Assessing Barriers and Motivators for Use of a Trail for Active Transportation in a
College Town

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ABSTRACT

BACKGROUND: Active transportation (AT), defined as walking/biking for transit, is low in the US at 3.4% of all commute trips. College campuses provide opportunities for AT due to the proximity of most residences to campuses. **PURPOSE:** To assess attitudes, motivations, and barriers to AT in students living in a community connected to a large university via a 1.9 mile paved, protected trail. **METHODS:** Bicycle and pedestrian counters were placed on the trail to determine its use. University students living in the study community were recruited via flyers, listerv, and signs to complete a 40-item online survey to examine attitudes, motivations, and barriers to AT for commute between Users (U, n=32) and Non-Users (NU, n=25). **RESULTS:** Weekday:weekend ratio from counter data revealed a commute pattern for the trail. No differences were found for social support between groups ($p<0.556$). U more strongly believed that using AT helps protect the environment (U=4.7 ± 0.6, NU=4.2 ± 0.8; $p<0.013$). NU were less likely to believe that using a bike was easy (U=3.8 ± 0.9, NU=3.1 ± 1.2; $p<0.001$) and safe (U =3.8 ± 1.1, NU=3.1 ± 1.2; $p<0.032$). For NU, the top reported barriers were the time of commute and the need to carry many things. A financial incentive for increasing AT use was the top motivator for both groups. **CONCLUSION:** Social support for AT is low in this community. Non-Users may be uncomfortable operating a bike and worry about carrying their items for class. Manipulating on-campus parking fees, placing signs with directions and time to campus, along with bike lessons may increase AT rates to campus.

General Audience Abstract

A high amount of the US population is not physically active, contributing to rates of heart disease and obesity. One strategy to increase physical activity is to use more active transportation, defined as walking or biking for transit. Besides increasing physical activity levels, active transportation can provide other benefits such as decreased air pollution from cars. College campuses provide opportunities for active transportation as most residences are close to campus. Therefore, we examined reasons for use and barriers to active transportation in students living in a community connected to a large university via a 1.9 mile, paved protected trail. Two pedestrian and bicycle counters were placed to find the number of walkers and bikers on the trail per day and students were recruited to take an online survey. We found that more people used the trail during the weekday compared to the weekend. Students did not receive much support from their friends and family to use the trail. Users of the trail were more likely to believe that using active transportation helps protect the environment while non-users were uncomfortable using a bike. Barriers included the time it took to use the trail and the need to carry items. Both users and non-users indicated that a financial incentive would motivate them to use the trail more. We conclude that non-users may be uncomfortable using a bike and worry about carrying their items for class. Changing university parking fees, providing bike lessons, and placing signs with directions and time to campus may increase active transportation to the university via this trail.

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Literature Review

Introduction

The U.S. Department of Health and Human Services developed the Physical Activity Guidelines to promote physical activity, health, and the skills for integrating physical activity into daily life.[1,2] However a high percentage of the U.S. population is physically inactive, leading to an increased risk for negative health consequences such as obesity and diabetes among others.[2,3] One proposed solution to increase the population's low physical activity rate is active transportation. Active transportation (AT: or active commuting or active travel) is defined as walking or biking to work or school.[4] The physical activity resultant of active transportation can help individuals meet the Physical Activity Guidelines, which could lead to improved health outcomes.[2,5] Along with increasing physical activity, active transportation can offer other co-benefits such as improved air quality. The purpose of this this literature review is to summarize the evidence on (1) the number and characteristics of individuals engaging in active transportation (AT), (2) the relationship between AT and improved physical activity and health (3) predictors and barriers to AT, and (4) describe other reported co-benefits of AT.

