Metrics for Evaluating Walking School Bus Programs: A Case Study of Waterloo Region, Ontario

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Normative planning concerns direct sustainable development planning; however, many assertions are made without empirical backing and discount many of the values and characteristics of today's populations. A potentially viable form of Active and Sustainable School Transportation (ASST) is the Walking School Bus (WSB) concept. The WSB can be defined as a group of students walking to school together under the supervision of one or more adults (or older students). Proponents often suggest the WSB as a means to address the barriers to ASST by taking into account the key values influencing school-based travel decisions.

The purpose of this thesis is to address the question to what extent and in which circumstances are WSB programs successful in addressing the key barriers to ASST. Using a case study of four elementary schools of the Waterloo Region District School Board (WRDSB) in Southwestern Ontario, WSB routing is developed using Geographic Information Systems software. To address the research question, metrics are established that evaluate WSB routes based on safety, convenience, and cost. These metrics are used to compare the WSB results at all four schools to determine if neighbourhood walkability and student density influence the outcomes. Further, the policy context in which student transportation services are provided in Ontario is explored.

The results of this study indicate that WSB programs can be successful in achieving a safe and convenient way for students to use ASST. Participation in WSB programs at four WRDSB schools would cut down exposure to unsupervised travel by 93%. This includes a 61% reduction in unsupervised intersection crossings. WSB programs are most convenient for parents as the results suggest an average of 16 minutes and 26 seconds per day may be saved by not accompanying their child to and from school. A student participating in a WSB program may experience only a minor inconvenience of 1 minute and 3 seconds on average extra per trip because of route detours. Finally, the cost of WSB programs, if led by paid adults, can be substantial. Approximately 11 Full-Time Equivalent positions would be required to operate WSB programs at all four case study schools using the parameters established for this study.

Comparison of the WSB results at all four schools indicated only nominal variations between neighbourhoods with high and medium walkability ratings and between neighbourhoods

with high and low student density. This shows that WSBs are feasible in varying neighbourhood types within the Region of Waterloo and has demonstrated that neighbourhood walkability and student density have no apparent effect on the achieving the primary objectives of a WSB program.

Human decision-making and individual's values influencing these decisions adds a substantial amount of complexity to the field of ASST. In a society that continues to be risk adverse, WSBs may become increasingly desirable despite the upfront cost. Therefore, this thesis does not draw any conclusions on whether or not WSB programs should be implemented, but rather provides the basis for evaluating the costs and benefits of WSB programs in a broader decision-making context.

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List of Abbreviations

ASRTS	Active and Safe Routes to School
ASST	Active and Sustainable School Transportation
BMI	Body Mass Index
CMA	Census Metropolitan Area
DA	Dissemination Area (Census)
FTE	Full-Time Equivalent
GIS	Geographic Information System
GPS	Global Positioning System
MPAC	Municipal Property Assessment Corporation
NEWPATH	Nutrition, Environment in Waterloo Region, Physical Activity, Transportation and Health
RGMS	Regional Growth Management Strategy
ROW	Region of Waterloo
SES	Socio-economic Status
STP	School Travel Planning
STSWR	Student Transportation Services of Waterloo Region
TDM	Transportation Demand Management
WCDSB	Waterloo Catholic District School Board
WRDSB	Waterloo Region District School Board
WSB	Walking School Bus

Chapter 1. Introduction

1.1 Research problem

Human travel has significant implications for environmental, social and economic outcomes. The transportation and development infrastructure that has dominated the North American landscape over the past several decades have created substantial economic growth and have improved mobility. These approaches have also increased traffic congestion, decreased accessibility and contributed to negative health and environmental outcomes. In an effort to address these problems, scholars of many disciplines have focused on ways in which land use planning and design can encourage more active and sustainable transportation systems.

Both rationalist and reform intellectual traditions helped shape the planning profession in North America (Lubove, 1967). Klosterman (1978) suggested these two approaches conflict in two ways. A rationalist planner is an applied scientist, whereas, a reformist planner is committed to change and works to improve government and society (Klosterman, 1978). Rational planning results in decision-making based on empirical data while often avoiding the question of value. In order to address this conflict, Friedmann (1966) and others have called for a type of planning that uses a combination of both intellectual traditions. This approach is known as “normative” planning. As Næss (1994) suggested, planning for a sustainable society requires combining several planning theories.

Sustainable development planning is directed by normative planning concerns, including place making, scale, access, opportunity and choice (Behrens & Watson, 1996). The link between sustainable development theories and normative planning is in the value implications. Many sustainable development theories make belief statements of what ought to be (the ideal state). These theories depend on the notion that values can change and that sustainability is an abstract ideal; however, these changes do not come quickly and often require strong drivers or interventions.

Among normative planning theories, the rational-comprehensive, or synoptic model is most widely used in urban and transportation planning. It is a decision-making model based on technocratic ideology that assumes a planner knows, or can discover other people’s needs

(Alexander, 1992). Theories that strategize how to produce a shift from inactive to active modes of transportation describe the ideal state in planning policies and practice. However, the extent to which these theories can been tested in practice is limited due to existing place-specific system characteristics and the values of the system's users.

Travel behaviour can be influenced by urban design, land use, and the transportation system (the built environment). As a result, the transportation planning field has taken an interest in this connection (Handy, Boarnet, Ewing, & Killingsworth, 2002). Urban design theories that attempt to influence travel behaviour are normative because they "demand that followers make a leap of faith and simply trust in the beneficial outcomes that they claim will occur" (Moudon, 2000, p. 38). New Urbanism and Neo-traditional planning theories, for example, suggest that cities designed with grid-like street patterns, rather than networks that include cul-de-sacs, encourage walking and bicycling. However, there is limited empirical research supporting this assertion (Dill, 2004), and these theories discount many of the values and characteristics of today's populations (e.g., assuming people would prefer not to drive if other alternatives were viable).

In the context of school-based travel, a similarly normative tone is expressed in a growing number of documents focusing on how children get to school. These writings suggest that traffic congestion, air quality, pedestrian safety and children's health issues can be at least partially addressed through active (human-powered) transportation. Furthermore, claims that physically active children are significantly more active as adults (Telama, et al., 2005) have added focus to this critical behaviour-forming life stage (Hodgson, Namdeo, Araujo-Soares, & Pless-Mulloli, 2012) given the potential downstream effects on healthy lifestyles. Parental and community values are what "drive" children's school-based travel modes since elementary school-aged children tend not to make the decisions about where they live and how they get to school. Therefore, these values need to be considered in any active and sustainable school transportation (ASST) planning strategies. Key values, including children's health and well-being (e.g., safety and daily physical activity), time, and convenience play an important role in ASST. Overall this assumes that ASST is a means to establish life-long travel mode habit-formation, leading to more sustainable transportation systems in the future.

A potentially viable form of ASST is the Walking School Bus (WSB) concept. The WSB can be defined as a group of students walking to school together under the supervision of one or more adults (or older students). Proponents often suggest the WSB as a means to address the barriers (both perceived and real) to ASST by taking into account the key values influencing school-based travel decisions. A plan that may encourage ASST (e.g., WSB programs) needs to account for local geography as the existing infrastructure, walkability and student densities may influence the success of an intervention such as the WSB.

Momentum has been growing in advocating for government policies to be supportive of ASST. For example, Green Communities Canada (2010) recommended the expansion of the Ontario Ministry of Education's transportation mandate to fund all students' travel regardless of where they live. Social equity serves as one of three interdependent elements of sustainability (the other two being environment and economy). This advocates the provision of equitable school-based transportation among all students is a key element of sustainability. Accordingly, before any systematic change can take place, there needs to be consideration for how a system-wide ASST program could be implemented, and what the implications are for implementing such a program.

1.2 Purpose and objectives

WSB programs have undergone pilot testing and have been implemented in several schools across a wide range of jurisdictions to test various health (Heelan, Abbey, Donnelly, Mayo, & Welk, 2009), social (Kingham & Ussher, 2007), safety (Mendoza, et al., 2012), and economic (Shiell, 2007) outcomes. For the most part, WSB programs have been successful in increasing the number of students who walk to school (Mendoza, Levinger, & Johnston, 2009; Mendoza, et al., 2011), presumably leading to other direct and indirect health, social, safety and economic benefits. However, in order for the WSB programs to be operationalized and sustained, WSBs require ongoing support in the form of volunteers (The National Center for Safe Routes to School and the Pedestrian and Bicycle Information Centre, 2006), and/or paid employees. As well, the potential personal benefits are limited only to those who are willing and able to participate, which tends to be a small proportion of students at a school or within a jurisdiction.

Several assumptions have been made through self-reporting (see for example, Mackett, Lucas, Paskins, & Turbin, 2003) about how WSB programs could be successful in addressing key barriers related to school-based travel (e.g., safety and convenience). As part of any empirical evaluation, metrics of success should be enumerated and trade-offs would be considered. Extant literature contains no metrics to evaluate the extent these barriers are addressed by WSB programs (see Chapter 2 Literature Review). In addition, where programs exist, generally they are non-inclusive (involving a subset of students and along few routes). Evaluation metrics would assist school boards and/or school communities to determine the extent to which WSB programs address the barriers to ASST in their school(s). Furthermore, it is unclear if neighbourhood walkability and student density influence WSB program operations.

A key question remains, to what extent and in which circumstances are WSB programs successful in addressing the key barriers to ASST? Principles of both sustainable transportation and transportation demand management (see Chapter 2 Literature Review) can support an examination of this question. Further, in order to address this question effectively, two empirical objectives were established:

1. Develop metrics for evaluating the potential for WSB programs based on three dimensions that facilitate mobility: (1) safety, (2) convenience, and (3) cost.
2. Analyze the circumstances under which it is feasible to operate WSB programs using neighbourhood walkability and student density as potential variables.

A third objective is to explore the policy context in which student transportation services are provided in Ontario. This thesis focuses on WSB routing for one school board in southern Ontario as an example.

1.3 Introduction to the study area

The neighbourhood-level analysis is based on data for selected elementary schools in the Waterloo Region District School Board (WRDSB), located within the Region of Waterloo, Ontario. The WRDSB provides student transportation services as part of the Student Transportation Services of Waterloo Region (STSWR) transportation consortium, which also provides operational support for Waterloo Catholic District School Board (WCDSB). The WRDSB was chosen for the study primarily for two reasons. First, the researcher is involved with the Active and Safe Routes to School (ASRTS) committee in Waterloo Region and works for the WRDSB. Second, the Region of Waterloo has also been a leader in ASST promotion (e.g., the adoption of an Active Transportation Charter in 2011 by the WRDSB and WCDSB) and therefore, represents a jurisdiction potentially prepared to experiment with alternative transportation methodologies.

1.3.1 The Ontario situation

Across the Province of Ontario (the Province), over two million students travel to school every day (Ministry of Education, 2013). The main school-based travel modes include busing, motorized travel in personal vehicles and active modes (e.g., walking and biking).

Busing represents a significant cost for many school boards across the Province. Consequently, boards have made notable changes in designing and implementing busing to increase efficiency and effectiveness. For example, one bus can be used for multiple school runs if school start times align (a run is defined as a trip along a route), and thus reduce costs. The current school board funding model in the Province requires the consolidation of transportation service delivery amongst coterminous school boards into transportation consortia (Hartmann, 2003). This reform started in the 2006-2007 academic year and has created a more efficient bus transportation system across the Province. As a result, the Province’s increase in its busing budget has been below inflation. For example, over the 2015-16 school year, the Ministry of Education budgeted $887.7 million on student transportation. This represented a 19 per cent increase since the 2005-06 school year and a 5 per cent increase since the 2010-11 school year (Ministry of Education, 2015). At the same time, the Provincial inflation ran at 19 per cent and 10 per cent.

In the majority of jurisdictions, however, non-motorized alternatives continue to be overlooked in student transportation policies and practices. At present, no Province-wide strategic direction addresses ASST, despite a clear trend of decreased active transportation to school and increased travel using personal motor vehicles (Buliung, Mitra, & Faulkner, 2009). This shift from active to inactive modes follows the same trend as observed in other countries, including the United States (National Center for Safe Routes to School, 2010) and New Zealand (O’Fallon, Sullivan, & Cottam, 2002).

1.3.2 Region of Waterloo, Ontario

The Region of Waterloo is a mid-sized community located in southwestern Ontario, approximately 100 kilometres west of Toronto. It consists of three urban cities (Cambridge, Kitchener and Waterloo) and four rural townships (North Dumfries, Wellesley, Wilmot and Woolwich). The total population for the Region according to the 2011 Census is 507,096, an increase of 6.1% from 2006, a rate 0.4% greater compared to the growth rate in the Province over the same period (Statistics Canada, 2012a). The majority of the Region's population (477,000) falls within the Census Metropolitan Area (CMA) of Kitchener – Cambridge – Waterloo, making it the fourth largest CMA in Ontario and tenth largest in Canada. The Kitchener – Cambridge – Waterloo CMA has a population density of 577 persons per square kilometre (Statistics Canada, 2012b). The proportion of the population of the Kitchener – Cambridge – Waterloo CMA that is school-aged (5 to 19 years) is 18.8%. This compares to 18.2% provincially (Statistics Canada, 2012b).

Travel in the Region of Waterloo is predominantly by automobile; however, 7.8% of afternoon peak hour trips are by walking and cycling (Region of Waterloo, 2014a). The regional transit system, Grand River Transit, operates 66 regular routes, spanning 12 million vehicle-kilometres (Region of Waterloo, 2014b). The Region also has approved a rapid transit system (ION), projected to be operational by 2017 (Region of Waterloo, 2012).

Due to continued population growth in its urban municipalities, the Region of Waterloo adopted a Regional Growth Management Strategy (RGMS) in June 2003. This Strategy called for intensification of development and highlighted the need for more active and sustainable transportation systems. The Region of Waterloo, City of Kitchener and City of Cambridge adopted Pedestrian Charters in 2005, followed by the City of Waterloo in 2008. These Charters formed the groundwork for new sidewalk policies in all municipalities. Further, a Cycling Master Plan, first adopted in 1994 and updated in 2004, has been integral in improving the cycling infrastructure across the Region (Region of Waterloo, 2004). A Regional Active Transportation Master Plan, entitled Walk Cycle Waterloo Region, is tasked with making it easier to walk and cycle in the Region "by promoting and integrating active forms of transportation" (Region of Waterloo, 2014a, p. 1.3). The Region also follows design standards for planning and designing complete streets that include space for all modes of transportation through the Context-Sensitive Regional Transportation Corridor Design Guidelines and other municipal policies and guidelines at the local level.

1.3.3 Waterloo Region District School Board (WRDSB)

The WRDSB is the ninth largest school board in Ontario, with an enrolment of approximately 63,000 students attending 120 schools (Ministry of Education, 2013a). Its jurisdiction is coterminous with the boundaries of the upper-tier Region of Waterloo; therefore, it has schools in both urban and rural locations. This district covers 1369 square kilometres and features a wide range of socio-demographic characteristics.

The projected Student Transportation Grant for the WRDSB for the 2015-16 school year was approximately $15.6 million. This represents an increase of 28% over 2005-06 even though the board's average daily enrolment increased by only 8% over the same period (Ministry of Education, 2015).

1.3.4 Student Transportation Services of Waterloo Region (STSWR)

The Ontario Ministry of Education introduced transportation reforms in the 2006-2007 academic year, requiring school boards across the province of Ontario to develop partnerships that involved combining transportation departments of local school boards into a fully integrated transportation organization. The objective of these reforms was to co-operatively "deliver safe, effective, and efficient transportation" (Ministry of Education, 2015b) for school boards that share common, coterminous geographical areas. In 2007, the co-operative student transportation service that had been established by the WRDSB and the WCDSB in 1996 evolved into the STSWR consortium.

STSWR is responsible for the planning, implementation, communication and monitoring of bus routes for the approximately 30,000 students eligible for transportation services across the Region of Waterloo (Student Transportation Services of Waterloo Region, 2015). STSWR uses computer software (Georef Systems Limited's BusPlanner software) to optimize school bus routing.

1.3.5 Active and Safe Routes to School Waterloo Region (ASRTS)

Like other urban boards, the majority of students in the Region of Waterloo are not bused because they live within what are deemed acceptable walking distances. Such active transportation is supported by the ASRTS Workgroup whose purpose is to plan, support and encourage ASRTS program and policy initiatives for schools and students in the Region of Waterloo (Region of Waterloo, 2015). The ASRTS Workgroup, established in 2002, comprises representatives from Region of Waterloo Public Health, Waterloo Region District School Board, Waterloo Catholic District School Board, Student Transportation Services of Waterloo Region, City of Cambridge, City of Kitchener, City of Waterloo, Region of Waterloo Transportation, Ontario Ministry of Transportation, and Sustainable Waterloo Region. The Workgroup envisions a community where getting to and from school by active transportation is the preferred option.

The ASRTS Workgroup has been involved in several national pilot programs since 2007, including development and testing of the national School Travel Plan model (2007-2009 involving three WRDSB elementary schools), testing of the national School Travel Plan model (2010-2012 at two WCDSB elementary schools), and the Wheeling to School pilot (2011-2012). On May 16, 2011, both the WRDSB and WCDSB adopted Active Transportation Charters prepared by the Workgroup. These Charters were a formal recognition of the value of active transportation to the boards. The Charter includes "a statement of principles that recognizes the value of active modes of transportation for the journey to and from school" (Waterloo Region District School Board, 2011).

1.4 Thesis outline

Including this introductory chapter outlining the context, purpose and rationale for undertaking a study that examines to what extent and in which circumstances are WSB programs successful in addressing the key barriers to ASST, this thesis is comprised of five chapters. The subsequent chapters explore this question beginning with a literature review (Chapter 2), followed by the methods (Chapter 3). Results are described in Chapter 4, and conclusions, are drawn in the final chapter (Chapter 5).

Chapter 2. Literature review

2.1 Introduction

The field of travel analysis draws on a number of interrelated disciplines. The evolution of thinking in the field has included many theoretical models, massive increases in data collection, and improved understanding of variables/factors that influence outcomes. Most of the understanding of the core concepts comes from studying adult travel and the journey to work problem, even though most trips are non-work-related. Work-based trips have been of interest to researchers because of the volume of trips that occur at peak periods. By comparison, non-work related trips are not as well understood. Moreover, until recently children and adolescents were studied far less as a travel group than adults (Yarlagadda & Srinivasan, 2008).

2.2 Key decisions

Generally, travel behaviour can be analyzed in the context of key decisions relating to automobile ownership, housing location, and end-of-trip activities. Since the majority of trips generated are home-based, it is important to understand residential location decisions. This is especially true for the journey to work, but also for school trips. This section focuses on residential location choices, especially in urban areas where high concentrations of students and their families live. Families in urban areas are mostly responsible for making decisions about school-based travel, unlike rural families who are largely bused to school.

Urban transportation planners have traditionally used a four-step transportation demand modeling approach. Conventional transportation forecasting models (see for example, models introduced in the 1950s for the Detroit Metropolitan Area Traffic Study, 1955; and the Chicago Area Transportation Study, 1959) consist of four steps: (1) trip generation, (2) trip distribution, (3) mode choice and (4) route choice (McNally, 2000). Traditionally, trip generation analysis has been treated as inelastic, focusing on the frequency of trips as a function household size, income and other socio-demographic factors, and discounting the effect of location and land use (Ewing, DeAnna, & Li, 1996). Trip distribution is commonly predicted by trip movements between zones, using methods such as the gravity model (Schneider, 1959), which incorporate predictor variables such as population density and destination attractiveness, moderated by travel distance (Thomas & Huggett, 1980). It is the third step, mode choice, that is of greatest interest in school travel forecasting because it predicts the proportion of trips of a particular type (mode) that take place between an origin (i.e., home) and destination (i.e., school).

2.2.1 Residential mobility and location choice

The distance-decay effect (land value decreases as one moves away from the core area) is a central tenet of economic geography, and the related concept of land-rent is a key component of residential location decision-making. In the context of active transportation, residential location can play a role in mode choice. Haig (1926) theorized about urban land values, explaining that residential choice is based on the rent, time, and transportation costs (claiming that lot size is not important). This theory, however, falls short in explaining the complexity of the residential location decision-making process.

Rossi (1955), and Brown and Moore (1970) were the first to recognize that early aggregate-level residential mobility models fell short in their ability to predict household mobility patterns, thereby influencing the current understanding about urban residential mobility. Rossi (1955) discussed residential mobility in terms of individual households and movement behaviours, emphasizing "…the interconnection between mobility and neighbourhoods and mobility as a specific phenomenon of the housing market" (Rossi, 1980, p. 10). Brown and Moore (1970), working with Rossi's idea of interconnectivity, introduced the concept of "place utility," measuring levels of satisfaction or dissatisfaction for a given location.

