

ACTIVE TRAVEL BEHAVIOR

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ABSTRACT

Physical inactivity has become a dominant feature of most American's lives over the past quarter century. This has spurred an entire research domain straddling several different disciplines. Although model development within the field of travel behavior as a whole continues today with more momentum than ever, the focus on active mode choice has largely been overlooked and left to a small fragment of transportation and public health researchers. Research regarding active mode choice has been primarily conducted outside the field of travel behavior and has utilized research methods designed for other purposes. This leads to results which address behavioral causality in a superficial way while also neglecting the role of residential self-selection. This paper provides an overview of existing travel behavior analysis regarding active mode choice, presents potential threats to validity in this type of research, and critiques existing intervention methodologies. Additionally, a conceptual model of active travel behavior is presented and the roots of each component are discussed. By applying the rigor of travel behavior research to the subfield of active travel behavior research, and incorporating the conceptual model provided, great strides can be made relatively quickly in understanding active mode choice and active travel behavior.

INTRODUCTION

As overweight and obesity have become a bigger issue in Americans' daily lives, they have been attributed multiple times to the lack of physical activity in today's society. This has spurred a renewed interest in the aforementioned arena, and many researchers now claim that current lifestyle patterns such as the prolific reliance on personal vehicle use as well as a separation of land uses, have "engineered physical activity for non-exercise purposes out of many Americans lives" (Sallis, Frank, Saelens, and Kraft, 2004).

Recent studies of the connection between physical activity and the built environment have produced masses of data focusing on every possible connection from time allocation and personal characteristics, to the natural and built environment, as well as lifestyles and attitudes. Many key environmental variables have been identified as promoters or deterrents to active travel, which have given researchers as well as planners and policy makers guidance when trying to incorporate more bicycle and pedestrian travel opportunities. One drawback of a majority of these studies, however, is that many claim causality whenever a correlation exists, without the thought of a possible spurious relationship (attributing causality to a variable that correlates with another variable when it is not actually the cause) or confounding variables (variables included in the study that are not intended to be a causal variable but affect one of the measured variables-Montello and Sutton 2006). Most studies relating to this topic have been cross-sectional in design, measuring only a sample of a population at one point in time, not taking into account time order constraints or possible self-selection issues. This includes but is not limited to residential self-selection which happens when an individual chooses to live in an area due to the presence of specific amenities or factors.

Although model development within the field of travel behavior as a whole continues today with more momentum than ever, the focus on active mode choice has largely been overlooked and left to a small fragment of transportation and public health researchers. Many public health agencies have obesity and lack of physical activity on their radar screens and have begun to commence programs relating to those problems, however, transportation policies do not generally address the epidemic and the possible associations that exist between transportation systems and physical activity.

Section 2 of this paper provides an overview of existing research as it applies to travel behavior analysis by separating it into four distinct categories: the connection between transportation and physical activity, public policy, general travel behavior, and infrastructure and environment. Following this review, Section 3 discusses potential problems faced by active travel behavior research methodologies with regard to determining causality and the potential for self-selection. Section 4 discusses the benefits of using intervention studies, which if properly designed can avoid many of the problems discussed in Section 3. Finally, Section 5 introduces a conceptual model of active travel behavior based upon the existing research.

EXISTING RESEARCH

Transportation and Physical Activity

Transportation systems impact physical activity in a variety of ways. One hundred years ago the majority of Americans utilized walking as their primary mode of transportation. Other options were available such as horse cars, trolleys, and even early automobiles, but walking remained a major component of all trips. That transportation paradigm has changed with technological improvements and the transportation system of today looks and acts very differently than at any

prior time period (Muller 2004). This section describes current automobile and travel statistics and public health and active living separately, and concludes by discussing how they relate to one another today.

Automobile & Travel Statistics

Analysis of data from the U.S. Department of Transportation's 2001 Nationwide Household Transportation Survey showed that automobiles account for 86.5% of all trips taken, whereas walking and bicycling account for only 10.3% of trips (Bureau of Transportation Statistics, 2001). Additional analysis by Killingsworth and Schmid (2001) found that approximately 25% of all trips in the United States are less than one mile in distance, but nearly 75% of those trips are made by automobile. This data shows that both short and long trips are utilizing the automobile as the primary mode of travel. These statistics however, may not be entirely accurate as they are extracted from travel diaries known to have two biases: 1) Reporting persons forget short trips (i.e. walking the dog around the block), and they do not include access trips to other modes (such as walking to a parking lot to drive a car back home from work- Handy 2005); 2) These surveys do not include children and has high non-response rates among the very young and the very old – children and older adults are more likely to bike and walk than individuals in middle age groups (Burbidge, Goulias, and Kim 2006). These biases may result in consistent underestimation of the amount of active trips taken by US residents.

Public Health and Active Living

From 1980 to 2003 the United States experienced a 40% increase in the number of residents who are "overweight". The rates have compounded yearly leading to 65-73 percent of the U.S. population that is currently overweight or obese (Center for Disease Control-CDC 2004). Although increased body weight is a problem, it is the result of many bigger issues. This increase in overweight and obesity has been partially attributed multiple times to lack of physical activity (Department of Health and Human Services-DHHS 1996). Lack of physical activity has a far more pronounced effect on public health than obesity or overweight do in and of themselves. This is because individuals who are relatively physically fit may still be technically overweight due to other reasons (i.e. chemical imbalance, medications, muscular build, etc.). Research has shown that increasing physical fitness plays the largest role in improving health regardless of other factors (CDC 2004).

According to the surgeon General's report on physical activity and health, currently 70% of U.S. adults do not obtain the recommended amount of physical activity, and approximately 25% of individuals report being completely inactive when not at work (DHHS 1996). Reliance on personal vehicle use, along with work in employment sectors that require no physical activity are contributing to more sedentary lifestyles in which individuals acquire no physical activity. It is important to note that this phenomenon does not only affect adults, but spills over to the very young as well. The U.S. Environmental Protection Agency (Environmental Protection Agency-EPA 2003) recently revealed that between 1969 and 2003 the number of children walking to school has decreased by 33%.

Connection between Transportation and Activity

The personal choice or need to utilize the automobile for transportation has kept U.S. residents from getting the minimum amounts of physical activity that were once accumulated through participation in a daily routine. This is evident in the Bureau of Transportation Statistics data,

which show that between 1977 and 1995 the total number of U.S. residents walking and cycling declined by about 40% (Bureau of Transportation Statistics, various years at www.bts.gov).

Active transportation is one simple way that activity can be included in people's daily lives. "Active transportation" refers to the use of any mode that requires using human physical power (Saelens, Sallis, and Frank 2003). For the purposes of this paper, however, active transportation will refer to animate modes of walking and bicycling. According to many researchers, integrating additional walking and biking into daily routines may prove to be a better public health strategy than traditional structured and organized programs (Handy 2004, Litman 2003b, and Saelensminde 2002). The basic assumption is that changing trip-making behavior to include more non-motorized trips can translate into favorable public health consequences.

To combat the problem of inactivity, the US Public Health Service created a national objective for the year 2010 of more than a 50% increase in walking trips made by adults for trips less than one mile (DHHS 1996). This poses a problem, however, because it is not currently known how much U.S. residents walk or bike in a day. There is no good baseline which makes it difficult to set a target for or ultimately to judge any improvement.

The Surgeon General recommends both walking and bicycling as forms of physical activity (DHHS 1996). Walking is the most regular physical activity for most people and can be done at any age for transportation, health, or leisure purposes. Walking is already an important part of human transportation, and Litman's review of existing travel survey data (2003a) discovered that although only 5-10% of trips are made completely by walking, 15-30% of urban trips involve at least one walking link. Walking and biking links to other modes are frequently ignored, but active modes often serve as connections to many other mode trips such as: home to transit, parking lot to destinations, and within airports and shopping centers. By increasing the walking and biking links used for transportation, there may concomitantly be an increase in physical activity levels.

The Impact of Public Policy

Walking as a mode of transportation is often undervalued because it is difficult to measure, low cost, and many decision makers believe that walking will take care of itself since it is inherently possible to walk anywhere without specific facilities. Promoting walking, however, can save individuals and communities a great deal of money. Litman's (2003a) analysis asserts that shifting travel from driving to walking can provide a savings of approximately \$0.25-\$0.50 per mile depending on the existing conditions.