Active Transportation and Physical Activity and Health

The Physical Activity Guidelines for Americans were developed to provide guidance to the public on the amount and type of physical activity required to decrease the risk for cardiovascular disease.[1] The recommendations include 150 minutes of moderate aerobic activity or 75 minutes of vigorous aerobic activity per week.[1] However, it is estimated that only 48% of adults meet the guidelines and that 30-40% of U.S. adults are inactive.[6] Additionally, these self-report estimates may be over-estimated since objective assessment of physical activity in one study of NHANES 2003-2004 subjects using accelerometers estimated less than 5% of adults met the guidelines.[7]

Contribution to Physical Activity Recommendations

AT can help individuals reach the physical activity recommendations. Sisson and Tudor-Locke[8] studied 50 college students at the University of Arizona dividing them into two groups: 26 that cycled to campus and 24 that drove to campus (see Table 1). Using accelerometers and travel logs, the researchers tracked the physical activity levels. The cyclists were found to have 59 minutes of physical activity from active commuting alone, compared to 29.5 minutes of daily physical activity for motorists. Additionally, 100% of the cyclists met the physical activity recommendations through AT alone, while only 89% of motorists met the recommendations, but this was not significant. Another study by Audrey et al.[9] recruited 103 adult participants that lived within two miles of their workplace. The researchers provided participants with an accelerometer and travel log for 7 days. Those that walked to and from work had 80.3 minutes of physical activity, of which 38.0 minutes came from active commuting (47.3% of physical activity). Finally, a study by Gordon-Larson et al.,[10] studied adolescents active commuting patterns and found that adolescents who met the physical activity recommendations were more

likely to walk to school and to work compared to those that did not meet the recommendations. Thirty-seven percent of adolescents who met the recommendations walked to school compared to 25.6% of adolescents who did not meet the recommendations. About 15% of adolescents who met the recommendations walked to work while only 7.5% of adolescents who did not meet the recommendations walked to school.

Associated with Decreased Premature Mortality

Due to the increased physical activity provided by AT, a few studies have shown that individuals who actively commute may have a decreased risk of premature mortality. A study conducted by Anderson et al.[11] comparing mortality with leisure time physical activity, sport activity, and cycling to work reported that those who cycled to work had a 28% decreased risk for premature mortality. This decreased risk is very similar to a recent meta-analysis done by Nocon et al.[12] that found that overall physical activity reduced all-cause mortality by 33%.[12] Some studies have estimated the impact of increasing AT on mortality with modeling studies. Lindsay et al.[13] conducted a study estimating the health implications of replacing 5% of trips ≤7km (≤4.3 miles) made by motor vehicles with bicycles in New Zealand and estimated that there would be 116 fewer deaths per year due to the increase in physical activity. Additionally, if 30% of these trips were replaced by bicycling, the author's estimated that 716.2 deaths would be prevented due to increased physical activity. A study estimating the health implications of replacing 50% of trips 2.5 miles in length made by car with bicycling in 11 large Midwestern cities estimated a decrease of 700 deaths per year from premature mortality due to increased physical activity levels.[5]

Correlated with a Healthy Weight Status

A correlation between a healthy weight status and AT has been reported in multiple

studies. In a cross sectional study, Basset et al.[14] examined the obesity rates of Europe, the

United States, and Australia and how this related its relationship to AT rates. Countries that had

higher rates of AT had lower rates of obesity. Using anthropometric measurements, the lowest

rates of obesity were found in the Netherlands (11.2%) and Latvia (13.7%), while the United

States had the highest rate of obesity at 34.3% of people. These rates were reciprocal to those for

AT, 52% in the Netherlands and 67% of trips in Latvia, compared to 8% in the United States.

The same study also estimated the amount of calories burned per day by AT.[14] Europeans

expended 48-83 calories per day compared to 20 calories per day in the United States. This

equated to Europeans burning 5 to 9 lbs of fat per year compared to Americans burning only 2

lbs of fat per year due to AT. Frank et al.[15] analyzed a travel survey in Atlanta, GA and found

that each hour an individual spent in a car for transportation was associated with a 6% increased

risk for being obese, while every kilometer walked for transportation lead to a 4.8% decreased

risk for being obese. Flint et al.[16] examined a commuting component in the UK Household

Longitudinal Study and found that those that active commuted had lower BMIs and body fat

percentages. Men who actively commuted had BMIs 1.01 less and 1.35 less percent body fat (6.6

lbs less) and women who actively commuted had 1.39% less percent body fat (5.5 lbs less)

compared to men and women who did not actively commute. The study by Lindsay et al.[13]

mentioned earlier estimated that replacing 5% of short car trips by bicycle would lead the whole

