

Stretching the limits of walkability: comparing walk and bus trips in urban Seattle neighborhoods

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Abstract

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This study challenges traditional distance-based notions of walkability. The objective of this research was to determine whether it is feasible and realistic to replace relatively short bus trips with walking in urban Seattle, Washington neighborhoods. Through the collection of sixty data points, comparing walking and taking the bus from three origin points of varying distance (2.3, 1.5, and 0.9 miles) to the same location helped to determine that taking the bus is always fastest, less reliable, and less energy intensive than walking. However, the point at which walking becomes faster than taking the bus is a critical distance—0.9 miles—and is the upper limit at which the neighborhoods based in this study are deemed walkable. The comparability of travel time between walking and taking the bus at this distance shows that traditional distance-based definitions of walkability—usually 0.5 miles and less—may need to be extended under certain urban conditions.

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Chapter 1: Introduction

This study challenges traditional distance-based notions of walkability. The objective of this research was to determine whether it is feasible and realistic to replace relatively short bus trips with walking in urban Seattle, Washington neighborhoods. Distances traveled by bus are generally perceived as too far to walk. However, due to various hindrances associated with bus schedules that mandate specific travel times and lack of reliability of bus travel, walking may be actually be a faster choice, more reliable, and burn a higher number of calories. If this is the case, the extent to which an area was once considered walkable now becomes larger and blurs customary distances associated with walkability.

A Study of Walkability

While this study examines two modes of transportation, the structure of this research falls into the larger discussion of sustainable transportation. The urban environment offers residents myriad travel options such as the automobile, bus, rail, trolley, streetcar, boat, bicycle, walk, vanpool, car share, and more. What mode a person decides to use is dependent upon numerous factors including access to transit, street connectivity, population density, proximate destinations, and route choice, among other factors (Cervero and Gorham 1995, Leslie et al. 2005, Lee and Moudon 2006). Each mode has its appeal but there is increasing frustration with the emphasis placed so heavily on the single-occupancy automobile and the subsequent lack of attention paid toward other modes that are less burdensome to the environment, people's wallets, and the condition of the street surface (Litman 2003). The modes that offer benefits that the single-occupancy vehicle does not—such as walking, bicycling, or taking the bus—are associated with what is termed sustainable transportation. Currently, sustainable transportation options do not rival the overall public appeal of the automobile. As a result, the impact of sustainable transportation options needs to be better

understood and communicated to a wider audience if sustainable transportation mode share is to increase and thus gain the benefits that Litman cites. Fortunately, this is happening in some places such as cities in the Western United States where the encouragement and participation of sustainable transportation modes has received greater attention in recent years (Pucher, Buehler, Seinen 2011).

A singular definition of sustainable transportation is difficult to ascertain. Litman (2003) suggests that sustainable transportation means utilizing the mode that is best for a situation—be that bike, pedestrian, or car (though emphasis is placed on the former two). A focus on access to transportation is also a large contribution to his definition. Rastogi (2011) focuses on reducing the subsidies that are provided to private automobiles in an effort to give greater financial deference to other modes, such as walking and bicycling. Rakshit (2009) focuses on environmental impacts and emphasizes finding fossil-fuel alternatives for transportation, such as biofuels. Most definitions hint at these major themes—access, financing, and environment—and are all critical sustainable transportation considerations. Given the high cost of funding transportation projects and the politicized nature of transportation financing, the path to truly realizing a sustainable transportation system means developing a suite of travel options that encourages ubiquitous access and choice, fuel efficiency, and financial viability.

Sustainable transportation is not an abstract notion confined to planning circles or scholarly journals. It is being applied in various forms across the country. In Washington State, sustainable transportation has been addressed through the Commute Trip Reduction (CTR) law. Codified by RCW 70.94.527, the CTR law mandates all counties that are designated growth areas (RCW 36.70A.110) and cities and counties with substantial traffic delay and contiguous growth to make an effort in reducing “the proportion of single-occupant vehicle commute trips” (RCW 70.94.527). This can mean one or two things: demand for single-occupancy vehicle commute trips decreases

while mode share for other modes remains the same or increases *or* the mode share of other modes increases while demand for single-occupancy vehicle commute trips remains the same. Regardless, people need to get to work and if commute trips are to be less focused on the single-occupancy automobile, then sustainable transportation need to be available, convenient, and accessible for all.

Two travel options that can help fulfill sustainable transportation goals include taking the bus and walking. These two modes are at the heart of this study. This study aimed to recreate that familiar question facing commuters when they are waiting for a bus: should they stay at the bus stop and continue to wait even if the bus is late or should they take a chance and attempt to walk to their destination. If commuters are better informed about their travel choice *before* they set out on a journey they will be better prepared to use the mode best suited to them and their resources. By using the mode that is best suited to an individual, Litman's notion of using the mode best for a situation helps further the goal of realizing a sustainable transportation system.

This study challenged maximum distances found in the literature that are associated with walkability through the comparative empirical testing of two transportation modes—walk and bus—for three origin points presumed to be walkable and beyond.

Like sustainable transportation, defining walkability yields multiple objective and subjective interpretations. A common approach to defining walkability is to use indicators that point to areas that may be conducive to walking—thus enhancing their walkability. Indicators of walkability include short street-block length, proximity to retail shops, a safe walking environment, perception that distances are not too great to walk, quality of origins and destinations, the absence or barriers such as divided highways, and more. In the literature, measuring walkability generally means measuring one of the elements listed above. However, measuring a complex phenomenon with a

singular metric makes it difficult to completely define walkability; walkability is an interplay of elements, not just one.

This study was conducted in a built environment in which walking is generally amenable; indicators such as street connectivity, short block-length, diverse origins and destinations, and density point to a walkable environment and are present in the study area. Even with these indicators that point to walkability, there is a notable factor missing from this assumption that muddles the definition of what is walkable: distance. How far are people truly willing to walk?

Even if the walkability indicators are point to an exceedingly walkable area—a person will only walk so far; no matter how connected a street is to the surrounding neighborhood or how dense an area. There is a threshold at which if a distance is too great then walking becomes a less attractive option than other modes perceived as faster, such as taking the bus. When this is the case, walking may seem too time-intensive or physical ability may inhibit the extent to which a person is actually able to walk.

But how far is too far to walk? A simplistic approach to gauge walkability is to select an origin point and draw a circle with a prescribed radius around that origin. The circle's diameter can be of any length and the area which ascribes that circle is considered the walkability of the reference point. This approach works better in areas with gridded street patterns opposed to more dispersed, poorly connected roadway networks. Regardless of street connectivity, this method ignores elevation gains, barriers, and other built environment features that inhibit walking. However, this buffer method quickly identifies the extent to which an area is conceived as walkable.

At three miles per hour (mph)—generally considered the average walking speed of an adult—twenty minutes enables one to travel an unobstructed mile; this assumes zero hindrances such as waiting for a crosswalk signal or other obstacles that may slow the walking pace. But is one mile large enough?

Can and should the walkable neighborhood be extended to include a larger area? If other modes of travel take thirty minutes, is it safe to assume a neighborhood is walkable if that same distance can also be traveled in thirty minutes on foot? This study aims to answer this question and in doing so, challenges distance-based definitions of walkability.

Temporal metrics of walkability are related to the idea of the “twenty-minute neighborhood”—areas in which one can travel at most twenty minutes and reach the services and amenities one desires. Though temporally rigid and straightforward in concept, the amount of time walked is ultimately subjective; what is one person’s twenty minutes may include an area either smaller or larger than another person’s twenty minutes due to perception, safety concerns, or ability.

Determining whether the “twenty-minute neighborhood” is valid and determining whether the geographic extent of walkability can be increased, the travel time, reliability, and calories expended of walking and taking the bus from three different origin points traveling to the same destination point were measured and evaluated.

Research Questions

The research questions, described below, help to answer which mode is fastest, most reliable, burns the most calories, and at which distance walking becomes the faster mode.

1. What is the time spent by mode (bus, walk) to travel from three distinct origins of varying distance to the same destination?
2. What is the variability in time by mode (bus, walk) to travel from three distinct origins of varying distance to the same destination?
3. Based on calories expended, what is the most energy intensive (calories burned) mode?
What is the relationship between expended calories and distance by mode?
4. At what distance does walking become faster than bus transit?

Hypotheses

These research questions were driven by two hypotheses that underscored this study.

1. If bus wait time and in-vehicle time vary from trip to trip, then the total travel time will become more variable relative to walk times for that same distance.
2. If bus wait time, in-vehicle time, and the number of traffic signals requiring the bus to stop increase total travel time, then walking travel time may be the fastest mode choice for that same distance.

Research Design

The research questions and hypotheses were answered and verified through empirical research based in urban neighborhoods in Seattle. The study measured the time it took—among other collected data elements—to travel distances of approximately 2.3 miles, 1.5 miles, and 0.9 miles using two different modes of transportation—walk and bus—from three different origin points to the same destination. The selection of three origin points to the same destinations mimics a typical work commute trip; travel flows from the origin to the destination in the morning and in the evening flows from the destination back to the origin. This is akin to traveling from a peripheral urban area to an urban core.

Data were collected from three origin points during King County Metro's (henceforth Metro) AM and PM-peak service periods. Due to the time limitations, it was impossible to always use the same departure time from each origin point (Fremont, Wallingford, or U-District) or the same departure time from the destination point (Gould Hall). Therefore, for example, the time of departure from the Fremont location during the AM-peak period falls anytime within that AM-peak service period rather than always at 7:30 a.m., for example.

To answer the research questions, start and end times were recorded for each trip—both walking and bus trips—along with total calories expended for each trip. There are other data elements that were collected and are further outlined in Chapter 4. Once all sixty data points were collected, the results were analyzed. The data were parsed and compared to calculate average travel times by service period and segment, average travel times by mode and segment, average calories expended by mode and segment, differences in time between modes for each segment, average time to expend one calorie by mode and segment, and the influence of traffic signals on average travel time for bus trips. To determine the influence of increased average travel speeds for both walking and taking the bus, paces above the 3 mph limit specified for this study were calculated to determine how average travel times decrease as speed increases. To determine at what distance walking is faster than taking the bus, interpolated average travel times were calculated for both walk and bus trips; these calculations quantify the differences in average travel times between the modes and depict the distance-time relationship between the two.

To maintain consistency between each collected data point across all segments, there are four minutes of waiting time built into each bus trip. Though the literature offers little guidance on the subject four minutes was the target time to arrive at a stop before the scheduled departure time. In actuality, seasoned bus riders may arrive at a stop just a few minutes prior to the scheduled departure time. As will be discussed, no real-time arrival/departure times applications or tools were used for this study.

This study is based on one east-west bus corridor—Route 44—in the Metro bus system. The route travels through the north Seattle neighborhoods of Ballard, Wallingford, and the University District. The heavily traveled corridor receives a lot of attention from the Seattle Department of Transportation (SDOT). For example, the Wallingford and Ballard sections of the corridor are

currently receiving transit improvements via SDOT's transit priority corridors program. That said, every transit corridor is different in terms of population density, ridership, headways, and origin/destination characteristics and may require a different approach than the one offered here if travel time, reliability, and walkability are to be measured and evaluated.

Bus and Walk

While there are other travel modes one could use to travel between two points such as single occupancy vehicle, bicycle, carpool, or rideshare, taking the bus and walking were selected for various reasons. First, the time available for this study and resources available mandated that the scope of the study be focused to select modes. Second, choosing two modes allowed for more trips to be made for each mode; fewer trips would have been the reality if additional modes were studied. Third, vehicle access was not guaranteed throughout the course of the study making automobile evaluation impossible. Additionally, incorporating vehicle trips would bring about questions of parking supply and other factors that are not pertinent to the focus of this study.

Emphasis on Walking, not Bus

This research does not claim that taking the bus is not a worthwhile pursuit if sustainable transportation is the goal. In fact, it is logical that a sustainable transportation framework embraces multiple modes, as mentioned by Litman (2003), such as walking *and* taking the bus, among other options; the mode that is best suited to a person's specific context is perhaps the best mode.

However, given personal interests in the promotion of walkable communities and the relatively small mode share walking has compared to the bus, it is sensible to provide background and emphasis on why walking is an attractive mode of travel for short and medium-distance trips.

Paper Structure

Following the introduction, a literature review examines some of the current trends in walking as a mode of transportation and the benefits associated with walking. The notion of walkability and popular methods of measuring walkability are also examined. A comprehensive analysis of the study area, including origin and destination characteristics and Metro route information is then provided. The methodology, which includes the logic behind what and why certain data were collected, follows the existing conditions. Analysis of the data, discussion, limitations, and future research conclude the document. The appendices detail all the raw data collected during the study period.

Chapter 2: Literature review

This literature review reveals that walking is not a highly utilized mode of travel, there are numerous benefits to walking, walking is a promoted travel mode choice in Seattle, and how to measure areas that are conducive to walking vary widely.

Walking Rate

The commute trip walking share is scant compared to the personal vehicle. The *2001 National Household Travel Survey* revealed that in the United States, just 2.8% of the sample walked to work while 91.2% used a personal vehicle (U.S. Department of Transportation Bureau of Transportation Statistics 2001).

The time spent walking as a simple daily activity is similarly low. According to the *National Survey of Bicyclists and Pedestrian Attitudes and Behaviors*, 41% of study participants reported walking—defined as 5 or more minutes a day—20-31 days in a month compared to 31% who walked only 1-7 days a month (Dawn and Miller-Steiger 2008). During the study period, 20% of adults 16 and older did not walk during a 30-day period citing lack of need or desire, inclement weather, or health impairments as the primary reasons for not doing so. Most trips (80%) began at a person's home with the intent of running errands, leisure, or exercise. Only 5% walked as part of their commute.

Benefits of Walking

General Benefits

Walking as a mode of transportation transcends the simple act of traveling from point A to point B. The 2009 *Seattle Pedestrian Master Plan*—which is intended to “make Seattle the most walkable city in the nation” (City of Seattle Department of Transportation 2009)—points to eight benefits associated with walking: accessibility (the ability for large numbers of population to walk), economics (cost

savings associated with walking), equity (pedestrian environments for all), health (public health benefits and personal exercise), environment (cities that tread lighter on the natural environment), economic vitality (areas that are pedestrian oriented are typically associated with areas of economic vitality), quality of life (increase in personal and community well-being), and congestion (shifting car users away from the road reduces congestion) (ibid).

Walking and Public Health

If walking is to replace bus trips, especially if walking takes longer than that same bus trip, then there needs to be a compelling reason to make that switch. The most compelling reasons for switching modes are benefits gained in public and individual health. The intersection of public health and active transportation has received increased attention in recent years (Dannenberg et al. 2003, Frank, Andresen, and Schmid 2004, Ewing et al. 2003). One reason for increased attention is due to the shift in what we eat and how we travel and the health ramifications of this switch. For instance, the increase in energy intake (calories) and the lack of opportunities to burn off those calories because “walking or bicycling has been replaced by automobile travel for all but the shortest distances” (Koplan and Dietz 1999) represents a vexing problem in the quest to be fit and healthy.

The U.S. Department of Health and Human Services (2008, 21), in providing recommendations to reduce chronic disease associated with lifestyle changes, recommends that adults receive 150 minutes of moderate-intensity aerobic exercise per week; walking and other active transportation choices count toward meeting the guidelines. Aside from meeting the recommended guidelines, walking as a form of commuting is considered one of the lowest risk forms of physical activity (compared to contact and collision sports, for example) (ibid, 36).

Some researchers have tried to quantify recommended physical activity in terms of walking and how many steps per day a person should take. Tudor-Locke and Basset (2004) cite 10,000 steps per day

as a goal; this is considered *active* and roughly equates to 30 minutes of activity. That said, Bassett, Cureton, and Ainsworth (2000, 1020) found that the average number of steps taken for adult females and males is 6,413 and 5,569, respectively. While these rates are well below the *active* level of 10,000 steps per day, the study discounted dedicated physical exercise and recreation which would propel the rate upward.

Walking has real ramifications on the personal health of individuals. Frank et al. (2006) discovered decreases in body mass index (BMI) and an increase in physical activity when walkability of neighborhoods increases by just 5%.

Walking and the Environment

Aside from personal and societal health benefits, walking also pollutes less than other modes of transport. Walking is the least environmental damaging mode of transportation in terms of carbon dioxide (CO₂) emissions (Sightline Institute 2008). Shifting mode choice from automobiles to what Higgins (2005, 198) calls exercise-based transportation—bicycling and walking—for those same automobile miles could substantially exceed the number of barrels of oil domestically produced each year. That is, because of the switch in modes, United States oil production could cease operations because bicycling and walking trips would erase the demand to fuel vehicles for those same trips. Frank et al. (2005) found that a 5% increase in a neighborhood's walkability index—net residential density, street connectivity, land use mix, and retail floor area ratio—presents a 6.5% decrease in vehicle miles traveled.

Walkability

The terms walkable and walkability are terms without firm parameters; one area that is conducive to walking for one person may not be conducive to walking for another person. The term is inherently

subjective and emotional. However, there are studies that attempt to measure walkability—both subjectively and objectively.

A few subjective analyses include Leslie et al.'s (2007) attempt to define walkability by creating indices of built form features using GIS. Ewing and Handy (2009) measured the perceptual qualities that encourage and hinder walking. These approaches are conceptually valid and offer insight into how a city's walkability can be modeled. Other studies use time and distance based approaches. Colabianchi (2007), in determining perceived neighborhood boundaries in adolescents (females in twelfth grade), found 14.8 minutes or roughly three-quarters of a mile to be the maximum distance that is appropriate to walk.

Southworth (2005, 248) melds a number of subjective factors together to define walkability as “the extent to which the built environment supports and encourages walking by providing for pedestrian comfort and safety, connecting people with varied destinations within a reasonable amount of time and effort, and offering visual interest in journeys throughout the network.” Southworth goes beyond using distance or amenities as the sole criterion in defining walkability (249) and proposes six attributes that must be considered if an area is truly considered walkable: connectivity of the path network, linkages with other modes, fine grained land use patterns, safety, quality of path, and path context. Lee and Moudon (2006, 210) also note that airline distance is not an effective measure of walkability but rather utilizing the street network to better reflect travel behavior is a more meaningful attribute in determining the maximum distances people are willing to walk.

Southworth's definition does an adequate job in encompassing what the built environment might look like if it is to be walkable. Understanding the elements that constitute walkability help to define and contextualize the urban environment in which this study takes place.

Moudon et al. (2000), using actual incidences of walking, objectively measured neighborhood walkability in King County, Washington. The researchers found that the geographic extent of a walkable neighborhood in King County is approximately 0.7 km (0.42 miles—airline distance—extending out from a center-point origin. While this figure is based more on neighborhood amenities than commute distances, it is interesting to note how small this area is and how little time it would take to travel such a distance at 3 mph: 8.4 minutes. Moudon et al.’s research is unique in that it combines objective and subjective measures of walkability—a method not usually applied due to the difficulty in ascertaining walking rates of individuals.

“Twenty-minute neighborhoods”— a phrase meant to represent the maximum time in which a person travels to access critical services and amenities—are gaining traction not just as an abstract idea but in application in cities like Portland, Oregon. In Portland, it forms the basis of that city’s strategic plan (*The Portland Plan*) to form a “more prosperous, educated, healthy and equitable city” (City of Portland 2012). A “twenty-minute neighborhood” would allow one to travel an obstructed mile at 3 mph.

Walking in Study Area

Walking in Seattle

Recently, the city of Seattle focused energies on planning specifically for the pedestrian. This is evident in the 2009 *Seattle Pedestrian Master Plan* which was published with the intent of making “Seattle the most walkable city in the United States” (City of Seattle Department of Transportation 2009). According to the 2006 American Community Survey, 8.4% of Seattle workers 16 and older commuted to work on foot; when combining public transportation, the figure rises to 26.2% (ibid).

This modal share helps to fulfill the *City of Seattle Comprehensive Plan: Toward a Sustainable Seattle* goal of increasing “walking and bicycling to help achieve City transportation, environmental, community

and public health goals” (City of Seattle 2005, TG-15, 3.11) and to meet the 2020 goal of 45% of all work trips made by non-single occupancy vehicle modes (ibid, 3.8).