Public policy can help mold the choices that individuals make regarding mode choices as certain policy approaches can be designed to help individuals and groups adopt healthier behaviors. An evaluation of 11 selected policy interventions by the Task Force on Community Preventive Services (2002) found that public interventions which change the local environment to create additional opportunities for physical activity are effective in increasing physical activity and fitness among adults. In a report produced by the Trust for America's Health, Glendening et al. (2005) also recommend that local governments, private developers, and community groups, work together to expand opportunities for physical activity through recreational facilities, parks, playgrounds, sidewalks, bike paths, routes for walking or bicycling to school, and safe streets and neighborhoods; especially concentrating on populations at risk for obesity.

General Travel Behavior Research

Past research has proven that a variety of personal factors make one individual behave differently than another (Golledge and Stimson 1997). These different factors also allow individuals to make personal decisions when it comes to their travel behaviors. Travel behavior can generally be referred to as the study of what people do over space and how people use transportation (Hayes 1993). Goulias (2000) gave a more comprehensive definition stating that travel behavior is “the modeling and analysis of travel demand on the basis of theories and analytical methods from a variety of scientific fields. These include but are not limited to, the use of time and its allocation to travel and activities, the use of time in a variety of time contexts and stages in the life of people, and the organization and use of space at any level of social organization, such as the individual, the household, the community, and other formal or informal groups”. As Handy (2005) well stated, however, the majority of travel behavior research to date has focused on automobile travel rather than animate or active travel. It is especially important to consider the following concepts with regard to active travel.

Time Allocation

The initial concept of spatial and temporal capacities and constraints on individual behavior were proposed in the 1960's. Hagerstrand (1970) originally emphasized the importance of time in human activity. He noted that “time has a critical importance when it comes to fitting people and things together for functioning in socio-economic systems.” So even if a given location is near an individual, they may not be able to allocate enough time to travel to it. Spatial proximity alone does not inherently make a difference. Hagerstrand's original research outlined the existence of a “time-space prism” which illustrates how individuals navigate through their spatial-temporal environments. The space around an individual is reduced to a multi-dimensional plane, on which the location and destination are represented as points (shown in Figure 1).

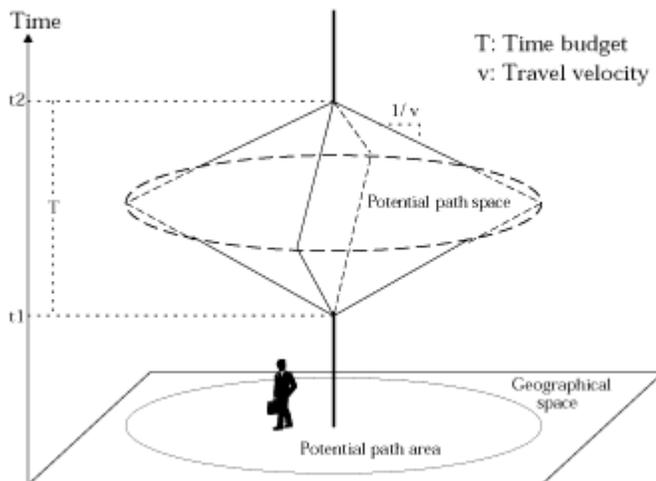


FIGURE 1. Time-Space Prism (BTS, various years)

Time is represented by a vertical axis which creates a three dimensional “aquarium” that represents a specific portion of space time (Corbett 2005). The path of an individual appears as the vertical line between the starting and end times, and a conic area represents the potential path space.

These time-space paths demonstrate how travel behavior is governed by limitations, and not entirely by independent decisions (Cullen and Godson 1975, and Hagerstrand 1970). Limitations or constraints can be classified in three distinct categories: capability constraints which place limitations on human movement due to physical or biological factors; coupling constraints which provide a need to be in one place for a given length of time often interacting with others; and authority constraints, or the imposition and control of access by an outside the individual entity (Hagerstrand 1970).

Temporal constraints also play a large role in active mode choice. Transportation systems reduce the amount of time required for movement across space. A person must trade time for space through movement or communication to participate in activities (Golledge and Stimson 1997). Greater separations inherently imply a lower level of accessibility. This especially holds true with regards to active mode choice. When destinations are located further apart the time required to reach those destinations increases. Choosing an active mode may not allow travel as quickly as other available modes resulting in a large capability constraint.

Travel behavior research also asserts that all individuals have a limited time-budget to allocate among flexible activities, such as shopping or other errands, which may not have stringent time restrictions and predetermined starting or ending times. The time-budget and the ability to trade time for space using transportation technologies or modes determines an individual’s accessibility to opportunities that exist in relatively few places for limited durations. Sallis, Frank, Saelens, and Kraft (2004) argue that there is a threshold of time at which time spent traveling is perceived as no longer reasonable. This is especially relevant considering active trips generally require more time for travel which may exceed any existing threshold.

An active travel choice often depends on the importance of combining exercise with utilitarian travel, and not simply walking or cycling to reach a specific destination (Transportation Research Board 2005). Individuals are likely to make decisions in their self-interest when given the option to do so. In other words, most choices are made on the basis of their feasibility and the relative costs and benefits to the individual. One would assume that people would be more likely to walk if walking trips were in any sense easier, if alternatives to walking became more difficult, or if the overall utility of walking was considered.

Taking all this into account, however, requires a somewhat different framework than current practice in policy. Until recently, traditional modeling of travel behavior and time allocation regarded trips as the primary focus of analysis. Travel diaries would inherently leave out “trips” which began and ended in the same location with no stopping points in the middle (i.e. recreation trips such as a walk around the neighborhood), and trips which were used as feeders to other modes (i.e. bicycling to the bus stop). Using this type of trip-based analysis inevitably left out a large number of active trips leading to drastic underreporting, since many participants in research did not consider recreation outings as “trips”, as outlined by the traditional research definition. Traditional trip-based analysis also operated under the assumptions of standard economic theory, and failed to incorporate behavioral characteristics into models (Johnston 2004). Many researchers analyzing time allocation were disappointed by the drawbacks of trip-based analysis and turned instead to a different type of measurement

framework; activity-based. According to Ettema and Timmermans (1997) "activity-based approaches typically describe which activities people pursue, at what locations, at what times, and how these activities are scheduled given the location and attributes of destinations, the state of the transportation network, aspects of the institutional context, and their personal and household characteristics." Activity-based approaches help researchers identify activity patterns that more accurately reflect how people plan and organize their days.

According to Henson and Goulias (2006), the first models which incorporated behavior processes were published in the late 1970's and early 1980's. Many of these utilized the time-space prisms described above as constraints. Since these early beginnings, over 40 activity-based models have been created (a majority of which are comprehensively outlined and discussed in Henson and Goulias, 2006). These models incorporate measurements of individual travel behavior and focus on everything from daily household scheduling and mode choice decisions, to predicting land-use transportation interactions and estimating leisure and vacation activity. Although substantial progress has been observed in the activity-based travel demand forecasting methods, there are still many areas that require further improvement. For example, currently no activity-based models exist that accurately predict pedestrian and bicycle mode choice. In addition, one key understanding we have from activity-based approaches is that mode choice should never be studied in isolation from human interactions, commitments, and constraints. Looking at demographic characteristics and their relationship with activity and travel behavior indicators is one way to gain this understanding.

Demographic Characteristics

There are multiple demographic factors which have been proven to play a role in mode choice, including age, economic status, gender, and education level. For both active and inactive mode choice, age is a significant correlate even in the presence of other demographic variables. Young people (under age 18) and older individuals (age 65+) are the groups most likely to utilize active modes of transportation (Burbidge, Goulias and Kim 2006, Ewing et al 2003, and Pucher and Renne 2003). It should be noted that one likely reason for this is that both the young and elderly are often captive to specific modes of transportation. For example, prior to age 16 individuals in the United States cannot legally obtain a driver's license. Older individuals may lose the ability to operate an automobile as they age due to vision loss, decreased response reflex, or other degenerative conditions. This makes both groups reliant on other drivers, active modes, or transit for transportation.

