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Examining the Active Transportation - Built Environment Relationship in London, Ontario

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Abstract

Research on the relationship between the built environment and active transportation has accelerated and expanded over the past 20 years. This growth is in large part due to continuing evidence of rising rates in obesity and Type-2 diabetes that coincides with decreasing rates of physical activity across all ages in the post-industrial world. Walking more is a simple solution to increasing rates of physical activity. While for most people walking is possible throughout the day, there has been a decrease in the use of walking as a means of transportation. This study examines environmental determinants of active transportation from two perspectives: 1) working adults and 2) elementary school children. It adopts multiple methodologies for identifying travel corridors in geographic information systems (GIS) analysis and tests a novel technique by applying a hexagonal grid to extract built environment measures. Results from this research suggest global positioning system (GPS) tracking is a viable method to capture built environment measures, especially for children. As in previous studies, this study found distance between origin and destination to be the most important determinant to active travel with socio-economic status also playing a key role for adults and children. Results from this research are concurrent with previous literature while employing hexagons as a geographic unit. Examining the active transportation/built environment relationship through the use of GPS and a hexagonal areal unit is a new approach that deserves serious consideration for further research.

Keywords

Active Transportation, Built Environment, Geographic Information Systems, Global Positioning System, Journey to Work, Active School Transportation

Co-Authorship Statement

Each integrated article within this dissertation will be submitted for publication in peer-reviewed journals. Chapters 3, 4, and 5 were written by Douglas Rivet, with Dr. Jason Gilliland and Dr. Andrew Clark as co-authors. Douglas Rivet is the primary author and performed all data collection, analysis, and writing in each article. Dr. Jason Gilliland was the Principal Investigator and designed the original STEAM study. Both Dr. Gilliland and Dr. Clark were involved in the development of procedures for the analyses in all studies and provided editorial comments. Dr. Don Lafreniere assisted with the analytical plan in Chapter 5. Below are the journal targets for both integrated articles.

Chapter 3: Rivet, D., Clark A., & Gilliland J. (2016). Examining built environment determinants of active travel: Synthesizing household travel surveys and GIS.

Chapter 4: Rivet, D., Clark A., & Gilliland J. (2016). Measuring built environment determinants of active transportation with GPS: The STEAM Project.

Chapter 5: Rivet, D., Clark, A., Lafreniere, D. & Gilliland, J. (2016). Move for Health in Old South: Investigating Active Transportation determinants through a community lens.

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CHAPTER ONE

INTRODUCTION

1 The Built Environment and Active Transportation

Over the last two decades, researchers have produced a continually-growing body of empirical evidence affirming the built environment (BE) and active transportation (AT) relationship. Often, this research has been focused on increasing active modes of travel to benefit physical activity levels and improve the health and well-being of a population, specifically targeting chronic diseases such as obesity (Broberg et al, 2013; Rodriguez, 2009; Frank et al, 2010; Gilliland 2010; Gilliland et al., 2013; Sallis et al, 2004). Other research examines how interventions to the BE, such as the creation of bicycle and pedestrian pathways, can improve health outcomes (Boone-Heinonen et al, 2009; Gordon-Larsen, 2008), increase local jobs (Garrett-Peltier, 2011) and provide savings in direct medical expenditures (Katzmarzyk, 2004). Even as this empirical evidence clearly defines the direct benefits of AT, rates of AT have continued to decrease from 42.0% in 1969 to 16.2% in 2001 for adults across North America (Ham, 2008). It has therefore become a priority for city planners, elected officials, municipal decision makers, and public health officials to increase AT rates by creating policies that will improve infrastructure to making active modes of travel a routine activity (Clark and Scott, 2014). To aid in their decision making, officials must turn to the empirical evidence provided by researchers.

These empirical findings definitively acknowledge the strong relationship between AT and the BE and the corresponding benefits, yet do not reach agreement on the extent of the relationship or the individual factors correlated with AT (Saelans and Handy, 2008). For example, Brownson (2009) has successfully identified six common variables that are measureable and statistically significant to observing the BE/AT relationship: population density, land-use mix, provision of recreation facilities, street pattern, sidewalk provision, and traffic. These direct measure variables account for Cervero and Kockelman's (1997) subtle, indirect impact the built environment has through density, diversity and design but does not offer an overarching measure applicable to urban environments across North America.

Frank (2000; 2010) has developed a measure synthesizing socioeconomic indicators, retail floor area, land-use mix, and intersection density into a 'walkability index' whose output provides a generally broad context to explore the BE/AT relationship. This index does an excellent job operationalizing key components of the relationship, proximity and connectivity, yet does not identify actionable solutions or interventions that can be utilized. Panter (2016) underlines this issue by analyzing a BE/AT intervention that is suggested by the successful research of Brownson (2009) and Frank (2010). These effective research examples solidify the BE/AT relationship yet illustrate the current disjointedness in the broader research.

This incoherence is likely due to the lack of consistency in defining and conceptualizing AT and the BE paired with the incongruity of the spatial delineation of the geography in the area of study. Rundle (2016) interprets this incoherence as a conceptual problem believing that the variability in the definition and operationalization of neighborhood in studies based specifically in empirical scholarship has led to conflicting analysis. Forsyth et al (2006) provides clear and concise guidelines stating that the issue requires a solid protocol to address the needs for consistency, purpose, geography, data resolution, accuracy, completeness, and time.

The purpose of this dissertation is to examine the relationship between the BE and AT in London, Ontario, Canada (Figure 1) across multiple ages and geographies by building upon the overwhelming yet inconclusive empirical evidence of the relationship between the BE and AT. London offers a wide range of built environments ranging from older, dense urban environments with gridded streets alongside sprawling loop and lollypop suburban housing. This research will put forth solutions to the lack of coherency in defining and conceptualizing the built environment and inconsistency in spatial

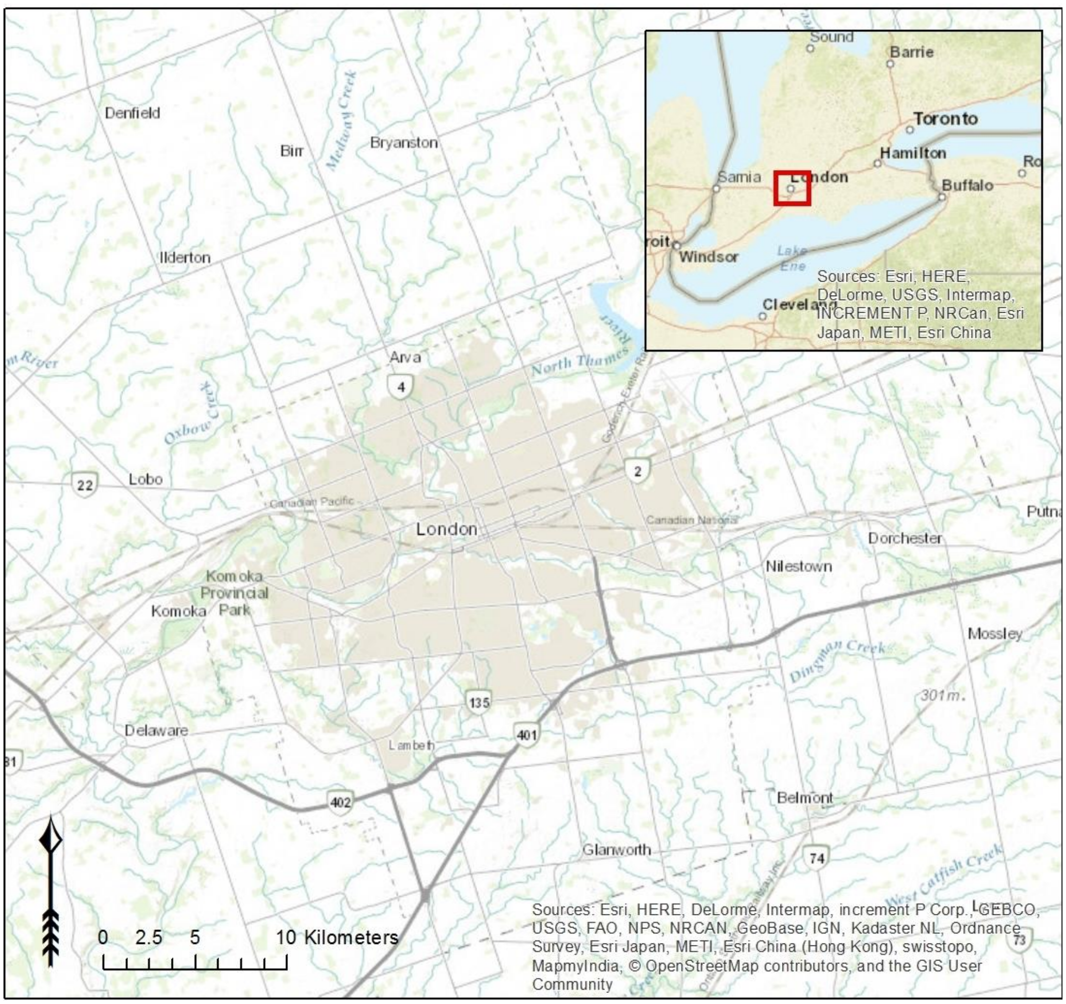


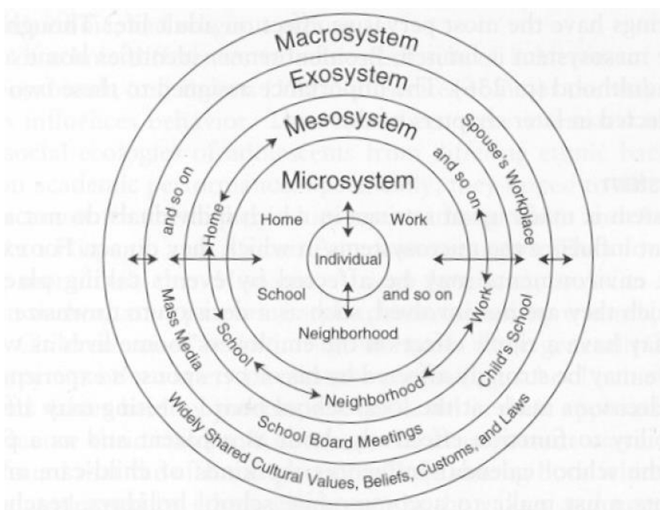
Figure 1 - Location of Study Site: London, Ontario, Canada

delineation with the anticipation of ascertaining methodologies that can identify practical and easily understood interventions.

1.1 Theoretical Framework

The overarching theoretical framework will be based on ecological systems theory. The ecological model will allow this research to address the multifaceted spatial and temporal characteristics of the BE/AT relationship. Proper research of the BE/AT relationship requires a theoretical framework to not only acknowledge the changing geographic scale but the complex agencies (school, media, cultural norms) of this interconnection.

Figure 2. Bronfenbrenner's Ecological Model



Bronfenbrenner's (1977) seminal work on the ecological model has been adopted by numerous studies across many disciplines since its conception. It recognizes that individuals are embedded in an infinitely complex world of political, economic, and social systems that interact and influence each component along with the individual and its behaviors (Bronfenbrenner, 1977) (Figure 2). The ecological model provides an adapting schema that accounts for the unique characteristics of an individual (age, gender, beliefs), their immediate setting (home, school, workplace), perception, culture, and institutional ideals (economic theory, legal system, political structure). For a geographic researcher, the ecological model is the working structure of Waldo Tobler's conception of spatial autocorrelation; everything is related to everything else, but near things are more related than distant things (Goodchild, 1986).

The ecological model works well for researching topics that are embedded in a network of individual, environmental, political, and social systems; however, researchers investigating the BE/AT relationship must resist the temptation to draw conclusions grounded only in quantitative evidence. The qualitative perspective of the individual or community being investigated, paired with empirical data, will result in better actionable interventions (e.g. policy, infrastructure) or practical and pragmatic outcomes stemming from quantitative and qualitative data. House (1994, pg 19) sums the logic up clearly stating "[the] choice does not have to be between a mechanistic science and intuitionalist humanism, but rather one of conceiving science as the social activity that it is, an activity that involves considerable judgement, regardless of the methods employed."

Following House's archetype this research will incorporate community-based research at the geographic neighborhood level. By cultivating relationships in the community based on trust and cooperation this research will be enhanced by the skills, assets, and institutional memory inherent to the community. Leveraged with quantitative data and fostered under the ecological model an integration of knowledge from the conclusions of the research will be returned with a direct action component.

1.1.1 Research Question and Objectives

The overarching **research question** to be addressed in this dissertation is: What is the influence of the built environment on travel behaviors of adults and children? The objectives of this study are:

1) To examine how individual characteristics and modelled exposure to the built environment influence the transport mode choices of adults for travel to work and shop.
2) To examine how children's individual characteristics and objectively-measured features of the built environment influence their choice to travel actively during their trips to and from school,
3) To use community-based research approaches to better understand influences to active travel beyond what can be observed through empirical evidence.

1.1.2 Dissertation Framework

Grounded in the ecological model and bolstered by exposure measures of the built environment this dissertation will leverage two unique data sets, one for adults and one for children, to allow for a careful exploration of travel mode choice. To gain a deeper understanding of the BE/AT relationship at the neighborhood level the research will also use a community-based, geographical approach to discover more intangible factors in the relationship. This was accomplished in the following three studies.

Study I demonstrates statistically relevant built environment determinants of travel mode choice for adults using a population-based travel recall survey. This study evaluated how individual and socio-economic characteristics paired with variables measuring exposure to the built environment influence adult utilitarian travel mode choice. This study provided an excellent foundation for the development of geo-spatial decision making tools that allow for precise identification of built environment determinants that can be targeted for intervention.

Study I addresses the following research questions:

1. What individual level factors influence adults' utilitarian travel mode choice?
2. What are the built environment determinants that influence decisions to choose an active or non-active mode of travel?
3. Does the relationship between active transportation and exposure to the built environment among adults align with relationships found when using traditional measures of the built environment?

This study used the *Smart Moves 2030* Transportation Master Plan survey data compiled by the City of London in 2009, leveraging the survey's large sample size and high spatial stratification to model the daily travel of adults in London, Ontario. Using this data set provided 'front door to front door' modelling of the shortest routes in a GIS environment using address-based origins and destinations provided by the respondents. The resulting routes were intersected with an array of hexagons containing built environment variables in a GIS across the city of London. The result was highly accurate measurements of the built environment that each survey respondent is exposed to for each route.

Study II explored how exposure to the built environment influences the mode of travel children use during their journeys to and from school. This study was conducted using a mixed-methods approach to data collection which included direct observation from passive GPS tracking of the route children take while traveling to and from school.

Revealing these determinants using true observations of travel instead of proxies (i.e. shortest network paths), more accurately characterized children's active travel, spatially and temporally, than methods traditionally used in previous studies (e.g., buffers, areal units).

Study II addressed the following research questions:

1. What are the individual characteristics (i.e., sex, age) of children who travel actively to school?
2. What built environment exposure characteristics influence children's mode of travel to school?
3. Does the relationship between active transportation and exposure to the built environment among children align with relationships found when using traditional measures of the built environment?

This study utilized data from the *Spatial Temporal Environmental and Activity Monitoring* (STEAM) research project completed by the Human Environments Analysis Laboratory at Western University. The project followed a mixed methods approach which included passive GPS tracking, accelerometry, activity diaries, youth and parent surveys, and focus groups. The sample used for this study included passive GPS tracking and youth survey for children who live and attend school within the city of London. This study contributes empirical evidence that hexagonal areal units paired with individual level variables can perform better than traditional administrative units.

Study III aims to gain a better understanding of the perceptions that influence decision making surrounding the choice to use active modes of travel. This study used a community-based collaborative approach to identify the barriers and enablers to AT within a neighborhood through resident map-based interviews and a survey. The results helped support the development of a ‘Neighborhood Active Travel Map’ that identifies barriers, enablers and recommended routes to navigate through the neighborhood helping to facilitate AT.

Study III addressed the following research questions:

1. How do residents in a walkable urban environment define their neighbourhood?
2. What types of barriers and enablers to walking were identified by different sub-groups of the population (i.e., by sex, age)?
3. How can one use a community-based collaborative approach to develop a neighbourhood strategy to increase active transportation opportunity?

This study made use of a neighborhood survey and mapping exercise by residents, utilizing the valuable insight that community members and local experts can provide to BE/AT research. Using these observations, clear results were found for neighborhood identification, travel corridors, and AT barriers and enablers.

1.2 Contributions

It is expected that research in this dissertation will make three substantial contributions to the field of research on the built environment and active transportation.

1. To make empirical contributions to the literature by examining the impact of built environment on purposeful trips (i.e., to work, to shop) by adults and journeys to school by elementary school children in London, Ontario.

2. To make a methodological contribution to the literature on the built environment, active travel relationship by advancing innovative applications of geospatial technologies (i.e., GPS, GIS) for generating and analyzing data on environments (social, built, and natural) and individual travel behaviours.
3. To make a theoretical contribution to the literature by adapting concepts from an ecological framework and adapting methodologies to overcome the inherent difficulties created by the Modifiable Areal Unit Problem and the Uncertain Geographic Context Problem

The combined result will provide policy and decision makers in London, Ontario and other municipalities a comprehensive understanding of the AT/BE relationship. The analysis of different sub-populations (children, adults) using mixed methodologies (survey, direct observation, participatory research) will provide a clearer picture of the AT/BE across multiple demographics and spatial resolutions.

1.3 Structure of Dissertation

This dissertation is in an integrated article format. The following chapter features a literature review outlining the basics of the AT/BE relationship along with the basis for the theoretical framework. The following chapters will include reviews of literature in support of the subsequent research, along with methodology, and results. Chapters 3-5 are written in a manuscript format for publications in academic journals. Chapter 6 concludes the dissertation, exploring the results of the following research and offering suggestions for future research.

1.4 References

Alton, D., Adab, P., Roberts, L., Barret, T. (2007). Relationship between walking levels and perceptions of the local neighbourhood environment. Archives of Disease in Childhood. 92, 29-33.

Broberg, A., Salminen, S., Kytta, M. (2013). Physical environmental characteristics promoting independent active transport to children's meaningful places. Applied Geography. 38, 43-52.

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development American Psychologist. 32(7), 513-531.

Brownson, R., Hoehner, C., Day, K., Forsyth, A. and Sallis, J. (2009). Measuring the built environment for physical activity: state of the science. American Journal of Preventative Medicine, 36(4 Suppl), S99-123.

Boarnet, M., Anderson, C., Day, K., McMillan, T., Alfonzon, M. (2005). Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. American Journal of Preventative Medicine, 2(Suppl 2), 134-140.

Boone-Heinonen, J., Evenson, K., Taber, R., Gordon-Larsen, P. (2009). Walking for prevention of cardiovascular disease in men and women: a systematic review of observational studies. Obesity Reviews, 10(2), 204-217.

Cervero, R., Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. Transportation Research, 2, 199-219.

Clark, A. (2014). Understanding the impact of the modifiable areal unit problem on the relationship between active travel and the built environment. Urban Studies, 51(2), 284-299.

Copperman, R., Bhat, C. (2007). An analysis of the determinants of children's weekend physical activity participation. Transportation. 34, 67-87.

Davis, J., and Robinson, G. (2012). A geographic model to assess and limit cumulative ecological degradation from Marcellus Shale Exploitation in New York, USA. Ecology and Society, 17(2), 25.

Duncan, M. and Mummery, W. (2007). GIS or GPS? A comparison of two methods for assessing route taken during active transport. American Journal of Preventative Medicine. 33(1), 51-53.

Evenson, K., Birnbaum, A., Bedimo-Rung, A., Sallis, J., Voorhees, C., Ring, K., Elder, J. (2006). Girls' perception of physical environmental factors and transportation; reliability and association with physical activity and active transport to school. International Journal of Behavioral Nutrition and Physical Activity. 3(1), 1

Forsyth, A., Schmitz, K., Oakes, M., Zimmerman, J., Koepp, J. (2006). Standards for environmental measurement using GIS: Toward a protocol for protocols. Journal of Physical Activity and Health. 3(Suppl 1), S241-S257.

Frank, L. (2000). Land use and transportation interaction: Implications on public health and quality of life. Journal of Planning Education and Research 20, 6-22.

Frank, L., Sallis, J., Saelens, B., Leary, L., Cain, K., Conway, T., Hess, P. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44, 924-933.

Gilliland, J. (2010). The built environment and obesity: Trimming waistlines through neighbourhood design. In T. Bunting, P. Filion & R. Walker (Eds.), Canadian cities in transition: New directions in the twenty-first century (4th ed.). Oxford,MA: Oxford University Press.

Gilliland, J. A., Rangel, C. Y., Healy, M. A., Tucker, P., Loebach, J. E., Hess, P. M., He, M., Irwin, J. D., & Wilk, P. (2012). Linking childhood obesity to the built environment: A multi-level analysis of home and school neighbourhood factors associated with body mass index. Canadian Journal of Public Health, 103(Suppl. 3), S15-S21.

Garrett-Pelrier, H. (2011). Pedestrian and bicycle infrastructure: A national study of employment impacts. Political Economic Research Institute. University of Massachusetts, Amherst.

Goodchild, M. F. (1986). Spatial autocorrelation (Vol. 47). Geo Books.

Gordon-Larsen, P., Hou, N., Sidney, S., Sternfeld, B., Lewis, C., Jacobs Jr, D., Popkin, B. (2008). Fifteen-year longitudinal trends in walking patterns and their impact on weight change. American Journal of Clinical Nutrition. 89(1), 19-26.

Gilhooly, P., Low, D. (2005). Primary school travel behavior in Midlothian, UK. Proceedings of the Institution of Civil Engineers-Municipal Engineer. 158, 129-136.

Ham, S., Martin, S., Kohl, I. (2008). Changes in the percentage of students who walk or bike to school-United States, 1961 and 2001. Journal of Physical Activity and Health. 5, 205-215.

House E. (1994). Integrating the quantitative and qualitative. In The Qualitative, Quantitative Debate: New Perspectives, ed. CS Reichardt, SF Rallis. New Dir. Program Eval. 61:13–22. San Francisco: Jossey-Bass. 98 pp.

Katzmarzyk, P. and Janssen, I. (2004). The economic costs associated with physical inactivity and obesity in Canada: An update. Canadian Journal of Applied Physiology. 29(1) 90-115.

Kerr, J., Rosenberg, D., Sallis, J., Saelens, B., Frank, L., Conway, T. (2006). Active commuting to school: associations with environmental and parental concerns. Medicine and Science in Sports and Exercise. 38, 787-794.

Larsen, K., Gilliland, J., Hess, P. (2012). Route-Based Analysis to Capture the Environmental Influences on a Child's Mode of Travel between Home and School. Annals of the Association of American Geographers 102(6), 1348-1365.

Panter, J., Heinen, E., Mackett, R., and Ogilvie, D. (2016). “Impact of New Transport Infrastructure on Walking, Cycling, and Physical Activity”. American Journal of Preventative Medicine. 50(2), e45-e53.

Rodriguez, D., Aytur, S., Forsyth, A., Oakes, J., Clifton, K. (2009). Relation of modifiable neighborhood attributes to walking. Journal of Public Health Management and Practice. 47(3), 367-385.

Rundle, A., Sheehan, D., Quinn, J., Bartley, K., Eisenhower, D., Bader, M., Lovase, G., and Neckerman, K. (2016). Using GPS Data to Study Neighborhood Walkability and Physical Activity. American Journal of Preventative Medicine. 50(3), e65-e78.

Saelens, B., Handy, S. (2008). Built environment correlates of walking: A review. Medicine and Science in Sports and Exercise, 40, 550-566.

Sallis, J., Frank, L., Saelens, B., Kraft, M. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. Transportation Research Part A: Policy and Practice. 36(5), S329.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-Corti, B., Simmons, D., Baur, L., Crawford, D. (2006). Personal, Family, Social, and Environmental Correlates of Active Commuting to School. American Journal of Preventative Medicine, 30(1), 45-51.

CHAPTER TWO

2 Setting the Stage

Each chapter will contain a literature review covering relevant scholarship to the scope and scale of the corresponding research. This chapter reviews the broader themes inherent in BE/AT research and lays the groundwork for the research found in the following chapters.

2.1 Literature Review

2.1.1 Defining Active Transportation and the Built Environment

“Active transportation” or “active travel” is concisely defined as any form of human-powered transportation. Primarily research on AT has focused on walking (Saelens and Handy, 2008). More accurate and complete definitions of AT need to include walking but not overlook other forms of non-motorized transportation such as a bicycle or scooter. Unfortunately, nomenclature for AT can be as diverse as it is convoluted. AT’s aliases are as follows but not limited to, walking for exercise (Lubans, 2011; Sallis et al, 2004), walking for leisure (Lachapelle, 2015), origin-destination walking (Oliver, 2007), bicycling (Chamberlain and Riggs, 2016), or simply active transportation.

The term built environment is much more abstract in nature, which leads to difficulties when attempting to settle on a definition (Gauthier and Gilliland 2006; Gilliland and Gauthier 2006). Brownson et al (2009) defines it as the physical form of communities, including land-use pattern, built and natural features, and the transportation system. Handy et al (2002) includes many components of Brownson’s definition (transportation system, land-use) but also includes concepts of urban design and the accompanying patterns of human activity. Saelens and Handy (2008) echo these definitions by being more precise to explicitly include the infrastructure of roads, sidewalks, and bike paths and the arrangement and appearance of them in the community.

This dissertation adopts an AT and BE concept as follows. AT includes all forms of human-powered transportation with a focus on origin-destination travel for purpose (i.e. to work) and will exclude AT that can occur when using public transit (i.e., before/after use of a bus). The BE definition for this study will take its lead from Brownson et al (2009) and Handy et al (2005) as anything perceptible that has been built and adapted by humans and will include concepts of transportation infrastructure and land-use.