The presence of sidewalks are an amenity that directly support walking. Sidewalks total 2,256 miles throughout the city of Seattle. Though sidewalks are largely absent north of North 85th Street, a boundary the study area does not cross, sidewalks generally cover the entire study area with just a few short stretches absent of sidewalk infrastructure (City of Seattle Department of Transportation 2009).

Walking Trips in the Puget Sound

There have been numerous studies indicating how willing people are to walk to various destinations. In a 1999 survey of Puget Sound households, 95% of trips made on foot were less than 1.4 miles. The mean trip length by foot was 0.39 miles—distances considered a “short-distance” (Kim and Ulfarsson 2008, 726). Of all trips that characterize this “short-distance,” 23% were completed on foot, 75% by automobile, 1% by bus, and 1% by bicycle (ibid., 727). Moudon et al.’s (2000) study of walkable neighborhoods in King County indicates that the geographic extent for walkable neighborhoods is 0.7 kilometers or approximately 0.4 miles, corresponding to the results also found in the *National Household Travel Survey*.

Walking Speed

The walking pace of any one person is dependent upon numerous factors thus potentially influencing the extent to which a person is willing to walk. In a review of pedestrian walking speeds in New Zealand, Finnis and Walton (2008) found variance in walking speed based on gender, age, shoe type, terrain, presence of children, and more. Their study revealed an average walking pace on flat ground (less than 2° slope) of 88.08 meters per minute or 3.28 miles per hour. Their review of literature from an additional 22 studies from around the world revealed an average pace of 80.43

meters per minute or 3 miles per hour. Bornstein (1979) conducted walking speed tests in Seattle and found an average pace of 1.46 meters per second or 3.27 miles per hour.

Distance to Transit

Average distance to Metro transit stops is currently unknown; a request was submitted to Metro to determine this figure but a reply was not received as of the time of this writing. However, the generally accepted distance from origin to transit stop is one-quarter mile. This is affirmed in the Transportation Research Board's *Transit Capacity and Quality of Service Manual, 2nd Edition* where 75-80% of passengers in the study area—sample data collected from low and high income cities in both the United States and Canada—walked one-quarter mile or less to a bus stop (Kittelson et al. 2003, 3-9).

There are other studies that have investigated distance to transit stops and returned results that do not align with the standard one-quarter mile interpretation. In Detroit, using Monte Carlo analysis, the average one-way walking distance as part of a transit trip from home to work was 0.46 miles—0.36 miles from home to the bus stop and an additional 0.1 miles once getting off the bus to the final destination (Hoback, Dutta, and Anderson 2008). In Portland, Oregon the total one-way distance people walked to transit stops was 0.196 (Sanchez 1999). Agrawal, Schlossberg, and Irvin (2008) noted that the average distance study participants walked to five light rail stations in San Jose, San Francisco, and Portland, Oregon was 0.52 miles, with the maximum distance being 1.88 miles. The majority of survey respondents selected their path of travel based on the shortest/fastest route signifying a premium on time and not on convenience, attractiveness, or safety.

While many researchers focus on the average distance (miles) people walk to transit locations, other researchers have expressed how long it takes one to travel from an origin point to a transit stop, expressed in minutes. Besser and Dannenberg (2005, 276) found, using *National Household Travel*

Survey data, that the average time people traveled to and from bus stops was 23.7 minutes. This roughly translates to twelve minutes each way. At an unobstructed pace of 3 mph, a person could walk 0.60 miles in 12 twelve minutes—considerably more than the 0.25 miles usually assumed to be the upper threshold for people to walk to transit.

Given the variation in the literature of distance to bus stops and lack of firm guidance from Metro, a distance of 0.25 miles to the bus stop is assumed for this study with approximately 0.05-0.1 miles from where the bus trip ends to the final destination—a total walking distances of 0.3-0.35 miles.

Gaps in the literature

The review of the literature points toward several findings. First, subjective measurements of walkability—such as measuring block length or proximity to transit stops or origins—help to describe areas that might encourage people to walk but do not reveal any objective patterns of walking rates in those areas. Second, few studies indicate how far a person might be willing to walk if other modes—bus, for example—are inconvenient or are not time-competitive. The notion of how far people travel to transit stops is apparent but how far people are willing to walk in the absence of that transit is not indicated. Related, there is minimal exploration of comparing the costs/benefits associated with walking and taking the bus from the same origin to the same destination. Third, many of the studies—especially those that relate to transit accessibility—fail to take into account geographic features and other hindrances that impact travel time. This study aims to fill in the aforementioned three gaps by using objective, empirical research to measure willingness to walk in light of delays associated with transit.

Chapter 3: Existing Conditions

Context of Study Area

First-hand observations of delayed bus times traveling to and from the Wallingford neighborhood in North Seattle to the University of Washington in Northeast Seattle—a distance of approximately 1 mile was the impetus for this study. Anecdotally, the travel time on the bus from Wallingford to the University of Washington was perceived to be longer than the time one might walk that same distance. It was also noted that travel on Metro’s Route 44—which connects the neighborhoods of Ballard and the University of Washington via Wallingford— during rush hour was slow and that sidewalk pedestrians were often traveling faster than the bus. It was this observation that gave rise to the question: why would someone sit on a slow bus when they could walk to their destination faster and receive the added benefit of exercise?

For this study, the area was extended beyond the anecdotal mile to include distances of varying length ranging from just under one mile to over two miles. By extending the boundary and including several origin points, broader comparisons between the two modes were made.

Selection of origin and destination points

As the study mimicked commute trip patterns—traveling one direction in the morning and the opposite direction in the evening while also recreating a core/periphery relationship—suitable origin and destination points were found to reflect this relationship. The congested area around the Wallingford neighborhood and its proximity to a major urban center—the U-District—was the perfect environment to test commute trip style travel patterns and reflect this core/periphery relationship.

There were three origin points for this study with each origin point representing an increase in distance from the destination—Gould Hall. The shortest distance between origin and destination, approximately 0.9 miles, was termed the U-District location. (note: unless otherwise indicated, the distances listed are measured using network distances as opposed to airline distance measurements.) The second origin, the middle distance—approximately 1.5 miles—was termed the Wallingford location. The third and farthest location—about 2.3 miles—was termed the Fremont location. All origins assumed a fictitious “home” start point to emulate a person traveling from one’s home to a nearby bus stop. The U-District “home” site was located at the corner of Northeast 48th Street and 8th Avenue Northeast. The Wallingford “home” site was located at Sunnyside Avenue North and North 50th Street. The Fremont “home” site was located on North 50th Street beneath Aurora Avenue North. The destination for all three origin points was Gould Hall located on Northeast 40th Street between University Way Northeast and 15th Avenue Northeast.

Gould Hall is home to the University of Washington’s College of Built Environments and Department of Urban Design and Planning—where the Master of Urban Planning program, of which this thesis is a requirement, is located. It was logical, given the time personally spent in and traveling to Gould Hall, its proximity to the University of Washington campus and other off-campus buildings, the presence of numerous bus routes, and its location in a densely populated Seattle neighborhood, to use the building as an appropriate destination point.

The origin points were also selected partially for their relative transit isolation. To get to Gould Hall from the three origin points, there are few bus alternatives available without transferring. As transfers would introduce an unwanted source of travel time variation, it was imperative to find similar sites that were served by low-headway routes but rather limited route choice. Figure 1 depicts the study area including the three “home” sites, bus stops, and routing for the bus line.



Figure 1 Map depicting study area with Metro's Route 44 highlighted, bus stops, and origins and destination.

Areas of Study

Origin points did not begin at a bus stop as this would not mirror reality. A person who takes the bus does not simply arrive at a bus stop; there is intermediate travel time to get from their home to the bus stop. As such, the origin points were designed to start at a fictitious “home” address a predefined distance—approximately 0.25 to 0.3 miles—from the bus stop.

While an exact location was chosen at each site to maintain study consistency, an exact address was not selected as to not imply that a specific household was involved in this study. Henceforth, “home” refers to the location of the origin address and not the bus stop.

Study Locations

The following section highlights the characteristics and precise locations for each “home” origin point and associated bus stop.

Fremont location

The first location was termed the Fremont location. The “home” starting point was located at North 50th Street beneath the Aurora Avenue North bridge (Figure 2). This represented a distance of 0.3 miles north of the Fremont transit stop located at North 46th Street and Aurora Avenue North (Metro stop #29200). Route 44 represented the only option of getting from “home” to Gould Hall without transferring and by maintaining the 0.35 mile walking distance for bus trips requirement. The Fremont bus stop was twelve stops, including the boarding location and disembarkment location, from the destination. See Figure 3 for the bus stops that comprised the Fremont segment. In the AM-peak there were two signalized crosswalks that were navigated while there was only one during the PM-peak. The difference in number of crosswalks between the morning and evening was due to the location of the bus stop when the bus travels west during the evening. Trying to hold the number of crosswalks constant was not possible less the walking route choice would be unnecessarily circuitous.



Figure 2 The “home” location or starting point for the Fremont segment is directly under the Aurora Avenue North Bridge on North 50th Street

Upon returning “home” during the PM-peak period, Metro bus stop #29557 on the north side of North 46th Street, east of Green Lake Way North was used.

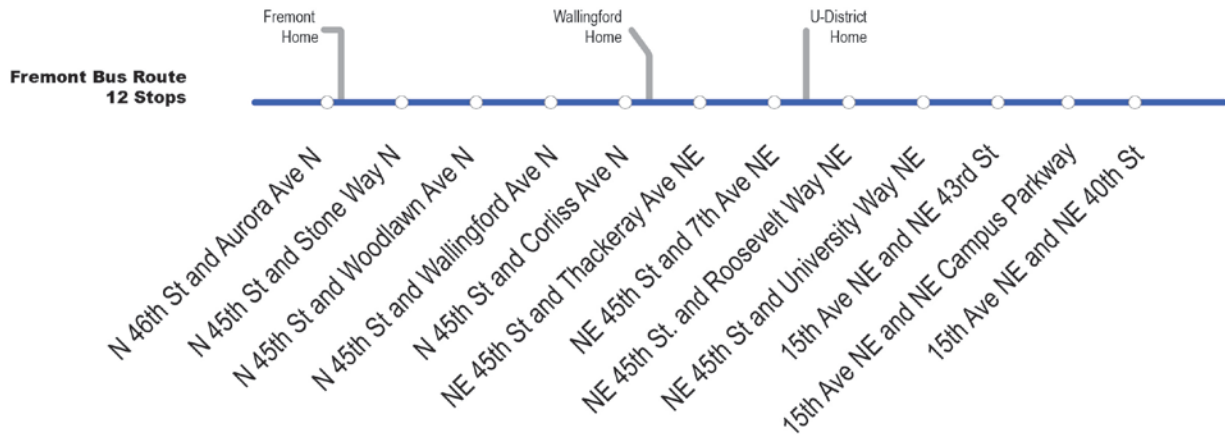


Figure 3 Bus stops along the Fremont segment—traveling to Gould Hall

Wallingford Location

The second location was termed the Wallingford location. The “home” starting point was located at the intersection of Sunnyside Avenue North and North 50th Street. This represented a distance of 0.3 miles north of the Wallingford transit stop, located at Corliss Avenue North and North 45th Street—Metro stop #29234 (see Figure 4). Route 44 represented the only option of getting from “home” to Gould Hall without transferring while maintaining the 0.35 total walking distance requirement. The Wallingford bus stop was eight stops from the destination. See Figure 5 for the stops that comprised the Wallingford segment. In the AM-peak, there was one signalized crosswalk requiring navigation and zero during PM-peak trips.



Figure 4 Route 44 travels through Wallingford on North 45th Street; this view looks west from the Wallingford bus stop

Upon returning 'home' during the PM-peak period, Metro bus stop #29500 on the north side of North 45th Street was used.



Figure 5 Bus stops along the Wallingford segment—traveling to Gould Hall

U-District Location

The third location was termed the ‘U-District’ location. The “home” starting point was located at the intersection of 8th Avenue Northeast and Northeast 48th Street. This represented a distance of 0.25 miles north of the U-District transit stop, located at Roosevelt Way Northeast and Northeast 45th Street (Metro stop #29865). The U-District location was the only origin point for which there are other bus options besides Route 44. However, Route 67 which travels to the University of Washington campus has higher headways than the 44 and therefore would violate the conditions set forth in this study while Routes 43 and 49 have low headways but are slightly farther away than Route 44 making them ineligible. While there are many other routes that pick up passengers at this stop, to maintain consistency, Route 44 was the only route available for travel for the purposes of this study. No transfers were required while still maintaining the 0.35 mile walking distance requirement. The U-District bus stop was five stops away from the destination. See Figure 6 for the stops that comprised the U-District segment. There were two signalized crosswalks requiring navigation in the AM-peak and zero during the PM-peak.

Upon returning “home” during the PM-peak period, Metro bus stop #29455 on the north side of Northeast 45th Street, west of Roosevelt Way Northeast was used.



Figure 6 Bus stops along U-District segment—traveling to Gould Hall

Table 1 highlights the total distance the bus traveled from origin bus stop to destination bus stop, the total walking distance, and number of bus stops and traffic signals between origin and destination for both AM and PM-peak periods..

Table 1 Summary of site characteristics

	Fremont	Wallingford	U-District
Bus Distance (excludes walking component of bus trips)	2.1 miles	1.3 miles	.7 miles
Walking Distance	2.3 miles	1.5 miles	0.9 miles
Number of stops (AM-peak)	12	8	5
Number of traffic signals (AM-peak)	21	15	10
Number of stops (PM-peak)	11	7	4
Number of traffic signals (PM-peak)	20	14	10

Gould Hall

Gould Hall was the destination for each origin point (Figure 7). The bus stop used to disembark was located just south of Northeast 40th Street on 15th Avenue Northeast (Metro stop #10917).

After arriving, it was approximately 0.05 miles to walk from the bus stop to the northeast corner entrance of Gould Hall. There was slight variation in travel distances from the bus stop to the entrance due to the location at which the bus comes to a stop in the bus bay.



Figure 7 The bus stop used during the PM-peak period is located adjacent to Gould Hall (background) on Northeast 15th Street

During PM-peak periods, Metro bus stop #29440 located north of Northeast 40th Street on 15th Avenue Northeast was used to get to the three “home” sites. The distance from the northeast entrance of Gould Hall to this stop was roughly 0.065 miles and required crossing the Northeast 40th Street/15th Avenue Northeast intersection at two signalized pedestrian crosswalks.

King County Metro

The bus route used in this study is operated by King County Metro. Metro is the transit agency for King County, Washington and provides bus and bus rapid transit service to the Greater Seattle Metropolitan area. Metro serves approximately 110 million annual passengers a distance of 496 million miles (King County Metro 2011a, 1) in the Central Puget Sound Region.

Metro divides service into three periods: peak period, off-peak period, and night. Peak period lasts from 5-9 a.m. and 3-7 p.m. on weekdays. Off-peak lasts from 9 a.m.-3 p.m. weekdays and 5 a.m. -7 p.m. weekends. The night service extends from 7 p.m.-5 a.m. all days (King County Metro 2011b). As part of their planning process, Metro identifies certain corridors and nodes in the strategic plan as transit activity centers. These centers “include major destinations and transit attractions such as large employment sites, significant healthcare institutions, and major social service agencies” and “represent activity nodes throughout King County that form the basis for an interconnected transit network throughout the urban growth area of King County” (ibid, SG-4). Route 44 travels through such transit activity centers and nodes.

Route 44

Metro’s Route 44 (see Figure 8) is a primarily east-west route that connects the North Seattle neighborhoods of Ballard and the University District while passing through the Wallingford neighborhood. The route, starting in Ballard, travels along Northwest Market Street, North 46th Street in Upper Fremont, North 45th Street in Wallingford, and Northeast 45th Street and 15th Avenue Northeast in the University District (see Figure 9). Total route distance is approximately 5.5 miles and carries 1,976,578 annual passengers on a total of 60,792 trips and is one of the busiest in the Metro system. Table 2 offers annual ridership figures for Route 44.



Figure 8 Coaches used on Route 44 have three doors for entry and exit and utilize Seattle’s electrified trolley system



Figure 9 Context of study area in relation to Metro Route 44

Table 2 2010 ridership for Metro Route 44 (Seattle Transit Blog 2011)

Service Period	Annual Rides (2010)
Night	520,733
Peak	617,940
Off-Peak	837,905

Route 44 operates with 10-15 minute headways throughout much of the weekday. During early morning in the six o'clock hour, headways are 13-24 minutes. Peak period headways are 11-13 minutes.

Travel time along the five-mile corridor from Montlake to the Ballard Locks is as high as 44 minutes during the PM-peak period (City of Seattle Department of Transportation 2010). This represents a speed of just 6.8 miles per hour. Roadway design not engineered for such capacity is often cited as a primary source for the delays (PB Farradyne Inc. 1997). Narrow lane width, I-5 backups, tightly spaced bus stops, difficulty for buses to re-enter traffic after picking up passengers, and limited roadway capacity also contribute to significant travel delays.

Schedules

Schedule information for the three origin points and destination was garnered from OneBusAway's website. Metro does not provide stop-by-stop schedule information forcing passengers to interpolate departure times based on sporadically listed stops wherein departure time is provided. These times represent scheduled departure time and not real-time arrival information, information which is also provided by OneBusAway. The scheduled departure times were recorded prior to any data collection and were used for the duration of the study while the real-time arrival information was never used at any point in this study.

The schedule for stop #29200, the origin point for the Fremont segment, is found in Table 3.

Times highlighted in bold signify the range of times incorporated in the study.

Table 3 Bus schedule for Metro route 44 stop #29200—Fremont segment (OneBusAway 2012a)

44: N 46th St and Aurora Ave N					
5:17	5:34	5:58			
6:19	6:34	6:52			
7:02	7:18	7:31	7:42	7:49	7:59
8:11	8:24	8:37	8:50		
9:00	9:10	9:25	9:40	9:55	
10:10	10:25	10:40	10:55		
11:10	11:25	11:40	11:54		
12:08	12:23	12:38	12:53		
1:08	1:21	1:36	1:51		
2:07	2:24	2:40	2:56		
3:08	3:20	3:32	3:44	3:56	
4:08	4:20	4:32	4:44	4:58	
5:12	5:27	5:40	5:52		
6:02	6:15	6:29	6:42	6:53	
7:10	7:24	7:40	7:51	7:59	
8:07	8:21	8:36	8:51		
9:06	9:22	9:36	9:52		
10:09	10:23	10:38	10:54		
11:08	11:22	11:37	11:50		
12:05	12:22	12:47			
1:17	1:34				
2:04					

The schedule for stop #29234, the origin point for the Wallingford segment, is found in Table 4.

Times highlighted in bold signify the range of times incorporated in the study.

Table 4 Bus schedule for Metro route 44 stop #29234—Wallingford segment (OneBusAway 2012b)

44: N 45th St and Corliss Ave N				
5:21	5:38			
6:02	6:23	6:38	6:56	
7:06	7:23	7:37	7:42	7:55
8:05	8:16	8:29	8:42	8:55
9:05	9:15	9:30	9:45	
10:00	10:15	10:30	10:45	
11:00	11:15	11:30	11:45	11:59
12:14	12:29	12:44	12:58	
1:14	1:27	1:42	1:57	
2:12	2:30	2:46		
3:02	3:15	3:27	3:39	3:50
4:02	4:14	4:26	4:38	4:50
5:05	5:19	5:34	5:47	5:59
6:07	6:20	6:34	6:47	6:58
7:15	7:29	7:45	7:55	
8:03	8:11	8:25	8:40	8:55
9:10	9:26	9:40	9:56	
10:13	10:27	10:42	10:58	
11:12	11:26	11:42	11:54	
12:09	12:26	12:51		
1:21	1:38			
2:08				

The schedule for stop #29865, the origin point for the Wallingford site, is found in Table 5. Times highlighted in bold signify the range of times incorporated in the study.

