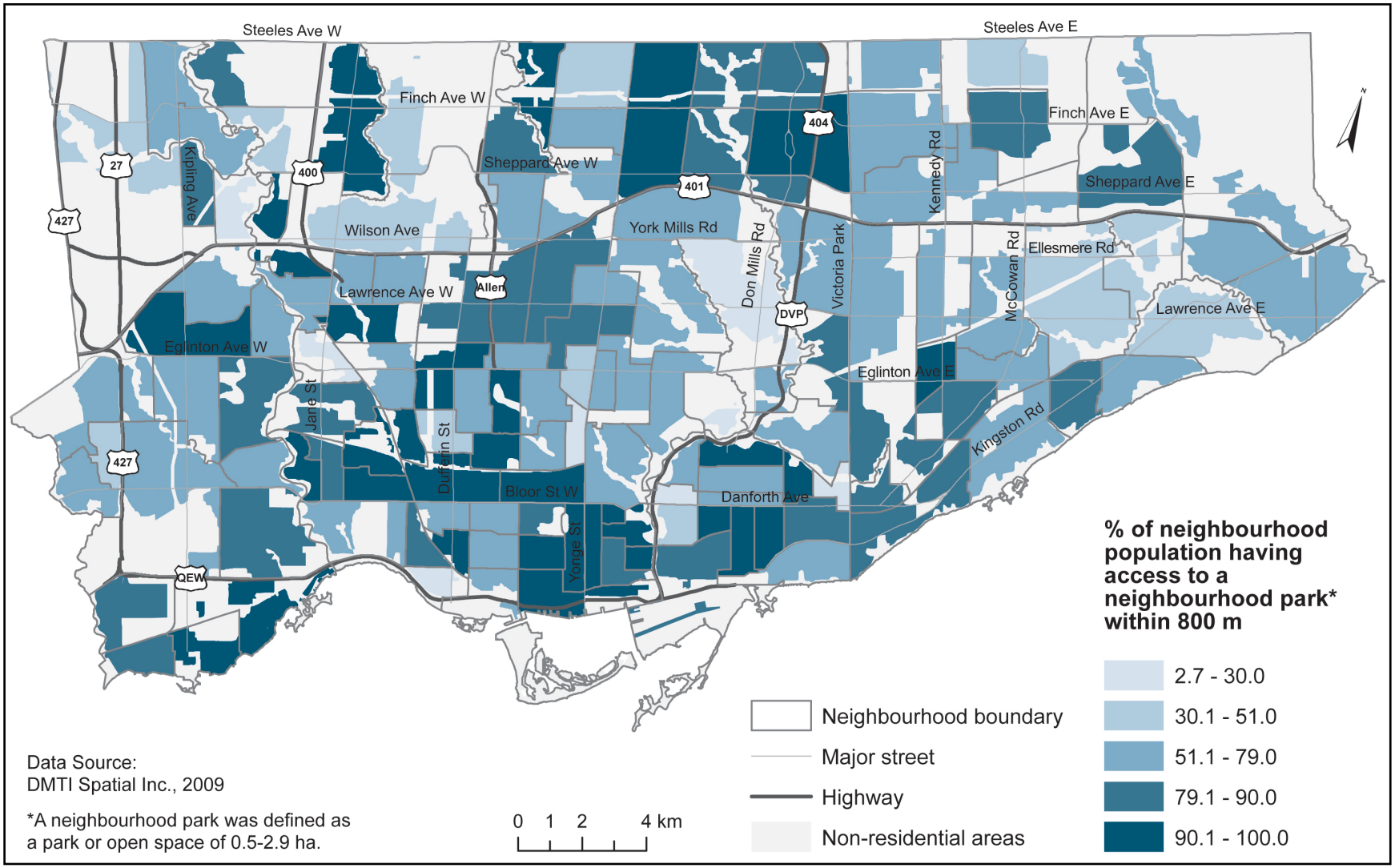


Figure 14. Per Cent of Neighbourhood Population Having Access to a Community Park* Within a 1.2 km Road Network Distance, 2009

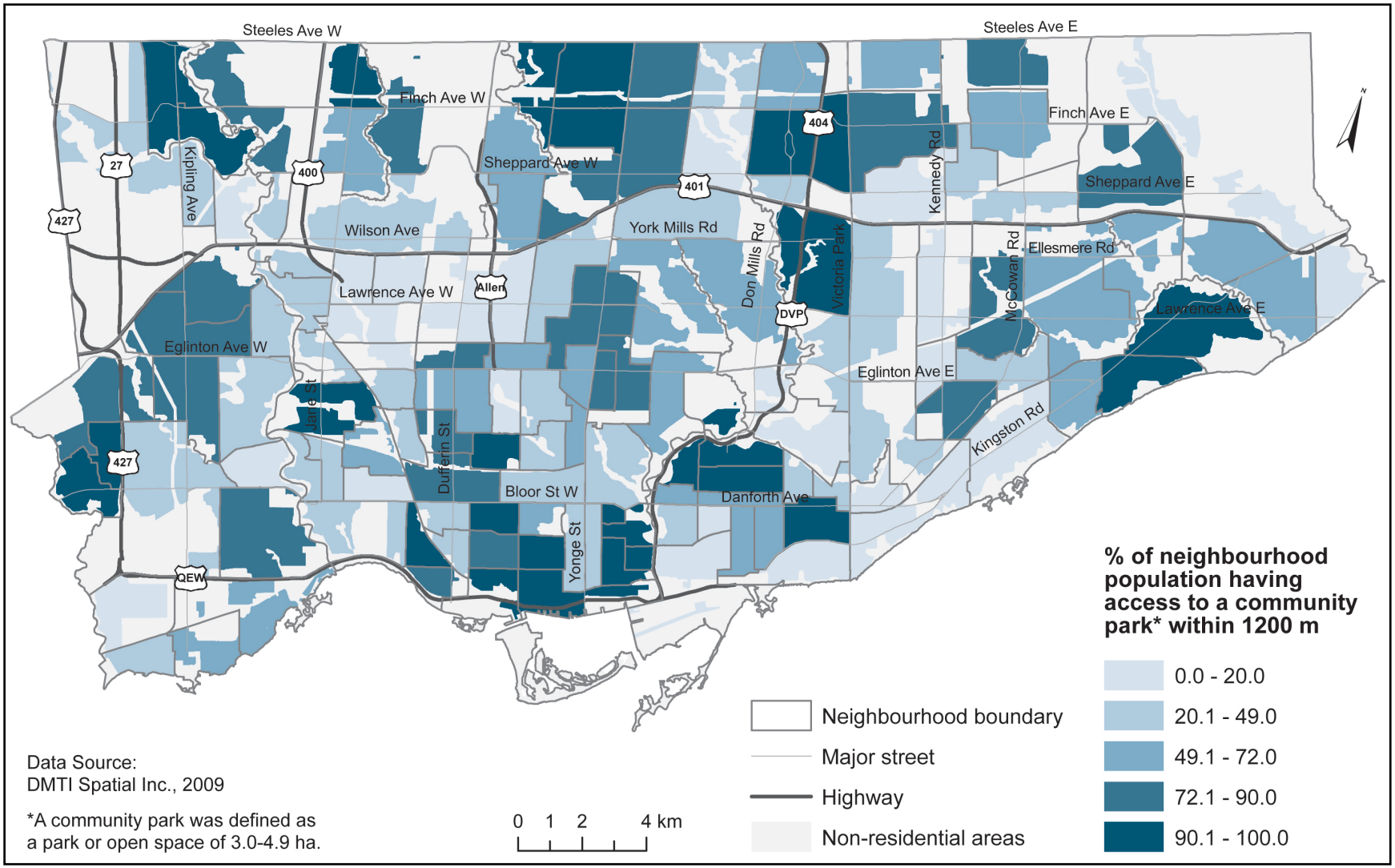


Figure 15. Per Cent of Neighbourhood Population Having Access to a District Park* Within a 3 km Road Network Distance, 2009

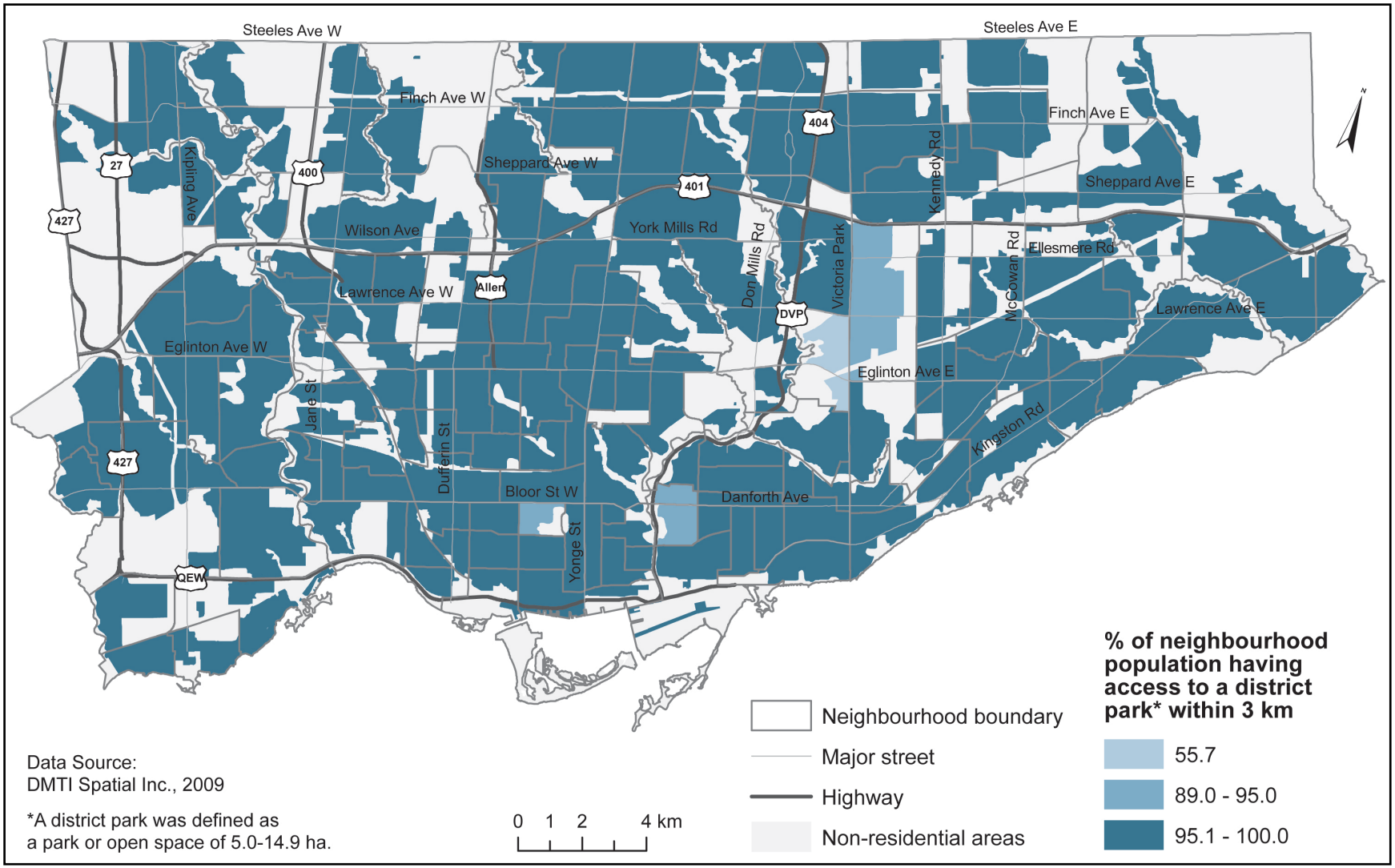


Figure 16. Per Cent of Neighbourhood Population Having Access to a City Park* Within a 5 km Road Network Distance, 2009

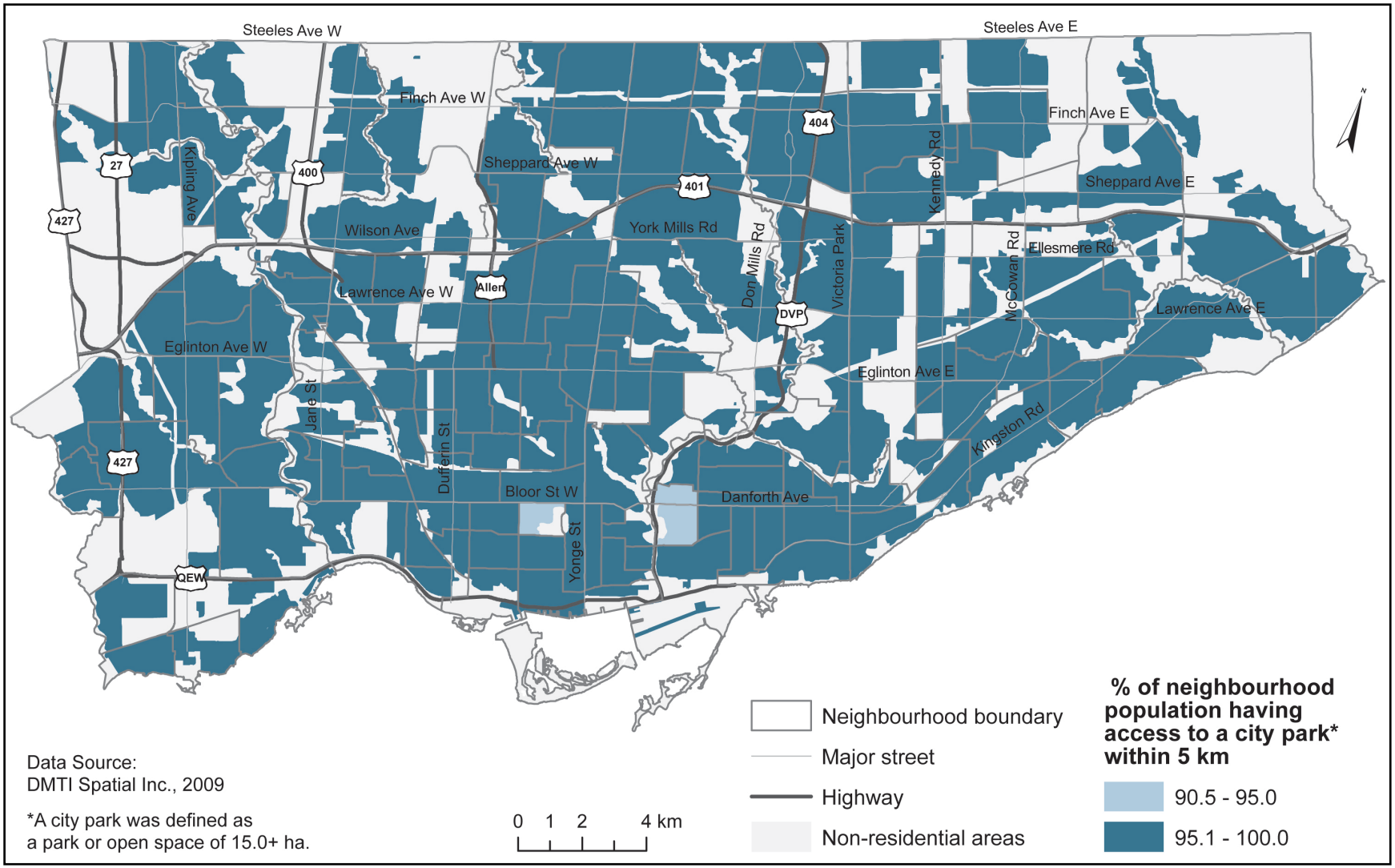
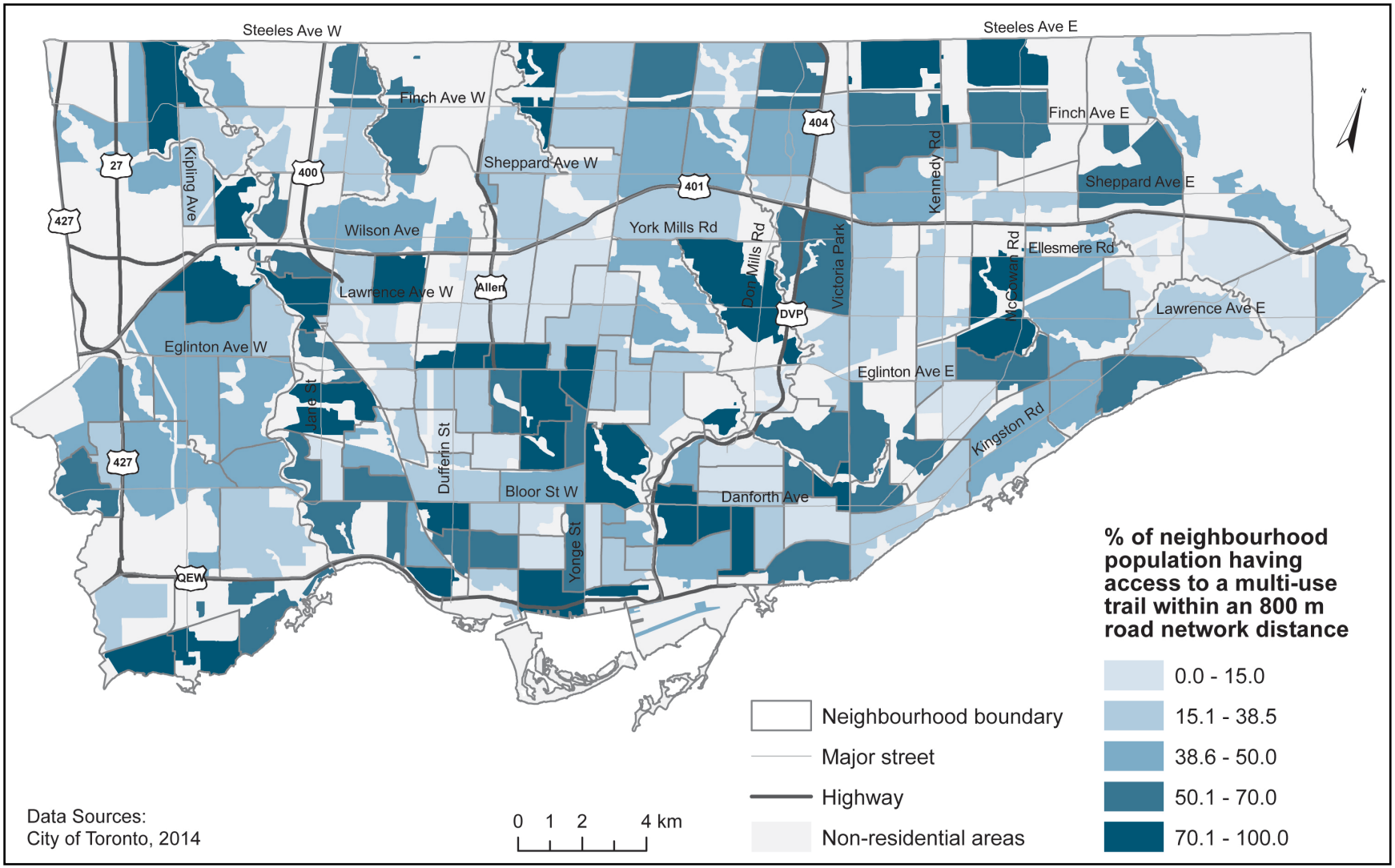


Figure 17. Access to Multi-Use Trails in Toronto Neighbourhoods, 2014



Figures 12 through 16 depict the per cent of each Neighbourhood's population that had access to five different categories of parks and open spaces within five corresponding travel distance cutoffs. Access to parkettes—parks and open spaces between 0.01 and 0.49 hectares in size—is presented in Figure 12 and varied considerably across Toronto. Neighbourhoods with the highest proportion of their population (40.1 to 83.0 per cent) having access to a parkette within a 400 metre distance were located in downtown, midtown, the west end, east end, and North York. There were a number of Neighbourhoods located in Etobicoke, Scarborough, and North York, in which only 0 to 4 per cent of the population had access to a parkette within 400 metres. Interestingly, some of these Neighbourhoods were located adjacent to larger community and district parks, but few residents had access to parkettes within a shorter travel distance.