2.1.2 Examining the BE/AT Relationship

The BE/AT relationship has numerous concomitant associations including connectivity, land use, proximity, accessibility, population density, AT infrastructure, and automobile traffic (McCormack and Shiell, 2011). Before any location can increase the rate of AT among its population the BE must facilitate or provide the means to travel actively. Many researchers agree that this contribution is found in proximity and connectivity (Owen, 2010; Frank, 2000). Their assertion lies in clear definitions that take into account one of geography's key fundamentals, distance decay. Proximity is an expression of mixed-land uses that create shorter distance between origins and destinations (e.g. home to work). Connectivity is an expression of directness and variety of routes from a destination to an origin and are found in higher quantity in gridded street patterns (Owen, 2007; Clark et al. 2016).

The sub-population studied for the BE/AT relationship is primarily focused on healthy, middle aged adults. This is inherently due to ease of access to the population and the ease of instituting policy to change behavior. This dissertation will build upon the recent literature and advances in understanding of the BE/AT relationship. It will also study the BE/AT relationship with children. It is important to make a clear distinction that the variables in the BE affecting AT in adults is different from those in children (Larsen, Gilliland and Hess, 2012).

2.2 Determinants of Active Transportation

2.2.1 Adults

An academic consensus has been established that the BE/AT relationship exists with adults. Unanimity of exact variables and BE features correlate to increase AT has not been established. Previous examinations of literature have revealed over fifty unique measures for adults to represent the built environment (Brownson et al, 2009; Saelens, and Handy, 2008). Cao et al (2011) found that proximity and connectivity create positive correlations to AT when adults have access to an appropriate amount of pedestrian entrances in commercial areas. Boarnet et al (2005) confirmed the necessity of connectivity finding an increase in distance walked when census blocks contained more street intersections.

Brownson (2009) has identified six common variables in previous research that continually show a clear relationship between AT and BE: population density, land-use mix, recreation facilities, street pattern, sidewalk provision, and traffic. This research will use Brownson's (2009) recommendation to narrow the focus from the myriad of variables found to correlate with AT.

2.2.2 Children

Children were neglected in much of the early research on active transportation; however, over the past five years or so there has been a proliferation of studies on this sub-population, primarily focusing on travel to and from school. The link between rates of AT and distance between home and school has been confirmed in multiple studies finding that the smaller the distance between home and school is the best indicator of the likelihood of a child walking or biking to school (Larsen et al, 2012; Larsen et al, 2009). Specific variables found positively correlated to increasing children's AT include; residential density, land-use mix, street connectivity, street trees, and sidewalk availability.

While studying the AT/BE relationship, the reliance on origin-destination surveys and shortest network paths may not accurately reflect travel paths actually taken by participants (Timperio, 2006; Boarnet, 2005). This is especially true for children and their travel to and from school (Larsen, Gilliland, and Hess 2009). To overcome this deficiency in methodology, an acceptable alternative tool is a Global Positioning System, or GPS (Duncan, 2007). GPS can provide high precision of space and time of the traveler for the researcher. This dissertation will incorporate GPS tracking when studying children to utilize the tools fidelity and flexibility.

2.3 Methodological Problems in BE/AT Research

Research on the BE/AT relationship has been unable to reach a consensus on the particulars of variables and methodology. This is likely due to the necessity of using aggregated spatial units in analysis that study human behavior or require intervention, such as the BE/AT relationship. Inevitably geographic researchers run into two methodological problems. The first is the Modifiable Areal Unit Problem (MAUP). MAUP occurs when “arbitrarily defined boundaries are used for measurement and reporting of spatial phenomena” (Heywood et al, 2006, p. 192). This characterization is well made as MAUP can lead researchers to incorrect assumptions, known as an ecological fallacy, when aggregating data into areal units for geographical analysis especially when the analytics are completed utilizing GIS (Openshaw, 1983; Malczewski, 1999).

The second methodological problem draws directly from MAUP and named by Kwan (2012) as the Uncertain Geographic Context Problem (UGCoP). This problem again touches on the hindrance of geographically delineating space to solve a research problem but instead of finding faults in scale or aggregation, the problem is defined as contextual. Put another way, the actual spatial delineation of the variables that have influence on behavior or outcome being studied on individuals can be incorrectly identified or completely unknown (Kwan, 2012). This would create analytical results different each time a methodology was replicated, even if controlling for all other factors.

Each of these methodological problems manifests itself in GIS analysis that commonly employ four predefined – and variable – ‘neighborhoods’: circular buffers (Mitra, 2012), polygon-based road network buffers (Frank, 2006), standard deviation ellipses (Zenk, 2011), and GPS point buffering (Zenk, 2011). These spatial units are chosen due to the ease and availability of data that can be included in modeling, specifically from the census and surveys (Kwan, 2012). These problems will be discussed below.

2.3.1 The Modifiable Areal Unit Problem

Fotheringham and Wong (1991, pg 1026) describes MAUP as "one of the most stubborn problems related to the use of areal data." This characterization is well made as MAUP can lead researchers to incorrect assumptions, known as an ecological fallacy, when aggregating data into areal units for geographical analysis (Openshaw, 1983; Malczewski, 1999; Gilliland and Olson, 2010). MAUP and its corresponding ecological fallacy can be broken down into two effects; scale effect and zonal (also known as aggregation) effect.

2.3.1.1 Zonal or Aggregation Effect

The zonal, or aggregation, effect can be described as the configuration of different zones at a predetermined, fixed spatial level. Changing the shape of the zone, or spatial unit, in which you calculate or measure a variable creates the zonal effect. This problem exacerbates itself when you begin aggregating the spatial units together. Aggregation generates variations in data values and measurements that result from the recalculation of values from one spatial unit into another on the same scale (Zhang and Kukadia, 2005).

2.3.1.2 Scale Effect

The scale effect can be described as the specific spatial aggregation of zones used to combine, or aggregate data to be used for research (Clark and Scott, 2014). Simply, changing the size of the zone from which you draw a variable creates the scale effect.

This can create variation in data values and measurements due to the aggregation of data from one spatial unit into another (Zhang and Kukadia, 2005). For example, moving population density data from census tracts to census blocks may give a false sense of the 'true' density, specifically if a tract contains a high-density residential complex. This can have drastic effects on the outcomes of spatial models (Malczewski, 1999).

2.3.2 MAUP, Active Transportation, and the Built Environment

The relationship between the BE and AT is influenced inevitably by MAUP. The inherent problems in the relationship between a complex human behavior such as AT, that can include non-geographical variables such as economics, and the continuous and diverse nature of environments, especially in cities, makes it extremely difficult to create spatial units with the proper shape (aggregation effect) or size (scale effect). Research involving urban form is sensitive to the scale and zonal effects of MAUP especially in transportation research.

Zhang and Kukadia (2005) found evidence of instability in spatial analysis coefficients, especially in regression modeling, due to changing scales and definition of zones used to aggregate and measure specific BE variables. Divergent results in studies of automobile commuting are likely caused by MAUP as changes in data aggregation and spatial unit definitions drastically changed the results (Horner and Murray, 2002; Zhang and Kukadia, 2005). Zhang and Kukadia (2005) also comment that one of the large indications that MAUP is a problem when studying any transportation problem is the large volume of spatial units that are used in analysis and consequently the mixed results.

2.3.2.1 Zonal Effect in AT/BE Research

The zonal effect of MAUP on BE/AT research is rarely quantified even when specifically targeted. This is due to the inability of researchers to adjust their scale of study (i.e. 800-meter grid) and analyze it in different orientations (Clark and Scott, 2014). As a result, pseudo-analysis is completed by comparing different forms of aggregation, such as buffers to grids. Results are overwhelmingly anonymous, showing that any changes in zonal type or size will result in a measurable change in the relationship between AT and BE (Clark and Scott, 2014; Mitra and Builing, 2011; Zhang and Kukadia, 2005).

2.3.2.2 Scale Effect in AT/BE Research

The scale effect often impacts the coefficients and associated significance of BE variables when attempting to model AT (Clark, 2013). This was found to be especially true in five BE variables that Clark and Scott (2014) found significant to the propensity of AT; retail floor area, pedestrian infrastructure, population density, entropy index, and street connectivity. The influence of MAUP's scale effect becomes even clearer when using Frank's (2000) entropy index or including measures of street connectivity. When measured using a 1600-meter buffer the variables were found to decrease AT use. However, when using a 200-meter grid street connectivity significantly increased the use of AT (Clark and Scott, 2014).

Zhang and Kukadia (2005) found similar problems in coefficients when comparing areal unit size to BE variables associated with travel mode choice. The coefficient for land-use mix changed considerably from statistically significant and high impact in a 2-mile cell size areal unit to not statistically significant and little impact in a 1/16-mile cell areal unit. There was also similar result with population density.

Clark (2012) and Mitra and Builing (2011) found that basic analysis of coefficients and significance had no pattern from scales beginning at 200 meters up to 1600 meters. This suggests that the results of spatial modeling of the BE/AT are entirely dependent upon the methodology and spatial unit applied when the MAUP scale effect is analyzed. A realistic and possible solution to minimize the scale problem is the creation of a standardized spatial variable.

2.3.3 The Uncertain Geographic Context Problem

Kwan (2012) touches on the complication of geographically delineating space to solve a research problem but instead of finding faults in scale or aggregation, the failing is defined as contextual and named the Uncertain Geographic Context Problem (UGCoP). The actual spatial delineation of variables that have influence on behavior or outcome being studied on individuals can be incorrectly identified or completely unknown (Kwan, 2012). This would create analytical results different from each time a methodology was replicated, even if all other factors were controlled for. UGCoP also includes the issues that can occur because of the uncertainty in the timing and duration of exposure to the variables under study (Kwan, 2012).

2.3.3.1 Spatial Dimension

When studying the influence that the built environment (BE) may have on active transportation (AT) the core theoretical framework that has been utilized is the ecological model (Sallis, 2006; Dietz-Rouz and Mair, 2010, Kwan, 2012). These models are designed to help to begin to understand the causal pathways that occur between AT and the BE. Based on these hypothetical casual pathways geographic variables or spatial delineations are created to begin evaluation with appropriate spatial or statistical models.

Unfortunately, while the influence that the BE has on AT has been well established (Duncan, 2007; Jones, 2009; Larsen, 2012; O'Loghlen, 2011) a comprehensive, all-encompassing solution ("true causal relevance" (Kwan, 2012, pg 959)) to increase the prevalence of AT has remained out of reach. Due to this, when creating spatial units, studies utilize a static administrative zone, such as a census track or postal code, or create a more relevant unit to represent 'neighborhood'. GIS analysis commonly employ four predefined – and variable – 'neighborhood': circular buffers (Mitra, 2012), polygon-based road network buffers (Frank, 2006), standard deviation ellipses (Zenk, 2011), and GPS point buffering (Zenk, 2011). These spatial units are chosen due to the ease and availability of data that can be included in modeling, specifically from the census and surveys (Kwan, 2012).

While easy to visualize, create, and incorporate data these commonly employed spatial units may not represent the actual areas in which BE/AT relationship is expressed. For example, if analyzing AT for adults and children utilizing the home postal code of each may not be appropriate. Adults and children represent two distinct population groups each with user specific influences. Children's destinations are vastly different from adults and are often out of their control (e.g. taking a bus to school). Their extrinsic mobility restrictions (e.g. inability to drive, afford transport, parental controls) make them significantly more vulnerable to elements in their environments and their ability to make decisions (Larsen, 2009). Simply, a postal code may not accurately represent a 'neighborhood' and may not even be the 'neighborhood' that is being used by a participant or associated to the outcome being studied (Healy and Gilliland, 2012).

The BE/AT relationship is complicated, encompassing multilevel and multi-scale influences which often overlap or integrate. The ability of the ecological model process to include comprehensive variables from the environment is strength and weakness (Langille, 2010). Geographical uncertainty is created in the spatial dimension due to the dynamic characteristics of the BE/AT relationship (Gatrell, 2011; Kwan, 2012).

2.3.3.2 Temporal Dimension

Geographical uncertainty is not confined to the spatial dimension. As noted by Gatrell (2011) health outcomes are inevitably connected to the movement of people at the spatial scale and also the temporal scale. People's daily activities are not confined to one space while daily activities do not always occur over the same time. Social groups, socio-economic groups, and ethnicities have been seen to have recognizable activity patterns in space-time (Hanson and Hanson, 1981; Kwan, 2000; Lee and Kwan, 2011; Kwan, 2012). People may spend a significant amount of time outside their geographically defined 'neighborhood'.

Geographers studying the BE/AT relationship have not ignored this problem. To accurately measure and track movements, participants in research projects are often asked to wear Global Positioning System (GPS) or similar devices. Duncan (2007) confirmed the validity of this method while Larsen (2012) made the methodology more robust, including school travel surveys. Even with these advancements the "true casual relevance" has yet to be made.

The spatial and temporal variability of human activity is complex. Daily activities do not take place at one point in time and cannot be contained wholly within a predefined spatial context, such as a neighborhood. The need for people to use the BE as a resource in different times and locations can be different in sub-populations and at the individual level (Kwan, 2012, pg 959). This temporal component adds to the dynamic characteristics of the relationship between the BE and AT.

2.3.3.3 GIS and the Uncertain Geographical Context Problem

Similar to MAUP a solution to overcome the complex nature of UGCoP would need to address two issues; spatial complexity and temporal configuration (Kwan, 2013). Kwan (2013, 960) suggests that researchers should take a more dynamic approach to conceptualizing the geographic context to the problem they are attempting to solve by creating geography that is “individual-based, person-specific, and delineated based on where people go, how much time they spend there and their travel routes”. This could be addressed easily by the use of geospatial technologies, specifically GIS and GPS, qualitative GIS and web-based GIS.

2.3.3.3.1 GIS and GPS

The high spatial and temporal resolutions provided by GPS data can allow researchers to create contextual spaces, or neighborhoods, using GIS that accurately take into account the various spatial and temporal variations. This space has been attempted to be expressed in numerous studies, without GPS including Larsen (2012) who by creating a 100 meter wide buffer from a calculated shortest network path from the participant’s home postal code to their school. Sherman et al (2005) also created road network based delineation combining standard deviational ellipses and a 30 minute standard travel time polygon. GPS specific research has been done by Zenk (2011) and Shoval (2011) and while making significant contributions to methodology the full nature of UGCoP has not been overcome.

2.3.3.3.2 Qualitative GIS and Web-based GIS

Kwan (2013) also suggests that capturing social interactions and experiences from the participants themselves may also help overcome UGCoP. This would be the result of a mixed-method approach combining qualitative methods, such as self-drawn neighborhoods created by the subject under study as suggested by Clark (2013), incorporated into GIS to allow researchers to better see the complexities of the participants under study. Matthews (2005) completed such a study with a method he called geo-ethnography. The participant specific neighborhoods could also be mapped by the user themselves as Chaix (2012) has done using web-based Google Maps highly interactive mapping functionality. Loebach and Gilliland (2013) examined neighborhood mobility and activities through the use of perceptive mapping and child-led tours. Fitzpatrick (2013) used an analogous methodology examining the AT/BE relationship using child-led perception mapping and ArcGIS analysis to explore children's perceptions of their school's built environment.

2.3.4 Minimizing MAUP and UGCoP

While MAUP as it relates to the AT/BE relationship has been studied (Clark ans Scott, 2014; Zhang and Kukadia, 2005; Mitra and Builing, 2011; Forsyth et al., 2006) there has been few concrete solutions put forth. The establishment of an ideal scale to measure BE variables would be difficult as the solution would need to address both the zonal and scale effects of MAUP along with the spatial and temporal dimensions of the UGCoP. Clark and Scott (2014) has suggested that the conceptualization of the neighborhoods for spatial analysis should be created using self-drawn neighborhoods by the subjects under study. This runs somewhat parallel to Zhang and Kukadia's (2005) recommendation that a possible solution is to disaggregate data down to an individual or variable specific level where ever feasibly possible. The disaggregation would increase the independence of the dependent variable (in this case AT) from the scale and zonal effects of MAUP.

In the transportation field, testing of methods of data aggregation concluded that spatial units with equal area yield the best model fit for transportation based data (Ding, 1998). The aggregation of data into a scheme that uses a grid also yields better results than spatial units that are subjectively or arbitrarily created (Zhang and Kukadia, 2005). Furthermore, predicable results were found in BE coefficients when addressing MAUP in administration zones (e.g. Planning Districts) likely coinciding with Zhang and Kukadia's (2005) findings that spatial units and zones need to be disseminated appropriately based on the human behavior that is being investigated (Clark and Scott, 2014).

2.4 Binning GPS Data by Hexagonal Areal Units

As way to incorporate the suggested solutions described above this study utilized hexagonal-shaped areal units to bin GPS point data on individual locations to account for personal exposure to environmental factors. Hexagonal tessellation of a research area provides an avenue for overcoming MAUP's effects and the corresponding ecological fallacies (Gilliland and Olson 2010; Gilliland, Olson and Gauvreau 2012). According to Gilliland and Olson, "The hexagon is, of course, the most effective shape with which to tessellate land masses and to bin data for visualization" (2010, pg 39). Hexagons placed in an array over a study area would provide even spatial coverage, be isotropic, and is much less likely to be coincident with anthropogenic features in the environment (Davis and Robinson, 2012). The decision for 20 meter hexagons was finalized by the author and extended research team on the STEAM project. Using a 20 meter diameter, hexagons will be able to capture the important socioeconomic and built environment variables that significantly relate to AT without overreaching the actual spatial extent of the exposure that an individual may have to them. Furthermore, this distance also accommodates the positional inaccuracies inherent in the GPS units (i.e., typically accurate to sub-10m). Furthermore, the hexagon of 20m accommodates some positional inaccuracies The consistency created by the hexagonal array will allow observed or directly reported destination-origin trips to be examined uniformly without the variability created by common GIS analysis.

Hexagonal-shaped areal units will also allow for flexibility in aggregation when adjusting policy or infrastructure by allowing the user to define the neighborhood (operationalized in GIS as the number of hexagons). The use of hexagons can allow for a true analysis of the zoning effect of MAUP because their use in spatial aggregation is fixed, which could not be done in other research (Clark, 2013). The zonal effect from hexagon would also be limited as a change in the orientation of the hexagon results in smaller changes in study area as compared to standard square (Hales, 2001). The anticipation would be a lack of significance and the possibility of a standardized spatial unit.

Hexagons placed in an array over a study area will provide even spatial coverage, be isotropic, and is much less likely to be coincident with anthropogenic features in the environment (Davis and Robinson, 2012). At the 20 meter diameter, hexagons will be able to capture the important socioeconomic and built environment variables that significantly relate to AT without overreaching the actual spatial extent of the exposure that an individual may have while traveling to and from destinations. The consistency created by the hexagonal array will allow observed or directly reported destination-origin trips to be examined uniformly without the variability created by common GIS analysis. Further consistency with finding could also be achieved through the use of dynamically changing diameter adjusted for mode of travel or building height.

Intersecting hexagons and the built environment that fall within their spatial delineation will be extracted and tied to each modelled route. The key built environment variables that will be used to measure exposure include residential density, land-use mix, street connectivity, sidewalk availability, retail floor area ratio, and other key variables found in the literature. Univariate logistic regression will be used to examine the relationship between the built environment and all modes of travel (i.e., private motorized modes, public transportation, and active transportation) while controlling for individual characteristics (i.e., sex, age, neighborhood level income).

2.5 References

Boarnet, M., Anderson, C., Day, K., McMillan, T., Alfonzon, M. (2005). Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. American Journal of Preventative Medicine, 2(suppl 2), 134-140.

Brownson, R., Hoehner, C., Day, K., Forsyth, A. and Sallis, J. (2009). Measuring the built environment for physical activity: state of the science. American Journal of Preventative Medicine, 36,(4 Suppl), S99-123.

Chamberlain, F., and Riggs, W. (2016). Shifting the Tide: Transit-orientated development and active transportation planning in Los Angeles. Focus: The Journal of Planning Practice and Education, 12(1).

Cao, X., Handy, S., Mokhtarian, P. (2006). The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX, Transportation, 33, 1-20.

Clark, A. (2013). Understanding the impact of the modifiable areal unit problem on the relationship between active travel and the built environment. Urban Studies. 43, 130-151.

Clark, A. F., Bent, E. A., & Gilliland, J. A. (2016). Shortening the trip to school: Examining how children's active school travel is influenced by shortcuts in London, Canada. Environment & Planning B: Urban Design, 43 (3), 499-514.

Davis, J. and Robinson, G. (2012). A geographic model to assess and limit cumulative ecological degradation from Marcellus shale exploitation in New York, USA Ecology and Society. 17(2), 25.

Dietz-Roux, A., and Mair, C. (2010). Neighborhood and health. Annals of the New York Academy of Sciences. 1186, 125-145.

Ding, C. (1998). The GIS based human interactive TAZ design algorithm: Examining the impact of data aggregation on transportation planning analysis. Environment and Planning B: Planning and Design, 25, 601-616.

Duncan, M. and Mummery, W. (2007). GIS or GPS? A comparison of two methods for assessing route taken during active transport. American Journal of Preventative Medicine. 33(1), 51-53.

Forsyth, A., Oakes, M., Schmitz, K. and Hearst, M. (2007). Does residential density increase walking and other physical activity? Urban Studies, 44(4), 679-697.

Frank, L. (2000). Land use and transportation interaction: Implications on public health and quality of life. Journal of Planning Education and Research, 20, 6-22.

Frank, L., Sallis, J., Conway, T., Chapman, J., Saelens, B., and Bachman, W. (2006). 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, 75-87.

Frank, L., Sallis, J., Saelens, B., Leary, L., Cain, K., Conway, T., Hess, P. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44, 924-933.

Fotheringham, A. and Wong, D. (1991). The modifiable areal unit problem in multivariate statistical analysis. Environment and Planning A, 23(7), 1025-1044.

Gatrell, A. (2011). "Mobilities and health" Aldershot, UK: Ashgate.

Gauthier, P. & Gilliland, J. (2006). Mapping urban morphology: A classification scheme for interpreting contributions to the study of urban form. Urban Morphology, 10(1), 41-50.

Gilliland, J. & Gauthier, P. (2006). The study of urban form in Canada. Urban Morphology, 10(1), 51-66.

Gilliland, J. A., & Olson, S. (2010). Residential segregation in the industrializing city: A closer look. Urban Geography, 31 (1), 29-58.

Gilliland, J. A., Olson, S. H., & Gauvreau, D. (2011). Did segregation increase as the city expanded? Montreal 1881-1901. Social Science History, 35 (4), 465-503.

Handy, S. (2002) Travel behaviour—land use interactions: An overview and assessment of the research. In perpetual motion: Travel behavior research opportunities and application challenges 223-36.Horner, Mark W., and Alan T. Murray. (2002) Excess commuting and the modifiable areal unit problem, Urban Studie,s 39(1), 131-139.

Handy, S., Weston L., Mokhtarian, P. (2005). Driving by choice or necessity? Transportation Research Part A: Policy and Practice, 39(2), 183-203.

Hanson, S. and Hanson, P. (1981). The travel-activity patterns of urban residents: Dimensions and relationships to sociodemographic characteristics. Economic Geography, 57, 332-347.

Healy, M. A., Gilliland, J. A. (2012). Quantifying the magnitude of environmental exposure misclassification when using imprecise address proxies in public health research. Spatial and Spatio-Temporal Epidemiology, 3 (1), 55-67.

Heywood, I., Cornelius, S., Carver, S. (2006). An introduction to Geographical Information Systems, 3rd edn. Harlow: Pearson Education.

Jones, A., Coombes, E., Griffin, S., Sluijs, E. (2009). Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems. International Journal of Behavioral Nutrition and Physical Activity, 6(42).

Kwan, M. (2000). Interactive geovisualization of activity-travel patterns using three dimensional geographical information systems: A methodological exploration with a large data set. Transportation Research C, 8, 185-203.

Kwan, M. (2012). The Uncertain Geographic Context Problem. Annals of the Association of American Geographers, 102(5), 958-968.

Kwan, M. (2013). How GIS can help address the uncertain geographic context problem in social science research. Annals of GIS, 18(4), 245-255.

Larsen, K., Gilliland, J. A., Hess, P. M., Tucker, P., Irwin, J., & He, M. (2009). The influence of the physical environment and sociodemographic characteristics on children’s mode of travel to and from school. American Journal of Public Health, 99 (3), 520-526.

Larsen, K., Gilliland, J., Hess, P. (2012). Route-Based Analysis to Capture the Environmental Influences on a Child's Mode of Travel between Home and School. Annals of the Association of American Geographers, 102(6), 1348-1365.

Lachapelle, U., Frank, L. Sallis, J., Saelens, B., Conway, T. (2015). Active transportation by transit-dependent and choice riders and potential displacement of leisure physical activity. Journal of Planning Education and Research. 1-14.

Langille, J. and Rodgers, W. (2010). Exploring the influence of a social ecological model on school-based physical activity Health Education and Behavior. 37(6), 879-894.

Lee, J. and Kwan, M. (2011). Visualization of socio-spatial isolation based on human activity patterns and social networks is space-time. Tijdschrift voor Economische en Sociale Geografie, 102(4), 468-485.

Loebach, J. and Gilliland, J. (2010). Child-led tours to uncover children's perceptions and use of neighborhood environments. Children, Youth and Environments, 20 (1), 52-90.

Lubans, D., Borehamn, C., Kelly, P., Foster, C. (2011). The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. International Journal of Behavioral Nutrition and Physical Activity, 8, 5.

Malczewski, J. (1999). GIS and multicriteria decision analysis. John Wiley and Sons; Toronto.

McCormack, G. and Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Journal of Behavioral Nutrition and Physical Activity. 8, 125.

Mitra, R. a. Builing., R. (2012). Built environment correlates of active transportation: neighbourhood and the modifiable areal unit problem. Journal of Transport Geography, 20(1), 51-61.

Oliver, L., Schuurman, S., Hall, A. (2007). Comparing circular and network buffers to examine the influence off land use on walking for leisure and errands. International Journal of Health Geographics. 6, 41.

O'Loghlen, S., Pickett, W., Janssen, I. (2011). Active transportation environments surrounding Canadian schools. Canadian Journal of Public Health, 102(5), 364-368.

Openshaw, S. (1983). The modifiable areal unit problem Geo Books: Norwick Norfolk

Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L., Bauman, A., Hugo, G., Saelens, B., Sallis, J. (2007). Neighbourhood Walkability and the Walking Behavior of Australian Adults. American Journal of Preventative Medicine, 33(5), 387-395.