Socio-economic status has been found in various studies to affect active mode choice as well. Giles-Corti and Donovan used a cross-sectional survey to study 1803 adults near Perth, Australia, and found that survey respondents in low socio-economic areas had superior spatial access to many recreational facilities but were less likely to use them when compared with those living in high socio-economic areas (2002a). After adjustment, respondents living in low socio-economic areas (not explicitly defined in the research) were 36% less likely to undertake vigorous activity. Research has also shown that lower income individuals utilize active modes of transportation less than those with higher income, even when both groups live within the same neighborhoods with similar infrastructure available (Brownson et al 2001, and Pas and Koppelman 1986). It is interesting that this phenomenon exists because Pucher and Renne's (2003) analysis of the 2001 National Household Travel Survey found that higher income households make more long trips per day covering almost twice the total mileage per day of lower income households. One would generally assume that lower income individuals traveling

shorter distances would utilize active modes more often, but this does not seem to be the case, even when considering low income individuals who are captive and may not have access to an automobile or do not have the ability to drive a car.

Gender has also proven to influence travel behavior. Brownson et al's (2000) cross-sectional survey of 1269 adults in rural Missouri showed that women are significantly more likely to participate in physical activity and utilize neighborhood trails than men. When individuals do travel actively, women are more likely to walk for transportation, but men are more likely to utilize a bicycle for active travel (Pucher and Renne 2003).

Also notable for its social affect on travel behavior is education level. Burbidge, Goulias, and Kim (2006), and Coogan (2003), showed that individuals with higher levels of education walk significantly more than those with lower levels of education. The Coogan study was based on National Household Travel Survey Data (the drawbacks of which are discussed previously), and the Burbidge study involved surveying individuals residing or working within Centre County Pennsylvania (home of the Pennsylvania State University), which could exhibit some representative bias for national inference due to geographic location and demographic make-up of the study group. These factors may cause some difficulty in generalizing these results to different populations.

Personal Characteristics

Many personal characteristics including attitudes play a role in mode choice decisions. As defined by social psychologists, attitudes are "learned predispositions to respond in a consistently favorable or unfavorable way towards a given object, person, or event" (Hayes 1993). A study by Beldon, Russonello, and Stewart (2003) surveyed 800 adults nationwide by telephone. This study found that opinions about walking and cycling are generally positive, and the majority of the public recognize their virtues. A separate review by the Federal Highway Administration (USDOT-FHWA 1992) also showed that a majority of Americans stated that they would like to walk more than they currently do.

These stated preference surveys, however, only represent what an individual claims they would do in a given situation. They do not show what behavior a person would actually exhibit in that situation (Sanko 2002). A wealth of research conducted over the past century has shown repeatedly, that attitudes do not always determine behavior (Fishbein and Ajzen 1974, LaPiere 1934, and Weinstein 1972). A number of other factors must be considered such as situational factors, characteristics of the attitudes themselves, personal factors, and habitual behavior (Wicker 1969).

Habitual behavior and the role that personal habit plays on mode choice decisions is an important component of travel behavior research. Habits are "learned sequences of acts that have become automatic responses to specific cues, and are functional in obtaining certain goals or end states (Verplanken and Aarts 1999)". In each transportation situation individuals must decide how to get where they are going. Research has shown that eventually individuals may become so familiar with a situation and the accompanying decisions that they may not consider any alternatives, but will automatically utilize whatever transportation means they have used in the past (Bamberg, Rolle, and Weber 2003, and Moller 2002). The challenge in dealing with habits with regard to travel behavior and mode choice is that they happen without awareness. That is, many everyday choices and decisions are made without the decision maker being conscious of making the choices (Vanderplanken and Aarts 1999). Moller (2002) concludes that any attempt to change travel mode choice will largely depend on the motivation behind the

behavior, and that policies to change habits should focus on making individuals more conscious of their choices.

One last personal characteristic often associated with travel behavior is the idea of travel utility. Recent research has sought to study in more detail the possibility of an intrinsic utility of travel, or the utility that travelers obtain from the travel itself (i.e. sense of speed, fresh air etc. - Janelle 2004). Across societies there are variations in what is considered acceptable in terms of travel time. Additionally, utility may change as an individual moves across their lifecycle stage or life-course. For example, a teenager with a new driver's license may view a five hour road trip differently than someone who has been driving for many years. Technologies can also change the way that people view travel utility. Driving in a luxury car with a nice stereo system, climate control, and heated seats may be more pleasurable than driving in an older vehicle with no heat or air conditioning. Mokhtarian and Salomon (2001) provide theoretical arguments and empirical evidence that travel is valued in its own right and not simply as a means to a destination. Their work specifically seeks to differentiate between intrinsic utility (the utility gained from the trip itself) and derived utility (utility derived from an activity once you reach the destination). Additionally, Ratner and Kahn et al (19991), showed that some individuals are "willing to sacrifice real-time enjoyment for the sake of variety". Rather than always optimizing their utility many individuals will change their routine simply to "change the scenery". Related to this, Janelle (2004) argues that there is no definitive proof that an optimal amount of travel time exists, but he notes that the average value is relatively stable at approximately 30 minutes.

Infrastructure and Environment

Cullen and Godson (1975) stated that "individual behavior patterns are an important element of urban structure, and their activities in time and space are at least as important as those which have been studied to date." This urban structure, or what is often referred to as community design or the built environment, is proving to play a large role in decision making and should not be overlooked as a key element and determinant of travel behavior.

Community design is one of the most important and most researched aspects associated with the decision to travel actively to date. The built environment is broadly defined to include land use patterns, the transportation system, and design features that together generate needs and provide opportunities for travel and physical activity (Transportation Research Board 2005). Community design has long been proven to affect the travel decisions that people make for their daily trips (Cullen and Godson 1975). Development patterns also play a role in levels of physical activity for residents. Killingsworth, De Nazell, and Bell (2003) even argue that the automobile-dominant design of most suburban communities has contributed to unsafe environments for walking and bicycling. Sprawling land use has been proven to be directly related to overweight and obesity. Ewing (2005) utilized the metropolitan sprawl database to analyze elasticities of walking and transit-mode shares with respect to the metropolitan sprawl index. He found that an increase in sprawl is associated with a significant increase in chronic medical conditions and a decline in health related quality of life. Additionally, the 2001 National Household Travel Survey (NHTS) data found that individuals in urban environments are more likely to walk or bike than those in suburban or exurban areas (Coogan 2003).

Accessibility

Accessibility unavoidably plays a role in mode choice and active travel, and it is directly affected by the layout of a community. Accessibility reflects the ease of reaching necessary or simply

desired activities and therefore reflects characteristics of both the land-use and transportation systems (Handy and Clifton 2001a). There are many ways to measure accessibility, such as counting the number of opportunities reached within a given distance or travel time. Accessibility is affected not only by the basic land-use and transportation characteristics of an area, but also the scale at which a specific mode operates. For example, if a community is designed with land-uses completely separated and located far from one another accessibility may be severely restricted based on travel time, and mode choice will be affected. Research by Abreu da Silva, Golob, and Goulias (2006) conclusively showed for commuters in Lisbon, Portugal, that land-use patterns do significantly affect travel behavior when considered as home-based and work-based and included in a system of equations that account for self selection of location choices. They also note that these same relationships affect commute distance and total travel time. Using the same overall method, similar strong connections between land use and travel are found in the Seattle metropolitan area by Abreu da Silva and Goulias (2007). Handy and Clifton (2001a), however state that many factors other than distance and travel time play a role in assessing accessibility. For bicycling and walking, the availability of amenities and the quality of the travel environment may be just as important. Additional factors such as ease of street crossing, sidewalk continuity, local street connectivity, and topography, all affect accessibility for pedestrians and should not be overlooked. These types of factors are discussed more in the following section.

Design and Activity

The built environment can facilitate or constrain physical activity. Physical environment factors have consistent associations with physical activity and active travel behavior. It is important to remember, however, that the relationship between the built environment and walking is different than the relationship between the built environment and driving. This key point is overlooked by most transportation researchers.