Figure 13 displays the per cent of each Neighbourhood's population that had access to a neighbourhood park (0.5 to 2.9 hectares in size) within a 800 metre road network distance. Neighbourhods in the highest category, with between 90.1 and 100 per cent of residents having access, were found in all areas of the city and were particularly concentrated in downtown Toronto, the west end, east end, North York, and parts of Etobicoke. Scarborough had fewer Neighbourhoods with the highest category of access. Neighbourhoods in which only 2.7 to 30 per cent of residents had access to a neighbourhood park within 800 metres were located in northern and central Etobicoke, the west end, and parts of uptown and the east end adjacent to the Don Valley Parkway. In a majority of Toronto Neighbourhoods, at least 51.1 per cent of residents had access to a neighbourhood park within 800 metres.

The per cent of each Neighbourhood's population that had access to a community park (3.0 to 4.9 hectares in size) within a 1200 metre road network distance is depicted in Figure 14. There was considerable variation in access to community parks across the city. Neighbourhoods

in which 90.1 to 100 per cent of residents had access to a community park within a 1200 metre distance were found in west and north Etobicoke, North York, Scarborough, downtown, the west end, and east end. Neighbourhoods in which the lowest proportion (0 to 20 per cent) of residents had access to community parks within 1200 metres were also found scattered throughout the city. Pockets of low access existed in southeast and north Etobicoke, southeast and west North York, southeast and west Scarborough, midtown, and the east end. Many of these areas had higher proportions of access to both neighbourhood parks and district parks, however.

Figures 15 and 16 display the per cent of each Neighbourhood's population that had access to a district park (5.0 to 15.9 hectares in size) and a city park (15.0 or more hectares in size) within travel distances of 3 and 5 kilometres, respectively. Both of these maps show very little variation in access to larger parks within these travel distances across the City. The vast majority of Neighbourhoods had very high proportions of residents (95.1 to 100 per cent) that had access to district parks and city parks within the distances of 3 and 5 kilometres, respectively. A select few Neighbourhoods had lower levels of access. These were one Neighbourhood near Yonge Street and Bloor Street, one Neighbourhood on the western edge of the east end, and a cluster of neighbourhoods on the western edge of Scarborough. Even in these Neighbourhoods access was relatively high, however, with only one Neighbourhood in which fewer than 89 per cent of the population had access to either a district or city park.

The per cent of each Neighbourhood's population that had access to a multi-use trail entrance within a 800 metre road network distance is presented in Figure 17. Neighourhoods with the highest proportion of access (70.1 to 100 per cent) were scattered across all areas of the city, and were often located adjacent to ravine parks or hydro corridors that contain multi-use trails. Areas in which a low proportion of residents (0.0 to 15.0 per cent) had access to a multi-

use trail were located in southern North York (near the Allen Expressway), eastern Scarborough, and some parts of downtown, the west end, and east end.

Figure 18. Proximity of More Healthy Food Sources* to Dissemination Block (DB) Centroids in Toronto Neighbourhoods, 2009

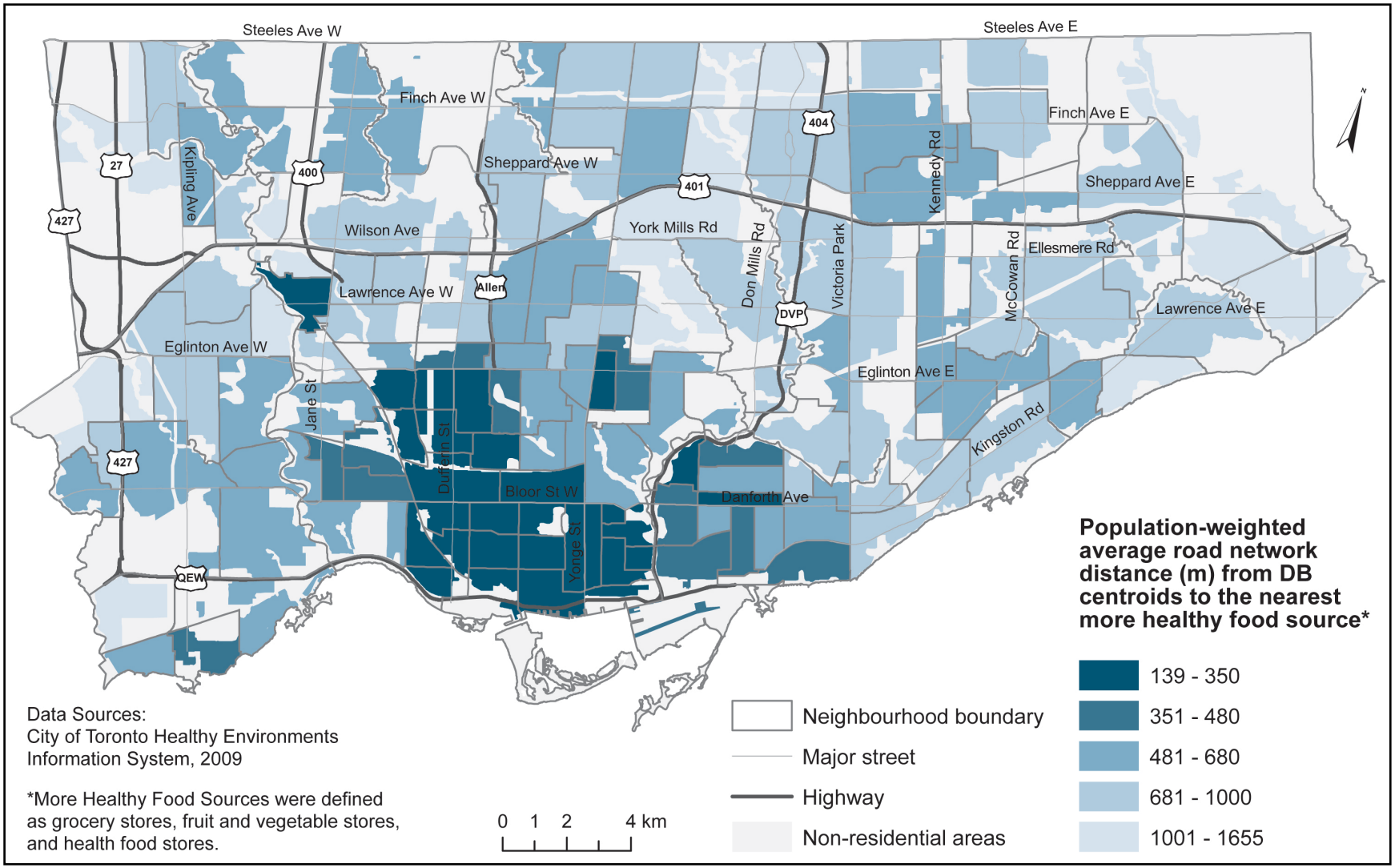


Figure 19. Density of More Healthy Food Sources* in Toronto Neighbourhoods, 2009

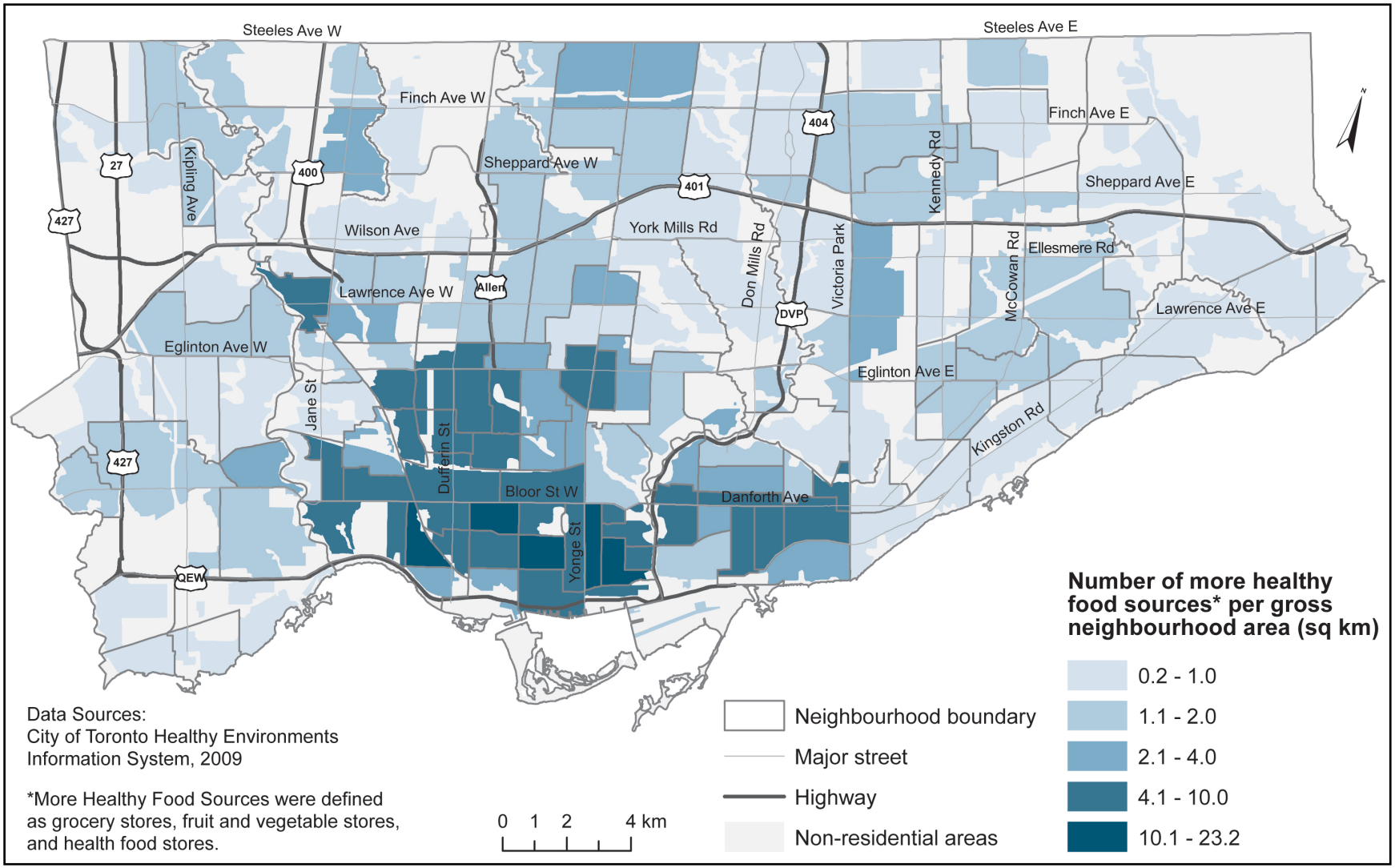


Figure 20. Proximity of Less Healthy Food Sources* to Dissemination Block (DB) Centroids in Toronto Neighbourhoods, 2009

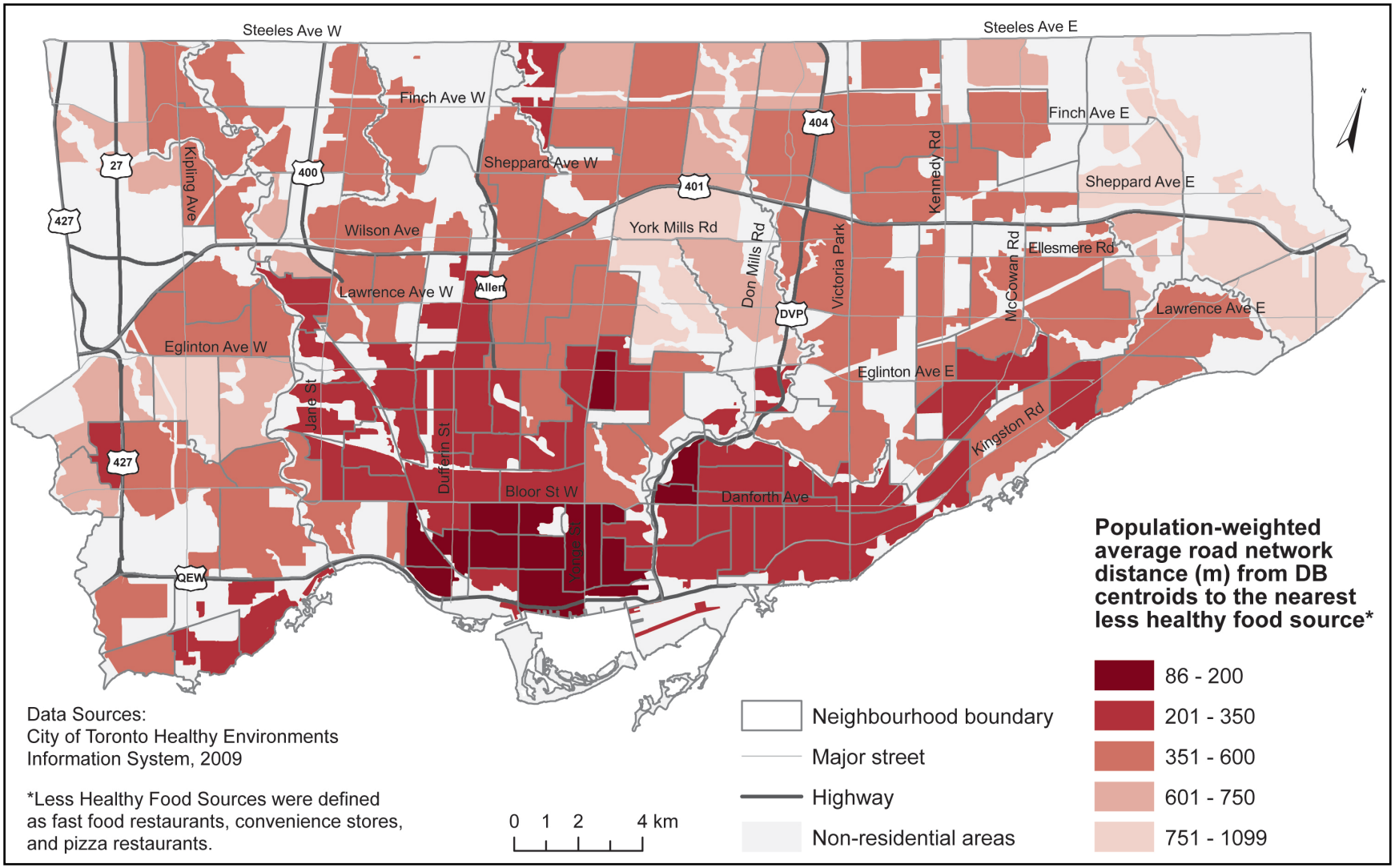
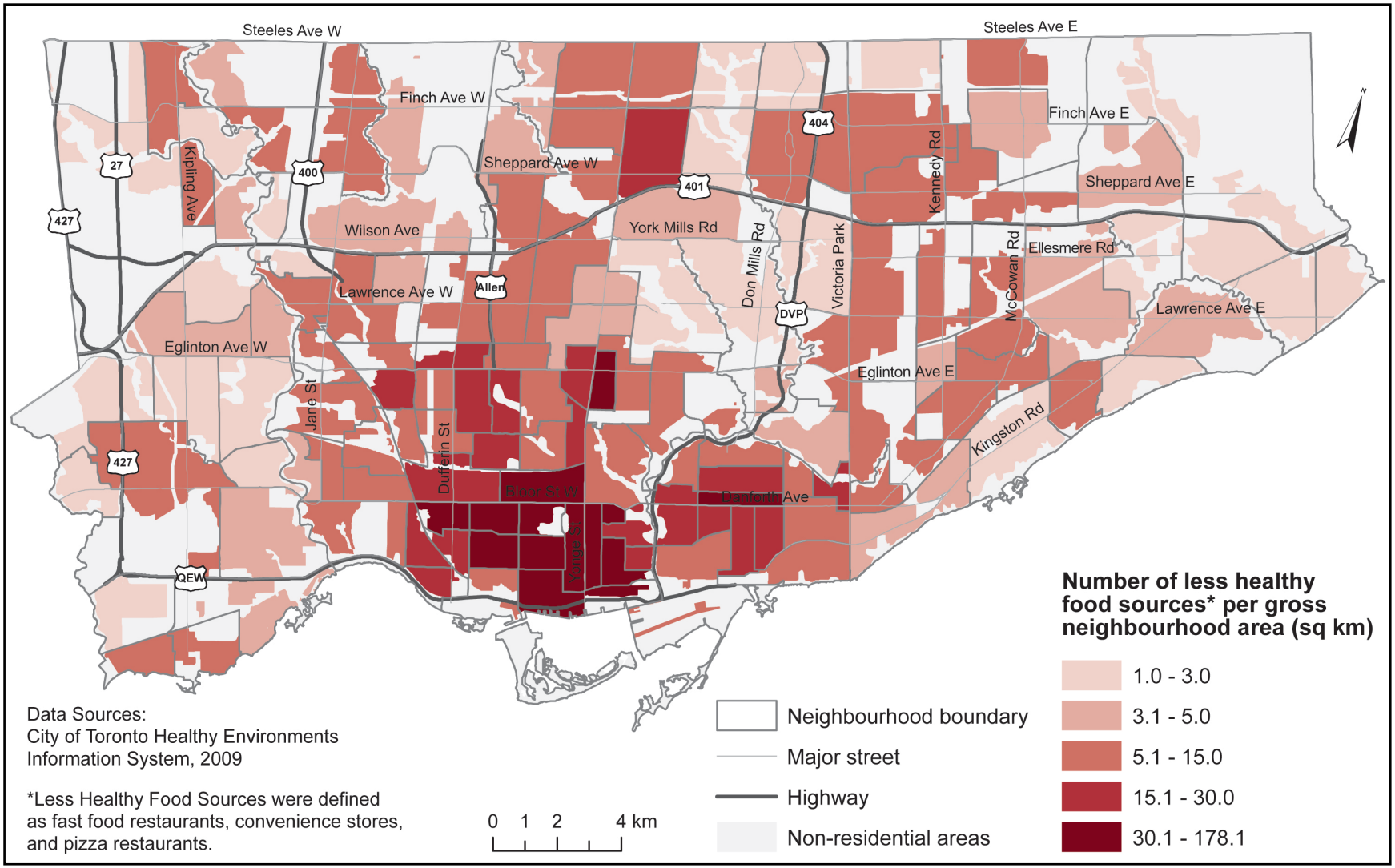


Figure 21. Density of Less Healthy Food Sources* in Toronto Neighbourhoods, 2009



Figures 18 and 19 depict the proximity to and density of more healthy food sources (grocery stores, fruit and vegetable stores, and health food stores) in Toronto Neighbourhoods. Neighbourhoods with the shortest population-weighted average travel distance (139 to 350 metres) from DB centroids to the nearest more healthy food source were located in downtown, the west end, and a few Neighbourhoods in midtown and the east end, as well as the Neighbourhood of Weston. The longest average travel distances (1,001 to 1,655 metres) from DB centroids to the nearest healthy food source were found in Neighbourhooods located in Etobicoke, North York, uptown, and Scarborough. Parts of Scarborough, Etobicoke, North York, and midtown also had medium average travel distances (481 to 680 metres) to the nearest more healthy food source.