Saelens, B., Handy, S. (2008). Built environment correlates of walking: A review. Medicine and Science in Sports and Exercise, 40, 550-566.

Sallis, J., Frank, L., Saelens, B., Kraft, M. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. Transportation Research Part A: Policy and Practice. 36(5), S329.

Sallis, J., Cervero, R., Ascher, W., Henderson, K., Kraft, M. and Kerr, J. (2006). And ecological approach to creating active living communities. Annual Review of Public Health, 27, 297-322.

Sherman, J., Spencer, J., Preisser, J., Gesler, W. and Arcury, T. (2005). A suite of methods for representing activity space in a healthcare accessibility study. International Journal of Health Geographics. 4, 24.

Shoval, N., Wahl, H., Auslander, G., Isaacson, M., Oswald, F., Edry, T., Landau, R. and Heinik, J. (2011). Use of global positioning system to measure the out-of0home mobility of older adults with differing cognitive functioning. Ageing and Society. 31, 849-869.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-Corti, B., Simmons, D., Baur, L., Crawford, D. (2006). Personal, Family, Social, and Environmental Correlates of Active Commuting to School. American Journal of Preventative Medicine, 30(1), 45-51.

Zenk, S., Schultz, A., Mathews, S., Odoms-Young, A., Wilbur, J., Wegrzyn, K., Gibbs, K., Brauschweig, C., Stokes, C. (2011). Activity space environment and dietary and physical activity behaviors: A pilot study. Health and Place, 17(5), 1150-1161.

Zhang, M. and Kukadia, N. (2005). Metrics of urban form and the modifiable areal unit problem. Transportation Research Record: Journal of the Transportation Research Board. 1902: 71-79.Research. Ed. Smedley, B. and Syme, S. p.417-449. Washington DC: National Academy.

CHAPTER THREE

3 Examining Built Environment Determinants of Active Travel: Synthesizing Household Travel Surveys and GIS

Research exploring the relationship between the built environment (BE) and active transportation (AT) has provided a wealth of empirical evidence exploring determinants of AT. Active travel is defined as any form of human-powered transportation, including walking and cycling. These determinants, especially ones in the BE, are important as they represent the tangible and controllable part of the transportation system that can be influenced by planning policy and resource allocation (Frank and Engelke, 2001).

The empirical findings on BE and AT acknowledge that a relationship exists, yet do not agree on the extent of the relationship or factors involved (Lachapelle et al, 2016; O'Hern and Oxley, 2015; Feng et al. 2010; Saelans and Handy, 2008). This incoherence is likely due to the lack of consistency in defining and conceptualizing the BE, paired with the incongruity of the spatial delineation of the geography in the area of study. Forsyth et al (2006) explains this problem as a necessity for protocol to address the needs for consistency, purpose, geography, data resolution, accuracy, completeness, and time.

The purpose of this study is to examine the relationship between the BE and AT for among adults in London, Ontario, Canada by building upon the as of yet inconclusive empirical evidence on the relationship between the BE and AT. The study will focus on AT for utilitarian purposes (i.e., to work and to shop). This purpose will be met by addressing the following research questions:

1) What individual level factors influence adults' choice of travel mode for utilitarian trips?

2) What are the built environment determinants that influence decisions to choose an active or non-active mode of travel?

3) Does the relationship between active transportation and exposure to the built environment among adults align with relationships found when using traditional measures of the built environment?

3.1 Active Travel and the Built Environment

3.1.1 Defining and Conceptualizing

Most of the active travel research is focused primarily on walking (Saelens and Handy, 2008); however, to provide a more accurate and complete definition more activities of non-motorized transportation need to be included, most prominently cycling (Chamberlain and Riggs, 2016). Nomenclature for active transportation can include walking for exercise (Lubans, 2011; Sallis et al, 2004), walking for leisure (Lachapelle, 2015), origin-destination walking (Oliver, 2007), active travel (Zander, 2014) or simply active transportation.

The term built environment is much more abstract in nature when being defined. Brownson et al (2009) defines it as the physical form of communities, including land-use pattern, built and natural features, and the transportation system. Handy et al (2002) includes many components of Brownson's definition (transportation system, land-use) but also includes concepts of urban design and the accompanying patterns of human activity. Saelens and Handy (2008) echo these definitions by being more precise to explicitly include the infrastructure of roads, sidewalks, and bike paths and the arrangement and appearance of them in the community.

Continued iteration of the characterization of active travel and the built environment begins to convolute the importance of examining the relationship. These intertwined definitions highlight the difficulties in researching a complex human behavior like active transportation, in relation to a constantly changing, equally complex system, the built environment. This often results in a wide-range of research that becomes more specific to the adopted definitions finding strong associations but fails to find causality in the relationship (McCormack and Shiell, 2011).

This study will adopt active travel and built environment concepts as follows. Active travel includes all forms of human-powered transportation with a focus on origin-destination travel for purpose (i.e. to work) and will exclude active travel that can occur when using public transit. The built environment is defined as anything that has been built and adapted by humans and will include concepts of transportation infrastructure and land-use.

3.1.2 Determinants of Active Transportation

Research on the relationship between the BE and AT has come to agree that the BE plays a critical role in the rates of active travel. This is important as the built environment as a system can be influenced and controlled through planning policy (Frank and Engelke, 2001). While consensus has been established that the relationship exists and is important, unanimity of exact variables and BE features to increase active travel has not been established. An examination of the literature reveals over fifty unique measures to represent the built environment (Brownson et al, 2009; Saelens, and Handy, 2008).

Any research on the BE/AT relationship must include a fundamental component, connectivity (Berrigan, 2010; Owen, 2007; Cervero and Kockelman, 1997). Connectivity is a central component to the BE/AT relationship as it is a characterization of directness and the ease of travelers getting from an origin to a destination (Panter, 2016; McCormack and Shiell, 2011; Owen, 2007; Clark et al 2016). There is no single BE determinant of connectivity though it can be extrapolated from select variables. Boer (2007) found that intersections had a significant impact on the likelihood of taking at least one walking trip per day when the street network was based on a grid system. Rodriguez and Joo (2004) established that with all other variables held equal a participant's willingness to walk was significantly correlated to the availability of sidewalks. Tilahun et al (2007) discuss the importance of bike lanes and multiuse paths finding that individuals were willing to commute farther distances and for longer times on a bike when biking infrastructure was improved.

Land use is an often explored and utilized BE determinant as it inherently offers a depiction of physical characteristics and implicit uses of the space being described. Often land use is expressed through indices that describe land use mix or land use entropy (Lachapelle et al, 2016; Feng et al. 2010; Larsen et al, 2009; Leslie et al, 2007). While significance between AT and BE is repeatedly found significant, the use of these indices make it impossible to understand what land use types need to be increased in order to facilitate active travel. When land use types are examined individually in analyses researchers can fully understand the impact each have on active models of travel (Oliver el al, 2007).

The individual-level measures also need to be considered, as the underlying characteristics of a population will influence mode choice, especially when working under ecological systems theory (Bronfenbrenner, 1992). These factors include age, gender, employment, and trip purpose (Slater, 2016; Lachapelle, 2016; Carlson, 2016; Thrun, 2016; Heeswijck, et al, 2015; Berrigan et al, 2010; Oliver, 2007). Results from research that utilizes factors is not consistent yielding results like Oliver (2007) where no significance between income and walking were found and Lachapelle (2016) where a clear, significant relationship was established between socio-economic status and active transportation.

3.2 GIS Spatial Delineation and Active Transportation

The failure of researchers to come to consensus on the particulars of variables and methodology while using Geographic Information Systems (GIS) in BE/AT research may likely have its roots in one of geography's fundamental obstacles: the modifiable areal unit problem or MAUP (Clark and Scott, 2014, Zhang and Kukadia, 2005). Fotheringham and Wong (1991, pg 1026) describe MAUP as "one of the most stubborn problems related to the use of areal data." This characterization is appropriate as MAUP can lead researchers to incorrect assumptions, known as an ecological fallacy, when aggregating data into areal units for geographical analysis (Openshaw, 1983; Malczewski, 1999). MAUP and its corresponding ecological fallacy is impacted by two effects: scalar and zonal effects.

The zonal effect, or aggregation effect, can be described as the configuration of different zones at a predetermined, fixed spatial level. Changing the shape of the zone, or spatial unit, in which you calculate or measure a variable creates the zonal effect. This problem exacerbates itself when you begin aggregating the spatial units together. Aggregation generates variations in data values and measurements that result from the recalculation of values from one spatial unit into another on the same scale (Zhang and Kukadia, 2005).

The scalar effect can be described as the specific spatial aggregation of zones used to combine or aggregate data across space (Clark, 2013). Simply, changing the size of the zone from which you draw a variable creates the scale effect. This can create variation in data values and measurements due to the aggregation of data from one spatial unit into another (Zhang and Kukadia, 2005). For example, moving population density data from census tracts to census blocks may give a false sense of the ‘true’ density, specifically if a tract contains a high-density residential complex. This can have drastic effects on the outcomes of spatial models (Malczewski, 1999).

3.2.1 MAUP, Active Transportation and Built Environment

The relationship between the BE and AT is inevitably influenced by MAUP. The inherent problems in understanding this relationship between AT and BE is directly related to the inability of researchers to fully understand the proper aggregation of spatial units that should be used to minimize both the zonal and scalar effects of MAUP. This issue is exacerbated by the fact that AT is such as a complex human behaviour that is impacted by other factors, such as age, SES, health, and safety. As a result, transportation researchers have spent a great deal of time trying to understand how MAUP impacts the BE/AT relationship and determine ways in which MAUP can be minimized.

Zhang and Kukadia (2005) found evidence of instability in spatial analysis coefficients, especially in regression modeling, due to changing scales and definition of zones used to aggregate and measure specific BE variables. Similarly, Clark and Scott (2014) found that changing the scale and zone used to measure the BE can significantly alter the coefficients when estimating the relationship between walking for utilitarian travel use (binary) and the BE. Divergent results in studies of automobile commuting are likely caused by MAUP as changes in data aggregation and spatial unit definitions drastically changed the results (Horner and Murray, 2002; Zhang and Kukadia, 2005). Zhang and Kukadia (2005) also comment that one of the large indications that MAUP is a problem when studying any transportation problem is the large volume of spatial units that are used in analysis and consequently the mixed results.

3.2.2 Minimizing MAUP

While MAUP as it relates to the AT/BE relationship has been studied (Clark and Scott, 2014; Zhang and Kukadia, 2005; Mitra and Builing, 2011; Forsyth et al., 2006) there has been few concrete solutions put forth. The establishment of an ideal scale to measure BE variables would be difficult as the solution would need to address both the zonal and scalar effects of MAUP. Clark and Scott (2014) has suggested that the conceptualization of the neighborhoods for spatial analysis should be created using self-drawn neighborhoods by the subjects under study. This runs somewhat parallel to Zhang and Kukadia's (2005) recommendation that a possible solution is to disaggregate data down to an individual or variable specific level where ever feasibly possible. The disaggregation would increase the independence of the dependent variable (in this case AT) from the scale and zonal effects of MAUP.

In the transportation field, testing of methods of data aggregation concluded that spatial units with equal area yield the best model fit for transportation based data (Ding, 1998). The aggregation of data into a scheme that uses a grid also yields better results than spatial units that are subjectively or arbitrarily created (Zhang and Kukadia, 2005). Furthermore, predicable results were found in built environment coefficients when addressing MAUP in administration zones (e.g. Planning Districts) likely coinciding with Zhang and Kukadia's (2005) findings that spatial units and zones need to be disseminated appropriately based on the human behavior that is being investigated (Clark, 2013).

3.2.3 Hexagonal Data Bins

Hexagonal tessellation of a research area provides an avenue for overcoming MAUP's effects and the corresponding ecological fallacies. Hexagons placed in an array over a study area would provide even spatial coverage, be isotropic, and is much less likely to be coincident with anthropogenic features in the environment (Davis, 2012). The use of 20 meter diameter hexagons to capture the important socioeconomic and built environment variables that significantly relate to AT without overreaching the actual spatial extent of the exposure that an individual may have to them. The consistency created by the hexagonal array will allow observed or directly reported destination-origin trips to be examined uniformly without the variability created by common GIS analysis.

Hexagons also allow for flexibility in aggregation when adjusting policy or infrastructure by allowing the user to define the neighborhood (operationalized in GIS as the number of hexagons). Testing the effects of MAUP with hexagons using methods of standard-difference-in-means test is well established in research (Clark, 2013; Zhang and Kukadia, 2005; Ding, 1998) and will help determine if aggregating hexagons into neighborhoods would be significantly different than the hexagons alone. The use of hexagons can allow for a true analysis of the zoning effect of MAUP because their use in spatial aggregation is fixed, which could not be done in other research (Clark, 2013). The zonal effect from hexagon would also be limited as a change in the orientation of the hexagon results in smaller changes in study area as compared to standard square (Hales, 2001). The anticipation would be the possibility of a standardized spatial unit.

3.3 Methods

3.3.1 Household Travel Survey and Study Sample

A comprehensive household travel survey was completed by the City of London, Ontario, Canada (2009-2010). The survey was undertaken in an effort to support the continuing public outreach portion of the City of London's Smart Moves 2030 study, the guiding document to be applicable to the updating and overhauling of the city's Transportation Master Plan. The aim of the survey was to capture weekday trips under the pretext that each captured trip would represent a typical weekday from the respondents and only be "for purpose" (not recreational) travel.

The survey was completed using random telephone survey of residents within the London Census Metropolitan Area (LCMA). Eligibility for the survey only included a minimum age of 15. To ensure an accurate representation of the LCMA the survey acquired 14,476 respondents from 6,290 households which represent 4.96% of the LCMA (age 15 and older). The survey method included computer-assisted randomizing techniques and tabulation methods to ensure a broad and representative geographic distribution for the survey. This step is important to capture neighborhoods of differing built environment and socio-demographic characteristics and allow higher degree of fidelity when assessing travel mode choices.

For each reported trip the respondents were asked questions on the mode of travel, purpose of trip, destination of trip, dwelling type, age, gender, employment, education, transit accessibility and usage, and household income. Most importantly the location of each trip's origin and destination was recorded by requesting the address. If the respondent was apprehensive about disclosing an address, the closest street intersection was obtained.

A total of 30,689 trips (average of 2.09 trips per participant) were acquired. Using GIS software each origin and destination was geocoded to the road network for the City of London at a tolerance of 50 meters. This tolerance removed any possible inaccurately reported addresses resulting in the removal of 768 trips. Trips that had either an origin or destination outside of the City of London or recorded no geographic data were also removed. The final sample includes 29,027 trips from 14,474 respondents (City of London, 2013) (Figure 3).

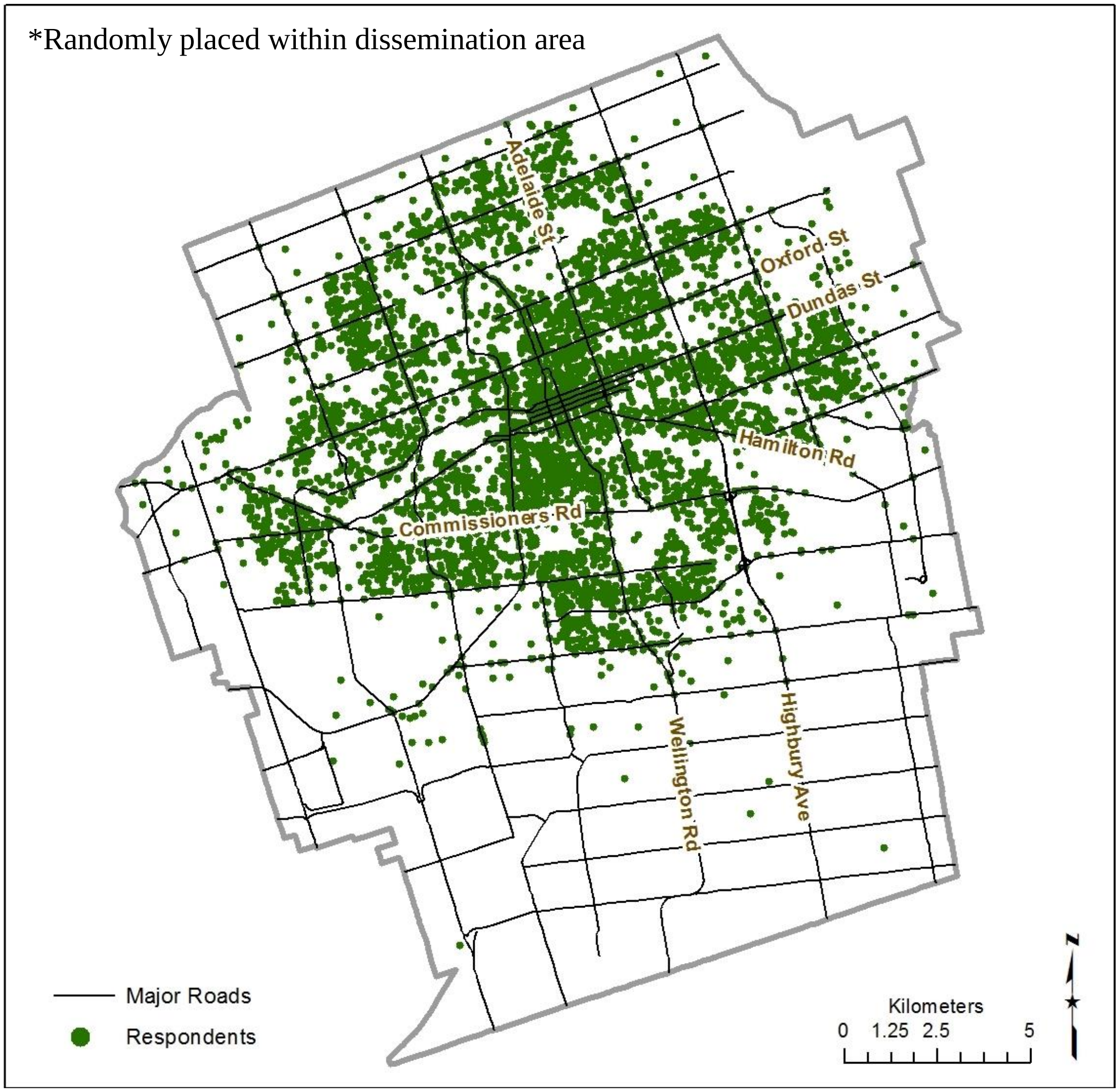


Figure 3 - Distribution of Respondents from Household Travel Survey

3.3.2 Dependent Variable

The dependent variable was derived from the survey responses to the mode of travel for each reported trip. Trips were classified into three categories. The first encompassing all non-active modes including use of automobile as a driver or passenger, public transportation, and hired services, such as taxi services or chartered bus. The final two categories include walking and cycling, both AT modes. The decision to separate AT into two categories is based on the continual finding that distance is an overwhelming factor in AT decision making (Slater, 2016; Ermagun and Samimi, 2015). The increased range of a cyclist compared to walking trips often results in different correlates.

3.3.3 Independent Variable

A series of socio-economic variables are used to control for individual-level factors that have been found related to AT in past literature. These measures include age, sex, employment status, trip distance, and trip purpose (Carlson, 2016; Heeswijck, et al, 2015; Berrigan et al, 2010). Additionally, this study will also account for neighborhood-level factors and socio-economic status (SES) through the use of median household income measured at the census dissemination area, which is the smallest geography in which Statistics Canada releases economic data. Neighborhood level income is used in this study due to a lack of individual level SES data available from the survey (Thrun et al, 2016).

The built environment is measured at the trip level, where the shortest network path between each respondent's origin and destination on a circulation network are modeled in ArcGIS 10.2 (ESRI). This method follows practices of previous research examining the BE using origin/designation type data (Larsen et al, 2009; Schlossberg, 2006). Global Positioning System tracking can be the most practical method for identify exact travel paths (Dessing et al, 2015), the shortest path still provides high fidelity of the respondent's route from origin and destination due to the use of exact addressing in the dataset. This improves upon past travel demand data that simply aggregate origins and destinations in traffic aggregation zones or similar aggregation units.

Each travel route was then intersected with a 20-meter diameter hexagonal grid that has been created across the entirety of Middlesex County to encompass the LCMA (Figure 4). Using a grid that stretches beyond the LCMA study area will eliminate any problems associated with an edge effect (Sadler et al, 2011) for trips that occur close to boundaries of the study area. The results of this intersection are a hexagonal tessellation travel corridor for each trip. These travel corridors form the basis of trip-based BE variables,

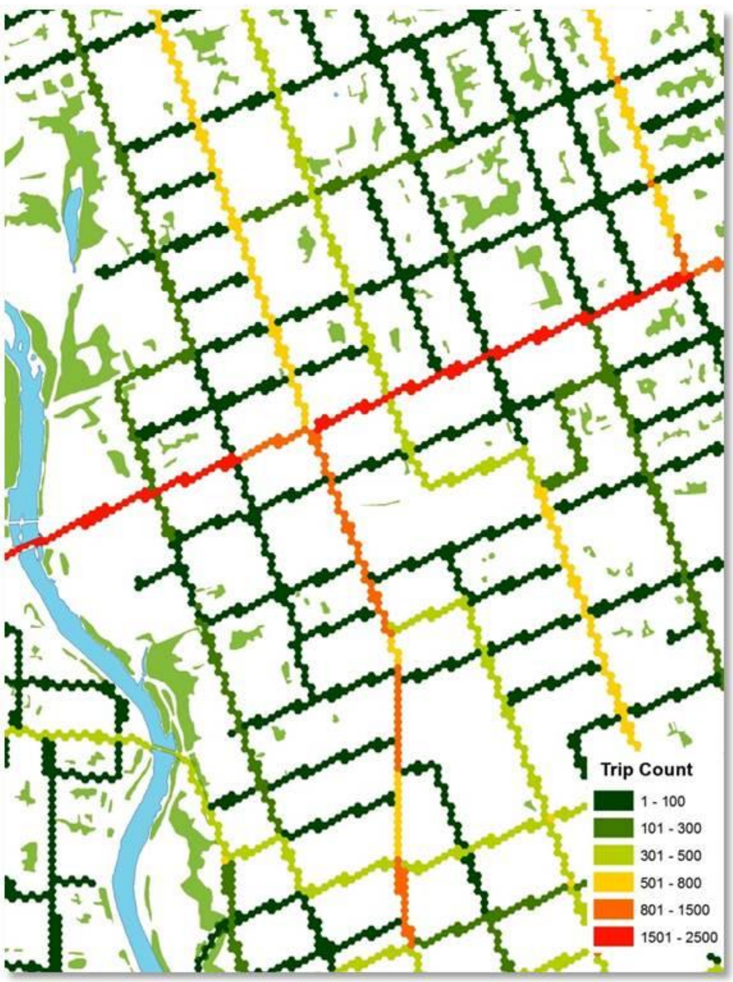


Figure 4 - Example of Hexagon Routes

that are selected and measured based on those that are consistently found to be significant in past literature.

The following built environment variables are measured for each travel corridor using ArcGIS 10.1 (ESRI):

- *Sidewalk Coverage* is a measure of the total length of sidewalk in the travel corridor divided by the total length of roads in the same corridor creating a variable between zero and two. This measure represents the sidewalk availability on both sides of the road network. Consequently, values that fell below one represent less than half the possible sidewalk availability. Values calculated above one represented above average sidewalk coverage or more than half the possible sidewalk coverage.

- *Bike Lane Coverage* is the total length of bike lanes divided by the total length of roads for each travel corridor. The range is between 0 for areas within no bike lanes and 2 for areas with bike lanes on both sides of the street. As with sidewalk coverage values above 1 represent average coverage or more than half the possible sidewalk coverage.

- *Intersection Density* is the total number of 3- or 4-way intersections within the travel corridor divided by the corridor's total area and is a measure of street connectivity.

- *Tree Count* is the total number of trees found within the road network right-of-way that are maintained by the City of London and are found in each travel corridor.

- *Multiuse Path* is the total length of multiuse paths that are found within each travel corridor.

- *Maximum Traffic Volume* is the measure of the highest amount of traffic encountered by the travel corridor between the origin and destination.

- *Land Use* was measure using parcel level land use data provided by the City of London. Five classifications could be identified: residential, commercial, industrial, recreation, and institutional. The total area of each classification was calculated within each travel corridor.

3.3.4 Analysis

The method of analysis is multinomial logistic regression with relative risk ratio (RRR). Two models were run to answer the research questions: 1) All trips within the dataset; and 2) Trips within a reasonable distance to actively travel defined as the average distance traveled by active modes plus one standard deviation. A step-wise approach was then applied to each model to account for (a) trip characteristics, (b) individual and neighborhood factors, and (c) built environment variables. This process allows for observation of model fit and potential issues of multicollinearity between variables to be accounted for during modelling. To account for variations in the predictive power of the models and to monitor its success, pseudo r-squared and pseudo log likelihood will be calculated and reported. To minimize the bias due to heteroscedasticity robust cluster standard errors are estimated at the individual level (Stock and Watson, 2008).

3.4 Results

3.4.1 Descriptive Statistics

The characteristics of the 29,029 participants can be found in Table 1. The sampling methodology used for this study provides a representative sample. The age of respondents is fairly evenly distributed across the age spectrum with 22.7% of participants being 40 to 49 years old, 17.1% being between 20 and 29 years old. There were only 8.1% of respondents 70 years of age and older. The distribution of the gender of respondents was relatively even with 49.4% of respondents being male and 50.6% female.

The average distance between origin and destination for non-active participants as measured by shortest network path was 5,755 meters. Average age for non-active participants was 42.3 years old with a median household income of $55, 875 CAD. 57.1% reported being employed in a full or part time capacity, 17.9% were enrolled as high school or university students, and 25.3% were not employed. Split between male and female respondents mirrored the overall distribution with 50.4% female and 49.6% male.

Walkers were found to have travelled an average of 3,056 meters between origin and destination, though this is skewed by outliers. The median distance traveled was 1,885 meters and provides a more accurate description of walkers travel distance. Median household income was $52,139 CND and the average age was 34.3 years old. As with distance, average age is misleading as the median age of the sub-sample is 42.0 years old. 42.4% were enrolled as a high school or university student, 28.4% were employed full or part time, and 29.2% were not employed. This sub-sample was slightly more female (55.2%) than male (44.8%).