Table 5 Bus schedule for Metro route 44 stop #29865—U-District segment (OneBusAway 2012c)

44: NE 45th St and Roosevelt Way NE					
5:24	5:42				
6:06	6:27	6:41			
7:00	7:10	7:26	7:41	7:52	7:59
8:09	8:20	8:33	8:46	8:59	
9:09	9:19	9:34	9:49		
10:04	10:19	10:34	10:49		
11:04	11:19	11:34	11:50		
12:04	12:19	12:34	12:49		
1:03	1:19	1:32	1:47		
2:02	2:17	2:35	2:51		
3:07	3:20	3:32	3:44	3:55	
4:07	4:19	4:31	4:43	4:55	
5:10	5:24	5:39	5:52		
6:04	6:12	6:25	6:38	6:51	
7:02	7:18	7:32	7:48	7:59	
8:07	8:15	8:29	8:44	8:59	
9:14	9:30	9:44	9:56		
10:00	10:17	10:31	10:46		
11:01	11:15	11:29	11:44	11:57	
12:12	12:29	12:54			
1:24	1:41				
2:11					

The schedule for stop #29440, the point used during the PM-peak period to get from Gould Hall to the three origin points, is found in Table 6. Times highlighted in bold signify the range of times incorporated in the study.

Table 6 Bus schedule for Metro route 44 stop #29440—Gould Hall (OneBusAway 2012d)

44: NE 40th St and 15 th Ave NE					
5:26	5:43	5:58			
6:13	6:24	6:35	6:43	6:56	
7:03	7:16	7:29	7:39	7:49	
8:01	8:13	8:25	8:37	8:51	
9:05	9:20	9:35	9:50		
10:05	10:20	10:36	10:51		
11:06	11:21	11:36	11:51		
12:06	12:21	12:35	12:50		
1:05	1:20	1:34	1:48		
2:03	2:15	2:25	2:36	2:47	2:59
3:11	3:23	3:36	3:49		
4:02	4:15	4:28	4:41	4:54	
5:07	5:20	5:33	5:46		
6:00	6:13	6:27	6:41	6:55	
7:11	7:21	7:34	7:47		
8:02	8:17	8:31	8:46		
9:00	9:16	9:30	9:45	9:59	
10:14	10:28	10:42	10:57		
11:12	11:40				
12:10	12:38	12:58			
1:28					

As mentioned, Route 44 travels from Ballard to Montlake stopping 32 times on its westward journey—including the study origin points in Fremont, Wallingford, and the U-District. By the time the coach reaches these points, the trip is well underway from its true origin at Northwest 54th Street and 32nd Avenue Northwest in Ballard. The coach makes its 18th, 22nd, and 25th stops at Fremont, Wallingford, and the U-District, respectively. In contrast, the Gould Hall stop is much closer to the Montlake start point at State Route 520. The coach makes its fifth stop by the time it reaches Gould Hall for the PM-peak data points. The nearness or farness from origin points impacted the timeliness of arrival times; the results of these differences are quantified in the results section.

Centers and Activity Centers

As mentioned, Route 44 travels through many of the Metro-designated transit activity centers.

Additionally, the route travels through areas designated by the metropolitan planning organization—Puget Sound Regional Council (PSRC)—as regional growth centers and manufacturing/industrial centers. Regional growth centers are “characterized by compact, pedestrian-oriented development with a mix of residences, jobs, retail, services, and entertainment” (Puget Sound Regional Council 2011b, 2). They are intended to absorb future growth with the goal of supporting high-capacity transit. Manufacturing and industrial centers focus on “intensive industrial activity” but are not intended to comele with retail and residences (ibid).

Sidewalks

The study area was almost entirely covered by sidewalks. There is a small section along the south side of Northeast 40th Street from Latona Avenue Northeast to 7th Avenue Northeast that is lacking sidewalk. Additionally, due to construction of new University of Washington buildings near the intersection of Northeast 40th Street and Brooklyn Avenue North there were times when a sidewalk on one side of the street was closed.

Chapter 4: Methodology

The study measured and tracked numerous variables to analyze the following questions: What was the time spent by mode (bus, walk) to travel from three distinct origins of varying distance to the same destination? What was the variability in time between mode (bus, walk) to travel from three distinct origins of varying distance to the same destination? Based on calories expended, what was the most energy intensive mode? What was the relationship between expended calories and distance by mode? At what distance does walking become faster than bus transit?

These questions were answered through a carefully designed research experiment that was developed to ensure data collection accuracy, comprehensiveness, and study validity.

Data Collection

Primary Study Conditions

This chapter outlines the study conditions—the parameters that guided the research design—under which the sixty data points were collected. The reasoning for using these conditions is expounded in the following pages. The conditions are briefly as follows:

- There were few, if any, alternative bus options to make a trip from an origin to a destination;
- The bus route had small headways;
- Transfers were not permitted;
- Total walking distance from “home” to bus stop and disembarked bus stop and destination was 0.3 miles,
- A 3 mph walking pace for both walk and bus trips was used; and
- The trips mimicked a commute pattern with travel from a peripheral area to a core area during the morning and from the core to the periphery during the afternoon.

Data Points

Three key “home” origin points were identified approximately 0.3 miles away from three different transit stops along Metro’s Route 44. The points were 0.9, 1.5, and 2.3 miles away—traversing the street network (network distance), not airline distance—from the destination point of Gould Hall.

There were a total of sixty data points collected. For each origin point, a total of fourteen bus trips and six walking trips were made; seven bus trips during each the AM and PM-peak service periods and three walk trips during each of these periods.

Collection Dates

Data were collected from April 9, 2012 to April 30, 2012 over a span of fourteen individual days. Multiple trips were conducted each day to ensure the data collection remained on-track and on-time (see Figure 17 for a summary data points collected on each weekday).

Collection Periods

For the purposes of this study, service periods set forth by Metro were the initial basis for data collection periods. To mimic a normal commute pattern, only AM-peak and PM-peak trips were considered while midday, night, and weekend trips were not. However, as there is a large difference in passenger volume even within peak periods, certain times were designated within the peak periods to identify those times that represent the bulk of passenger travel and congestion levels. As passenger data by schedule time or by the hour was not obtainable, headways were used as a proxy to determine passenger volume demand and thus congestion levels, as these two are related. For example, during the 5 and 6 o’clock hours, headways average 19 minutes while between 6:52 and 9:10, headways average 11.5 minutes) signaling that demand and congestion are relatively light in the early hours of the AM-peak.

Using this logic, the AM-peak trips for this study fell between 6:52 and 9:10 a.m. The 9:10 a.m. trip obviously falls outside the official AM-peak period but headways indicate that demand warrants trips with small headways even beyond the strict definition of peak/off-peak hours. Even though the AM-peak starts at 6:00 a.m. the headways during this time indicate that passenger volume is relatively light and thus probably not a realistic indication of when people are actually traveling.

Using similar logic, PM-peak trips were collected between 3:44 and 6:15 p.m.

There may be some argument to only collect data on certain days (e.g. Tuesday-Thursday) as studies have shown that these are the best days to conduct traffic counts, bicycle counts, and pedestrian counts (Puget Sound Regional Council 2011a). By extension, it could be argued that bus collection data should follow similar logic. Given limited data collection opportunities, including Monday and Friday in the sample considerably increased the ability to collect a more robust sample.

Bus Schedule

Bus time schedule departure data were gathered from the OneBusAway website. OneBusAway uses King County Metro schedules to interpolate the scheduled stop time based on times provided for points on either side of the timepoint (see Figure 11)—a major intersection or neighborhood center that provides the departure time for a bus; for all bus stops in between timepoints, passengers interpolate their departure time based on their location relative to the two adjacent timepoints. There are seven timepoints for Metro’s Route 44 at relatively even-spaced arterial intersections. None of the origin points for any segments are located at a timepoint. This is the only OneBusAway service used for this study and is not to be confused with the real-time arrival information service that some passengers use to determine the arrival time of their bus. That service uses a combination of schedule information, global positioning system (GPS), radio beacons, and

wheel turns to approximate the arrival time for any particular bus based in real-time (OneBusAway Blog 2012). This real-time bus arrival service was not used in this study.

Weekday	Saturday	Sunday	Route Map & Snow Route				
To MONTLAKE (Weekday):							
NW 54th & 32nd Av NW	Ballard Av NW & NW Market	N 46th & Phinney Av N	N 45th & Stone Way N	NE 45th & Univ Way NE	Montlake NE & NE Pacific Pl	On Montlake Blvd at SR-520	To Route
5:06am	5:09am	5:16am	5:19am	5:25am	---	5:33am	43
5:23am	5:26am	5:33am	5:36am	5:43am	---	5:50am	43
5:47am	5:50am	5:57am	6:00am	6:07am	---	6:14am	43
6:06am	6:09am	6:17am	6:21am	6:28am	6:35am	---	
6:21am	6:24am	6:32am	6:36am	6:42am	---	6:50am	43
6:38am	6:41am	6:50am	6:54am	7:01am	7:08am	---	
6:48am	6:51am	7:00am	7:04am	7:11am	7:18am	---	
7:03am	7:06am	7:16am	7:20am	7:28am	7:35am	---	
7:16am	7:19am	7:29am	7:34am	7:43am	7:50am	---	
7:27am	7:30am	7:40am	7:45am	7:54am	8:01am	---	

Figure 10 An excerpt from the Metro’s Route 44 bus schedule (King County Metro 2012). Timepoints are listed at intervals, usually corresponding to major arterials or intersections that require passengers to interpolate the scheduled departure time for their bus trip if the stop falls between two timepoints.

If Metro’s timepoints were used, passengers are expected to infer what time the bus is coming based on gaps of time that are as large as nine minutes. This could prove problematic for precisely when passengers are to arrive at the stop. Therefore, the OneBusAway interpolation of scheduled bus arrivals was appropriate.

Arriving at the Bus Stop

There is little consensus on how many minutes prior to a scheduled arrival an individual should arrive at a bus stop. Metro offers no specific guidance on this matter. An inquiry into this matter to a representative at Metro stated that the recommended people arrive at a stop based on the time listed in the schedule for the previous timepoint. If a stop is located one stop downroute from a timepoint then the recommended time to arrive could be less than one minute. If it is the farthest stop downroute from the previous timepoint then it could be as much as seven minutes until the bus actually arrives.

Further muddling the accuracy of bus arrival times is that Metro considers a bus to be on-time if it is anywhere from one minute early to five minutes late. On-time performance for 2011 was the lowest in years with only 73.1-78.2% of trips arriving on-time (King County Metro 2011a). While the data do not offer whether the 21.8-26.9% of buses that are *not* on-time are either early or late and the lack of guidance from the literature in determining the optimal passenger arrival time, four minutes prior to scheduled departure is the targeted passenger arrival time for this study as it provides a cushion of time and consistency in case the bus is early.

Variables

To maintain internal validity, there were several factors held constant for each of the origin points.

Each bus stop is approximately 0.3 miles away from each “home” site. Related, the destination bus stop at Gould Hall is located 0.065 miles from the chosen northeast entrance into the building.

Knowing what time to leave for the bus from “home” or from Gould was a simple calculation based on the literature and the structure of Metro scheduling:

$$\textit{time to leave} = (\textit{scheduled bus time}) - (4 \textit{ minutes}) - (\textit{time to walk to stop})$$

Because each “home” location was approximately 0.3 miles from the bus stop, the time of departure from “home” was always 10 minutes earlier than the scheduled bus time; 0.3 miles at 3 miles per hour is 6 minutes (plus the 4 minute pad yields 10 minutes).

The time of departure from Gould Hall during the PM-peak period, based on the above formula, should be five minutes prior to the scheduled bus arrival. However, after a few data points were collected, it became evident that the time it took to travel from the northeast corner of Gould Hall to the bus stop just north of North 40th Street on 15th Avenue Northeast took longer than the estimated one minute for the 0.065 mile distance. This was due to lengthy times waiting for the crosswalk at the aforementioned intersection. Thus, one extra minute was built into the schedule to

maintain the required four minute waiting pad resulting in leaving Gould Hall six minutes prior to the scheduled departure time.

To test the hypotheses to determine which mode is faster, most reliable, and burns more calories, several dependent and independent variables were identified. These variables, found in Table 7, were measured for each trip and are analyzed in Chapter 5.

Table 7 Dependent and independent variables

Dependent Variables	Independent Variables
Total travel time	Walk time to transit stop
Reliability	Bus delay/time waited at bus stop
In-vehicle time	Number of traffic lights
Calories/steps	Distance
	Transit stops

To illustrate the impact the independent variables have on the dependent variables, see the conceptual model illustrated in Figure 11.

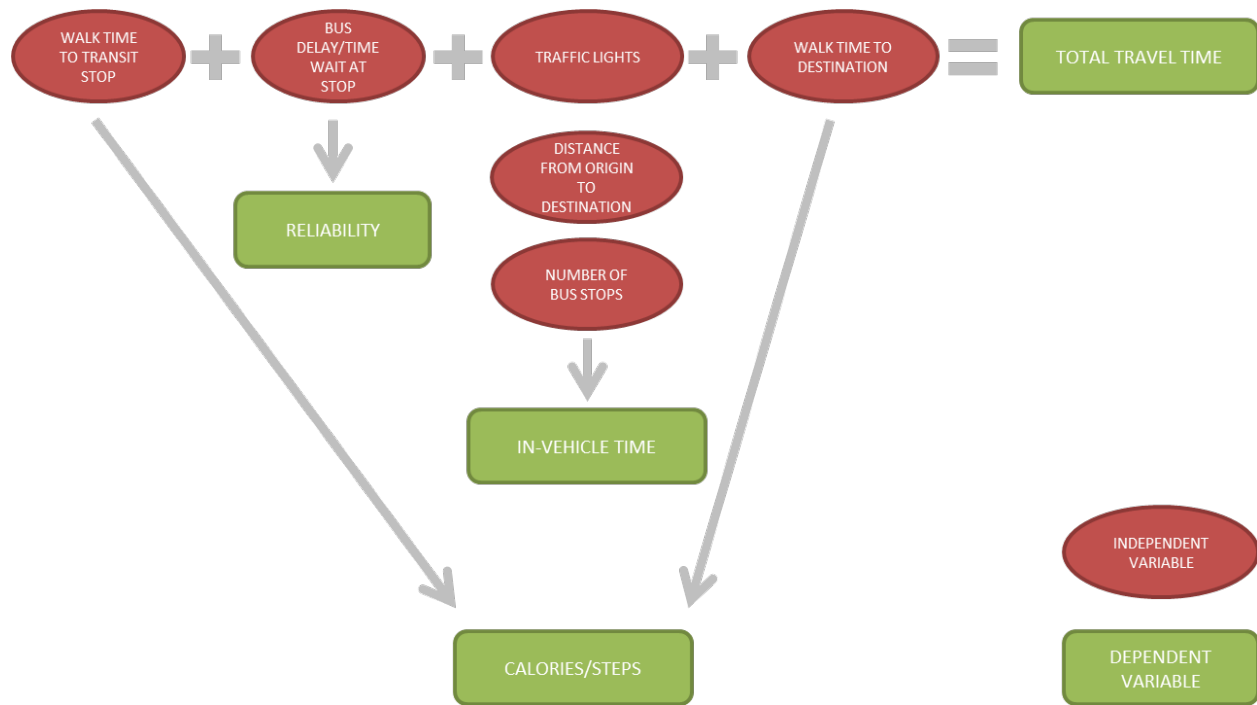


Figure 11 Conceptual model depicting the interplay of independent and dependent variables

Use of Technology

No real-time arrival information was used to aid in the planning of transit trips. Examples of real-time arrival information include the Seattle-based OneBusAway which runs on many mobile platforms including SMS, iOS, and Android. OneBusAway alerts users to how many minutes early or late their bus is relative to the scheduled arrival time. While it would appear sensible that many transit users have access to a cell phone—83% of Americans according to a recent study (Pew Internet and American Life Project 2011)—other studies indicated that transit riders do not necessarily utilize this technology at the stop. Watkins et al. (2011, 842) noted that 544 out of 655 people surveyed—or 83% of the sample—arrived at their bus stop without utilizing real-time arrival information. The remaining 13% were OneBusAway users while 3% used other real-time tracking information, such as a tool provided by Metro. Employing mobile technology, such as

OneBusAway, to aid in trip planning can induce inaccurate departure times from “home.” As the technology is relatively new, there are glitches that can provide inaccurate information to the user.

Concerns over inaccuracies of real-time arrival information are expressed on social media platforms.

In the Seattle area, there have been grumblings (Figure 12) on Twitter about the efficacy of applications such as OneBusAway causing frustration and confusion among users.

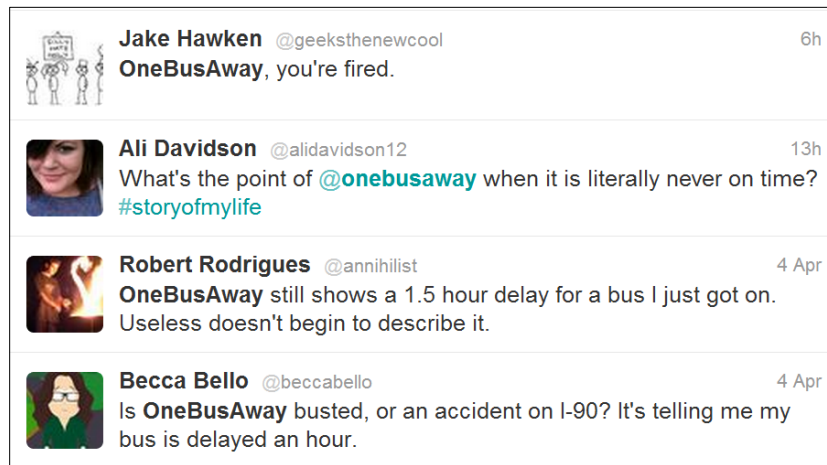


Figure 12 Example of frustration with real-time arrival mobile application OneBusAway

The issue of time inaccuracies was also addressed by the engineer of OneBusAway in a February 28, 2012 OneBusAway blog post titled “On OneBusAway Inaccuracies.”

While the real-time arrival information provided by OneBusAway was never used, the scheduled departure times published on OneBusAway.org were used. The times published on the website are akin to paper timetables; the times represent the expected arrival for that particular day. The published times do not take into account any real-time arrival information.

Transfers

The study assumed zero bus transfers which corresponds to results found in the 2001 *National Household Travel Survey* where 86.2% of linked bus trips did not have transfers reported (Polzin and Chu 2005, 35).

Sample Size

Part of this research determined how reliable certain modes of travel are for short and medium-distance urban trips. A previous study that investigated 1.5 mile trips found that walking was the most reliable mode yielding the smallest differences in travel time based on repeated trips while taking the bus proved the least reliable (University of Washington 2001). The sample size for each location in the University of Washington study for both walking and busing was only three trips. Given that walking can be assumed to be impacted the least by traffic congestion and other time-of-day considerations, a smaller sample size of walking trips is appropriate compared to bus trips.

Based on the spread in the University of Washington report, the range for bus trips was 15:35-34:00 whereas the spread for walking trips was 29:55-34:05 (University of Washington 2001, appendix B). The wider range for bus trips warrants a larger sample size than the relatively small spread experienced with walking trips. Early collection points for this study also indicated a much smaller range in variation and thus a smaller sample size.

To quantify sample size, a simple random sampling without replacement (SRSWOR) formula for continuous data was used.

$$n = \left(\frac{zS}{d} \right)^2$$

Where:

- n = number of samples needed
- z = confidence interval
- S = standard deviation of variance
- d = level of precision

For each origin—Fremont, Wallingford, and U-District—a z -score of 2 or 95% was used, 5.45 for S (the square root of the mean; early tests indicated a mean of 29.8 for Fremont trips) and a level of precision of 3, meaning that 95% of tests would fall within in ± 3 of the mean.

$$13(\textit{rounded}) = \left(\frac{2 * 5.45}{3} \right)^2$$

Based on this reasoning, there were fourteen total bus trips collected for each segment.