Many authors have attempted to model residential location decisions. McFadden (1978) discussed the theory of economic choice behaviour using a discrete choice modelling framework. Using measurements of transportation and residential location demand, Anas (1982) created an equilibrium simulation model to determine travel and residential choices. Anas examined how transportation alternatives affected consumer bid-rents in Chicago. Zorn (1985) suggested that cities were experiencing urban decay because of decreasing transportation costs encouraging households desiring large homes to relocate to the suburbs. Zorn concluded that an "accessibility model is better at explaining the flight of middle-income households and families with children to the suburbs while the Flight from Blight model is better at predicting the flight of high-income households to the suburbs" (Zorn, 1985, p. 206). These models confirmed that residential location decisions are strongly tied to transportation demand and cost.

Residential location models that consider transportation are primarily employment-focused and provide little consideration of school-based trips. These models likely do not consider children's travel patterns because the parent is often the primary decision-maker. This begs the question regarding the amount of consideration given to the child's commute to school in a family's residential location decision-making process. Dieleman and Mulder (2002) suggested that in households consisting of more than one person, the geographic location of a household is a concession among individual household members. A further complexity is added when school-aged children are present, as parents tend to place a priority on the presence of good schools in the neighbourhood. Some studies (for example Jud & Bennett, 1986; Margulis, 2003) identify quality of school in the decision-making process, but make no mention of the proximity of the school.

Various empirical studies confirm Tiebout's (1956) hypothesis that households consider the cost-benefits of public service facilities (e.g., schools) in their residential location choices. Yang, Schlossberg, Johnson, and Parker (2010) for example, found "…about 78 percent of parents had thought about school transportation when they chose their current residence" (p. 25). A second example is provided by a study of home values in Québec. Des Rosiers, Lagana, and Theriault (2001) found that not only does the proximity to a school (a 12-minute walk from home) have an increasing impact on home values, but so does the size of the school. They suggest that there are other benefits to having a school close by (regardless if the household has students at the school) that could influence the affordability and availability of homes near school sites.

Schools are distributed throughout urban areas in close physical proximity to their users; however, often a threshold population size is required to support a school's operation, resulting in an uneven distribution of facilities. In other words, population density and distance (can be measured as straight-line distance, transport-cost distance, time, etc.) affect the school location and accordingly the spatial pattern of accessibility. In low-density areas, the threshold population required for a school creates greater distance between facilities, thereby creating a greater need for motorized transportation. As aptly summarized by Guttenberg (1960), distance can be overcome in two ways: "[p]eople can be transported to facilities or facilities can be distributed to people" (p. 108). Therefore, where densities are low and schools cannot be provided within walking proximity, motorized transportation tends to dominate.

When considering the preference of families locating in close proximity to a school, friction of distance (or distance decay) may play an important role – the further apart two places are the fewer people will migrate between them. However, a variety of other criteria – environmental (e.g., accessibility, services and facilities), dwelling specific requirements (e.g., housing type, cost), etc. – influence the decision-making process (Rossi, 1955; Simmons, 1968). Levy, Murphy, and Lee (2008) added gender and cultural background to that list. The willingness to pay for these factors, not just cost, is integral to the decision-making process. In fact, Levy et al. (2008) discovered that families, even after undertaking structured house searches "make their final decision based on a general feeling, which in many cases they found hard to articulate or explain" (p. 287). This confirms that the housing market is not necessarily, as it is often depicted, "... an intrinsically rational, readily comprehendible and ultimately self-regulating mechanism" (Smith, Munro, & Christie, 2006, p. 85). It is clear that although a good school that is close to the home may be desirable to families, it is not the only factor taken into account in deciding where to live.

2.2.2 Mode choice

Transportation mode refers to the means by which people achieve mobility. In the case of multimodal trips (i.e., more than one mode in a trip sequence), mode type is usually recorded in surveys as the mode that is used for the longest leg of the trip. Mode choice can be influenced by the attributes of a mode including, speed (time), cost, accessibility and safety. The predominant mode for commuting to work in Canada is by private automobile (73.8%), followed by public transit (11.0%) and only 6.4% by walking (Statistics Canada, 2008). Nationally representative data (Canadian Fitness and Lifestyle Research Institute, 2010) for children 5 to 17 years old show that 24% of parents say their children use only active modes for school trips (20% walk, while 4% bike); whereas, the remaining 76% use inactive (motorized) modes (34% by bus or train, 24% by car, 18% a mixture of motorized modes). Mode choice for school-based travel is often impacted by a parent's morning and afternoon travel patterns (Yarlagadda & Srinivasan, 2008).

Recently, research interest in active or non-motorized modes (e.g., walking, cycling, etc.) has grown substantially primarily over sustainability and population health concerns. Observed increases in the modal share towards inactive or motorized modes (e.g., personal vehicle, bus, etc.) have further necessitated study in this area. The distance between a student's home and school is consistently found to be the most important variable in determining school travel mode, where a student is less likely to use active modes as distance increases (Larsen, et al., 2009; McDonald, 2007; Schlossberg, Greene, Phillips, Johnson, & Parker, 2006; Timperio, Crawford, Telford, & Salmon, 2004). For more on the influence of distance, refer to Section 2.4.1.

2.2.3 Route choice

Route choice as it relates to walking is of specific interest to this paper because it will inform the criteria to use in developing and evaluating WSB routes. Hill (1982) empirically corroborated several hypotheses about pedestrians, including: (1) pedestrians nearly always choose distance-minimizing routes, (2) young pedestrians select relatively more complex routes than adults, (3) a stranger who asks for directions generally receives structurally simple routes, and (4) adult pedestrians exhibit more complexity in their own walking routes compared to the complexity of routes given to a stranger asking for directions. The pedestrian behaviour theory, developed by Hoogendoorn and Bovy (2004) assumed "that *all actions of the pedestrian*, let it be performing an activity or walking along a certain route, *will provide utility* (or equivalently, induce cost) to him" (p. 171). Their theory recognizes, however, it will not take into account all real-life human decision-making, but provide a framework for modeling human decision-making.

Children can easily be influenced by parents and peers in their selection of routes. Reiss (1977) found that routes selected by schoolchildren differed between males and females. More often, the males said they chose a route to school because it was the shortest way; however, females frequently said they "choose the route taken to school because they are taken by parents" and would go a different way if told to do so by parents or if it was 'safer'" (p. 42). Kelly and Fu (2014) suggest that pattern and predictability of school-based trips should easily allow for "…the evaluation and design of policies, services or infrastructure-focused interventions that can influence the choices made by these individuals to reduce the associated negative impacts" (p. 221).

Dill (2004) concludes that there are several factors that influence the attractiveness of walking or bicycling on a network, including "…slope, the presence of sidewalks, bike lanes, and bike paths, the amount of motorized vehicle traffic, aesthetics, and pavement or sidewalk quality. Some factors, such as stop signs, may be attractive to pedestrians but annoying to some cyclists" (p. 18). This suggests that routing choices may vary between active modes; however, in the context of walking, the most relevant influences for routing include the presence of sidewalks, sidewalk quality and intersection controls.

Establishing a travel route is an optimization problem. While distance is critical in route selection for all modes, it is of paramount consideration for active modes because of the physical cost and increased travel time associated with undertaking longer trips. There are four key methods to evaluate distance measurements in the context of active commuting through walking or bicycling: self-estimated distance, straight-line distance, Geographic Information System (GIS) shortest-route distance, and Global Positioning System (GPS)-measured distance (Stigell & Schantz, 2011).

2.3 Core Concepts

2.3.1 Accessibility

The past decade has seen a notable shift in transportation planning characterized by decreased emphasis on mobility and increased emphasis on accessibility. Accessibility in this context refers to the ease by which one can reach a destination or opportunity and, if measured, can be an indicator of the effectiveness of a transportation system, whereas, to measure mobility is to focus on movement. Increasing health and environmental risks associated with historic mobility-oriented (or vehicle-centred) transportation planning has led to an inherent need to shift to an accessibility-oriented (or person-centred) focus. This shift is already evident in the general transportation planning environment (Litman, 2012).

In the first explicit discussion about accessibility, Hansen (1959) emphasized, "accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation" (p. 73). The accessibility and land use conversation was continued by Wingo (1961) and Alonso (1964), claiming that as land use intensity increases, so does accessibility and land value. Hansen (1959), who defined accessibility as a measure of potential opportunities for interaction, highlighted how accessibility decreases as the distance from the origin to opportunity increases (gravity-based accessibility model). This concept of the friction of distance is especially relevant to active transportation modes.

2.3.2 Connectivity

In the context of transportation planning, connectivity refers to the time, cost or ease of travelling (Alstadt, Weisbrod, & Cutler, 2012). Without regard for distance, connectivity is a measure of accessibility. Increasing network connectivity can reduce travel distances for all modes because there is a wider range of routes to choose from (Dill, 2004). Street connectivity is an important aspect of trip routing because it describes the directness of routes between origins and destinations. It is maximized by traditional grid-based networks that create both more and shorter routes (Saelens & Handy, 2008). More connected street networks are thought to increase walkability and thus walking activity; however, no definitive association between connectivity measured by intersection density and rates of active transportation has been determined. Some studies (see De Meester, Van Dyck, De Bourdeaudhuij, Deforche, & Cardon, 2013; Schlossberg, et al., 2006) have found a positive association, whereas others (see Timperio et al., 2004; Ulfarsson & Shankar, 2008) have not. Higher levels of active transportation have been consistently found to be associated with shorter distances to school and higher residential densities (see De Meester et al., 2013; Kerr et al., 2006; Larsen, Gilliland, & Hess, 2012; McDonald, 2008; Timperio et al., 2006).

2.3.3 Walkability

No consensus definition of walkability exists; however, Galanis and Eliou (2011) suggest it “can be explained as the suitability that the urban road environment offers to pedestrians” (p. 386). Walkability has been highlighted in many urban studies because it is a measure of sustainable transportation (Moayedi, et al., 2013). There are several indicators of walkability that are identified in the built environment and health literature, including intersection density, residential density, land use mix, and retail design. Walkability can be estimated using connectivity and accessibility measurements (Frank, et al., 2006). Environmental attributes can be assessed with the aid of GIS (Leslie, et al., 2007) and walkability assessment or audit tools (e.g., Millington et al., 2009; O'Hanlon & Scott, 2010; Walk Score, 2015).

Studies evaluating the effect of walkability on active transportation mode choices for all age groups (Frank et al., 2006; Saelens & Handy, 2008) suggest a strong positive correlation between walkable neighbourhoods and the prevalence of walking to destinations. This supports the notion that walkability is closely tied to accessibility – the more accessible a neighbourhood, the more walkable it is.

2.4 Children's mobility

2.4.1 Influence of distance

Distance, when directly related to travel time, consistently has been found to be the most influencing environmental variable on mode choice for children 5-18 years old (for review of environmental correlates, see Pont, Ziviani, Wadley, Bennett, & Abbott, 2009). Several studies have also shown that short distances are predictive of active mode school-related trips (see Larsen et al., 2009; McDonald & Aalborg, 2009; Mitra, Buliung, & Faulkner, 2010; Wen et al., 2008; Yarlagadda & Srinivasan, 2008). This negative correlation is likely related to the time advantage of motorized travel over active modes when distances are greater, since the quality and feasibility of a substitute mode directly affects the choice of mode. Several studies related to school travel (McDonald & Aalborg, 2009; Mitra et al., 2010; Schlossberg et al., 2006) have found this threshold to be between 0.8 and 1.6 kilometres. Although the relationship between distance and travel mode is intuitive, it does not explain all mode choices.

2.4.2 Individual and household characteristics

The possible link between household socio-economic status (SES) and active commuting to school has been considered in many studies (see for example, Braza, Shoemaker, & Seeley, 2004; DiGuiseppi, Roberts, Li, & Allen, 1998; Ewing, Schroeer, & Greene, 2004; Larsen et al., 2009; McMillan, 2007; Mitra et al., 2010; Pabayo & Gauvin, 2008; Spallek et al., 2006). SES measures can include household income (Spallek et al., 2006), parental employment status (Ewing et al., 2004), and car ownership (see DiGuiseppi et al., 1998; Ewing et al., 2004; Wen et al., 2008). Although some studies have found that children from low SES backgrounds are more likely to actively commute to school (Braza et al., 2004; Ewing et al., 2004), others have revealed conflicting results. For example, Mitra et al. (2010) found students with low SES characteristics were less likely to use active school travel modes. Similarly, when all children's trips are considered (not just school travel), Pont et al. (2009) found consistent evidence of a negative relationship between household income and rates of active transportation. Given none of the above-noted studies control for specific SES characteristics (e.g., income, education, wealth, and/or place of residence), and the inconsistent results around school-related trips, it is unknown if income in isolation is a strong predictor of school travel mode. Further, international or cultural influences may also play a role, highlighting the need to evaluate the locational context of any conclusions related to SES characteristics and their influence on mode choice.

Other than income, several other individual and household characteristics have been studied in relation to school travel mode. These include: race/ethnicity (Braza et al., 2004; Evenson, Huston, McMillen, Bors, & Ward, 2003), gender (Evenson et al., 2003; Larsen et al., 2009; McDonald, 2007; Pabayo & Gauvin, 2008; Robertson-Wilson et al., 2008) and age (Dellinger & Staunton, 2002; DiGuiseppi et al., 1998; Evenson et al., 2003; Mitra et al., 2010; Robertson-Wilson et al., 2008). Once again, no strong correlation has been found. Several studies (see Evenson et al., 2003; Larsen et al., 2009; Pabayo & Gauvin, 2008; Robertson-Wilson et al., 2008) have found a positive association between being male and the likelihood of walking or biking to school; however, results from a study conducted by McDonald (2007) found no association. Interestingly, Dellinger and Staunton (2002) reported no association between age (elementary versus secondary) for walking trips, indicating that the proportions of students walking and biking were similar for both age groups (households with children aged 5-18 years were surveyed). Others, however, (see Mitra et al., 2010; Pabayo & Gauvin, 2008; Robertson-Wilson et al., 2008) have concluded that older students were less likely to walk or cycle to school than their younger counterparts. There may be several factors contributing to these differences, including distance to school and social pressures. These findings suggest that individual and household characteristics may not drive decisions about children's school travel modes – at least not in consistent ways.

Pooley et al. (2010) argued that studies of mode choice have been mainly quantitative and those about children's movement in the outdoor environment have been qualitative. They therefore combined these methods (qualitative and quantitative) to reveal that personal and family circumstances often become a key factor in determining travel mode. Their in-depth qualitative data revealed that the complex household decision-making process, family responsibilities, personal commitments, and preferences produced varied sets of school journeys. They argue that these factors should be given greater prominence in the analysis of modal choice.

Sirard, Ainsworth, McIver, and Pate (2005) found bus trips to increase after school, replacing before school auto trips. They also reported an increase in bicycle trips in the afternoon as some students were dropped off in the morning by an automobile and the bicycle was dropped off with the student. Alternatively, parents met children after school with a bicycle for them to ride. This phenomenon was also observed by McMillan (2003), Schlossberg, Phillips, Johnson, and Parker (2005) and Heelan et al. (2005). These after-school decreases in motorized transport suggest that many school trips are a result of parental trip chaining since trip chaining and mode decisions are simultaneous (Islam & Habib, 2012). For example, parents may drive their children to school in the morning because it is on their way to work or other daily activities. A parent may then be unable to pick up child in the afternoon because school lets out before they are finished work. Cole, Leslie, Donald, Cerin, and Owen (2007) confirmed this with their finding that for school trips fewer than two kilometres, 56% of parents who drove went directly to work after driving their child to school, whereas, only 19% of parents who walked their child to school went to work afterward. For the trip home, these rates changed to 47% and 8% respectively.

2.4.3 Physical and social environments

An expanding body of literature examines the physical environmental factors influencing children's modal choice for the school journey. These factors include, but are not limited to land use mix, presence of street trees, sidewalks, intersection density, and residential density. Larsen et al. (2009) found the likelihood of active school travel rose with both increased land use mix and greater number of street trees for the journey to school; however, the presence of street trees was not significant in the journey home from school. In a review of 14 studies that have used GIS-based measurement tools, Wong, Faulkner, & Buliung (2011) concluded that, other than distance, there is no consistent evidence to support an association between geometric aspects of the built environment (including land use mix, walkability, and street design) and active school travel. This suggests that there are non-environmental factors that influence mode choice;

however, the focus on environmental factors has been significant in the literature perhaps because, with the exception of weather, environmental factors have the potential to be altered.

Intersection density as it relates to traffic safety is often discussed in transportation literature. Dellinger and Staunton (2002) cited traffic danger as the second most reported barrier to walking and biking to school behind long distances. Timperio et al. (2004) concluded that among children in 19 Australian primary schools, “parental perceptions of issues regarding safe pedestrian and cycling conditions (e.g., the need to cross several roads to reach destinations and a lack of lights or crossings) were negatively associated with 10- to 12-year-old children’s walking or cycling to local destinations” (p. 45). Oluyomi et al. (2014) found similar results in Texas, where the likelihood of students walking increased when parents reported safe road crossings in their neighbourhood. These studies, however, are based on subjective measures (based on perception alone), and do not take into account any collision data.

The effect of parents’ perceptions of environmental factors and active school travel also has been studied (see Cole et al., 2007; Kerr et al., 2006; Lee, Zhu, Yoon, & Varni, 2013; Timperio et al., 2004; Timperio et al., 2006). These studies indicate that the difference between the actual and perceived environments independently influence active school travel decisions. Cole et al. (2007) surveyed parents who usually drove as well as parents who usually walked to school with their children and lived less than two kilometres from school. Their study found that parents who walked their children to school had significantly fewer traffic concerns and rated the ease of walking to school much higher than those who drove. Further, in a study that controlled for home-to-school distance, Lee et al. (2013) found that parental attitudinal and preference factors were stronger than environmental perception variables for predicting school travel mode choices. This confirms that perception can be a major influencer in mode choice and highlights the need for sharing accurate information and addressing attitudinal barriers in behavioural interventions.

Environments that stimulate or are conducive to active school travel (i.e., walkability) may not be the same for children and adolescents as for adults. A Belgian study found that children living in a highly walkable core area within a short distance of their schools walked and biked less frequently than children living in a less walkable suburb further from their schools (Van Dyck, Cardon, & De Bourdeaudhuij, 2009). This finding is in contrast to other studies with adults that suggest walkability is linked to increased physical activity (Owen, et al., 2007; Van Dyck, et al., 2009; Hosler, Gallant, Riley-Jacome, & Rajulu, 2014).

Social factors, including parental fears about "stranger danger," have also been found to influence school travel modes. DiGuiseppi, Roberts, Li, and Allen (1998) concluded that although distance to school and car ownership were the principal determinants of car travel, concerns over "stranger danger" played a role in car-based school travel. These concerns are especially true for parents of 5-to 6-year-olds and girls more than boys (Timperio, Crawford, Telford, & Salmon, 2004). McDonald (2007) suggested the WSB concept as an intervention to address these concerns.

2.4.4 School characteristics

Since schools act as destinations for school-related trips, it is important to examine the potential influences a school may have on mode choices. Studies in this regard have focused on four main school characteristics: administration, school siting, population density in the school neighbourhood, and enrolment levels.

Dellinger and Staunton (2002) discussed opposing school policies as a barrier to active school travel; however, only 7% of their respondents reported this as a barrier to walking and biking to school, behind long distances (55%), traffic danger (40%), adverse weather conditions (24%), crime danger (18%) and other reasons (26%). This suggests there are barriers that cannot be addressed through school policies and should be addressed by other means. Much of the literature focused on ASST combines all modes (e.g., walking, biking, bussing, driving, etc.); however, walking is of most importance to this thesis.

In recent years, a trend towards building schools on available and inexpensive land in areas away from residential neighbourhoods has drawn attention to school siting decisions. This is especially true especially in the United States. Ewing et al. (2004) and Sharp (2008) argued for neighbourhood schools to service nearby residential areas instead of schools located in remote areas. Since distance to school is a strong predictor of walking, locating schools central to the populations they serve is especially important to creating environments where children can walk to school. Further, Giles-Corti et al. (2011) concluded that schools in highly walkable neighbourhoods (i.e., high connectivity, and low traffic volume) have more students walking to school regularly than schools in neighbourhoods with low walkability. This confirms the importance of considering street design in neighbourhoods where schools are planned.

For school-based trips, school population size may influence mode type (Wilson, Marshall, Wilson, & Krizek, 2010). Kouri (1999) and Braza et al. (2004) found that as school size increased, fewer students walked to school. Since schools with larger populations typically draw students from broader geographic areas, this correlation makes sense. However, Ewing et al. (2004) found no association for walking trips after controlling for travel time between home and school. The issue with these studies is that they are examining the mode choice of the entire student population, and not considering what this means for students within reasonable walking or biking distances. If the data were re-examined to show the proportion of students at schools with larger enrolments living within reasonable distances to choose active modes as viable alternatives, results would be more meaningful.

Since several variables have shown statistically insignificant influences on children's mobility, it is important to understand why. There are important geographical variations in modal competition. The availability of transportation infrastructure and networks varies enormously. Other factors that can explain the variation in results include the sample size (often small), differentiation in analysis design/research method, difference in context (and not accounting for it), the target group, the magnitude of distance (geographical/spatial variation), cultural differences (e.g., values), and the school system (public and private). Given the dominance of time, distance, infrastructure and safety in the urban transportation literature, it can be concluded that these are the variables most relevant to walking in the context of an urban environment. Although SES is also discussed, it does not appear to be a strong predictor of walking.