Table 1 - Descriptive Statistics

Variables	**n**	**%**
Trip Characteristics		
# of trips	29,027	
Trip Mode		
Non-Active	26,567	91.5%
Walk	2,324	8.0%
Bike	136	0.5%
Trip Purpose		
Work	7,257	25.0%
School	2,913	10.0%
Discretionary	18,857	65.0%
Individual Characteristics		
# of Respondents	14,476	
Sex		
Male	7,151	49.4%
Female	7,325	50.6%
Employment		
Employed	7,918	54.7%
Student	2,895	20.0%
Not Employed	3,662	25.3%
	Mean (Std. Dev.)	
Individual Characteristics		
Age (Mean, Std Dev)	41.69	18.416
Neighbourhood Characteristics		
Median Household Income (Mean, Std Dev)	55,075	5,350

Bikers were found to have traveled an average of 4,326 meters during their trips. Average age was 41.36 years old with a median household income of $50,215. Employment status for bikers was similar to walkers with 43.4% employed full or part time, 29.4% not employed, and 27.2% were students. Bikers show the largest gender split with the sub-sample being 77.9% male and 22.1% female.

3.4.2 Model Results

3.4.2.1 Model 1a – Trip Characteristics – All Trips

Model 1 (Table 2) finds that for every 1 km of additional trip distance the propensity of respondents to walk or bike decreases by a factor of 0.754 and 0.888 respectively, with distance having a smaller effect on biking. The purpose of the trip is only found to be significant with walkers. School-based trips are 4.044 times more likely to use walking compared to work-based trips. Similarly, discretionary trips, defined as any trip taken for shopping, recreation, or similar activity, are also found to have a significantly higher likelihood of walking compared to work-based trips, with the propensity of walking increased by a factor of 1.731.

3.4.2.2 Model 1b – Individual level factors + Socio-Economic factors – All Cases

Distance remains a significant factor with only slight adjustments to the RRR for walk (0.7615) and bike (0.8944) for each kilometer of trip distance added (Table 2). The addition of age to the model finds significance for walkers and bikers for each year of age added, though their impact is low. Gender is also significant but its implications on walkers and bikers are completely opposite. Female participants have a 16.1% increase in likelihood to walk than use a non-active form of transportation with a 73.6% decrease in likelihood to bike than use a non-active form of transportation. Every $10,000 increase neighborhood median household income decreases the likelihood of using any AT mode by a factor of 0.907. Participants who are students are 2.4425 times the likelihood (144.2% increase) of being a walker than non-AT user. Not employed participants are 3.0950 times the likelihood (209.5% increase) of being a walker than a non-AT user.

3.4.2.3 Model 1c – Individual level factors + Neighborhood SES + Built Environment – All Cases

The addition of BE variables finds a better fitting model but with results that show less influence from dependent variables with the exception of employment status (Table 2). Sidewalk coverage, intersection density, and average tree count are all significant but only sidewalk coverage has an effect that adjusts likelihood more than 5%. An increase in sidewalk coverage results in 0.6501 times the likelihood (34.9% decrease) of being a walker. As with model 2, female respondents have a large decrease in likelihood of using non-AT transportation than biking, 73.9% decrease.

3.4.2.4 Model 2a – Individual level factors – Reasonable AT

At the individual level results are consistent with model 1 (Table 3). For walkers distance continues to be significant but its effect on likelihood is stronger. A 1 km increase in distance results in 0.5736 times the likelihood (42.6% decrease) of being a walker. Trip purpose continues to play a key role with school providing the largest increase in likelihood. Dependent variables with bikers found no significant variables.

3.4.2.5 Model 2b - Individual level factors + Socio-Economic Factor – Reasonable AT

With the inclusion of median household income and employment status distance again is significant and remains a strong factor (Table 3). Age and median household income are significant but play nearly no role decreasing the likelihood of being a walker by 2.8%

and 4.2% respectively. No significant factors were found for bikers except for gender. As with models 2 and 3 being a female dramatically decreases your likelihood of being a biker.

3.4.2.6 Model 2c - Individual level factors + Neighborhood SES + Built Environment – Reasonable AT

The inclusion of BE variables finds that distance, age, and employment continue to be significant and contribute findings consistent with the previous models (Table 3). Specifically to the BE, max traffic count, intersection density, average tree count, and recreational land use are found significant. Max traffic and recreational land use decrease the likelihood of being a walker as the trip is presented with higher max traffic counts and larger amounts of recreation land use. A $10m^2$ increase in intersection density and 1 tree increase in average tree count per travel corridor is found to increase the likelihood of walking over non-AT but each by less than 1%.

Table 2 - Logistic regression model for mode choice by all trips

	Model 1a: Trip Characteristics						Model 1b: Trip Characteristics & Individual/Neighbourhood Factors						Model 1c: Trip Characteristics & Individual/Neighbourhood Factors & Built Environment Factors					
	Risk Ratio	Walk Std Error	*p*-value	Risk Ratio	Bike Std Error	*p*-value	Risk Ratio	Walk Std Error	*p*-value	Risk Ratio	Bike Std Error	*p*-value	Risk Ratio	Walk Std Error	*P*-value	Risk Ratio	Bike Std Error	*p*-value
Trip Characteristics																		
Distance	0.754	0.00	0.000	0.888	0.024	0.000	0.762	0.013	0.000	0.894	0.030	0.001	0.827	0.016	0.000	0.957	0.035	0.235
Purpose *(Ref: Work)*																		
School	4.044	0.318	0.000	1.752	0.549	0.074	1.021	0.066	0.746	0.912	0.299	0.778	1.012	0.066	0.855	0.898	0.295	0.744
Discretionary	1.731	0.113	0.000	1.338	0.298	0.192	1.011	0.048	0.828	1.161	0.199	0.385	0.996	0.048	0.927	1.114	0.195	0.539
Individual Factors																		
Employment *(Ref: Employed)*																		
Student							2.443	0.243	0.000	1.868	0.907	0.198	2.297	0.235	0.000	1.348	0.647	0.551
Not Employed							3.095	0.317	0.000	1.586	0.703	0.298	3.361	0.355	0.000	1.899	0.877	0.165
Age							0.974	0.002	0.000	0.998	0.012	0.902	0.973	0.002	0.000	0.996	0.012	0.746
Female							1.161	0.074	0.020	0.264	0.077	0.000	1.175	0.076	0.014	0.268	0.079	0.000
Neighbourhood Factors																		
Median Household Income							0.970	0.010	0.005	0.914	0.038	0.035	0.983	0.010	0.128	0.965	0.042	0.419
Built Environment Factors																		
Sidewalk Coverage													0.650	0.113	0.014	2.964	2.083	0.122
Bike Lane Coverage													1.180	0.159	0.219	0.913	0.461	0.857
Intersection Density													1.001	0.000	0.007	1.000	0.000	0.487
Average Tree Count													1.004	0.001	0.012	0.987	0.010	0.237
Multiuse Path													0.945	0.195	0.784	1.043	1.174	0.970
Max Traffic Volume													0.963	0.004	0.000	0.979	0.017	0.230
Proportion of Land Use																		
Residential													0.996	0.008	0.597	1.177	0.133	0.151
Parks & Recreation													0.981	0.010	0.067	1.094	0.120	0.415
Commercial													1.007	0.008	0.402	1.181	0.133	0.142
Institutional													1.008	0.008	0.309	1.210	0.134	0.087
Industrial													1.004	0.008	0.665	1.186	0.132	0.129
Constant	0.163	0.011	0.000	0.007	0.001	0.000	0.460	0.073	0.000	0.017	0.010	0.000	0.768	0.600	0.736	0.000	0.000	0.069
Loglikelihood	-8073.0904						-7745.6531						-7541.3518					
Pseudo R2	0.0980						0.1346						0.1541					

Table 3 - Logistic regression model for mode choice by trips within

	Model 2a: Trip Characteristics						Model 2b: Trip Characteristics & Individual/Neighbourhood Factors						Model 2c: Trip Characteristics & Individual/Neighbourhood Factors & Built Environment Factors					
	Risk Ratio	Walk Std Error	*p*-value	Risk Ratio	Bike Std Error	*p*-value	Risk Ratio	Walk Std Error	*p*-value	Risk Ratio	Bike Std Error	*p*-value	Risk Ratio	Walk Std Error	*P*-value	Risk Ratio	Bike Std Error	*p*-value
Trip Characteristics																		
Distance	0.574	0.010	0.000	1.000	0.058	0.998	0.570	0.016	0.000	1.006	0.087	0.944	0.613	0.020	0.000	1.209	0.126	0.070
Purpose *(Ref: Work)*																		
School	3.545	0.308	0.000	1.743	0.610	0.113	0.955	0.068	0.519	0.838	0.269	0.583	0.952	0.068	0.495	0.840	0.272	0.592
Discretionary	1.511	0.108	0.000	1.357	0.342	0.227	0.965	0.050	0.497	1.136	0.189	0.445	0.955	0.050	0.381	1.092	0.189	0.612
Individual Factors																		
Employment *(Ref: Employed)*																		
Student							2.168	0.239	0.000	2.042	1.040	0.161	2.049	0.232	0.000	1.393	0.735	0.530
Not Employed							2.731	0.312	0.000	1.517	0.672	0.347	2.946	0.342	0.000	1.887	0.883	0.175
Age							0.972	0.003	0.000	0.999	0.012	0.912	0.971	0.003	0.000	0.996	0.013	0.778
Female							1.138	0.081	0.069	0.332	0.102	0.000	1.147	0.082	0.057	0.341	0.107	0.001
Neighbourhood Factors																		
Median Household Income							0.958	0.011	0.000	0.934	0.046	0.172	0.976	0.012	0.055	1.007	0.053	0.892
Built Environment Factors																		
Sidewalk Coverage													0.834	0.147	0.306	4.304	3.313	0.058
Bike Lane Coverage													1.161	0.156	0.267	0.952	0.563	0.934
Intersection Density													1.000	0.156	0.048	1.000	0.000	0.685
Average Tree Count													1.003	0.001	0.042	0.984	0.012	0.197
Multiuse Path													1.023	0.122	0.848	1.479	1.724	0.737
Max Traffic Volume													0.982	0.004	0.000	0.962	0.021	0.073
Proportion of Land Use																		
Residential													0.987	0.008	0.123	2.509	0.926	0.013
Parks & Recreation													0.978	0.010	0.034	2.235	0.833	0.031
Commercial													0.995	0.008	0.586	2.523	0.933	0.012
Institutional													0.999	0.008	0.955	2.582	0.953	0.010
Industrial													0.997	0.008	0.804	2.513	0.931	0.013
Constant	0.334	0.025	0.000	0.005	0.001	0.000	1.151	0.193	0.402	0.011	0.007	0.000	2.741	2.177	0.204	0.000	0.000	0.009
Loglikelihood	-6286.5034						-6027.2278						-5901.3504					
Pseudo R2	0.1037						0.1406						0.1545					

3.5 Discussion

This study demonstrates that leveraging a large population transportation survey and delineating spatial variables using hexagons can successfully model individual, economic, and built environment variables to identify contributing factors to AT specific mode decisions. Results show distinct changes in the likelihoods of non-AT and AT mode choices based upon these categories of variables. These findings are consistent with those from the last decade of AT research but includes a spatial delineation that provides a solution to the Forsyth et al (2006) argument for the need of consistency, purpose, geography, data resolution, accuracy, completeness, and time in AT/BE research.

As found throughout the AT literature, distance is the most important contributor in the decision to use AT. Each model, regardless of what was included, found distance as significant and having a high level of influence. This provides strong confirmation that no matter what individual or BE variables are targeted for intervention by municipalities or similar decision makers, people must be within a distance of their intended destination that they perceive to be short enough for them to walk.

While distance is a forefront contributor, purpose of the trip must be factored in as well (O'Hern and Oxley, 2015). Before the inclusion of variables that explore socio-economics, the purpose of the trip was easily the most influential factor influencing walking over non-AT after distance, and is consistent with other findings (O'Hern, 2015; more). When a control for distance was added into the final three models purpose continued to be a strong indicator for AT. With the inclusion of socio-economic variables, specifically median household income, the significance moved away from purpose and to employment status, with students and those not employed having increases in walking likelihood. These findings suggest that respondents with lower economic means (i.e. not employed or a student) are far more likely to walk then someone working.

The differences that gender plays between bikers and walkers were noticeable. Female respondents were more likely to walk and very less likely to bike. This finding held true through each step of modelling and more so when the model controlled for distance. While finding that females are less likely to be bikers has been shown in previous studies, the strength of this influence is nevertheless compelling. The results suggest that when all trips are included and all other variables remain constant, men are more likely to choose a bike as a transportation method and women are more likely to choose walking. This evidence clearly needs further investigation and a target for policy, perhaps with qualitative methods (i.e., interviews and gender-specific focus groups) to investigate further.

The presence and/or mix of certain land uses is often found to increase rates of walking for adults (Leslie et al, 2007; Larsen et al, 2009; Feng et al. 2010). This study found evidence of the influence of land use ($p<0.05$) only when controlling for distance and only when on a bike. This was also the only time that all five categories of land use were significant simultaneously (i.e. statistically relevant to mode choice) and the only time distance was a positive factor (i.e. helped) choosing an AT mode. Generally, the results find that bikers are willing to travel further distances to their destinations and greatly prefer a BE with mixed land use (Tilahum et al, 2007).

Distance has been found to be an overwhelming factor when investigating travel mode choices and the findings from the first three models confirms these conclusions (Table 3). In order to get a clearer picture on the variables that take part in participant travel behavior some measure of controlling for distance was needed. The second branch of modelling controls for distance including only trips that occurred within a reasonable distance for AT. This measure was calculated by finding the average distance travelled by participants that used an AT mode of travel (walk, bike) plus one standard deviation.

The results of this study show the clear potential of hexagonal binning as a mode of spatial delineation. With more investigation hexagon's fixed spatial locations can provide decision makers with a valuable tool that can be used for intervention by providing specific built environment variables in specific locations, an outcome not available to other methods, specifically buffers. The research also contributed to the literature by providing more evidence that individual, socio-economic, and built environment factors have statistically significant relationships to AT uses, most notably distance, purpose, and employment status.

Although this research advances GIS methodologies, further investigation into the creation of the travel corridor using hexagonal binning is needed. Hexagons work well for representing a more sensitive measure of exposure. Previous methods tend to measure too much of the BE around a traveler's actual route, often extracting measures that can be 500 meters away from the true route. Hexagonal buffering resulted in 20-meter wide exposure to the built, social, and physical environments following a trend of smaller exposure measures in route based research (Dessing, 2016). These smaller exposure measures allow for a more precise spatial resolution, with consistent geography, and are easily replicable.

The effect that directness may have on travel mode of choice is limited by the use of shortest network paths. It is plausible and logical that the shortest route to a destination would not be the automatic choice for any preferred mode of travel. Current conditions of traffic, visual appeal of the route or off the road network travel can all have effects on travel mode and route choice. Routes taken, especially when walking, could be very indirect and circuitous. Further investigation using direct methods of measurement and observation with equipment like a global positioning device would be beneficial.

In conclusion, this study finds overwhelming evidence that hexagons can be a solution to inconsistent findings in AT/BE research by providing an areal unit not reliant on administrative units, less susceptible to problems of MAUP, and that meets the needs of consistency and viability. With further work hexagonal tessellation can become a standard in BE exposure measurement in the study of AT and the development of BE based interventions to increase AT.

3.6 References

Berrigan, D., Pickle, L., and Dill, J. (2010). Associations between street connectivity and active transportation. International Journal of Health Geographics. 9(20).

Boer, R., Zheng, Y., Overton, A., Ridgeway, G., Cohen, D. (2007). Neighbourhood design and walking trips in ten US metropolitan areas. American Journal of Preventive Medicine. 32, 15-22.

Bronfenbrenner, U. (1994). Ecological models of human development. In International Encyclopedia of Education, Vol. 3, 2nd Ed. Oxford: Elsevier.

Brownson, R., Hoehner, C., Day, K., Forsyth, A. and Sallis, J. (2009). Measuring the built environment for physical activity: state of the science. American Journal of Preventative Medicine, 36(4 Suppl), S99-123.

Carlson, J., Sallis, J., Kerr, J., Conway, T., Cain, K., Frank, L., Saelens, B. (2013). Built environment characteristics and parent active transportation are associated with active travel to school in youth age 12-15. British Journal of Sports Medicine. 093101.

Cervero, R., Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. Transportation Research, 2, 199-219.

City of London, Ontario. A new mobility transportation master plan for London: 2030 Transportation Master plan: SmartMoves. AECOM. Final Report: Volume 2. May 2013.

Clark, A. (2013). Understanding the impact of the modifiable areal unit problem on the relationship between active travel and the built environment. Urban Studies, 51(2), 284-299.

Davis, J. and Robinson, G. (2012). A geographic model to assess and limit cumulative ecological degradation from Marcellus shale exploitation in New York, USA Ecology and Society. 17(2), 25.

Dessing, D., de Vries, S., Hegeman, G., Verhagen, E., van Mechelen, W., and Pierik, F. (2016). Children’s route choice during active transportation to school: difference between shortest and actual route. International Journal of Behavioral Nutrition and Physical Activity. 13:48.

Ermagun, A. and Samimi, A. (2015). Promoting active transportation modes in school trips. Transport Policy. 37, 203-211.

Feng, J., Glass, T., Curriero, F., Stewart, W., Schwartz, B. (2010). The built environment and obesity: a systematic review of the epidemiologic evidence. Health and Place. 16(2), 175-190.

Fotheringham, A. and Wong, D. (1991). The modifiable areal unit problem in multivariate statistical analysis. Environment and Planning A. 23(7), 1025-1044.

Forsyth, A., Schmitz, K., Oakes, M., Zimmerman, J., Koepp, J. (2006). Standards for environmental measurement using GIS: Toward a protocol for protocols. Journal of Physical Activity and Health. 3(S1), S241-S257.

Frank, P. and Engelke, P. (2005). Multiple Impacts of the built environment on public health: walkable places and the exposure to air pollution. International Regional Science Review. 28(2), 193-216.

Gilliland, J. (2010). The built environment and obesity: Trimming waistlines through neighbourhood design. In T. Bunting, P. Filion & R. Walker (Eds.), Canadian cities in transition: New directions in the twenty-first century (4th ed.). Oxford,MA: Oxford University Press.

Hales, T. (2001). “The Honeycomb Conjecture” Discrete and Computational Geometry. 25: 1-22.

Handy, S., Boarnet, M., Ewing, R. and Killingsworth, R. (2002). How the built environment affects physical activity: Views from urban planning. American journal of Preventive Medicine. 23(2) Suppl. 1, 64-73.

Heeswijck, T., Paquet, C., Kestens, Y., Thierry, B., Morency, C., Daniel, M. (2015). Differences in associations between active transportation and built environment exposures when expressed using different components of individual activity spaces. Health and Place. 33, 195-202.

Lachapelle, U., Frank, L., Sallis, J., Saelens, B., and Conway, T. (2016). Active transportation by transit- dependent and choice riders and potential displacement of leisure physical activity. Journal of Planning Education and Research. 36(2), 225-238.

Larsen, K., Gilliland, J., Hess, P. (2012). Route-Based Analysis to Capture the Environmental Influences on a Child's Mode of Travel between Home and School. Annals of the Association of American Geographers, 102(6), 1348-1365.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A. Hugo, G. (2007). Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. Health and Place. 13, 111-122.

Lubans, D., Borehamn, C., Kelly, P., Foster, C. (2011). The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. International Journal of Behavioral Nutrition and Physical Activity. 8,5.

Malczewski, J. (1999). GIS and multicriteria decision analysis. John Wiley and Sons; Toronto.

McCormack, G. and Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Journal of Behavioral Nutrition and Physical Activity. 8, 125.

O'Hern, S. and Oxlet, J. (2015). Understanding travel patterns to support safe and active transport for older adults. Journal of Transport and Health. 2, 79-85.

Oliver, L., Schuurman, N., and Hall, A. (2007). Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. International Journal of Health Geographics. 6, 41.

Openshaw, S. (1983). The modifiable areal unit problem. Geo Books: Norwick Norfolk

Owen, N., Cerin, E., Leslie, E., duTroit, L., Coffee, N., Frank, L., Bauman, A., Hugo, G., Saelens, B., and Sallis, J. (2007). Neighborhood walkability and the walking behavior of Australian adults. American Journal of Preventive Medicine. 33, 387-395.

Panter, J., Heinen, E., Mackett, R., and Ogilvie, D. (2016). “Impact of New Transport Infrastructure on Walking, Cycling, and Physical Activity”. American Journal of Preventative Medicine. 50(2), e45-e53.

Rodriquez, D. and Joo, J. (2004). The relationship between non-motorized mode choice and the local physical environment. Transportation Research Part D, 9, 151-173.

Saelens, B., Handy, S. (2008). Built environment correlates of walking: A review. Medicine and Science in Sports and Exercise, 40, 550-566.

Sallis, J., Frank, L., Saelens, B., Kraft, M. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. Transportation Research Part A: Policy and Practice. 36(5), S329.

Sadler, R., Gilliland, J., Arku, G. (2011). An application of the edge effect in measuring accessibility to multiple food retailer types in Southwestern Ontario, Canada. International Journal of Health Geographics. 10, 34.

Slater, M., Kelly, A., Sadak, K., and Ross, J. (2016). Active Transportation in adult survivors of childhood cancer and neighborhood controls. Journal of Cancer Survivorship. 10, 11-20.

Stock, J. and Watson, M. (2008). Heteroskedasticity-robust standard errors for fixed effects panel data regression. Econometrica. 76, 155-174.

Tilahun, N., Levison, D., and Krizek, K. (2007). Trails, lanes, or traffic: valuing bicycle facilities with an adaptive stated preference survey. Transportation Research Part A: Policy and Practice. 41(4), 287-301.

Thrun, E., Leider, J., and Chriqui, J. (2016) Exploring the cross-sectional association between transit-oriented development zoning and active travel and transit usage in the United States, 2010-2014. Frontiers in Public Health. 4, 113.

Zander, A., Rissel, C., Rogers, K., and Bauman, A. (2014). Active travel to work in NSW: trends over time and the effect of social advantage. Health Promotion Journal of Australia. 25(3), 167-173.

Zhang, M. and Kukadia, N. (2005). “Metrics of urban form and the modifiable areal unit problem” Transportation Research Record: Journal of the Transportation Research Board. 1902, 71-79.

CHAPTER FOUR

4 Measuring built environment determinants of active transportation with GPS: The STEAM Project

A growing body of literature investigating children's active travel (AT) has been developing across the globe most notably in Canada, the United States, Australia, and the United Kingdom (Raja, 2015; Stanley, 2015; Gutierrez et al, 2014; Aarts, 2013; Turner et al, 2013). Interest in the matter has matured as examination into reports of rising rates of obesity and type-2 diabetes in children find evidence that decreases in physical activity are a substantial contributing factor to these conditions (Tremblay, 2010; Dencker, 2008; Dollman, 2005). D'Haese (2015) asserts that the simple solution is to identify determinants of children's physical activity and develop feasible interventions aimed to increase physical activity (Gilliland et al., 2016).

The built environment (BE) presents the perfect opportunity to enact solutions as evidence suggests that current trends in the expansion and improvement of the BE away from pedestrian orientation and toward automobile orientation are contributing factors to a severe decline in the rate of AT to school (Bassett, 2015; McDonald, 2012; Builing, 2009; Bassett, 2008). The most common form of physical activity at any age is walking, making AT to school an optimal target for intervention as it is regularly an integral part of a child's daily routine (Larsen, 2012). This is especially true for children in urban environments where busing may be unavailable due to proximity to the school (Larsen, 2012) and being driven by a parent is inconvenient (Carlson, 2013).

To ensure that interventions aimed at increasing children's AT are completed correctly and without wasting resources (e.g. time, money) a better understanding of the determinants of AT is required. Previous studies have been completed exploring numerous built environments, socio-economic, and individual measures producing results that are generally inconclusive, contradictory, and ambiguous. This study strives to improve on previous work by employing fresh geographic information systems (GIS) methodologies to answer three research questions. 1) What are the individual characteristics (i.e., sex, age) of children who travel actively to school? 2) What built environment exposure characteristics influence children's mode of travel to school? 3) Does the relationship between active transportation and exposure to the built environment among children align with relationships found when using traditional measures of the built environment?

4.1 Active Travel Determinant for Children

The built environment has been found to play an important role in whether children will travel actively to school (Raja et el, 2015; Carlson, 2013; Saelens and Handy, 2008). AT to and from school is an essential process to investigate as it presents an excellent opportunity to increase rates of AT through changes in the BE or policy (Frank and Engelke, 2005). The opportunity presents itself as a result of the limited freedom in children's transportation choices stemming from parental controls and lack of transportation selection due to limited economic or individual (e.g. age) means. This idea is critical since it situates children in a captive built and social environment susceptible to interventions in the BE or policy (Frank and Engelke, 2005).

The relationship between the BE and AT has numerous concomitant associations in measures including land use, population density, infrastructure and more (McCormack and Shiell, 2011). The result of this is a nearly endless list of BE, socio-economic, trip specific, and social environment variables establishing a statistically significant relationship that affects AT outcomes (Brownson et al, 2009). Distance is excluded from this discordance as it has been repeatedly established that an increase in distance between home and school decreases the probability of AT (Duncan, 2016; Helbich, 2016; Carlson, 2013; Panter, 2013; Schoeppe, 2013; McDonald, 2012; Trapp, 2013; Timperio, 2006). This agreement makes it imperative that some control is given for distance. The purpose of the trip is excluded as well due to the nature of the research (i.e. active travel to/from school) and an equally growing body of research supporting positive associations to it (Carlson, 2013; Schoeppe, 2013).