New Zealand population to burn 19.1 billion kj (4,565,009,560 kcals) and 506,000 kg (230,000

lbs) of body fat a year. Furie and Desai[17] conducted a study in 2012 in which participants were

categorized into three categories of AT: none (0 min/week), low (1-149 min/week), high (150

min/week). Individuals in the low category had BMIs 0.9 less and individuals in the high

category had BMIs 1.2 less than those who didn't use AT. Waist circumference was 3.1 cm less for those in the high and 2.2 cm less for the low active commute category compared to those who did not actively commute.

Associated with Decreased Risk of Hypertension

Several studies have shown that AT may decrease an individual's chances of having hypertension. The study by Furie and Desai[17] found that those that were low active commuters (1-149 min/week) had a 24% lower risk for hypertension compared to those who did not active commute. Those in the high category had an even lower risk at 31% decreased risk compared to those with no AT. In a study examining commuting patterns and their relationship to cardiovascular disease risk factors in India, Millett et al.[18] found that individuals who biked to work were half as likely to have doctor diagnosed hypertension (risk ratio of 0.51).

May Decrease Risk for Diabetes

Actively commuting may decrease an individual's risk for developing type II diabetes. In the study conducted by Furie and Desai[17], 1520 participants who were in the high category of active travel were 31% less likely to develop diabetes compared to participants in the no AT category. Millet et al.[18] also examined the relationship between commuting patterns and diabetes and found that individuals who bicycled to work were 0.65 times as likely to have been diagnosed with diabetes compared to individuals who commuted by a private vehicle.

Summary

In summary, AT can provide adults and adolescents with health-related benefits such as increasing the likelihood of meeting the physical activity recommendations, decreased mortality risk, and maintenance of weight status. Currently a low percentage of Americans are meeting the recommendations but AT has the potential to improve this. Studies have shown that individuals

can meet the physical activity recommendations through AT alone and that adolescents that meet the recommendations are more likely to actively commute. The increased physical activity provided by AT has the potential to decrease the death rate by decreasing all-cause premature mortality. Studies have shown that it can help individuals have lower BMIs, burn more calories, and a have a lower body fat percentage. AT may also help decrease the risk for developing a cardiovascular disease as studies have shown this behavior is associated with less hypertension and type II diabetes.

Limitations

Limitations to these studies exist. Most studies reported in this section were correlational, cross-sectional, or modeling studies, meaning causation cannot be determined. More studies using randomized controlled designs are needed to demonstrate causality. Additionally, more studies of AT should include health measurements such as blood measurements (cholesterol and glucose levels) aerobic capacity, and anthropometrics to further improve our understanding of the impact of AT on health status.

Table 1. AT as a means to be physically active and healthy			
Article	**Purpose**	**Methods**	**Findings**
Andersen 2000 – All Cause Mortality Associated with Physical Activity During Leisure Time, Work, Sports, and Cycling to Work	Analyze if the risk of being physically inactive is consistent across sex and age groups	Studied data from three epidemiological surveys that examined various physically activities (including AT) and compared these to mortality levels (N = 30,896).	1. Cycling to work = 28% decreased risk of premature mortality. 2. Avg. time cycling to work = 3 hr/week.
Basset 2008 - Walking, Cycling, and Obesity Rates in Europe, North America, and Australia	Determine if difference in active transportation trips between Europe, North America, and Australia are associated with differences in obesity prevalence	Analyzed travel reports and consulted with various committees that focus on obesity	1. Countries with higher rates of AT had lowest obesity rates: 8% of trips for U.S., most European countries >30%.
Flint 2014 – Associations between active commuting, body fat, and body mass index: population based, cross sectional study in the United Kingdom	Determine relationship between AT and two markers of obesity (BMI and Body fat percentage)	Analyzed data from Understanding Society, the UK Household Longitudinal Study (UKHLS) (N = 7,534)	1. Men who used AT = decrease in BMI (1.01 lower) and 1.35% less body fat than those who drove 2. Women who used AT = decrease in BMI (0.86 lower) and 1.39% less body fat than those who drove
Frank 2004 – Obesity relationships with community design, physical activity, and time spent in cars	To find relationship between built environment, self-reported travel patterns, BMI, and obesity	Travel survey from Strategies for Metro Atlanta's Regional Transportation and Air Quality (N =10,878) in Atlanta, Georgia collected between 2000 and 2002	1. Each hour spent in a car associated with 6% increase in risk of obesity 2. Ever km walked = 4.8% decrease in being obese
Furie and Desai 2012 – Active Transportation and Cardiovascular Disease	Examine the relationship between AT and cardiovascular disease risk in U.S. adults	Cross-sectional design that studied data from 2007-2008 and 2009-2010 cycles of NHANES. (N = 9,933, aged ≥20)	1. Low and high AT users had BMI 0.9 and 1.2 less respectively vs. non-users.