2.5 School-based travel

Transportation research regarding commuting has a strong focus on home-to-work trips and very little on home-to-school trips. This is likely due to the minimal share (6%) that school-related travel contributes to the transportation system on a daily basis in comparison to work-related travel (17%) (Transportation Tomorrow Survey, 2006). In Canada and internationally, there has been an observed decline in active commuting to school over the past several decades (Buliung et al., 2009; Sirard & Slater, 2008). For example, in the Greater Toronto Area of

Canada, a 9% decline for 11-13 year olds and 8% for 14-15 year olds in walking mode share trips to school occurred between 1986 and 2006 (Buliung et al., 2009). This decline has been even more substantial (26% decline between 1969 and 2001) in the United States (Centers for Disease Control and Prevention, 2008).

Research on school-related travel has expanded significantly in recent years with contributions from a range of disciplines. The health and transportation demand management fields, which can often be interconnected, have taken the lead in the literature related to ASST. The interests of these two disciplines are connected – both seek to find ways to increase walking and biking mode shares; however, the approach and rationale of the studies vary.

2.5.1 Health and school travel

There is a growing body of research in the public health field related to ASST. This literature focuses on key health indicators associated with commuting such as physical activity (Mendoza, et al., 2011; Pabayo et al., 2012; Rosenberg et al., 2006), body mass index (BMI) (Heelan et al., 2005; Rosenberg et al., 2006), and cardiovascular fitness (Cooper et al., 2003; Davison et al., 2008; Heelan et al., 2005; Sirard et al., 2005). Studies show that active school travel is positively associated with higher levels of daily physical activity (Rosenberg et al., 2006) and higher cardiovascular fitness in children (Cooper et al., 2003; Davison et al., 2008; Heelan et al., 2005; Sirard et al., 2005). Although studies have been conducted (see for example Heelan et al., 2005), no positive connections have been found between children's active commuting and reduced BMI. Others have studied the link between ASST and academic achievement (see literature review by, Fedewa & Ahn, 2011; Singh et al., 2012). In their analysis of the literature, Fedewa and Ahn (2011) concluded that physical activity is positively associated with academic achievement and cognitive outcomes, with aerobic exercise having the greatest effect. This suggests that there may be benefits to active school travel on student achievement, for example increased alertness (Mackett et al., 2003) because walking and biking constitute aerobic exercise.

Although the above noted studies speak to positive benefits of active school travel, there are also potential negative health-related impacts. Exposure to potentially harmful pollutants (NO_2, PM_{10}) has been studied with respect to children's school trips (Ashmore et al., 2000;

Pooley et al., 2010; Wilson, Wilson, & Krizek, 2007), concluding that walkers are exposed to higher levels of coarse particulates which can have serious health implications for those who choose to walk. Pooley et al. (2010) revealed that, although walking and cycling can lead to increased exposure to fumes, "the most consistently raised levels of exposure were experienced by those children who travelled to and from school by bus, and that some walking and cycling routes produced low levels of exposure" (pp. 960-961). This demonstrates the need for alternative route choices for pedestrians where they have minimal exposure to traffic. Davies and Whyatt (2009) offered a method for defining alternative, low-exposure route selections for children using Geographic Information Systems (GIS). In general, a reduction in the number of vehicles in neighbourhoods during peak travel periods would minimize the exposure impact on children.

2.5.2 Transportation demand management and school travel

Encouraging more efficient travel patterns and getting more out of existing infrastructure has been labelled transportation demand management (TDM). The TDM era in urban transportation planning began in 1985 as a shift in planning approaches from supply-oriented to demand-oriented (Ferguson, 1998). TDM, in its broadest sense, is any action aimed at influencing travel behaviour in such a way that alternative mobility options are presented (Meyer, 1999). These actions require cooperation between many agencies and organizations, including all levels of government (Meyer, 1999; Weiner, 1999). Since 1985, much of the transportation planning literature has focused on managing travel demand and increasing transportation efficiencies. The goal of TDM is to utilise the infrastructure already in place and develop ways to make the current supply work more efficiently. TDM relies on behaviour modification and in order to modify behaviour usually there needs to be a modification of policy, pricing, and/or programs. TDM incentives make behaviour modification more desirable, whereas, disincentives attempt to modify behaviour by making it more difficult to make unsustainable choices.

The most popular school-related TDM program internationally is known as School Travel Planning (STP). STP-related programs operate under different names in various countries, for example 'Safe Routes to School' or SRTS in the United States (National Center for Safe Routes to School, 2013), and ASRTS in Canada (Green Communities Canada, 2013). The primary objective of STP is to mobilize key community stakeholders to promote ASST (Buliung, Faulkner, Beesley, & Kennedy, 2011).

According to Metrolinx (2012), the STP model "…is iterative and evidence-driven as it collects baseline measurements to inform the creation of the School Travel Plan (i.e., a 'living document') and then completes follow-up measurements at intervals to adjust the plan accordingly" (p. 2). These plans can include the coordination of programs such as the WSB. An evaluation of STPs in 103 Canadian schools found that 17% of parents reported driving their children to/from school less often because of a STP intervention. Of those parents who reported driving less, the majority (83%) had switched to active transportation, thus highlighting the potential of STP interventions to increase ASST in parents and their children (Mammen, Stone, Buliung, & Faulkner, 2014).

2.5.3 Safety and school travel

One of the commonly cited barriers to active school travel is safety. Absolute safety suggests the absence of unsafe outcomes. According to the TAC Geometric Design Guide for Canadian Roads, however, "[i]t is impossible to make a road completely safe, if by 'safe' we mean a road on which we can guarantee that there will never be a collision" (Transportation Association of Canada, 2007, p. 1.1.1.2). A study of population data sets from California, Denmark, United Kingdom and the Netherlands by Jacobsen (2003) concluded that the likelihood of a motorist colliding with a pedestrian or cyclist decreases as the number of pedestrians and cyclists increases. When collisions do occur within school zones, Warsh, Rothman, Slater, Steverango, and Howard (2009) found they most frequently occurred at midblock locations. This suggests safer outcomes may be achieved if more students walk and bike to school and follow routes that do not include midblock crossings.

Given the limitations on how children view their surroundings and interact with traffic, organizations, such as the Safe Kids Worldwide (2015), recommend that children under the age of ten cross the street with an adult or older child. It is for this reason (supervision) that walking to school can be a challenge for families with busy schedules. As stated in previous sections, motorized trips to school are often the result of parental trip chaining. Therefore, finding ways to facilitate student supervision on their journey to school, such as WSB programs, is of particular interest in addressing barriers to ASST.

2.5.4 The walking school bus

The walking school bus has been suggested as a safe alternative to motorized travel. David Engwicht (1992) originally introduced the 'Walking Bus' concept as a solution to the vicious school traffic cycle whereby "parents drive their children to school because it is too dangerous for them to walk. This increases traffic, forcing other parents to drive because it is now too dangerous for *their* children to walk" (p. 143). Engwicht's concept suggested that adults "walk a set route, much like a school bus, collecting children along the route and delivering them safely to school" (Engwicht, 1992, p. 143). Reports suggest that the first formal WSB program began in Toronto, Canada in 1996 and has spread across Canada and other countries since (Victoria Transport Policy Institute, 2012). Kingham and Ussher (2007) have claimed that even though WSBs are inherently good, their benefits are frequently questioned because their positive outcomes are not easily quantified. They further explain that traditionally, transportation investments are assessed on financial costs and benefits and if the benefits cannot be quantified, it is difficult to justify the costs.

The vicious school traffic cycle as described by Engwicht lacks one critical influencing component – distance. Over the years, the distance individuals are willing to travel has decreased. Typically, this is linked to the amount of time it takes and convenience (see section 2.2.2 about mode choice); therefore, a viable alternative to the WSB when distances are greater may be to utilize bicycles (at least when the weather is suitable).

Kingham and Ussher (2007) found the most commonly cited benefits of WSBs are social, followed by health and safety, and timesaving. Increases in ASST because of WSB or related interventions have been reported in both Scotland (McKee, Mutrie, Crawford, & Green, 2007) and the United States (Alhassan, Spencer, & Robinson, 2008; Heelan, Abbey, Donnelly, Mayo, & Welk, 2009; Mendoza, Levinger, & Johnston, 2009; Staunton, Hubsmith, & Kallins, 2003). More recently, Smith et al. (2015) found some evidence of a positive association between WSBs and increased proportions of children walking to school, as well as increased activity levels. There were, however, no reports of WSBs reducing traffic congestion around the school. It was also noted that generally research outcomes highlight the barriers (including safety concerns, time constraints and recruitment of volunteers and children) which make setting up and maintaining WSBs challenging. Therefore, Smith et al. (2015) have recommended:

> that a WSB champion or coordinator role could be formalized and paid with teaching assistant or equivalent role being paid an extra hour or 2 to run WSBs at the beginning and at the end of the school day. This would help to address barriers of recruitment for WSBs and time constraints of parents getting involved in the running of WSBs. (p. 208)

This raises the question of how one would operationalize WSB programs at a school if they were formalized and run by a paid staff person, rather than a volunteer.

Yang, Diez-Roux, Evenson, and Colabianchi (2014) used an agent-based model to simulate the locations of WSB routes that maximize the effects of the WSB on ASST. Their model suggested that each day a child (or his/her parent) would consider three travel options: (1) joining the WSB, (2) walking on their own, and (3) being driven. A student would decide to join the WSB if:

> …the value assigned for safety along the route was above the value assigned for household concern regarding traffic safety…and if the value for child's attitude toward AST [active school travel] was higher than a threshold value that depended on the distance to the school along the WSB route (the WSB route might necessitate a detour from the most direct route that the child would normally take if he or she walked alone…and the additional time needed for the trip (to accommodate waiting times for the WSB, the possibility of slow walkers in the group, and the need to wait for other children at later stops). (Yang et al., 2014, p. 1198)

These studies have concluded that for a WSB program to be sustainable, it needs to be organized and run by paid employees, not volunteers. Further, the values of child (and child's family) need to be considered in establishing the WSB programs to maximize the number of students participating.

2.6 Summary of literature review

It is clear that there are two overarching components contributing to school travel decisions – safety and convenience. Few other correlations have been consistently proven to play such a predictable role in travel decisions.

Accessibility comes into effect where infrastructure exists or does not exist, which may explain geographic variances in rates of walking to school. However, within a jurisdiction where accessibility factors are uniform, rates of walking to school still vary. Accessibility, although important, cannot explain all trip decisions. Further, various jurisdictions have different policies related to infrastructure (for example, requirements to build sidewalks on both sides of the street) and therefore, it is difficult to translate the findings of the literature to all geographies.

As for residential location choice, the literature has shown that accessibility to schools affects housing choice, but where someone lives does not necessarily explain their school-travel mode choices. Mode choice therefore is more likely influenced by the work-home relationships of parents.

It is evident from the literature that human decision-making is influenced in many ways. From a behaviouristic standpoint, neighbourhood walkability and student density factors have the strongest influence. Mode choice decisions are based largely on the time and cost of alternatives and may not be tied to socio-demographic characteristics. Safety perceptions, especially in school-based travel, are also tied to mode decisions and route options. Therefore, the provision of safe and convenient walking options could result in more students using ASST. This thesis explores the WSB as one option.

Chapter 3. Methods

3.1 Introduction

As outlined in section 1.2, three objectives were established to address the problem statement and study purpose outlined in Chapter 1. Theoretical and practical dimensions are used to facilitate exploration of the two empirical objectives. Through experimentation, WSB routes are generated and evaluated on three dimensions that facilitate mobility: (1) safety, (2) convenience, and (3) cost. These results provide a theoretical basis for implementing WSB programs. Further, there is practical merit in using a case study to test a WSB routing methodology. The case study involves four schools from the Waterloo Region District School Board (WRDSB). Chapter 1 provides the background and basis for the selection of this jurisdiction as a test case. The circumstances under which it is feasible to operate WSB programs using neighbourhood walkability and student density as potential variables are analyzed. Four different neighbourhoods within the Region of Waterloo were chosen to ascertain if these neighbourhood characteristics have any impact on safety, convenience and cost outcomes of WSBs.

A complementary approach is used to explore the third study objective. The third objective is to explore the policy context in which student transportation services are provided in Ontario. Therefore, the policy framework that Ontario school boards use to support student transportation is synthesized. This provides the current context for the WRDSB's student transportation decisions.

3.2 Evaluation metrics

In any evaluation exercise, it is important to establish a method to measure the results. In this case, metrics are used to set a standard of measurement for WSB programs. These success indicators can produce robust data to facilitate the comparison of the WSB routes for each of the four case study schools.

The literature review (Chapter 2) revealed three key critical factors (or dimensions) that can influence mode choice and facilitate mobility – safety, convenience and cost. Both safety and convenience have the greatest influence on mobility from the perspective of a student or parent.

Although cost can also be important to students and parents, it has the greatest influence on the implementation of WSB programs from the perspective of a school board. Since the intention of a WSB is to provide a safe and convenient way for students to choose ASST, it is important to evaluate empirically how well WSB programs can facilitate these intentions. Table 3-1 outlines the metrics established to measure these three dimensions.

Table 3-1. *Metrics used to evaluate the success of a Walking School Bus program*

Dimension	Metric	Perspective
Safety		Student/parent
	Exposure to risk - supervision	
	Unsupervised intersection crossings	
	Unsupervised travel distance	
	Exposure to vehicular traffic (optional)	
Convenience		Student/parent
	Distance	
	Detour length between modes	
	Time	
	Difference in travel time between modes	
Cost		School board
	Human resources	
	Walking School Bus leader	
	Adult Crossing Guards	
	Program Coordinator	
	Transportation Technician	
	Parking Lot Attendant	
	Liability	

3.3 Case study approach

The purpose of a multiple case study approach in this research is to assess empirically the impact of neighbourhood walkability and student densities on walking school bus routing outcomes in multiple locations. Using evaluation metrics, the WSB routes generated in different types of neighbourhoods will help to understand if geographical variances affect the success of a WSB program.

According to Cousin (2005), “case study research aims to explore and depict a setting with a view to advancing understanding of it” (pp. 421-422). Further, it is “an inquiry that focuses on describing, understanding, predicting, and/or controlling the individual (i.e., process, animal, person, household, organization, group, industry, culture or nationality)” (Woodside, 2010, p. 16). The case study approach taken in this paper is considered a collective case study – a selection of more than one school (or case) to achieve a representation of geographically varied student population density and neighbourhood walkability.

The challenge of case study research is that the cases chosen do not represent a random sample, thus limiting generalizability in the statistical sense; however, the outcomes can be related to the convenience sample provided. The benefit of cases is that they provide rich insight into the complexities of real-world planning. This information can be used to inform further research and/or operations.

3.3.1 Walkability score calculation

Walkability can be measured or estimated in various ways (refer to section 2.3.3 for examples). The current study uses the NEWPATH measurement. This measurement comes from a research project conducted by the Region of Waterloo and the Universities of British Columbia, Alberta and Waterloo. Walkability ratings were categorized as high, medium or low based on calculations using four objective land use features: intersection density, residential density, rate of mixed land use, and retail design (Region of Waterloo, 2014c). Walkability ratings for the Cities of Cambridge, Kitchener and Waterloo, calculated by six-digit postal code, are publicly available on the Region of Waterloo's website.

A low score means that the neighbourhood has low intersection densities, low residential densities, and minimal land use mix (see section 2.4.3 for information on how these characteristics relate to students walking to school). The expectation is that individuals living in neighbourhoods with low walkability are likely to be car-dependent. A high walkability score means that the neighbourhood has high residential density, a mix of land uses, and high intersection density. It is expected that people in neighbourhoods with high walkability are more likely to travel by means other than personal vehicle (e.g., walk, bus or bike).

NEWPATH walkability ratings were generated for all WRDSB Junior Kindergarten to Grade 6 elementary schools based on the school's address. Of the twenty-two schools in the cities of Cambridge, Kitchener and Waterloo, four generated high walkability ratings, and five low. Therefore, the majority (thirteen) of the schools in the area generated medium walkability ratings. Since the research shows walkability is linked to ASST, a decision was made to focus this case study on schools with high and medium walkability ratings.

3.3.2 Student density calculation

The literature review (section 2.4.1 Influence of distance) showed that the number of students walking to/from school decreases as the distance from the school increases, with a threshold between 0.8 and 1.6 kilometres (McDonald & Aalborg, 2009; Mitra et al., 2010; Schlossberg et al., 2006). This distance is also consistent with the WRDSB's policy on bus transportation (except for Kindergarten). Therefore, an area using the shortest-path distance of 1.6 kilometres from the school was created. A 1.6 kilometre walk is estimated to take just over 20 minutes based on an average walking speed of 1.22 metres per second for younger pedestrians (Knoblauch, Pietrucha, & Nitzburg, 1996). The WRDSB provided a list of students' addresses attending the schools and living within the 1.6 kilometre area. This information was used to determine student density for each selected school.

For this study, a low student density was considered fewer than 150 students per square kilometre, whereas greater than 151 students per square kilometre were considered a high student density. Of the four elementary schools in the cities of Cambridge, Kitchener and Waterloo with high walkability ratings, one had a high student density and three had low student densities.

3.4 Case study selection criteria

Many factors influence school travel mode choices. These factors and their types of influence are summarized in Table 3-2. To determine if the evaluation metrics established in this study can identify the circumstances in which WSB programs can support ASST, it is important to study neighbourhoods with contrasting mobility patterns and similar population densities for maximum variation. Walkability and student population density have been found to contribute to an increase in walking to school; and therefore have been used as the primary measures for selecting neighbourhoods/schools of focus. Four schools were selected, two in neighbourhoods with high walkability and two with medium walkability. Two of the schools have high student density and two have low student density. The controls used for the schools with either high or low student densities were household income and grades offered at the school (Figure 3-1 illustrates these relationships). It is important to isolate all potential external influences that may affect the results of this evaluation.

The criteria and logic for selecting the four schools in the case study included:

1. Level of neighbourhood walkability, evaluated using the Region of Waterloo's Nutrition, Environment in Waterloo Region, Physical Activity, Transportation and Health (NEWPATH) tool. The NEWPATH measurement was chosen because it was created locally, and utilizes many key components that influence ASST rates in its measurement (i.e., intersection density, residential density, rate of mixed land use, and retail design).
2. Student density was measured by the number of students living within a 1.6 kilometres of the school (using shortest active transportation distance, or shortest path). The 1.6 kilometre distance was chosen because it is the threshold for bus transportation eligibility for the majority of elementary school students to WRDSB schools (see Table 4-18). All students living within 1.6 kilometres of a school, within the school's assigned attendance area (boundary), are the target for active school travel. It is important to note that students living outside of the established attendance area but attend the school for various reasons (e.g., French Immersion), were left out of the analysis because they are ineligible for transportation under the WRDSB's transportation policy.
3. Grades offered at the school (elementary schools were chosen because they have been the focus of the majority of school travel literature). The selection of schools was delimited to those with Junior Kindergarten to Grade 6 specifically because it is the most common grade configuration for WRDSB schools.
4. Household income (or income level) was chosen as a control because it has been found in some studies to have a negative relationship with active transportation rates (Pont, Ziviani, Wadley, Bennett, & Abbott, 2009). Further details about household income and active transportation can be found in Section 2.4.2.