Past research does agree that certain community design factors play a role in active mode choice. The same components or similar variations appear in nearly every study. And while they all agree that there is some level of impact, each come to their own conclusions regarding the measure of affect that the components have on active mode choice. The agreed upon components of active friendly communities include: density and intensity of development and mix of land uses, the functionality of destinations, connectivity of the street network, and aesthetic qualities of place (See Handy 2005, and Transportation Research Board 2005). Communities that exhibit these characteristics are sometimes referred to as “walkable communities” while communities that do not, are referred to as “auto-oriented communities” (Burden 2004). It has been implied that residents of pedestrian and bicycle-oriented neighborhoods make more walking, bicycling and public transportation trips than residents of automobile-oriented neighborhoods. Abad (2005) argues that linked paths throughout the city should be available for exercise, recreation, transportation, and tourism to promote healthier lifestyles for the community, and the Brownson et al (2001) telephone survey of 1818 adults nationwide found that approximately 66% of individuals indicated that they were most likely to engage in physical activity on neighborhood streets, or on walking and jogging trails.

Table 1 provides additional information for the studies mentioned in the above literature review, including information on methodology and exact research findings. This is not intended to be a comprehensive or exhaustive review of travel behavior literature; the selected studies

merely aim to represent the relevant literature as it applies to active mode choice for transportation or recreation.

TABLE 1. Summary of Findings from Prior Bicycle and Pedestrian Studies

Study	Methods	Findings
Bamberg, Rolle & Weber 2003	Quasi experimental survey of 241 adults in Stuttgart, Germany	-A strong car use habit makes travel mode choice script-based, so that minimal information is needed to make it
Belden, Russonello, & Stewart 2003	Random telephone survey of 800 adults nationwide	-Opinions about walking and cycling are generally positive
Brownson et al 2000	Cross-sectional survey of 1269 adults in rural Missouri	-Women were more likely to report and increase in walking than men
Brownson et al 2001	Telephone Survey of 1818 adults nationwide	-66% of adults participate in physical activity on neighborhood streets or trails/paths -Lower income individuals are less likely to utilize active modes than higher income individuals
Burbidge, Goulias, and Kim 2006	Activity Diary Panel Survey of 1471 adults and children from Centre County, PA	-Active travelers are generally younger than inactive travelers -Individuals with the higher levels of education walk significantly more than those with lower levels of education
Coogan 2003	Analysis of the 2001 NHTS Data	-Individuals with the lowest levels of education report “never walking” significantly more than those with the highest levels of education
Ewing 2005	Analysis of health using the metropolitan sprawl index	-Residents of sprawling counties weighed more, were more likely to be obese, and were more likely to have high blood pressure than were their counterparts living in compact counties
Ewing et al 2003	Cross-sectional telephone survey of 382,601 adults from 448 counties and 83 metropolitan areas (BRFSS survey of 1998, 1999, & 2000)	-Adults age 65 and older are more likely to participate in leisure time walking than younger adults
Giles-Corti & Donovan 2002a	Cross-sectional survey of 1803 adults near Perth Australia	-Respondents in low socio-economic areas had superior spatial access but were less likely to use recreational facilities than those living in high socio-economic areas
Litman 2003a	<i>Not Specified</i>	-Shifting travel from driving to walking can provide a savings of approximately \$0.25-\$0.50 per mile depending on the existing conditions
Pas & Koppelman 1986	Five day record of travel for an unspecified number of adults in Reading England	-Individuals who have fewer constraints (high income) have higher levels of active trip making than those of lower income
Pucher & Renne 2003	Review and Analysis of the 2001 NHTS Data	-Not only do higher income households make more trips per day, but they also make longer trips, covering almost twice the total mileage per day of low-income households -Women are more likely than men to walk for transportation, but men are more likely to bike for transportation -Young individuals (under age 24) are the most likely to utilize active modes for transportation followed by individuals 65 years and over
USDOT-FHWA 1992	Report on existing research on walking and bicycling	-A majority of Americans would like to walk more than they currently do

POTENTIAL THREATS TO RESEARCH VALIDITY

The above research shows conclusively that there is a lack of research in two key areas. Correlating physical activity and travel behavior has been accomplished to date using research methods designed for other purposes making them methodologically weak and addressing behavioral causality in a superficial way. Although many current research projects show

correlation exists between the built environment and physical activity, the nature of most described methodologies (further discussed in Section 4) cannot sufficiently establish a causal relationship. Additionally, do active people choose to live in active environments, or do active environments produce active people? There is little information on the role that self-selection plays in determining physical activity levels as they relate to interaction with the built environment.

Determining Causality

As a part of a Transportation Research Board Special Report, Handy completed a thorough literature review of recent research studying the link between physical activity and the built environment (2005). Her literature review examined research in both the physical activity and travel behavior fields, and determined that the majority of the studies pertaining to physical activity and the built environment utilized cross-sectional methodologies (of the 50 studies that were examined, only one (1) was longitudinal in design at that time). This leaves open the possibility that resulting conclusions could be spurious in nature and causality can not be adequately determined as explained below.

According to Briss and Fielding et al (2000), “Cross sectional studies measure exposure and outcome in a single group at the same point in time, creating a potential for significant threats to validity.” Although cross-sectional data can tell us that a change has occurred, it tells us nothing about why the change occurred, nor can we reliably estimate how change may occur in the future (Miller 1999). Cross-sectional analysis can only provide a snapshot of a particular area or population at one particular point in time (Singer and Willet 1996). In order for causality to be established, five criteria must be considered: empirical association, appropriate time order, non-spuriousness, causal mechanisms, and the context in which the effect occurs (Schutt 2004). Kitamura also stated that “behavioral relationships identified based on cross-sectional observation would not represent behavioral changes over time...longitudinal data and analysis are prerequisite for proper identification and prediction of behavior (1990)”.

Longitudinal data are obtained through panel surveys; and although many variations exist on the exact definition on the type of a panel survey, general consensus defines a panel survey as a study conducted over time to evaluate the impact of change in an environment or change in behavior. Additional criteria by Singer and Willet (1996) suggest that a truly longitudinal panel should contain at least three waves of data collection. Literature differs regarding the number and types of panel surveys. Miller (1999) identifies four types which focus on: auto ownership and usage, transit, special purpose (i.e. before and after), and general purpose (also mentioned by Kitamura 1990). Longitudinal and rotating panel designs are also discussed by Tourangeau, Zimowski, and Ghadialy (1997).

When considering the analysis of panel data, Eccles, Grimshaw, Campbell, and Ramsay (2003) differentiate their focus from the others by emphasizing evaluative designs and non-randomized designs. Yafee (2003) also identifies six types of analysis strategies for panel data including: constant coefficient models, fixed effects models, and random effects models, as well as dynamic panel, robust, and covariance structure models.

There are many benefits to utilizing a longitudinal research design. Panel surveys have the ability to identify temporal variation in travel behavior through direct observations (Kitamura 1990). This observation reduces the effects of confounds and helps establish cause-effect relationships (Miller 1999). Forecasting based on longitudinal data collection, has shown improved predictive accuracy and increased statistical efficiency as well (Tourangeau,

Zimowski, and Ghadialy 1997). Additionally, Bandura (1986) observed that interactions between people, their environments, and behavior may not happen simultaneously and can play out over time. By establishing preliminary baseline data with regard to travel behavior and physical activity, data can then be gathered over time to identify if changes in behavior have occurred corresponding to changes in the physical environment, rather than predicting causality based on comparative data collection. The impact that the built environment, transportation in particular, has on physical activity and active travel behavior is a change over time, and can only accurately be measured and identified using longitudinal methodologies. All other methodologies will be ill suited to determining causality and may fall prey to threats to their internal validity.

Controlling for Self-Selection

Individual preference for physical activity may influence individual and household residential decision making. Current research presumes that individuals living in areas that support physical activity will be more physically active than those living in areas that do not support physical activity. In an alternative theory, individuals who are more physically active tend to live in areas that support physical activity, while individuals who have a low preference for physical activity may self select to live in areas which do not support physical activity (Handy 2005). The physical environment may simply reinforce a preferred behavior.

Studies by Handy and Clifton (2001b), Bagley and Mokhtarian et al (2002), and Greenwald and Boarnet (2001), provide strong evidence of self selection, although all are cross-sectional in nature which provides the possibility that the validity was compromised due to bias. According to Handy (2005), as of 2005 no study published had accounted relationships over time, associations between preferences and changes in the built environment, the built environment and changes in preferences, and changes in the built environment that lead to changes in preferences and changes in activity. Alternatively however, by surveying both residents who relocated to an area with a new trail as well as residents who lived in the area prior to the trail's construction, Burbidge (2008) found that new residents were not drawn to the area due to the presence of a trail, but they made their decision for residential location based on characteristics unrelated to opportunities for physical activity and active travel.