Additional BE measures are routinely found to significantly affect AT outcomes. Raja et al (2015) established that an increase in sidewalk coverage as measured by sidewalk presence on multiple sides of the street and width of the sidewalk correlates to children's AT rates. These findings fall in agreement with previous literature (Woldeamanuel and Kent, 2015; Panter, 2010; Larsen et al, 2012, Boarnet el al, 2005). Connectivity addresses the design of the urban morphology and is expressed in AT research through the use of intersections with more intersections yielding higher street connectivity (Giles-Corti et al, 2011). Consequently, higher amounts of intersections positively increase AT rates for children (Helbich, 2016; Panter, 2010; Bungum, 2009; Hume, 2009). Well connected streets make higher traffic counts more likely and with it the perception of pedestrian injury risk (Sirard and Slater, 2008). Accounting for this, max traffic volume has been investigated with strong negative effects on AT rates observed (Helbich, 2016; Mitra, 2012).

Land use is often operationalized in AT research through indices such as Frank's (2010) walkability index. This type of measure takes advantage of the unique statistical and spatial modeling power provided by GIS by allowing for the inclusion of proximity and connectivity measures (Leslie, 2007; Frank, 2003). The use of indices measures commonly misses variables that are connected to AT rates due to the broad measures required for the indices calculation (Frank, 2000). Trees, for example, have been linked to increases in AT rates and can easily be missed (Lovasi, 2013; Larsen et al, 2012). To ensure the inclusion of the impact of land use and allow for the flexibility for inclusion of measures that could otherwise be removed or forgotten, AT studies regularly break land use into five commonplace categories; residential, commercial, industrial, recreational, and institutional (Carlson, 2013).

Ecological system theory allows research investigating the BE/AT relationship to address the multifaceted spatial and temporal characteristics inherent to the relationship (Sallis, 2008). Therefore, the individual and socio-economic variables must be investigated alongside the built environment. Helbich (2016) found concurring research on age, establishing a significant positive association and calculating that an increase in age increases the likelihood of a child actively traveling to school (Larsen, 2012; McDonald, 2007). Sex has also been found to influence AT for children though findings vary from study to study and no consensus has been found on its influence (Helbich, 2016; Carlson, 2013; Lovasi, 2013; Larsen, 2012; McMillan, 2006). Income, operationalized through census data (Woldeamanuel, 2015) or parental survey (Carlson, 2014), also has contradictory results or is not included during analysis (Duncan, 2016; Helbich, 2016; Woldenmanuel, 2015).

4.2 GIS Methods in Active Travel Research

Previous studies have employed GIS methodologies that are reliant on origin-destination travel surveys (see TMP), shortest network pathing (Schlossberg, 2006), or Euclidean distancing (Owen et al, 2012) to measure BE exposure. These GIS driven, calculated routes may not accurately reflect the paths taken by the participants especially when children are the primary party (Harrison et al, 2014; Timperio, 2006). Where adults will intuitively strive to minimize their travel distances children rarely aspire to the same instead prioritizing meeting peers or finding routes that present opportunities for free play (Harrison et al, 2014). The results of these methodologies are significant errors in measured exposure between computed routes and the actual routes taken (Harrison et al, 2014). To overcome this deficiency studies are utilizing the global positioning system (GPS) to track where children travel to and from school (Dessing et al, 2014; Kerr et al, 2011). Duncan (2007) confirmed the validity of this method while Larsen (2012) made the methodology more robust by including school travel surveys. The utilization of the high spatial and temporal resolution of GPS tracking data represents a positive step forward in GIS methodologies paired with research in travel behavior.

Inherent in studying the link between mode of travel and the built environment is the need to aggregate neighborhood data for calculating exposure measures. Commonly this methodology is centered on locating the home (origin) and school (destination) and applying a predefined boundary around them to capture the BE. These types of methodologies are often employed in four approaches; circular buffers (Mitra, 2012), polygon-based road network buffers (Frank, 2006), standard deviation ellipses (Zenk, 2011) and GPS point buffering (Zenk, 2011). The methodologies and their implicit spatial units are chosen due to the ease and availability of data that can be used in modelling, specifically data from surveys or a census (Kwan, 2012).

The application of these methodologies for capturing the built environment has likely lead to the inconsistent findings through AT/BE literature. Kwan (2012) suggests that the problem is contextual stemming from the various manners in which environmental and socio-economic variables are contextualized and then operationalized. Research by Mitra and Builing (2011) and Clark and Scott (2014) suggest the modifiable areal unit problem and its corresponding ecological fallacy are to blame. Zhang and Kukadia (2005) advocates disaggregation of variables where ever feasible or the creation of a spatial unit appropriately specified for the phenomena being investigated (Clark, 2013).

Hexagonal tessellation placed in an array over a study area would provide even spatial coverage, be isotropic, and is much less likely to be coincident with anthropogenic features in the environment (Davis, 2012). At the 20 meter scale, hexagons will be able to capture the important socioeconomic and built environment variables that significantly relate to AT without overreaching the actual spatial extent of the exposure that an individual may have to them. The consistency created by the hexagonal array will allow observed or directly reported destination-origin trips to be examined uniformly without the variability created by common GIS analysis.

4.3 Data

4.3.1 The Steam Project

The data from this study draws from the Spatial Temporal Environment and Activity Monitoring (STEAM) project. This research study was a three-year program designed to explore the relationship between the built environment and children's health-related behaviors, notably their food environments, physical activity, and active transportation (www.steamproject.ca) (Mitchell et al, 2016; Loebach and Gilliland 2016a; 2016b; Clark et al., 2016; Sadler et al. 2016; Sadler and Gilliland 2015; Gilliland et al. 2015). The study targeted children aged 9-14 years as this time period is a critical life stage when independent mobility and environmental awareness is beginning to develop (Rissotto and Tonucci, 2002). This study was approved by the Non-Medical Research Ethics Board of the University of Western Ontario (NM-REB #: 17918S) prior to implementation.

To assure the capture of differing built environment and socio-demographic characteristics potential recruitment schools were selected across Southwest Ontario from contrasting urbanicities (urban, suburban, rural), neighbourhood socio-economic status (low, mid, high), and distinct urban morphology. The head administrator of each selected school was contacted, introduced to the project, and asked for permission to conduct the STEAM project in their school. If granted permission researchers gave a presentation to the age appropriate students explaining the project. All students were given an introductory letter of information along with a consent form for the parent and/or guardian.

Students who returned with a signed parental consent form, and were personally interested in participation, were also asked to sign a child assent form to finalize their acceptance into the project. The study was an 8-day multi-tool protocol designed to record and measure student's neighborhood activities, mobility, and daily experiences. Each student wore portable accelerometers to measure energy expenditure and Visiontac V-900 GPS units for environmental tracking. Along with the devices students completed a detailed daily activity diary recording the 'where and why' for their daily activities along with 'who' they may have completed them. Also any food they may have bought while traversing their neighborhood was recorded. A detailed survey querying information about demographics, behaviors, and perceptions was completed by each participating student along with their parent and/or guardian. Data from the surveys, accelerometer, and GPS were processed and integrated in GIS to allow for spatial analysis. This protocol was completed in two seasons, first in the spring and then the following fall. At completion of the STEAM project 34 elementary schools across four schools within Southwest Ontario had participated. Validation of each participant required complete demographic data from the parent or student survey, physical activity data from accelerometry, and GPS tracking.

4.3.2 Study Sample

At the conclusion of the STEAM project 851 participants from 34 schools in 4 school boards in London and Southwest Ontario had complete data sets based upon available demographic data usable from child and/or parent surveys, valid accelerometry, and completed activity diaries. Processing of GPS tracking data from the participants acquired 4125 trips (4.8 trips/participant) from and/or to school. Pairing the GPS data with GIS software allowed the identification of each participant's home and school. Participants that had homes outside of the City of London were excluded to fit the geographic scope of the study (Figure 5). Participants with homes further than 1.6 km from their school were excluded as students outside this area are eligible for bussing. Finally, any participant who identified their mode of travel as "School Bus" was also excluded to account for students who bus to school due to various exceptions. The final

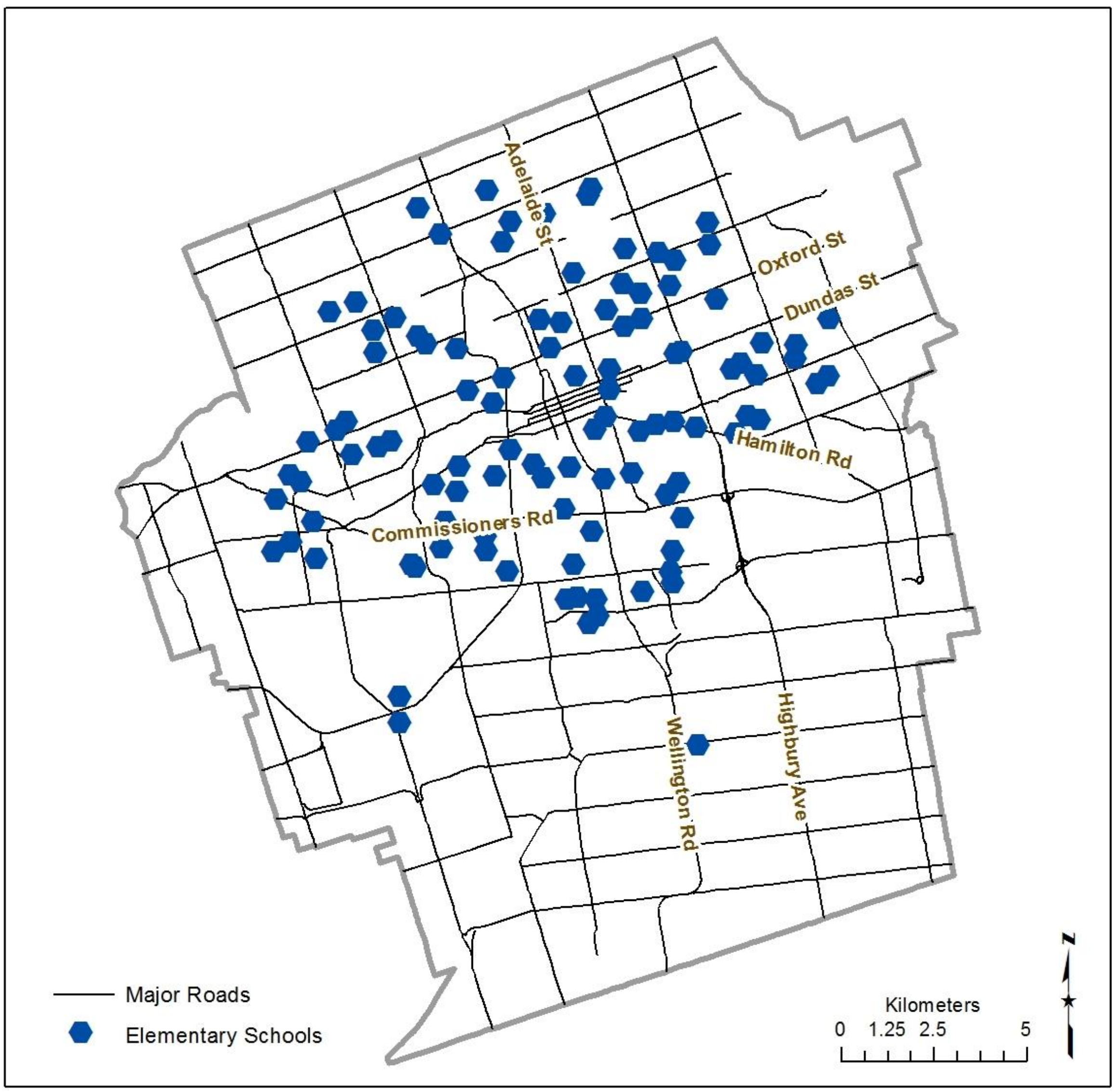


Figure 5 - London Elementary Schools

4.4 Measures

4.4.1 Dependent Variable

The dependent variable was derived from the child and parent surveys and validated through manual inspection of GPS data. These trips were classified into two categories. The first encompassed all non-active modes including public transportation and automobile. The second category contained all active modes including walking, bike, rollerblades, and scooters.

4.4.2 Independent Variables

Socio-economic variables were used to control for individual-level factors. These were comprised of sex, age, and parental employment status (Helbich, 2016; Woldeamanuel and Kent, 2015; Carlson, 2013; Larsen et al, 2012; Lovasi, 2013; Panter, 2010; Boarnet el al, 2005; McMillan, 2006). This study also accounts for neighborhood-level factors and socio-economic status through the use of median household income measured at the census dissemination area of each home along with the household income reported by parents in the surveys.

The built environment is measured at the trip level where the GPS tracking data identified trips to and from school. The use of GPS tracking improves upon typical origin/destination practices utilizing an exact path instead of an estimated measure such as shortest network pathing (Dessing et al, 2016). This methodology also moves away from previous travel research that relies upon aggregation.

Each participant's trip was intersected with a 20-meter diameter hexagonal grid created to encompass the entirety of the city of London. An additional 1000 meters of hexagons was added to avoid any concerns for the edge effect (Sadler et al, 2011) that may occur for trip that take place near the boundaries of the study area. The result is a hexagonal tessellation corridor for each participant's trip. These corridors form the structure by which the BE variables are selected measured.

The following built environment variables are measured for each travel corridor using ArcGIS 10.1 (ESRI):

- *Sidewalk Coverage* is a measure of the total length of sidewalk in the travel corridor divided by the total length of roads in the same corridor creating a variable between zero and two. This measure represents the sidewalk availability on both sides of the road network. Consequently, values that fell below one represent less than half the possible sidewalk availability. Values calculated above one represented above average sidewalk coverage or more than half the possible sidewalk coverage.

- *Bike Lane Coverage* is the total length of bike lanes divided by the total length of roads for each travel corridor. The range is between 0 for areas within no bike lanes and 2 for areas with bike lanes on both sides of the street. As with sidewalk coverage values above 1 represent average coverage or more than half the possible sidewalk coverage.

- *Intersection Density* is the total number of 3- or 4-way intersections within the travel corridor divided by the corridor's total area and is a measure of street connectivity.

- *Tree Count* is the total number of trees found within the road network right-of-way that are maintained by the City of London and are found in each travel corridor.

- *Multiuse Path* is the total length of multiuse paths that are found within each travel corridor.

- *Maximum Traffic Volume* is the measure of the highest amount of traffic encountered by the travel corridor between the origin and destination.

- *Land Use* was measure using parcel level land use data provided by the City of London. Five classifications could be identified: residential, commercial, industrial, recreation, and institutional. The total area of each classification was calculated within each travel corridor.

4.4.3 Analysis

The method of analysis is binary logistic regression with odds ratio (or). A step-wise approach was applied to the modeling to account for (a) trip characteristics, (b) individual and neighborhood factors, and (c) built environment variables. This operation allows for observation of model fit and potential issues of multicollinearity between each level of variables to be accounted for during modelling. To account for variations in the predictive power of the models and to monitor its success, pseudo r-squared and pseudo log likelihood will be calculated and reported. To minimize the bias due to heteroscedasticity robust cluster standard errors are estimated at the individual level (Stock and Watson, 2008).

4.5 Results

4.5.1 Descriptive Statistics

The average age of the 212 participating children was 11.34 years old with 56.1% of the participants being female (Table 4). Over half (73.6%) of the children walked to school and 22.6% of the subjects traveled to school via an automobile. Biking, rollerblading, and scootering constituted the remaining 3.8% of trip travel modes. Sampling with distance control measures limited the distribution of the trips. Overall the average trip distance was 459 meters and median distance was 351 meters with a standard deviation (SD) of 390 meters.

The average distance traveled for *non-active* children was 849 meters. Non-active participant's average age was 11.01 years old with females representing 63.8% of the respondents. Children came from homes with a median household income of $68,459 CAD. 55.9% of children's mothers reported obtaining a university or higher with 18.6% reporting a high school degree or lower. 25.5% preferred not to answer. Fathers reported similar figures with 45.5% stating they obtained a university degree or higher with 23.2% reporting a high school degree or lower. 31.4% preferred not answer.

Table 4 - Descriptive Statistics

Variables	n	%
Trip Characteristics		
# of trips	1,678	
Trip Mode		
Non-Active	376	22.4%
Active	1302	77.6%
Individual Characteristics		
# of Respondents	212	
Sex		
Male	93	43.9%
Female	119	56.1%
Individual Characteristics	**Mean (Std. Dev.)**	
Age (Mean, Std Dev)	11.34	.995
Neighbourhood Characteristics		
Median Household Income (CND)		
Active Travelers	$59,380	
Non-active Travelers	$68,459	

Children using a*ctive* modes of traveled traversed an average of 395 meters with median distance falling to 312 meters. Active travel participants were average aged of 11.43 years with 52.9% female participants and 47.1% male. Children from these homes had a median household income of $59,380 CAD. Education rates are similar to non-active travelers with 54.2% of mothers and 53.7% of fathers reporting to have obtained college degrees. 22.9% of mothers and 16.4% of fathers having a high school or less degree. 23.0% and 30.0% of mothers and father preferred not to answer respectively.

4.5.2 Model Results

Model 1 (Table 5) finds that an increase in trip distance significantly decreases the rate of active travel to school by a factor of 0.048. The inclusion of neighborhood and socio-economic variables (Model 2) continue to find increases in distance significant with a decrease in the likelihood of AT by a factor of 0.046. At this level of modelling the education level of neither parent is found to be significant. The inclusion of median household income measures results in a decrease in likelihood by a factor of 0.9999 as reported income increases.

The inclusion of BE variables into model 3 finds distance continuing to be a significant variable. The education level of participant's mothers and fathers continues to not have a significant finding. Median household income is found significant and its OR changes to 0.745 showing a stronger influence. Only two BE variables are found to significantly influence children's AT. The number of street trees increases the likelihood of the use of AT increases suggesting that walkers prefer a route with more nature via trees (Paddle and Gilliland, 2016). Conversely, as the maximum traffic increases the likelihood of AT decreases at a factor of 0.959.

4.6 Discussion

This study showed that the use of GPS based trip measures paired with hexagonal areal units achieve results on the AT/BE relationship for children's journey to and from school that is congruent with the established literature. This contributes empirical evidence that hexagonal areal units paired with individual level variables can perform better than traditional administrative units. This study did not find consistent findings for all built environment variables repeatedly found to be significant in BE/AT research.

Distance nonetheless was found to be a significant predictor in the rates of AT as found in many previous studies (Dessing et al, 2014; Aarts et al, 2013; Larsen et al, 2012). This occurred even as the average distance measured is higher than some of those previous studies (Dessing et al, 2014; Aarts et al, 2013; Larsen et al, 2012). When paired with the distance control measures aimed to remove outliers this finding supports the claim that children do not always use direct routes to or from school (Dessing et al, 2014; Kerr et al, 2011). The continued result of distance playing a large role should not be ignored especially when applied to school location planning. Shorter distances between home and school will result in higher rates of active travel.

Table 5 - Logistic Regression Model Results

	Model 1: Trip Characteristics			Model 2: Trip Characteristics & Individual/Neighbourhood Factors			Model 3: Trip Characteristics & Individual/Neighbourhood Factors & Built Environment Factors		
	Odds Ratio	Std Error	*p*-value	Odds Ratio	Std Error	*p*-value	Odds Ratio	Std Error	*p*-value
Trip Characteristics									
Distance	0.048	0.008	0.000	0.046	0.019	0.000	0.098	0.055	0.000
Individual Factors									
Age				1.588	0.214	0.001	1.544	0.236	0.005
Female				1.506	0.533	0.247	1.249	0.455	0.541
Mother's Education									
High School or Less				1.558	0.882	0.433	0.679	0.564	0.642
University				1.116	0.521	0.814	0.670	0.460	0.560
Graduate				1.463	1.000	0.577	1.213	1.123	0.835
Prefer not to answer				0.650	0.374	0.455	0.443	0.268	0.180
Father's Education									
High School or Less				0.398	0.204	0.073	0.386	0.193	0.058
University				0.596	0.462	0.504	0.585	0.599	0.601
Graduate				0.758	0.615	0.733	1.007	0.838	0.993
Prefer not to answer				0.740	0.604	0.713	0.867	0.999	0.902
Neighbourhood Factors									
Median Household Income				0.999	0.000	0.044	0.745	0.060	0.000
Built Environment Factors									
Intersection Ratio							1.969	1.011	0.187
Street Tree Ratio							1.013	0.005	0.018
Multiuse Path Ratio							1.208	0.631	0.717
Maximum Traffic							0.959	0.013	0.004
Land Use (Proportion)									
Commercial							1.027	0.067	0.681
Industrial							1.003	0.086	0.971
Institutional							1.003	0.078	0.666
Recreational							1.036	0.081	0.647
Residential							0.989	0.071	0.883
Constant	20.685	2.761	0.000	0.307	0.000	0.044	0.525	4.032	0.933
Loglikelihood		-703.9411			-632.1579			-549.085	
Pseudo R2		0.2115			0.2609			0.3581	

When BE measures were added (model 3) the strength of distance loses continues be strong. The high urbanicity of London may play a contributing role in this by changing the perception of distance as a result of the lack of direct routes to school due to the urban morphology (Helbich, 2016). Model 3's two significant findings, street trees and maximum traffic, are logical findings consistent with findings in the literature validating a major barrier to AT (traffic) and the role nature may play in children's health (trees).

Findings in model 2 that reported median household income as significant and that increases in this measure decreases the likelihood of AT are valuable. This finding is not important on its own as previous research has pinned income to decreases in AT rates (Woldeamanuel, 2015). However, this finding adds credence to the areal unit (hexagon) used for this study by adding more empirical evidence that measures based entirely on administrative units continue to convolute broader AT/BE relationship research.

This study advances GIS methodologies though further investigation is required. Research comparing direct relationship between hexagonal tessellation and more tradition forms of measuring the BE such as buffers and ellipses needs to be completed. Similarly, contextual evidence supports the aim of this study to capture BE measures more representative of actual travel routes of children through GPS tracking data. A more firm confirmation of this finding can be completed in future research by comparing these results to other methodologies used in travel mode research such as shortest network pathing (Larsen et al, 2012).

4.7 Conclusion

The AT/BE relationship as viewed through the lens of ecological systems theory places importance on the role individual, neighborhood and socio-economic, and built environment features act in determining AT outcomes. The results of this study confirm the importance of this view producing significant results for all three levels. Nevertheless distance continues to prove to be the objectively dominant component in the AT/BE relationship. This study urges school planners to make distance between the school and the students a priority during the site selection process.

4.8 References

Aarts, M., Mathijssen, J., van Oers, J., Schuit, A. (2013). Associations between environmental characteristics and active commuting to school among children: a cross-sectional study. International Journal of Behavioral Medicine. 20, 538-555.

Bassett, D. R., John, D., Conger, S. A., Fitzhugh, E. C., & Coe, D. P. (2015). Trends in Physical Activity and Sedentary Behaviors of United States Youth. Journal of physical activity & health, 12(8).

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D. L., & Crouter, S. E. (2008). Walking, cycling, and obesity rates in Europe, North America, and Australia. J Phys Act Health, 5(6), 795-814.

Boarnet, M., Anderson, C., McMillan, T., Alfonzo, M. (2005). California's safe routes to school legislation: Urban form changes and children's active transportation to school. American Journal of Preventative Medicine. 28, 134-140.

Brownson, R., Hoehner, C., Day, K., Forsyth, A. and Sallis, J. (2009). Measuring the built environment for physical activity: state of the science. American Journal of Preventative Medicine, 36(4 Suppl), S99-123.

Buliung, R. N., Mitra, R., & Faulkner, G. (2009). Active school transportation in the Greater Toronto Area, Canada: an exploration of trends in space and time (1986–2006). Preventive Medicine, 48(6), 507-512.

Bungum, T. J., Lounsbery, M., Moonie, S., & Gast, J. (2009). Prevalence and correlates of walking and biking to school among adolescents. Journal of community health, 34(2), 129-134.

Carlson, J., Sallis, J., Kerr, J., Conway, T., Cain, K., Frank, L., Saelens, B. (2013). Built environment characteristics and parent active transportation are associated with active travel to school in youth age 12-15. British Journal of Sports Medicine. 093101.

Clark, A. (2013). Understanding the impact of the modifiable areal unit problem on the relationship between active travel and the built environment. Urban Studies. 51(2), 284-299.

Clark, A. F., Bent, E. &Gilliland, J. (2016). Shortening the trip to school: Examining how children's active school travel is influenced by shortcuts in London, Canada. Environment and Planning B: Urban Design, 43(3), 499-514. doi:10.1177/0265813515614678

Davis, J., and Robinson, G. (2012). A geographic model to assess and limit cumulative ecological degradation from Marcellus Shale Exploitation in New York, USA. Ecology and Society, 17(2), 25.

Dencker, M. and Anderson, L. (2008). Health-related aspects of objectively measured daily physical activity in children. Clin.Phys.Function Imaging. 28(3), 133-144.

Dessing, D., de Vries, S., Hegeman, G., Verhagen, E., van Mechelen, W., and Pierik, F. (2016). Children's route choice during active transportation to school: difference between shortest and actual route. International Journal of Behavioral Nutrition and Physical Activity. 13, 48.

Dessing, D., de Vries, S., Graham, J., Pierik, F. (2014). Active transport between home and school assessed with GPS: a cross-sectional study among Dutch elementary school children. BMC Public Health 14, 1

D'Haese, S., Van Dyck, D., De Bourdeaudhuij, I., Deforche, B., & Cardon, G. (2015). Organizing "Play Streets" during school vacations can increase physical activity and decrease sedentary time in children. International Journal of Behavioral Nutrition and Physical Activity, 12(1), 1.

Dollman, J., Norton, K., Norton, L. (2005). Evidence for secular trends in children's physical activity behavior. British Journal of Sports Medicine. 39, 892-897.

Duncan, M. and Mummery, W. (2007). GIS or GPS? A comparison of two methods for assessing route taken during active transport. American Journal of Preventative Medicine. 33(1), 51-53.

Duncan, S. C., Strycker, L. A., Chaumeton, N. R., & Cromley, E. K. (2016). Relations of neighborhood environment influences, physical activity, and active transportation to/from school across African American, Latino American, and White girls in the United States. International journal of behavioral medicine, 23(2), 153-161.

Frank, L. (2000). Land use and transportation interaction: Implications on public health and quality of life. Journal of Planning Education and Research, 20, 6-22.