Multiple Trips in a Day

Multiple trips for the same route were permitted during a single day so long as they did not occur during the same service period. That is, two AM-peak trips on the same day originating from Fremont and Wallingford were permitted while two AM-peak trips from Fremont were not permitted.

Direction of Travel

While collecting data, direction of travel (from origin to destination or destination to origin) was only significant for the bus when the origin was always from “home” to Gould Hall during the AM-peak period and from Gould Hall to “home” during the PM-peak period. This helped to reflect an actual daily work commute trip. As walking was hypothesized and verified in the literature to yield

minimal variability, walking the same route in either direction was assumed to not impact the validity of the study and was done so when convenient.

Route Selection

Metro's Route 44 follows a fixed route (along North Street, North 45th Street, Northeast 45th Street, and 15th Avenue Northeast) and does not change routing unless inclement weather arises or emergencies or special events reroute traffic.

Walking routes were selected using Google Maps as their algorithm, though still in Beta, does appear to offer the most efficient—in terms of distance and time—walking routes. Because the walking route covered an environment that is largely gridded, there are numerous routes that could be taken from origin to destination and still yield the same distance. For example, traveling from the Fremont site to Gould Hall, one could travel south on Whitman Avenue North to North 46th Street to North 45th Street and then take just about any combination of streets south and east, assuming the grid is followed, and arrive at Gould Hall with the same total distance and time. Figure 13 depicts the walking routes that were used to travel from each origin point to Gould Hall.

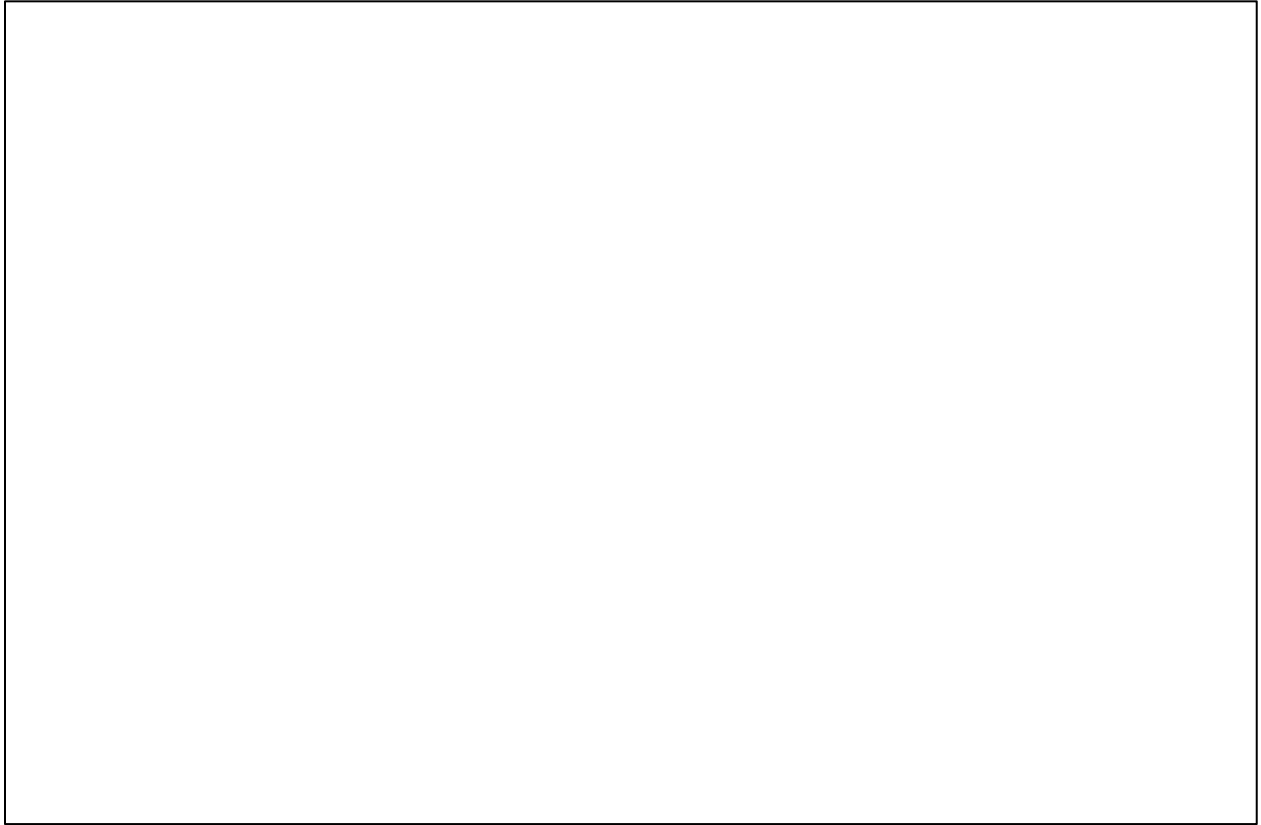


Figure 13 Map of study area showing walking routes from origins to destination

Measuring Distance, Calories, Speed, and Steps

While the most critical element of this study was the evaluation of time and reliability of modes of travel, a secondary research question addressed which mode—bus or walk—expended the greatest number of calories.

To measure calories, speed, steps, and distance, the \$2.99 pedometer PRO GPS+ application for the Apple iPhone 4S was used. It uses GPS signals to track distance and speed, an accelerometer to track footsteps, and translates user BMI to output calories expended. An example of the main pedometer screen is shown in Figure 14.



Figure 14 Screenshot of Pedometer PRO GPS+ application

Traffic Signals

Given that three locations of varying length were tested in this study, there was no way to control for the number of traffic signals encountered for each segment (Figure 15); each segment passed through a different number of traffic signals thus impacting travel time differently for each segment. For each collection point, it was noted which traffic signals required the bus to come to a stop; in some cases the bus never came to a complete stop but was being held in traffic due to several vehicles ahead stuck at the signal. On the data collection sheet (Appendix 1 – Collected Bus Data), the presence of a number (1-2) represents the number of times the bus was stopped at a particular light while a (0) represents continuous motion. During periods of heavy congestion, there were times when the bus had to wait two signal cycles before proceeding through the intersection.

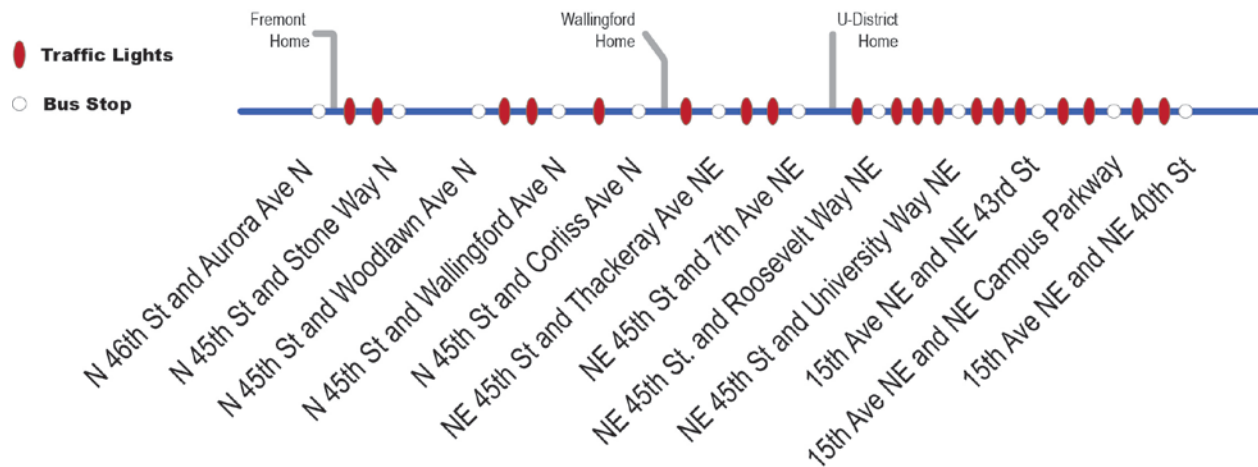


Figure 15 Traffic signals between origins and destination

Baggage

It was revealed by Finnis and Walton (2008) that carrying baggage actually relates to a higher walking pace compared to not carrying any baggage. That said, carrying baggage was not a consideration in this study given the adherence to the 3 mph walking pace.

Pilot Period

There were six pilot runs—two walk trips and four bus trips—conducted before actual data collection occurred to test the methods and to ensure all data that was needed was truly collected. Refinements to the methods were made upon completion of the pilot period. The data collected during the pilot were not used in the actual analysis.

The first pilot data bus point was collected on April 4, 2012 during the PM-peak period. Three additional bus trips were conducted on April 9, 2012 along with two walk trips. Data were recorded following the data collection sheet found in Figure 16. A major lesson was learned during this period in that it was difficult to measure the time stopped at each traffic light. Instead of measuring the time, simply denoting whether the bus stopped at a traffic signal or not was recorded.

Photographs

Photographs of relevant scenes—origins, destinations, anomalies—were collected during data collection. While these were not part of the formal analysis, they serve as reference material to situate the reader as to the where the study occurred.

Time

To ensure time was being recorded consistently from trip to trip, an iPhone clock was used as it is impossible to change and is thus consistent from day-to-day. Except in the case of time walked (to and from bus stops and time walked on the walk trips), time was recorded to the nearest minute.

Collected Data

For bus trips, there were many data elements that were recorded to aid in the analysis. A sample data collection sheet can be found in Figure 16. For completed forms, please see Appendix 1 – Collected Bus Data.

Data Collection: Wallingford--44 AM Peak		Trip #:	
Date:	Time arrived at disembarkment stop:		
Scheduled Bus Time:	Time to Gould:		
Time Let House:	Weather:		
Time Arrived at Stop:	Calories:		
Time walked to stop:	Walking Distance Traveled:	Total Distance Traveled:	
Time Bus Arrived:	Notes:		
Minutes early or late:			
Minutes spent waiting at stop:			
Time spent at each light:			9
1			10
2	11		
3	12		
4	13		
5	14		
6	15		
7	16		
8	17		
Input into Excel?		<input type="checkbox"/> Yes <input type="checkbox"/> No	

Figure 16 Example of data collection sheet

Qualitative Observations

While most of the data collected were of the quantitative nature—calories, distance, time—there were some qualitative observations collected during data collection periods simply to provide additional context and understanding of the study area. For example, if the bus was especially full or the time it took to get everyone on board was relatively slow then this was recorded in the ‘Notes’ section of the data collection sheet.

Chapter 5: Results and Analysis

This study explored the notion of walkability by measuring numerous variables associated with walking and taking the bus from three origin points of varying length to the same destination. In total, sixty total data points were collected: seven bus points were collected for the AM-peak period from each origin point, seven bus points during the PM-peak period from each origin point, three walking points collected from each origin point during the AM-peak period, and three walking points collected from each origin point during the PM-peak period.

To determine whether traditional definitions of walkability could be challenged, it is helpful to revisit the research questions to help guide the analysis and subsequent data interpretations:

1. What is the time spent by mode (bus, walk) to travel from three distinct origins of varying distance to the same destination?
2. What is the variability in time between mode (bus, walk) to travel from three distinct origins of varying distance to the same destination?
3. Based on calories expended, what is the most energy intensive mode? What is the relationship between expended calories and distance by mode?
4. At what distance does walking become faster than bus transit?

Overview of Data Points Collected

Data were collected on fourteen individual weekdays between April 11, 2012 and April 30, 2012.

No data were collected on weekends as this would not replicate a normal commute trip. During the AM-peak period, walking and bus trips were collected between the hours of 6:30 a.m. and 9:12 a.m.; this represents the time leaving either the home origin point or Gould Hall. In other words, travel continued past 9:12 a.m. but no trips began after this time. During the PM-peak period, walking and bus trips were collected between the hours 3:30 p.m. and 6:35 p.m. No trips began after 6:35 pm.

Multiple walking trips during each service period were permitted from the same origin to the destination for walking trips as walking trips are less susceptible to travel time impacts compared to bus trips where bus wait time and bus travel time is extremely variable. Only one trip per origin per bus service period was collected due to susceptibility to travel time variability.

Given the hypothesized minimal variation in travel time for walking, it is possible that walking trips could have been made any time of day during any day of the week. However, to maintain consistency and to increase internal validity, walking data points were only collected during the AM-peak and PM-peak periods. A summary of the number of data points collected by day can be found in Figure 17. There is wide variation in the number of trips taken on each day of the week due to time availability and also because when a data point was collected was not held constant.

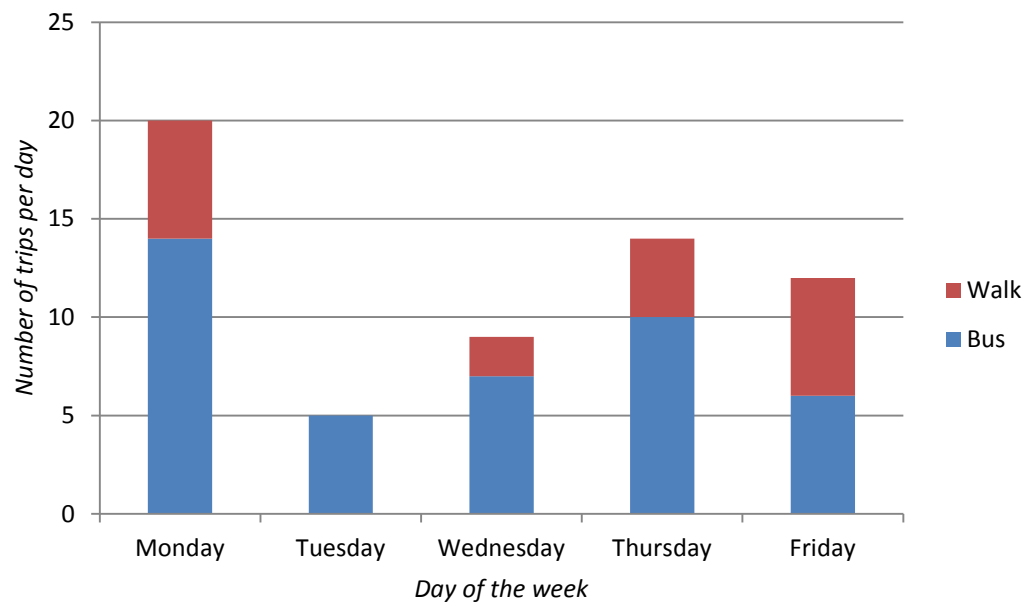


Figure 17 Number of data points collected by day of week, mode

While an analysis of the weather was not central to this study, it is worth summarizing the meteorological conditions under which the data points were collected. The average temperature was

51F with rain occurring for 15 or approximately 27% of the data points. (note: there are four data points for which weather information was not collected due to collection error resulting in $n=56$.)

For each bus trip, the following primarily quantitative data elements were collected. The unit of measurement is also identified (the only element directly measured to the second was walking time as the application measuring walking time enabled measurement to the second; time to burn one calorie was derived from total travel time and calories expended and thus is reported in seconds).

- Scheduled bus time (hour, minute)
- Time left “home” or Gould (hour, minute)
- Time arrived at stop (hour, minute)
- Time spent walking (minutes, seconds)
- Minutes spent waiting at stop (minutes)
- How early or late the bus arrived (minutes)
- What traffic signals required the bus to stop
- Total traffic signal stops
- Disembarked time (hour, minute)
- Time arrived at Gould or home (hour, minute)
- Time in transit (minutes)
- Total time walked (minutes, seconds)
- Weather
- Calories expended
- Distance traveled (miles)
- Number of steps

- Recommended daily steps taken (percentage)
- Steps achieved compared to average male (percentage)
- Time to burn one calorie (minute, second)

The following elements were collected for each walking trip:

- Service period (AM or PM)
- Origin/destination (could be either “home” or Gould)
- Time left origin (hour, minute)
- Time arrived destination (hour, minute)
- Total walk time (minutes, seconds)
- Distance (miles)
- Calories
- Pace (mph)
- Steps
- Recommended daily steps taken (percentage)
- Steps achieved compared to average male (percentage)
- Time to burn one calorie (minute, second)

For all data points, any noticeable qualitative observations—such as when the bus wheelchair ramp was used, for example—were also recorded. The full records with all data elements can be found in Appendix 1 – Collected Bus Data

Travel Time Calculations

Total travel times for bus trips were calculated to the minute by subtracting the time left from the origin (either home or Gould Hall) from the time arrived at the destination. Minutes spent waiting

at the stop, how early or late the bus was, and transit time were also recorded by finding the difference to the minute of two reference data elements collected (e.g. time arrived at bus stops subtracted from the time the bus arrived to determine how many minutes were spent waiting at the stop).

Walking trip times were calculated to the second as the Pedometer PRO GPS+ application allowed for such timekeeping and because it was the only temporal element captured for walking trips.

Bus Travel Summaries

The following sections detail the date of each data collection point, minutes spent waiting at each stop, how early or late the bus was, how many traffic signals required the bus to stop, in-vehicle time, total travel time, and time to burn one calorie for each segment.

Fremont Bus Travel Summary

There were seven points collected during the AM-peak period and seven points collected during the PM-peak period for the Fremont segment. Average travel time during the AM-peak was 28:51 while travel time during the PM-peak was 31:00; this means afternoon trips took on average 2:09 longer than AM-peak trips. Though more time was spent waiting at the bus stop in the morning, in-vehicle time was considerably less than in the evening— a difference of more than five minutes. The number of times stopped at traffic signals in the evening exceeded the morning trips by three and might help to explain the difference in travel time. The buses in the morning were never on-time according to the schedule (but are on-time given Metro’s definition of on-time performance which allows for a bus to be one minute early and up to five minutes late) averaging about 2:34 late. Conversely, the evening bus trips always arrived either early or right on schedule. This is probably explained by the proximity to the origin of the route for Route 44 as it begins in Montlake only 0.5 miles from the bus stop. In the morning, the bus stop is approximately 2.7 miles from the origin

meaning there are considerably more stops, traffic signals, and other factors that most likely caused the bus to be delayed. An abridged summary of the Fremont bus trips can be found in Table 8 while the full data record can be found in Appendix 1 – Collected Bus Data.

Table 8 Fremont Bus Travel Summary

Date	Service Period	Mins Spent Waiting	Early/late	Total Signals	In-vehicle time	Travel Time	Time to burn one calorie
11-Apr	AM	0:07:00	0:02:00	8	0:16:00	0:30:00	0:00:50
13-Apr	AM	0:05:00	0:01:00	9	0:17:00	0:29:00	0:00:56
16-Apr	AM	0:07:00	0:03:00	6	0:14:00	0:28:00	0:00:51
18-Apr	AM	0:06:00	0:03:00	4	0:13:00	0:27:00	0:00:43
19-Apr	AM	0:06:00	0:03:00	5	0:12:00	0:26:00	0:00:51
24-Apr	AM	0:05:00	0:02:00	7	0:16:00	0:29:00	0:00:53
30-Apr	AM	0:08:00	0:04:00	7	0:18:00	0:33:00	0:01:01
<i>AM Average</i>		0:06:17	0:02:34	6.6	0:15:09	0:28:51	0:00:52
11-Apr	PM	0:03:00	-0:01:00	9	0:19:00	0:30:00	0:00:59
13-Apr	PM	0:04:00	0:00:00	13	0:24:00	0:31:00	0:00:51
16-Apr	PM	0:05:00	0:00:00	9	0:19:00	0:31:00	0:01:06
17-Apr	PM	0:03:00	-0:02:00	10	0:21:00	0:30:00	0:00:57
18-Apr	PM	0:05:00	0:00:00	7	0:15:00	0:27:00	0:00:53
19-Apr	PM	0:04:00	0:00:00	9	0:25:00	0:36:00	0:01:08
27-Apr	PM	0:04:00	0:00:00	10	0:20:00	0:32:00	0:01:15
<i>PM Average</i>		0:04:00	-0:0:43	9.6	0:20:26	0:31:00	0:01:01
Fremont Average		0:05:09	0:00:55	8.1	0:17:47	0:29:56	0:00:56

Wallingford Bus Travel Summary

There were seven points collected during the AM-peak period and seven points collected during the PM-peak period for the Wallingford origin point. Average travel time in the AM-peak was 23:09 while travel time during the PM-peak was 22:17; this means afternoon trips took on average 0:52 shorter than AM-trips. Much like the Fremont trips, more time was spent waiting at the stop in the morning than in the evening, in-vehicle time was shorter in the morning, and more traffic signals

caused the bus to stop in the evening than in the morning. However, the discrepancy between waiting times in the morning likely caused the overall trip time to take longer than the evening trips. An abridged summary of the Wallingford bus trips can be found in Table 9 while the full data record can be found in Appendix 1 – Collected Bus Data.