The pattern of healthy food source density, presented in Figure 19, is similar to that of proximity to healthy food sources discussed above. The highest densities of healthy food sources (10.1 to 23.2 locations per sq km) were found in downtown and west end Neighbourhoods. Neighbourhoods with the second-highest densities (4.1 to 10.0 healthy food sources per sq km) were also located in downtown and the west end, as well as parts of midtown, the east end, and the Weston Neighbourhood. There were many Neighbourhoods that had only 0.2 to 1.0 healthy food sources per square kilometre. These neighbourhoods were scattered throughout Etobicoke, North York, uptown, and Scarborough, as well as parts of the west end bordering Etobicoke.

The population-weighted average distance from DB centroids to the nearest less healthy food source (fast food restaurant, convenience store, or pizza restaurant) is depicted in Figure 20. The pattern of proximity to less healthy food sources is quite similar to the pattern of proximity to more healthy food sources across the city. Neighbourhoods with the shortest travel distances (86 to 200 metres) to less healthy food sources were located in downtown, the west end, and

small portions of midtown and the east end. Many adjacent Neighbourhoods also had relatively short travel distances of 201 to 350 metres to the nearest less healthy food source. Some Neighbourhoods in this category were also located in southern Etobicoke, southern Scarborough, and northern North York. A relatively small number of Neighbourhoods had longer travel distances of 751 to 1,099 metres to the nearest less healthy food source. These Neighbourhoods were located in eastern Scarborough, uptown, southern North York, and central Etobicoke.

The pattern of less healthy food source density, depicted in Figure 21, is similar to the pattern of less healthy food source proximity, but also shows a greater variation in the density of less healthy food sources across the city compared with their proximity. Neighbourhoods in the highest category of less healthy food store density had 30.1 to 178.1 locations per square kilometre and were found primarily in downtown Toronto, with some Neighbourhoods also located in midtown, the west end, and east end. In general these are also Neighbourhoods that had high densities of more healthy food sources, though the relative densities of less health food sources are much higher. In Etobicoke, North York, Scarborough, and uptown, there were a number of Neighbourhoods with just 1.0 to 3.0 less healthy food sources per square kilometre, as well as Neighbourhoods with moderate densities of 5.1 to 15.0 sources per square kilometre. While these densities of less healthy food sources are relatively low compared with other areas of the city, they are much higher than the densities of more healthy food sources in these Neighbourhoods, which in general ranged from only 0.2 to 2.0 sources per square kilometre.

5 Discussion

5.1 Is Toronto's Built Environment Conducive to Healthy, Active Living?

The above results indicate that there is considerable spatial variation in built environment characteristics associated with healthy, active living in Neighbourhoods across Toronto. Measures of population, residential, and employment density had consistent patterns across the city. Neighbourhoods in the downtown area consistently had the highest densities for all three measures, while parts of Scarborough, Etobicoke, and North York had consistently low densities for all three measures. These findings may be due in part to the dominant urban planning ideologies in place at the time in which these areas developed. Scarborough, Etobicoke, and North York were all originally suburban areas that developed predominantly during the post-World War II period in which lower-density, automobile-centric planning was the norm.[266]

Gross population density and net residential density are two of the built environment characteristics for which the literature review identified specific thresholds associated with walking sufficiently to meet health recommendations. Interestingly, even Neighbourhoods in Toronto that had the lowest level of gross population density (928 to 3,100 persons per square kilometre) still generally met the threshold Lopez et al. identified as associated with increased walking.[267] Lopez and Hynes suggested that walking starts to increase at gross densities ranging from 1,000 to 3,999 persons per square mile, which is equivalent to 386 to 1,544 persons per square kilometre. Thus, on the basis of this threshold even the Neighbourhoods with the lowest level of population density in the City had levels sufficient to foster walking.

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[266] Derek Hayes, *Historical Atlas of Toronto*, (Vancouver, BC: Douglas & McIntyre, 2008), 154-157.
[267] Russ Lopez and H Patricia Hynes, "SPRAWL in the 1990S Measurement, Distribution, and Trends," *Urban Affairs Review (Thousand Oaks, Calif.)* 38, no. 3 (2003): 325–55.

Many of these same neighbourhoods, however, did not have net residential densities at a level that Moudon et al. identified as significantly associated with the probability of walking sufficiently to meet health recommendations. This net residential density threshold is 21.7 dwelling units per acre of residential land use, which is equivalent to approximately 5,362 dwelling units per square kilometre.[268] In Toronto, only Neighbourhoods in the highest and second-highest categories of net residential density met this threshold. There were many Neighbourhoods in Scarborough, Etobicoke, North York, and parts of uptown that had only 484 to 2,250 residential dwellings per residential square kilometre. Thus, while these areas have population densities at a level consistent with what Lopez et al. suggest fosters walking, it appears based on the work of Moudon et al. that these areas may not have net residential densities sufficient to foster a level of walking that meets health recommendations.

By comparison, measures of the presence of and proximity to utilitarian destinations were overwhelmingly uniform across Toronto Neighbourhoods. In most Neighbourhoods greater than 95 per cent of the population had access to a utilitarian destination within an 800 metre road network distance. Even in areas with lower levels of access, a minimum of 83.4 per cent of residents had access within 800 metres. Similarly, the longest average travel distance to the nearest utilitarian destination in a Toronto Neighbourhood was only 518 metres. Most Neighbourhoods had even shorter distances of between 30 and 200 metres. These results indicate that the presence of and proximity to a *single* utilitarian destination is quite high across the City of Toronto.

When looking at the results for density of utilitarian destinations, however, it is clear that certain Neighbourhoods in Toronto contain many more utilitarian destinations than others. Some

[268] Moudon et al., "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights."

Neighbourhoods with the highest level of density had over twenty times more utilitarian destinations per square kilometre than Neighbourhoods with the lowest levels of density. The literature review did not identify specific thresholds of utilitarian destination density associated with specific forms of recreational or physical activity. It is therefore difficult to draw conclusions regarding whether or not all of these Neighbourhoods had density levels sufficient to foster healthy, active living. This seems unlikely though, given the wide variation in density of utilitarian destinations across the City.

There was also considerable variation in the levels of both intersection density and average sidewalk length across Toronto Neighbourhoods. The higher densities (71 to 102 intersections per sq km) found in downtown Toronto Neighbourhoods may be reflective of the predominantly gridiron street design in these areas. By comparison, the lower densities (14 to 30 intersections per sq km) found in Etobicoke, North York, and Scarborough may be reflective of the predominantly curvilinear road network design in these areas that includes many cul-de-sacs. Though the road network used for analysis of this variable did include multi-use trails, it is nonetheless possible that the data was underinclusive of shorter pedestrian cut-throughs, for example from a cul-de-sac to an arterial roadway. This data limitation may have further amplified the differences in intersection density across the City.

Toronto Neighbourhoods also differed considerably with respect to their average sidewalk length within a 1 km road network buffer of DB centroids. Neighbourhoods with the highest category of sidewalk length had an average of 43 to 55 km within a 1 km buffer, compared with only 10 to 17 km of sidewalk in Neighbourhoods in the lowest category. Moudon et al. identified a threshold value of 52,800 feet (or approximately 16 km) of sidewalk within a 1

km buffer of respondents' homes.[269] This measure only included sidewalks on "major streets" (not "local streets") located within the buffer, however, and so direct comparison with our measure is difficult. It is possible that if our measure excluded sidewalks on local streets the values in all Neighbourhoods across the City wold be much lower.

There was considerable variation in the spatial pattern of access to each of five different categories of parks and open spaces within their corresponding cutoff distances. Nearly all Neighbourhoods had acesss to the two largest categories of parks (district parks and city parks) within road network distances of 3 km and 5 km, respectively. This may be due to the large number of parks located around ravines, rivers, and creeks that criss-cross the City of Toronto.

By comparison, there were greater differences across Neighbourhoods with respect to the other three categories of smaller parks and open spaces. Access to parkettes within a 400 metre distance was relatively high in downtown, midtown, the west end, east end, and North York, and relatively low in Etobicoke, Scarborough, and North York. There were some Neighbourhoods in these latter areas in which only 0 to 4 per cent of residents had access to a parkette within 400 metres. Some of these Neighbourhoods did have better access to larger community and district parks within their respective cutoff times, however. A similar general pattern was observed for access to Neighbourhood parks, though Neighbourhoods with better access were also found in parts of Etobicoke, Scarborough, and North York. In general these results indicate that some Neighbourhoods in these areas may benefit from improved access to smaller parks within shorter travel distances from places of residence. Smaller parks may be used at different times of the day and week and for different purposes than larger parks, so including a variety of park types within Neighbourhoods across the City may be important for fostering increased recreational physical

[269] ibid., 107.

activity. Some of the Neighbourhoods in which a lower proportion of residents had access to smaller parks were also identified as having relatively low access to multi-use trail entrances. This is a further indication that some parts of the City may be underserved with respect to park and open space facilities.

The food environment maps indicated that, overall, proximity to and density of both types of food sources (more healthy and less healthy) is highest in downtown Toronto and peripheral areas, and lowest in Etobicoke, North York, uptown, and Scarborough. Additionally, road network travel distances from residential areas to more healthy food stores were consistently longer than the travel distances to less healthy food stores. Similarly, the relative density of more healthy food stores was consistently lower compared with the density of less healthy food stores.

These results indicate that, across the City, it may be easier for residents to access sources of less healthy food than to access sources of more healthy food. In particular, parts of Scarborough, North York, and Etobicoke had travel distances of 1,000 metres of more to the nearest source of healthy food, compared with shorter travel distances of 601 to 750 metres to the nearest source of less healthy food. This difference may provide greater incentives to individuals living in these areas to purchase less healthy sources of food. Many of these Neighbourhoods are also home to a higher proportion of low income and ethnic minority residents,[270] groups that other research has identified as particularly susceptible to adverse health outcomes associated with this type of food environment.[271] Additional research in the City of

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[270] David J. Hulchanski et al., *The Three Cities Within Toronto*, 2nd ed., (Toronto, ON: Cities Centre, University of Toronto, 2010).

[271] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?," 231; See also Fleischhacker et al., "A Systematic Review of Fast Food Access Studies;" Fraser et al., "The Geography of Fast Food Outlets: a Review."

Toronto is required to further evaluate the potentially complex causal relationship between income, ethnicity, and the food environment in Neighbourhoods across the City.

These findings indicate that, overall, certain Neighbourhoods in Toronto perform very well with respect to measures of density, street pattern, access to parks and multi-use trails, and access to sources of more healthy and less healthy food stores. These Neighbourhoods were often, though not always, located in the downtown, midtown, west end, or east end areas of Toronto. Future analyses should consider whether dependent variables such as walking and bicycling for transportation or recreation purposes, fruit and vegetable consumption, and BMI are higher in these areas compared with other parts of Toronto. In comparison, certain Neighbourhoods in more suburban areas such as uptown, Etobicoke, North York, and Scarborough had lower population and dwelling densities, less connected streets with fewer sidewalks, and poorer access to small- and medium-sized parks. Other research indicates that these "inner suburbs" are also home to a higher proportion of low income and visible minority residents, whose health may be more strongly influenced by these less healthy environmental conditions.[272]

The findings also indicated that, in general, most residents of Toronto could access the nearest more healthy food source within a 1 kilometre travel distance. There were, however, several Neighbourhoods in uptown, Etobicoke, North York, and Scarborough that had longer average travel distances of up to 1.6 kilometres to the nearest source of more healthy food. In these areas the travel distance to the nearest source of less healthy food was comparatively short,

[272] Gillian L. Booth et al., "Unwalkable Neighborhoods, Poverty, and the Risk of Diabetes Among Recent Immigrants to Canada Compared with Long-Term Residents," *Diabetes Care* 36, no. 2 (February 2013): 302–8.

ranging from 600 to 1,099 metres. Densities of less healthy food sources were also generally several times higher than densities of more healthy food sources in these Neighbourhoods.

It is therefore possible that residents of these areas may face barriers with respect to accessing healthier food sources. The City of Toronto has undertaken various efforts, spearheaded by the Toronto Food Strategy and the Toronto Food Policy Council, toward addressing this phenomenon. These include a pilot project that has expanded access to healthier foods in corner stores in underserved areas of Toronto, and creation of a mobile food market that sells affordable produce and visits these communities on a weekly basis.[273] Efforts should be made to monitor the impact of these projects as population health interventions in order to assess their impact on the diet and weight status of residents in these underserved areas of Toronto. It is also notable that the the *Ontario Public Health Standards* contain a provision that the board of health shall "collaborate with local food premises" to "support environmental changes through policy development related to healthy eating."[274] It is possible that some of these pilot projects were developed as a result of this policy directive.

It is more difficult to evaluate the influence of planning policies in the *PPS* and provincial plans on the built environment characteristics assessed in this analysis. This is due in part to the fact that the *Growth Plan for the Greater Golden Horseshoe* came into effect in 2006, the same year as the census data used in this analysis. This analysis did identify high levels of density in downtown Toronto, midtown, and central North York, which are all areas designated as Urban Growth Centres having relatively high minimum density targets. There are two other Urban Growth Centres in Toronto, though, Etobicoke Centre and Scarborough Centre. The densities our analysis identified for these areas were comparatively low, and it is likely that

[273] City of Toronto, "Toronto Food Strategy – Projects," Accessed April 7, 2015, http://www1.toronto.ca/.
[274] Ministry of Health and Long-Term Care, *Ontario Public Health Standards*, 29.

considerable intensification in these areas is required to meet the density requirements in the *Growth Plan*. In general, these areas lacked many of the built environment characteristics our analysis identified as associated with transportation physical activity, healthy diets, and healthy weight status.

The one area in which most Toronto Neighbourhoods performed quite well was access to parks and open spaces. In particular, access to larger parks within longer travel distances was almost uniformly high across all Neighbourhoods. Thus, residents who may not live in Neighbourhoods with a built environment that promotes transportation physical activity may still have sufficient access to resources for recreational physical activity. Some researchers have suggested that individuals of similar social status who live in areas with different built environment characteristics may nonetheless have substantially similar levels of *overall* physical activity.[275] For example, one study conducted in Minneapolis-St. Paul, Minnessota, found that odds of transportation walking were higher for individuals living in higher density areas, and odds of leisure walking were higher for individuals living in lower density areas, but density did not have a significant influence on overall walking or physical activity.[276] It is therefore possible that individuals in lower density areas of Toronto may engage in relatively higher levels of recreational physical activity, especially in light of their generally high levels of access to larger parks. These observations are, however, highly speculative and further research is required to

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[275] Ann Forsyth, Mary Hearst, J Michael Oakes, and Kathryn H Schmitz, "Design and Destinations: Factors Influencing Walking and Total Physical Activity," *Urban Studies* 45, no. 9 (August 2008): 1973–96.

[276] J Michael Oakes, Ann Forsyth, and Kathryn H Schmitz, "The Effects of Neighborhood Density and Street Connectivity on Walking Behavior: the Twin Cities Walking Study," *Epidemiologic Perspectives & Innovations* 4 (2007): 16.

examine the complex interactions between density, connectivity, and parks and open spaces and their influence on different forms of physical activity in Toronto Neighbourhoods.

5.2 Limitations

There were several limitations to the analyses conducted in this paper that should be noted. First, the analyses were exploratory and cross-sectional in design. Examination of relationships between the built environment characteristics identified and specific dependent health outcomes in the City of Toronto was beyond the scope of this paper. Nonetheless these results represent an important first look at the spatial distribution in Toronto of built environment characteristics that other studies have identified as consistently associated with physical activity, diet, and weight status. This research should prove useful to both planning and public health professionals and researchers seeking to further examine specific causal relationships between built environment characteristics and health outcomes in Neighbourhoods across Toronto. Given that little variation was identified among some of the variables analyzed, future research may consider modifying the variables generated here in order to provide greater variability for regression with outcome measures.

Second, though considerable efforts were undertaken to clean and verify the data sources used in these analyses it is nonetheless possible that the data may have been underinclusive or contained some inaccuracies. In particular, it is possible that the road network files used did not contain all pedestrian routes that exist in the City. The only way to remedy this situation would have been through manual verification and editing of the data based on satellite imagery, a time-intensive process that was not feasible for this research. It is therefore possible that some of the travel distances identified were overestimated due to our inability to incorporate all possible pedestrian routes. The data containing point locations of utilitarian destinations, schools, and

food stores utilized in our analyses may also have been underinclusive, which could have also resulted in lower densities and longer travel distances than in reality.

Third, most of the analyses were conducted at the Dissemination Block level and results were then attributed to Neighbourhoods for mapping purposes. It is therefore possible that the results as depicted on the maps may fall subject to either the modifiable areal unit problem or the ecological fallacy. The former is a problem wherein the use of articial geographic units can cause artifical spatial patterning of geographic phenomena that actually exist in a spatially continuous manner (e.g., population density and land use mix).[277] The latter problem arises where ecological-level data is used to make causal inferences regarding individual-level behaviours.[278] Because the purpose of this study was exploratory rather than confirmatory, however, we are not claiming to offer evidence of causation. Thus, while the ecological-level results depicted on the maps in this paper may not represent the value of each built environment variable if it were calculated for each individual in the Neighbourhood, the problems of causality to which the ecological fallacy referes do not arise here.