INTERVENTION STUDIES

Travel behavior methodologies would suggest that the best way to identify if a proposed method would produce a desired effect is to test it in a real world experimental setting. For active travel behavior, that suggests using an intervention study to monitor changes in travel behavior and physical activity from before an intervention to after (i.e. construction of a facility). By carefully crafting an intervention experiment researchers can definitively identify causality while also controlling for residential self selection.

In recent years, there have been many studies correlating physical activity and travel behavior to exogenous factors, such as those summarized in Section 2. These include many variations on topics such as time allocation, personal characteristics, and infrastructure and environment. Although many studies claim that an increase in specific infrastructure (i.e. trails, sidewalks, bike lanes, etc) would inherently create an increase in physical activity, there have been few studies measuring the actual impact of active infrastructure development on travel behavior and physical activity. Although several studies have been conducted attempting to achieve this goal, most either refer to the topic distantly in research designed for another

purpose, or are methodologically weak and do little to address behavioral causality relating to the infrastructure's impact on physical activity. Each of the existing studies will be described below, along with a critique of their research design.

A study by Giles-Corti and Donovan (2002b) briefly addresses usage rates of local infrastructure by a cross-sectional survey of 1773 adults aged 18-59 years (one eligible respondent randomly selected from each contacted household) in Perth, Australia. Surveyors measured the individual, social, and physical environmental factors (not explicitly defined in the publication) that influence participation in physical activity. This study determined that 82.5% of survey respondents walked for either transportation or recreation, and that 100% of those who walked reported doing so on a facility near their home (i.e. sidewalk, trail, beach). The survey contained 255 questions and respondents were asked the frequency and duration of all types of physical activity undertaken in the previous two weeks. The unemployed, those who were physically active as part of a job, those with any medical condition likely to affect participation in recreational physical activity, those ages over 59, and those who had occupied the household for less than one year were intentionally excluded from the study.

Although Giles-Corti and Donovan (2002b) touch briefly on the impact of infrastructure on physical activity, their focus is still well outside the domain of attempting to prove causality between the active infrastructure and the physical activity performed. The study's methodology also likely results in incomplete data as respondents may forget a portion of their physical activity episodes over a time period that is two weeks long. It is also probable that the strict restrictions placed on sample selection (by intentionally leaving out the above mentioned groups), may have created an artificial population that is not likely to be representative of the public residing in that specific area as a whole, since it is likely that at least a small percentage of residents would fall into at least one of the eliminated categories.

Brownson et al (2000) provided the pioneering work on community walking trails and the impact that they have on physical activity. A cross-sectional telephone survey was conducted in 12 counties in rural Missouri, to ask a population based sample of 1269 residents (over 18 years of age) standard questions about walking behaviors, knowledge, and attitudes. This study was conducted by Public Health professionals, and utilized questions from the Behavioral Risk Factor Surveillance System (BRFSS) including: walking behavior in the past month, access to walking trails, use of walking trails, and whether exercise behavior had changed due to walking trail use. The study also asked residents how they found out about trails, and what aspects of the trails they most liked. The study concluded that approximately 37% of respondents reported having access to walking trails in their area, and 45% stated that they had walked in the past month for exercise. The authors recommend building walking trails as an intervention to promote physical activity, but their research does not conclusively prove that doing so would in fact increase physical activity.

By utilizing a telephone survey and asking about behavior over a one month time span, this study is open to many human errors in both recollection and self reporting. The BRFSS questions also only ask about walking for recreation, and do not incorporate the possibility of walking for transportation. It should be kept in mind that all walking, regardless of purpose or intent, provides physical activity and utilizes the same infrastructure. This study did not look at a specific geographical area and asked questions about trails in general terms, rather than collecting data about a specific trail.

Another study by Brownson et al (2004), examined creating a physical activity intervention program. Researchers sought to inspect changes in walking behavior in six intervention communities in Missouri, Arkansas, and Tennessee. Trail use data were collected (via electronic counting at trail heads), and trail users (over age 18) were asked to provide feedback to identify the best mechanisms for developing social and community support for physical activity. Intervention activities included having individuals fill out a brief one page questionnaire about issues such as perceived benefits or barriers, motivation, health related behaviors, resource availability, and preferences for walking. Brownson et al (2005) further examined the intervention issue from the 2004 work by utilizing a quasi-experimental design to quantify changes in walking behavior in the six intervention communities described above. This second phase of research included providing positive reinforcement to those who walked regularly and motivational and resource information to those who did not walk regularly. The researchers then measured changes in walking behavior in those who received the promotional materials versus those who did not receive promotional materials. These studies lacked an in depth quantitative methodology. The point of these interventions was to find ways to promote trail use and encourage citizens to become more physically active. It is important to note that all trails utilized in this study were at least 7 years old (built between 1975 and 1997) when the research was conducted, and of the residents surveyed only 8% actually used the trails. Also, the intervention discussed in this research was not an infrastructure intervention but rather a promotional intervention. Results from both studies lack statistical information regarding any change in behavior caused by the actual construction and implementation of the trails prior to their research.

Troped et al (2001), go further toward analysis of the impact of active infrastructure by examining associations between self reported and objective physical environmental variables and the use of the Minuteman Bikeway in Arlington, Massachusetts. This cross-sectional community study surveyed a random sample of 413 adults (age 18 and over). The survey consisted of 53 questions aimed at assessing physical activity habits as well as factors potentially associated with the use of the Minuteman Bikeway. The survey attempted to measure recent participation in recreational physical activity, and stages of change for both recreational and transportation related physical activity.

The survey relied on self reported behavioral data, asking respondents to list their activity over the prior two weeks. This research was cross-sectional in design, and although they sought to measure change in behavior, this methodology makes that increasingly difficult as it relies on respondents remembering all their physical activity episodes for the 14 days prior. Also, no long term change was measured in the research. Another major existing bias in this study was the age of respondents. The average age of survey participants was 52 years. This can cause many problems with regard to the generalizability and applicability of the study results.

A recent study conducted by Barnes, Thompson, and Krizek (2006), uses census data to describe changes in bicycle commute mode shares between 1990 and 2000 in Minneapolis-St. Paul, Minnesota. Their analysis specifically attempts to utilize longitudinal methods to analyze the impact of seven new facilities that were created during that decade. Their methods include an analysis of census journey to work data from 1990 and 2000, comparing bicycling commute rates over various parts of the city, and between specific origins and destinations taking into account their proximity to the above mentioned facilities. They assert that this method allows them to determine differences between geographic areas that existed prior to a trail's construction.

Their methodology introduces a number of assumptions which do not take into account actual travel behavior. For example, this study only took into account bicycle mode share for journey to work trips. This inherently neglects the inclusion of other trips and purposes which have proven more likely to utilize active modes (Burbidge, Goulias, and Kim 2006). Additionally, four of the seven paths analyzed were not constructed during the study time period; three were constructed prior to the 1990's, and one was completed in the year 2000, which would not have allowed any significant impact to be determined through the use of the 2000 census data. Lastly, this analysis purposely ignored analyzing areas around new bike paths in the suburbs due to "low usage rates". If the authors' intentions were to determine the impact of bike path construction, that would best be accomplished by including all types of bike paths rather than only those they already knew had a positive impact. This omission could prove to have a significant impact on the validity of the study. This study did find a statistically significant increase in bicycle mode share concentrated in areas around the "new" facilities, however the drawbacks discussed above would call in to question these results due to additional confounding factors which were not included in the analysis.

Using a quasi-longitudinal study Evenson, Herring, and Huston (2005) measured change in physical activity as it could be attributed to the construction of a multi-use trail. The research studied the impacts of a 2.8 mile multi-use trail in Durham, North Carolina. A random sampling of 2125 households (based on households with telephone numbers in the white pages) were surveyed over the six months prior to the trail's opening. Follow-up surveys ranged from one year and seven months, to two years and four months post opening. Approximately 63% of the participants in the baseline survey participated in the follow-up survey. The study found no significant change in physical activity levels after the installation of the trail. The study also determined that participants who claimed to use the trail were less likely to increase their walking per week from baseline than those who had never heard of the trail.