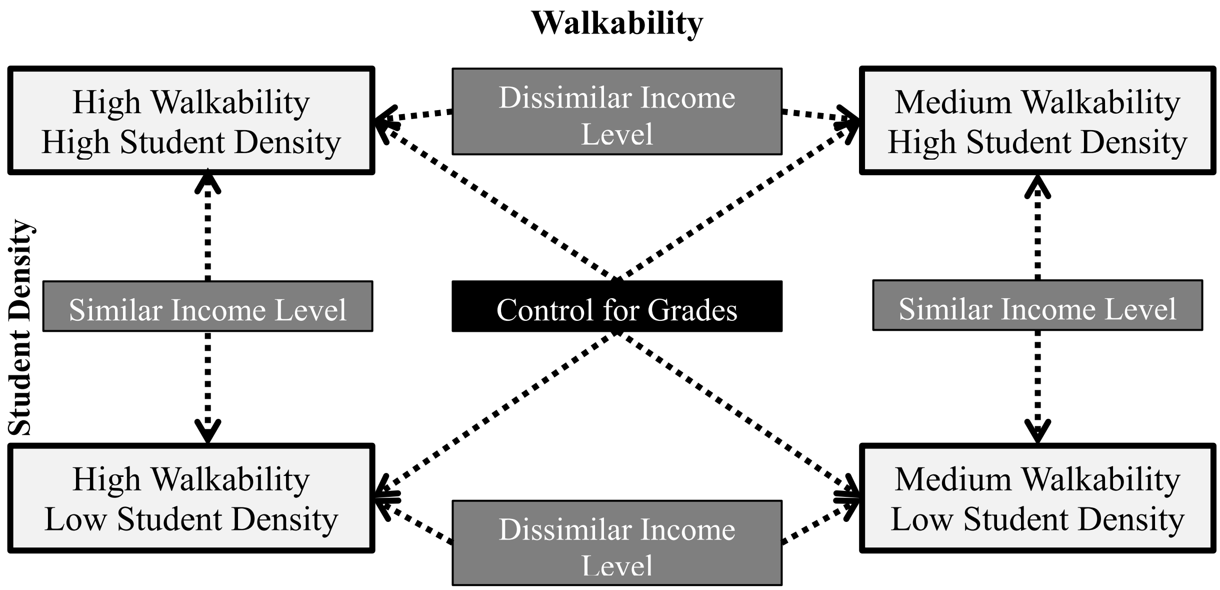


Figure 3-1. *Case study selection criteria*

Table 3-2. *Example factors that can influence school travel mode*

Factor	Effect	Mode	Association
Trip			
Type	from-school (vs. to-school)	w	(+) McMillan (2003), Schlossberg et al. (2005)
			(0) DiGuiseppi et al. (1998), Sirard et al. (2005)
		b	(+) McMillan (2003), Sirard et al. (2005), Schlossberg et al. (2005)
Travel distance	increase	w, b	(-) McMillan (2007), Schlossberg et al. (2005; 2006), Wen et al. (2008)
		a	(+) McMillan (2007), Schlossberg et al. (2005; 2006), Wen et al. (2008)
School attribute			
Choice	Magnet (vs. neighbourhood)	w, b	(-) Wilson et al. (2007)
		a	(+) Wilson et al. (2007)
Enrollment	increase	w	(-) Kouri (1999), Braza et al. (2004)
			(0) Ewing et al. (2004)
Child characteristic			
Grade	elementary (vs. secondary)	w	(0) Dellinger and Staunton (2002)
Sex	female (vs. male)	w	(-) Evenson et al. (2003); McMillan, Day, Boarnet, Alfonzo, & Anderson (2006)
			(0) McDonald (2007)
Household characteristic			
Vehicle	increase	w	(-) Ewing et al. (2004), Wen et al. (2008)
		a	(+) Ewing et al. (2004), Wen et al. (2008)
Sibling	presence	w	(+) McDonald (2008)
Income	increase	w	(-) California Department of Health Services (2004), Ewing et al. (2004)
		a	(+) California Department of Health Services (2004), Ewing et al. (2004)
Urban Form			
Population density	increase	w	(+) McDonald (2008), Braza et al. (2004)
			(0) Ewing et al. (2004)
Walkability index	increase	w	(+) Kerr et al. (2006)
Sidewalk connectivity	increase	w	(+) Ewing et al. (2004)
Street connectivity	increase	w	(+) Schlossberg et al. (2006)

Note: Adapted from Wilson et al. (2010). w = walk, b = bike, a = auto, (+) increase in travel mode; (-) decrease in travel mode; (0) no effect on travel mode

3.4.1 School HH: high walkability and high student density

The case study school for high walkability and high student density, “School HH”, is located in the core area of the City of Kitchener. Its main frontage is on a primary arterial road, and its secondary frontage is along a major collector road. The land use mix (commercial, institutional and residential) in the area accounts for the high walkability score. The transportation network in the area around the school is primarily grid-like.

School HH draws students from a relatively small geographic area such that no student’s home within the boundary exceeds 1.6 kilometres of the school (see Figure 3-2). The student density is 156 students per kilometre^2. The 2013-2014 school year enrolment was 420 with 25% of the students bused. Table 3-3 shows the income levels for households of Dissemination Areas (DAs) within in the school’s boundary.

Table 3-3. *Household income in 2005 of private households (20% sample data), School HH*

Household income	**% of households within income range**
Under $50,000	60%
$50,000 to $99,999	29%
$100,000 and over	10%

Note: Based on 2006 Census from Statistics Canada, catalogue number 94-581-XCB2006002 (Statistics Canada, No date).

When taking into account all 420 students (bused and non-bused), the mean walking distance from the school to students’ homes (measured by shortest path) is 467 metres. Table 3-4 shows that of the non-bused students living within 1.6 kilometres of the school, 94% (n= 269) live between 0 and 800 metres.

Table 3-4. *Proportion of non-bused students living within 1.6 kilometres from School HH*

	Distance from school (km)							
	≤ 0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6
% of students	13	26	36	18	4	2	0	0

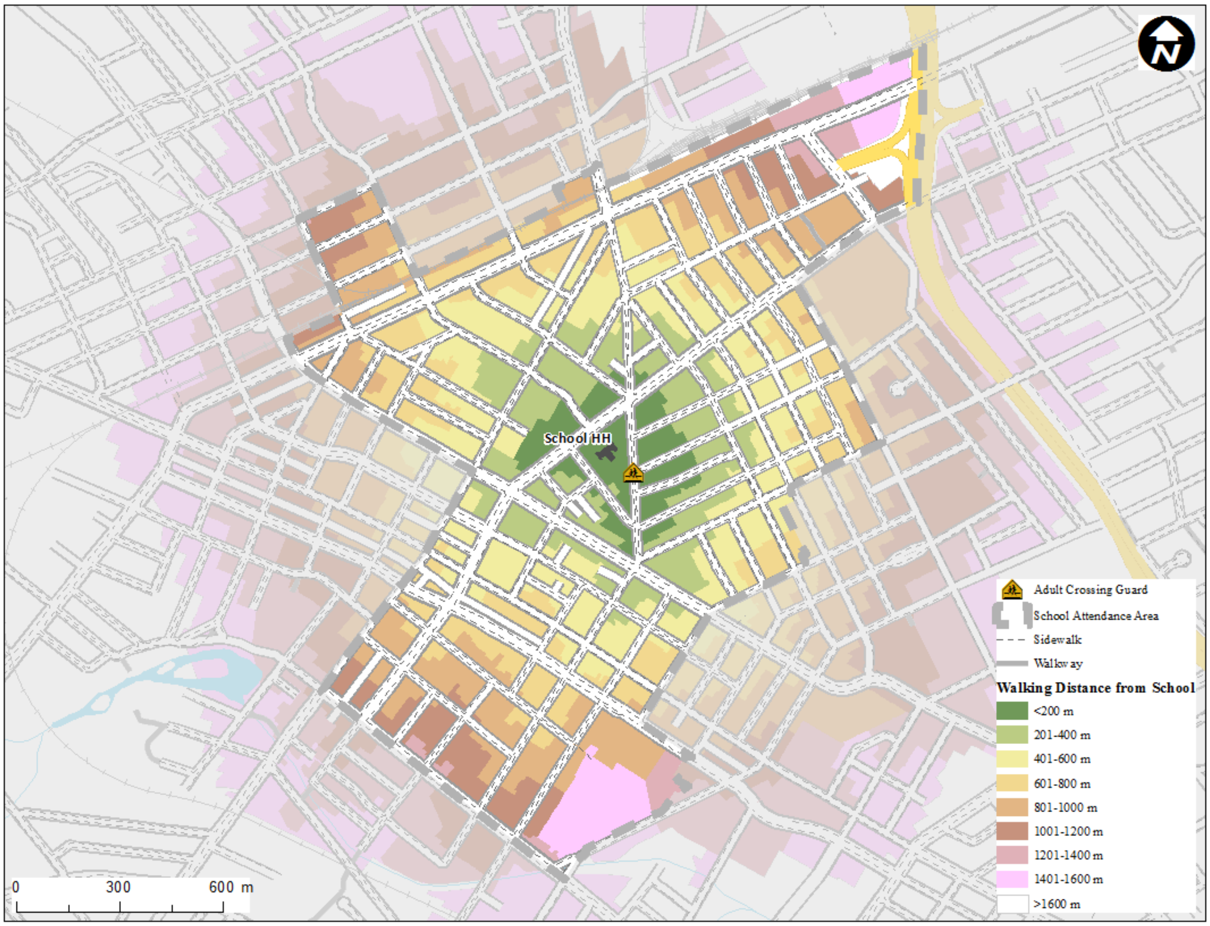


Figure 3-2. *Walking distances from School HH*

3.4.2 School HL: high walkability and low student density

The case study school representing high walkability and low student density, "School HL", is located in the core area of the City of Kitchener. Its frontage is on a primary arterial road and has two side yards fronting local connector roads. The surrounding area comprises a mix of institutional, residential and commercial uses. The transportation network in the area around the school is primarily grid-like, but is bisected in several places by railroad tracks. The student density for the school's attendance area is 90 students per kilometre^2. The 2013-2014 school year enrolment for this school was 289 with 11% of the students bused. Table 3-5 shows the income levels for households of DAs within in the school's boundary.

Table 3-5. *Household income in 2005 of private households (20% sample data), School HL*

Household income	% of households within income range
Under $50,000	62%
$50,000 to $99,999	28%
$100,000 and over	9%

Note: Based on 2006 Census from Statistics Canada, catalogue number 94-581-XCB2006002 (Statistics Canada, No date).

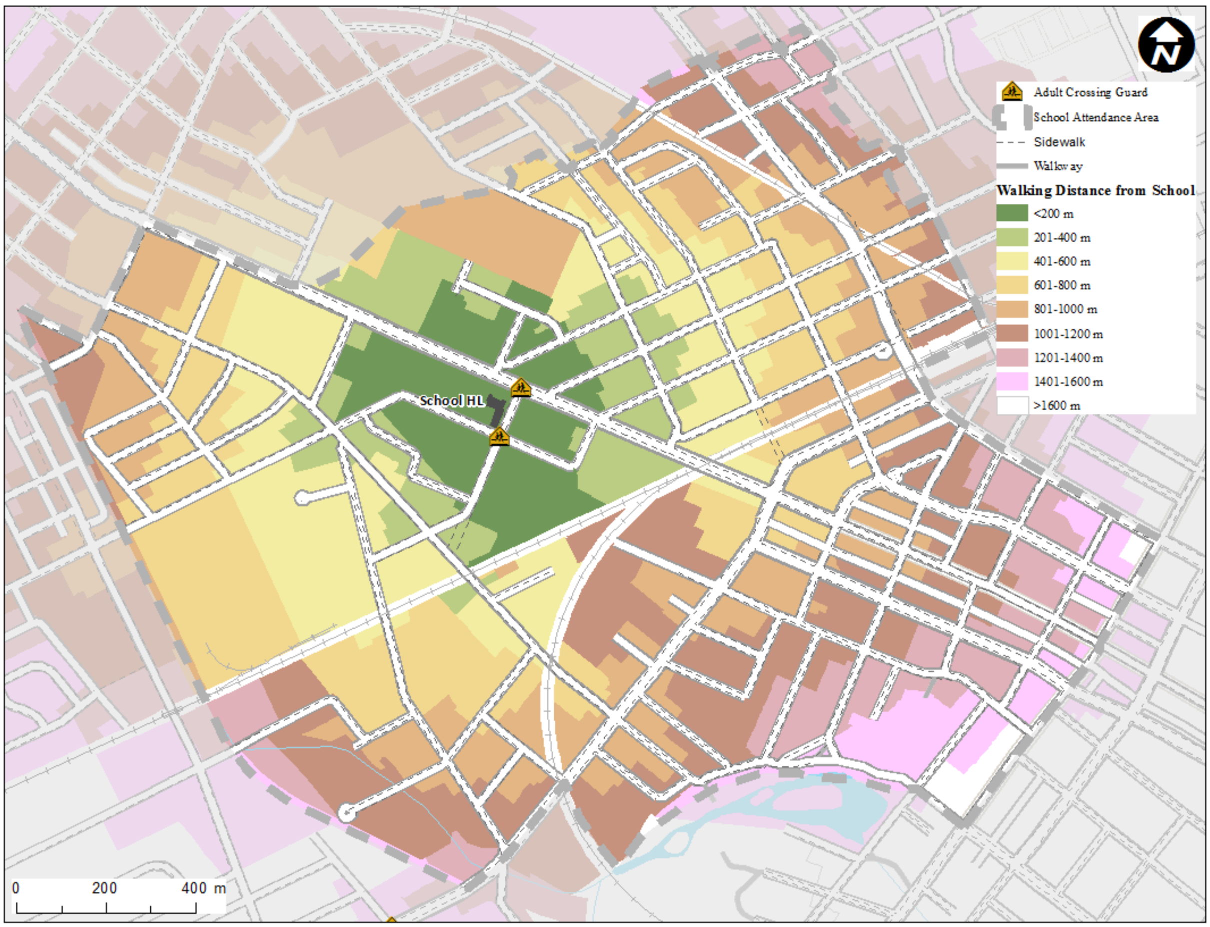


Figure 3-3. *Walking distances from School HL*

The mean walking distance from the school to all students' (bused and non-bused) homes is 849 metres (measured by shortest path). Table 3-6 shows that of the non-bused students living within 1.6 kilometres of the school, 44% (n=248) live between 0 and 800 metres.

Table 3-6. *Proportion of non-bused students living within 1.6 kilometres from School HL*

	Distance to school (km)							
	< 0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6
% of students	8	10	8	18	12	31	8	5

3.4.3 School MH: medium walkability and high student density

The case study school representing medium walkability and high student density is located in a suburban area of the City of Kitchener. This school, "School MH", has frontage on a primary arterial road. The surrounding land uses are institutional (it shares a campus with a municipal park and Catholic elementary school) and residential. The transportation network in the area around the school is primarily curvilinear with several pedestrian walkways connecting roads. There is very good sidewalk coverage in the area, with only a few streets without sidewalks on one or both sides of the road.

The total student density for the school boundary is 238 students per kilometre^2. The 2013-2014 school year enrolment for this school was 713 with 8% of the students bused. Table 3-7 shows the income levels for households of DAs within in the school's boundary.

Table 3-7. *Household income in 2005 of private households (20% sample data), School MH*

Household income	**% of households within income range**
Under $50,000	18%
$50,000 to $99,999	49%
$100,000 and over	32%

Note: Based on 2006 Census from Statistics Canada, catalogue number 94-581-XCB2006002 (Statistics Canada, No date).

When taking into account all 713 students (bused and non-bused), the mean walking distance from the school to students' homes (measured by shortest path) is 733 metres. Table 3-8 shows the percentage of non-bused students within walking distance living at various distances from the school. More than half (60%) of the non-bused students live within 800 metres of the school.

Table 3-8. *Proportion of non-based students living within 1.6 kilometres from School MH*

	Distance to school (km)							
	< 0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6
% of students	31	83	107	152	108	80	46	12

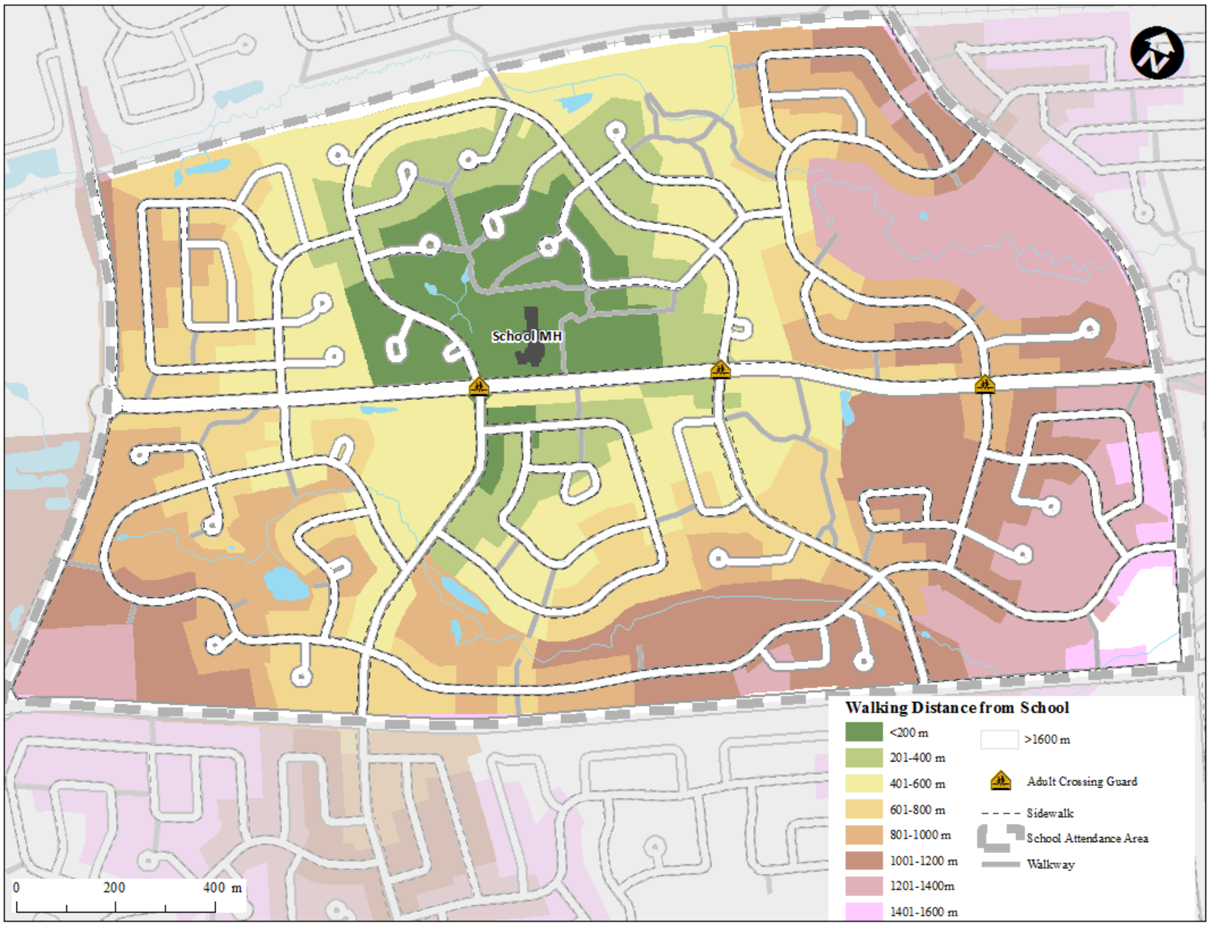


Figure 3-4. *Walking distances from School MH*

3.4.4 School ML: medium walkability and low student density

The case study school for medium walkability and low student density is located in a mature suburban neighbourhood in the City of Waterloo. The transportation network in the area around "School ML" is primarily curvilinear with several cul-de-sacs. A limited number of pedestrian walkways provide connections in strategic areas. There is very good sidewalk coverage in the area, with only a few streets without sidewalks on one or both sides of the road. The 2013-2014 school year enrolment for this school was 285 students. Of the 285 students, 44%

were bused and 15% were attending from outside of the boundary. The student density is 134 students per kilometre^2. Table 3-9 shows the income levels for households of DAs within in the school's boundary.

Table 3-9. *Household income in 2005 of private households (20% sample data), School ML*

Household income	% of households within income range
Under $50,000	28%
$50,000 to $99,999	43%
$100,000 and over	28%

Note: Based on 2006 Census from Statistics Canada, catalogue number 94-581-XCB2006002 (Statistics Canada, No date).