5.3 Suggestions for Legal and Policy Reform to Foster Healthy, Active Communities

With the above results in mind, this section presents three potential ways in which the legal and policy frameworks governing urban planning and public health in the City of Toronto could be reformed to better foster development of healthy, active communities. Though further research is required to demonstrate causal relationships between the factors explored in this paper and dependent health outcomes, the suggestions below provide an initial assessment of

[277] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 117.
[278] Sharon Schwartz, "The Fallacy of the Ecological Fallacy: the Potential Misuse of a Concept and the Consequences," *American Journal of Public Health* 84, no. 5 (1994): 819-824.

options for related legal and policy reform once stronger evidence comes forth. The first mechanism discussed is primarily policy-based and would involve implementation of healthy development standards within the City of Toronto's planning process. The Region of Peel's attempts in this regard are discussed, including barriers faced in implementation of the Peel Healthy Development Index that may also arise in Toronto. The second mechanism discussed is Health Impact Assessment. Under Quebec's *Public Health Act*, all ministries and agencies of the provincial Government are required to ensure the legislative provisions that they adopt do not adversely affect population health. Potential modification and application of this framework in the municipal context is considered. The third potential reform focuses on legislative and policy changes to the *Planning Act*, *Health Promotion and Protection Act*, and regulations and policies pursuant that may better foster collaboration between planning and public health, as well as the development of healthy, active communities.

5.3.1 Healthy Development Standards: The Region of Peel's Healthy Development Index and Health Background Study

The Region of Peel is an upper-tier municipality located to the west of Toronto and consists of the lower-tier (i.e., local) municipalities of Mississauga, Brampton, and Caledon. In 2005, Region of Peel Public Health staff began conducting reviews of and providing advice on the potential health-related impacts of planning development applications submitted to the Region.[279] In 2009, Peel Public Health sought to develop a tool or index that would provide a more consistent health rationale for incorporating health considerations into the development review process.[280] The Healthy Development Index, ("HDI") a checklist of evidence-based

[279] Dunn, Creatore, Peterson, Weyman, and Glazier, *Final Report - Peel Healthy Development Index*, 1.
[280] ibid., 1.

criteria for evaluation of development applications in the Region of Peel, was developed in partnership with a research team from St. Michael's Hospital.[281]

An extensive literature review was conducted to identify those aspects of the built environment associated with improved health outcomes and health behaviours. The literature review identified seven elements of built environment features associated with health-promoting design, and various quantifiable measures (such as residential density or block size) within each of these elements.[282] The strength of evidence in the literature for each of these measures was evaluated and corresponding weights were assigned to develop an index of prerequisite and credit measures. A feasibility assessment was performed for three existing Region of Peel communities to examine whether the targets could be met in any existing neighbourhoods in the Region of Peel.[283]

Following initial development and assessment of the HDI, the Region of Peel has taken several steps toward implementation of the tool at various stages of the development review process. Chronologically, these include Regional Official Plan Amendments containing enabling and supporting public health policies, further assessment of the benefits of and barriers to implementation of the HDI, development of a Health Background Study ("HBS") framework, and additional Regional Official Plan Amendments to support integration of the HDI / HBS framework into the development approvals process.

The first set of Regional Official Plan Amendments related to the HDI included policies that would better support and enable integration of this assessment tool into the development application assessment process. Regional Official Plan Amendment ("ROPA") 24 was adopted

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[281] Weyman et al., "Planning Health-Promoting Development: Creation and Assessment of an Evidence-Based Index in the Region of Peel, Canada."
[282] ibid.
[283] ibid.

by Regional Council on April 22, 2010 and a related settlement was approved by the OMB on November 30, 2012.[284] Resulting Official Plan Policy 7.9.2.9 provides that the Region will "[p]repare, jointly with the area [local] municipalities, an assessment tool that will allow evaluating the public health impacts of proposed plans or development as part of the approval process."[285] This policy enabled further development of the HDI and the subsequent HBS framework and Terms of Reference.

ROPA 25 was adopted by Regional Council on February 11, 2010 and on April 19, 2011 an appeal to the OMB regarding this ROPA was withdrawn, bringing the amendment into effect.[286] Resulting Official Plan Policy 7.3.6.2.2 includes "public health impact studies" as one of the types of studies that the municipality may require as part of a complete development application to amend the Regional Official Plan.[287] This is an important step towards implementation of a more comprehensive health impact development review framework in the Region, because it allows the municipality to *require* inclusion of a public health impact study as part of a complete development application. An applicant's right to appeal to the OMB in respect of council's failure to make a decision regarding the applicant's requested OPA is not engaged until 180 days after council has received all required materials in respect of the application.[288] These materials include "any other information or material that the council … considers it may need, but only if the [municipality's] official plan contains [related] requirements."[289] Thus, the applicant cannot attempt to circumvent Peel's decision to require the provision of a health impact

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[284] Region of Peel, "Official Plan: List of Amendments," *Region of Peel*, February 2013, accessed April 1, 2015, https://www.peelregion.ca/planning/officialplan/list-amendmts.htm.
[285] Region of Peel, "Official Plan," *Region of Peel*, 2014, accessed April 1, 2015, https://www.peelregion.ca/planning/officialplan/pdfs/rop-consolidation-oct2014.pdf.
[286] Region of Peel, "Official Plan: List of Amendments."
[287] Region of Peel, "Official Plan."
[288] *Planning Act*.
[289] ibid., s 22(5).

study through appealing to the OMB 180 days after submitting an incomplete application. Instead, the applicant's appeal right is not engaged at all until the required studies are submitted as part of a complete OPA application.

Following adoption of these ROPAs, the Region of Peel engaged in further assessment of the barriers to implementation of the HDI. Gladki Planning Associates, in association with du Toit Allsopp Hillier and the Region of Peel produced an HDI Recommendations Report focused on next steps for implementation of the HDI.[290] The report put forward recommendations regarding further refinement of the HDI itself, as well as how the HDI could best be used for assessment of planning and development applications. Suggested next steps included incorporating qualitative as well as quantitative goals within the HDI, and allowing for greater flexibility to implement the index in Peel's highly suburban environment. The report also noted that many existing regional and municipal policies and bylaws in Peel influence development and often contain standards that act as barriers to implementation of principles and standards in the HDI.[291] Thus, Gladki Planning Associates recommended conducting a comprehensive review of existing planning policies and standards in the Region to better integrate the healthy communities principles embodied in the HDI. This review could also help identify at which stages of the planning process (e.g., official plan, secondary plan, plan of subdivision, site plan approval) the various elements and measures within the HDI could be incorporated.

The work conducted in relation to the HDI set the foundations for the more recent Health Background Study jointly prepared by the Planning Partnership in association with the Region of

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[290] Gladki Planning Associates in association with du Toit Allsopp Hillier, "The Healthy Development Index Recommendations Report," *Region of Peel Public Health*, October 12, 2011, accessed April 1, 2015, http://www.peelregion.ca/health/resources/healthbydesign/pdf/GPA_HDI_Recomendations_Report.pdf.

[291] ibid., 27.

Peel, Toronto Public Health, and other organizations. The aim of the HBS was to build upon the evidence-based HDI and create a more "context-sensitive system for requiring the consideration of health impacts during the land use development approvals process."[292] This work resulted in the creation of Terms of Reference ("TOR") and a User Guide for conducting a Health Background Study in respect of a development application. The Terms of Reference contain health standards associated with density, service proximity, land use mix, street connectivity, streetscape characteristics, and parking. The TOR also discusses how these standards apply to both greenfield and infill developments. The User Guide contains a matrix indicating at which stages of the planning process each standard in the TOR should be assessed.[293] The HBS framework, including the TOR and User Guide, therefore address many of the recommendations put forth regarding implementation of the HDI.

The Region of Peel has undertaken further efforts toward implementation of the HBS as a framework for evaluating development applications in the Region. As part of the Region's mandatory five-year Official Plan review, the Region is proposing inclusion of Official Plan policies that support implementation of the HBS at all stages of the development application process. These policies include directions to area (local) municipalities within the Region to include policies in their Official Plans that endorse the HBS framework and require a health assessment as a component of a complete planning development application. The proposed

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[292] Region of Peel, The Planning Partnership, and Toronto Public Health et al., "Health Background Study Implementation Strategy," *Region of Peel*, May 2011, http://www.peelregion.ca/health/resources/healthbydesign/pdf/HBS-framework-6-strategy.pdf.

[293] ibid.

policies would also direct area municipalities to integrate elements of the HBS framework within planning instruments that are initiated at the local (as opposed to regional) level.[294]

As of March 30, 2015, information regarding the City of Toronto's further implementation of the HBS framework could not be found. The HBS Implementation Study notes that Toronto already has Official Plan policies that are broadly supportive of considering the impact of planning decisions on health, as well as some related requirements under the Toronto Green Standard.[295] The Toronto Green Standard contains two tiers of "performance measures for sustainable site and building design"[296] that are aimed at broader principles of sustainable development than just healthy communities.

While there may be some overlap between the HDS Framework and existing sustainability standards in Toronto,[297] the City of Toronto should consider implementing additional principles and standards from the HDS Framework. This could be accomplished through integrating HDS standards within the existing Toronto Green Standard framework and checklists, or through creation of a separate set of healthy development criteria against which development applications would be evaluated. The HDS Implementation Study notes in particular that Toronto's Official Plan identifies a number of residential areas across the City as

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[294] Edward R Sajecki, Commissioner of Planning and Building, *Memorandum Re: Regional Official Plan Amendment (ROPA) 27 - Peel 2041*, (City of Mississauga, March 25, 2014), accessed April 1, 2015, http://www5.mississauga.ca/research_catalogue/reports/PDC_Reports/April_14_2014_ROPA_27_Report.pdf.

[295] Region of Peel, The Planning Partnership, Toronto Public Health et al., "Health Background Study Implementation Strategy."

[296] City of Toronto, "Toronto Green Standard," *City of Toronto*, 2015.

[297] Region of Peel, The Planning Partnership, Toronto Public Health et al., "Health Background Study Implementation Strategy."

"stable areas [that] will see little physical change."[298] The Toronto Green Standard may also not generally apply to development in these areas, because the low-rise residential standards only apply to developments of 5 units or more.[299] Many of these "stables areas" are located in more suburban areas of the City, including parts of Scarborough, Etobicoke, and North York that were identified as having a built form less conducive to healthy, active living in our analysis. Accordingly these areas represent an opportunity for implementation of the HDS framework as part of the City of Toronto's ongoing five-year Official Plan review.

5.3.2 Health Impact Assessment and Quebec's *Public Health Act*

The second mechanism through which the City of Toronto could exercise greater influence over the creation of healthy, active communities in the City is through adoption and implementation of Health Impact Assessment ("HIA") bylaws, policies and standards. These could be modeled after the HIA requirements and framework created pursuant to section 54 of Quebec's *Public Health Act*, which provides that:

> The Minister is by virtue of his or her office the advisor of the Government on any public health issue. The Minister shall give the other ministers any advice he or she considers advisable for health promotion and the adoption of policies capable of fostering the enhancement of the health and welfare of the population.
>
> In the Minister's capacity as government advisor, the Minister shall be consulted in relation to the development of the measures provided for in an Act or regulation that could have significant impact on the health of the population.[300]

Under these provisions the Minister is required to give advice to other Ministries and agencies of the Province that in the Minister's opinion will encourage adoption of policies that will enhance the health and welfare of the population. All Ministries and agencies of the Province are also

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[298] ibid.; City of Toronto, "Toronto Official Plan," 2010, policy 2.3, accessed April 1, 2015, http://www1.toronto.ca/static_files/CityPlanning/PDF/chapters1_5_dec2010.pdf.
[299] City of Toronto, "Toronto Green Standard."
[300] *Public Health Act*, CQLR, c S-2.2.

obligated to consult the Minister in relation to proposed legislation that may significantly impact population health.

Implementation of this framework was accomplished through development of an intergovernmental HIA tool and guide, and through development and knowledge transfer of information regarding healthy public policies.[301] The HIA tool consists of five steps: screening; scoping and summary analysis; in-depth analysis; decision-making; and evaluation. These steps are consistent with those utilized in other North American jurisdictions that have implemented HIA frameworks.[302] Based on Quebec's intergovernmental implementation framework, the first two HIA steps are conducted by the Ministry or agency that is proposing the legislation. The further stages are only carried out if the first two stages identify a potential impact—positive or negative—on health.[303] The HIA tools and methods have also evolved since they were first implemented in 2002, through five-year reviews of the implementation strategy and development of a conceptual framework of social determinants of health.[304]

Broadly speaking, there are two types of HIAs that influenced development of the legislation and policies in Quebec. These are environmental impact assessments, focused on the environmental health impacts of proposed development projects, and a social determinants of health approach focused on a much broader definition of health that includes impacts on citizen

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[301] Philippe Poitras, Francois Benoit, Caroline Druet, Genevieve Hamel, and Louise St-Pierre, *Implementation of Section 54 of Quebec's Public Health Act*, (National Collaborating Centre for Healthy Public Policy, August 2012), 3, accessed April 1, 2015, http://www.ncchpp.ca/docs/Section54English042008.pdf.

[302] See Miller, Pollack, and Williams, "Healthy Homes and Communities - Putting the Pieces Together," 53-54.

[303] Poitras, Benoit, Druet, Hamel, and St-Pierre, *Implementation of Section 54 of Quebec's Public Health Act*, 3-4.

[304] ibid., 4.

groups and health inequities.[305] The former type of HIA exists in most provincial and federal environmental assessment legislation, while the latter approach is unique to Quebec at the provincial level.[306] The City of Toronto also conducts environmental impact assessments in relation to specific development projects, such as the proposed expansion of the Billy Bishop Toronto City (Island) Airport.[307] Toronto could also consider implementation of a broader HIA mechanism more similar to that employed in Quebec, however. This framework could require that an HIA be conducted in relation to all proposed policies and bylaws of the City that may significantly affect health.

The implementation of a broad HIA respecting all proposed policies and bylaws that may significantly affect the health of Toronto's population could be conducted through two legislative mechanisms at the local municipal level. First, municipal council could adopt an HIA bylaw that establishes HIA requirements using legislative language modified from section 54 of Quebec's *Public Health Act*.[308] The modified enabling provision in a draft bylaw could read as follows:

> The Medical Officer of Health is by virtue of his or her office the advisor of the City on any public health issue. The Medical Officer of Health shall give the City, including Council, local boards, committees, departments, and divisions, any advice he or she considers advisable for health promotion and the adoption of bylaws and policies capable of fostering the enhancement of the health and welfare of the City's population.
>
> In the Medical Officer of Health's capacity as advisor, the Medical Officer of Health shall be consulted in relation to the development of the measures provided

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[305] Louise St-Pierre, *Health Impact Assessment (HIA): a Promising Action Path for Promoting Healthy Public Policies*, (National Collaborating Centre for Healthy Public Policy, February 2008), 3, accessed April 1, 2015, http://www.ncchpp.ca/docs/BackgroundPaperHIA.pdf.

[306] But see Michael A Benusic, "Mandatory Health Impact Assessments Are Long Overdue," *BC Medical Journal*, June 2014, accessed April 1, 2015, http://www.bcmj.org/council-health-promotion/mandatory-health-impact-assessments-are-long-overdue.

[307] City of Toronto, *Health Impacts Associated with Billy Bishop Toronto City Airport Expansion*, (City of Toronto, November 25, 2013), accessed April 1, 2015, http://www.toronto.ca/legdocs/mmis/2013/hl/bgrd/backgroundfile-64222.pdf.

[308] *Public Health Act*.

> for in a bylaw, policy, plan, or planning decision that could have significant impact on the health of the City's population.

It is likely that the City of Toronto would have sufficient jurisdiction to adopt bylaws for the establishment and implementation of an HIA framework. The City has a general authority to enact bylaws respecting "[h]ealth, safety, and well-being of persons."[309] Jurisprudence indicates that this power should be interpreted broadly. In *Croplife Canada v Toronto (City)*, the City of Toronto's power to enact bylaws respecting health matters was challenged. The Ontario Court of Appeal held that a bylaw prohibiting pesticide use enacted pursuant to this power was valid, and that the City's general authorities under the *City of Toronto Act, 2006* should be interpreted broadly.[310] Thus, so long as the bylaw and HIA are sufficiently targeted at enhancing the health and welfare of the *City's* population, and the measures adopted are not in conflict with provincial or federal legislation, then it is likely that a bylaw establishing an HIA framework would be valid.

Second, the board of health may also have jurisdiction to require HIA at the municipal level based on its authority under section 9 of the *Health Protection and Promotion Act*. This provisions allows the board of health to "provide any other health program or service in any area in the health unit" if:

> (a) the board of health is of the opinion that the health program or service is necessary or desirable, having regard to the needs of persons in the area; and
>
> (b) the councils of the municipalities in the area approve of the provision of the health program or service.[311]

Based on the second requirement, this implementation method would still require council's approval in order to implement the program. So this implementation method is not one through

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[309] *City of Toronto Act, 2006*, s 8(2).
[310] *Croplife Canada v Toronto (City)*.
[311] *Health Protection and Promotion Act*.

which the board of health could circumvent the intent of council and establish an HIA on its own, if council did not approve of the implementation of an HIA. Additionally, reliance on this power would requirement demonstrating that that HIA is a "health program or service." This is not a defined term in the *HPPA*. Given the breadth of programs and services specifically enumerated as mandatory under section 5 of the *HPPA*, it is arguable that an HIA framework could fall within the meaning of the term. For example, a "health program or service" includes "[h]ealth promotion, health protection and disease and injury prevention, including the prevention and control of cardiovascular disease, cancer, AIDS and other diseases."[312] An HIA framework would likely target health promotion, health protection, and prevention of diseases such as obesity and diabetes. Accordingly the board of health may have sufficient jurisdiction to implement an HIA framework, subject to council's approval.

5.3.3 Legal and Policy Reforms under the *Planning Act* and *Health Protection and Promotion Act*

The final mechanism proposed to foster healthy, active communities in Toronto would be implemented primarily at the provincial level. The first related proposal primarily targets inclusion of additional policies that address creation of healthy, active communities within the *Provincial Policy Statement* and the *Growth Plan for the Greater Golden Horseshoe*.[313] The second proposal is regarding legislative reforms that would require all decisions of municipal councils to be consistent with the health programs and services standards under the *Health Protection and Promotion Act* and related regulations and guidelines.[314]

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[312] ibid., s 5.
[313] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement*; Ministry of Infrastructure, *Growth Plan for the Greater Golden Horseshoe, 2006*.
[314] *Health Protection and Promotion Act*.

As discussed in the first section of this paper, all decisions made by municipal councils, local boards, Ministers of the Crown, and ministries, boards, or agencies of the government that affect a planning matter must be consistent with the *PPS* and conform with (or not conflict with, as the case may be) provincial plans.[315] Both the *PPS* and the *GPGGH* (which is included in the definition of "provincial plan" in the *Planning Act*) contain some policies that address characteristics of healthy, active communities. For example, Policy 1.1.1 of the *PPS* provides that "[h]ealthy, liveable and safe communities are sustained by… avoiding development and land use patterns which may cause environmental or public health and safety concerns."[316] The *PPS* also provides that "[a]ppropriate development standards should be promoted which facilitate intensification, redevelopment and compact form, while avoiding or mitigating risks to public health and safety."[317] Lastly, Policy 1.5 encourages promotion of healthy, active communities through planning for and facilitating active transportation on public streets, and providing a "full and equitable distribution of publicly-accessible built and natural settings for recreation."