Although this study sought to identify if active infrastructure development plays a role in behavior modification, there were still some major drawbacks in the methodology. First of all, the sampling and survey technique included only households with working telephone numbers that were listed in the white pages. This would rule out all households who do not have a telephone (possibly a large number of low income), or households who choose not to have a landline telephone which is becoming more common with the prevalence of cell phone usage. Also, although this study seeks to look at change in the population and claims it is "examining changes longitudinally", it is more correctly identified as a repeated cross sectional design. Respondents were randomly chosen in two stages: the first stage at the household level, and the second stage at the individual level (the person with the closest birthday). This creates a large discontinuity of data due to the different scale at each stage. The study also only took into account the behavior of the household as a whole (in phase one) or of one adult member of each household (in phase two). This does not allow the researchers to specifically see changes in behavior within households or determine behavior differences between entire households over time and to study within household interactions.

These methods rely on BRFSS questions (the drawbacks of which are discussed previously), and only one survey question directly addressed the trail being studied. In order to determine whether participants were using the trail, all respondents who reported walking or biking were asked where that activity took place. The questions also did not address other modes of activity on the trail, such as rollerblading, etc. The majority of questions related solely

to recreational use with only two questions addressing transportation. The main drawback of this study is that even if the authors were able to document an increase in physical activity levels, they did not gather enough specific follow-up data to determine if the trail was the reason for the change. This leaves the possibility that confounding factors played a role. In their conclusion the authors mention that this trail was a part of a larger trail network and that a “cleaner” evaluation may occur if the geographic area evaluated does not contain any other trails.

Burbidge (2008), conducted the first study to use a truly longitudinal methodology to analyze active travel behavior and physical activity changes which occur after an environmental intervention. In this study households were randomly selected from the neighborhood where the proposed trail would be constructed, and 92 individuals from 32 households completed annotated activity diaries at three separate time points (1 prior to the trail’s construction, and 2 after construction). The use of an activity diary as opposed to questionnaires of a few questions allowed for the measurement of individual changes in the number of physical activity episodes, total time spent being physically active, total walking trips, and total biking trips. The study found that although there was not a significant increase in overall physical activity or active trip making, individuals ages 18-64 (traditionally known to be less active) did participate in significantly more physical activity episodes after the trail’s construction.

There are several drawbacks in this research beginning with the quasi experimental nature of the study. Although this research design provides the first true longitudinal study of this topic, the research is not truly experimental as it lacks a control group. This study’s results would be more robust if there was a control group which received no infrastructure change for comparison. This research also exhibited a relatively small sample size. A larger sample would have allowed for more rigorous analysis opportunities as well as providing greater generalizability for other areas. Also, the trail analyzed in this study was located in a bedroom community with little access to quality destinations, and few surrounding amenities. Lastly, the majority of residents surveyed reported no knowledge of the trail’s construction suggesting the need for some type of marketing or public outreach to encourage usage.

There continues to be a large gap in the existing research when it comes to physical activity levels in children as members of a household. Although Evenson, Herring, and Huston noted that the trail they examined was located near two schools, no school aged children were surveyed (2005). Of the previously described studies, only Burbidge (2008) took into account the behavior of children (under age 18) who as prior research has shown, are highly likely to participate in walking as a mode of transportation.

TABLE 2. Summary of Existing Research

Study	Methods	Findings	Limitations
Barnes, Thompson, & Krizek 2006	Comparison of census journey to work data from 1990 and 2000	-There was a statistically significant increase in bicycle mode share during the 1990’s concentrated in the areas around facilities. -Long trips (over 5 miles) significantly increased to the University of Minnesota campus.	-Only takes into account journey to work trips - 4 of the 7 paths analyzed were not completed during the study time period (3 prior to the 1990’s and 1 in the year 2000) -Analysis purposely ignored bike paths in the suburbs due to known “low usage rates”
Brownson et al 2000	Cross-sectional telephone survey of 1269 adults from 12 counties in rural Missouri including	-37% of respondents reported having access to walking trails -45% had walked in the past month for exercise	-Cross-sectional methods -Recollection and self reporting errors over one month time span -BRFSS questions only ask about walking for recreation

	standard BRFSS questions about walking behaviors, knowledge, and attitudes		-No focus on geographical area or a specific trail
Brownson et al 2004	Intervention with data collection at six trail heads in Missouri, Arkansas, and Tennessee – surveyed users regarding physical activity	Intervention included having individuals fill out a brief one page questionnaire about health, motivation, behavior, and preferences for walking	-No quantitative methodology or statistics -All trails studied were over 7 years old which did not allow researchers to identify behavioral change caused by trail construction
Brownson et al 2005	Quasi-experimental design to quantify changes from Brownson et al 2004	-Provided positive reinforcement for walkers, and information for non-walkers	-See <i>Brownson et al 2004</i>
Evenson, Herring, & Huston 2005	Repeated cross sectional mail survey of 2125 households in Durham, NC; Data collected six months prior to, one year and seven months following, and two years and four months following a trail's construction	-No significant change in physical activity levels after the installation of the trail -Participants who used the trail were less likely to increase their walking per week from baseline than those who had never heard of the trail	-Repeated cross-sectional methods -Only included households with working telephone numbers -BRFSS questions -Only one question addressed the specific trail -Two different methodological techniques (households in wave one & individuals in wave two) -No follow-up data collection to determine causality
Giles-Corti & Donovan 2002b	Cross-sectional mail survey of 1773 adults in Perth, Australia – measured types and duration of physical activity within two prior weeks as well as other social, individuals, and environmental factors	-82% of respondents walked for transportation or recreation -100% of those who walked did so on a facility near their home	-Cross-sectional methods -Excluded unemployed individuals, those with medical conditions limiting mobility, persons over age 59, and those occupying household for < 1 year -Relied on memory of participants over 2 week duration
Troped et al 2001	Cross-sectional mail survey of 413 randomly sampled adults in Arlington, VA examining associations between self-reported and objective environmental variables relating to a local bikeway	-Age and female gender showed significant inverse associations with bikeway use -Increases in distance were associated with decreased likelihood of bikeway use -Absence of steep hill barriers and busy streets were associated with bikeway use	-Cross-sectional methods -Relied on memory of participants over 2 week duration -Bias due to age of respondents (Mean =52 years)

In addition to methodological shortcomings of the aforementioned studies, there are several additional drawbacks to the analytical methods employed. Most of the studies discussed, provide only simplistic statistical analysis of the data. Brownson et al (2000, 2004, 2005) did not specifically identify which types of regression analysis were used in their studies, but output from the models suggests nothing more complex than simple linear regression estimated with ordinary least squares. Barnes, Thompson, and Krizek (2006), do not specifically identify their methods either, listing significance levels as only 1 or 2 with no further definitions. Troped et al (2001) employ Logit regression methods, but give no statistical diagnostics within the text not allowing a determination of model performance to be made. These methods may not be multifarious enough to determine causality and correlation between the given variables and physical activity. Evenson, Herring, and Huston (2005), and Giles-Corti and Donovan (2002b)

did acknowledge the use of multivariate statistics and 2 log-likelihood tests (chi-square) which suggests they used non-linear regression in their studies. Only Burbidge (2008) reported utilizing advanced statistical models including zero-inflated Poisson models, Discrete-Choice models, and fixed effects panel analyses.

CONCEPTUAL MODEL

After reviewing all existing active transportation research (and applicable research conducted in other fields), a conceptual framework was created for analyzing active travel behavior. This research proposes a conceptual model of active travel behavior which draws on components from the Theory of Planned Behavior (Ajzen, 1985) and Decision Field Theory (Busemeyer and Townsend, 1993). Additional components have been included based on the findings of the Academy Park Panel Survey (Burbidge, 2008).

The Theory of Planned Behavior (TPB) asserts that human behavior is the direct result of an individual's intent. Intent, Ajzen claims, is informed by three main components: The "attitude toward the behavior" which reflects an individual's desire to participate in a behavior; the "subjective norm", what others think of the behavior; and the "perceived behavioral control", which describes the individual's perception of how hard it will be to adapt the behavior (Ajzen, 1985). As an individual makes a decision, they first form their intent from these three components. Their intent then informs their decision which is reflected in their revealed behavior (shown in blue in Figure 2).