Risk Factors in U.S. Adults			2. Low and high AT users had waist circumference 2.2 and 3.1 cm less vs. non-users. 3. Low and high AT users had 24% and 31% decreased risk for hypertension vs. non-users 4. High AT users had 31% decreased odds for diabetes vs. non-users.
Gordon-Larsen 2005 – Associations among AT, Physical Activity, and Weight Status in Young Adults	Analyze the AT and non-AT usage in young adults and discover influential covariates.	Adolescents in grades 7-12 through use of The National Longitudinal Study of Adolescent Health Survey (N = 10,771)	1. Non-overweight adolescents walk to work (9.2% vs. 6.8%) and school (29.7 vs. 22.6%) more than overweight adolescents 2. Those meeting PA activity recommendations more likely to walk to work (15.2% vs. 7.5%) and bike to school (37% vs. 25.6%) compared to adolescents not meeting PA recommendations
Grabow 2012 - Air quality and exercise-related health benefits from reduced car travel in the Midwestern United States	Determine health, environment, and economy benefits for replacing 50% of short trips (<4km or 2.5 miles) by car with bikes in 11 large Midwestern cities	Used Community Multiscale Air Quality model, U.S. Environmental Protection Agency Benefits Mapping Analysis Program, World Health Organization Health Economic Assessment Tool to determine health, environment, and economic benefits of replacing 50% of <8 km (5miles) round trips with biking in the 11 cities.	1. Estimate a decrease of 700 deaths/year

Lindsay 2011 - Moving urban trips from cars to bicycles: impact on health and emissions	Find the impact of replacing 5% of short trips (≤7km or ≤4.3 miles) made by vehicles with bicycles on health, and GHGs in New Zealand	Analyzed New Zealand Household Travel Survey for sample study (restricted to adults aged 18-64 in populations ≥ 10,000) and applied World Health Organization's Health Economic Assessment Tool to determine possible health benefits	1. Estimate a decrease in 116 deaths 2. People would burn a combined 19 billion kj, about 500,000 kg of adipose tissue
Maizlish 2011 – Health Co-Benefits and Transportation-Related Reductions in Greenhouse Gas Emissions in the Bay Area.	Examine possible future scenarios of health and environment if 50% of short trips (<1.5 mi walking or 1.5-5 miles biking) made by motorized travel were replaced by walking and biking in Bay Area regions.	Gathered data from census and travel surveys of cities in Bay Area that have high rates of walking and biking and used Integrated Transport and Health Impacts Model to determine the co-benefits on health and environment if AT rates were to rise.	1. Replacing 15% of travel distance with AT = 154 min/week PA, 13% (2,236) decrease in premature deaths/year, 15% (+22,807) decrease in years of life lost for CVD and diabetes.
Millett 2013 – Associations between Active Travel to Work and Overweight, Hypertension, and Diabetes in India: A Cross-Sectional Study	Characterize modes of travel in urban and rural populations in India and examine associations between modes of travel and overweight, obesity, hypertension, and diabetes in India	Examined data from Indian Migration Study (IMS) from 2005-2007. IMS is a cross-sectional study analyzing cardiovascular risk factors N = 3902)	1. Risk ratio for obesity was 0.72 for walking and 0.66 bicycling to work 2. Risk ratio for hypertension was 0.51 for bicycling to work 3. Risk ratio for diabetes was 0.65 for bicycling to work
Sisson & Tudor-Locke 2007 – Comparison of cyclists' and motorists' utilitarian physical activity at an urban university	Compare distance from campus and mode of transport between cyclists and motorists	50 participants wore Accelerometers and completed a travel log for two non-raining days	1. Cyclists = 59 min/d of AT, 85.7 min/d moderate/vigorous activity 2. Motorists = 30 min/d of AT, 50.3 min/d moderate/vigorous activity
Von Huth Smith 2007 – Commuting Physical Activity is favourably associated with biological	Analyze the relationship between AT and leisure PA to serum lipids, blood pressure, and anthropometric measurements (controlling for confounders)	Studied data from Inter99 study (lifestyle intervention study) (N = 13,016)	1. ≥ 60 mins of AT = 8% higher HDL, 3% lower LDL, 13% lower triglycerides, ate 3.9 g more fiber, 4.7 cm less