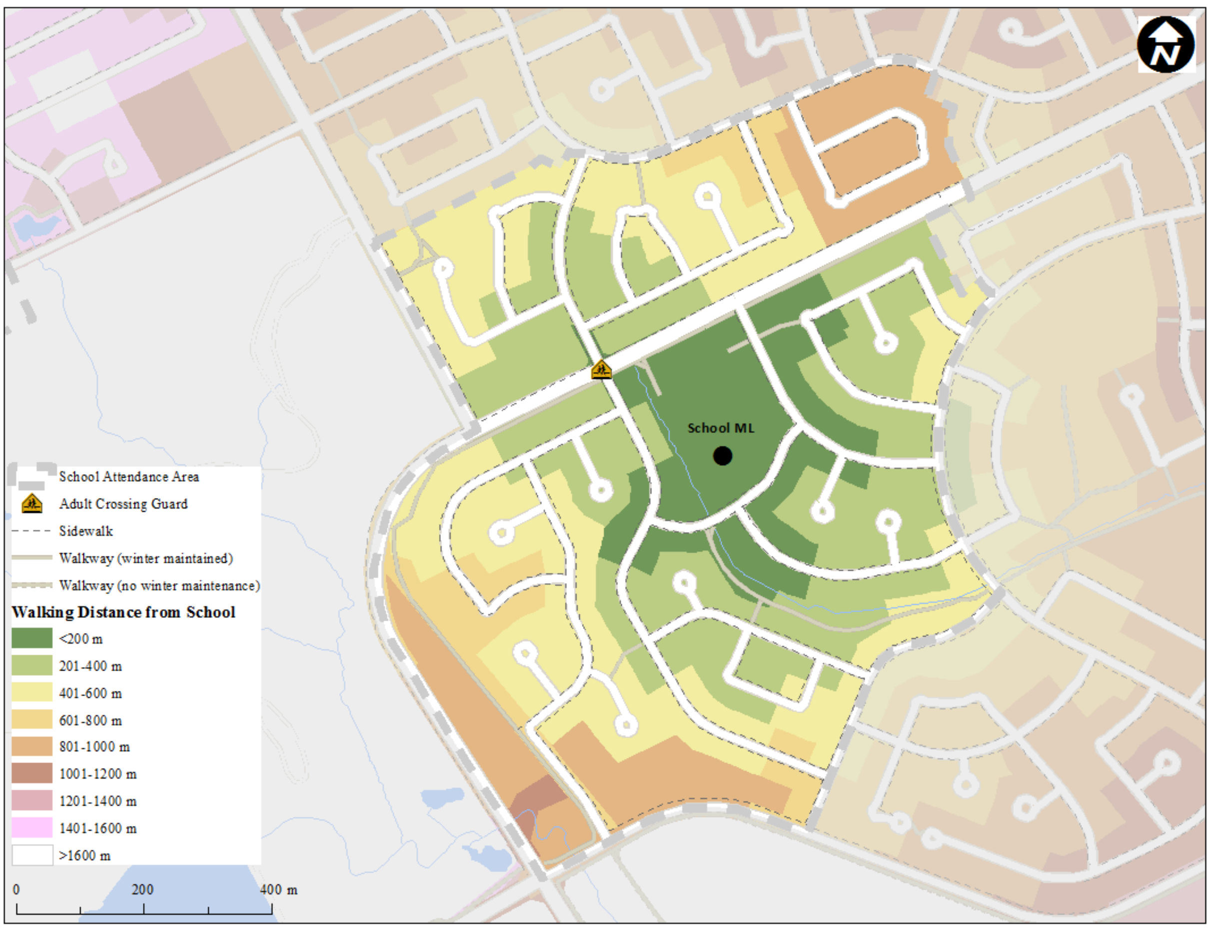


Figure 3-5. *Walking distances from School ML*

When taking into account the 116 non-bused students within 1.6 km of the school, the mean walking distance from the school to students' homes (measured by shortest path) is 456 metres. Table 3-10 that of the non-bused students living within 1.6 kilometres of the school, 88% (n=116) live between 0 and 800 metres.

Table 3-10. *Proportion of non-bused students living within 1.6 kilometres from School ML*

	Distance to school (km)							
	< 0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6
% of students	12	25	47	4	9	2	N/A	N/A

3.5 Analytical approach

While a number of traffic routing systems exist in spatial analysis software (such as GEOREF Systems Ltd.'s BusPlanner software, or ESRI's ArcGIS software), the intent of this research is to facilitate the evaluation of WSBs with existing planning approaches used by transportation consortiums. STSWR and several other transportation consortiums across Ontario use the GEOREF Systems Ltd. BusPlanner software for bus routing. The primary difference between BusPlanner software and the more commonly used GIS software, ArcGIS (ESRI), is its primary focus on school bus routing and optimisation. The BusPlanner software is user ready and is what the majority of transportation consortiums use and have staff trained in; therefore, it was the software chosen for this study.

3.5.1 Data and assumptions

The data for this study come from several sources including the WRDSB, STSWR and the Region of Waterloo. All data sets are from the 2013/2014 school year. The first step was to review and revise the database to determine any necessary adjustments required prior to running any routing trials. The data sets were checked for quality against Municipal Property Assessment Corporation (MPAC) property parcel data and Region of Waterloo (ROW) road network and addressing data. Street addressing in the BusPlanner database is displayed in ranges (from start to end of the road segment), whereas the MPAC/ROW data display addresses directly on the building for which the address is tied. There were several adjustments made to the BusPlanner road network so that addressing more accurately reflected the MPAC/ROW addressing. This is important because the road network is used to calculate distances – a key component of the routing problem. Of the case study schools, modifications to the database took approximately 5 hours per school. This highlights an area of improvement needed for future determinations of student transportation eligibility. Due to the amount of time it takes to do these checks, it would be most productive to start by adjusting the segments within approximately 1.7 kilometres of a school since transportation eligibility starts at 1.6 kilometres.

Since the data sets are typically used for motorized transportation, there were several manipulations required to make the transportation network appropriate for walking routes, including changing the properties of walkways to allow the software to recognize them as part of the routing network for WSBs. Further, roads without sidewalks were coded as roads to avoid for WSB routing.

Other errors that were fixed included addressing on the wrong side of the street, road alignments that did not match those that have been verified using orthophotos (geometrically corrected aerial photograph) and the addition of missing walkways that were winter maintained.

3.5.1.1 WSB stop placement decision

Yang et al. (2014) explained the challenge of selecting WSB routes and stops. They suggested identifying the most beneficial placement of a limited number of bus routes, while more routes might attract more students, this would necessitate the involvement of more adults. Optimizing stop placement would involve either minimizing resources required or the distance a WSB route travels. Therefore, three general stop placement methods were considered: (1) home-based stops, (2) shared stops with optimized placement within a short walk from home, (3) shared stops with optimized placement within an unspecified distance from home (i.e., centralized collection points). To date, there is no empirically tested information on how stop placement influences the use (i.e., participation rates) of a WSB run.

With respect to stop placement, the first method (home-based stops) would likely be the most attractive to parents as it is the most convenient for them and provides supervision directly from the home to the school. From a routing standpoint, home stops would create multiple runs with few students if the distance of the route were not increased from the most direct path a student could take to school. This could be a substantial cost if WSB leaders are paid. In addition, if run distances are increased, the time a run takes is increased, thereby decreasing the likelihood a student would choose to participate in the WSB. Further, not every student lives on the same side of the street; therefore home stops would require the WSB group to make several mid-block crossings, leading to potentially unsafe practices.

The second stop placement method (shared stops with optimized placement a short walk from home) could result in some students being picked up at home stops; however, for those not directly on a route, it could mean a short walk to get to the WSB stop (possibly unsupervised). This type of stop placement is the same used for the current motorized transportation system (busing) in Waterloo Region. The likelihood of use is still high because for many students the time and distance of the run will not vary substantially from their shortest path between home and school. In some instances, however, depending on the transportation network and the location of the students, this method of stop placement may result in runs with few students.

The third option (shared stops with optimized placement within an unspecified distance from home) would result in routing efficiencies as more centralized collection points could be used to generate the most optimal WSB routes. This option minimizes the distances and routes required. The con of this stop placement method, however, is the unspecified distance a student may be required to travel to reach the stop. Since the intention of a WSB program is to provide a convenient way for students travel safely to school, this WSB stop placement method would compromise the program's intentions. Students may be subject to long, possibly unsupervised distances to WSB stops and waits if any of the students on the route happened to be tardy.

Choosing the second stop placement method (shared stops with optimized placement a short walk from home) was based on the pros and cons of all three options. It is the stop placement method already used for busing, and offers a solution that allows for some flexibility in routing decisions without requiring substantial detour distances for students. A maximum distance of 200 metres to the collection point was used. This distance was established after some initial routing trials with the data. It seemed to provide enough of a buffer to allow students to walk to the closest intersections to cross if they were on the opposite side of the road from where the run travelled, or if the student lived on a dead-end street or cul-de-sac. This distance is also corroborated by Yang et al. (2014) who found the greatest proportion of students using the WSB was most effective when routes were placed 200 or 400 metres from existing routes. It is possible to adjust this distance to suit local circumstances.

3.5.1.2 Ratio of students to adults on a WSB run

There is limited research on an appropriate maximum group size for a WSB run. A WSB study conducted by Mendoza et al. (2012) involving Grade 4 students had approximately 8-12 children for every two staff members and averaged 0.8 miles in total length; however, no rationale for using this ratio was provided. The US Centers for Disease Control and Prevention (CDC) recommend "one adult per three children for children ages 4 to 6; one adult for six children for older elementary children ages 7 to 9; fewer adults may be necessary for children ages 10 and older" (The National Center for Safe Routes to School and the Pedestrian and Bicycle Information Centre, 2006, p. 5) in order to allow for adequate adult supervision.

Given the range of ages and lack of definitive research regarding WSB adult-to-student ratios, two options were considered for this study: (1) load WSBs with an unlimited number of students or (2) limit the number of students based on an appropriate student-to-adult ratio. Given one of the objectives of a WSB is to provide a way for students currently ineligible for transportation under the current policies to get to school in a way that is perceived as safe, the number of students on a run needed to be limited. Since the average class size for primary students (Grades 1 to 3) in Ontario is 20, this was the maximum group size used in this analysis. A maximum adult-to-student ratio of 1 to 10 was also used given the range of ages participating in the WSB program (older students can assist with younger ones). Since previous research in this area is limited, it is uncertain if a 1 to 10 ratio in this circumstance is appropriate for the proper function of a WSB.

3.5.1.3 Distance of a WSB run

The maximum distance a student in Grades 1-6 is required to walk to school under existing WRDSB policy is 1.6 kilometres. It was determined that no WSB run should exceed this distance; otherwise, it would be contrary to the policy.

3.5.1.4 Students included in a WSB run

Students who were eligible for bus transportation under existing policies were excluded from the analysis. The only exception to this was for one of the schools where 70 students were considered eligible for bus transportation due to an exception area (i.e., hazard) that deemed it unsafe to cross an arterial road. Since the WSB would provide a supervised crossing in this area, these students were included in the analysis.

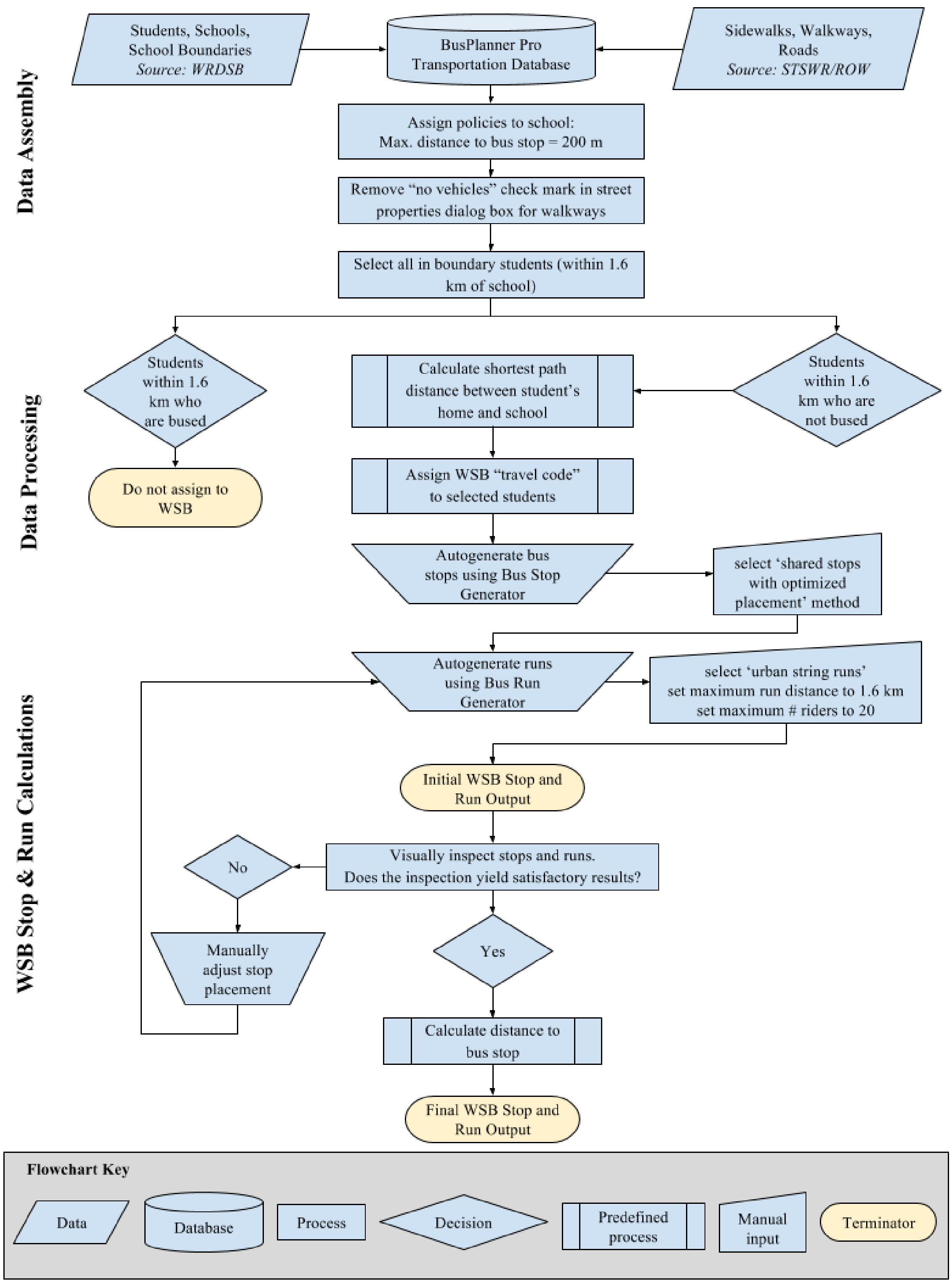
Due to the change in transportation eligibility from Kindergarten to Grade 1, there were no Kindergarten students assigned to WSB runs beyond 0.8 kilometres from the school. Further, no students considered to be out of boundary, regardless of their distances to the school, were included in the analysis. Under existing policy, these students would not qualify for bus transportation; therefore, to exclude these students from the analysis is consistent with existing policy.

3.5.1.5 Number of stops on a WSB run

Each WSB stop contributes to the overall time of a run and therefore necessitates an adjustment to the time at which the first student has to be picked up. There is no research to suggest an ideal number of stops along a WSB run. Given the assumptions already made around stop placement and the maximum distance required to travel to a stop, it was decided not to include a maximum number of stops on a run as a criterion in this analysis.

3.5.2 Routing method

Once the criteria were established BusPlanner Pro software was used to generate the WSB runs. Figure 3-6 illustrates the steps that were taken to determine the best routes along the network between the students' homes and the school. In the context of BusPlanner, "the optimization process is one whereby one or more outcomes of a complex system (a number of busses traveling on a street network) are determined to be the most appropriate or best solution based on given criteria. In this case, "best" normally means the minimum resources required or the shortest distance traveled" (GEOREF Systems Ltd., n.d., p. 2).



Note: WRDSB refers to Waterloo Region District School Board, STSWR refers to Student Transportation Services of Waterloo Region, ROW refers to Region of Waterloo, and WSB refers to Walking School Bus

Figure 3-6. *Walking School Bus routing methodology*

3.6 Policy summary

Policies have the potential to influence travel behaviours. Therefore, student transportation policies can influence school travel modes. To meet the third objective of this thesis (to explore the policy context in which student transportation services are provided in Ontario), it is important to look at the student transportation policies of school boards in Ontario. CMAs with minimum populations of 300,000 (based on the 2011 Census) are of the most relevance in order to provide context to the policies in place at the WRDSB.

Of the nearly two million students in the Province of Ontario, approximately three-quarters live in larger urban areas that comprise the eight largest CMAs in Ontario, each with a population over 300,000 in the 2011 Census. These eight CMAs are characterized by higher urban densities; consequently, large proportions of students live walkable distances from their schools. This context is appropriate for considering walking school buses. Table 3-11 shows these jurisdictions and their respective populations:

Table 3-11. *Census Metropolitan Areas >300,000 and English-Language School Board Jurisdiction*

Census Metropolitan Area Name	2011 Population	English-Language School Board Names
Toronto	5,769,7590	Toronto District School Board Toronto Catholic District School Board Halton District School Board *(Oakville, Milton, Halton Hills)* Halton Catholic District School Board Peel District School Board *(Oakville, Milton, Halton Hills)* Dufferin-Peel Catholic District School Board York Region District School Board York Region Catholic District School Board
Ottawa - Gatineau (Ontario and Quebec)	1,270,232	Ottawa-Carleton District School Board Ottawa Catholic School Board
Hamilton	742,498	Hamilton-Wentworth District School Board Hamilton-Wentworth Catholic District School Board Halton District School Board *(Burlington)* Halton Catholic District School Board *(Burlington)*
Kitchener - Cambridge - Waterloo	492,961	Waterloo Region District School Board Waterloo Catholic District School Board
London	489,461	Thames Valley District School Board London District Catholic School Board
St. Catharines - Niagara	402,563	District School Board of Niagara Niagara Catholic District School Board
Oshawa	367,266	Durham District School Board Durham Catholic District School Board
Windsor	328,321	Greater Essex County District School Board Windsor-Essex Catholic District School Board

Note: Population data is based on 2011 Census counts from CANSIM, table 051-0056 (Statistics Canada, 2015).

Table 3-12 shows the total student enrolment for each English-language school board within these same eight CMAs. These school boards accounted for 74.5% of the total English-language enrolment in the 2012-2013 academic year (Ministry of Education, 2013a). Just two English-language school boards with enrolments over 100,000 are not included in this list: Simcoe County District School Board and the Upper Canada District School Board. French-language boards were not included because of their vast geographies and the difference in population served when compared to English-language schools in general and to the WRDSB in particular. The WRDSB is the ninth largest English-language school board in the Province in terms of total enrolment.

Table 3-12. *Enrolment at English-Language School Boards in CMAs >300,000 (2012-2013 academic year)*

School Board	Elementary	Secondary	Grand Total
London District CSB	12,113	7,623	19,736
Waterloo CDSB	14,814	6,984	21,798
Durham CDSB	14,524	8,165	22,689
Windsor-Essex CDSB	14,269	8,431	22,700
Niagara CDSB	15,164	7,975	23,139
Hamilton-Wentworth CDSB	18,594	11,182	29,776
Halton CDSB	20,325	10,286	30,611
Greater Essex County DSB	23,930	12,551	36,481
DSB Niagara	24,146	13,620	37,766
Ottawa CDSB	24,369	14,699	39,068
Hamilton-Wentworth DSB	34,178	16,972	51,150
York CDSB	37,374	18,440	55,814
Halton DSB	41,277	18,875	60,152
Waterloo Region DSB	*41,778*	*21,339*	*63,117*
Durham DSB	46,635	23,192	69,827
Ottawa-Carleton DSB	48,140	24,744	72,884
Thames Valley DSB	50,479	25,431	75,910
Dufferin-Peel CDSB	50,403	34,171	84,574
Toronto CDSB	60,682	30,932	91,614
York Region DSB	80,606	39,678	120,284
Peel DSB	109,232	45,164	154,396
Toronto DSB	172,545	83,512	256,057
Grand Total	955,577	483,966	1,439,543

Note: Adapted from *Ontario public schools enrolment*. Ministry of Education (2013a). Retrieved from *http://www.ontario.ca/education-and-training/ontario-public-schools-enrolment*. Queen's Printer for Ontario.

Chapter 4. Results

4.1 Introduction

A child's ability to move independently in a safe manner is defined by the range of environmental contexts in which they can safely travel: the younger they are the more restrictive the dimensions. One objective of this study was to develop a set of metrics to evaluate the potential for the implementation of WSB programs and to measure these metrics by establishing WSB routes for four WRDSB elementary schools in neighbourhoods with varying levels of walkability and student density. The results of these metrics provide a standard of measurement to determine the extent to which a WSB program is successful, and to compare the results amongst four different neighbourhoods.

The following four sections utilize the metrics outlined in Table 3-1 to complete this evaluation. Since the case study schools do not presently operate WSB programs, these metrics first are applied to the current situation (i.e., the shortest path walking distance) in each of the four neighbourhoods. This provides a baseline against which to compare the results of the WSB runs. Next, the metrics are applied to the WSB routing developed for each of the four schools to ascertain if neighbourhood walkability and student density characteristics have any impact on safety, convenience and cost outcomes of WSBs.

The final section of this chapter provides the synthesis of the policy context in which student transportation services are provided in Ontario. This section synthesizes the transportation eligibility criterion for Ontario school boards with CMAs greater than 300,000. This provides the context for the policies in place at the WRDSB.

4.2 Current situation (shortest path) all schools

Considering the situation where a school has no WSBs, the shortest path is therefore the walking distance between two nodes (home and school) using the available street, sidewalk and walkway network. The shortest path may not take into account short cuts through private property that students may use in reality. Prior to applying the metrics outlined in Table 3-1 to the WSB routes, it is important to understand first the current situation at all four schools.

4.2.1 Safety (shortest path) all schools

Safety can be evaluated in several different ways; however, the most important in this case is exposure to risk. Risk exposure can be measured in two ways: (1) exposure to unsupervised travel and (2) exposure to vehicular traffic. It is important to note these are both proxy measures of risk; actual risk is a function of many variables that are not easily measured or quantified. Since this study did not involve any traffic counts or observations, the focus of this evaluation is on unsupervised travel.

Currently no formal programs at any of the four case study schools offer supervision of students on their journey to school (other than parental supervision); therefore, the entire journey is classified as unsupervised. For the purposes of this evaluation, under the current situation a student's route to school by walking is considered to have 100% exposure to unsupervised travel.