It is notable, however, that all of the policies in the *PPS* regarding "protecting public health and safety" are focused on natural and human-made environmental health hazards.[318] Thus, additional policies that emphasize the risks to population health associated with certain built environment characteristics should be added to the *PPS*. These could include policies that target and discourage low density, single-use, automobile-centric development. While the *PPS* already encourages higher-density, mixed-use development in certain designated growth areas, it does not discourage or preclude the opposite in other urban areas of the Province. The *PPS* could also contain policies to encourage a land use planning approach that integrates public health

[315] *Planning Act*, s 3(5).
[316] Ministry of Municipal Affairs and Housing, *Provincial Policy Statement*.
[317] ibid., Policy 1.1.3.4.
[318] ibid., Policy 3.

perspectives and expertise from within municipalities and other Ministries. Policy 1.2 of the *PPS* currently addresses coordination and integration requirements, and provides for a comprehensive planning approach that should integrate a number of enumerated principles. "Health" and "public health" are not listed as principles that should be integrated into this comprehensive approach. It is therefore advisable that revisions to the *PPS* also include "fostering public health and health promotion" as one of the principles that should be integrated into the comprehensive land use planning approach required under the *PPS*.

The *GPGGH* also contains some policies that relate to characteristics of healthy, active communities. These include the minimum density requirement of 50 residents plus jobs per hectare in greenfield development areas, and higher minimum density requirements in designated urban growth centres. The *GPGGH* also broadly encourages higher-density, mixed-use development around major transit stations and along intensification corridors. These requirements are generally consistent with density and land-use characteristics of healthy, active communities. However, it is questionable whether the minimum density requirement for greenfield areas is sufficient to foster healthy, active communities. The threshold value of minimum density required to increase walking sufficiently to meet health recommendations is 21.7 *dwellings* per acre, equivalent to 53.6 *dwellings* per hectare.[319] Even if the majority of greenfield development is residential, the standard of 50 *residents* (plus jobs) per hectare under the *GPGGH* is far lower than this threshold given that many dwellings are occupied by multiple residents. The *GPGGH's* minimum density requirement is also calculated and applied as an average across the entire grenfield area within each municipality. Thus, many greenfield areas may be built at even lower densities so long as some areas are built with higher densities to

[319] Moudon et al., "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights."

compensate.[320] A more effective density threshold could instead set out a minimum number of *dwellings* per hectare required for each plan of subdivision.[321] This would allow for easier evaluation and implementation of the density criteria at a neighbourhood scale.

A final legal and policy reform that could be implemented at the provincial level would involve the extension of conformance requirements under sections 3(5) and 3(6) of the *Planning Act* to include the minimum standards for health programs and service delivery set out under the *Health Protection and Promotion Act*. Essentially, all decisions of municipal councils, local boards, Ministers of the Crown, and ministries, boards, or agencies of the government that affect a planning or health matter could be required to be consistent with the *Ontario Public Health Standards*. This would create reciprocity between the existing conformance requirements under the *Planning Act* and the *HPPA*. Currently, decisions of boards of health that affect a planning matter are required to be consistent with the *PPS* and conform with provincial plans. Yet there is no requirement that decisions of municipal council be consistent with the board of health's duties and responsibilities under the *HPPA* and regulations and guidelines issued pursuant. Including such conformance requirements may help better foster collaboration between planning and public health, and encourage a more integrated approach to land use planning in the Province.

6 Conclusions

The goal of this major research paper was to identify the built environment components of healthy, active communities and examine the spatial distribution of these components in the City of Toronto. Healthy, active communities were defined as communities that foster transportation or recreational physical activity, healthy eating, and a healthy body weight among

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[320] Neptis Foundation, *Commentary on the Ontario Government's Proposed Growth Plan for the Greater Golden Horseshoe*, 3rd ed., (Toronto, ON: Neptis Foundation, 2006), 17-18.
[321] ibid., 17-18.

residents. A review of existing planning and public health literature was conducted to identify characteristics of the built environment associated with these outcomes.

The literature review identified strong evidence for associations between transportation physical activity and variables capturing density, land use mix, street pattern, and walkability or urban sprawl. Evidence was also relatively strong for relationships between the buit environment and recreational physical activity, though some of the specific components with strong associations differed. In particular, access to walking trails, availability of specific sizes of parks and open spaces, and the quality but not density of recreational facilities were all associated with recreational physical activity, as were measures of street pattern and safety.

Evidence for associations between objectively quantifiable aspects of the food environment and dietary outcomes was less strong. The only measures that had somewhat consistent significant associations with diet were proximity and density of more healthy and less healthy food stores. While not the main focus of this paper, research indicates that access to healthier food sources may be particularly poor in areas with higher proportions of low income and visible minority residents.[322] Future research should therefore consider the influence of this phenomenon on diet and weight in particular communities and population sub-groups using longitudinal study methods.

The relationships between the built environment, physical activity, diet, and weight status are even more complex. The literature review indicated that the only two physical activity environment variables consistently associated with weight status are population density and land use mix entropy. The sprawl index was also identified in some studies as a potential correlate. There was similarly limited evidence of associations between characteristics of the food

[322] Townshend and Lake, "Obesogenic Urban Form: Theory, Policy and Practice;" Black and Macinko, "Neighborhoods and Obesity."

environment and weight status outcomes, though the potential influence of less healthy food sources in particular requires further research. These variables were nonetheless analysed for the City of Toronto, given that this location is relatively underexamined in the literature.[323]

This paper then used Geographic Information Systems to calculate and map the spatial distribution of built environment components identified in the literature review. The spatial patterns of individual variables within the component categories of density, land use mix, street pattern, parks and recreational facilities, and sources of more and less healthy foods varied considerably across the City. Measures of population density, residential density, employment density, and intersection density were generally highest in downtown and adjacent Neighbourhoods, and lowest in parts of Etobicoke, uptown, North York, and Scarborough. Patterns of proximity to and presence of utilitarian destinations followed a similar pattern, though the range of values in the results was much more constrained. This indicated that access to a *single* utilitarian destination is relatively high across Toronto. Considerably more variation was observed with respect to the density of utilitarian destinations, however, with some Neighbourhoods in downtown Toronto having twenty times more utilitarian destinations per square kilometre than Neighbourhoods in Etobicoke, uptown, North York, and Scarborough.

Availability of smaller parks and open spaces within shorter travel distances was generally highest in parts of downtown, the west end, east end, midtown and North York. There were some areas of Etobicoke, Scarborough, and North York that also had access to smaller parks within these same travel distances, while others did not. Further analyses could focus on

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[323] But see Glazier et al., "Density, Destinations or Both? a Comparison of Measures of Walkability in Relation to Transportation Behaviors, Obesity and Diabetes in Toronto, Canada;" Jane Y Polsky, Rahim Moineddin, Richard H Glazier, James R Dunn, and Gillian L Booth, "Foodscapes of Southern Ontario: Neighbourhood Deprivation and Access to Healthy and Unhealthy Food Retail," *Canadian Journal of Public Health* 105, no. 5 (September 2014): e369–75.

these areas to determine the appropriate size and proximity of different types of parks that may best foster recreational physical activity in Toronto. In comparison, access to larger parks within longer travel distances was almost uniformly high across the City. There was only one Neighbourhood in which fewer than 89 per cent of residents had access to a district park within 3 kilometres.

The spatial distribution of healthy and unhealthy food sources across the City was very similar. Neighbourhoods in downtown, the west end, and the east end generally had the shortest travel distances to the nearest food source in both categories, and the highest density of both more and less healthy food sources. Conversely, some Neighbourhoods in Etobicoke, uptown, North York, and Scarborough consistently had longer travel times to and lower densities of both types of food sources. In some of these areas the travel distances to the nearest healthy food source were longer than 1 kilometre, which may present a barrier to purchasing healthy food given that less healthy food sources were more readily accessible. The density of less healthy food sources was also consistently higher than the density of more healthy food sources in these areas. This presents greater options for purchasing less healthy food and may limit the availability and purchasing of more healthy food options in some Neighbourhoods.

These findings present an important first step toward understanding the spatial pattern of healthy built environment characteristics across the City of Toronto, and help identify particular Neighbourhoods and areas of the City for examination in future research. Though we were unable examine associations with specific health outcomes in Toronto, future researchers with access to such data are encouraged to do so and select independent variables for analysis based on the results of this paper. In particular, future research efforts could focus on the influence of

specific built environment components identified in this paper on physical activity, diet, or weight status outcomes in specific Neighbourhoods or population sub-groups within the City.

This paper also presented an overview of the legal and policy framework governing land use planning and public health in the Province of Ontario and the City of Toronto. Reforms that would promote increased integration of health principles into the land use planning process were also discussed. These reforms include implementation of the Health Background Study framework in the City of Toronto, adoption of a Health Impact Assessment framework at the municipal level, and higher-level policy and legislative reforms to the *PPS*, *GPGGH*, *Planning Act*, and *Health Protection and Promotion Act*. The overview and reforms should prove of particular interest to researchers and professionals in both public health and planning fields, and if implemented will encourage further collaboration between these groups at all stages of the planning process.

This research indicated that relationships between socio-economic factors, the built environment, physical activity, diet, and weight status are myriad and complex. The literature on the topic is voluminous. Through synthesizing the literature from both public health and planning fields, and highlighting the legal and policy frameworks that underlie these complex interactions, this paper presents an important contribution to a highly interdisciplinary literature.

7 Appendix A: Search Keywords

Combinations of the following keywords were used to query articles for potential inclusion in the literature review. Separate queries were conducted to capture articles that examined the relationship between the built environment and one or more of the health outcome categories examined in this paper. Each query combined multiple built environment search keywords with

keywords representing one of the four health outcome categories using the "AND" Boolean search function.

Built Environment Keywords:

"*built environment" OR sprawl OR neighbourhood* OR neighborhood* OR urban* OR "urban form" OR facilit* OR destination* OR location OR feature* OR distance* OR density OR access* OR planning OR plan* OR "urban design" OR "neighborhood development" OR "neighbourhood development" OR "smart growth" OR connectivity OR "new urbanism" OR "land use" OR amenit* OR "green space" OR "public space" OR "open space" OR "mixed use*" OR "mixed-use*" OR housing OR street* OR "cul-de-sac" OR playground* OR park OR parks OR trails OR path OR sidewalk OR equipment OR trail OR "rail-trail" OR greenway* OR "health* communit*" OR school OR playground.[324]

Transportation Physical Activity Keywords:

"active living" OR inactiv* OR walk* OR cycl* OR bik* OR bicycl* OR utility OR utilitarian OR "transport* activ*" OR "activ* transport*" OR *motor* OR multimodal OR multi-modal OR driv* OR car* OR auto* OR journey OR travel* OR commut* OR vehicle OR pedestrian* OR transit OR route* OR walkab* OR "transit oriented development" OR "transit-related physical activity." [325]

Recreational Physical Activity Keywords:

fit* OR leisure OR sedentary OR exercis* OR "physical* activ*" OR recreation* OR play* OR ("leisure" or "recreation*") AND "activity" OR "physical activity" OR "exercise").

Weight Status Keywords:

obesit* OR overweight OR BMI OR "body mass index" OR "weight status" OR "waist circumference" OR "adipos*" OR obesogenic.

Dietary Intake Keywords:

fruit* OR vegetable* OR diet OR "fast food" OR "fast-food" OR nutrition OR "health* food*" OR food OR "food store" OR "food outlet*" OR "food environment" OR "supermarket*" OR "food desert*" OR "food retail*" OR "grocer*" OR "restaurant*" OR "community nutrition*" OR "nutrition* resourc*."

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[324] Adapted from J L Kent, S Thompson, and Bin B Jalaludin, *Healthy Built Environments: a Review of the Literature*, *Be.Unsw.Edu.Au*, (Syndey: Healthy Built Environments Program, City Futures Research Centre, UNSW, 2011).

[325] Adapted from ibid.

8 Appendix B: A Discussion of Objective Built Environment Measures

8.1 Objective Observational Measures: Community Audits

Objective observational measures, such as community audits, are tools developed to measure the built environment as it is directly observed in the field. These tools often capture indicators of both the presence and quality of built environment characteristics hypothesized to influence either physical activity or food purchasing behaviours.[326] Observational tools are generally best used to capture built environment factors that are most appropriately assessed through direct observation (e.g., aesthetics, landscape maintenance) or are not included in readily available GIS data (e.g., sidewalk width).[327] These tools typically require direct observation of built environment characteristics in the field, either on foot or in a vehicle. In the case of tools focused on the physical activity environment, the unit of analysis is typically the street segment.[328] Tools focused on the food environment may instead involve store audits to examine food prices, variety and availability of healthy food products, or shelf space devoted to certain types of foods.[329]

A variety of observational tools have been developed, including the Physical Activity Resources Assessment Tool (PARA), Walking Suitability Assessment Tool, and the Community Health Environment Scan Survey (CHESS).[330] Observational tools focused on the physical

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[326] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science;" Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review."

[327] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 106.

[328] ibid.

[329] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review," 1175; Fiona Wong, Denise Stevens, Kathleen O'Connor-Duffany, Karen Siegel, Yue Gao, Community Interventions for Health (CIH) collaboration, "Community Health Environment Scan Survey (CHESS): a Novel Tool That Captures the Impact of the Built Environment on Lifestyle Factors," *Global Health Action* 4 (2011): 5.

[330] ibid.; Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

activity environment generally include one or more measures of built environment characteristics such as land use, streets and traffic, sidewalks, bicycling facilities, public space, amenities, architectural quality, parking, maintenance, and safety.[331] Observational tools focused on the food environment generally contain one or more measures of accessibility (e.g., whether or not a store sells fresh fruits and vegetables) and affordability (e.g., the cost of healthy food products at a given store). These tools also often classify food stores and restaurants into different categories (e.g., mega supermarket, small non-chain grocery, chain fast food restaurant, etc.).[332]

Observational tools are considered the best method for assessing built environment characteristics that require direct observation either because they are not generally included in GIS data or because they capture some qualitative aspect of the built environment.[333] For example, it may be difficult to obtain GIS data that contains information regarding sidewalk width or the availability of certain food products at different food stores. But observational tools are also highly time- and resource-intensive given that they necessarily require in-person observation and manual data entry. Assessors generally require some background in urban planning to properly observe various aspects of the built environment. Training is also critical to improving inter-observer reliability, a problem where different assessors may record different observations for the same sample segment.[334] Thus, researchers should consider utilizing community audit tools as a supplement to readily available GIS data, which may be more time- and cost-effective than conducting a full environmental audit.

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[331] ibid., 117.
[332] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review;" Wong et al., "Community Health Environment Scan Survey (CHESS): a Novel Tool That Captures the Impact of the Built Environment on Lifestyle Factors."
[333] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 107.
[334] ibid.

8.2 Objective Geographics Information Systems Measures

Objective GIS measures, in the context of built environment research, refer to "measures of the built environment derived primarily from existing data sources that have some spatial reference [e.g., an address or postal code]."[335] These measures are derived using GIS software such as ArcGIS that allow for overlay, analysis, and mapping of spatially referenced data. Because GIS measures are calculated using computer software, they are generally less time- and resource-intensive than conducting an in-person audit of a study area. It is therefore much more feasible to develop objective built environment measures for use in a study with large numbers of participants or neighbourhoods using GIS methods than an observational audit.[336]

Based on a review of more than fifty studies that examined the associations between objective GIS measures of the built environment and physical activity, Brownson et al. identified nine categories representing the most commonly assessed built environment variables. These categories are population density, land use mix, access to recreational facilities, street pattern, sidewalk coverage, vehicular traffic, crime, other (e.g. public transit, greenness), and composite indices.[337] Variables within these categories are often calculated in different ways, using measures of density, accessibility (proximity), intensity, or pattern. Within these sub-categories variables that require distance measurements are also calculated in different ways, using either Euclidean, Manhattan (right-angle city block) or road network methods to generate buffers or travel times. The food environment is similarly categorized based on density of or proximity to various stores or restaurants, within a specific buffer or travel time.[338]

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[335] ibid., 112.
[336] ibid., 112.
[337] ibid.
[338] ibid.; Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review," 1780.

Population density is one of the most commonly measured built environment characteristics. It is usually measured as either the gross or net population density (i.e., population per total land area or population per residential area), or net residential density (i.e., housing units per residential area). This measure is relatively easy to calculate because it is derived from census or parcel-level population or housing data that are generally readily available from government sources.[339]

Land use mix measures aim to capture the mixing of different land uses within a neighbourhood, defined based on either administrative units or buffers. Accessibility measures of land use mix are calculated based on the distance to the closest destination of a certain category, or to a grouping of specific destinations. Intensity measures are calculated as the number of destinations from different land use categories within a neighbourhood, or as the per cent of total neighbourhood area devoted to specific land uses. Pattern measures capture the homogeneity of land uses within a neighbourhood using an entropy index such as that developed by Frank et al.[340] Calculation of land use mix variables generally requires access to parcel-level data, and availability of such data can be limited depending on the study area examined.[341]

Access to facilities for recreation or exercise is also generally measured using accessibility or intensity metrics. Accessibility includes measures such as the network or Euclidean distance to the nearest recreation facility. Intensity includes measures such as the number of recreation facilities per area or number of recreation facilities within a specified buffer

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[339] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 112.
[340] Lawrence D Frank et al., "Linking Objectively Measured Physical Activity with Objectively Measured Urban Form: Findings From SMARTRAQ," *American Journal of Preventive Medicine* 28, no. 2 (January 31, 2005): 117–25.
[341] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

distance. Some studies have included schools within their calculation of recreational facilities, or only included public rather than private recreational facilities in calculating this variable. [342]

Street pattern includes several different variables that attempt to capture the connectivity of the street network in a given neighbourhood. For example, people may walk more for transportation purposes if streets are well connected and routes between origins and destinations are shorter. Street pattern has been calculated as the number of intersections within a defined area (intersection density) or number of intersections per length of street network. Other studies have examined the per cent of intersections within an area that are 4-way as opposed to 3-way or dead-end cul-de-sacs. Brownson et al. note that street network data is also often used in generating the network buffers or calculating network distances used in deriving other built environment variables.[343] Problems can arise where a study is attempting to capture walking distances between origins and destinations, but the street network data is based solely on the road network. In such circumstances the network data may not capture pedestrian paths and cut-throughs, while including non-walkable streets such as freeways.[344] Paths and cut-throughs can be added to the network manually, and freeways can be excluded from available travel routes, but researchers rarely report how such methodological issues are handled in analysis.