risk factors for cardiovascular disease			waste circumference, 1.2 less BMI, compared to those with <15 mins AT

Key
AT = Active Transportation
Avg = Average
PA = Physical Activity
HDL = High Density Lipoprotein
LDL = Low Density Lipoprotein

Demographics of Active Transportation: United States

The US has a relatively low AT rate compared to other countries. In addition, AT rates vary across the different geographical regions of the US. According to the American Community Survey, conducted annually by the U.S. Census Bureau, the Western region of the United States is the most likely to actively commute at 6.3% of its population followed by the Midwest at 2.5%, the South at 2.4%, and the East at 2.3%.[19] Here, we will explore the demographics characteristics of the US population in relation to AT.

Gender

Males are more likely to commute via bicycle compared to females. According to the Bicycling and Walking 2012 Benchmarking report, males make up 73% of all bicycle commuters in the United States and bicycle to work at a higher rate than females across all 50 states.[20] Buehler[21] found that males are 2.06 times more likely to bike to work compared to females in the US (see Table 2). Babey et al.[22] also found that males are more likely to commute than females in the US.

Age

Studies have found that age influences AT. Adolescents and youth under the age of 16 make up 39% of bicycling trips and 17% of walking trips, despite only making up only 21% of the U.S. population.[20] Those between the ages of 16 and 64 make up 54% of bicycle trips and 73% of walking trips.[20] Individuals aged 65 years and older make up 6% of bicycling trips and 10% of walking trips.[20] In a study examining youth and adolescent attitudes towards bicycling in California, Underwood[23] found using a bike for transportation purposes was highest in the 12-15 year old age group. The researchers also

reported that biking rates decreased as a person aged. Furthermore Babey et al.[22] found that adolescents whose parents were not available to pick them up after school were 77% more likely to actively commute home after school and reported that as a person aged, AT rates decreased. Buehler[21] found a similar result, finding that after retirement Americans will make 90% of their trips via vehicles. Underwood[23] believed this is because at the age of 16 individuals are able to obtain a driver's license and this is viewed as a rite of passage. However according to Sivak and Schoettle[24] the percentage of young people earning their driver's license has decreased from 1983-2008. If this continues, this may lead to reduction in car use over time.

Relationship Status

Relationship status may impact AT usage. Campbell and Bopp[25] examined AT usage in employees working for moderate to large sized companies in the mid-Atlantic region. The researchers found that married/partnered individuals reported AT 1.35 times/week, while unmarried/singled individuals reported using AT 2.01 times/week.

Income Status

An individual's income status may influence AT patterns. According the 2012 Bicycling and Walking Benchmark Report, individuals with an income of less than $15,000 per year make up 45% of people who walk to work in the USA.[20] Those who earn less than $35,000 a year make up 62% of walking commuters.[20] Babey et al.[22] found that lower income families were 84% more likely to actively commute than higher income individuals. Buehler[21] found that AT usage decreased as income increased in the United States. Those within the lowest quartile range of income actively commuted for 12% of their trips; individuals in the mid quartile range actively commuted for 9% of

their trips; and those in highest quartile actively commuted for 9% of their trips. Buehler[21] argues that as income increases, owning and maintaining a car becomes easier. Furthermore a higher income also increases the opportunity costs of travel time making vehicles more attractive.[21] Having more vehicles than eligible drivers leads to lower AT rates as Buehler[21] found that households with more cars than drivers only used AT for 9% of trips.