Decision Field Theory (DFT) was formed by combining two behavior theories from psychology: approach-avoidance theories of motivation, and information-processing theories of choice response time. DFT seeks to "understand the motivational and cognitive mechanisms that guide the deliberation process involved in making decisions" by integrating information that comes from the external environment with information coming from an individual. Decision Field Theory asserts that this "information" is used in a deliberation or "choice process" which weighs the potential consequences of actions. After deliberating, a preference state is created and a threshold is applied which includes all external "inhibitory criteria" (i.e. distance, time, topography, etc.) regarding a possible decision. The result of this process and threshold application is "revealed behavior" (Busemeyer and Townsend, 1993). Stern and Richardson (2005) expanded on this theory to incorporate situational dynamics of general travel behavior by including cultural and societal norms (included below as "subjective norm" similar to the TPB framework), type of trip (included as trip purpose in the model), and personality attributes. The conceptual model presented in this research utilizes both the components of the original theory as well as the additions provided by Stern and Richardson (shown in green in Figure 2).

Past research described above (Tables 1 and 2) has documented that each of the additionally included factors, shown in yellow, play a substantial role contributing to behavior.

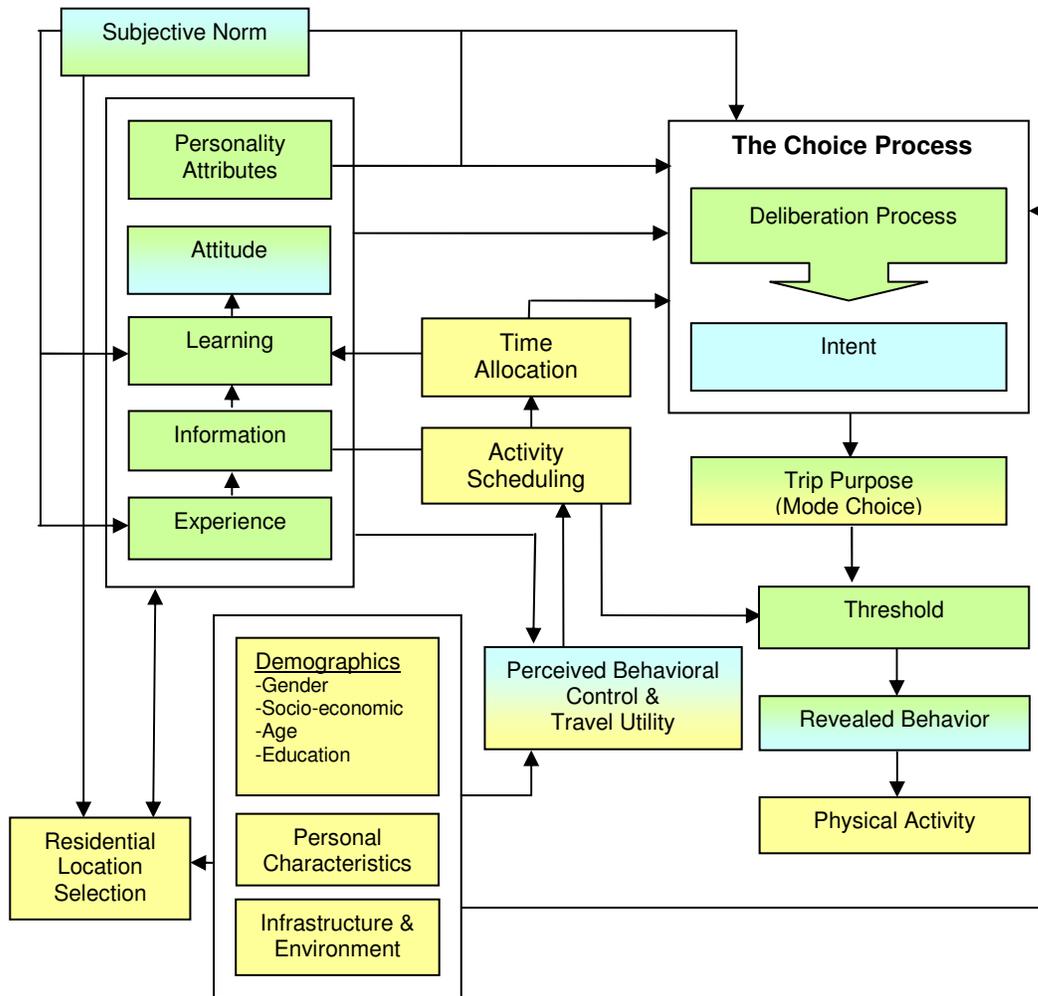


FIGURE 2. Conceptual Model of Active Travel Behavior

1-Blue shaded boxes taken from Ajzen's Theory of Planned Behavior (1985)

2-Green shaded boxes taken from Busemeyer and Townsend's Decision Field Theory (1993)

The subjective norm refers to what others (friends, family, peers, etc.) think of a behavior or circumstance (Ajzen, 1985). This outside opinion impacts an individual's attitude directly as many individuals value the opinion of others (Gollege and Stimson, 1997). Subjective norm also contributes to learning and experience as outside opinions increase the amount of information available to the decision maker, thereby influencing their attitude and subsequently their choice process.

Shown in one large box on the left, are the interrelated components of experience, information, learning, attitude, and personality attributes. Individuals acquire experience by living through different events. This experience provides them with new information, news, or knowledge (Gollege and Stimson, 1997). By processing information, individuals participate in a synthesis or learning which subsequently contributes to a formation of attitude. As previously defined, attitudes are "learned predispositions to respond in a consistently favorable or unfavorable way towards a given object (Hayes, 1993)". Not all individuals will respond the

same to the learning process and individuals will inevitably develop different attitudes toward given stimuli. Additionally, individual personality attributes (i.e. insecure vs. confident, or impulsive vs. organized) couple with individual attitudes to inform the choice process (Collins and Chambers, 2005). Burbidge found that attitudes do in fact influence revealed active behavior (2008) for example, the perception of danger or accident risk had significant impact on walking trips with the likelihood of walking decreasing as an individual's perception of risk increased. However, individuals whose perceptions of safety level were contingent upon improved sidewalks did not significantly differ from those who believed that the existing infrastructure was adequate. Preference for specific exercise types was found to significantly impact active behavior as well (Burbidge, 2008).

The second large box of components shown in the lower left quadrant of the model includes demographics, personal characteristics, and infrastructure and environment. Demographic characteristics include individual attributes such as age, sex, socio-economic status, education, etc. Personal characteristics include physical and emotional limitations (potential capability constraints), as well as additional things such as possession of a drivers' license, automobile ownership, bicycle ownership, or ownership of other amenities (i.e. cell phone, internet, cable television, exercise equipment, etc). Each of these personal characteristics have been proven to impact active travel behavior (as shown in Table 1). The built environment includes land-use patterns, the transportation system, and urban design features that together generate needs and provide opportunities for travel and physical activity (Transportation Research Board, 2005). The connection between each of these components and active travel behavior and physical activity has been described in detail above. As shown in the model, these components work together to account for travel utility and perceived behavioral control, and subsequently provide for activity scheduling and time allocation, as well as the choice process. However, recent research has shown that changes to the built environment do not necessarily create an induced demand for active travel behavior and physical activity, and suggests that specific characteristics of the infrastructure may be more important than the availability or the infrastructure itself (Burbidge, 2008).

In the bottom left hand corner, the model includes a component identifying residential location selection, which encompasses the influence that neighborhood characteristics or residential decision making has on overall behavior (physical activity and travel). Residential location selection is impacted by a number of factors including demographics, personal characteristics, local infrastructure and environment, as well as experience, information, and attitude. Residential location decision is also somewhat based on the subjective norm. Additionally, residential location decision impacts the learning cycle by providing new experiences which contribute to new information. Handy (2005), Handy, Cao, and Mokhtarian (2006), and Dill (2003) each suggest that residential location selection has an impact on the choice process, but Burbidge (2008) found that new residents are not necessarily drawn to new areas due the presence or absence of active infrastructure but rather for lifestyle factors (i.e. housing affordability, proximity to work, friends, and family, etc). This suggests some degree of demographic and personal characteristic similarity among residents as shown in the model. However recent research has revealed that new residents to an area may have very different attitudes than historic residents about the same area, which calls into question the connection between residential location selection and individual attitudes (Burbidge, 2008).