Table 9 Wallingford bus travel summary

Date	Service Period	Mins Spent Waiting	Early/late	Total Signals	In-vehicle time	Travel Time	Time to burn one calorie
12-Apr	AM	0:08:00	0:04:00	7	0:13:00	0:28:00	0:00:47
13-Apr	AM	0:04:00	0:00:00	7	0:08:00	0:19:00	0:00:33
16-Apr	AM	0:05:00	0:01:00	6	0:07:00	0:20:00	0:00:34
18-Apr	AM	0:07:00	0:03:00	4	0:10:00	0:23:00	0:00:44
19-Apr	AM	0:05:00	0:01:00	5	0:09:00	0:20:00	0:00:43
24-Apr	AM	0:07:00	0:04:00	5	0:10:00	0:25:00	0:00:45
30-Apr	AM	0:10:00	0:06:00	5	0:10:00	0:27:00	0:00:56
<i>AM Average</i>		0:06:34	0:02:43	5.6	0:09:34	0:23:09	0:00:43
11-Apr	PM	0:06:00	0:02:00	7	0:12:00	0:25:00	0:00:40
13-Apr	PM	0:03:00	-0:01:00	10	0:14:00	0:25:00	0:00:46
16-Apr	PM	0:03:00	-0:01:00	8	0:11:00	0:22:00	0:00:48
17-Apr	PM	0:03:00	-0:02:00	5	0:12:00	0:20:00	0:00:43
18-Apr	PM	0:04:00	0:00:00	6	0:09:00	0:22:00	0:00:48
19-Apr	PM	0:03:00	-0:01:00	8	0:12:00	0:22:00	0:00:42
27-Apr	PM	0:01:00	-0:04:00	7	0:13:00	0:20:00	0:00:42
<i>PM Average</i>		0:03:17	-0:1:00	7.3	0:11:51	0:22:17	0:00:44
Wallingford Average		0:04:56	0:00:50	6.4	0:10:43	0:22:43	0:00:44

U-District Bus Travel Summary

There were seven points collected during the AM-peak period and seven points collected during the PM-peak period for the U-District origin point. Average travel time in the AM-peak was 19:43 while travel time during the PM-peak was 16:34; this means afternoon trips took on average 3:09 shorter than AM-trips. Much like the Fremont and Wallingford trips, more time was spent waiting at

the stop in the morning than in the evening. However, in-vehicle time was quite similar between the two service periods meaning the delays in the morning were the contributing factor to the longer travel time in the morning. An abridged summary of the U-District bus trips can be found in Table 10 while the full data record can be found in Appendix 1 – Collected Bus Data.

Table 10 U-District bus travel summary

Date	Service Period	Mins Spent Waiting	Early/late	Total Signals	In-vehicle time	Travel Time	Time to burn one calorie
12-Apr	AM	0:05:00	0:01:00	3	0:04:00	0:16:00	0:00:32
16-Apr	AM	0:08:00	0:04:00	2	0:07:00	0:21:00	0:00:35
18-Apr	AM	0:04:00	0:00:00	2	0:05:00	0:15:00	0:00:28
19-Apr	AM	0:05:00	0:01:00	1	0:05:00	0:17:00	0:00:32
25-Apr	AM	0:09:00	0:05:00	3	0:06:00	0:23:00	0:00:47
26-Apr	AM	0:12:00	0:08:00	4	0:08:00	0:26:00	0:00:50
30-Apr	AM	0:04:00	0:09:00	3	0:08:00	0:20:00	0:00:41
<i>AM Average</i>		0:06:43	0:04:00	2.6	0:06:09	0:19:43	0:00:38
12-Apr	PM	0:03:00	-0:01:00	5	0:07:00	0:16:00	0:00:34
16-Apr	PM	0:03:00	-0:01:00	3	0:05:00	0:16:00	0:00:30
17-Apr	PM	0:05:00	0:01:00	2	0:04:00	0:16:00	0:00:39
19-Apr	PM	0:04:00	0:00:00	4	0:05:00	0:16:00	0:00:35
23-Apr	PM	0:03:00	-0:01:00	5	0:07:00	0:17:00	0:00:33
24-Apr	PM	0:03:00	-0:01:00	5	0:06:00	0:16:00	0:00:37
27-Apr	PM	0:06:00	0:02:00	4	0:06:00	0:19:00	0:00:34
<i>PM Average</i>		0:03:51	-0:00:09	4.0	0:05:43	0:16:34	0:00:35
U-District Average		0:05:17	0:01:56	3.3	0:05:56	0:18:09	0:00:37

Comparing Bus Trips

The time spent waiting at the bus stop in the morning was universally longer than the time spent waiting in the evening due to the proximity of the bus stops to the origins of the bus route (Figure 18). It stands to reason that the farther along a stop is compared to the origin point then there is a

greater chance for a bus to be delayed resulting more time spent waiting at each stop. This is the case for this study when the average time spent at the Fremont, Wallingford, and U-District stops was 6:17, 6:34, and 6:43, respectively. In other words, each stop farther from the origin point was associated with an increasing amount of time spent waiting for the bus to arrive. The wait times at Gould Hall do not follow a similar pattern due to the more erratic waiting times experienced at the Gould Hall stop.

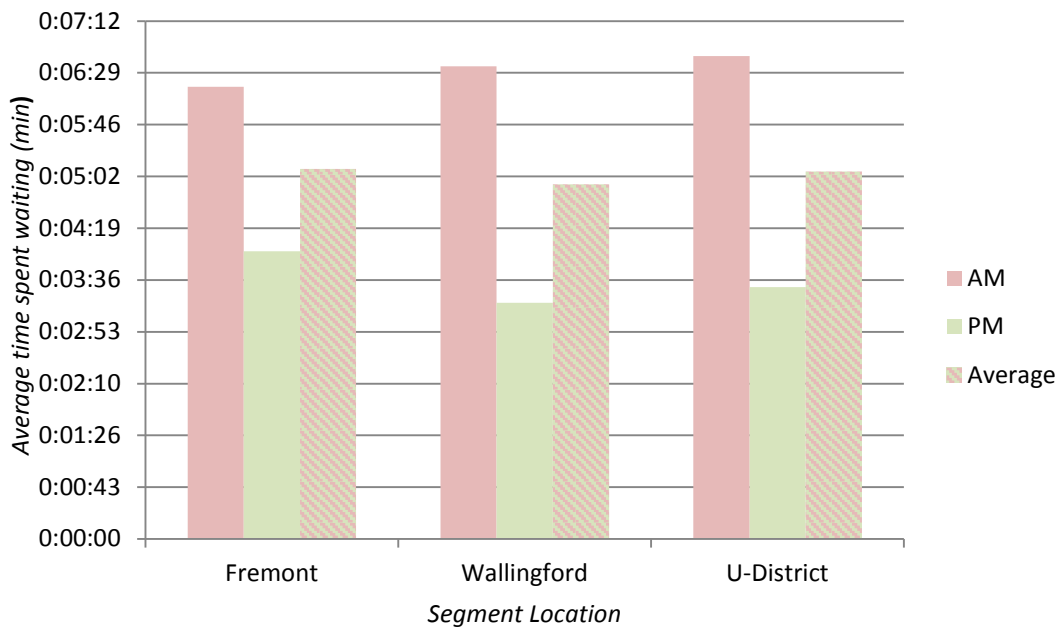


Figure 18 Average time spent waiting at each bus stop--AM-peak, PM-peak, and average of both AM and PM service periods (the PM-peak bus stop for all segments is located adjacent to Gould Hall)

Another pattern across all trips was the higher incidence of traffic signals that required the bus to stop in the evening compared to the morning (Figure 19). Percentage is used in this case due to the varying number of traffic signals encountered for each origin point and trip (Fremont: 21 in the morning, 20 in the evening; Wallingford: 16 in the morning, 15 in the evening; and U-District: 10 in both morning and evening). The lower percentage of signals requiring the bus to stop in the U-

District for both morning and evening trips may indicate that the signals causing stoppages were more in the Wallingford area than in the U-District area.

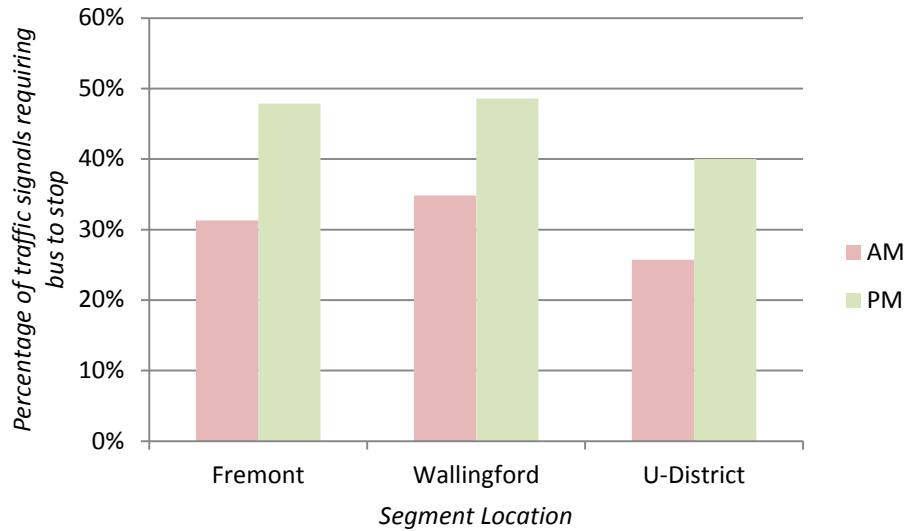


Figure 19 Percentage of traffic signals requiring the bus to stop—AM-peak, PM-peak

The time it took to burn one calorie greatly varies across each trip segment but decreases as travel time decreases (Figure 20). This is easily explained given the relationship between time spent walking—which was roughly the same for each bus segment—and overall travel time. Each bus segment required a distance of approximately 0.3 miles to be walked regardless of overall travel time. Given the shorter travel time for the U-District segment compared to the Wallingford and Fremont segments, it is sensible that one burns a calorie considerably faster for the former segment compared to the latter two segments.

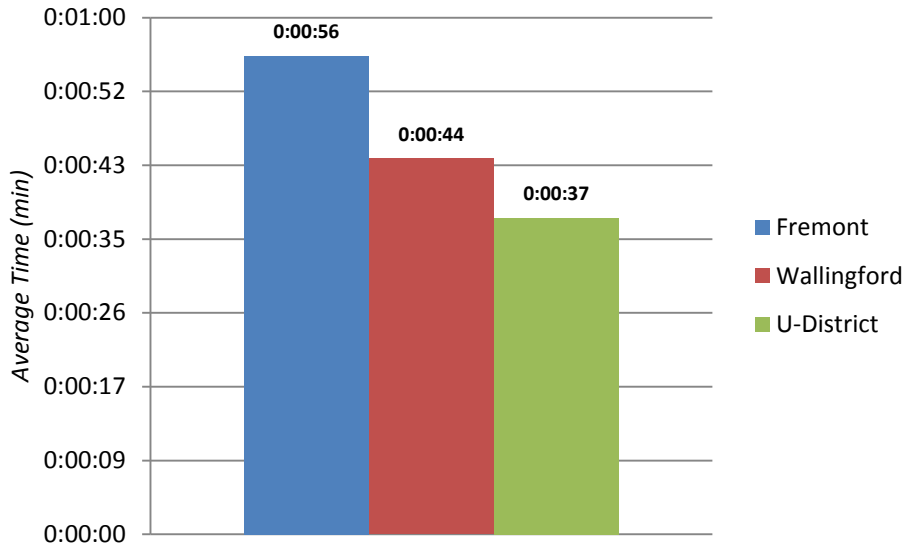


Figure 20 Average time (min) to burn one calorie for bus trips

Walk Travel Summaries

There were fewer data elements collected for walking trips compared to bus trips. Nonetheless, the following sections detail the date the data point was collected, whether the trip was conducted in the morning or evening, origin and destination point (regardless of when the trip was conducted, a walk trip could begin at either “home” or Gould Hall), total walk time, distance, calories, steps, and time to burn one calorie. Full data records can be found in Appendix 2 – Collected Walking Data

Fremont Walk Travel Summary

There were six total walking points collected for the Fremont segment—three in the morning and three in the evening (Table 11). Whereas total travel time for bus trips was contingent upon uncontrollable factors such as signal timing and bus delays, walking trips did not involve as many variables that impacted travel time. As a result, the lone temporal element recorded was total walk time which averaged 45:46 over a course of 2.3 miles for the Fremont segment.

Given the limited factors that impacted travel time, travel direction occurred in any direction during any service period. That is, a trip could start at “home” or at Gould in the morning and at “home” or at Gould in evening.

Table 11 Fremont walk travel summary

Date	Service Period	Origin	Destination	Total Walk Time	Distance	Calories	Steps	Time to burn one calorie
9-Apr	PM	Gould	Home	0:47:08	2.35	224.4	4069	0:00:13
11-Apr	PM	Home	Gould	0:44:58	2.31	214.9	4118	0:00:13
13-Apr	PM	Home	Gould	0:46:08	2.28	222.8	3883	0:00:12
27-Apr	AM	Gould	Home	0:44:48	2.30	214.8	4065	0:00:13
27-Apr	AM	Home	Gould	0:44:34	2.22	209.7	3844	0:00:13
30-Apr	AM	Gould	Home	0:47:01	2.44	226.4	4228	0:00:12
Average				0:45:46	2.32	218.8	4035	0:00:13

Wallingford Walk Summary

Six data points were collected for the Wallingford segment: three in the morning and three in the evening (Table 12). Total walk time averaged 29:17 over a course 1.49 miles.

Table 12 Wallingford walk travel summary

Date	Service Period	Origin	Destination	Total Walk Time	Distance	Calories	Steps	time to burn one calorie
12-Apr	PM	Home	Gould	0:28:42	1.47	136.7	2573	0:00:13
13-Apr	PM	Home	Gould	0:29:50	1.49	139.8	2600	0:00:13
16-Apr	PM	Home	Gould	0:29:09	1.50	135.0	2723	0:00:13
26-Apr	AM	Home	Gould	0:28:48	1.47	142.8	2504	0:00:12
26-Apr	AM	Gould	Home	0:29:30	1.50	141.6	2615	0:00:13
30-Apr	AM	Home	Gould	0:29:46	1.52	142.2	2625	0:00:13
Average				0:29:17	1.49	139.7	2607	0:00:13

U-District Walk Summary

Six data points were collected for the U-District segment: three in the morning and three in the evening (Table 13). Total walk time averaged 18:14 over a course 0.90 miles.

Table 13 U-District walk travel summary

Date	Service Period	Origin	Destination	Total Walk Time	Distance	Calories	Steps	time to burn one calorie
13-Apr	PM	Gould	Home	0:18:40	0.88	85.3	1547	0:00:13
16-Apr	AM	Home	Gould	0:19:18	0.92	88.9	1585	0:00:13
16-Apr	PM	Home	Gould	0:18:36	0.94	88.2	1661	0:00:13
19-Apr	PM	Home	Gould	0:17:13	0.88	84.5	1559	0:00:12
25-Apr	AM	Gould	Home	0:17:15	0.88	86.2	1546	0:00:12
27-Apr	AM	Home	Gould	0:18:20	0.91	87.5	1570	0:00:13
Average				0:18:14	0.90	86.8	1578	0:00:13

Comparing Walk Trips

The differences in travel time were commensurate with distance traveled. This is evident in Figure 21 where the relationship between travel time and distance is nearly linear. Given this relationship, the time to burn one calorie is the same—thirteen seconds—for each trip segment.

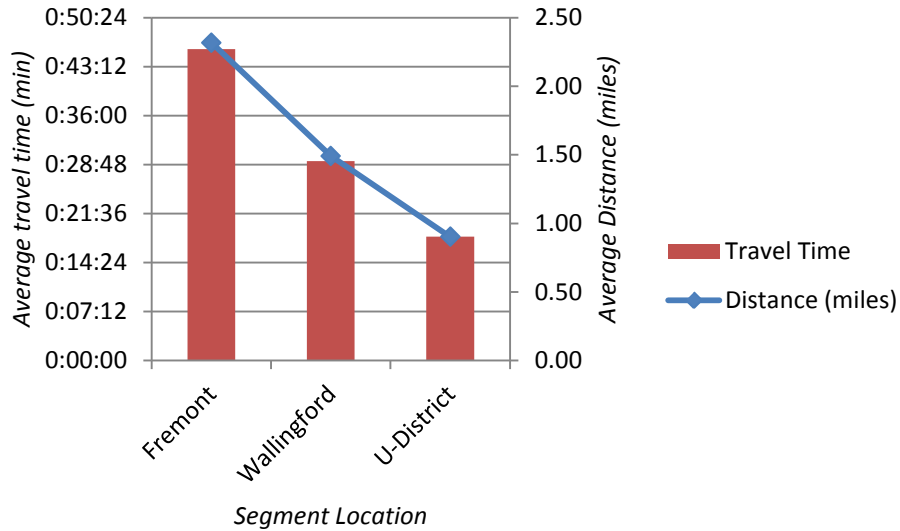


Figure 21 Average walk travel time (minutes) and average distance (miles) for each segment

Comparing Walk and Bus Trips

A key component of this research was to determine which mode of travel was fastest at each origin point (Figure 22). Taking the bus from Fremont and Wallingford “home” points, 2.3 miles and 1.5 miles from home to Gould Hall, respectively, proved to be faster than walking the same distance.

However, travel time between the two modes was roughly equal to travel the 0.9 miles from the U-District home site to Gould Hall. As expected, the closer the “home” origin point was to Gould Hall, the more time-competitive walking became as a mode of transport. For the Fremont segment, it was approximately sixteen minutes faster to take the bus than to walk. It was just over six minutes faster to take the bus from the Wallingford location and just five seconds faster to take the bus from the U-District location.