Frank, P. and Engelke, P. (2005). Multiple Impacts of the built environment on public health: walkable places and the exposure to air pollution. International Regional Science Review. 28(2), 193-216.

Frank, L., Sallis, J., Conway, T., Chapman, J., Saelens, B., and Bachman, W. (2006). 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, 75-87.

Frank, L., Sallis, J., Saelens, B., Leary, L., Cain, K., Conway, T., Hess, P. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44, 924-933.

Giles-Corti, B., Wood, G., Pikora, T., Learnihan, V., Bulsara, M., Van Niel, K., & Villanueva, K. (2011). School site and the potential to walk to school: The impact of street connectivity and traffic exposure in school neighborhoods. Health & place, 17(2), 545-550.

Gilliland, J., Clark, A., Tucker, P., Prapavessis, H., Avison, W., & Wilk, P. (2015). The ACT-i-Pass study protocol: How does free access to recreation opportunities impact children's physical activity levels? BMC Public Health, 15(1). doi:10.1186/s12889-015-2637-x

Gilliland, J., Holmes, M., Irwin, J. & Tucker, P. (2006). Environmental equity is child's play: Mapping recreational opportunities in urban neighbourhoods. Vulnerable Children and Youth Studies, 1(2), 1-13..doi.org/10.1080/17450120600914522

Gutierrez, C. M., Slagle, D., Figueras, K., Anon, A., Huggins, A. C., & Hotz, G. (2014). Crossing guard presence: impact on active transportation and injury prevention. Journal of Transport & Health, 1(2), 116-123.

Harrison, F., et al., 2014. How well do modelled routes to school record the environments children are exposed to? A cross-sectional comparison of GIS modelled and GPS-measured routes to school. Int. J. Health Geogr. 13, 5

Helbich, M., van Emmichoven, M., Dijst, M., Kwan, M., Pierik, F., de Vries, S. (2016). Natural and built environment exposures on children's active school travel: A Dutch global positioning system-based cross-sectional study. Health and Place. 39, 101-109.

Kerr, J., et al., 2011. Using global positioning systems in health research: a practical approach to data collection and processing. Am. J. Prev. Med. 41, 532–540.

Kwan, M. (2012). The Uncertain Geographic Context Problem. Annals of the Association of American Geographers. 102(5), 958-968.

Larsen, K., Gilliland, J., Hess, P. (2012). Route-Based Analysis to Capture the Environmental Influences on a Child's Mode of Travel between Home and School. Annals of the Association of American Geographers 102(6), 1348-1365.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A. Hugo, G. (2007). Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. Health and Place. 13, 111-122.

Loebach, J., & Gilliland, J. (2016). Neighbourhood play on the endangered list: Examining patterns in children’s local activity and mobility using GPS monitoring and qualitative GIS. *Children’s Geographies*, *14*(5),1-17.

Loebach, J. E., & Gilliland, J. A. (2016). Free range kids? Using GPS-derived activity spaces to examine children’s neighborhood activity and mobility. Environment & Behavior, 48 (3), 421-453.

Loebach, J. & Gilliland, J. (2010). Child-led tours to uncover children's perceptions and use of neighborhood environments. Children, Youth & Environments, 20(1), 52-90.

Lovasi, G. S., Schwartz-Soicher, O., Neckerman, K. M., Konty, K., Kerker, B., Quinn, J., & Rundle, A. (2013). Aesthetic amenities and safety hazards associated with walking and bicycling for transportation in New York City. Annals of behavioral medicine, 45(1), 76-85.

McDonald, N. C. (2008). Children’s mode choice for the school trip: the role of distance and school location in walking to school. Transportation, 35(1), 23-35.

McCormack, G. and Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Journal of Behavioral Nutrition and Physical Activity. 8:125.

McDonald, K., Hearst, M., Farbakhsh, K., Patnode, C., Forsyth, A., Sirard, J., & Lytle, L. (2012). Adolescent physical activity and the built environment: A latent class analysis approach. Health & Place, 18(2), 191–198.

McMillan, T., (2006). Urban form and a child's trip to school: the current literature and a model for future research. J. Plan. Lit. 19, 440–456

Middlesex-London Health Unit (2012) Healthy City/Active London: Evidence-Based Recommendations for Policies to Promote Walking and Biking. London, Ontario: Author

Mitchell, C., Clark, A., Gilliland, J. (2016). Built environment influences of children’s physical activity: Differences by neighbourhood size and sex. International Journal of Environmental Research and Public Health, 13(1), 130. doi:10.3390/ijerph13010130

Mitra, R. (2013). Independent mobility and mode choice for the school transportation: a review and framework for future research. Transportation Review. 33, 21-43.

Mitra, R.. Builing., R. (2012). "Built environment correlates of active transportation: neighbourhood and the modifiable areal unit problem." Journal of Transport Geography, 20(1), 51-61.

Owen, C., Nightingale, C., Rudnicka, A., van Sluijs, E., Ekelund, U., Cook, D., Whincup, P. (2012). Travel to School and Physical Activity Levels in 9–10 Year-Old UK Children of Different Ethnic Origin; Child Heart and Health Study in England (CHASE).

Paddle, E., & Gilliland, J. (2016). Orange is the new green: Exploring the restorative capacity of seasonal foliage in schoolyard trees. International Journal of Environmental Research and Public Health, 13(5), 497. doi:10.3390/ijerph13050497

Panter, J., Heinen, E., Mackett, R., and Ogilvie, D. (2016). “Impact of New Transport Infrastructure on Walking, Cycling, and Physical Activity”. American Journal of Preventative Medicine. 50(2), e45-e53.

Panter, J., et al., 2010. Neighborhood, route, and school. Environments and children's active commuting. Am. J. Prev. Med. 38, 268–278.

Raja, S., Booth, J., Norton, J. T., Crowell, B., Gouck, J., & Bonaro, K. (2015). Promoting active commuting to school through environmental and policy supports in Buffalo, New York. Journal of Public Health Management and Practice, 21, S110-S115. PLoS One 7, e30932.

Rissotto, A., and Tonucci, F. (2002). Freedom of Movement and Environmental Knowledge in Elementary School Children. Journal of Environmental Psychology, 22(1-2), 65–77.

Sadler, R., Gilliland, J., Arku, G. (2011). An application of the edge effect in measuring accessibility to multiple food retailer types in Southwestern Ontario, Canada. International Journal of Health Geographics. 10, 34.

Sadler, R., Clark, A., Wilk, P., O'Connor, C., & Gilliland, J. (2016). Using GPS and activity tracking to reveal the influence of children's food environment exposure on junk food purchasing. Canadian Journal of Public Health, 107, 14-20. http://dx.doi.org/10.17269/cjph.107.5346

Sadler, R. C., & Gilliland, J. A. (2015). Comparing children's GPS tracks with non-objective geospatial measures of exposure to junk food. Spatial and Spatio-Temporal Epidemiology, 14, 55-61. doi:10.1016/j.sste.2015.09.001

Saelens, B., Handy, S. (2008). "Built environment correlates of walking: A review." Medicine and Science in Sports and Exercise, 40, 550-566.

Sallis JF, Owen N, Fisher EB. (2008). Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K.eds Health behavior and health education: theory, research and practice. 4th edn. San Francisco: Josey-Bass, 2008, 465–86.

Schoeppe, S., et al., 2013. Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: a systematic review. J. Sci. Med. Sport 16, 312–319.

Stanley, R. M., Maher, C., & Dollman, J. (2015). Modelling the contribution of walking between home and school to daily physical activity in primary age children. BMC public health, 15(1), 1.

Sirard, J., Slater, M., 2008. Walking and bicycling to school: a review. Am. J. Lifestyle Med. 2, 372–396.

Thrun, E., Leider, J., and Chriqui, J. (2016) Exploring the cross-sectional association between transit-oriented development zoning and active travel and transit usage in the United States, 2010-2014. Frontiers in Public Health. 4, 113.

Timperio, A., Ball, K., Salmon, R., Roberts, B., Giles-Corti, B., Simmons, D., Baur, L., Crawford, D. (2006). Personal, family, social, and environmental correlates of active commuting to school. American Journal of Preventative Medicine. 30, 45-51.

Trapp, G. S., Giles-Corti, B., Christian, H. E., Bulsara, M., Timperio, A. F., McCormack, G. R., & Villaneuva, K. P. (2012). Increasing children's physical activity individual, social, and environmental factors associated with walking to and from school. Health Education & Behavior, 39(2), 172-182.

Tremblay, M. S., Warburton, D. E. R., Janssen, I., Paterson, D., Latimer, A. E., Rhodes, R. E., … Duggan, M. (2011). New Canadian Physical Activity Guidelines. Applied Physiology, Nutrition, and Metabolism, 36(1), 36–46. http://doi.org/10.1139/H11-009

Tucker, P., Irwin, J., Gilliland, J., Larsen, K., He, M., & Hess, P. (2009) Environmental influences on physical activity levels in youth. Health & Place, 15(1), 357-363.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: A systematic review. Public Health, 121(12), 909-922. http://dx.doi.org/10.1016/j.puhe.2007.04.009

Turner, L., Chriqui, J., & Chaloupka, F. (2013). Walking school bus programs in US public elementary schools. J Phys Act Health, 10(5), 641-645.

Woldeamanuel, M., & Kent, A. (2015). Measuring walk access to transit in terms of sidewalk availability, quality, and connectivity. Journal of Urban Planning and Development, 142(2), 04015019.

Zenk, S., Schultz, A., Mathews, S., Odoms-Young, A., Wilbur, J., Wegrzyn, K., Gibbs, K., Brauschweig, C., Stokes, C. (2011). Activity space environment and dietary and physical activity behaviors: A pilot study. Health and Place, 17(5), 1150-1161.

Zhang, M. and Kukadia, N. (2005). Metrics of urban form and the modifiable areal unit problem. Transportation Research Record: Journal of the Transportation Research Board. 1902: 71-79.Research. Ed. Smedley, B. and Syme, S. p.417-449. Washington DC: National Academy.

CHAPTER FIVE

5 *Move for Health in Old South:* Investigating Active Transportation determinants with Community

5.1 Introduction

Geographic information systems (GIS) offer researchers the ability to investigate complex problems in the fields of geography, urban planning and transportation, by linking quantitative data to spatial units, which has brought numerous advances in the understanding of their interactions. Even so, Hume-Cook (2007) believes the addition of participatory action research (PAR) can improve outcomes in research that requires community collaboration, including work examining the BE/AT relationship. PAR provides AT research a degree of authenticity moving beyond a strictly oversight design and implementation and engaging the actual individuals who are the target and beneficiaries of the program. PAR allows for a higher degree of authenticity by including the population being studied to be deliberate and contributing actors.

There are numerous elements of the BE that are associated with AT including connectivity, land use, proximity, accessibility, population density, AT infrastructure, and automobile traffic (McCormack and Shiell, 2011). Before any municipality can increase the rate of AT among its population the BE must facilitate or provide the means to travel actively. Many researchers agree that this contribution is found in dimensions of proximity and connectivity (Owen, 2007; Frank, 2000). Their assertion lies in clear definitions that take into account one of geography's key fundamentals, distance decay. Proximity is an expression of mixed-land uses that create shorter distance between origins and destinations (e.g. home to work). Connectivity is an expression of directness and variety of routes from a destination to an origin and is found in higher quantity in gridded street patterns (Owen, 2007).

Researchers investigating the BE/AT relationship must resist the temptation to draw conclusions utilizing evidence collected and analyzed without the consideration of human agency. The human perspective of the community being investigated, paired with empirical data, will result in better actionable interventions (e.g. policy, infrastructure) or practical and pragmatic outcomes stemming from quantitative and qualitative data. House (1994, pg 19) sums the logic up stating "[the] choice does not have to be between a mechanistic science and intuitionalist humanism, but rather one of conceiving science as the social activity that it is, an activity that involves considerable judgement, regardless of the methods employed." In other words, whatever the methodology applied to a problem, a researcher must consider scientific reasoning and human activity.

Grounded visualization is an analytical method developed by Knigge and Cope (2006) that adopts ideas of grounded theory and harnesses the visualization techniques available in GIS. The purpose of a grounded theory approach is to allow researchers to collect data and build theories on concepts that are 'grounded' in the experience and actions of people's everyday lives. This allows the researcher to gain insight into the phenomena that is being investigated discovering human agency, detailed occurrences, and broad themes (Knigge and Cope, 2006). Grounded theory is an instrument of critical thinking recognizing the dynamic nature of the world with individuals who respond to that dynamism and produce consequences (Bailey et al, 1999).

The second component of Knigge and Cope's (2006) approach is visualization. The term visualization refers to methods that visually represent geographic or scientific data and information. For centuries, geographic data has been represented cartographically to portray information, relying on the human brain's ability to detect patterns and concepts (Knigge and Cope, 2006). With the advent of GIS and the advancement of the technology and GIS-based methodologies, visualization has reached MacEachren's (1994) prediction of high interaction for researchers and subjects, not only for information dissemination, but in data collection as well, including qualitative data sources.

Interaction between subject and researcher can be accomplished through perceptive or cognitive mapping exercises, which often produce 'sketch maps' of relevant features in one's local surroundings, such as environmental hazards (Cheung et al, 2016). Community mapping projects have been used to understand how travel mode influences spatial knowledge (Mondschein et al, 2010), to help delineate neighborhood boundaries (Coulton et al, 2001), and understand perceptions of place (Haney and Knowles, 1978).

The goal of the study presented in this chapter is to better understand active transportation behavior, barriers, and facilitators in London's Old South neighborhood using a community-based participatory mapping approach. This will be achieved through three research objectives: 1) to understand how participants define their neighborhood; 2) To identify traffic corridors commonly used for AT within the neighborhood; and 3) To understand resident perceptions of physical barriers to their safety that impact their choice whether or not to use active modes of travel.

5.2 Methods

5.2.1 Study Area

The study area of this research is the Old South neighborhood of London, Ontario, Canada (Figure 7). Recently, the neighborhood has garnered attention locally and nationally claiming the Canadian Institute of Planners ‘Great Places in Canada’ grand prize for best neighborhood and the ‘People’s Choice Award’ for the same category (Carruthers, 2013). This positive attention and a high degree of community involvement has seen the creation of partnerships between the local health unit (Middlesex-London Health Unit (MLHU)), local community organization (Old South Community Organization), and Western University (Human Environments Analysis Laboratory, Department of Geography, School of Nursing) to initiate and validate policy and programs designed to improve the health of the neighborhood through increased physical activity and the use of active transportation. The community’s willingness and eagerness to be involved in the policy and intervention creation process falls in line with the PAR focus. This effort has contributed to one of the most successful and ongoing of these programs is Move for Health in Old South.

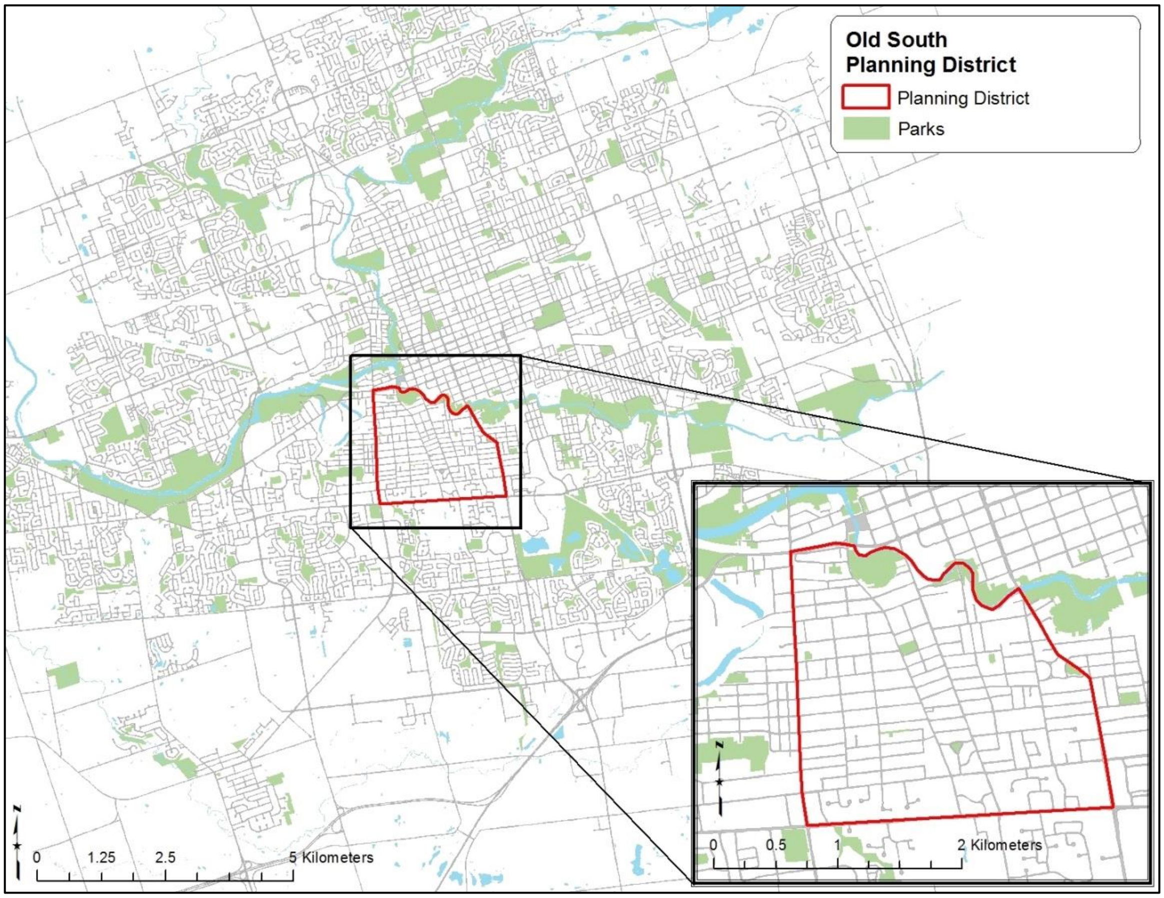


Figure 7 - Old South Planning District

The Old South neighborhood's urban design and land use distribution creates an ideal pedestrian experience with short blocks, high connectivity, and walkable destinations. Currently home to a population of 13,500, a remarkable 18.3% of working adults in the neighborhood use an active mode of transportation to travel to their place of employment, compared to the city of London average of 7% (Statistics Canada, 2011). Ongoing difficulties and public discussion related to overcrowded parking and excess traffic in Old South's commercial corridor, along Wortley Road were raised as barriers to AT within the neighborhood and became a focus for a collaborative program called Move for Health in Old South.

5.2.2 Research Design

The primary focus of the Move for Health in Old South program is to “promote safe and active travel for community members of all ages”. To understand the behaviors and environment within the Old South neighborhood, a survey and perceptual mapping exercise were conducted with members of a local expert advisory panel of community leaders (i.e., board members of the Old South Community Organization (OSCO)), as well as a large group of Old South community members.

5.2.3 Study Participants

The data collection took place between April and July of 2014 with 15 local experts and 148 community members. The 15 local experts were recruited by the project lead from the MLHU at a monthly meeting of OSCO. The leaders of OSCO are concerned citizens elected by the broader membership of OSCO to represent them in neighborhood affairs and include a diversity of citizens on terms of age, gender and professional background. Their inclusion was used as a pilot program to allow their input into the process.

The 148 community members were recruited by public health nurses from the MLHU, with the assistance of student volunteers from Western University at OSCO’s annual community event, “Gathering on the Green”. The event is a way for community members to get together to celebrate the community, interact with their neighbors, and learn about community/municipal organizations within the city. This was an ideal venue to gather firsthand information from residents to learn about the active transportation behaviors, barriers, and facilitators in the Old South neighborhood. All attendees of the OSCO meeting and Gathering on the Green event were eligible to participate in the survey and data collection.

5.2.4 Data Collection

The two instruments used to collect data on active transportation behavior, barriers and facilitators were a survey and perception mapping exercise. The survey was administered to all participants to gather contextual data, including demographic information, travel behavior, perceptions on active transportation, and general comments about the neighborhood. Demographic questions elicited information on the characteristics of the sample, such as age, gender, family size, and the postal code of their home. To understand the travel behavior of participants, they were asked about their usual travel modes and number of trips they made within the neighborhood per week. Questions involving perceptions on active transportation were Likert-scale questions about safety in the neighborhood and accessibility to opportunities. Finally, participants were asked to provide additional comments about their traveling through the Old South Neighborhood.

A mapping exercise was also completed as an integral part of the research design. Participants were provided an 11” x 17” map of the Old South neighborhood (defined as the City of London planning district plus the adjacent two blocks in each cardinal direction), which was created in ArcGIS 9.3 (ESRI). The map consisted of the road network, road labels, and local landmarks of the neighborhood overlaid on a high-resolution satellite image to allow sufficient detail for participants to easily orient themselves. Facilitators were also familiar with the neighborhood to assist participants to find locations if required.

Three questions were asked of participants to guide the mapping exercise: 1) Identify the boundary of the Old South neighborhood; 2) Draw lines to identify the road and paths that you use most often; and 3) Outline areas in Old South that you believe are unsafe to walk or cycle. Instructions were provided as to the symbology that should be used to annotate the map in order to aid the participants in answering these questions and to ensure that consistent symbology was used for all participants. To gather further insight into the map annotations, participants were also asked to provide any further information and context of their concerns and to emphasize or explain any of the responses from the questions included in the exercise.

5.2.5 Map Data Analysis

The sketch maps created through the mapping exercise were converted from a paper copy into a digital format so that they could be analyzed in ArcGIS 9.3. This process started by digitally scanning the maps and importing them into Adobe Photoshop for image enhancement. This facilitated the removal of unwanted digital artifacts created from the digitization process (Lafreniere and Rivet, 2010). Each map was then imported into ArcGIS and georectified using control points that coincided with the creation of the maps to ensure spatial accuracy.

All map annotations were then digitized using heads-up digitization based on the answers from the three questions (i.e., neighborhood boundary, travel routes, and areas with safety concerns). Vector polygons were created from the drawings identifying neighborhood boundaries and areas with safety concerns exactly as they were drawn. Vector lines were created from the drawings using heads-up digitizing and snapping the routes to the City of London road GIS file.

Three spatial analyses were conducted with the resulting vector files: 1) neighborhood boundary identification; 2) spatial clustering of active transportation barriers; and 3) travel corridor identification. Neighborhood boundary identification and spatial clustering of AT barriers followed protocols similar to that of Coulton et al (2001). Geoprocessing tools were used to union all polygons, the resulting polygons were then spatially joined together and creating a count field using computing statistics to identify the number of times each location was identified by participants. The neighborhood boundary analysis provides a surface that shows how participants perceive the Old South neighborhood in order to provide a boundary in which the MLHU and other municipal organizations can utilize for future neighborhood-based interventions. The AT barriers analysis provides a surface identifying hot spots where barriers have been identified for a cluster of participants. Addition of contextual content was placed over the barrier analysis to provide qualitative perspective for further investigation into why the area was identified as unsafe.

Active transportation corridors were completed using a similar method as the polygon analysis, by using geoprocessing tools to *union* all lines, the resulting lines were then *spatially joined* together and a count field created using *computing statistics* to identify the number of times each route segment was identified by participants. This analysis provides the corridors that have the highest frequency of use for AT by participants, which is necessary as the municipal data typically available from traffic studies focuses on automotive travel only, and only includes data for major roads with have high traffic volume.

Table 6 - Descriptive Statistics

	n	%
Respondents	148	100.0%
Gender		
Male	43	29.1%
Female	99	66.8%
Did Not Answer	6	4.1%
Age		
18-25	7	4.7%
26-30	21	14.2%
31-35	8	5.4%
36-40	10	6.8%
41-45	15	10.1%
46-50	17	11.4%
51-55	17	11.5%
56-60	14	9.5%
61-65	15	10.2%
65+	17	11.5%
Did Not Answer	7	4.7%
# of children in family		
0	83	56.1%
1	22	14.8%
2	25	16.9%
3 or more	14	9.5%
Did Not Answer	4	2.7%

5.3 Results

5.3.1 Sample Characteristics

The demographic characteristics of the 148 survey respondents can be found in Table 6. The age of the respondents is skewed toward middle-aged with the average age of participants being 47.2 years old; however, a high percentage of respondents (15.3%) were between the ages of 26 and 30. There are more female participants than male, with 69.7% of the sample being female. Over half (57.2%) of the participants have no children under the age of 18 in the family household, with 15.3% having 1 child and

17.4% having two children. These sample characteristics are representative of the Old South neighborhood, which has an aging population with a large proportion of older empty nesters and young families who are starting to move in (Carruthers, 2013).

An overwhelming majority of the respondents (71.1%) travel at least 5 days a week to a location within the Old South neighborhood that is not their home (Table 7). Nearly half of the respondents (45.7%) reported trips to Old South locations 7 days a week. When asked about the modes in which they travel through the neighborhood, 71.6% of respondents mentioned that they walk, 37.2% bike, and 56.1% use an automobile at least on occasion. If given a choice on the mode they would use, 50.2% of respondents claimed they would walk, 37.5% would bike, 9.4% would use an automobile, and 2.8% would rollerblade. The vast majority (90.5%) of respondents felt that the transportation infrastructure is accessible for everyone.

Table 7. Travel behavior within the Old South Neighborhood

	n	**%**
# of days traveled within Old South Neighbourhood		
0 days of travel	5	3.4%
1 - 2 days of travel	9	6.1%
433 - 4 days of travel	28	18.9%
5 or more days of travel	101	68.2%
Did Not Answer	5	3.4%
*Mode of travel taken within Old South Neighbourhood**		
Walk	106	42.8%
Bike	55	22.2%
Automobile	83	33.4%
Other	4	1.6%
Was pedestrian supportive infrastructure accessible?		
Yes	134	90.5%
No	14	9.5%
Did Not Answer	0	0.0%

**Respondents were allowed multiple responses regarding their mode choice.*

Despite the fact that use of AT in the neighborhood is already high, participants still indicated they were concerned about the safety of traveling actively within Old South. This led to some recommendations of transportation infrastructure changes that could be made to help overcome barriers to active transportation for their families (Table 8). The neighborhood has a number of one-way streets and 20.9% felt those streets should be converted into two-way streets. The top infrastructure changes that participants felt would make AT easier, include adding bike paths and lanes (37.8%), reducing speed limits (14.2%) and improving sidewalk conditions (12.8%).