Exposure to risk can also be measured by the number and type of intersections students would be required to cross on their own. A major intersection in this case is defined as an intersection containing at least one arterial road that generally contains more than two lanes of traffic. In the absence of a WSB program, nearly all major intersections would be considered a potential risk. The exception would be where there is already the supervision of an adult crossing guard or student safety patrol. Table 4-1 summarizes the average number and types of intersections crossed when a student travels on his/her shortest path.

Table 4-1. *Average number and type of intersections crossed via shortest path*

	School HH	School HL	School MH	School ML	Total
Total number of students (n)	269	248	619	116	1252
Total number of intersections (n)	851	1166	1733	243	3993
Intersections*	3.2	4.7	2.8	2.1	3.2
Major intersections*	1.4	1.0	1.4	0.2	1.2
Intersections with traffic signals*	0.9	1.7	1.1	0.2	1.1
Intersections with Adult Crossing Guard (supervised)*	0.4	0.8	1.1	0.2	0.8
Intersections with Student Safety Patrol (supervised)*	0.6	0.0	0.0	0.4	0.2
Proportion of intersections that are major	38%	25%	50%	10%	38%
Proportion of intersections that are supervised	37%	20%	41%	33%	30%

*average (or per student)

Another measurement of risk exposure is travel distance – as distance increases, exposure to risk increases all other factors being held equal. The total shortest path distance for all 1252 students modelled is 842,773 metres, or an average of 673 metres. Table 4-2 shows the variation in shortest path travel distances for all four schools.

Table 4-2. *Shortest path travel distances by school*

	School HH	School HL	School MH	School ML
Total number of students (n)	269	248	619	116
Total distance (metres)	125,586	210,538	453,749	52,899
Average distance (metres)	467	849	733	456
Maximum distance (metres)	1206	1497	1450	1088
Minimum distance (metres)	8	48	65	13

4.2.2 Convenience (shortest path)

From the perspective of a student, there are two dimensions in evaluating convenience: (1) distance as measured by the length of the shortest path between home and school; and, (2) time as measured by the travel time between home and school. Distance and time have a positive relationship – as distance increases, travel time increases. Indeed, given the lack of data on individual students, a constant walking speed is assumed for all; and thus these two variables effectively are surrogates for one another.

The convenience of school travel is highest for those with the lowest shortest path distance. As Table 4-2 shows, the average total distance between a student's home and school varies between schools. This variation may be explained by a number of factors including, but not limited to the size of the attendance area, land use (proximity of residential land uses to the school) and presence of supportive infrastructure (e.g., sidewalks, walkways, etc.). For example, 88% of School ML and 94% of School HH non-bused students live within 800 metres of the school; therefore, these two schools have the lowest average shortest path travel distances (see Table 4-2). In comparison, School HL with 44% and School MH with 60% of non-bused students living within 800 metres of the school, results in the highest average and total shortest path travel distances (see Table 4-2).

There is a likely a difference in trip time when walking to school in a group versus alone since the pace of the group is only as fast as the slowest student. Using the accepted average walking pace for younger pedestrians of 1.22 metres per second (Knoblauch et al., 1996), the shortest path distance travel time between home and school was estimated for each student. The results are shown in Figure 4-1 and Figure 4-2. For all schools combined, the greatest number of trips are between 7 and 8 minutes long, and over half (53%) of all trips are less than 8 minutes.

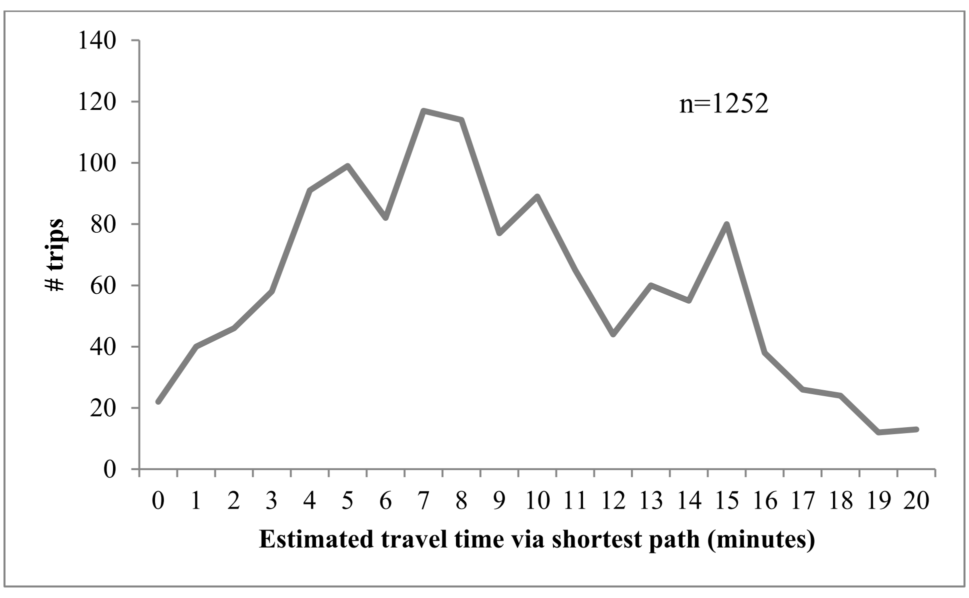


Figure 4-1. *Estimated travel time via shortest path (all schools)*

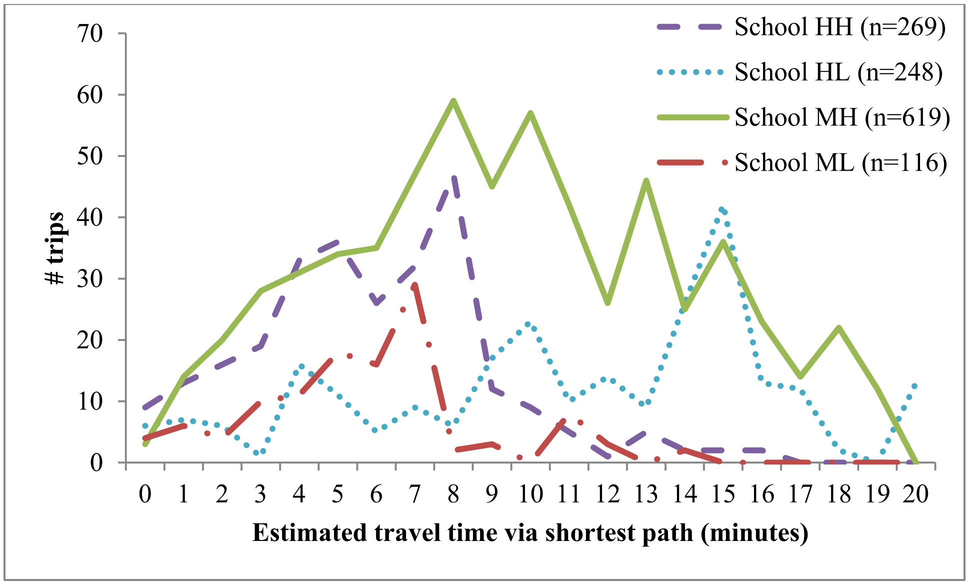


Figure 4-2. *Estimated travel time via shortest path by school*

Convenience for a parent as it relates to ASST must also be taken into account. As noted in Section 2.5.3, Safe Kids Worldwide (2015) recommends that children under the age of ten cross the street with an adult or older child. Therefore, the majority of elementary school-aged students may require supervision to and from school.

Generally, it takes a parent nearly twice as long to walk their child to school as it takes the student because the parent is making a return trip (there may be, however, instances where the parent continues on to other activities). According to Bohannon (1997), the average comfortable walking speed of adults aged 20 to 79 years is 1.38 metres per second. Using the average walking pace for children (1.22 metres per second) for the first leg of the trip (to school) and the average walking pace for adults (1.38 metres per second) for the second leg of the trip (to home), the estimated shortest path time for parents was calculated. It is important to note the calculations are done with the assumption these trips are walking trips only, which may not be the case. Table 4-3 summarizes the shortest path travel times for parents. On average, it would take parents just over 17 minutes to walk their children to school and return home. If done twice a day (drop-off and pick-up), it would amount to approximately 35 minutes daily.

Table 4-3. *Shortest path travel times by school (parent)*

	School HH	School HL	School MH	School ML	Total
n	269	248	619	116	1252
Average walking time (minutes)	12:01	21:50	18:52	11:44	17:19
Maximum walking time (minutes)	31:02	38:31	37:20	28:00	38:31
Minimum walking time (minutes)	00:12	01:14	01:40	00:20	00:12

4.2.3 Cost (shortest path)

The current costs associated with the journey to school are direct and indirect human resources. First, each of the four schools has at least one adult crossing guard in the neighbourhood; the guard assists students with crossing major intersections. The adult crossing guards are employed by the local municipalities and work every school day before the morning bell time and after the afternoon bell time.

The next cost is associated with school administration or school employees. Two schools employ a parking lot attendant to control traffic on the school site every morning and afternoon. For the schools without parking lot attendants, often a teacher, Principal or Vice-Principal is assigned to monitoring vehicular traffic around the school site. Table 4-4 provides a breakdown of these human resources for all four schools under the current situation.

Table 4-4. *Human resources allocated for current situation (shortest path)*

Resource	School HH	School HL	School MH	School ML
Adult Crossing Guard	0.17 FTE	0.33 FTE	0.92 FTE*	0.13 FTE
Parking Lot Attendant	0.00 FTE	0.14 FTE	0.14 FTE	0.00 FTE
Total	**0.17 FTE**	**0.47 FTE**	**1.06 FTE**	**0.13 FTE**

Note: FTE refers to Full-Time Equivalent
* shared between two schools

4.3 Walking School Bus program at School MH

WSB routes were developed for all four case study schools. The following analysis focuses on the routes developed for case study School MH (medium walkability and high student yield). All four schools will then be compared in Section 4.4.

4.3.1 Safety (WSB) School MH

For students at School MH, participation in a WSB program would reduce the exposure to unsupervised travel by 95% (from an average of 733 metres to 35 metres). Table 4-5 shows the extent of this exposure by demonstrating the frequency of unsupervised travel for all 619 students attending School MH. When participating in a WSB, only 1% of students would be unsupervised for more than half of their routes (average unsupervised distance for those with more than 50% of their route unsupervised is 122 metres). The remaining 99% had an average supervised distance of 37 metres. This remnant exposure to risk due to the lack of supervision (the distance between home and the WSB stop) is shown on Figure 4-3.

Table 4-5. *School MH: Exposure to unsupervised travel via Walking School Bus*

Proportion of route unsupervised	% of all students
0-10%	80.3%
11-20%	12.9%
21-30%	3.4%
31-40%	1.8%
41-50%	0.6%
51-60%	0.2%
61-70%	0.0%
71-80%	0.2%
81-90%	0.6%
91-100%	0.0%

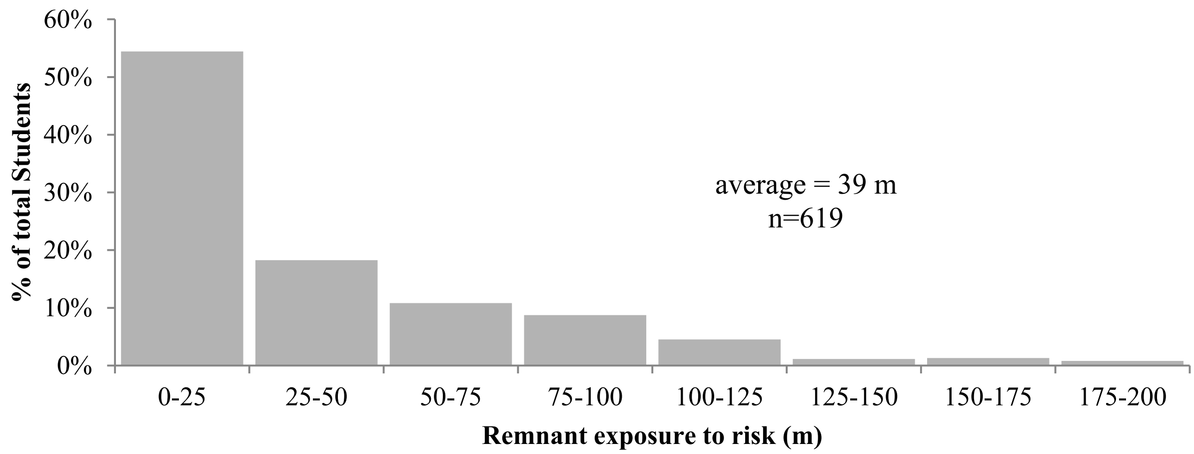


Figure 4-3. *School MH: Remnant exposure to risk (unsupervised travel distance) via Walking School Bus*

When participating in a WSB program, the average number of unsupervised crossings is reduced by 29% (from 39% to 10% of all intersections remaining unsupervised). The unsupervised crossings that remain are the result of travel to the WSB stop. Further, all the major intersections would be supervised (i.e., 38% of the intersections crossed). In comparison, only 79% of all major intersections crossed by students via shortest path are supervised. Table 4-6 summarizes the average number and types of intersections crossed when students travel by WSB.

Table 4-6. *School MH average number and type of intersections crossed via Walking School Bus*

	School MH
Total students (n)	619
Total intersections (n)	1854
All intersections*	3.0
Major intersections*	1.1
Intersections with traffic signals*	1.0
Intersections with Adult Crossing Guard (supervised)*	1.1
Intersections with Student Safety Patrol (supervised)*	0
Proportion of intersections that are major	38%
Proportion of intersections that are supervised	90%

*average (or per student)

The average distance traveled for a School MH student on a WSB is 781 metres, but the average run distance is 944 metres. Table 4-7 breaks down the WSB run distances for School MH.

Table 4-7. *School MH Walking School Bus run distances*

	School MH
Average run distance (metres)	944
Minimum run distance (metres)	322
Maximum run distance (metres)	1587

Some safety aspects were mitigated in the routing decisions. For example, streets without sidewalks were avoided where possible. If the WSB route was on one side of the street and a student lived on the other, the student was directed to the nearest intersection to join the WSB. For some students this resulted in backtracking, but for others, it increased the unsupervised distance of their route. In addition, if a road segment had sidewalks on both sides of the road the WSB route followed the side with the fewest intersection crossings, provided it did not add distance to the route.

Other safety aspects considered in the routing included the location of WSB stops. In cases where large groups of students were assigned to a single stop, the stop was placed at a location that could hold students as they wait for the WSB to arrive. For example, stops were located at the entrances to pathways or along stretches of sidewalk along “side yards” to provide sufficient space to accommodate a group of students without blocking driveways.

The reduction of vehicular traffic in neighbourhoods as a result of WSBs replacing vehicular trips to school may also contribute to a reduction in injury potential as a result of pedestrian-vehicle collisions, thereby improving safety overall. This metric cannot be calculated without knowledge of the extent to which current vehicular trips would be substituted for WSB trips. Risk reduction could be measured by traffic counts before and after the implementation of a WSB program to determine the extent of the mode shift achieved through the program.

4.3.2 Convenience (WSB) School MH

When analysing the overall walk times for students traveling on WSB routes (using a walking pace of 1.22 metres per second), it would take the majority of students (85%) from School MH 15 minutes or less to walk to school (see Figure 4-4). This is 4% fewer students (89% within 15 minutes or less) than the time calculated for the shortest-path (see Figure 4-2). It takes a School MH student on average 39 seconds more to get to school via WSB (average shortest path time is 10:01, and average WSB time is 10:40).

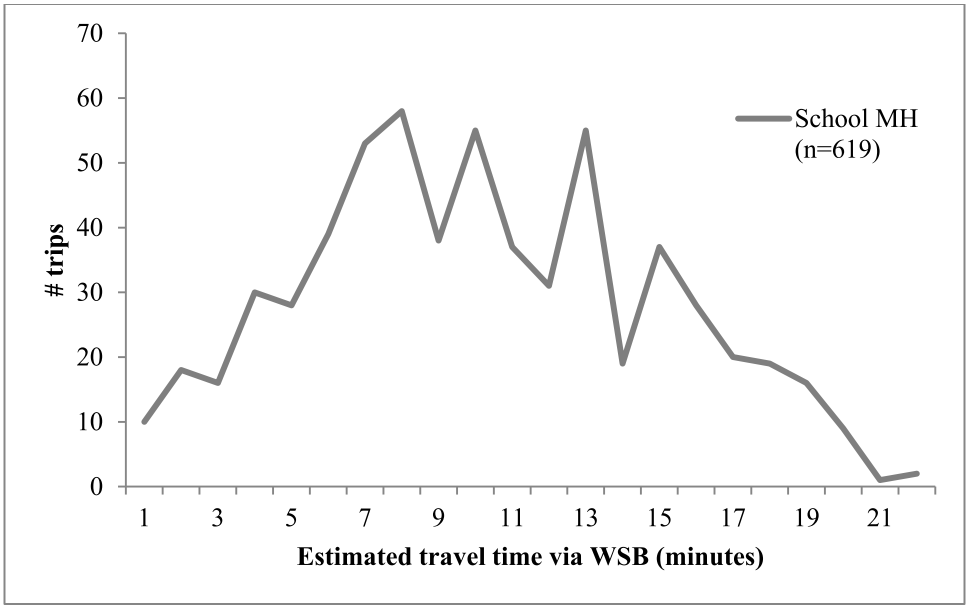


Figure 4-4. *Estimated travel time via Walking School Bus (School MH)*

The design of the WSB could affect the amount of time a route takes, especially if the group is required to wait at WSB stops or at intersections. Further, the number and age of students on a run could also affect the pace. It is therefore assumed that notwithstanding design, it would take a student participating in a WSB more time to travel the same route as their shortest path.

An average savings of approximately 36 minutes per day can be realized for School MH parents who currently accompany their children on the walk to and from school. The parental timesaving for the entire school are summarized in Table 4-8.

Table 4-8. *Walking School Bus parental timesaving for a School MH parent*

	School MH
n	619
Average walking time savings (minutes)	17:58
Maximum walking time savings (minutes)	37:18
Minimum walking time savings (minutes)	00:00

The downside to the parent no longer supervising their child on the journey to and from school is that they would not be achieving the health benefits of the physical activity (walking). If the parent were not currently transporting their child by inactive modes, this physical activity would be built into their daily schedule. Instead, the parent would have to make up this time in another way. Therefore, if choosing to forego replicating the physical activity time not achieved through escorting their child to school, a parent would not achieve a net timesaving benefit through their child's participation in a WSB program.

Parents most commonly cited "perceived distance from school" as their reason for not using active transportation (see Section 2.4). In the case of determining whether a student would join a WSB, the extent of the detour (measured by distance) a student may encounter via WSB relative to shortest path is a critical decision point. Figure 4-5 shows the frequency distribution of students by their detour distance (includes the distance between home and the WSB stop) via their assigned WSB route. The distance to school by WSB accounts for distance to the pick-up point and from the pick-up point to the school via WSB.

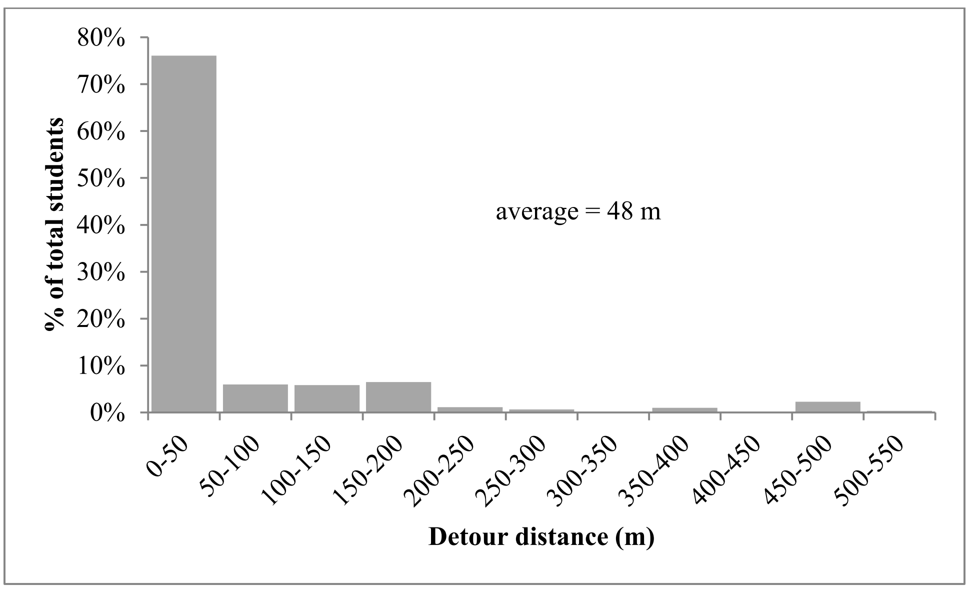


Figure 4-5. *Frequency distribution of the calculated detour distance via WSB for School MH*

The majority (82%) of students from School MH had a calculated detour distance of less than 100 metres and 3% of students had a calculated detour distance between 400 and 550 metres. For 66% of the students, this distance was less than 10 metres and over half (54%) of students had no detour at all.