Summary

In summary, in the United States, those living in the western region of the country are the most likely to use AT. Males are more likely to bicycle to work than females while adolescents and youth are more likely to walk or bike for transportation compared to older age groups. Those who are unmarried/single are more likely to actively commute while having young children in the household decreases the likelihood that an individual will use AT. Individuals with a lower income are more likely to walk to work due to their lower ability to own and maintain a vehicle.

Demographics of Active Transportation: Europe

As mentioned earlier, the US has low rates of AT compared to the rates in Europe. Here, we will explore the demographics characteristics of the Europe population in relation to AT and how they compare to the US population.

Gender

Gender does not impact usage of AT in Europe, in contrast to the United States. Buehler[21] found that there is no significant difference in active commuting rates between genders in Germany. In a study comparing AT characteristics between those that rode their bikes to work and those that didn't in Flanders Belgium, De Gues et al.[26] found that differences between gender did not exist. Scheepers et al.[27] found the same in a study analyzing annual household survey data from 2004-2009 in the Netherlands.

Age

Unlike in the US, in Europe AT usage continues as a person ages. Scheepers et al.[27] found that trips made via AT increased as a person aged in the Netherlands. The researchers believed that when a person reaches retirement, they have more time and therefore can engage in active commuting. Buehler[21] found this as well, reporting that retirees in Germany are much more likely to cycle to their destinations compared to the United States. Underwood[23] argued that Europeans continue to use bicycles throughout life because the driving age in most European countries is 18 compared to 16 in the United States. This leads to European adolescents developing more of a habit of walking and biking for transportation until older ages when they begin to drive.[23]

Weight Status

An individual's weight status may be influences or make them more likely to use AT in Europe. De Gues et al.[26] found that those who cycled to work had lower BMI's compared to those that drove to work as cyclists had a BMI of 23.9 and drivers had a BMI of 24.4. In a study looking at changes in AT over a two year period in Cambridge, England, Panter et al.[28] reported that an individual that is normal or underweight (according to BMI) is 1.37 times more likely to take up commuting by walking, and 1.11 times more likely to take up commuting by biking. However, it is not possible to determine whether lower BMI individuals are more likely to commute actively or that active commuting reduces their body weight to be lower than others.

Children

Having children in the household has been found to influence AT in one study of European individuals. Panter et al.[28] found that people who did not have a child in the household were 2.18 times more likely to walk to work and 1.74 times more likely to bike.

Education

An individuals' education can impact AT usage in Europe. De Gues et al.[26] found that 64.6% of cyclists had a high level of education, compared to non-cyclists, where only 45.5% had a high level of education. Scheepers et al.[27] found that individuals in Cambridge were 16% less likely to actively commute when users had a high school or secondary degree compared to those with college degrees. The same study also reported that individuals with a primary or lower general secondary degree were 12% less likely to use AT compared to those with a college degree.

Income Status

Just as in the United States, income influences AT usage in Europe. Buehler[21] found in Germany that individuals in the lowest income quartile actively commuted for 39% of their trips; the middle quartile commuted for 32% of trips; and the highest quartile commuted for 27% of trips.

Summary

In summary, demographics of European commuters differ from American commuters. Gender and age do not impact use of AT as these factors do in the US. Weight status may influence active commuting rates, as those with lower BMIs are more likely to walk or bike to work. Having young children discourages AT while having a higher education increases the likelihood of using it. Finally, Europeans with a lower income are more likely to actively commute than those with higher incomes.