Other measures such as sidewalk coverage, vehicular traffic, crime, slope, and vegetation are less commonly included in studies on the built environment and physical activity.[345] Sidewalk coverage is generally measured as sidewalk length divided by road length, and street width (exclusive of sidewalks) is used as a proxy for vehicular traffic. Greenness has been captured in some studies using a Normalized Difference Vegetation Index calculated using

[342] ibid.
[343] ibid., 114.
[344] ibid., 114.
[345] ibid.

remote sensing data. GIS measure of crime are typically calculated as the number of crimes per population, but data sources are limited in many urban areas.[346]

Several researchers have also developed composite measures that combine multiple built environment variables into a single index or set of composite variables. Indices are "thought to capture the inter-relatedness of many built environment characteristics, minimize the effect of spatial collinearity, and ease the communication of results."[347] Index measures are typically generated using either principal component analysis or normalization (e.g., using z-scores) and weighted combination of the underlying built environment variables.[348] For example, a widely used index developed by Frank et al. consists of a weighted combination of z-scores of net residential density, intersection density, land use mix entropy, and retail floor area ratio (a measure of building footprint).[349] The "sprawl index" Ewing et al. developed using principal component analysis is comprised of 22 underlying variables, including multiple measures of residential density, land use mix, street networks, and degree of centering of employment and population across census tracts and metropolitan areas. Both indices rely on multiple data sources, including parcel land use data that can be difficult to obtain for some urban areas.

GIS measures are also used to calculate variables that measure the food environment. Most of these measures capture the presence, density or proximity of specific food resources

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[346] ibid., 114.
[347] ibid., 115.
[348] See Frank et al., "Linking Objectively Measured Physical Activity with Objectively Measured Urban Form: Findings From SMARTRAQ;" Reid Ewing et al., "Relationship Between Urban Sprawl and Physical Activity, Obesity, and Morbidity," *Am J Health Promotion* 18, no. 1 (August 2003): 47–57.
[349] L D Frank, J F Sallis, B E Saelens, L Leary, K Cain, T L Conway, and P M Hess, "The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study," *British Journal of Sports Medicine* 44, no. 13 (2010): 924–33.

within defined neighbourhood areas or travel times.[350] Density measures generally capture the number of a specific type of food outlet within a defined area, whereas proximity measures capture the distance or travel time to the nearest food outlet of a certain type. Many density measures are calculated using either Euclidean or road network buffers around study participants' homes or schools, with buffer sizes ranging from 100 m to 2500 m based on estimations of neighbourhood walkability or distances individuals might travel to reach food outlets.[351] Proximity measures are also typically assessed using either defined distances or travel times. Studies have assessed the shortest distance between home or school and specific categories of food outlets using either Euclidean, Manhattan, or road network distance. Proximity has also been measured based on travel time along the street or transit network, based on different modes of transportation (e.g. car, bus, or walking).[352] Some studies have also calculated ratios of less healthy to more healthy food availability, using measures such as the Retail Food Environment Index ("RFEI") or Physical Food Environment Indicator ("PFEI"). The RFEI is a ratio of the number of fast-food outlets and convenience stores within a neighbourhood to the number of supermarkets and produce vendors within a neighbourhood.[353]

There are benefits and disadvantages to the use of GIS measures of the built environment. These measures are often the only feasible way in which to measure the built environment for a large population or study area.[354] Definition of variables using network buffers around study participants' homes also allows for improved specificity in capturing the neighbourhood

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[350] Caspi, Sorensen, Subramanian, and Kawachi, "The Local Food Environment and Diet: a Systematic Review;" Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review."
[351] ibid., 1780.
[352] ibid., 1781.
[353] K Truong et al., "Measuring the Physical Food Environment and Its Relationship with Obesity: Evidence From California," *Public Health* 124, no. 2 (February 2010): 115–18.
[354] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."

environment surrounding each participant. However, the appropriate buffer size for use in defining different variables remains a subject of considerable debate. Charreire et al. suggest that researchers should take care to define buffer sizes based on the hypothesized relationship between the environmental variable and the specific behaviour examined.[355] Yet a huge variety of buffer sizes, variable definitions, and analytical methodologies still exist in the literature and continue to prevent meaningful between-study comparison of results.[356]

Data quality, in terms of its accuracy in categorizing different land uses or types of food outlets, as well as its comprehensiveness in identifying and including all actual food, retail or service locations can also vary widely between different data providers and study areas. Additionally, there is often a mismatch between built environment variables as conceptualized by researchers during study design and the data available to GIS analysts for generating these variables. Brownson et al. therefore suggest that studies should aim to report in greater detail the discussions and decisions made in cleaning data for analysis, to allow for development of consistent analysis protocols across studies.[357] Researchers could also aim to follow the technical specifications of analysis protocols that already exist, such as the Environment and Physical Activity GIS Protocols Manual developed by Forsyth et al., in an effort to adopt consistent analysis protocols and increase between-study comparability of results.[358]

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[355] Charreire et al., "Measuring the Food Environment Using Geographical Information Systems: a Methodological Review," 1782.

[356] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?;" Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence."

[357] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 118-119.

[358] Forsyth et al., "Neighborhood Environment for Active Transport--Geographic Information Systems Protocols."

9 Appendix C: Detailed Literature Review Results

9.1 Transportation Physical Activity

9.1.1 Population and employment density

Gross population density (persons per gross neighbourhood or buffer area) and net residential density (dwellings per net residential area within a neighbourhood or buffer) were consistently identified as significant positive correlates of transportation physical activity. In a review of 34 publications that examined associations between objectively measured characteristics of the built environment and objectively measured transportation physical activity, Grasser et al. found that all publications which examined gross population density and net residential density identified significant positive associations with either walking for transport or walking and bicycling for transport.[359] Brownson et al.'s review of measures of the physical activity environment also identified that increases in population or residential density are consistently associated with walking for transportation.[360] In an older review conducted on studies published in 2005 and 2006, Saelens and Handy found that of 8 studies which examined the relationship between population or employment density and walking for transportation, six studies identified significant associations in the expected positive direction.[361]

In a pooled meta-analysis of 17 studies focused on the influence of the physical environment on travel behaviour, Leck identified that gross residential or population density and gross employment density are both significantly positively associated with the probability of commuting by public transit or walking, and the per cent of trips by public transit or walking.[362]

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[359] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," 618.
[360] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science," 112.
[361] Saelens and Handy, "Built Environment Correlates of Walking: a Review," 559.
[362] Leck, "The Impact of Urban Form on Travel Behavior: a Meta-Analysis," 51.

While this is an older study, it is one of only two identified in this review that conducted a pooled meta-analysis of the relationship between density and walking for transportation purposes. The other meta-analysis, conducted by Ewing & Cervero, identified that population and employment densities have a small influence on walking for transport after controlling for other built environment characteristics, including land use mix and intersection density.[363] The elasticity of walking for transport was 0.07 in relation to dwelling and population density, and 0.04 in relation to employment density. By comparison, the elasticity of walking for transport in relation to intersection density was 0.39.[364]

These findings may be due in part to the fact that higher population and employment densities often coexist spatially with increased land use mix, proximity to destinations, and intersection density. Kent et al. suggest that increased residential density on its own is not necessarily sufficient to encourage higher levels of physical activity. Instead, a combination of density, mixed land use, connectivity (intersection density) and pedestrian-friendly design elements (e.g., aesthetics) is most likely to influence transportation physical activity.[365] Ewing and Cervero also suggest that the combined effect of multiple built environment characteristics on travel demand could be considerably larger than any of the individual elasticities examined in their meta-analysis.[366] It is possible, for example, that density is an intermediate or proxy variable that captures many of the other built environment characteristics that commonly exist with it (e.g., land use mix, and intersection density) and that these variables more strongly influence walking for transport than density alone.[367]

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[363] Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis," 274.
[364] ibid.
[365] Kent, Thompson, and Jalaludin, *Healthy Built Environments: a Review of the Literature*, 187-188.
[366] Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis," 275.
[367] ibid.

The question also remains as to what level of density is sufficient to increase walking or bicycling for transport. Some studies have examined potential thresholds. Lopez and Hynes suggest that walking starts to increase at gross densities ranging from 1,000 to 3,999 persons per square mile.[368] Moudon et al. also examined thresholds of objective built environment measures to identify those significantly related to the probability of walking sufficiently to meet health recommendations, and identified a net residential density threshold of 21.7 dwelling units per acre of residential land use.[369] This is equivalent to 13,888 dwellings per square mile, a much higher threshold than that suggested by Lopez and Hynes considering that multiple persons generally occupy one residential dwelling. However, Moudon et al.'s measure is net and Lopez and Hynes' is gross, making it difficult to draw meaningful comparison between the two. A common theme stated among more recent reviews is the need for future research to examine in greater detail the thresholds of different built environment characteristics after which the probability of walking or bicycling for transport is significantly more likely.[370] Planners and policymakers would find such research particularly useful in advocating for changes to the built environment that would promote physical activity.

An additional measure of density significantly associated with walking for transportation purposes was also reported in one study included in this review. Ewing and Cervero's meta-analysis included four studies that examined measures of "jobs-housing balance," the ratio of jobs to dwelling within a neighbourhood. The weighted average elasticity of walking for transport across these studies in relation to jobs-housing balance was 0.19, after controlling for

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[368] Lopez and Hynes, "SPRAWL in the 1990S Measurement, Distribution, and Trends."
[369] Moudon et al., "Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights."
[370] Sugiyama et al., "Destination and Route Attributes Associated with Adults' Walking: a Review," 1280.

the other built environment characteristics examined. Though this variable is a less commonly examined measure of density, it was included in the results of our view and generated for the City of Toronto because sufficient data was available.

9.1.2 Land Use Mix

Land use mix is generally captured using one of two methods in built environment studies. The first is a measure of the heterogeneity of square footage devoted to different categories of land use within a neighbourhood.[371] This measure is calculated using an entropy equation that generates a value from 0 to 1 for each neighbourhood, where a value of 1 indicates a perfectly even distribution of the square footage devoted to each land use across the neighbourhood and a value of 0 indicates that all land uses in the neighbourhood are of a single type.[372] The second is a measure of the proximity or density of different "utilitarian" (retail and service) destinations. This includes variables such as the distance from a study participant's place of residence to the nearest grocery store, supermarket, restaurant, post office, bank, or public transit stop—utilitarian destinations hypothesized to influence walking or bicycling for transportation purposes. It also includes variables such as the presence or density of these types of destinations within a neighbourhood area defined based on administrative units or geographic buffers.[373]

A number of studies have identified significant positive assocations between variables falling into either category of land use mix measure and transportation physical activity

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[371] Frank et al., "Linking Objectively Measured Physical Activity with Objectively Measured Urban Form: Findings From SMARTRAQ," 119.

[372] Eva Leslie et al., "Walkability of Local Communities: Using Geographic Information Systems to Objectively Assess Relevant Environmental Attributes," *Health and Place* 13, no. 1 (February 28, 2007): 116.

[373] Glazier et al., "Density, Destinations or Both? a Comparison of Measures of Walkability in Relation to Transportation Behaviors, Obesity and Diabetes in Toronto, Canada."

outcomes. In the same meta-analysis discussed above, Ewing and Cervero found that the weighted average elasticity of walking for transport in relation to land use mix entropy was 0.15, after controlling for other built environment variables, across the eight studies that examined the measure.[374] In a review focused on identifying causal relationships between the built environment and physical activity, McCormack and Shiell identified six eligible studies that examined the relationship between land use mix and various forms of physical activity. Of these studies, all of those that examined the relationship between land use mix and either transportation walking, general walking, general bicycling, or combined walking and bicycling outcomes reported statistically significant positive associations.[375] Conversely, the one study included in this review that also examined recreational walking reported no statistically significant relationships between that outcome and land use mix. [376] The results of this review are particularly persuasive because the authors only included quasi-experimental studies that focused on longitudinal changes in the built environment and physical activity, as well as cross-sectional studies that controlled for neighbourhood self-selection.[377] Neighbourhood self-selection is the theory that individuals with a greater inclination toward physical activity may choose to live in environments that support that behaviour.[378] This phenomenon may obscure the measured influence of the built environment on physical activity unless studies are designed to control and adjust for it using statistical techniques. Despite acknowledgment of this potential

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[374] Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis," 274.
[375] Gavin R McCormack and Alan Shiell, "In Search of Causality: a Systematic Review of the Relationship Between the Built Environment and Physical Activity Among Adults," *The International Journal of Behavioral Nutrition and Physical Activity* 8, no. 1 (2011): 5.
[376] ibid., 5.
[377] ibid., 3.
[378] Janne Boone-Heinonen et al., "Environment and Physical Activity Dynamics: the Role of Residential Self-Selection," *Psychology of Sport and Exercise* 12, no. 1 (January 1, 2011): 56.

bias, relatively few reviews have grouped studies based on those that adjust for self-selection and those that do not,[379] so McCormack and Shiell's findings are especially persuasive.

In a review of 29 studies that examined relationships between GIS measures of the built environment and physical activity, Butler et al. identified land use mix as one of the prevailing significant correlates of transportation physical activity, as well as leisure-time physical activity and total physical activity.[380] Saelens and Handy also found that, of the 11 studies they reviewed which examined the relationship between land use mix and transportation walking, 8 reported significant positive associations and 3 reported null or unexpected findings.[381] By comparison, 4 out of 7 studies that examined land use mix and recreational walking reported null or expected results.[382] Leck's pooled meta-analysis of studies that examined the relationship between land use mix and the probability of commuting by or per cent of trips by walking also reported a significant positive association ($p<0.001$).[383] Another review focused on walking for transport reported more equivocal results: of the four studies Grasser et al. identified as having examined the relationship between land use mix and walking for transport, two studies reported significant positive associations and two studies reported null associations.[384] Nonetheless the majority of studies reviewed indicated that there is a consistent positive association between land use mix and walking for transportation purposes.

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[379] McCormack and Shiell, "In Search of Causality: a Systematic Review of the Relationship Between the Built Environment and Physical Activity Among Adults," 2.
[380] Butler, Ambs, Reedy, and Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature," 93.
[381] Saelens and Handy, "Built Environment Correlates of Walking: a Review," 559.
[382] ibid.
[383] Leck, "The Impact of Urban Form on Travel Behavior: a Meta-Analysis."
[384] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," 620.

Many reviews and studies also identified associations between the presence, proximity, or density of utilitarian destinations and transportation physical activity. Sugiyama et al. found that significant associations between either the presence or proximity of utilitarian destinations and walking for transportation were reported in the expected direction in 80% (24 out of 30) of studies reviewed.[385] By comparison, the presence, proximity, or quality of recreational destinations such as parks and open spaces was only associated with transportation walking in 25% of the studies examined.[386] Butler et al. also identified proximity to common destinations as a consistent correlate of transportation physical activity.[387] In Saelens and Handy's review, 7 of 9 studies that examined the relationship between distance to (i.e. proximity of) nonresidential destinations and walking for transport reported significant associations in the expected direction; in these studies, neighbourhoods with shorter distances to nonresidential destinations had significantly higher rates of walking for transport.[388] By comparison, 4 out of 5 studies that examined the relationship between destination proximity and recreational walking reported null or unexpected associations.[389] The results of these reviews add support to the contention that different aspects of the built environment may influence different types of physical activity behaviours.

In a review of 70 studies conducted on European adult populations, Van Holle et al. identified consistently strong significant positive associations between proximity of shops,

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[385] Sugiyama, Neuhaus, Cole, Giles-Corti, and Owen, "Destination and Route Attributes Associated with Adults' Walking: a Review," 1278.
[386] ibid.
[387] Butler, Ambs, Reedy, and Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature," 93.
[388] Saelens and Handy, "Built Environment Correlates of Walking: a Review," 559.
[389] ibid.

services, and places of work, and bicycling for transportation.[390] A strong positive association was also identified for destination proximity and studies that examined general active transportation outcomes, but an equal number of positive and null or negative findings were identified in relation to walking for transportation.[391] However, all of the walking for transportation studies utilized subjective rather than objective measures of destination proximity and as such these findings may not be directly comparable.

Certain studies have also focused on identifying the influence of specific types of utilitarian destinations on walking. Lee and Moudon examined the proximity and density of 24 different types of destinations and 11 different combinations of destinations as potential correlates of walking sufficiently to meet health recommendations. Having a shorter distance to a grocery store, a bank, or an eating/drinking place was significantly associated with increased walking, as was having a shorter distance to a "neighbourhood centre" where grocery, retail, and restaurant destinations were located in close proximity to each other.[392] Higher densities of grocery stores and grocery-retail-restaurant neighbourhood centres within a 1km buffer were also significantly associated with increased walking.[393] Interestingly, a *lower* density of educational uses within a 1km buffer was also associated with increased walking among adults in this study, though no significant relationships were reported regarding distance to the nearest educational use.[394]

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[390] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," 9-10.
[391] ibid.
[392] Chanam Lee and Anne Vernez Moudon, "The 3Ds+R: Quantifying Land Use and Urban Form Correlates of Walking," *Transportation Research Part D: Transport and Environment* 11, no. 3 (2006): 212.
[393] ibid.
[394] ibid.

9.1.3 Street Pattern

Street pattern is objectively measured in multiple ways, including intersection density, sidewalk length, and block size.[395] Intersection density is another consistent positive correlate of transportation physical activity, while other measures of street pattern have emerged as less strong correlates in the literature. For example, in a review of GIS-based built environment measures thought to influence active transportation, Grasser et al. found that all good and fair quality publications that examined the relationship between intersection density and either walking for transport or overall active transportation reported significant positive associations.[396] By comparison, only one study of good or fair quality identified a significant association between block size and active transportation. Sugiyama et al. also found that a majority of studies that examined the relationship between intersection density and walking for transport reported significant associations.[397] Some studies that examined presence or maintenance of sidewalks also reported significant associations with walking for transport, but not a majority.

Perhaps the most convincing evidence in support of the contention that areas with higher intersection densities promote active transportation is the results of Ewing & Cervero's meta-analysis. Of all the built environment characteristics examined in this meta-analysis, walking for transport had the highest weighted average elasticity with respect to intersection density (0.39).[398] McCormack and Shiell also reviewed measures of street pattern, including intersection density, in their study focused on quasi-experimental studies and studies that controlled for neighbourhood self-selection. Their findings were more equivocal, in part because only five

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[395] Brownson et al., "Measuring the Built Environment for Physical Activity: State of the Science."
[396] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," 618-620.
[397] Sugiyama et al., "Destination and Route Attributes Associated with Adults' Walking: a Review," 1278.
[398] Ewing and Cervero, "Travel and the Built Environment: a Meta-Analysis," 274.

included studies examined measures of street pattern and only two of these studies examined the same category of outcome measure.[399] The one study that examined transportation walking found that having more pedestrian connections between residential streets and commercial streets was associated with an increase in walking to stores within the neighbourhood.[400] This finding is difficult to compare with other studies focused on the more common measure of intersection density, however, and so this paper's analysis for the City of Toronto also focuses on intersection density.