4.3.3 Cost (WSB) School MH

There are several cost implications that can be highlighted in the routing outcomes. First, if the intention were for the WSB leaders to be paid, costs would increase as the number of runs increases. When the maximum number of riders per run is set to 20 students, 34 runs are required for School MH (see Figure 4-6). Since the adult-to-student ratio was set to 1:10 (1 adult to 10 students), then 68 adults would be needed to operate an inclusive WSB program at School MH (a program that would see all 619 students participating).

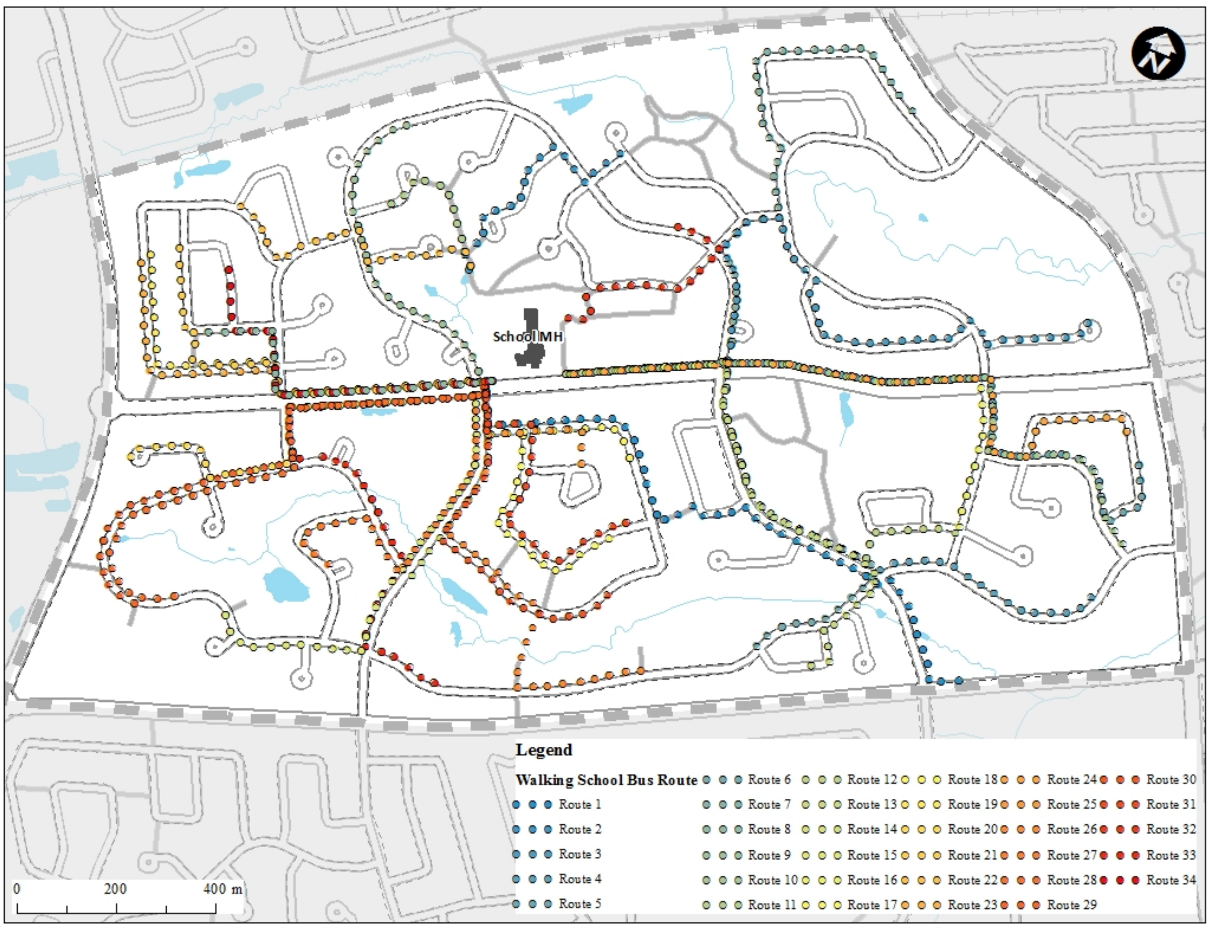


Figure 4-6. *School MH Walking School Bus routes*

If WSB leaders are paid, it is important to understand the amount of time they would be required to work on a daily basis. The average return trip for School MH WSB routes is 24 minutes and 18 seconds. The travel time for each route on the way to school (with students) is calculated by the average walking pace of a child (1.22 metres per second). The travel time for the return trip, (back to the starting point) is calculated by the average walking pace of an adult (1.38 metres per second). Table 4-9 summarizes the WSB leader time for School MH.

Table 4-9. *Walking School Bus leader time for School MH for morning run*

	School MH
Number of runs	34
Number of students	619
Average run time with students (minutes)	12:54
Average return time without students (minutes)	11:24
Average total daily time (minutes)	24:18
Minimum total daily time (minutes)	8:17
Maximum total daily time (minutes)	40:51

If calculating staff time on a 35 hour a week work schedule, then the 34 WSB runs at School MH would require the equivalent of 2.18 FTE (when run times are rounded up to the closest minute). However, it is unlikely that WSB leaders would be paid by the minute, so rounding up to the nearest quarter of an hour, the 34 WSB routes at School MH would require the equivalent of 5.07 FTE for all morning and afternoon runs.

One of the challenges to supporting the inclusive WSB model at School MH would be finding 68 adults willing to work a couple of hours a day for a minimal rate of pay, 10 months of the year. Some parents who are already making the trip with their child, however, may be interested in leading a WSB to supplement their income. Further, there are substantial budget implications considering these students cost the board nothing under the current transportation policy. Therefore, the implementation of WSBs routes at a 1:10 ratio with paid WSB leaders is likely cost-prohibitive if implemented at a large scale.

4.4 Walking School Bus program all schools

4.4.1 Safety (WSB) all schools

Considering all four case-study schools, the WSB program would cut down exposure to unsupervised travel by 93%. Table 4-10 shows the extent of this exposure reduction by demonstrating the frequency of unsupervised travel for all 1252 students included in the analysis. When participating in WSBs, approximately 98% of the students would receive supervision for more than half of their route (average unsupervised distance is 33 metres). The remaining 2%

would have an average unsupervised distance of 120 metres. Overall, this translates into an average reduction of 717 metres of unsupervised travel (from 752 metres by shortest path to 35 metres by WSB). Figure 4-7 shows this remnant exposure to risk (the distance to the WSB stop).

Table 4-10. *Exposure to unsupervised travel when participating in a Walking School Bus program*

Proportion of route unsupervised	% of total students
0-10%	78.8
11-20%	14.0
21-30%	3.8
31-40%	1.2
41-50%	0.6
51-60%	0.3
61-70%	0.0
71-80%	0.5
81-90%	0.6
91-100%	0.3

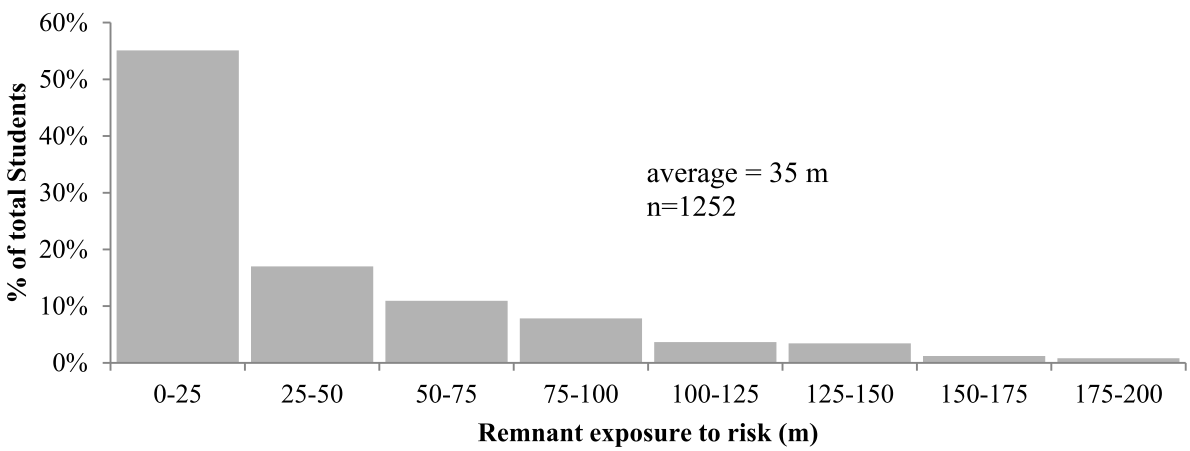


Figure 4-7. *Remnant exposure to risk (unsupervised travel distance) when participating in a WSB program*

When participating in a WSB program, the average number of unsupervised crossings is a reduction of 61% (from 70% to 9% of all intersections remaining unsupervised). Further, all the major intersections would be supervised (33% of the intersections crossed). In comparison, only 66% of all major intersections crossed by students via shortest path are supervised. Table 4-11 summarizes the average number and types of intersections crossed when students travel by WSBs.

Table 4-11. *Average number and type of intersections crossed via Walking School Bus*

	School HH	School HL	School MH	School ML	All Schools
Total students (n)	269	248	619	116	1252
Total intersections crossed (n)	901	1241	1854	259	4255
All intersections*	3.3	5.0	3.0	2.2	3.4
Major intersections*	1.1	1.6	1.1	0.2	1.1
Intersections with traffic signals*	0.8	2.0	1.0	0.2	1.1
Intersections with Adult Crossing Guard (supervised)*	0.4	0.8	1.1	0.2	0.8
Intersections with Student Safety Patrol (supervised)*	0.4	0.0	0.0	0.4	0.3
Proportion of intersections that are major	34%	31%	38%	10%	33%
Proportion of intersections that are supervised	90%	93%	90%	88%	91%

* Average (or per student)

As Table 4-11 shows, School HL has the most intersections per student (all intersections and major intersections) and School ML has the least. School HL, however, has the highest proportion of intersections that are supervised amongst all four schools and School ML has the lowest. School ML students have by far the fewest major intersections to cross (21-28% fewer than the other schools).

The average distance traveled for a student on a WSB is 717 metres, but the average run distance is 954 metres. Table 4-12 breaks down the WSB run distances for all schools.

Table 4-12. *Walking School Bus run distances for all schools*

	School HH	School HL	School MH	School ML	All Schools
Total runs (n)	14	15	34	8	71
Average run distance (metres)	876	1162	944	740	954
Minimum run distance (metres)	386	328	322	417	322
Maximum run distance (metres)	1368	1525	1587	1098	1587

4.4.2 Convenience (WSB) all schools

It would take the majority of students (86%) 15 minutes or less to walk to school (see Figure 4-8) when travelling by WSB (using a walking pace of 1.22 metres per second). This is 5% fewer students (91% within 15 minutes or less) than the time is calculated for the shortest-path (see Figure 4-2). It takes a student on average an additional 1 minute and 3 seconds more to get to school via WSB (average shortest path time is 9:12, and average WSB time is 10:15).

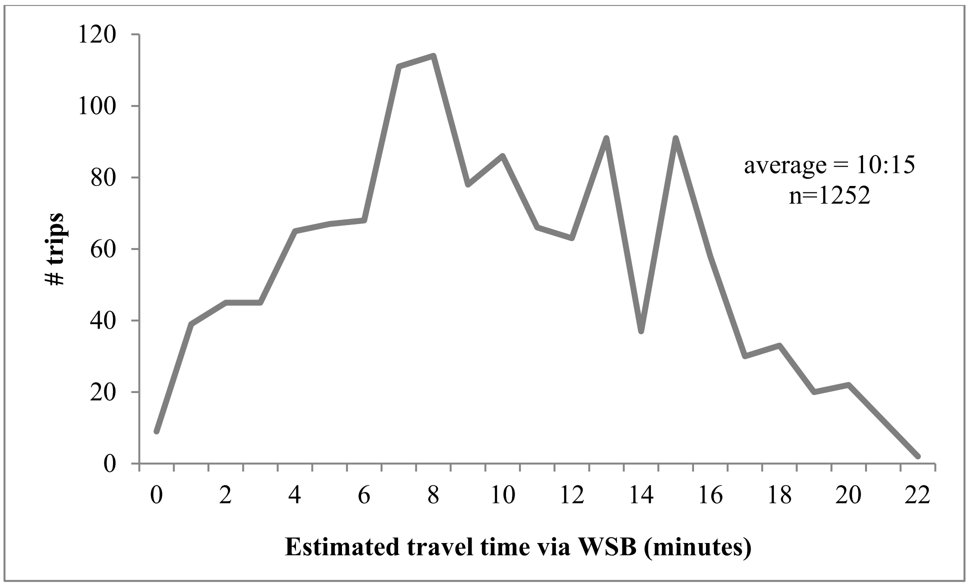


Figure 4-8. *Estimated travel time via Walking School Bus (all schools)*

An average savings of approximately 16 minutes can be realized for parents if their children participate in WSB programs – especially for parents of younger students who do not make the journey without supervision. That translates in to an average of almost 33 minutes saved per day. The parental timesaving by school is summarized in Table 4-13. The average time saved varies by school, with School HL benefiting from the greatest time saved (approximately 21 minutes).

Table 4-13. *WSB parental timesaving by school (based on one round trip)*

	School HH	School HL	School MH	School ML	All Schools
n	269	248	619	116	1252
Average walking time saved (minutes)	10:59	21:03	17:58	10:55	16:26
Maximum walking time saved (minutes)	30:57	38:31	37:18	27:40	38:31
Minimum walking time saved (minutes)	00:00	00:03	00:00	00:00	00:00

4.4.3 Cost (WSB) all schools

The number of WSB runs varied significantly between the four schools. Basic calculations suggest that if every run were loaded fully to 20 students, approximately 63 runs would be required for all four schools; however, eight additional runs were necessary to account for the geographical distribution of students and to limit the length of the runs to 1.6 kilometres. Table 4-14 summarizes the WSB leader time for all schools.

Table 4-14. *Walking School Bus leader times for morning run (all schools)*

	School HH	School HL	School MH	School ML	All Schools
Number of runs	14	15	34	8	71
Number of students	269	248	619	116	1252
Average run time with students (minutes)	11:58	15:52	12:54	10:06	13:02
Average return time without students (minutes)	10:35	14:02	11:24	8:56	11:31
Average total daily time (minutes)	22:33	29:54	24:18	19:03	24:33
Minimum total daily time (minutes)	9:56	8:27	8:17	10:44	8:17
Maximum total daily time (minutes)	35:12	39:16	40:51	28:15	40:51
Estimated FTE (rounded to ¼ hr)	2.00	2.71	5.07	0.93	10.71

Note: FTE refers to Full-Time Equivalent

If calculating staff time on a 35 hour per week work schedule, the 71 WSB runs at all four schools, would require the equivalent of 10.71 FTE for all morning and afternoon runs if rounding times up to the nearest quarter of an hour.

The other cost is the time it takes to generate WSB routes for a school (labour), and ultimately all of the schools in the system. Although the GIS software and data sets already exist, there was a considerable amount of time required to modify the network to account for pedestrian rather than automotive connectivity (e.g., changing the properties of a walkway or pathway to allow the software to classify it as a usable segment in the routing network). The initial routing was done through the software's built-in auto-generation algorithms; however, manual manipulation and interpretation was also required. This is a significant consideration for the initial set-up of WSB routing. Once the routes are established, and the students remain geographically distributed in a similar fashion, there would be a reduction in the time required for route/run maintenance. A program coordinator is an additional human resource cost that needs to be considered. The capacity of the coordinator (i.e., the number of schools a coordinator could support) is unknown at this time.

In terms of cost-savings, there are unmeasured health benefits that students may receive through participation in WSB programs that feed directly into the health care system. There may also be further long-term cost-saving implications on the environment and transportation systems. These cost-savings are not easily quantifiable.

4.5 Walking School Bus program neighbourhood comparison

4.5.1 Safety (WSB) neighbourhood comparison

Between neighbourhoods, there was little variation with respect to exposure to unsupervised travel. Table 4-15 shows the extent of this exposure by demonstrating the frequency of unsupervised travel for all four schools included in the analysis. When participating in WSBs, the proportion of students supervised for more than half of their route varied between 97.4% and 99%. The remaining 1% to 2.6% had an average unsupervised distance ranging from 116 to 188 metres (School HH =123, School HL = 116, School MH = 122, School ML = 188 metres). Figure 4-9 shows this remnant exposure to risk (the distance to the WSB stop).

Table 4-15. *Exposure to unsupervised travel when participating in a Walking School Bus program (school-by-school comparison)*

	% of total students				
Proportion of route unsupervised	School HH	School HL	School MH	School ML	All Schools
0-10%	72.1	85.1	80.3	72.4	78.8
11-20%	17.1	11.3	12.9	18.1	14.0
21-30%	7.1	1.6	3.4	3.4	3.8
31-40%	1.1	0.0	1.8	0.9	1.2
41-50%	0.0	0.0	0.6	2.6	0.6
51-60%	0.4	0.8	0.2	0.0	0.3
61-70%	0.0	0.0	0.0	0.0	0.0
71-80%	0.0	0.8	0.2	2.6	0.5
81-90%	0.7	0.4	0.6	0.0	0.6
91-100%	1.5	0.0	0.0	0.0	0.3

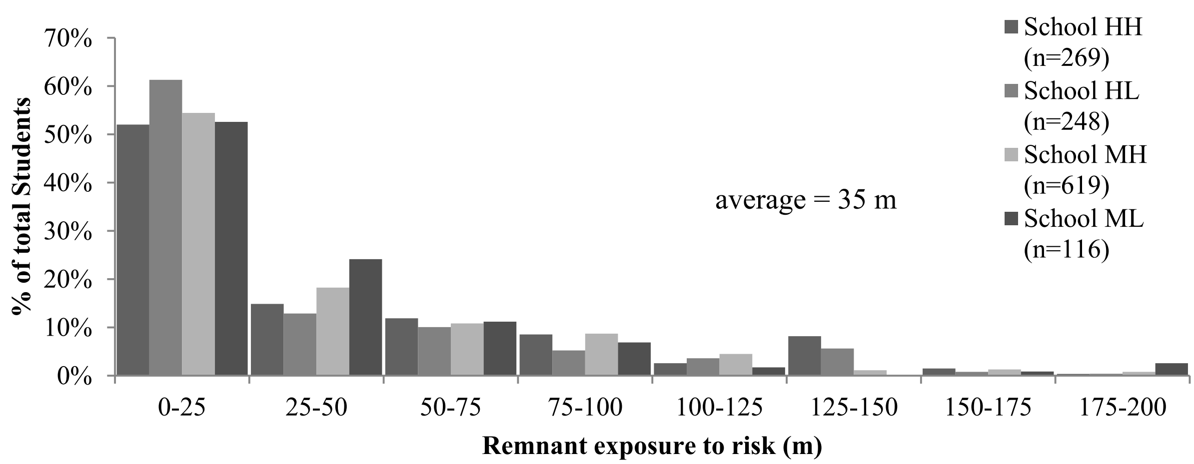


Figure 4-9. *Remnant exposure to risk (unsupervised travel distance) when participating in a WSB program (school-by-school comparison)*

4.5.2 Convenience (WSB) neighbourhood comparison

When comparing neighbourhoods, the overall distance students live from the school plays an important role in the time it takes to walk to school via WSB (see Figure 4-10). School ML, for example, had no students living beyond 1.2 kilometres; therefore, all trips were less than 15 minutes. In contrast, 13% of School HL students live between 1.2 and 1.6 kilometres (see Table 3-6); therefore, 30% of the WSB trips were greater than 15 minutes.

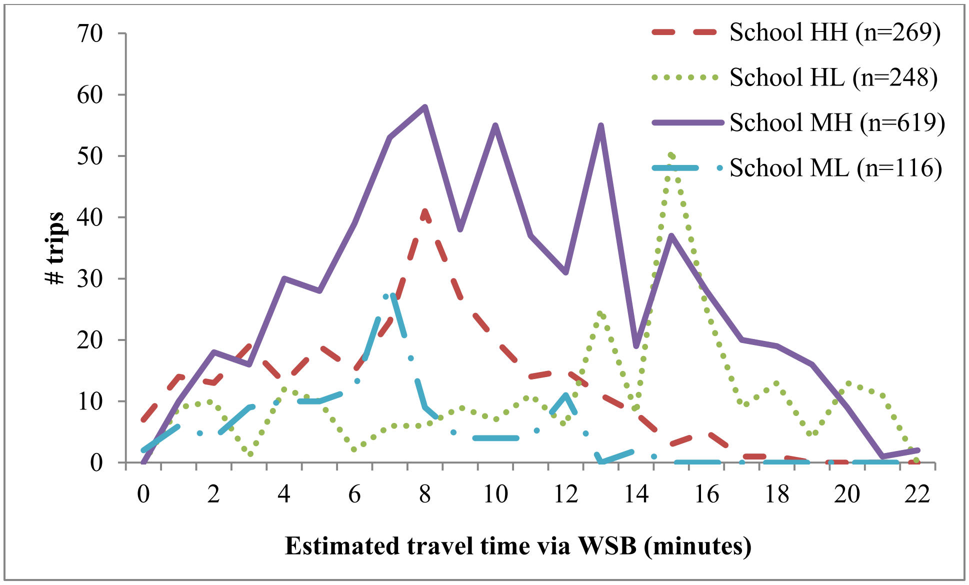


Figure 4-10. *Estimated travel time via Walking School Bus (school-by-school comparison)*

As Table 4-16 illustrates, it takes students at Schools MH and ML less additional time to get to school via WSB than by shortest path (39 and 0 seconds different respectively) than it takes students at Schools HH and HL (1:37 and 1:31 respectively). Overall, the additional travel time is minimal and there appears to be no correlation between the amount of additional time and neighbourhood type or student density.