Table 2. AT demographics			
Article	**Purpose**	**Methods**	**Findings**
Babey 2009 - Sociodemographic, Family and Environmental Factors Associated with Active Commuting to School among US Adolescents (USA)	Examine sociodemographic, family, and environmental characteristics associated with AC to school among adolescents	Analyzed 2005 California Health Interview Survey (random telephone survey) data for more than 43,000 households. Used data for households that had adolescents ages 12-17.	1. Age was inversely associated with active commuting 2. Males more likely to commute than females 3. Latino adolescents 37% more likely and mixed-race adolescents 71% more likely to active commute than whites and African Americans 4. Lower income families 84% more likely to commute than higher-income 5. Adolescents whose adults are not present or present some of the time are 77% more likely to active commute
Buehler 2011 – Determinants of transport mode choice: a comparison of Germany and the USA	To discover the factors that determine mode choice in Germany and USA	Use of two national travel surveys: the National Household Travel Survey in the USA and the Mobility in Germany Survey in Germany.	1. **USA** Income & AT usage: Lowest quartile = 12%, Mid quartile = 9%, highest quartile = 9% Gender: Males 2.06 higher odds to bike to work compared to females Vehicle ownership: Households with more cars than drivers use AT for 9% of trips 2. **Germany** Income & AT usage: Lowest quartile = 39%, Mid quartile = 32%, Highest quartile = 27% Gender: No significant difference between sexes

			Vehicle Ownership: Households with more cars than drivers use AT for 29% of trips
(USA & Germany)			
Campbell 2013 – An Examination of the Relationship of Interpersonal Influences With Walking and Biking to Work (USA)	Advance the understanding of AT and social support	Cross-sectional cohort through an online survey distributed between August 2011 to December 2011 to employees working at moderate to large sized companies located in the mid-Atlantic region.	1. Married/partnered individuals reported AT 1.35 times/week 2. Unmarried individuals reported AT 2.01 times/week.
De Gues – Psychosocial and environmental factors associated with cycling for transport among a working population (Europe)	Aim was to examine psychosocial and environmental predictors of cycling for transportation between cyclists and non-cyclists	Cross-sectional design using a self-reported survey (N = 343, age 18-65) in Flanders, Belgium.	1. C had lower BMI's compared to NC (23.9 vs. 24.4) 2. 64.6% of cyclists had a high education. 45.5% of non-cyclists had a high education
Handy 2012 – Adolescent Attitudes Towards Active Transportation: Bicycling in Youth in Retrospect from Adulthood (USA)	Examine youth and adolescent attitudes towards bicycling	Survey questionnaire along with in person interviews of adults that focused on adult's attitudes towards cycling from their youth through their adolescence (N = 54).	1. 12-15 y/o age group = highest bike rates 2. Decreasing attitudes towards biking with age (70% liked in elementary school, 39% liked in middle school, 20% liked in high school)
Panter 2014 – Patterns and predictors of changes in active commuting over 12 months	Describe changes in AT and analyze the predictors of uptake and maintenance of AT and other commute patterns vs. vehicle commute	Analyzed Commuting and Health in Cambridge data: Thos who lived within 30 km (18.6 miles) took a survey and another survey one year later (N = 1,164, age 16+).	1. No children in the household = 2.18x more likely to walk, 1.74x more likely to bike

(Europe)			2. Report normal or underweight = 1.37x more likely to walk, 1.11x more likely to bike
Scheepers 2013 – Personal and Environmental Characteristics Associated with Choice of Active Transport Modes verses Care Use for Different Trip Purposes of Trips up to 7.5 Kilometers in The Netherlands (Europe)	Analyze trip purposes and choice of AT vs. car transport modes for short distance trips among different age groups and explore influence of personal and neighborhood characteristics of these choices.	Used Data from Mobility Research Netherlands (annual household survey) from 2004-2009. N = 277,292, age 18+)	1. 92.42% of males had driver's licenses compared to 82.17% of females 2. Bike owners were 2.23x more likely to actively commute 3. Those with university or college degree were more likely to commute (OR= 1) compared to those with high school or secondary degree (OR=0.84) and those with primary school or lower general secondary degree (OR =0.88) 4. No difference between gender 5. AT increased with age

Key
AT = Active Transportation
C = Cyclists
NC = Non-cyclists
OR = Odd Ratio

Active Transportation and the Built Environment:

The built environment can directly impact the use of AT. For example, factors such as population and residential density, land use mix, street connectivity, and retail floor area ratio have been associated with higher use of AT.[21,29-31] Thus, these factors are typically used in "walkability" measures.