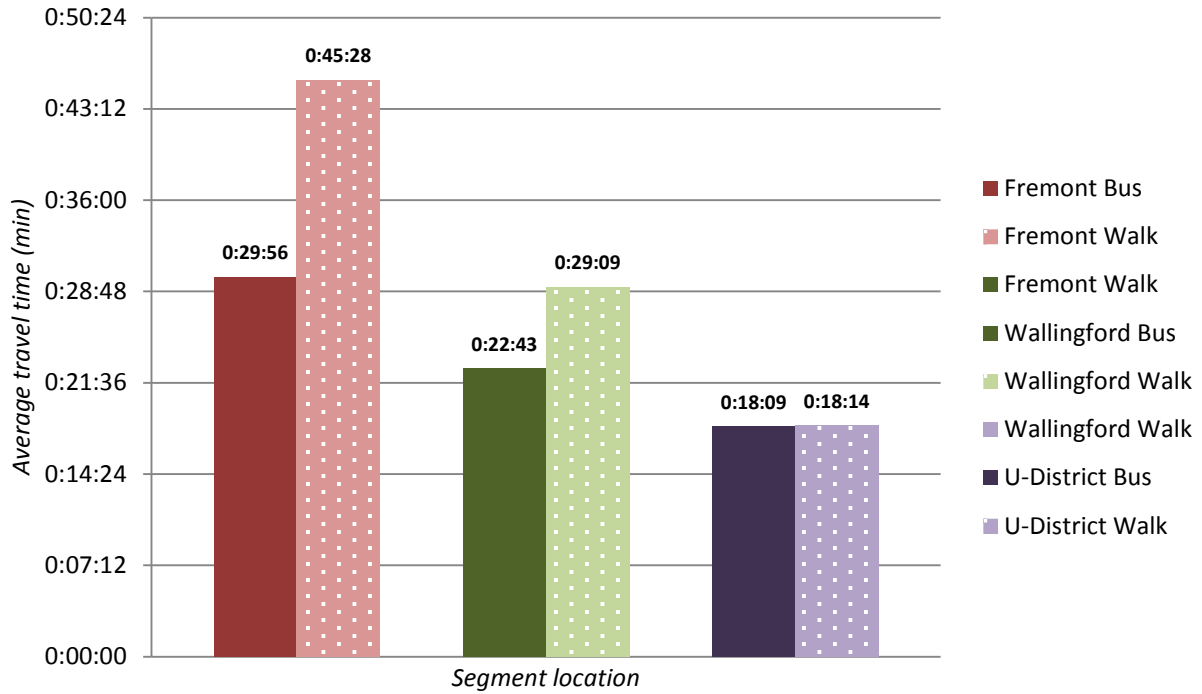


Figure 22 Average travel time (minutes) for all trips (bus $n = 14$, walk $n = 6$ for each mode/origin)

It is of little surprise, given the overall walking distances covered for each mode, that the time to burn one calorie was much less for walking trips than bus trips (Figure 23). Assuming an equal pace, the distance could increase or decrease by any factor and the time to burn one calorie for walk trips should be in the vicinity of thirteen seconds. However, as bus trips gain length (note: the walking portion of bus trips is held constant for each segment), the time to burn one calorie increases. If the relationship between distance and time is linear—a relationship that this study is unable to confirm for distances *outside* the study range—then the relationship between time and calories burned is also linear.

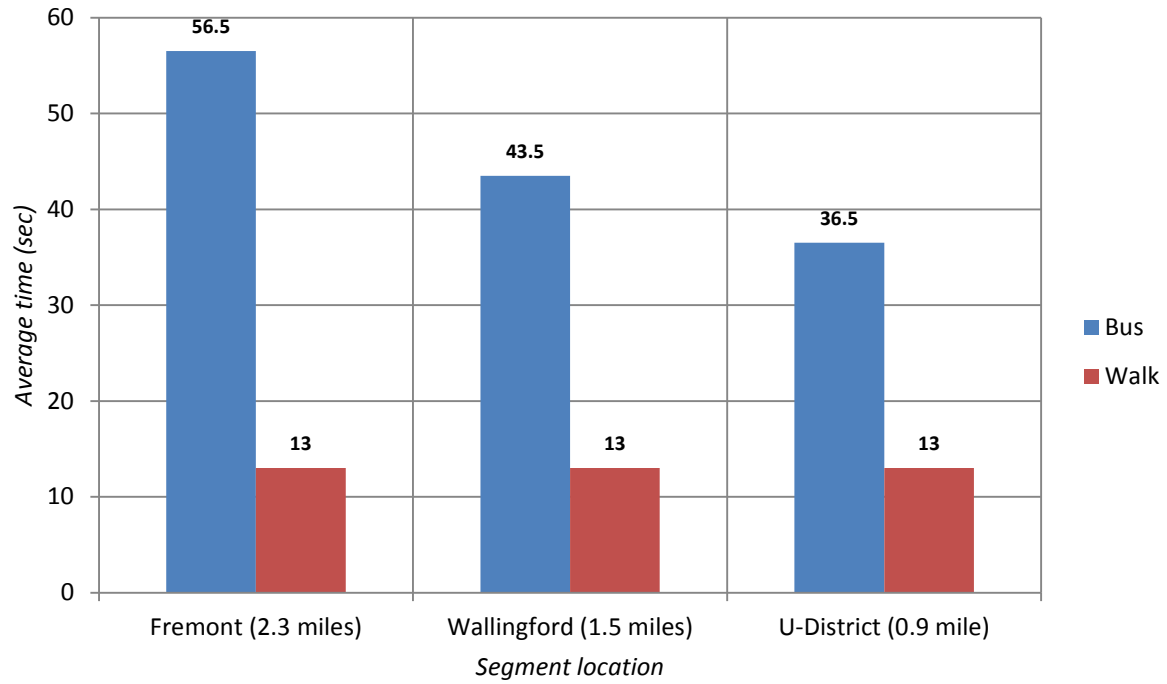


Figure 23 Average time (seconds) to burn one calorie by mode, by segment

Variability

To determine which mode was the most reliable, the standard deviation was calculated for each mode and segments' sample size ($n=14$ for bus, $n=6$ for walking). See Figure 24 for a comparison of standard deviations.

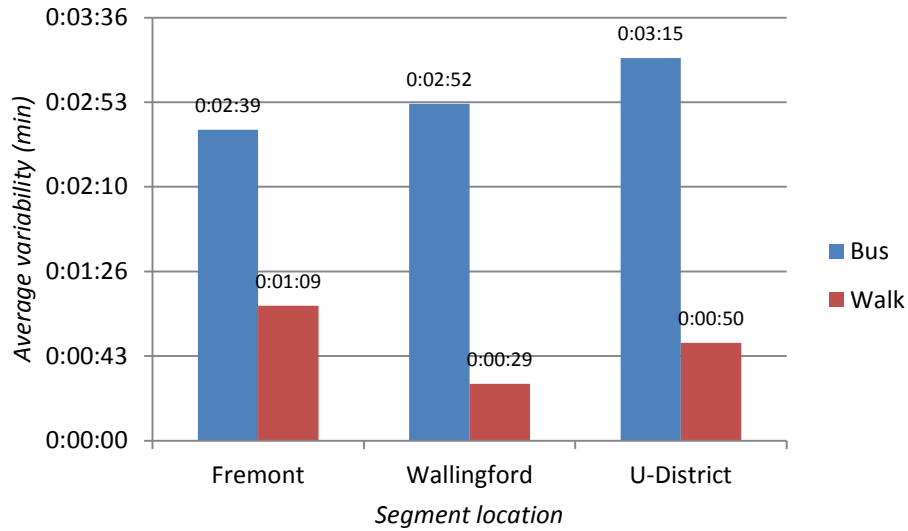


Figure 24 Variability of average travel time (minutes) by mode, segment (standard deviation)

Though the overall trip time is always longer for walking trips, the variability across walking times is minimal. In fact, comparing the two modes shows that taking the bus is more variable than walking by factors of 2.3, 5.9, and 3.9 for the Fremont, Wallingford, and U-District segments, respectively.

Interestingly, there is more variability with U-District bus trips compared to Fremont and Wallingford bus trips. As other results indicate, this is most likely attributed to the presence of the U-District bus stop being well into the overall route and thus subject to larger time delays compared to stops that are closer to the origin.

Chapter 6: Discussion

Hypotheses Revisited

To determine whether traditional notions of walkability with regards to distance can be extended, it is worthwhile to revisit the hypotheses that underscore this study:

1. If bus wait time and in-vehicle time vary from trip to trip, then the total travel time will become more variable relative to walk times for that same distance.
2. If bus wait time, in-vehicle time, and the number of traffic signals requiring the bus to stop increase total travel time, then walking travel time may be the fastest mode choice for that same distance.

The four research questions helped to verify hypothesis one and disprove hypothesis two. As will be explained, the fact that hypothesis two was disproved does not negate the notion that distance-based definitions of walkability can be challenged. While no average walking trip was faster than taking the bus, the bus time for the U-District segment—approximately 0.9 miles—was only five second than walking that same distance.

The time difference for the Wallingford segment was approximately six minutes in favor of the bus. However, that additional six minutes of travel time on foot yields nearly five times as many calories burned as taking that same trip by bus. Similarly, the Fremont segment is nearly sixteen minutes faster by bus than by foot. However, Fremont walk trips affords burning nearly seven times as many calories burned as that same trip by bus.

While there is a cost associated with time, the net benefit offered by additional exercise makes a convincing case for people to walk rather than take the bus, especially if they have an additional

exercise regime that takes longer than sixteen minutes. That said, the lack of walking being a faster mode than bus for any segment results in hypothesis two being disproved.

With regards to hypothesis one, this is confirmed given the evidence described in the 'Variability' section in the preceding chapter. The time spread for walking trips is substantially smaller than for bus trips by factors ranging from three to six.

This study shows a generally linear relationship between time and distance for both walk and bus trips. As a result, times of intermediate distances can be interpolated to further quantify the relationship between walking and taking the bus for the same distance. Figure 25 shows this relationship. The slope of the line for walk trips is steeper than for bus trips meaning as distance increases, the time that separates the two modes becomes exponentially larger. For the lay person, this is perhaps a very useful piece of information that can be referenced to quickly determine whether a person should walk to a destination or take the bus.

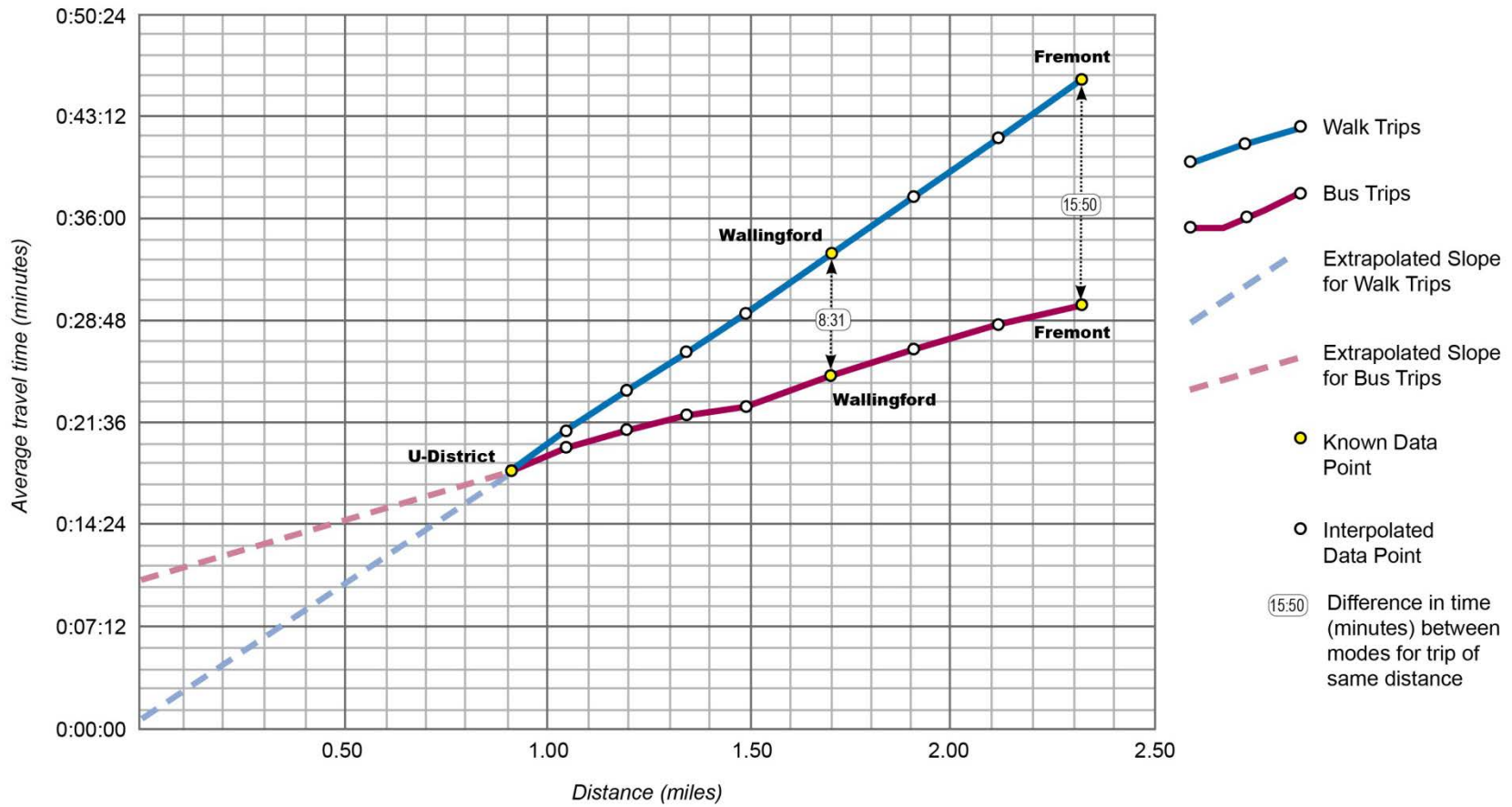


Figure 25 Difference in time between walk and bus trips for three known origin points and six intermediate interpolated points. The slopes of the bus and walk lines are also extrapolated out beyond the U-District pivot point—the point at which average time to walk a distance is equal to the average time to travel that same distance by bus

Figure 25 is vital to this research as it shows the exact point at which travel walking time and travel time are essentially equal—at the U-District location. Extrapolating the data to include distances of less than 0.9 miles reveals that walking will always be faster, on average, than taking the bus. To the right of the pivot point are known travel times and interpolated travel times for those points in between. It is at this pivot point that average bus travel time becomes less than average walk travel time for the same distance. The differences in travel time for the Wallingford location (8 minutes 31 seconds) and Fremont (15 minutes 50 seconds) is also highlighted to emphasize that as distance increases, the average travel time distance between the two modes becomes exponentially larger.

This pivot point is highly mobile, subject to shifting to the left, right, up, or down based on changes in the street pattern, bus headway characteristics, walking pace, distance to transit, reliability of transit, and in-vehicle time. Subtle changes to any number of characteristics will change the nature of the bus slope, possibly creating irregular relationships between points opposed to the linear relationship seen here. Tweaks to walking pace should only change the angle of the slope for walk trips; the relationship should remain linear.

An illustration of how this may be useful is further evident in (Table 14). If a person has an additional five minutes to spare—that is, their schedule allows an additional five minutes to arrive at their destination—then they might be comfortable walking a distance of 1.34 miles; based on the data and interpolated points between actual times and distances for the U-District location and Wallingford location, then at a distance of 1.34 miles, it would take an additional 04:28 to walk the same distance as would be covered by bus (26:35 for the walk trip versus 22:07). Using this logic, if an additional ten minutes is permitted, then the distance that is considered walkable increases to nearly 1.9 miles.

It should be noted that this example ignores stop placement and subsequent proximity from the stop to a person’s actual origin point.

Table 14 Comparison of travel times from three known origins and six intermediate interpolated points

Location	Distance	Walk Time	Bus Time	Walk Mile Rate	Bus Mile Rate	Walking slower than bus by how much per mile	Total Difference
Fremont (actual)	2.32	0:45:46	0:29:56	0:19:44	0:12:54	0:06:50	0:15:50
Fictional Distance A	2.11	0:41:38	0:28:30	0:19:43	0:13:29	0:06:13	0:13:09
Fictional Distance B	1.91	0:37:31	0:26:49	0:19:42	0:14:04	0:05:37	0:10:42
Fictional Distance C	1.70	0:33:24	0:24:53	0:19:41	0:14:40	0:05:01	0:08:31
Wallingford (actual)	1.49	0:29:17	0:22:43	0:19:40	0:15:15	0:04:25	0:06:35
Fictional Distance D	1.34	0:26:35	0:22:07	0:19:48	0:16:29	0:03:20	0:04:28
Fictional Distance E	1.20	0:23:51	0:21:10	0:19:57	0:17:42	0:02:15	0:02:41
Fictional Distance F	1.05	0:21:04	0:19:50	0:20:06	0:18:56	0:01:10	0:01:13
U-District (actual)	0.90	0:18:14	0:18:09	0:20:15	0:20:10	0:00:05	0:00:05

Impact of Traffic Signals

As pointed out, wait times in the afternoon were uniformly less than in the mornings for all segments given the proximity of the Gould Hall bus stop to the origin point of the transit route. However, travel time in the afternoon for both Fremont and Wallingford trips was considerably higher than in the morning. Looking to the number of traffic signals that required the bus to stop may help to answer why this occurred (Table 15). In-vehicle time for the Fremont segment in the

morning and evening was 15:09 and 20:26, respectively. The number of times the bus stopped at traffic signals for those trips was 6.57 and 9.57, respectively; in the afternoon; the bus stopped on average three more times in the evening than in the morning. For Wallingford trips, the difference between morning and evening was 1.72. Afternoon trips in the U-District stopped on average an additional 1.63 times than in the morning. However, given the amount of time spent waiting for the bus in the morning, the afternoon trip was actually shorter than the morning trips.

Table 15 Impact traffic signals have on total bus travel time

	Walk Time	+	Wait Time	+	In-vehicle time	=	Total Travel Time*	<i>Lights</i>	<i>Time Between Signals</i>
Fremont AM	0:07:29	+	0:06:17	+	0:15:09	=	0:28:51	6.57	0:02:18
Fremont PM	0:07:13	+	0:04:00	+	0:20:26	=	0:31:00	9.57	0:02:08
Wallingford AM	0:06:49	+	0:06:34	+	0:09:34	=	0:23:09	5.57	0:01:43
Wallingford PM	0:06:33	+	0:03:17	+	0:11:51	=	0:22:17	7.29	0:01:38
U-District AM	0:07:19	+	0:06:43	+	0:06:09	=	0:19:43	2.57	0:02:24
U-District PM	0:06:19	+	0:03:51	+	0:05:43	=	0:16:43	4.00	0:01:26

Pushing the definition of walkability

As mentioned in the first chapter, this study was conducted in a built environment that was amenable to walking. As such, the intent of this study was not to influence decision-maker’s priorities to encourage density, create better connected street patterns, or to facilitate some other attribute that encourages walking. Rather, the focus is primarily on the individual; to show that travel times between walking and taking the bus may be not be as great as perceived and thus the area they perceive to be walkable might be larger than they thought. This section largely argues that

given the results from this research and from examples from the literature that a definition of walkability rooted in distance or time may be larger than originally thought.

Though the results from switching modes from the bus to walking are most likely to be most pronounced to the individual, there are numerous benefits to the planners and policymakers. Incrementally converting trips will help to fulfill Seattle's comprehensive plan goals of increasing "walking and bicycling to help achieve City transportation, environmental, community and public health goals" (City of Seattle 2005, TG-15, 3.11) and to meet the 2020 goal of 45% of all work trips made by non-single occupancy vehicle modes (ibid, 3.8). Educating the public about their transportation choices can clear misconceptions people may have about certain modes and encourage mode shifting. This achievement would also help to the social, environmental, individual benefits outlined in the *Seattle Pedestrian Master Plan*.

The results of this study are located in a specific section of Seattle but could aid in better understanding walkability throughout the city. As mentioned, the point at which walking becomes the faster mode than the bus will vary across the city based on local conditions. Understanding where these intersections occur throughout numerous locations in the city could help to better understand citywide walkability through the introduction of more robust objective walkability indicators—such as the data used in this study. If citywide walkability is better understood, land use policies and transit service could better fill in those areas where walking takes much longer than the bus (or perhaps vice versa if the intent is to bolster transit service). The pivot point found in Figure 25 is critical to understanding where walkability is poor and where it is strong. Multiple investigations using this model could provide a holistic, composite image of Seattle walkability.

While many studies of walkability are concerned with perception of time traveled or distance traveled, including Moudon et al., the empirical results from this study directly challenge how far is too far to walk.

Research by Moudon et al. (2000) determined the geographic extent of a walkable neighborhood in King County, Washington is 0.42 miles. This is substantially less than the 0.9 miles found to be walkable in this study. As noted earlier, the distance can be extended beyond 0.9 miles if walking pace is increased. This study did not measure other modes of transport—such as bicycling or car. However, it could be said—if time is the determining factor and that the only two modes available to a person are walking or taking the bus—that the geographic extent to which that person could feasibly walk is twice as large as the distance determined by Moudon et al. given the similarities in average travel time between modes for distances up to 0.9 miles.