9.1.4 Composite Indices

Two types of composite indices representing combinations of built environment characteristics were identified as consistently associated with transportation physical activity. The first is a composite "walkability" index comprised of weighted z-scores of three or four variables, including residential density, intersection density, land use mix, and sometimes retail floor area ratio.[401] The second is a sprawl index comprised of twenty two land use and street network variables reduced to four factors representing residential density, land use mix, degree of centering, and street accessibility using principle components analysis.[402]

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[399] McCormack and Shiell, "In Search of Causality: a Systematic Review of the Relationship Between the Built Environment and Physical Activity Among Adults," 5.

[400] Xinyu Cao, Susan L Handy, and Patricia L. Mokhtarian, "The Influences of the Built Environment and Residential Self-Selection on Pedestrian Behavior: Evidence From Austin, TX," *Transportation* 33, no. 1 (January 2006): 1–20.

[401] See Lawrence D Frank et al., "Many Pathways From Land Use to Health: Associations Between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality," *Journal of the American Planning Association* 72, no. 1 (2006): 75–87; Frank et al., "The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study;" Leslie et al., "Walkability of Local Communities: Using Geographic Information Systems to Objectively Assess Relevant Environmental Attributes."

[402] Ewing, "Can the Physical Environment Determine Physical Activity Levels?;" Ewing, Pendall, and Chen, "Measuring Sprawl and Its Transportation Impacts."

In a review conducted by Grasser et al., three out of four "good" or "fair" quality studies that examined associations between composite walkability indices and walking reported significant positive associations. Of the two studies that focused on walking for transportation purposes, both reported significant positive associations. One study examined overall active transportation and reported a significant positive association, as did the one study focused on bicycling for transport.[403]

Another review that categorized existing literature based on different physical activity outcomes also identified consistent positive associations between composite walkability indices and total physical activity, walking for transportation purposes, and bicycling for transportation purposes. Of the 8 studies Van Holle et al. identified as having examined objectively calculated walkability indices, all but one had a significant positive association with total physical activity.[404] Similarly strong results were identified for transportation walking, with 4 out of 5 studies reporting significant positive associations between an objectively calculated walkability index and walking for transportation purposes.[405] A majority of studies also reported similar results for transportation bicycling, if studies that used subjective environmental measures are included. However, only 50% of the studies that examined objectively calculated walkability indices reported a significant association with bicycling for transportation.[406] Interestingly, a majority of studies reported no associations between objectively calculated walkability indices and *recreational* walking or bicycling, further lending support to the contention that different

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[403] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," 619-620.
[404] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," 7.
[405] ibid., 11.
[406] ibid., 12.

environmental variables may influence different types or purposes of physical activity behaviours.[407]

The results reported in the studies above regarding walking for transportation are also consistent with Frank et al.'s validation of a composite walkability index consisting of net residential density, land use mix, intersection density, and retail floor area ratio. This study validated the index against household travel behaviours in Seattle, WA and the Washington, DC – Baltimore Area. Frank et al. reported that the per cent of residents who walked to work was 4 to 6 per cent higher in neighbourhoods with high walkability index values and high median household incomes compared with low walkability index / high income neighbourhoods.[408] Among lower income neighbourhoods, the per cent of residents who walked to work was 4 to 7 per cent higher in high walkability index neighbourhoods than low walkability index neighbourhoods.[409] In a separate analysis conducted using data from the same study, Sallis et al. reported that the walkability index had a highly significant effect on both overall moderate to vigorous physical activity and walking for transport in neighbourhood analyses stratified based on income and walkability.[410] These effects also remained significant after adjusting for neighbourhood self-selection bias.[411] These studies indicate that composite indices capture important components of the built environment that are likely to influence both total physical activity and walking for transportation purposes.

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[407] ibid., 10.
[408] Frank et al., "The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study," 929.
[409] ibid., 929.
[410] J F Sallis, B E Saelens, L D Frank, T L Conway, D J Slymen, K L Cain, J E Chapman, and J Kerr, "Neighborhood Built Environment and Income: Examining Multiple Health Outcomes," *Social Science & Medicine* 68, no. 7 (2009): 1291.
[411] ibid., 1292.

Ewing et al.'s sprawl index, developed in the early 2000s, has received somewhat less attention in more recent literature.[412] However, Ewing et al.'s early work indicated that the sprawl index was significantly associated with both the per cent of workers walking to work and the per cent of workers taking public transit to work in a metropolitan area.[413] Elasticities calculated for each of these dependent variables indicated that, for every 1% increase in the sprawl index, the per cent of commuters walking to work increases by 0.93% and the per cent of commuters taking public transit to work increases by 1.78%.[414] Calculation of this index is relatively complex, as it combines twenty two different built environment variables using principal components analysis. It therefore requires individual generation of each component variable, as well as a second principal components analysis to combine them. The index is also calculated over relatively large areas, at the county- or metropolitan-level, and may thus include both urban and rural regions in some areas. The complexity and large scale of the index may explain in part why most current studies have tended to focus on Frank et al.'s composite walkability index instead.[415]

9.1.5 Other Variables

Only one additional variable was identified in this literature review as a consistent correlate of transportation physical activity. This variable is slope or "hilliness." The rationale behind this variable is that neighbourhoods or travel routes with a greater slope may deter individuals from walking or bicycling for transportation purposes due to the increased intensity of walking or bicycling in such an environment. A review of European studies found that two of

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[412] Ewing, Pendall, and Chen, "Measuring Sprawl and Its Transportation Impacts."
[413] Ewing, "Can the Physical Environment Determine Physical Activity Levels?," 71.
[414] ibid., 71.
[415] See Frank et al., "The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study."

three studies that examined the association between slope and bicycling for transportation reported a statistically significant negative association.[416] In these studies, adults who lived in areas with more hills (i.e., a greater slope) were less likely to bicycle for transportation purposes. The only North American study identified in this review found that slope was negatively associated with walking for transportation purposes but positively associated with walking for recreation purposes.[417] Intuitively this makes sense, as individuals motivated to exercise recreationally may seek out hills for a more intense workout. In the UK, one study reported that higher variability of slope within a 1km distance of study participants' residences was significantly associated with *lower* BMI.[418] This study did not examine the association between slope and physical activity, however.

In sum, the literature review identified measures of density, land use mix, and street pattern as consistent significant positive correlates of transportation physical activity. Composite walkability indices that combined these measures were also consistently associated with walking for transportation purposes and total physical activity. The slope or hilliness of the built environment may also influence physical activity, but in different directions for different purposes. Relatively few studies have examined this last measure and additional research is required to confirm its validity.

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[416] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review," 12.

[417] C Lee and A Moudon, "Correlates of Walking for Transportation or Recreation Purposes," *Journal of Physical Activity & Health* 3, Suppl 1 (2006): S77-S98, S95.

[418] Chinmoy Sarkar, John Gallacher, and Chris Webster, "Built Environment Configuration and Change in Body Mass Index: the Caerphilly Prospective Study (CaPS)," *Health and Place* 19 (2013): 39.

9.2 Recreational Physical Activity

With a few exceptions, most of the factors identified as significant built environment correlates of transportation physical activity are generally unrelated to recreational or leisure-time physical activity. This is consistent with the theoretical notion that different environmental influences may act differently on different types of behaviours in different contexts. For example, access to a walking trail or a park may have a much stronger influence on walking or running for recreational purposes, than on transportation physical activity related to commuting or running errands. Other than intersection density, most of the reviews identified quite different correlates of recreational physical activity compared with transportation physical activity. Each of these correlates is discussed in turn below.

9.2.1 Parks and Recreational Facilities

There are three main variables within the category of parks and recreational facilities that the reviewed studies identified as significant correlates of recreational physical activity. These are the quality of recreational facilities, access to and availability of parks, green and open space, and access to walking trails. Interestingly, proximity to or density of recreational facilities was generally identified as having no significant association with recreational physical activity in a majority of studies that examined that relationship.[419]

Quality of recreational facilities is difficult to measure using GIS, and is generally assessed either through objective audits of attributes of parks and recreational facilities, or through survey questions asking study participants about the attractiveness of or their satisfaction

[419] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," 8.

with parks and recreational facilities.[420] Sugiyama et al. identified four studies that examined this measure in relation to walking for recreational purposes, and all four studies reported significant positive associations.[421] The findings of Ward Thompson et al. and Lee and Maheswaran were similar.[422] By comparison, Van Holle et al.'s extensive review of studies that examined the proximity and presence of recreational facilities reported that a strong majority of studies found no associations with recreational walking and cycling, total walking/cycling, and leisure-time physical activity.[423]

The size and proximity of parks and open spaces is also an important correlate of recreational physical activity. Some studies have shown that size and proximity can interact with the quality of park and open space facilities to influence how much people engage in certain types of physical activity. Sugiyama et al. examined the relationships between park size, attractiveness, and proximity, and reported that having a shorter distance to an attractive park of any size influenced whether or not study participants undertook any recreational physical activity. When examining *how much* participants walked, however, immediate proximity had less influence and park size had a greater influence.[424] The presence of a large, high quality park within a 1.6km distance of participants' homes had a stronger significant association with

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[420] Sugiyama et al., "Destination and Route Attributes Associated with Adults' Walking: a Review," 1280.

[421] ibid.

[422] Catharine Ward Thompson, "Activity, Exercise and the Planning and Design of Outdoor Spaces," *Journal of Environmental Psychology* 34 (2013): 86; A C Lee and R Maheswaran, "The Health Benefits of Urban Green Spaces: a Review of the Evidence," *Journal of Public Health (Oxford, England)* 33, no. 2 (2011): 217-217.

[423] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review," 8-10.

[424] Takemi Sugiyama, Jacinta Francis, Nicholas J Middleton, Neville Owen, and Billie Giles-Corti, "Associations Between Recreational Walking and Attractiveness, Size, and Proximity of Neighborhood Open Spaces," *American Journal of Public Health* 100, no. 9 (September 2010): 1755-1756.

participants' likelihood of engaging in more than 150 minutes of recreational walking per week, compared with having a smaller, high quality park within the same distance.[425]

Sugiyama et al. further investigated the influence of the presence, proximity, and density of public open spaces on recreation *walking* in a more recent cross-sectional study. In this study, none of these measures of access to or availability of public open spaces—defined as public open spaces larger than 1.2 hectares with activity and sport facilities—were associated with occasional or frequent recreational walking.[426] However, significant interactions were observed between the aesthetics of public open spaces and the presence of public open spaces on occasional walking. Access to walking trails and intersection density also had significant associations with frequent recreational walking.[427] These results indicate that access to or availability of public open spaces may have less of an influence on recreational walking as compared with other forms of recreational physical activity, and that built environment variables such as walking trails, intersection density, and aesthetics may more strongly influence recreational walking.

Various reviews have also examined in a more general manner the influence of park and open space availability on different types of recreational physical activity and physical activity generally. Butler et al. reported that GIS measures of green and open space proximity were significantly associated with both total physical activity and leisure-time physical activity in a majority of studies they examined.[428] Two other articles focused on the influence of parks and

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[425] ibid., 1755-1756.
[426] Takemi Sugiyama, Catherine Paquet, Natasha J Howard, Neil T Coffee, Anne W Taylor, Robert J Adams, and Mark Daniel, "Public Open Spaces and Walking for Recreation: Moderation by Attributes of Pedestrian Environments," *Preventive Medicine* 62 (2014): 26-27.
[427] ibid., 26-27.
[428] Butler, Ambs, Reedy, and Bowles, "Identifying GIS Measures of the Physical Activity Built Environment Through a Review of the Literature," 93.

recreations spaces and facilities on physical activity, broadly defined.[429] These reviews both reported that a majority of studies reported some form of association between the proximity of a park or recreation facility and physical activity outcomes.[430] But these results were not summarized based on the specific purpose or type of physical activity examined and thus are relatively difficult to interpret compared with the studies discussed above. The evidence therefore indicates that the quality or attractiveness of recreational facilities, as well as the presence of certain sizes or types of parks within specific travel distances are most likely to influence recreational physical activity. Access to walking trails may also play a stronger role in influencing recreational *walking* than the presence or proximity of a public open space does.

9.2.2 Street Pattern

Two variables that capture the built environment's street pattern were identified as potential correlates of recreational walking. The evidence was not as strong for these variables as it was for parks and recreation facilities, and relationships with total recreational physical activity or leisure-time physical activity were not identified in the literature. In one study intersection density, measured as the number of 3-way or greater intersections per area within a 1km buffer, was examined as a potential moderator of the relationship between public open space presence, proximity and density, and recreational walking.[431] No significant interactions were observed, however, intersection density and access to walking trails were the only two variables in the

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[429] See K Lachowycz and A P Jones, "Greenspace and Obesity: a Systematic Review of the Evidence," *Obesity Reviews* 12, no. 5 (February 23, 2011): e183–89; Kaczynski and Henderson, "Environmental Correlates of Physical Activity: a Review of Evidence About Parks and Recreation."

[430] See Lachowycz and Jones, "Greenspace and Obesity: a Systematic Review of the Evidence," 4; Kaczynski and Henderson, "Environmental Correlates of Physical Activity: a Review of Evidence About Parks and Recreation," 345.

[431] Sugiyama et al., "Public Open Spaces and Walking for Recreation: Moderation by Attributes of Pedestrian Environments."

multinomial logistic regression that were significantly associated with walking for recreation.[432] Study participants who lived in areas with higher intersection density had 35% higher odds of walking five or more times per week for recreation (versus non-walking) compared with study participants who lived in lower intersection density areas.[433]

The relationship between intersection density and other recreational physical activity outcomes is less clear, however, in part due to a lack of evidence. Most of the studies identified in this review examined intersection density, either individually or as a component of a composite walkability index, in relation to transportation physical activity or overall walking. One recent European review identified only four studies that had examined intersection density in relation to either leisure-time physical activity or recreational walking/cycling, and all of these studies reported either null or negative associations.[434] It is therefore possible that intersection density may have a stronger influence on walking behaviours, for transportation or recreational purposes, than on other forms of recreational physical activity.

The second street pattern variables identified as a potential correlate of recreational walking is sidewalk length. In an older study focused on identifying specific built environment correlates of walking for transportation and walking for recreation, Lee and Moudon examined sidewalk length calculated as the total length (in miles) of sidewalk within a 1km buffer of participants' homes.[435] Participants with higher total sidewalk length were 11.7% more likely to walk frequently for recreation purposes versus not walking for recreation purposes.[436] In the same study, total sidewalk length was not associated with transportation walking. This may

[432] ibid., 26.
[433] ibid., 26-27.
[434] Van Holle et al., "Relationship Between the Physical Environment and Different Domains of Physical Activity in European Adults: a Systematic Review."
[435] Lee and Moudon, "Correlates of Walking for Transportation or Recreation Purposes."
[436] ibid., 94.

indicate that having a number of high-quality walking routes is a stronger influence on recreational walking, whereas overall connectivity between routes has a stronger influence on transportation walking.

9.3 The Food Environment

Evidence regarding the relationships between measures of the food environment and dietary intake is mixed and inconsistent. Many studies have found no signification correlations between the presence or density of food outlets selling more or less healthy foods and measures of dietary intake. This may be due to the considerable heterogeneity in food environment measures and definitions of "neighbourhood" across studies, as some buffer sizes may more accurately capture the specific environment-behaviour influence than others. It is also possible that objective measures of the food environment, such as the presence or density of a food store category assumed to sell healthy foods, may fail to capture whether healthy foods are actually stocked and affordable at a given food store location. While this review was focused on adults and not on population sub-groups, a majority of research does support the proposition that access to fast food outlets (which sell less healthy foods) is higher in neighbourhoods that have a higher proportion of low income and visible minority populations. These results support the need for interventions targeted at improving access to affordable, healthy foods in low-income communities.

Perhaps the most comprehensive assessment of the relationship between objective measures of the food environment and dietary outcomes is the "review of reviews" conducted by Black et al.[437] This article summarized reviews focused on the relationship between objectively

[437] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?."

assessed proximity and density of stores selling healthy or less healthy foods and dietary outcomes. Significant positive expected associations between these independent variables and measures of dietary intake were identified in some studies, but overall the majority of studies reported null associations. The per cent of studies that identified significant positive expected associations for proximity to and density of stores selling health foods (supermarkets, grocery stores, and green grocers) was 20% and 27%, respectively.[438] In studies that examined proximity to and density of stores selling less healthy foods (convenience stores and fast food outlets), significant expected associations were reported in 13% and 22% of studies, respectively.[439]

Most of these studies summarized in Black et al.'s review were conducted in the United States. The one Canadian study identified also reported null associations between objective measures of the food environment and dietary intake, however. Minaker et al. examined associations between various objective food environment measures and dietary intake in Waterloo, Ontario, using multilevel regression analyses stratified by gender. None of the food environment measures assessed using GIS were associated with dietary intake among men or women.[440] These associations remained insignificant in a secondary analysis that controlled for individual's perceptions of the food environment.[441] Objective measures examined in this study included proximity to supermarkets, convenience stores, and fast-food outlets, as well as the total number of stores and total number of restaurants within a 1km buffer of participants' homes. The density of specific types of food stores was not examined.[442]

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[438] ibid., 236.
[439] ibid., 236.
[440] Leia M Minaker, Kim D Raine, T Cameron Wild, Candace I J Nykiforuk, Mary E Thompson, and Lawrence D Frank, "Objective Food Environments and Health Outcomes," *American Journal of Preventive Medicine* 45, no. 3 (2013): 293.
[441] ibid.
[442] ibid., 291.

It is possible that the mixed results identified in the food environment literature are attributable in part to the fact that many studies focused on adult or child populations generally, whereas the specific environment-behaviour relationships examined may differ between population sub-groups. Reviews have identified ecological differences in neighbourhood food environments based on neighbourhood-level deprivation, income, or ethnicity. For example, Black et al.'s review also focused on assessing inequalities in neighbourhood food environments and concluded that, at least in the United States, residents of low income or high ethnic population neighbourhoods have greater access to stores selling less healthy foods and poorer access to stores selling more healthy foods compared with residents of more affluent neighbourhoods.[443] In studies focused on Canada, there is also compelling evidence that residents of more deprived neighbourhoods have greater access to stores selling *less* healthy foods. Evidence of inequalities in access to stores selling *more* healthy foods by level of neighbourhood deprivation in Canada was more mixed, however.[444]

The summary results that Black et al. reported for Canada are similar to another recent Canadian study focused on neighbourhood deprivation and food environments in southern Ontario. Polsky et al. examined variations in access to food outlets selling more healthy and less healthy foods by level of neighbourhood deprivation in Toronto, Mississauga/Brampton, and Hamilton.[445] Results indicated that access to outlets selling less healthy foods was significantly greater in the most deprived neighbourhoods in Hamilton and Mississauga/Brampton, compared

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[443] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?," 231; See also Fleischhacker et al., "A Systematic Review of Fast Food Access Studies;" Fraser et al., "The Geography of Fast Food Outlets: a Review."