Table 4-16. *Estimated travel times for students by school (school-by-school comparison)*

	School HH	School HL	School MH	School ML	Total
n	269	248	619	116	1252
Average SP walking time (minutes)	6:23	11:36	10:01	7:04	9:12
Average walking time via WSB (minutes)	8:00	13:07	10:40	7:04	10:15
Minimum SP walking time (minutes)	0:07	0:39	0:53	0:10	0:07
Minimum WSB walking time (minutes)	0:08	1:21	1:12	0:30	0:08
Maximum SP walking time (minutes)	16:28	20:27	19:49	14:52	20:27
Maximum WSB walking time (minutes)	18:41	21:15	22:10	14:58	22:10

Note: SP = Shortest path, WSB = Walking School Bus

As Table 4-17 shows, the average time saved by parents if their children participate in WSB programs appears not to correlate to neighbourhood walkability or student density, but rather the distance between their homes and the school (the greater the distance, the more time it takes to walk between destinations).

Table 4-17. *Walking School Bus parental timesaving by school (school-by-school comparison)*

	School HH	School HL	School MH	School ML	Total
n	269	248	619	116	1252
Average walking time saved (minutes)	10:59	21:03	17:58	10:55	16:26
Maximum walking time saved (minutes)	30:57	38:31	37:18	27:40	38:31
Minimum walking time saved (minutes)	00:00	00:03	00:00	00:00	00:00

4.5.3 Cost (WSB) neighbourhood comparison

Minimal differences were observed with respect to student density and the number of WSB runs. Schools with high student density had slightly fewer runs per student than schools with low student density (0.05 runs/student versus 0.06 runs/student). There were no differences observed between high walkability and low walkability neighbourhoods (both types had 0.06 runs/student).

The individual WSB runs had several variances between neighbourhoods and within each neighbourhood. Figure 4-11 is an example of how two direct runs in a neighbourhood were routed using the criteria set out in the methodology. These runs follow the same general path, but due to the number of students in the area, two separate runs, on either side of the road were required to accommodate the adult-to-student ratio.

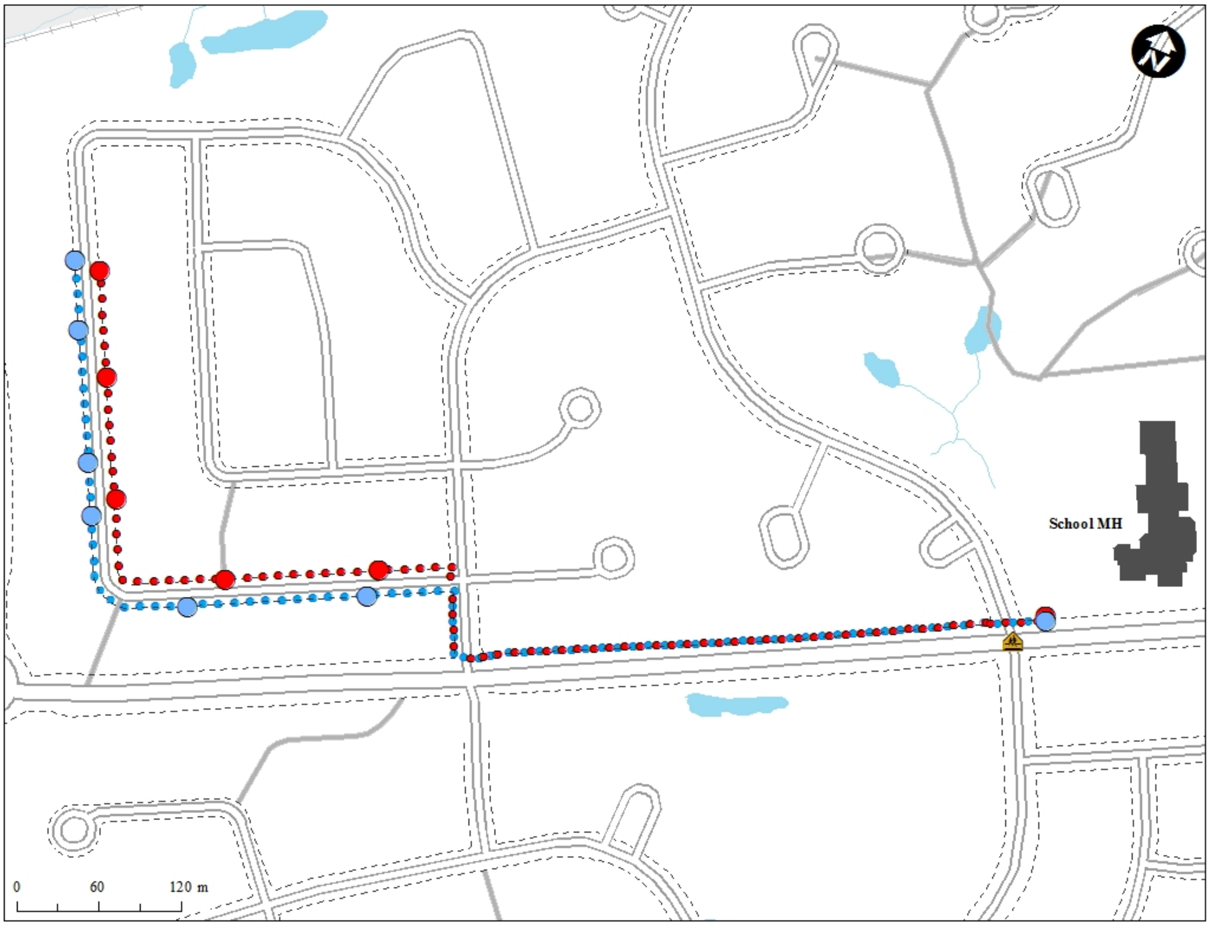


Figure 4-11. *Example of two direct routes with no variations from shortest-path distance*

4.6 Policy context

Ontario has no provincial standard or guideline for student transportation policies. Individual boards set policies and these vary with respect to transportation eligibility criterion (e.g., distance, program, etc.). The Province allocates funding to boards for transportation services. Individual boards determine how to allocate this funding. Table 4-18 illustrates how the policies vary across Ontario by showing the distance threshold used to determine busing eligibility in school boards with CMAs greater than 300,000.

As Table 4-18 illustrates, the median distance students are required to live from their school before qualifying for transportation varies by grade – where younger students (elementary school-aged) qualify for transportation beyond 1.1 to 1.6 kilometres and older students (secondary school-aged) beyond 1.6 kilometres from their school. The most frequently used distances are 1.6 kilometres for elementary school students and 3.2 kilometres for secondary school students. There is minimal variation between qualifying distances of students attending English-language Catholic and Public schools, especially those in co-terminus boards.

While no provincial standard or guideline exists for establishing transportation policies, clearly all boards' busing eligibility policies consider a student's grade, which can be correlated to age. This can be tied back to the information presented in Chapter 2 related to age and distance as factors in mode choice. Further regional variations are generally explained by the presence of supportive infrastructure (e.g., public transit), and possibly market share (e.g., using transportation eligibility as method of gaining students between co-terminus boards). It is important to note that these distance thresholds do not take into account the local school community context. Significant variations can exist within a board's jurisdiction with respect to what is considered 'walkable' (e.g., land use and infrastructure variations); therefore, although these board-wide policies may be considered equitable to the majority of students within the jurisdiction, there may need to be exceptions to account for these variations.

Table 4-19 shows that the maximum distance students are required to travel to their pick-up point follows a similar trend to overall distance from school eligibility – younger students are required to travel a shorter distance to a pick-up point than their older counterparts. Although there is variation between boards with respect to the maximum distance a student may travel to reach a pick-up point, generally, the distance tends to be approximately half of the minimum distance from home to school to be eligible for transportation. The most frequently used pick-up point distance is a no greater than 0.8 kilometres for elementary students and 1.6 kilometres for secondary students.

Table 4-18. *Minimum distance (in km) from home to school to be eligible for transportation by grade and board policy*

School Board	Elementary									Secondary
	K	1	2	3	4	5	6	7	8	9-12
Dufferin-Peel CDSB	1.0	1.0	1.6	1.6	1.6	2.0	2.0	2.0	2.0	3.8
Durham CDSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Durham DSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	4.0
Greater Essex County DSB	1.0	1.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Halton CDSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Halton DSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Hamilton-Wentworth CDSB	1.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Hamilton-Wentworth DSB	1.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
London District CSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Niagara CDSB	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.5
DSB Niagara	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.5
Ottawa CSB	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Ottawa-Carleton DSB	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Peel DSB	1.0	1.0	1.6	1.6	1.6	2.0	2.0	3.2	3.2	3.8
Thames Valley DSB	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Toronto CDSB	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	N/A
Toronto DSB	1.6	1.6	1.6	1.6	1.6	1.6	3.2	3.2	3.2	4.8
Waterloo CDSB	0.8	0.8	0.8	0.8	1.6	1.6	1.6	1.6	1.6	3.2
Waterloo Region DSB	*0.8*	*1.6*	*1.6*	*1.6*	*1.6*	*1.6*	*1.6*	*1.6*	*1.6*	*3.2*
Windsor-Essex CDSB	1.0	1.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
York CDSB	1.2	1.2	1.2	1.2	1.6	1.6	1.6	1.6	1.6	4.8
York Region DSB	1.2	1.2	1.2	1.2	1.6	1.6	1.6	1.6	1.6	3.2*
Mean	1.2	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	3.3
Median	1.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2
Mode	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2

Note: DSB refers to District School Board; CDSB refers to Catholic District School Board. Distances reflect those reported in school board policies in effect as of June 2015.
* if not served by public transit, otherwise ineligible by any distance

Table 4-19. *Maximum distance (km) to pick-up point by grade and board*

School Board	Elementary									Secondary
	K	1	2	3	4	5	6	7	8	9-12
Dufferin-Peel CDSB	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.2	1.2	1.2
Durham CDSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Durham DSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Greater Essex County DSB	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Halton CDSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6
Halton DSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6
Hamilton-Wentworth CDSB	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.6
Hamilton-Wentworth DSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
London District CSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	3.2
Niagara CDSB	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.5
DSB Niagara	0.8	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.5
Ottawa CSB	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Ottawa-Carleton DSB	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Peel DSB	0.4	0.8	0.8	0.8	0.8	0.8	0.8	1.2	1.2	1.2
Thames Valley DSB	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6
Toronto CDSB	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Toronto DSB	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Waterloo CDSB	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.6
Waterloo Region DSB	*0.5*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.6*
Windsor-Essex CDSB	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.2
York CDSB	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
York Region DSB	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.6
Mean	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.5
Median	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6
Mode	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.6

Note: DSB refers to District School Board; CDSB refers to Catholic District School Board, N/D = No data available. Distances reflect those reported in school board policies and/or procedures in effect as of June 2015.

Interestingly, the maximum walking distance to a bus pick-up point for students in Grades 1 to 3 at the Waterloo Catholic District School Board (WCDSB) is 0.2 kilometres greater than the distance by which they qualify for transportation (see Table 4-18 and Table 4-19). It is possible this was an oversight on the part of the WCDSB when modifying their transportation procedure.

To date, no student transportation policies in the Province contain language around ASST. The current focus of transportation policies is motorized transportation (i.e., yellow school buses). The political climate seems to be shifting, however, and it is very likely that some policies will soon be updated to include ASST principles as several jurisdictions have now passed Charters in support of ASST (e.g., Waterloo Region DSB, Waterloo CDSB, Hamilton-Wentworth DSB, Hamilton-Wentworth CDSB, Toronto DSB, Toronto CDSB, Ottawa CSB, and Ottawa-Carlton DSB). Incorporating these Charters into current student transportation policies could go a long way in advancing ASST within the Province.

Chapter 5. Conclusions

5.1 Summary of findings

There are trade-offs that exist in all transportation mode decisions. In the case of ASST, the critical trade-offs are between safety, convenience and cost. Results of the current research indicate that the trade-off for improved safety of students for school-based travel is primarily cost, and secondarily convenience. Additional positive outcomes, including health, social, environmental and economic benefits, however, may negate the cost and convenience barriers in the long-term.

Through experimentation, WSB routes were generated and evaluated on three dimensions that facilitate mobility: (1) safety, (2) convenience, and (3) cost. It has been shown that WSB programs at four WRDSB schools can reduce exposure to the safety risks of active school-based travel substantially if all students participate. Safety improvements included a 61% reduction in unsupervised intersection crossings and an average reduction of 717 metres of unsupervised travel. There was nominal variation between neighbourhoods with high and medium walkability ratings and between neighbourhoods with high and low student density.

The convenience of ASST when participating in WSB programs is the most beneficial to parents. On average, 16 minutes and 26 seconds can be saved daily for parents whose children participate in WSB programs. For students, participation in WSB programs would only increase travel times by 1 minute and 3 seconds on average. There were only minor differences between neighbourhoods with high and medium walkability ratings and between neighbourhoods with high and low student density with respect to travel time.

The cost of WSB programs, if led by paid adults, can be substantial. Approximately 11 FTE positions would be required to operate WSB programs at all four case study schools using the parameters established for this study. Only slight variations with respect to the number of runs required for a school are attributable to student density, and there is no indication of a difference amongst neighbourhoods of varying walkability. Additional costs, such as the labour to develop routes and coordinate the program, make this model cost-prohibitive from a school board perspective.

5.1.1 Limitations

There are at least two notable limitations of this research. First, the WSB runs created assumed a 100% participation rate. Given the current modal split and the variation in familial schedules and contexts, it is very unlikely that all students would participate in a WSB program. Further, the routes did not take into account Accessibility for Ontarians with Disabilities Act (AODA) regulations; therefore, some students may not be able to participate due to their specific accessibility requirements. On the other hand, participation rates lower than 100% may only have a minimal impact on the results of this study, as there was very little variation between schools with high and low student density. A sensitivity analysis could test whether low participation rates lead to any meaningful changes in the results.

Second, no test was conducted to operationalize the WSB runs. It is unknown if operationalizing the WSB runs would result in different outcomes than what the evaluation metrics produced. Given the possible range of ages for Junior Kindergarten to Grade 6 students (between 3 and 12 years-of-age), the pace at which students travel may vary. The average walking pace used in this study was not adjusted based on age. Further, the shortest path distance calculations did not take into account real-world data related to the paths that students actually travel. This may affect the difference in distance between the shortest path and WSB route. Other factors, such as neighbourhood cohesiveness, crime, traffic, among others, may influence the results further when operationally tested – especially with respect to participation rates.

When establishing a WSB program. There are several different parameters to select. Parameters including the number of students per run, the grades and/or ages served, and the distances served, for example, can all affect the quantity and locations of WSB runs. This study only examined one combination of these parameters. Further study may determine the impact of changes to these parameters.

The following additional considerations need to be made prior to implementing a WSB program:

- Sidewalk and pathway maintenance and/or snow removal on the identified routes
- Liability and risk management responsibilities

- Changes or adaptations to the WSB routes may be necessary as students move into and out of neighbourhoods – with the greatest changes taking place for the start of each school year
- Consider charging a fee for service to cover the salary of the WSB leader. This would benefit those who value the safety of participation in a WSB program and would be willing to pay for the parental convenience factor. Unless adjusted for income, user fees would not be equitable because it would exclude those who could not afford it.
- Site visits should be conducted to check that what is shown a map is accurate on the ground
- Setting criteria for prioritizing schools and/or routes to implement first

The BusPlanner Pro software used in this analysis had several limitations, and was not capable of conducting much of the analysis required for the evaluation component of this exercise. As a result, often time-consuming manual data manipulation was required. It also required the use of other software tools such as Microsoft Excel for calculations and ESRI's ArcGIS for intersection analysis. Further, using the automatic generation of optimization processes or techniques in the BusPlanner Pro software is not always transparent, meaning it is unclear how something is being optimized. Future studies should consider utilizing a software product with fewer limitations.

The NEWPATH walkability measurement used for the analysis may not capture an accurate representation of walkability from the perspective of a student, or for school-based trips. For example, the measurement calculates information on mixed land use rates, and retail design that may not influence walkability to school as much as they would for other trips. Additional study may be required to ascertain if there is a more appropriate measure of walkability to evaluate WSB programs, and/or if different measurements affect the outcomes of the evaluation metrics.

Despite these limitations, this study has added to the general knowledge about how to evaluate the potential successes achievable through WSB programs.

5.1.2 Areas for further investigation

Several results highlighted in this study warrant further investigation. First, the WSB stop placement method used for this study involved centralized collection points at a set distance from the student's home. This is not the only method available, and variations between the distance from a student's home and the WSB stop can exist. Further, it is unknown if the stop placement method and distances should be adjusted to suit local circumstances. Therefore, this warrants further investigation and testing.

Second, it is unknown if the adult to student ratio of 1:10 used in this study is the most appropriate for WSB programs. Further investigation may assist in determining the ideal adult to student ratios, including whether or not the age of the students and the complexity of the WSB route travelled should affect the ratio.

Although this study focused specifically on WSB programs, application of these evaluation metrics may also apply to other ASST programs. These programs include bicycle trains where students travel to school as a group on bicycles instead of walking, and "walking buddies" where older students or community members are paired up with younger students to walk to school together.

5.2 Contributions

This research has advanced the knowledge in the field of ASST in several ways. First, the policy context identified that there are inconsistencies and variances amongst school boards in student transportation policies due to the lack of guidelines provided by the Province in this regard. Incorporating the principles outlined in ASST Charters (adopted by several school boards) into current student transportation policies could go a long way in advancing ASST within the Province. The results of this study show that despite its limitations, it is feasible to use the BusPlanner Pro software conventionally used by Ontario school boards for motorized bus transportation routing for ASST purposes (i.e., to establish WSB routes).

Second, the metrics developed to evaluate three critical dimensions that facilitate mobility (safety, convenience and cost) have provided an empirical tool that enables informed decision-making in the implementation of WSB programs. The metrics inform the extent of the trade-offs that impact the feasibility of operating WSBs. Since a 93% reduction unsupervised travel exposure can be achieved with just over minute of additional student travel time, the results of this study indicate that WSB programs can be successful in achieving a safe and convenient way for students to use ASST. Although WSBs reduce risk exposure with minimal inconvenience to students and parents, these outcomes may come at a significant cost. This suggests a paid adult WSB leader model is not feasible in achieving a sustainable system-wide ASST solution. Further, the cost of delivering a paid adult WSB leader model may result in undesirable trade-offs, such as a forced reduction in participation rates and affecting the equitability of a WSB program. If a paid model is pursued, it is likely implementation would be phased. Therefore, a mechanism for prioritizing the routes to be implemented first would need to be developed (e.g., areas under the bus eligibility threshold that are transported because of busy intersections).

Next, this study has shown that WSBs are feasible in varying neighbourhood types within the Region of Waterloo. It has demonstrated that neighbourhood walkability and student density have no apparent effect on the achieving the primary objectives of a WSB program. That said, this may be a result of the minimal variation between the neighbourhoods studied within the Region of Waterloo, and there may be other variables confounding this lack of variation. For example, the study only examined neighbourhoods with high and medium walkability. There may be greater variations between neighbourhoods on alternative ends of the spectrum (e.g., high and low walkability). The primary effect expected with varied student density is the number of routes required, or ratio of routes to students. Student density may not have had this effect because of the stop placement method and adult to student ratio used.

Finally, the normative tone of current ASST research is challenged. The outcomes do not draw any conclusions on whether or not WSB programs should be implemented, but rather provides the basis for evaluating the costs and benefits of WSB programs in a broader decision-making context. This research provides metrics to evaluate when WSB programs are most effective at achieving the desired outcomes. This does not suggest that assertions about what "ought to be" should be ignored, but rather that when assertions are made, they should be supported by empirically based research.

In conclusion, human decision-making and individual's values influencing these decisions adds a substantial amount of complexity to the field of ASST. It is therefore important not to focus on the ideal state as the only possible outcome, but to consider that it may never be fully achieved. To this end, personal values must be taken into account. For example, in a society that continues to be risk adverse, WSBs may become increasingly desirable. This is especially true as children's safety, health and well-being is valued at any cost. Lower cost alternatives, including student-led or volunteer based WSB programs may be more cost-effective and sustainable than paid adult-led programs. There may not be a ‘one size fits all’ solution, therefore, it is important to continue to explore alternative options and best practices from other jurisdictions.

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