Besser and Dannenberg (2006, 276) determined that the average time to and from bus stops is 23.7 minutes which equates to roughly 1.2 miles at an unobstructed 3 mph pace. If twelve minutes is spent simply walking to or from a bus stop and does not include additional wait and travel time, then given the presence of transit, people may be more willing to convert those bus trips to walking trips if the total walking time is comparable to the total bus time. (For this study, a perhaps conservative distance of approximately 0.3 miles total walking distance for transit trips was used. As the literature indicates, the distance may be substantially more.) While the Besser and Dannenberg study does not take into account how far people travel—either during the walking portion of the transit trip or the distance covered by transit—nor does it take into account total trip time, it is revealing that people are willing to walk for a long time (more time is likely associated with a greater distance) just to get to a transit stop. See results from Besser and Dannenberg’s study in the recreated chart found in Figure 26. The chart recreated here took Besser and Danneberg’s data

which showed total walking *time* in minutes and converted time to distance assuming a 3 mph pace of travel. Additionally, instead of using total distance to and from a transit stop, one-way distances were calculated.

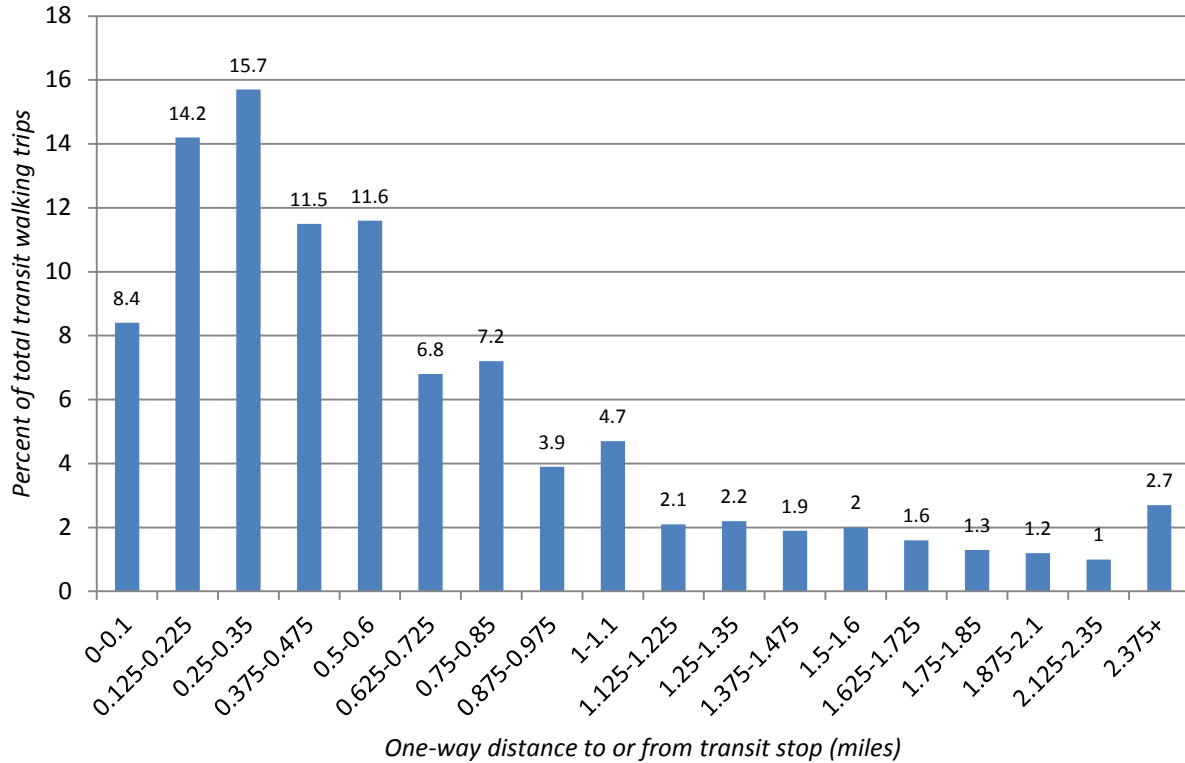


Figure 26 Daily walking distance (miles) to or from transit (one-way) (Besser and Dannenberg 2006)

What is revealing about the Besser and Dannenberg results is the willingness or necessity some people have with regards to walking to a transit stop. While 61.4% of the sample travels 0.6 miles each way to or from a transit stop, there is a significant number of people walking above—and sometimes well above—0.625 miles. In fact 20.7 percent walk at least one mile to or from a transit stop which is substantially higher than the accepted 0.25 mile distance articulated by the Transportation Research Board’s *Transit Capacity and Quality of Service Manual, 2nd Edition*.

Dawn and Miller-Steiger (2008) note in a study of bicyclist and pedestrian attitudes, that 31% of the study sample walked five minutes or more only one to seven days a week and only 5% walked as part of their commute. While not everyone is able to walk to work or make walking part of their daily routine, those who can convert non-walking trips to walking trips can do so incrementally. The results from this research do not suggest that because of similarities between walking and bus times, especially for shorter distances, that all non-walk trips should be converted to walking trips. Rather, given the temporal similarity between trips in this study—2.3 miles and less—time could be made during select days of the week to convert non-walk trips to walk trips. For example, if walking is feasible for a commute, converting just two days a week to walking would instantly generate at least eight days of walking activity of at least five minutes—a step in the right direction in promoting public health while simultaneously encouraging a slow rather than dramatic shift away from other modes.

This study assumed a constant rate of walking speed of 3 mph for both bus trips and walk trips. As the literature indicates, 3 mph may be a bit conservative as the walking speed in Seattle was observed to be 3.27 mph (Bornstein 1979). What would happen if the walking speed was increased to the Seattle average or an even slightly higher rate? Figure 27 displays these results. The times shown reflect the difference in average bus travel time minus the average walk time to depict how much slower or faster walking is compared to taking the bus.

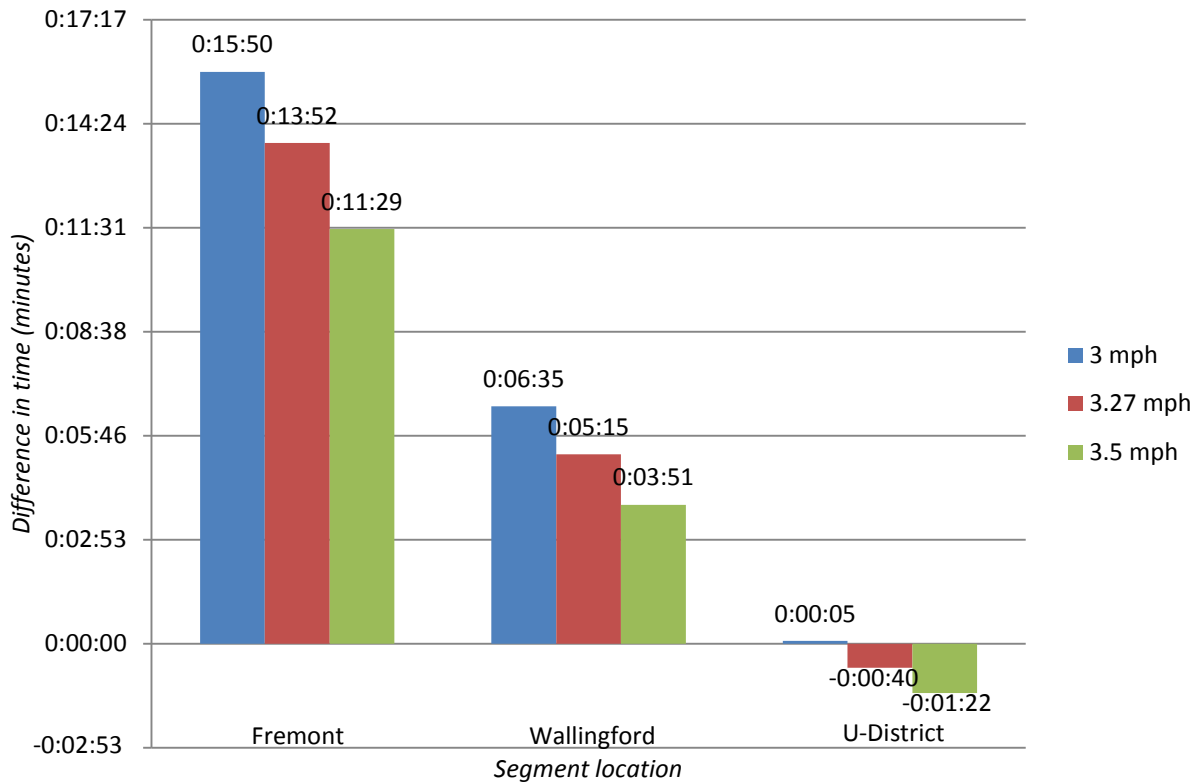


Figure 27 How much slower or faster walking is compared to bus if walking paces increased; comparison of average travel times (minutes) for walking trips if walking rate increased by 0.27 mph and 0.5 mph

Increasing the walking rate to 3.27 mph—the Seattle average—with the exception of a distance 0.9 miles (the U-District segment) will not bring walking rates down to the level of bus travel time but will reduce travel time by two to three minutes. As walkability is often framed around time, such as the “twenty minute neighborhood”, a reduction of two to three minutes is significant. Increasing the walking pace for the walking portion of bus trips only reduces total travel time by approximately thirty to sixty seconds.

If walking speeds were to increase to 3.5 mph, then the walking time drops even more—from three to six minutes making the largest time gap between bus trips and walk trips less than 12 minutes for all segments.

Though walking time and bus travel time was essentially equal for distances of 0.9 miles but not 1.5 or 2.3 miles does not mean that walking should be ruled out. Though the largest gap between travel time was sixteen minutes for distances of 2.3 miles, the health benefit gleaned from walking that distance contributes largely to the total number of steps and time recommended for daily exercise.

Tudor-Locke and Bassett (2004) recommend that adults accumulate 10,000 steps per day while the U.S. Department of Health and Human Services recommends that adults receive 150 minutes of moderate-intensity aerobic exercise per week, of which walking contributes. In this study, no single one-way segment achieved the 10,000 recommended steps for either a bus trip or walk trip.

However, as walking occurs outside of simply commuting, it might be feasible that if conducted in certain combinations, some segments may push the step limit above 10,000 when coupled with other normal walking activities.

If it is assumed that the only walking is conducted during such longer-distance trips as described in this study, meeting health recommendations can occur quickly. For example, to meet the Department of Health and Human Services 150 minutes of recommended aerobic exercise per week, one need only to walk the Fremont segment—2.3 miles—four times total during the week.

This discounts any other physical activity or commute patterns later in the week. More realistically, if this distance is a normal commute distance, a person could walk both ways for one day during the week (90 minutes) and take the bus for the remaining days to accumulate an additional 60 minutes; roughly 15 minutes is spent each day when taking the bus.

The Wallingford segment would require only two round trips to be made on foot and three by bus.

The U-District segment would require four days of walking both ways and one day of taking the bus both ways. For all bus segments, if the bus was taken every weekday in both the morning and evening, nearly half of the recommended 150 minutes physical activity is achieved.

The above analysis is simplistic but the overall messaging is clear: active transportation—whether it is taking the bus, walking, or some combination of the two—can easily and quickly contribute to recommended levels of physical activity. It is reasonable to assume that a person continues to accumulate steps and minutes of aerobic activity during other parts of the day such as running errands, grabbing coffee, or simply walking around the house of office.

Chapter 7: Conclusion

Key Findings

The results from this study point to several key findings:

1. For short distance trips, those under a mile, the time difference walk trips and bus trips is negligible (less than 30 seconds). Given the physical benefits associated with walking, it is easy to suggest that walking could be a preferred choice as it provides the greatest net benefit.
2. Between walking and taking the bus for distances of 0.9, 1.5, and 2.3 miles, walking is consistently the most reliable mode.
3. For distances of up to 2.3 miles, the differences between walking and taking the bus is sixteen minutes while the difference for distances of 1.5 miles is approximately six minutes.
4. With this in mind, traditional distance-based definitions of walkability may not hold given the added benefit associated with walking and the relatively scant differences in travel time, especially for the 1.5 mile segment

Ultimately the hypotheses were verified: walking is at least a comparable mode of travel for distances of less than one mile in terms of total travel time, longer distances while longer to walk offer the added benefit of substantially more exercise, and walking is the most reliable mode of travel as there are fewer elements that will influence and dictate overall travel time.

Future Research and Limitations

Obviously this research focuses on one specific transit route that operated in a primarily east-west direction serving predetermined origins and destinations. Any other transit line—bus, rail, or streetcar—will serve different origins and destinations, run at different headways, have sporadically

spaced stops, and other factors that will influence travel time. As such, the exact specifications by which travel time was measured and the subsequent results from this study may not be universally applied to another transit line without considering those elements and urban form patterns that will influence travel time for that route. That said, the general approach to measuring travel time, variability, and calories burned could be borrowed and tweaked based on subsequent conditions.

Furthermore, this study assumed a general distance of approximately 0.3 miles of total walking as part of a transit trip. As the research indicates, walking distance to and from transit stops can vary dramatically. As a result, the walkability for one person living right next to door to another person may be drastically different if the destination characteristics also widely vary. That is, the same origin bus stop may be used but one person's final destination may require a walk farther than that of the other person. This difference will impact their respective interpretation of the maximum distance that can be willingly walked.

While the notion of walkability—especially distance-based interpretations—in a dense, fairly well-connected gridded street pattern is at the center of this research, dramatically changing the scale of urban form would most likely alter the results of this study. For instance, low-density development with curvilinear street patterns could drastically influence walking times, transit availability, and origin/destination characteristics. Moudon and Hess (2000, 252) note, in a comparison of suburban-style development originating in the 1980s in Everett, Washington with 1920s gridded street patterns found in Wallingford in Seattle, that the lower-density, less-connected street patterns in the Everett example inhibits “movement between residential and commercial land uses” due to the lack of connections between these uses” and that “wide thoroughfares and large blocks also deter pedestrian travel.” Their graphic representation on a one-mile diameter circle (Figure 28) of these case studies illustrates the connectivity patterns between these two styles of development.

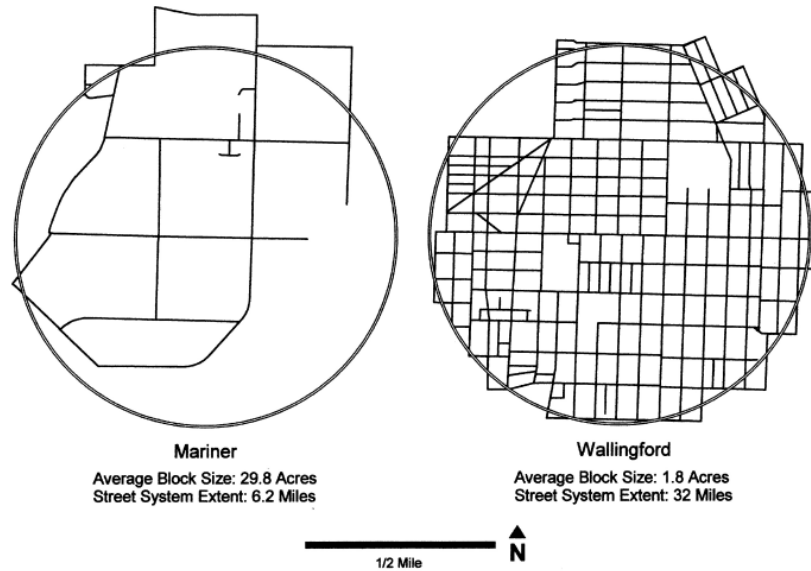


Figure 28 Comparison of street network connectivity and density between the Mariner neighborhood in Everett, Washington and the Wallingford neighborhood in Seattle, Washington

A key question of this research was to determine which mode of travel expended the most calories. The application that calculated expended calories—Pedometer Pro GPS+—was calibrated with the author’s specific body type including weight, height, and age (175 pounds, 6 feet 1 inch, and 29 years old). Additionally, the 3 mph walking pace ensured that the rate at which a calorie was burned would remain relatively static over time. While other body types will obviously raise or lower the number of calories burned, the general relationships revealed in this study should remain. For walking trips, the time to burn one calorie should be consistent regardless of how long the trip is. For bus trips, the time to burn one calorie should be commensurate with total travel time; the longer one travels, the longer it will take to burn one calorie. While intuitive, it is worth noting that exact number of calories burned will be dictated by body type, age, walking pace, and topography of the area and thus subject to vary.

Given the limitations and contextual sensitivities—such as route ridership, built environment characteristics, time of year the study was conducted, physical characteristics of the data collector, among others—associated with this study, there are elements from this study that can be used in future studies if travel times for multiple modes of transportation are to be compared.

The elements that influence travel time and ultimately walkability are outlined in data record worksheets found in Appendix 1 – Collected Bus Data and Appendix 2 – Collected Walking Data.

Subsequent research could quantify the differences between travel times and walkability between less-connected, curvilinear street patterns and well-connected area and also adjust which elements to hold constant, such as examining an area that experiences high bus headways with low headways or including an area where only one transit option is available with an area where there are multiple travel choices.

While a comparable transit route with different headways was not studied, it would be interesting to note differences between travel time and ultimately walkability for those living proximate to routes that offer less frequent service. If this approach was considered, then the researcher need be aware of all the potential factors that could make direct comparisons between the two routes difficult. For example, the impact of direction of travel, even if street connectivity and all other elements are held constant, could play a substantial effect on overall travel time.

The approach used in this research is certainly more transferable to urban environments with dense street connectivity and a transit route exhibiting similar characteristics. Future research may consider the comparison of multiple routes with elements that vary (or do not) between them. Adding more routes or more data collection points at increasing distances would help to provide the basis for a model that may help to predict tradeoffs between taking the bus and walking.

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Appendix 1 – Collected Bus Data

The information contained within Appendix 1 represents the raw data entered into a spreadsheet immediately following the time a data point was collected. There are references to Code numbers and letters in the notes section; these codes cross-reference a hard-copy version of the data. The hard-copies are not reproduced here.