[444] Black, Moon, and Baird, "Dietary Inequalities: What Is the Evidence for the Effect of the Neighbourhood Food Environment?," 231.

[445] Polsky, Moineddin, Glazier, Dunn, and Booth, "Foodscapes of Southern Ontario: Neighbourhood Deprivation and Access to Healthy and Unhealthy Food Retail."

with the least deprived neighbourhoods.[446] These areas also had greater access to stores selling more healthy foods, however. In Toronto, the results differed. Access to outlets selling less healthy food was generally greater in less deprived neighbourhoods.[447] This may be due in part to the large concentration of fast food outlets in the downtown core of Toronto, an area that has experienced increased population and income growth in recent years.[448]

The results of these studies indicate that further research into the link between perceptual and environmental measures of the food environment and dietary intake among different population sub-groups is required. It is possible, for example, that objective or subjective access to healthy or unhealthy food stores may differently influence specific measures of dietary intake among low-income populations or specific ethnic minority groups. One study in the United States reported an increase in fruit and vegetable consumption after a new supermarket opened in a more deprived community, though another study in a different region found no association for the same relationship.[449] Other studies have suggested that supermarket presence may more strongly influence dietary behaviours in Latin-American than in African-Americans.[450] One review also found that 10 out of 12 studies that examined the relationship between fast food availability and race identified a significantly higher number of fast food outlets in areas with greater populations of ethnic minority groups, compared with areas that had greater Caucasian populations.[451]

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[446] ibid., 372.
[447] ibid.
[448] See Hulchanski et al., *The Three Cities Within Toronto*.
[449] Rahmanian, Gasevic, Vukmirovich, and Lear, "The Association Between the Built Environment and Dietary Intake - a Systematic Review," 192.
[450] ibid., 192.
[451] Fleischhacker et al., "A Systematic Review of Fast Food Access Studies," 465.

Further examination of the complex relationships between the food environment, dietary intake, income, race, and sex is necessary to advance the literature, but is also outside the scope of this paper. Accordingly, despite the somewhat mixed results identified in this review, it remains pertinent to further examine the patterns of proximity to and density of stores selling more healthy and less healthy foods in the City of Toronto. The variables selected for further analysis are the proximity and density of more healthy food stores and less healthy food stores. Though the evidence regarding associations between these objective food environment measures and dietary intake is mixed, the majority of the literature has focused on the United States and only one known study has previously examined these variables in the City of Toronto.

9.4 Physical Activity Environment and Food Environment Correlates of Weight Status

A total of 31 studies were identified that reviewed or examined the relationship between various measures of the physical activity environment and/or the food environment and various indicators of weight status (e.g., BMI, overweight, obesity, waist circumference). Together these studies indicated that very few of the independent variables examined in the literature demonstrate consistent significant associations with weight status. The evidence is mixed and inconsistent for a number of physical activity environment variables, including measures of street pattern, access to parks, green spaces and recreational facilities, and composite walkability indices. Several recent reviews concluded that the only two measures of the physical activity environment consistently associated with weight status outcomes were density and land use mix, and even among these reviews there was some disagreement.[452] With respect to the food

[452] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review;" Mackenbach et al., "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and

environment, the only objective measure that has emerged as a potential correlate of weight status is proximity to or density of fast food outlets.[453] The evidence regarding this measure is still relatively equivocal,[454] though one of the few longitudinal studies identified in this review reported significant increases in weight and waist circumference among participants living in areas with higher densities of fast food outlets.[455] More detailed evidence regarding the relationships between measures of density, land use mix, and proximity to and density of fast food outlets and weight status outcomes is discussed below.

Several recent reviews examined relationships between components of the physical activity environment and weight status outcomes. Grasser et al. reviewed 34 articles with a focus on GIS-based measures of the physical activity environment and their potential associations with active transportation and weight status outcomes.[456] A majority of studies in this review that examined gross population density reported significant negative associations with weight measures (i.e., greater population density was associated with lower weight). There was less consistency in reported results regarding residential density, land use mix entropy, intersection density, and walkability indices. Among studies that examined each of these variables in relation to indicators of weight status, at least 50 per cent of studies reported null associations or significant associations in an unexpected direction.[457] Lebel et al. and Durand et al. similarly

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Adult Weight Status, the SPOTLIGHT Project;" Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence."

[453] Fleischhacker et al., "A Systematic Review of Fast Food Access Studies;" Li et al., "Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults: Portland Neighborhood Environment and Health Study."

[454] Fraser et al., "The Geography of Fast Food Outlets: a Review."

[455] Li et al., "Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults: Portland Neighborhood Environment and Health Study."

[456] Grasser, van Dyck, Titze, and Stronegger, "Objectively Measured Walkability and Active Transport and Weight-Related Outcomes in Adults: a Systematic Review."

[457] ibid., 621.

conclude that there is limited evidence of associations between most measures of the physical activity environment and weight status.[458] Lachowycz and Jones also reported that a majority of studies focused on the relationship between indicators of green space and BMI, a majority of studies reported weak or null relationships.[459]

Despite the fact that Grasser et al. reported that 50 per cent of studies have identified null or unexpected associations between land use mix and weight status, other reviews have reported that land use mix entropy and sprawl indices are the only two physical environment variables that have somewhat consistent associations with weight status and obesity. Mackenbach's systematic review, which utilized the Quality Assessment Tool for Quantitative Studies to assess the methodological quality of the studies examined, reported that the only built environment factors consistently associated with weight status in North America are land use mix and urban sprawl.[460] This conclusion is consistent with Feng et al.'s earlier systematic review, which also concluded that of all the potential environmental correlates of obesity examined in the literature only land use mix and the county sprawl index demonstrated clear associations with obesity.[461]

These findings are perhaps not surprising given the complex pathways through which the physical activity environment may influence physical activity and weight status. Relationships are complex, context- and individual-specific, and the great heterogeneity in measures used to calculate independent variables and define neighbourhods has limited comparability of results

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[458] Lebel et al., "Lifestyles and Consumption in Cities and the Links with Health and Well-Being: the Case of Obesity;" C P Durand et al., "A Systematic Review of Built Environment Factors Related to Physical Activity and Obesity Risk: Implications for Smart Growth Urban Planning," *Obesity Reviews : an Official Journal of the International Association for the Study of Obesity* 12, no. 5 (May 2011): e173–82.

[459] Lachowycz and Jones, "Greenspace and Obesity: a Systematic Review of the Evidence."

[460] Mackenbach, et al., "Obesogenic Environments: a Systematic Review of the Association Between the Physical Environment and Adult Weight Status, the SPOTLIGHT Project," 9.

[461] Feng et al., "The Built Environment and Obesity: a Systematic Review of the Epidemiologic Evidence," 182.

across studies. Of note is the fact that population density, land use mix entropy, and the county sprawl index are measures that have been calculated using relatively similar methodologies across studies. By comparison, methods used for calculation of access to or availability of utilitarian destinations, parks, green spaces, and recreation facilities vary widely. It is possible that if studies adopted more consistent measurement techniques the influence of these variables could be determined more definitively.

Some longitudinal studies have also suggested that individuals' perceptions of the physical activity environment may attenuate relationships with obesity. Gebel et al. conducted a four-year longitudinal study aimed at examining whether individuals who perceive objectively measured high walkability environments as having low walkability walk less and gain more weight over time than individuals' with matched perceptions.[462] This study found that "participants who perceived objectively measured high walkability" (based on a composite index), land use mix entropy, and retail store density as low gained significantly more weight over the four-year study period than participants "whose perception matched the objective measure."[463]

Results regarding the influence of objectively assessed food environment variables on obesity are similarly complex. With the exception of proximity to or density of fast food outlets, reviews have not identified any consistent food environment correlates of obesity. Fleischhacker et al. conducted a systematic review of fast food access studies and reported that six out of ten studies identified significant associations between greater access to fast food outlets and higher

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[462] Klaus Gebel, Adrian E Bauman, Takemi Sugiyama, and Neville Owen, "Mismatch Between Perceived and Objectively Assessed Neighborhood Walkability Attributes: Prospective Relationships with Walking and Weight Gain," *Health and Place* 17, no. 2 (2011): 519–24.

[463] ibid., 522.

obesity prevalence among adults.[464] Fraser et al. reported similar results, with 50% of the studies that examined associations between proximity to and/or density of fast food outlets reporting significant associations with obesity.[465] Giskes et al.'s review also reported similar results.[466] These results are supported by one of the few longitudinal studies that examined associations between fast food access and weight status. Li et al. found that, among residents who visited fast food restaurants 1 or more times per week, living in a neighbourhood with a high density of fast-food outlets was significantly associated with a one-year increase in weight of 1.40 kg and an increase in waist circumference of 2.06 cm, after adjusting for neighbourhood and individual-level sociodemographic characteristics.[467]

In conclusion, relatively few consistent environmental correlates of weight status were identified in the literature review. Density, land use mix, and the sprawl index were the only measures of the physical activity environment that studies indicated had clear associations with body weight. The only food environment variable consistently associated with body weight was proximity to or density of fast food outlets. Despite these findings, it is nonetheless possible that other built environment factors (either individually or in combination with each other) may influence weight status through complex pathways in specific population sub-groups. For example, research supports the notion that neighbourhoods with high populations of low-income and visible minority residents have better access to unhealthy food stores and worse access to

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[464] Fleischhacker et al., "A Systematic Review of Fast Food Access Studies," 467.
[465] Fraser et al., "The Geography of Fast Food Outlets: a Review."
[466] K Giskes et al., "A Systematic Review of Environmental Factors and Obesogenic Dietary Intakes Among Adults: Are We Getting Closer to Understanding Obesogenic Environments?," *Obesity Reviews: an Official Journal of the International Association for the Study of Obesity* 12, no. 5 (2011): e95–e106.
[467] Li et al., "Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults: Portland Neighborhood Environment and Health Study," 405-406.

healthy food stores, as well as a higher risk of obesity, especially among women. [468] Most of the studies that support this premise utilized cross-sectional methodologies, however, and further longitudinal research is required to demonstrate causality.

10 Appendix D: Additional Methodological Procedures

10.1 Data Cleaning Procedures for Units of Analysis

Several data cleaning procedures were used to clean the Dissemination Block ("DB") and Neighbourhood units used for our GIS analyses. The first step was the removal of the Toronto Islands from both the DB and Neighbourhood units. While there are a small number of permanent residents on the Toronto Islands, these areas were excluded from analysis because they are primarily park land, with few other destinations or community resources, and individuals rely on a ferry service to travel to and from the Islands and City. Thus, the polygons comprising the Toronto Islands were removed from both DB and Neighbourhood unit files. Population data for the corresponding Neighbourhood, which also included waterfront portions of the City, was adjusted accordingly.

Additional cleaning was also performed on the DB units. Because the focus of the analyses that used DBs was on capturing the built environment within an area surrounding individuals' places of residence, DBs that had fewer than 5 residents or dwellings were removed from the analysis. Additionally, to define residentially-weighted centroids (geometric centre points) of DBs for use as "origin" points in road network-based analyses, the DB polygons were clipped based on residential areas within the City of Toronto. This procedure resulted in some multi-part polygons, due to the fact that DB boundaries are defined based only on the road

[468] Townshend and Lake, "Obesogenic Urban Form: Theory, Policy and Practice;" Black and Macinko, "Neighborhoods and Obesity."

network and not based on natural boundaries such as ravines, rivers, and streams. For example, where a DB straddled a ravine it typically consisted of two or more residential areas on opposite sides of the ravine. Therefore, to improve the accuracy of road network-based analyses, a residentially-weighted centroid was created for each individual residential polygon area within a DB. Population values were allocated to each residential area within a DB proportionally based on their area in relation to the other residential areas within the DB.

10.2 Utilitarian Destinations

For the purpose of these analyses, utilitarian destinations were defined based on categories of "diverse uses" in the LEED for Neighbourhood Development rating system.[469] These diverse uses capture a variety of food retail, community-serving retail, service, and civic and community facility destinations. A list of Standard Industrial Classification ("SIC") codes that capture destinations similar to those in the categories of diverse uses was generated and used to query an initial selection of utilitarian destinations from DMTI Spatial Inc. Enhanced Points of Interest data for the year 2009. These SIC codes are presented in Table D1. Selected destinations whose SIC code description contained the terms "Auto & home supply stores" or "Hotels & Motels" or "Household Appliance Stores" or "Lumber & other building materials" or "Paint, glass & wallpaper stores" and whose business name did not contain the terms 'CANADIAN TIRE' or 'HARDWARE' were excluded. This query was combined with public elementary and

[469] Congress for New Urbanism et al., *LEED 2009 for Neighbourhood Development Rating System with Canadian Alternative Compliance Paths*, 145.

secondary school data from the Ministry of Education for the year 2009 to create the final utilitarian destinations dataset.[470]

Table D1. Standard Industry Classification Codes used to Select Utilitarian Destinations

SIC CODE	DESCRIPTION
79990000	Amusement And Recreation Services, nec
84220000	Arboreta And Botanical Or Zoological Gardens
55310000	Auto & home supply stores
72410000	Barber Shops
72310000	Beauty Shops
59420000	Book Stores
79330000	Bowling Centers
82440000	Business And Secretarial Schools
59460000	Camera And Photographic Supply Stores
54410000	Candy, nut & confectionery stores
83510000	Child Day Care Services
56410000	Children's & infants' wear stores
79930000	Coin-Operated Amusement Devices
72150000	Coin-Operated Laundries & Dry Cleaning
82210000	Colleges, Universities, & Professional Schools
57340000	Computer And Computer Software Stores
57340000	Computer And Computer Software Stores
60610000	Credit Unions, Federally Chartered
60620000	Credit Unions, Not Federally Chartered
54510000	Dairy Products Stores
79110000	Dance Studios Schools & Halls
82430000	Data Processing Schools
53110000	Department Stores
57140000	Drapery & upholstery stores
58130000	Drinking Places (Alcoholic Beverages)
59120000	Drug Stores And Proprietary Stores
58120000	Eating Places
56510000	Family Clothing Stores
57130000	Floor Covering Stores
59920000	Florists
54310000	Fruit & vegetable markets

[470] Data from the Ministry of Education was provided for informational purposes only. Although the Ministry of Education endeavours to keep the information accurate and current, it cannot be held responsible for any damage resulting from its use.

Table D1. Standard Industry Classification Codes used to Select Utilitarian Destinations

SIC CODE	DESCRIPTION
57120000	Furniture Stores
72120000	Garment Pressing & Agents For Laundries & Drycleaners
59470000	Gift, Novelty, And Souvenir Shops
54110000	Grocery Stores
52510000	Hardware Stores
59450000	Hobby, Toy, And Game Shops
70110000	Hotels & Motels
57220000	Household Appliance Stores
83220000	Individual And Family Social Services
59440000	Jewellery Stores
83310000	Job Training And Vocational Rehabilitation Services
82220000	Junior Colleges And Technical Institutes
82310000	Libraries
59210000	Liquor Stores
59480000	Luggage And Leather Goods Stores
52110000	Lumber & other building materials
54210000	Meat & fish markets
79970000	Membership Sports And Recreation Clubs
56110000	Men's And Boys' Clothing And Accessory Stores
56990000	Miscellaneous Apparel And Accessory Stores
54990000	Miscellaneous Food Stores
53990000	Miscellaneous General Merchandise Stores
57190000	Miscellaneous Home Furnishings Stores
72990000	Miscellaneous Personal Services, nec
59990000	Miscellaneous Retail Stores, nec
78320000	Motion Picture Theaters, Except Drive-In
84120000	Museums And Art Galleries
57360000	Musical Instrument Stores
60210000	National Commercial Banks
59940000	News Dealers And Newsstands
59950000	Optical Goods Stores
52310000	Paint, glass & wallpaper stores
73340000	Photocopying And Duplicating Services
72210000	Photographic Studios Portrait
79910000	Physical Fitness Facilities
72110000	Power Laundries, Family & Commercial
57310000	Radio, Television, And Consumer Electronics Stores
57350000	Record And Prerecorded Tape Stores
54610000	Retail Bakeries

Table D1. Standard Industry Classification Codes used to Select Utilitarian Destinations

SIC CODE	DESCRIPTION
52610000	Retail nurseries & garden stores
82990000	Schools And Educational Services, nec
59490000	Sewing, Needlework, And Piece Goods Stores
72510000	Shoe Repair Shops & Shoeshine Parlors
56610000	Shoe Stores
59410000	Sporting Goods And Bicycle Shops
60220000	State Commercial Banks
59430000	Stationery Stores
59930000	Tobacco Stores And Stands
47240000	Travel Agencies
59320000	Used Merchandise Stores
53310000	Variety Stores
78410000	Video Tape Rental
82490000	Vocational Schools, nec
56320000	Women's Accessory And Specialty Stores
56210000	Women's Clothing Stores

10.3 Parks and Open Spaces

Land use data for the year 2009 from DMTI Spatial Inc. that contained park and open space polygons was queried based on polygon area to create the five park and open space categories listed in Table D2, below. In order to examine the availability of each of these park categories within their corresponding road network distance cutoffs, it was necessary to convert the lines representing the boundaries of each park and open space polygon into points. This is because the Network Analyst extension in ArcGIS can only analyze the distance between two points along the road network, not polygons. The points were spaced at an even distance of 50 metres along the park boundary lines, and additional points were added to represent the location of each DB centroid that fell within a park or open space polygon in the land use data. The latter situation occurred for some DB centroids in north-east Scarborough, an area of Toronto that is relatively sparsely populated and contains protected park, open space, and agricultural lands. A field was created that contained, for each park boundary point, a value corresponding to the area

of park it represented. The park boundary points were further edited to remove all points that fell outside a 50 metre buffer of the road network. It was assumed that only those points falling within the 50 metre buffer represented locations at which an individual could access or enter a given park or open space.

Table D2. Categories of Parks and Open Spaces and Corresponding Travel Distances.

Category	Size	Travel Distance
Parkette	0.01-0.49 Ha	400m
Neighbourhood Park	0.5-2.9 Ha	800m
Community Park	3.0-4.9 Ha	1200m
District Park	5.0-14.9 Ha	3km
City Park	15.0+ Ha	5km

An origin-destination cost matrix network analysis was then performed in ArcGIS Network Analyst. This analysis calculated the distance from each DB centroid to all park boundary points within a 5 kilometre road network distance. The resulting output table contained the travel distance between each DB and all park access points within a 5 kilometre network distance, as well as the size of park that each park access point represented. This data was queried to calculate, for each DB centroid, whether or not a park of each size category existed within the travel distance cutoff specified for a given park size category. The result was five fields, each indicating whether a park of a given size was accessible within its corresponding travel distance cutoff. For mapping purposes, these results were attributed to Neighbourhood units. The per cent of the population within a Neighbourhood that had access to a given park category within the corresponding travel distance cutoff was calculated, based on the population of each DB located within a given Neighbourhood.

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