The proposed model also incorporates perceived behavioral control and travel utility. Perceived behavioral control describes how difficult an individual perceives a change in behavior to be (i.e. how hard it would be to change from driving to walking or using transit). This perceived behavioral control is impacted by demographics, personal characteristics, and characteristics of the built environment, as well as experience, attitude, and personality. Also, behavior varies based on travel utility. Travel utility was described previously as the benefit derived from traveling. This is directly related to perceived behavioral control, as it is perception based. Travel utility differs based on the same characteristics which make perceived behavioral control unique for individuals. Therefore these components are included together. These components then provide input to individual and household activity scheduling and subsequently time allocation. Prior research on stated versus observed behavior however, asserts that intent does not necessarily equate to revealed behavior (Fishbein and Ajzen, 1974 and Wicker, 1969). Because perceived behavioral control and intent have not been examined in depth, the relationship between these components and active travel behavior remains unclear and should be examined in more complete way in future research. Additionally, future work provides the opportunity to utilize a longitudinal methodology such as that employed in the Academy Park Survey (Burbidge, 2008) to first ask about preferences and intentions, then collect data on revealed behavior, and subsequently follow-up with participants asking why they did not follow through with their original intentions; in other words, why did they not end up doing something they claimed they would. This can provide additional insight into the correlations between intentions and revealed behavior as they occur over time.

The next model components are activity scheduling and time allocation. Activity scheduling describes the process by which households or individuals create a daily schedule of events (Gollege and Stimson, 1997). Activity scheduling includes coupling constraints which delineate all potential interactions that may restrict time allocation, such as the need to coordinate your schedule with other individuals both in and outside your own household (Arentze, Hofman, van Mourik, and Timmermans, 2000). Activity scheduling also incorporated details about scheduling such as departure time, activity duration, and interaction with others (Miller and Roorda, 2003, and Goulias, Kim, and Patten, 2004). As shown in the model, activity scheduling utilizes available information as well as perceived behavioral controls and travel utility to develop a schedule of subsequent time allocation. Time allocation refers to the way that individuals utilize their time or trade time for space in order to accomplish tasks over the course of the day. The time allocation component of the model is more general than activity scheduling and includes all potential temporal constraints. Activity scheduling is directly analyzed in the pilot study through the use of an activity diary. The increased use of activity diaries in travel behavior research allows researchers to examine an individual's activity scheduling and time allocation throughout the course of the entire day by putting active travel behavior and physical activity choices in context with other activities. This technique has only recently been used in an active transportation context but shows great promise for future work (Burbidge, 2008).

All of the above model components result in a choice process. The choice process first involves a deliberation process, in which each individual synthesizes all of the components described above in order to formulate their intent. This is referred to by Stern and Richardson (2005) as "preference state". Intent describes what an individual expects or plans to do given the current situation (Ajzen, 1985, Verplanken and Aarts, 1999). An individual's intent informs a mode choice decision (based on trip/activity purpose) which may include a variety of options

such as driving alone, getting a ride, taking transit, walking, bicycling, or some combination of modes (Moller, 2002).

After formulating an intended behavior and identifying the trip/activity purpose and mode choice, an individual then either consciously or unconsciously identifies any boundaries or thresholds which would restrict that intention from being carried out. Thresholds may include limitations such as distance, time, or lack of individual capacity (Jannelle, 2004). As shown in the model these thresholds are often directly impacted by time allocation, and reflect capability, temporal, and coupling constraints. All of these components ultimately come together to produce a revealed behavior, which either consists of physical activity or does not.

Although not specifically incorporated as a component of the model, it is important to note that human interactions inevitably impact human behavior. There is potential for future research which includes an analysis of the interactions experienced both between individuals as well as within households. These interactions and relationships could prove to significantly impact the way that individuals make decisions regarding active transportation and physical activity.

TABLE 3. Source Theories of Conceptual Model Components

Model Component	Source
Subjective Norm	Ajzen 1985
Experience, Information, and Learning	Busemeyer and Townsend 1993 Gollege and Stimson 1997
Attitudes	Ajzen 1985 Bamberg, Rolle and Weber 2003 Beldon-Russenello 2003 Burbidge 2008 Busemeyer and Townsend 1993 Handy, Cao, and Mokhtarian 2006 Moller 2002 Pas and Koppelman 1986
Personality Attributes	Busemeyer and Townsend 1993 Collins and Chambers 2005
Demographics	Brownson et al 2000 Burbidge, Goulias, and Kim 2006 Ewing et al 2003 Pas and Koppelman 1986 Pucher and Renne 2003
Personal Characteristics	Burbidge 2008 Burbidge, Goulias, and Kim 2006
Infrastructure and Environment	Brownson et al 2001 Burbidge 2008 Dill 2004, EPA 2003 Evenson, Herring, and Huston 2005 Giles-Corti and Donovan 2002a
Residential Location Selection	Burbidge 2008 Dill 2003 Handy 2005 Handy, Cao, and Mokhtarian 2006
Perceived Behavioral Control and Travel Utility	Ajzen 1985 Burbidge 2008 Mokhtarian et al 2001 Mokhtarian and Salomon 2001 Ratner and Kahn 1999

Activity Scheduling	Arentze et al, 2000 Goulias, Kim, and Patten, 2004
Time Allocation	Burbidge 2008 Hagerstrand 1970 Golledge and Stimson 1997 Sallis, Frank, Saelens, and Kraft 2004 Transportation Research Board 2005 Cervero and Radisch 1995 Golob, Bradley, and Polak 1995
Deliberation Process	Busemeyer and Townsend 1993
Intent	Ajzen 1985 Verplanken and Aarts 1999
Trip Purpose and Mode choice	Burbidge, Goulias, and Kim 2006 Moller 2002
Thresholds	Burbidge, Goulias, and Kim 2006 Jannelle 2004

CONCLUSIONS

Physical inactivity has become a dominant feature of most American's lives over the past quarter century. This has spurred an entire research domain straddling several different disciplines. Recent studies of the connection between physical activity and the built environment have produced masses of data focusing on every possible connection from time allocation and personal characteristics, to the natural and built environment, as well as lifestyles and attitudes. Transportation is clearly connected to physical activity. Statistics show that we Americans are utilizing inactive modes of transportation (mostly the automobile) more than ever before and for short as well as long trips. Additionally, what the little activity that was once accumulated during participation in the daily routine is now limited through the benefits of technology. The Surgeon General has recommended an increase in physical activity and other national organizations have set goals to this end, but without a baseline, improvements are difficult to measure. Modification in travel behavior, however, is one way that individuals could easily increase their physical activity as most trips include at least one walking link. Researchers even assert that this approach may be more successful at increasing physical activity than other organized programs, and could save communities and individuals money in the process.

Although model development within the field of travel behavior as a whole continues today with more momentum than ever, the focus on active mode choice has largely been overlooked and left to a small fragment of transportation and public health researchers. Different components of travel behavior have been studied with regard to active mode choice, but a majority of these studies are methodologically weak and were conducted by researchers outside the travel behavior field. Because of this indirect approach to this research, two strong threats to validity have been uncovered. Correlating physical activity and travel behavior has been accomplished to date using research methods designed for other purposes addressing behavioral causality in a superficial way. Additionally, minimal research has been conducted to measure what role self-selection plays in determining physical activity levels as they relate to interaction with the built environment. Moving forward, the most beneficial way to address the impact of a changed built environment on active travel behavior is through the use of intervention research designs. By carefully crafting this type of methodology, researchers can definitively identify causality while also controlling for residential self selection.

The conceptual model provided by this research uses the existing active travel behavior research to position active travel behavior research within the broader framework of behavioral theory by providing a context in which these types of decisions are made and identifying appropriate contributing factors. Although innovation in travel behavior analysis provides state of the art capabilities for more robust modeling than has been traditionally exhibited in intervention research, only one study to date has utilized these advance travel behavior modeling techniques. This area of research provides ample opportunity for advancement through tailored travel behavior research which tests the components of this model in the real world. By applying the rigor of travel behavior research to this subfield, and incorporating the conceptual model provided, great strides can be made relatively quickly in understanding animate mode choice and “active” travel behavior.

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