Fremont Bus Data—AM-peak

Data Collection: Fremont—44 AM Peak																																													
Date	Scheduled Bus Time	Time Left House	Time Arrived at Stop	Time Spent Walking	Time Bus Arrived	Mins Spent Waiting at Stop	On Time?	Stopped at each light?																				Total Stops	Disembarked Time	Time Arrived at Gault	Time to Gault	Time in Transit	Time Walked	Total Travel Time	Weather	Calories	Distance Traveled	Stops	% recommended	% of average mile (5569)	Time to burn one calorie	Time converted	Notes		
								A	S	D	M	S	T	L	R	B	A	4	C	P	A	4	0	1	h																				
1	4/15/12	7:42	7:31	7:37	6:26	7:44	0:07:00	0:02:00	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	2	0	0	8	8:00	8:01	0:53	0:16:00	7:19	0:30:00	50 cloudy	36.0	0.354	622	6.22%	11.17%	0:00:50	50	Code F
2	4/15/12	9:00	8:50	8:56	6:09	9:01	0:05:00	0:01:00	1	1	1	1	0	1	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0	9	9:18	9:19	0:59	0:17:00	7:08	0:29:00	48 Fair	31.2	0.336	607	6.07%	10.90%	0:00:56	56	much traffic backed up at Wallingford; standing room only from Wallingford on; code 1
3	4/15/12	8:11	8:01	8:07	6:35	8:14	0:07:00	0:03:00	1	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	6	8:28	8:29	0:49	0:14:00	7:24	0:28:00	50 light rain	32.7	0.329	614	6.14%	11.03%	0:00:51	51	earlier bus arriving just as I approached opposite crosswalk; code 2
4	4/16/12	7:49	7:39	7:46	6:30	7:52	0:06:00	0:03:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	4	8:05	8:06	0:53	0:13:00	7:23	0:27:00	46 rain	38.1	0.379	635	6.35%	11.40%	0:00:43	43	code 14
5	4/19/12	8:24	8:14	8:21	7:03	8:27	0:06:00	0:03:00	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	5	8:39	8:40	0:47	0:12:00	7:50	0:26:00	48 cloudy	30.3	0.311	603	6.03%	10.83%	0:00:51	51	code 18
6	4/24/12	7:31	7:21	7:28	7:15	7:33	0:05:00	0:02:00	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	7	7:49	7:50	1:03	0:16:00	8:18	0:29:00	52 cloudy	32.9	0.327	611	6.11%	10.97%	0:00:53	53	code 27
7	4/30/12	8:11	8:01	8:07	6:16	8:15	0:08:00	0:04:00	1	0	0	1	0	0	1	0	1	0	2	0	0	0	0	0	1	0	0	0	0	7	8:33	8:34	0:48	0:18:00	7:04	0:33:00	49 cloudy	32.2	0.361	659	6.59%	11.83%	0:01:01	61	code 39
Average							0:06:17	0:02:34	0:57	0:57	0:23	0:43	0:09	0:29	0:08	0:57	0:14	1:00	0:09	0:14	0:09	0:29	0:43	0:06	0:09	0:29	0:09	0:43	6:57	0:53	0:15:00	7:29	0:28:51		33.5	0:339	615	6.33%	11.16%		52.1				
Minimum							0:05:00	0:01:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	4:00	0:47	0:12:00	7:04	0:26:00		30.3	0:311	603	6.03%	10.83%		43.0				
Maximum							7:15	0:08:00	0:04:00	1:00	1:00	1:00	0:00	1:00	1:00	1:00	1:00	2:00	0:00	1:00	1:00	1:00	1:00	0:00	2:00	0:00	1:00	0:00	9:00	1:03	0:18:00	8:18	0:33:00		38.1	0:379	635	6.35%	11.83%		61.0				
Median							6:30	0:06:00	0:02:30	1:00	1:00	0:00	0:00	0:00	0:00	0:00	1:00	0:00	0:00	0:00	0:00	0:00	0:00	1:00	0:00	0:00	0:00	7:00	0:53	0:15:00	7:23	0:28:30		32.8	0:333	613	6.13%	11.00%		51.0					
Spread							1:56	0:03:00	0:03:00	1:00	1:00	1:00	0:00	1:00	1:00	1:00	2:00	0:00	1:00	0:00	1:00	1:00	1:00	0:00	2:00	0:00	1:00	0:00	5:00	0:16	0:06:00	1:14	0:07:00		7.8	0:068	32	0:56%	1.01%		18.0				

Wallingford Bus Data—AM-peak

Data Collection: Wallingford-44 AM Peak																																									
	Date	Scheduled Bus Time	Time Left House	Time Arrived at Stop	Time Spent Walking	Time Bus Arrived	Mins. Spent Waiting at Stop	On Time?	Stopped at each light?																Total Stops	Disembarked Time	Time Arrived at Gould	Time to Gould	Time in Transit	Time Walked	Total Travel Time	Weather	Calories	Distance Traveled	Steps	% recommended	% of average male (3500)	Time to burn one calorie	Time converted	Notes	
									S	U	N	A	C	Y	N	Y	J	I	D	E	R	O	S	B																	F
1	4/12/12	8:05	7:55	8:01	5:43	8:09	0:08.00	4	0	0	0	1	0	1	0	0	1	1	1	1	0	1	0	0	7	8:22	8:23	0:57	0:13:00	6:40	0:28:00	47 Mostly Cloudy	35.6	0.363	612	6.12%	10.99%	0:00:47	47.0	standing room only until 4:30; small delays because the bus was so crowded and getting everyone on board was an arduous task; code C	
2	4/13/12	8:05	7:55	8:01	5:57	8:05	0:04.00	0	1	0	1	1	1	1	0	0	0	1	0	0	1	0	0	0	7	8:13	8:14	0:57	0:08:00	6:54	0:19:00	43 Fair	34.3	0.357	608	6.08%	10.92%	0:00:33	33.0	there were a few empty seats at the time of boarding; code H	
3	4/16/12	7:23	7:13	7:19	6:25	7:24	0:05.00	1	0	1	0	1	0	1	0	0	0	0	0	1	1	1	0	0	0	6	7:31	7:33	1:13	0:07:00	7:38	0:20:00	49 Light Rain	35.1	0.362	625	6.25%	11.22%	0:00:34	34.0	code 1
4	4/18/12	8:29	8:19	8:25	5:37	8:32	0:07.00	3	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	4	8:42	8:42	0:38	0:10:00	6:15	0:23:00	47 cloudy	31.1	0.312	528	5.28%	9.48%	0:00:44	44.0	shorter distance because I cut across the street at the crosswalk and not the signal; code 15
5	4/19/12	9:15	9:05	9:11	5:18	9:16	0:05.00	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	5	9:25	9:25	0:36	0:09:00	5:54	0:20:00	49 cloudy	27.6	0.292	521	5.21%	9.36%	0:00:43	43.0	code 19
6	4/24/12	8:16	8:06	8:13	7:11	8:20	0:07.00	4	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0	5	8:30	8:31	0:48	0:10:00	7:59	0:25:00	52 cloudy	33.4	0.327	615	6.15%	11.04%	0:00:45	45.0	code 28; longer time walking because I got caught crossing 45th
7	4/30/12	8:55	8:45	8:51	5:46	9:01	0:10.00	6	0	0	0	1	0	2	0	0	0	0	0	1	1	0	0	0	0	5	9:11	9:12	0:39	0:10:00	6:25	0:27:00	49 cloudy	28.7	0.319	614	6.14%	11.03%	0:00:56	56.0	code 40
Average					5:59		0:06:24	3	0.29	0.39	0.14	0.86	0.17	1.14	0.00	0.00	0.23	0.42	0.37	0.71	0.20	0.14	0.29	0.00	5.57			0:49	0:09:34	6:40	0:22:00		32.2	0.292	589	5.9%	10.6%		42.1		
Minimum					5:18		0:04:00	0	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00			0:36	0:07:00	5:54	0:19:00		27.6	0.292	521	5.2%	9.4%		33.0		
Maximum					7:21		0:10:00	6	1.00	1.00	1.00	1.00	1.00	2.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	7.00			1:13	0:13:00	7:59	0:28:00		35.6	0.363	625	6.3%	11.2%		56.0		
Median					5:46		0:06:00	3	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	5.00			0:43	0:10:00	6:40	0:21:30		33.4	0.327	612	6.1%	11.0%		44.0		
Spread					1:53		0:06:00	6	1.00	1.00	1.00	1.00	1.00	2.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	3.00			0:37	0:06:00	2:05	0:09:00		8.0	0.071	104	1.0%	1.9%		23.0			

Wallingford Bus Data—PM-peak

Data Collection: Wallingford-44 PM Peak																																										
ID	Date	Scheduled Bus Time	Time Left Gould	Time Arrived at Stop	Time Spent Walking	Time Bus Arrived	Mins Spent Waiting at Stop	On Time?	Stopped at each light?																	Total Stops	Disembarked Time	Time Arrived at Home	Time to Home	Time in Transit	Time Walked	Total Travel Time	Weather	Calories	Distance Traveled	Steps	% Recommended	% of average male (5'6.5)	time to burn one calorie	time converted	Notes	
									Campus	41st	42nd	43rd	44th	Avon	Brookfield	Brookline	Brookline	Brookline	Brookline	Brookline	Brookline	Brookline	Brookline	Brookline	Brookline																	Brookline
1	12-Apr	4:15	4:09	4:11	1:59	4:17	0:06	2	0	0	0	2	0	1	1	1	1	0	0	0	1	0	1	0	0	0	7	4:29	4:34	4:47	0:12	6:46	0:25	Partly Cloud	37.8	0.382	626	6.26%	11.24%	0:00:40	40.0	Standing room only until Brooklyn; code D
2	13-Apr	5:20	5:14	5:16	1:46	5:19	0:03	(1)	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	10	5:33	5:39	5:03	0:14	6:49	0:25	55 fair	32.8	0.338	563	5.63%	10.11%	0:00:46	46.0	code L	
3	16-Apr	5:33	5:27	5:29	1:27	5:32	0:03	(1)	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	1	0	8	5:43	5:49	5:02	0:11	6:29	0:22	mostly cloud	27.4	0.314	573	5.73%	10.29%	0:00:48	48.0	code 7	
4	17-Apr	5:46	5:40	5:41	1:35	5:44	0:03	(2)	0	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	5	5:56	6:01	4:42	0:12	6:17	0:20	49 rain	28.1	0.315	577	5.77%	10.36%	0:00:43	43.0	code 11	
5	19-Apr	5:33	5:27	5:29	1:32	5:33	0:04	0	0	1	0	1	1	1	0	0	0	0	1	1	0	0	0	1	0	6	5:42	5:49	4:48	0:09	6:20	0:22	50 light rain	27.6	0.291	510	5.10%	9.16%	0:00:48	48.0	code 21	
6	23-Apr	4:41	4:35	4:37	1:52	4:40	0:03	(5)	0	1	0	1	1	1	1	0	0	1	0	1	1	1	1	0	0	8	4:52	4:57	4:47	0:12	6:39	0:22	partly cloud	31.1	0.32	558	5.58%	10.02%	0:00:42	42.0	code 24	
7	30-Apr	4:54	4:48	4:49	1:22	4:50	0:01	(4)	1	0	1	0	1	1	1	0	0	0	1	0	0	1	0	0	1	0	7	5:03	5:08	5:10	0:13	6:32	0:20	partly cloudy	28.7	0.311	555	5.55%	9.97%	0:00:42	42.0	code 43
Average					1.39	5:07	0:03:17	1.00	0.286	0.429	0.571	0.714	0.857	0.857	0.571	0.000	0.571	0.429	0.857	0.286	0.429	0.429	0.000	7.29		5:25	4:54	0:11:51	6:33	0:22:17		30.5	0.324	566.0	5.7%	10.2%		44.1				
Minimum					1:22	4:17	0:01	4.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.00		4:34	4:42	0:09	6:17	0:20		27.6	0.291	510.0	5.1%	9.2%		40.0				
Maximum					1:59	5:44	0:06	2.00	1.000	1.000	2.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	10.00		6:01	5:30	0:14	6:49	0:25		37.8	0.382	626.0	6.2%	11.2%		48.0				
Median					1:35	5:19	0:03	1.00	0.000	0.000	0.000	1.000	1.000	1.000	1.000	0.000	1.000	0.000	1.000	0.000	0.000	0.000	0.000	7.00		5:39	4:48	0:12	6:32	0:22		28.7	0.315	563.0	5.6%	10.1%		43.0				
Spread					0:37	1:27	0:05	6.00	1.000	1.000	2.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	5.00		1:27	0:28	0:05	0:32	0:05		10.4	0.091	116.0	1.2%	2.1%		8.0				

U-District Bus Data—PM-peak

Data Collection: UDistrict-44 PM Peak																																			
	Date	Scheduled Bus Time	Time Left Gould	Time Arrived at Stop	Time Spent Walking	Time Bus Arrived	Mins Spent Waiting at Stop	On Time?	Stopped at each light?											Total Stops	Disembarked Time	Time Arrived at Home	Time to Home	Time in Transit	Time Walked	Total Travel Time	Weather	Calories	Distance Traveled	Steps	% recommended	% of average male (5566)	Time to Burn one calorie	Time Converted	Notes
									P C O 2 L 1 S T	4 1 2 N D	4 2 3 R D	4 3 5 T H	A V E	B R O O K L I N	1 2 T H	1 1 T H	R O S E V E L I T																		
1	12-Apr	5:20	5:15	5:16	1:21	5:19	0:03	(1)	1	0	0	1	1	1	1	1	0	0	0	5	5:26	5:31	4:48	0:07	6:09	0:16	50 Partly cloudy	28.1	0.3	533	5.33%	9.57%	0:00:34	34.00	code A
2	16-Apr	6:41	6:35	6:37	1:45	6:40	0:03	(1)	1	0	0	0	0	1	1	0	0	0	3	6:45	6:51	5:05	0:05	6:50	0:16	52 mostly cloudy	31.6	0.356	645	6.45%	11.58%	0:00:30	30.00	code 9	
3	17-Apr	6:27	6:21	6:23	1:43	6:28	0:05	1	0	1	0	0	1	0	0	0	0	0	2	6:32	6:37	4:27	0:04	6:10	0:16	49 rain	24.8	0.273	522	5.22%	9.37%	0:00:39	39.00	code 12	
4	19-Apr	6:27	6:21	6:23	1:39	6:27	0:04	0	1	0	0	0	1	0	0	1	1	0	4	6:32	6:37	4:36	0:05	6:15	0:16	50 light rain	27.3	0.292	532	5.32%	9.55%	0:00:35	35.00	code 23	
5	23-Apr	5:33	5:27	5:29	1:41	5:32	0:03	(1)	1	0	1	1	0	1	1	0	0	0	5	5:39	5:44	4:46	0:07	6:27	0:17	66 partly cloudy	30.6	0.301	525	5.25%	9.43%	0:00:33	33.00	code 26	
6	24-Apr	6:13	6:07	6:09	1:35	6:12	0:03	(1)	1	0	1	0	1	0	0	1	0	1	5	6:18	6:23	4:34	0:06	6:09	0:16	56 cloudy	25.9	0.29	564	5.64%	10.13%	0:00:37	37.00	code 29	
7	27-Apr	5:07	5:01	5:03	1:58	5:09	0:06	2	0	1	0	0	1	1	1	0	0	0	4	5:15	5:20	4:21	0:06	6:19	0:19	55 partly cloudy	33.1	0.341	577	5.77%	10.36%	0:00:34	34.00	code 35	
Average					1:40		0:03:51	(0)	0.714	0.286	0.286	0.286	0.714	0.571	0.571	0.286	0.143	0.143	4.000			4:39	0:05:43	6:19	0:16:34		28.05	0.302	554	5.57%	10.00%		24.57		
Minimum					1:21		0:02	(1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000			4:21	0:04	6:09	0:16		24.80	0.272	522	5.22%	9.27%		20.00		
Maximum					1:58		0:06	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	5.000			5:05	0:07	6:50	0:18		31.60	0.356	645	6.45%	11.58%		39.00		
Median					1:41		0:03	(1)	1.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	0.000	4.000			4:36	0:06	6:15	0:16		28.10	0.300	533	5.33%	9.57%		34.00		
Spread					0:37		0:03	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	3.000			0:44	0:03	0:41	0:03		6.80	0.083	123	1.23%	2.21%		9.00		

Appendix 2 – Collected Walking Data

Fremont Walk Data

Data Collection: Fremont Walk																
	Date	Service Period	Origin	Destination	Time Left Origin	Time Arrived Destination	Total Walk Time	Distance	Calories	Pace	Steps	% Recommended	% of Average Male (5569)	Time to burn one calorie	Time converted	Notes
1	4/9/12	PM	Gould	Home	3:47	4:34	0:47:08	2.35	224.4	3	4069	40.70%	73.07%	0:00:13	13	got stuck at NE 46th and Aurora due to 1) not hitting the right crosswalk signal and 2) it's a long intersection
2	4/11/12	PM	Home	Gould	6:25	7:11	0:44:58	2.31	214.9	3.1	4118	41.18%	73.95%	0:00:13	13	
3	4/13/12	PM	Home	Gould	4:21	5:08	0:46:08	2.28	222.8	3	3883	38.83%	69.73%	0:00:12	12	code K
4	4/27/12	AM	Gould	Home	7:15	8:00	0:44:48	2.301	214.8	3.1	4065	40.65%	72.99%	0:00:13	13	47 cloudy; code 37
5	4/27/12	AM	Home	Gould	8:00	8:45	0:44:34	2.223	209.7	3	3844	38.44%	69.02%	0:00:13	13	47 light rain; code 38
6	4/30/12	AM	Gould	Home	9:12	9:59	0:47:01	2.435	226.4	3.1	4228	42.28%	75.92%	0:00:12	12	48 cloudy; code 42
Average							0:45:46	2.32	219	3	4035	40.35%	72.45%		12.67	
Minimum							0:44:34	2.22	210	3	3844	38.44%	69.02%		12.00	
Maximum							0:47:08	2.44	226	3	4228	42.28%	75.92%		13.00	
Median							0:45:33	2.31	219	3	4067	40.68%	73.03%		13.00	
Spread							0:02:34	0.21	17	0	384	3.84%	6.90%		1.00	

Wallingford Walk Data

Data Collection: Wallingford Walk																
	Date	Service Period	Origin	Destination	Time Left Origin	Time Arrived Destination	Total Walk Time	Distance	Calories	Pace	Steps	% Recommended	% of Average Male (5569)	time to burn one calorie	time converted	Notes
1	4/12/12	PM	Home	Gould	4:35	5:04	0:28:42	1.469	136.7	3.1	2573	25.73%	46.20%	0:00:13	13.00	50F Partly Cloudy; code E
2	4/13/12	PM	Home	Gould	5:42	6:12	0:29:50	1.492	139.8	3	2600	26.00%	46.69%	0:00:13	13.00	55 Fair; code M
3	4/16/12	PM	Home	Gould	4:20	4:49	0:29:09	1.498	135	3.1	2723	27.23%	48.90%	0:00:13	13.00	52 partly cloudy; code 6
4	4/26/12	AM	Home	Gould	7:05	7:34	0:28:48	1.465	142.8	3.1	2504	25.04%	44.96%	0:00:12	12.00	68 partly cloudy; code 25
5	4/26/12	AM	Gould	Home	8:43	9:13	0:29:30	1.5	141.6	3.1	2615	26.15%	46.96%	0:00:13	13.00	48 light rain; code 33
6	4/30/12	AM	Home	Gould	6:30	7:00	0:29:46	1.518	142.2	3.1	2625	26.25%	47.14%	0:00:13	13.00	47 cloudy; code 44
Average							0:29:17	1.49	139.7	3.1	2606.7	26.07%	46.81%		12.83	
Minimum							0:28:42	1.47	135.0	3.0	2504.0	25.04%	44.96%		12.00	
Maximum							0:29:50	1.52	142.8	3.1	2723.0	27.23%	48.90%		13.00	
Median							0:29:19	1.50	140.7	3.1	2607.5	26.08%	46.82%		13.00	
Spread							0:01:08	0.05	7.8	0.1	219.0	2.19%	3.93%		1.00	

U-District Walk Data

Data Collection: U-District Walk																
	Date	Service Period	Origin	Destination	Time Left Origin	Time Arrived Destination	Total Walk Time	Distance	Calories	Pace	Steps	% Recommended	% of Average Male (5569)	time to burn one calorie	time converted	Notes
1	04/13/12	PM	Gould	Home	6:16	6:35	0:18:40	0.878	85.3	2.8	1547	15.47%	27.78%	0:00:13	13.00	55 Fair; code N
2	04/16/12	AM	Home	Gould	8:34	8:53	0:19:18	0.916	88.9	2.8	1585	15.85%	28.46%	0:00:13	13.00	code 3
3	04/16/12	PM	Home	Gould	6:07	6:25	0:18:36	0.941	88.2	3	1661	16.61%	29.83%	0:00:13	13.00	52 mostly cloud; code 8
4	04/19/12	PM	Home	Gould	6:04	6:22	0:17:13	0.883	84.5	3.1	1559	15.59%	27.99%	0:00:12	12.00	50 light rain; code 22
5	04/25/12	AM	Gould	Home	7:55	8:13	0:17:15	0.882	86.2	2.9	1546	15.46%	27.76%	0:00:12	12.00	54 cloudy; code 31
6	04/27/12	AM	Home	Gould	9:04	9:22	0:18:20	0.907	87.5	3	1570	15.70%	28.19%	0:00:13	13.00	48 light rain; code 36
Average							0:18:14	0.901	86.77	2.9	1578	15.78%	28.34%		12.67	
Minimum							0:17:13	0.878	84.5	2.8	1546	15.46%	27.76%		12.00	
Maximum							0:19:18	0.941	88.9	3.1	1661	16.61%	29.83%		13.00	
Median							0:18:28	0.895	86.85	2.95	1564.5	15.65%	28.09%		13.00	
Spread							0:02:05	0.063	4.4	0.3	115	1.15%	2.07%		1.00	