Table 8. Percent who agree what new pedestrian infrastructure is needed in the Old South neighborhood

	N	%
Add bike paths and lanes	56	37.8%
Change one-way	31	20.9%
Reduce speed limits	21	14.2%
Improve sidewalk conditions	19	12.8%
Reduce Crime	17	11.5%
Reduce traffic volumes	12	8.1%
Add stop signs	6	4.1%

5.3.2 Neighborhood Identification

Of the 148 maps that were completed and digitized, 79 had drawn complete neighborhood boundaries as specified by the instructions. When split into quartiles the variations in what respondents considered to be the Old South neighborhood becomes quite clear (Figure 8). The 'inner-core' consists of 60 or more boundaries and encompasses the commercial corridor of the area and the two major west-east streets, Ridout and Wortley roads. Looking on the east side of the core most residents drew boundaries far enough to encompass Tecumseh Public School and London South Collegiate Institute (the neighborhood's only public high school).

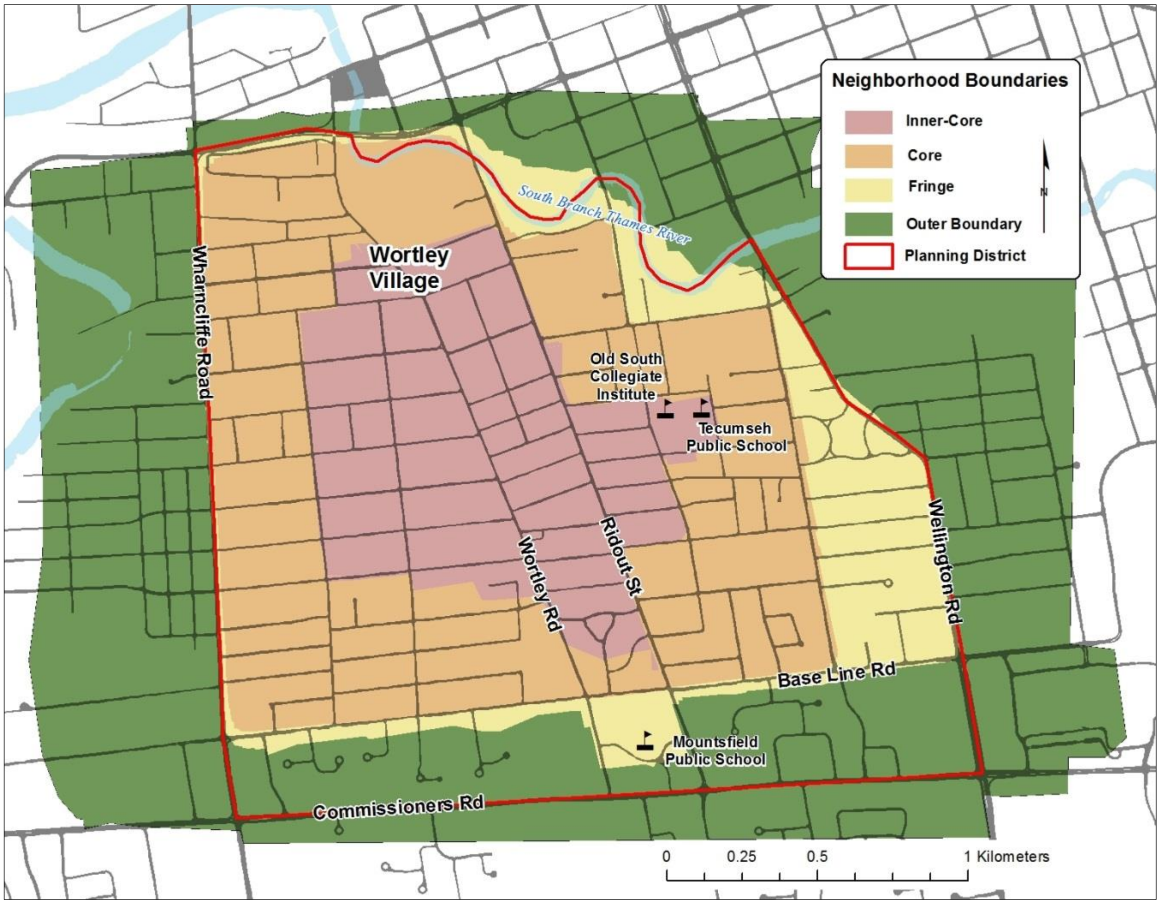


Figure 8. Results of the neighborhood identification analysis developed from the participant defined neighborhood boundary drawings of the Old South neighborhood

The ‘core’ of the Old South neighborhood, 40 or more boundaries, distinctly follows the urban morphology of the area. The western edge is along one of London’s highest traffic volume streets, Wharncliffe Road. The southern edge follows Base Line Road, a street that demarcates a noticeable change in urban morphology with a traditional grid system north and more culs-de-sac (a.k.a. “loop and lollypop”) street configuration to the south. The eastern side of the ‘inner-core’ displays the largest discrepancy of what environmental features should constitute the boundary of Old South with the ‘inner-core’ boundary following roads with far less traffic volume than their western counterpart, Wharncliffe Road.

The ‘fringe’ neighborhood, 20 or more boundaries, follows nearly identical boundaries as the ‘inner-core’ with three key differences. First, the southern boundary along Base Line Road includes a similar bulge to the ‘core’ making sure to include Mountsfield Public School as part of the neighborhood. In the northeast, instead of using the urban morphology as the delimiter this quartile uses the South Branch of the Thames River and its public access parks as the defining boundary. On the eastern edge this quartile reaches Wellington Road, a high traffic volume north-south road with characteristics similar to Wharncliffe Road.

5.3.3 Paths Traveled

All 148 maps included at least one path traveled within the Old South neighborhood resulting in 9,571 unique travel segments (Figure 5). Every road segment that fell within the fringe, core, or inner-core boundary as identified in Figure 1 was identified at least once with the most traveled sections of the neighborhood identified up to 106 times. These road segments with the highest frequency of trips fell within the highest commercial density area of Old South, along Wortley Road. The roads with the highest traffic volumes in the neighborhood (i.e., Wharncliffe Road, Wellington Road, Commissioners Road) have very few AT trips identified by participants, suggesting that they are avoiding these busy roads during intra-neighborhood AT. The distribution of routes traveled and the definitions of neighborhood perfectly align. This finding is unsurprising but reinforces that the most important destinations are within the inner-core as 72% of all trips ended in the Wortley Village area.

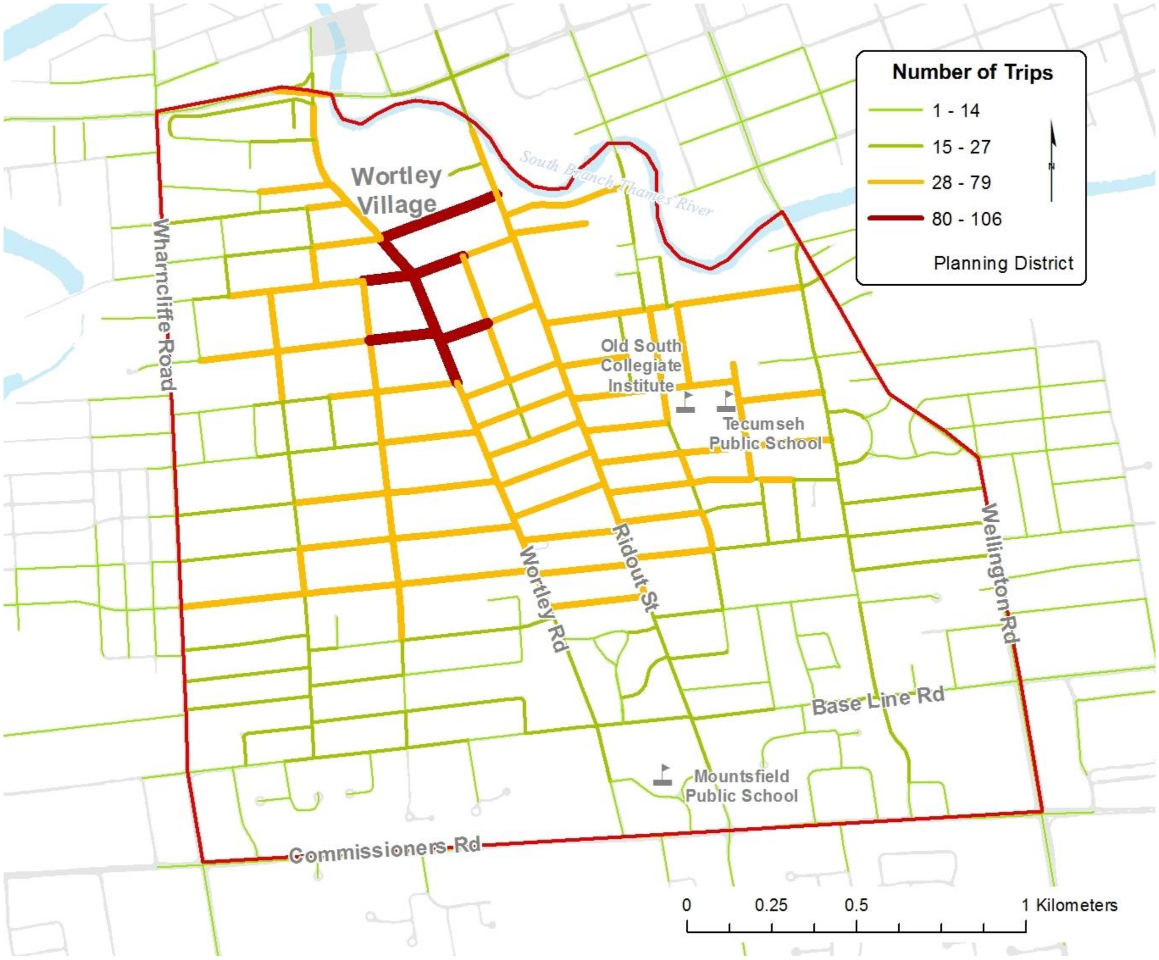


Figure 9 -Results of the active transportation corridor analysis based on routes taken using active modes in the Old South neighborhood

5.3.4 Barriers to Active Travel

Locations identified as barriers to active travel follow along the major road corridors within the Old South neighborhood, with Wharncliffe Road providing the greatest safety concerns for participants using active modes of travel (Figure 10). This area features a fragmented road network (i.e. few straight-line streets), major roadways, and direct east-west access to the Wortley Village commercial corridor via Elmwood Avenue, Duchess Avenue, and Tecumseh Avenue. The main north-south arterial streets of Wortley Road and Ridout Street run straight through the Old South neighborhood and were also identified. These streets provide the main access into the interior of the neighborhood and, similarly to Elmwood Avenue and Duchess Avenue, provide direct access to the commercial corridor. Wellington Road, on the eastern fringe, is a main north-south arterial road for the city of London featuring five lanes, higher speed limits and few marked or lighted crossings for pedestrian traffic. Due to this Wellington Road was also identified as being a barrier to AT. The intersections that surround two of the neighborhood's primary public schools and the secondary school were identified as locations with barriers to AT and stand out as outliers in similar fashion to the neighborhood boundaries. The inner, most residential sections of the neighborhood that are away from arterial streets were not identified as having any barriers to AT.

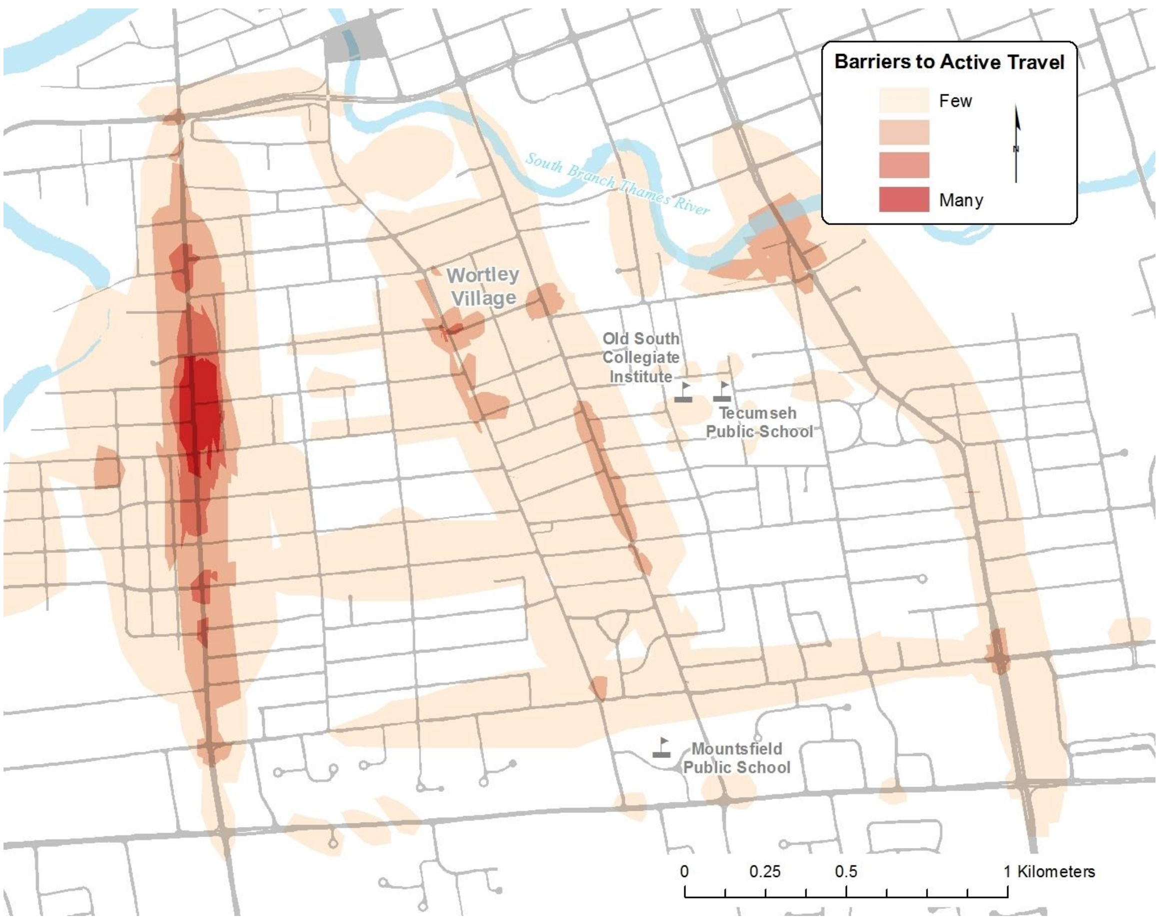


Figure 10 - Results of the analysis examining spatial clustering of barriers to active transportation within the Old South neighborhood

With the addition of the contextual, qualitative content of the participant's maps, the specific and important impediments can be shown (Figure 11). The Wharncliffe Road corridor is mentioned for traffic and safety concerns on nine different occasions. The Wellington Road corridor has six separate mentions of traffic and safety concerns with notes about traffic speed and safety near a curve. Automobiles are cited around the Wortley Village area not for volume but due to the perceived lack of concern for pedestrians most notably that "[cars] run stop signs."

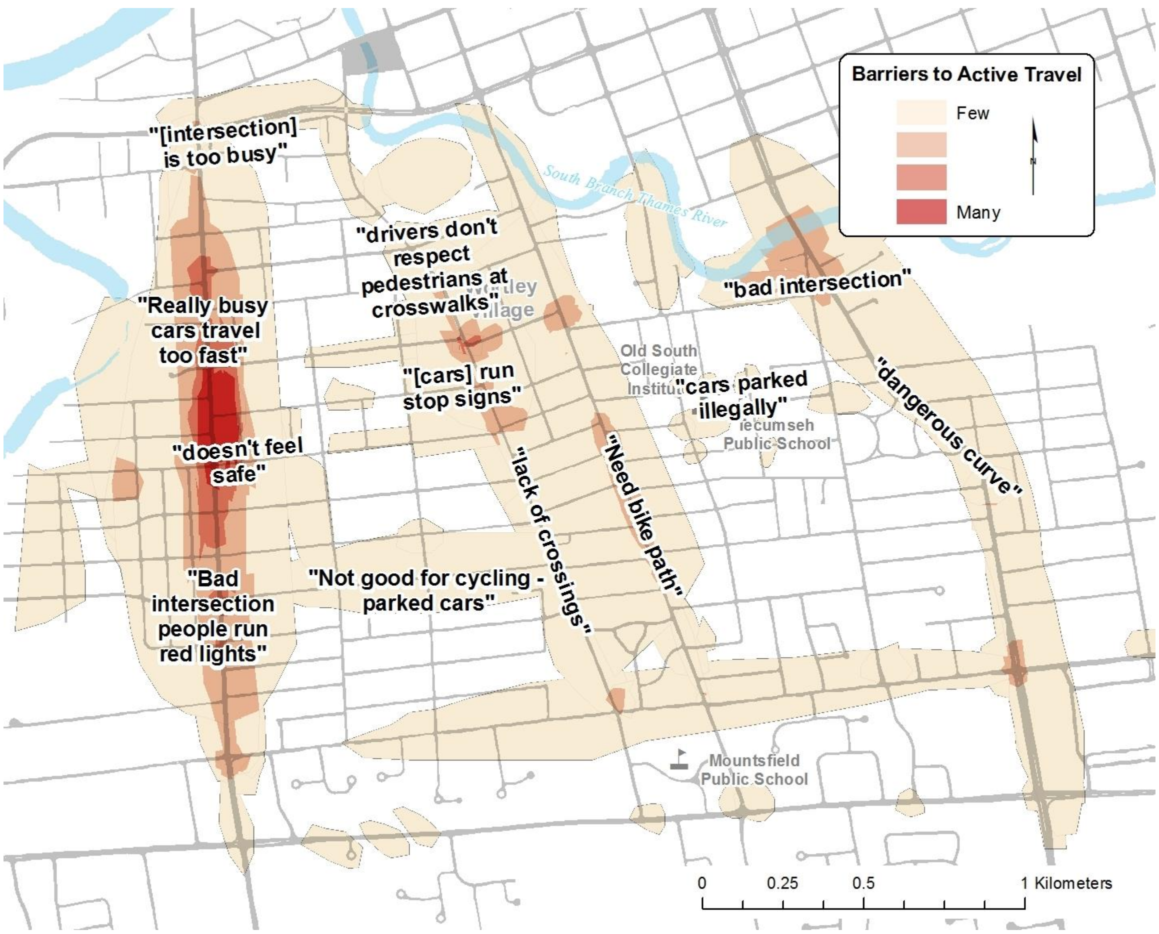


Figure 11 - Reasons for clustering of active transportation barriers within the Old South neighborhood

5.4 Discussion and Conclusions

This research demonstrates how a community-based participatory mapping exercise that combines engaged members of the community with expert neighborhood leaders, can contribute valuable insight into neighborhood identification, intra-neighborhood travel, and AT barrier identification. This research found that the definition of where a neighborhood's boundaries are defined can vary tremendously from individual to individual but through the combined weight of each observation a clear consensus of the core, or most important, section of the neighborhood can easily be described. In some cases, the locations of distinct boundaries between where the neighborhood ends and another begins can easily be seen in the urban morphology.

Identification of neighborhood boundaries brought to light two interesting conclusions on what the community finds important. First, in two separate cases a bulge appears in the different neighborhood classifications and each coincides with a primary school and attached play area. This suggests that the participants understand the inherent value of the schools to the community but do not place that same value on the actual students and their families as the schools' catchment areas are never included in their entirety as part of the Old South neighborhood. This pattern is apparent even though the morphology between Base Line Road and Commissioners Road is drastically different than the rest of Old South and most participants do not include the area south of Base Line in their neighborhood boundary.

While the cumulative result of neighborhood boundary identification resulted in a neighborhood definition that resembled the boundaries of the City of London's South London planning district, this result should not be overstated. Not one participant drew the boundaries coinciding to where the planning district's boundaries are located. The individual results are a clear finding that the participants do not perceive the Old South neighborhood according to the administrative geography. This type of result needs to be accounted for when creating an intervention or policy. While an administrative geographical unit like a planning district makes for ease of organization for implementation of interventions or policy, complete reliance on it could result in targeting the wrong population or a misallocation of resources (Frank, 2010; Coulton et al, 2001; Darling and Steinberg, 1997).

The identification of paths traveled allowed for a verification of the most traveled to, and therefore, most popular locales in the Old South neighborhood. This is useful information for the Move for Health in Old South program for designing interventions aimed at increasing active transportation rates. As the district with the highest use, the Wortley Village area should be the destination of both active transportation interventions and the location of the corresponding marketing. Results from the study that explores barriers to AT suggest that any intervention designed to increase AT will need to include ways of decreasing traffic or increasing pedestrian's sense of safety in regards to the number of automobiles on the road. The urban morphology of the Old South neighborhood was the key contributor to this finding as locations that featured high traffic volume streets, commercial businesses, and schools were identified the most.

While this research produced important findings and methodological steps in the application of community mapping exercises for research on neighborhood identification, intra-neighborhood travel, and AT barrier identification, there are some limitations. The study respondents were a non-random sample from an upper-middle income neighborhood and were also skewed toward middle-aged participants. This inherent high socio-economic status combined with the forum in which the data was collected, likely had an influence on the outcome. Furthermore, the survey questions have an ideological lean towards safety. It can be assumed that the study participants have an active interest and knowledge base in the objectives of this study. While these limitations may affect the breadth of the data collection, the reciprocal depth that an engaged and knowledgeable community can provide should not be undervalued, especially when investigating localized phenomena.

The culmination of this work has led to the development of an active transportation map distributed by the MLHU to the residents of the Old South neighborhood. Through an integration of survey results, neighborhood identification, paths travelled, and barriers to AT an 11”x17” foldable map available for free online or at local businesses and libraries (Appendix E). The purpose of this map was to introduce residents to the accessibility of their neighborhood, identify for them where perceived barriers to AT can be overcome through infrastructure measures such as crosswalks, and provided them with a visual aid of the frequently visited locations in the neighborhood. The desired final outcome of this map for the MLHU is to increase AT use in the Old South neighborhood. This study provides a vital baseline upon which future work can be completed to evaluate the effectiveness of the AT map.

In conclusion, this approach provides valuable results from the integration of quantitative and qualitative data sources in the assessment of neighborhood identification, intra-neighborhood travel, and AT barrier identification. Collaboration within a community with multiple agencies all striving to achieve a mutually beneficial goal can be a difficult undertaking that can produce meaningful results. The successful use of this methodology can be a shining example to neighborhoods across London and throughout North America that communities can have a voice with proper commitment from residents and partnership with collaborators in the creation of policy and built environment interventions. Successful combination of various methodologies and data sources in AT research can lead to better allocation of resources by community leaders and decision makers.

5.5 References

Bailey, C., White, C., Pain, R. (1999). Evaluating qualitative research: dealing with the tension between ‘science’ and ‘creativity’. Area. 31, 169-183.

Brownson, R., Hoehner, C., Day, K., Forsyth, A. and Sallis, J. (2009). Measuring the built environment for physical activity: state of the science. American Journal of Preventative Medicine, 36(4 Suppl), S99-123.

Boarnet, M., Anderson, C., Day, K., McMillan, T., Alfonzon, M. (2005). Evaluation of the California Safe Routes to School Legislation. American Journal of Preventative Medicine. 28(2S2).

Carruthers, D. (2013). Wortley Village has been picked as nation’s best neighbourhood. The London Free Press. http://www.lfpress.com/2013/11/07/wortley-village-has-been-picked-as-the-nations-best-neighbourhood

Cheung, W., Houston, D., Schubert, J., Basolo, V., Feldman, D., Matthew, R., Sanders, B., Karlin, B., Goodrich, K., Contreras, S., Luke, A. (2016). Integrating resident digital sketch maps with expert knowledge to assess spatial knowledge of flood risk: A case study of participatory mapping in Newport Beach, California. Applied Geography. 74, 56-64.

Hume-Cook, G., Curtis, T., Potaka, J., Tangaroa Wagner, A., Woods, K., & Kindon, S. (2007). Uniting people with place through participatory video: a Ngaati Hauiti journey. Participatory Action Research: Connecting People, Participation and Place Eds S Kindon, R Pain, M Kesby (Routledge, London) pp, 160-169.

Coulton, C., Korbin, J., Chan, T., Su, M. (2001). Mapping residents' perceptions of neighborhood boundaries: A methodological note. American Journal of Community Psychology. 29(2).

Darling, N. and Steinberg, L. (1997). Community influences on adolescent achievement and deviance. In. Brooks-Gumm J., Duncan, G., Abner, J. (Eds), Neighborhood poverty: Context and consequences for children, 120-131, New York: Sage.

ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Frank, L. (2000). "Land use and transportation interaction: Implications on public health and quality of life." Journal of Planning Education and Research, 20, 6-22.

Frank, L., Sallis, J., Saelens, B., Leary, L., Cain, K., Conway, T., Hess, P. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44, 924-933.

Haney, W. and Knowles, E. (1978). Perception of neighborhoods by city and suburban residents. Human Ecology. 6, 201-214.

House E. (1994). Integrating the quantitative and qualitative. In The Qualitative, Quantitative Debate: New Perspectives, ed. CS Reichardt, SF Rallis. New Dir. Program Eval. 61:13–22. San Francisco: Jossey-Bass. 98 pp.

Hume-Cook, G., Curtis, T., Potaka, J., Tangaroa Wagner, A., Woods, K., & Kindon, S. (2007). Uniting people with place through participatory video: a Ngaati Hauiti journey. Participatory Action Research: Connecting People, Participation and Place Eds S Kindon, R Pain, M Kesby (Routledge, London) pp, 160-169.

Knigge, L. and Cope, M. (2006). "Grounded visualization: integrating the analysis of qualitative and quantitative data through grounded theory and visualization." Environment and Planning A. 38, 2021-2037.

Lafreniere, D., & Rivet, D. (2010). Rescaling the past through mosaic historical cartography. Journal of Maps, 6(1), 417-422.

MacEachren, A. (1994). "Visualization in modern cartography: Setting the agenda". In Visualization in modern cartography Eds: A. MacEachren, D. Taylor, Pergamon Press, New York, 1-26.

McCormack, G. and Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Journal of Behavioral Nutrition and Physical Activity. 8, 125.

Mondschein, A., Blumenberg, E., Taylor, B. (2010). Accessibility and cognition: The effect of transport mode on spatial knowledge. Urban Studies. 47(4), 845-866.

Owen, N., Cerin, E., Leslie, E., duTroit, L., Coffee, N., Frank, L., Bauman, A., Hugo, G., Saelens, B., and Sallis, J. (2007). Neighborhood walkability and the walking behavior of Australian adults. American Journal of Preventive Medicine. 33, 387-395.

Panter, J., Heinen, E., Mackett, R., and Ogilvie, D. (2016). “Impact of New Transport Infrastructure on Walking, Cycling, and Physical Activity”. American Journal of Preventative Medicine. 50(2), e45-e53.

Saelens, B., Handy, S. (2008). "Built environment correlates of walking: A review." Medicine and Science in Sports and Exercise, 40, 550-566.

Statistics Canada. (2007). Focus on Geography Series 2011. Census subdivisions in London census metropolitan area. Table 1. Ottawa, Ontario. August 13. https://www12.statcan.gc.ca/census-recensement/2011/as-sa/fogs-spg/Facts-cma-eng.cfm?LANG=Eng&GK=CMA&GC=555

CHAPTER SIX

6 Discussion

6.1 Summary

Continued iteration of the contextualization and characterization of active travel and the built environment has convoluted the importance inherent in the BE/AT relationship. The intertwined definitions highlight the difficulties in researching a complex human behavior (e.g. active transportation) in relation to a constantly changing, equally complex system (e.g. built environment). This has often resulted in a wide range of research that becomes more specific to the adopted definitions finding strong associations but failing to find causality. Using a clear and concise definition of AT and BE in this dissertation has removed some of the intricacies that have muddled past research and moved closer to causality.

Using the ecological model as a theoretical framework this study was able to cross the lines of the multifaceted spatial and temporal components in analysis of the BE/AT relationship. It was further strengthened by the inclusion of community based qualitative inquiry to leverage quantitative data and integrate the knowledge for results that return a direct action component. In short, this study added to the growing body of research on the BE/AT relationship and was able to give back to the community a tangible result (i.e. Appendix i) that was put to use immediately.

To mitigate the effect of MAUP and UGCoP this dissertation adopted a hexagonal grid as a method of spatial delineation. Hexagons placed in an array over the study area provided even spatial coverage and was isotropic. Hexagons allowed for flexibility in aggregation when adjusting policy or infrastructure by allowing each study (Chapter 3 and 4) to define the neighborhood (operationalized in GIS as the number of hexagons) to fit the size and scope of the research.

Past research has relied on origin-destination surveys and shortest network paths when examining the relationship between BE and AT, and likely do not accurately reflect actual routes taken by participants (Timperio, 2006; Boarnet, 2005; Larsen and Gilliland, 2012). To overcome this deficiency in methodology, passive GPS tracking is needed to provide high spatial precision of the movement of an individual within space and time (Duncan, 2005). This was accomplished by utilizing the GPS tracking data for the STEAM project collected for 7 consecutive days of the study in elementary schools across London. GIS processing allowed for the routes to and from school to be identified for each trip taken by each child in the project. The inclusion of GPS data tracking and the subsequent high precision travel route tracking was a large step forward for school boards and policy makers in the City of London looking to improve AT to and from school. These actual realities allowed for the identification of barrier and enablers to AT that can then be specifically and correctly targeted for intervention.

Finally, this dissertation successfully demonstrates how a community-based participatory mapping exercise, that combines engaged members of the community with expert neighborhood leaders, can contribute valuable insight into neighborhood identification, intra-neighborhood travel, and most importantly AT barrier identification. This dissertation found that the definition of where a neighborhood’s boundaries are defined can vary tremendously from individual to individual but through the combined weight of each observation a clear consensus of the core, or most important, section of the neighborhood can easily be described. It is important to use a mixed methods approach such as this to ensure that policy and decision makers are remedying the proper problems. It is hoped that this work will be recognized as an example of the power of community-based research bolstering quantitative research.

6.2 Contributions

Study I demonstrated that leveraging a large population transportation survey and delineating spatial variables using hexagons can successfully model individual, economic, and built environment variables to identify contributing factors to AT specific mode decisions. As found throughout the AT literature, distance was confirmed to be the most important contributor in the decision to use AT. Each model, regardless of what was included, found distance as significant and having a high level of influence. This provides strong confirmation that no matter what individual or BE variables are targeted for intervention by municipalities or similar decision makers, people must be within a distance of their intended destination that they perceive to be short enough for them to walk.

Study II establishes that the use of hexagons as an areal unit produces results that are analogous to findings in previous BE/AT research. This is the first use of hexagons as an areal unit in BE/AT research. Distance was found to be a significant predictor to AT usage rates a result that mirrors numerous other studies. When distance control measures are utilized the result is complementary and confirms the claim that children do not always use the most direct routes to school. Results from this study should urge school planners to make distance between the school and the students a priority during the site selection process.

Study III successfully demonstrates how a community-based participatory mapping exercise, that combines engaged members of the community with expert neighborhood leaders, can contribute valuable insight into neighborhood identification, intra-neighborhood travel, and AT barrier identification. This research found that the definition of where a neighborhood's boundaries are defined can vary tremendously from individual to individual but through the combined weight of each observation a clear consensus of the core, or most important, section of the neighborhood can easily be described. In some cases, the locations of distinct boundaries between where the neighborhood ends and another begins can easily be seen in the urban morphology.

6.3 Limitations

The accomplished aim of the three studies was to investigate the AT/BE relationship from three distinct perspectives. First, the AT/BE relationship was examined for adults through the use of household travel surveys. Next, the relationship was investigated for children through the use of recall surveys and GPS tracking. Finally, barriers of neighborhood AT were studied using a participatory mapping exercise. While the culmination of the results was successful there were a few limitations.

Study I advanced GIS methodologies with the use of hexagons. Hexagonal buffering resulted in 20-meter wide exposure to the built, social, and physical environments following a trend of smaller exposure measures in route-based research (Dessing, 2016). These smaller exposure measures allow for a more precise spatial resolution, with consistent geography, and are easily replicable.

Study II provided compelling evidence that distance and the BE surrounding a school need to be addressed when an effort to increase children's AT rates is undertaken. This is accomplished through the use of hexagons and GPS tracking technology with great success. However research comparing the direct relationship between hexagonal tessellation and traditional forms of BE variable capturing needs to be completed.

Study III produced important findings and methodological steps in the application of community mapping exercises for research on neighborhood identification, intra-neighborhood travel, and AT barrier identification, there are some limitations. The study respondents were a non-random sample from an affluent neighborhood and were also skewed toward middle age participants. This inherent high socio-economic status and corresponding higher education level, combined with the forum in which the data was collected, likely had an influence on the outcome. It can be assumed that the participants have an active interest and knowledge base in the objectives of this study. While these limitations may affect the breadth of the data collection, the reciprocal depth that an engaged and knowledgeable community can provide to an understanding of the AT/BE relationship should not be underestimated, especially when investigating localized phenomena.

6.4 Future Direction

This dissertation was built upon the excellent work of previous researchers that have explored the important relationship between AT and the BE. Upon that framework this dissertation provides a modest platform for future researchers to continue this exploration to identify determinants in the AT/BE relationship and increase the AT rates for people across North America. There is multiple ways forward but the most important one is through the use of hexagonal tessellation. Hexagons do a great job in hypothesizing a more true measure of exposure as previous methods measure too much of the BE around a traveler, often extracting measures that can be 500-5000 meters away from where the participant was located. This work provides the framework for this methodology to be utilized in urban environments across North America.

Additionally there are opportunities to perfect the integration of GPS tracking into BE exposure measurements. Establishing reliable techniques will allow researchers the ability to dig deeper into the overwhelming quantity of data inherent in this research to explore the AT/BE relationship in finer spatial and temporal resolutions. The results from this work would allow interventions whose objective is to increase of AT rates to target more exact BE measures in more exact time frames.

6.5 Conclusion

The purpose of this dissertation was to examine the relationship between the BE and AT in London, Ontario, Canada across multiple ages and geographies by building upon the overwhelming yet inconclusive empirical evidence of the relationship between the BE and AT. Advancements in GIS methodologies were made by the use of hexagonal tessellation. When examining the AT/BE relationship through this spatial lens, findings are clear that distance plays the most important component to determining whether an active mode of transportation is used. The findings also suggest that gender, purpose of travel, employment status, and land use play crucial though not as strong parts in AT choice. Investigation of AT barriers through a community lens found strong associations with commercial land use and AT choice. All three studies provide a unique and informative look at how AT/BE relationship unfold in London, Ontario.

Appendices

Appendix A Research Ethics Approval Forms for Use of Human Participants (Redacted)

Re-issued

Use of Human Participants - Ethics Approval Notice

Research Western

Principal Investigator: Dr. Jason Gilliland
Review Number: 17918S
Review Level: Delegated
Approved Local Adult Participants: 1200
Approved Local Minor Participants: 1200
Protocol Title: Identifying casual effects on the built environment on physical activity, diet, and obesity among children.
Department & Institution: Social Science\Geography, University of Western Ontario
Sponsor: Canadian Institutes of Health Research
Heart and Stroke Foundation of Canada

Ethics Approval Date: June 08, 2011 **Expiry Date:** August 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Other	Revised Healthy Neighbourhood Survey for Parents.	
Other	Revised Health Neighbourhoods Survey for Youth	
Other	Revised Activity and Travel Diary for School Days and Weekend Days.	

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]

Ethics Officer to [redacted]

This is an official document. Please retain the original in your files.

The **University** *of* **Western Ontario**
Office of Research Ethics
Support Services Building Room 5150 • London, Ontario • CANADA - N6G 1G9
PH: 519-661-3036 • F: 519-850-2466 • ethics@uwo.ca • www.uwo.ca/research/ethics

Appendix B Research Ethics Letter of Information for Parents (3 pages)

Western

Examining the Influence of the Neighbourhood Environment on Children's Health and Well-Being

Dear parent or guardian,

We would like to invite you and your child to participate in a study aimed at understanding how the neighbourhood environment around your child's school affects his or her health. The study involves grade 5, 6 and 7 classes at elementary schools across South Western Ontario.

What is being studied?
Our research team is studying the various places or facilities in their neighbourhood that children use (or intentionally don't use) on a regular basis for recreational or physical activities, including the way they travel to these places – for example, how they travel to and from school each day. We are also interested in looking at some of their eating patterns, especially the locations in their neighbourhoods where they might eat or purchase food. In addition, we'd like to learn more about how children feel about their local environments, and how this may affect the activities they do, or how and where they travel around their neighbourhood.

What will happen in this study?
If you and your child agree to participate in our project, **your child will be asked to:**

1. **Complete the *Healthy Neighbourhoods Survey for Youth*.** This survey primarily asks children about how they feel about their neighbourhood environments, the local facilities (such as parks) that they use for activities, places they may go to eat or buy food, and how they travel around their neighbourhood. Surveys usually take about 20-30 minutes to fill out and will be done in their classroom at a time decided by their teacher. (Note: students not filling out the survey will be given quiet activities by their teacher to do at their desks). Our research team will be on hand to help children fill out their surveys and to answer questions. All children will be given as much time as they need to complete the survey.

2. **Wear two small pieces of equipment each day during the hours they are awake, for two 7-day periods about 6 months apart – once during their Gr.5 or 6 year (Spring) and again in their Gr.6 or 7 year (in the Fall).** The lightweight 'GPS Logger', worn on a collapsible neck strap, maps out the general places the child visits in the neighbourhood and they routes taken to get from place to place. The tiny 'Accelerometer', worn on a thin elastic belt around the student's waist (can be worn under clothes), is like a pedometer that counts steps but it can also tell how 'intense' the activity of the student is. These tools will help us to see patterns in children's neighbourhood activities and travel. Because students will wear the tools during two different weeks we can also better understand how children's activities change over time.

3. **Complete a short activity diary for each day** they wear the 2 pieces of equipment, briefly telling us about their activities and any food purchases that day.

4. **OPTIONAL** – If they would like, participating students can also meet together with the researchers and classmates for a **group discussion** to talk more about how they feel about their neighbourhood and how their local environment helps or prevents them from enjoying the recreational activities they like, or easily buying the foods they want, or travelling easily around the neighbourhood. There will be about 10-20 students in a group. The discussion will take place either at lunch recess or outside school hours, and will last about 1 hour. It will be held at the school or another community location. Participation is <u>completely voluntary</u>; a child can decide <u>not</u> to join in the group discussion and still be allowed to join in Steps 1-3.

As the child's parent/guardian, **you will be asked to:**

1. **OPTIONAL - Complete the *Healthy Neighbourhoods Survey for Parents***. The survey asks many of the same questions as the Youth survey, as well as questions about your home and family and your own feelings about your neighbourhood. It usually takes about 15-25 minutes to fill out. The Parent Survey is completely voluntary – your child can still join the study themselves even if you decide not to fill it out. However, it gives us valuable information from the point of view of parents so we would really appreciate your participation.

2. **OPTIONAL** - Parents of participating students will also have a chance to meet together with the researchers and other local parents for a **group discussion** about your neighbourhood environment and how it helps or prevents you and your family from doing the activities you like, buying the foods you need, or travelling easily around your neighbourhood. There will be about 8-12 parents in each group. The discussion will take place at a time outside school hours, and will last about 1-1.5 hours. It will be held at the school or another nearby community location. Participation in the group discussion is completely voluntary; a parent can decide not to participate and their child will still be allowed to participate in their own part of the study as outlined above.

Do we have to participate in this study?
Your participation in this study is completely voluntary. You and your child do not have to participate. You can each refuse to answer any survey questions, and can choose to leave the study at any time. Your decision will not affect your child's academic record in any way.

What are the benefits and risks if my child participates?
Recent research shows that our health is not only related to our personal lifestyle, such as the food we eat or physical activity we undertake, but also to the characteristics of the neighbourhood(s) we live in. This study will help us to better understand the links between our neighbourhoods, our activities, and our health. The results may help local municipal planners and school boards make decisions that will help plan healthier local communities.

There are no costs to you or your child for participating in this study. However, during each 7-day periods in which they participate, your child will receive $2 each day from the research team when your child hands in their completed activity diary for the previous day and data from their equipment is collected. Your child will receive an additional $1 on the last day when they return all their equipment. The total for EACH completed 7-day period is $15.

The equipment in this study is easy to use, and the researchers will spend time with your child to make sure they understand how to use and care for the equipment. But, if any pieces of equipment break or become lost during the time your child is using them, we will give them a replacement unit right away without any cost to you or your child.

There may be risks to your child if he/she participates in this study. Getting tired or becoming disinterested in continuing with the project for the full 7 days are considered the largest risks. However, each piece of equipment weighs less than 60g (0.12 pounds) and should not be difficult for a child to carry. And a child can decide to quit the project at any time. The height and weight of your child will also need to be measured before they start in order to properly set up the accelerometer. These measurements will be taken in a private room at the child's school in the presence of a trusted adult (e.g. school nurse or teacher); no other children or people outside of the research team will be present. The equipment used to measure a child's weight also has no visible display - the measurements are automatically sent wirelessly to a laptop and so will not be visible to either your child or anyone else in the room.

There is little risk that you or your child will be identified or identifiable in any of the documents related to the study. All of the information collected in this study is kept strictly confidential. You and your child will be assigned a unique identification code – your name or personal information will not appear on any materials or data files. Also, materials and data files will ONLY be viewed by members of the research team and will be stored in a locked filing cabinet or on a password protected computer in a secure room at the University of Western Ontario. Parents and children who participate in the group discussions will be asked to keep everything they hear confidential and not to discuss it outside of the meeting. However, we cannot guarantee that confidentiality will be maintained by other participants in the focus group. Children can ask to see the maps of their own travel patterns and to change any information that feel is incorrect. However, to protect the privacy of each child, parents will not be able to view children's data or maps.

If you or your child decides to leave the study at any time (even up to 30 days AFTER the study has been completed), any of personal data collected from you or your child will be immediately destroyed and excluded from the study analysis.

You do not waive any of the legal rights you would otherwise have as a participant in a research study.

Follow Up
As the study involves a second round of participation this coming Fall (approximately 6 months after the first round this Spring), we may need to contact you at your home by phone or email in order to find out if your child changed schools between Spring and Fall. **We would therefore ask that you include one or both of these pieces of information on the attached consent form.**

Who do I contact if I have any other questions?
Should you have any questions or concerns about participating in this project, you can contact the lead researcher, Dr. Jason Gilliland, at the University of Western Ontario. Phone: (519) 661-2111 ext. 81239 or email: jgillila@uwo.ca

If you have any further questions regarding your rights as a study participant, please contact the Office of Research Ethics at 661-3036 or at: ethics@uwo.ca

Research Team
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Dr. Colleen Gobert, Division of Food & Nutrition Sciences, Brescia University College
Mr. John Fleming, Director of Planning, City of London

This letter is for you to keep. Please return the attached Parent/Guardian consent form. You will also be given a copy of this consent form once it has been signed.

Appendix C Research Ethics Parent Consent Form

Western

Examining the Influence of the Neighbourhood Environment on Children's Health and Well-Being

Parent / Guardian Consent Form

<u>Regardless</u> of whether you are consenting to let your child to participate in this study, we would ask that you return this form to school with your child, sealed in the envelope provided. Envelopes will be collected by your child's teacher. Thank you!

Consent: I, ____________________________ ***(name of parent/guardian- please print)***, have read this letter and have been given the opportunity to ask questions. Any questions I had have been answered to my satisfaction. (Check all boxes that apply):

☐ I agree to participate by completing the *Healthy Neighbourhoods Survey for Parents* (***optional***; *if yes, please seal the survey in the envelope provided and return <u>with</u> signed consent form*)

☐ I am interested in being contacted about participating in a group discussion for parents (***optional;*** *if yes, please provide either phone or email contact information below)*

Please select one of the following 2 options:

☐ I agree to let my child ________________________________ ***(child's full name – please print)*** participate in the full 14 days (two 7-day periods within the next 6-8 months) of the project as outlined. ***REQUIRED: My child <u>has</u> health issues which restrict their ability to walk/exercise or otherwise participate in this study*** ☐ ***YES*** ☐ ***NO***

<u>OR</u> if your child is not interested in the full project but would still like to participate in the survey

☐ I agree to let my child _________________________________ ***(child's full name – please print)*** participate **ONLY** by way of completing the *Healthy Neighbourhoods Survey for Youth* (to be administered at child's school) rather than the full study.

_________________________________ _________________________________

Parent / Guardian's signature Date

If your child IS participating, please provide a phone and/or email address (both is preferable) so that we may contact you this Fall to confirm whether or not your child has changed schools since the Spring. This information will be kept strictly confidential.

_________________________________ _________________________________

Parent/Guardian Email Address Home or Cell Phone

Appendix D Research Ethics Child Assent Form

Western

How Healthy is the Environment in Your Neighbourhood?

Hello! We are researchers from the University of Western Ontario and we are doing a study in your neighbourhood! We need students in Grades 6, like you, to help us with this project!

What are we going to study?

We all know that getting lots of exercise and eating the right foods can help keep us healthy. We'd like to know if the places or services that you have and use in your neighbourhood also help to keep you healthy.

What would you have to do?

If you agree to be in the study there are 4 things we would like you to do:

Equipment looks like this!

1. Wear 2 small pieces of equipment every day for a week this Spring. A small GPS unit will help to make a map of all the places you visit every day. You would also wear a 'loonie'-sized piece of equipment on an elastic band around your waist that will tell us when you are doing physical activity, like running or playing sports. Both pieces of equipment are very light and easy to use. We will also come to your school every day in case you need help.
2. Fill out a short 1-page diary everyday about the activities you did that day.
3. Fill out a short survey on what you think about your neighbourhood. You will fill this out one day at school with your classmates. It takes about 20-30 minutes to finish but you can take as much time as you need.
4. Then you would wear the equipment and fill out the diary again for a week later this Fall when you are in grade 7 (even if you are then going to a different school).

After both weeks are done, you could also join in a group discussion with some of your classmates to talk to us about where you like to go in your neighbourhood and the activities you like to do. You do not have to join in this group activity. The talk will take place at your school. We would like to audio record our talk.

To work some of the equipment we'll need to measure your height and weight. We'll do this in a private room at your school. Your teacher can be in the room. We won't share the information with anyone else.

Do you have to join this project?

No – you will only join if you would like to. You can also decide at any time that you would like to stop. We will never share your information with anyone else, even your parents, but you can ask to see it at any time. You can ALWAYS talk to your teacher or the researchers if you have any questions or worries.

I want to participate in this study!

If you would like to join this study in some way, choose one of the following two options:

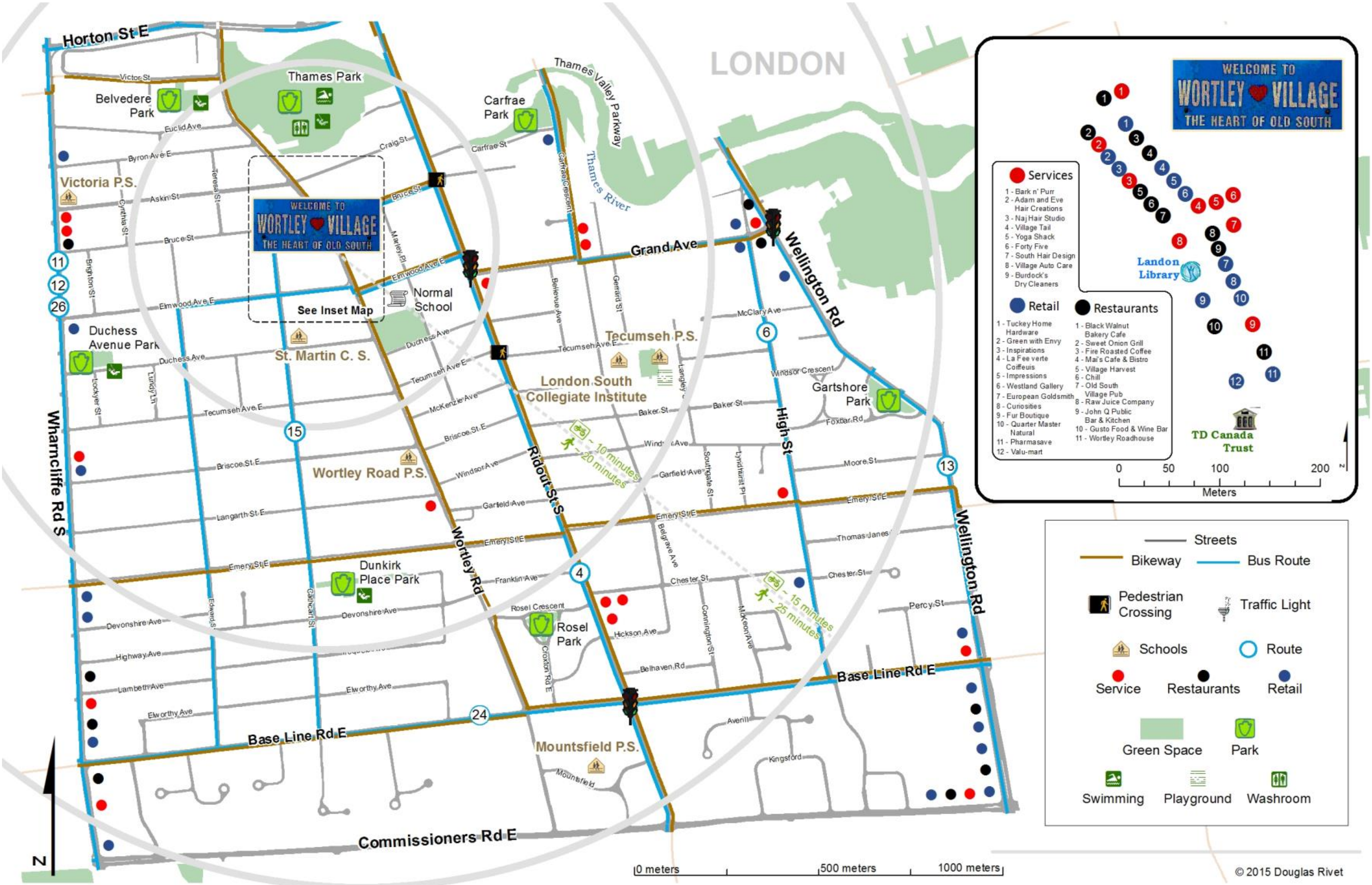
☐ I want to participate in the full 2 week study **OR** ☐ I only want to complete the in-class survey

____

Print First and Last Name of Child

________________________________	____________	____________________
Signature of Child	Age of Child	Date
________________________________		____________________
Signature of Person Obtaining Assent		Date

Appendix E – *Move for Health in Old South* Walking Map



Curriculum Vitae

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Western Michigan University
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2011 M.A.

The University of Western Ontario
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2016 Ph.D.

Honors and Awards

Graduate Research and Creative Scholar Award, Western Michigan University, 2011 (Awarded to the top graduate researcher at the university)

Graduate Scholastic Achievement Award, Department of Geography, Western Michigan University, 2011 (Awarded to the top graduate student in the department)

Best Paper of the Year, Journal of Maps, for Lafreniere, D., and Rivet, D. 2010. Rescaling the Past through Mosaic Historical Cartography Journal of Maps v2010: 417-422

Related Work Experience

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Publications:

Baker, K, Roehsner, P, Lake, T, Rivet, D, Benston, S, Bommersbach, B, Kirk, W. (2014). Point-trained models in a grid environment: Transforming a potato late blight risk forecast for use with the National Digital Forecast Database. Computers and Electronics in Agriculture. 105:1-8.

Lafreniere, D. and Rivet, D. (2010). Rescaling the Past through Mosaic Historical Cartography, Journal of Maps. v2010: 417-422.