Population and Residential Density

Population density, the amount of people per land area and a surrogate for residential density, was shown in a study conducted by Buehler[21] to predict AT (see Table 3). He compared modes of travel in Germany finding that for every 1000 more people per km^2 there were 1.23 greater odds that Germans would choose walking for transportation over driving. Residential density, the number of a residential buildings divided by the land area[30], is also correlated to active commuting rates. Forsyth et al.[32] suggested that creating environments that increase the residential density encourages walking while discouraging car use because of traffic congestion and delays of travel time.

Land Use Mix and Retail Floor Area

Land use mix refers to intermixing types of buildings that make up an area, such as libraries, restaurants, schools, etc. as well as building proximity.[30] While deciding on modes of transportation, Buehler[21] found that environments in Germany with a high mixed land use were associated with a 7.9% decrease in driving, 4.1% increase in walking, and 3.2% increase in cycling for transportation. In the US, Buehler[21] found a similar directional effect of lesser magnitude. High mix land use led to a 1.6% decrease in driving and a 1.7% increase in walking for transportation. Another study by Hoehner et

al.[33] found that land-use mix exhibited a dose-response effect on AT use. Individuals

living in a high mix land use area were 2-3 times more likely to actively commute or

meet physical activity recommendation through AT compared to individuals living in

areas with low mix land use. Buehler[21] argued that AT could be increased by creating

environments with a high land use mix while simultaneously discouraging car use by

increasing the gasoline tax. The retail floor area ratio is "the retail building square

footage divided by retail land square footage."[31] Frank et al.[31] reported that a smaller ratio

reflects retail areas with more available parking spaces while a higher ratio reflected less

available parking which could lead to more pedestrian travel. This ratio has been shown

to be a reliable indicator in determining the use of active travel.[29,31]

Street Connectivity

Street connectivity denotes the ease of reaching destinations through the road

network.[34] In a meta-analysis summarizing environmental correlates of AT, Sallis et al.[34]

described high street connectivity as a grid-like pattern of compacted, interconnected

streets. The same study found that areas with low street connectivity are expanded,

lengthy road networks where the grid like pattern is absent. Street connectivity directly

impacts the distance between destinations as Frank et al.[35] found that environments with

high street connectivity offered individuals a variety of ways to reach different locations

as well as a more direct pathway to destinations further encouraging use of AT. In a study

comparing environments in St. Louis, MO and Savannah, GA, Hoehner et al.[33] found that

lower travel distance was the strongest correlate of active commuting. Furthermore,

Deforche et al.[36] suggested that for adolescents, street connectivity might by the strongest

predictor of AT use. Low street connectivity causes more reliance on vehicle travel due to the increased distances between location further decreasing AT use.

Walkability and use of AT

Putting all the factors discussed above into one index, high walkability environments are associated with higher rates of AT compared to low walkability environments.[30,34,36-38] Hankey et al.[37] conducted a study comparing high and low walkability environments in Southern California. The researchers found that individuals living in high walkability environments were 3.6 times more likely to use AT compared to individuals living in a low walkability environment. Those living in a high walkability environment reported 102 min/week of physical activity, of which AT accounted for 50% of activity, compared to those living in a low walkability environment who reported 68 min/week of physical activity where AT only accounted for 20% of activity. Hoehner et al.[33] conducted a study looking at the interaction of walkability and income comparing AT rates in a St. Louis, MO (low walkability environment) and Savannah, GA (high walkability environment). The researchers found that in the high walkability/high income areas, 55.4% reported use of AT while 82% of individuals living in a high walkability/low income area actively commuted. Further evidence is provided by Saelens et al.,[39] who found that individuals living in high walkability neighborhoods reported 30 minutes more AT than those living in a low walkability neighborhood.

Low walkability environments discourage the use of AT. A study conducted by Frank et al.[30] in Atlanta, GA, a city with low walkability, found very low rates of AT and many areas had no AT reported. Qualities of the environment, including the poor state of sidewalks and pathways, discourage AT.[30] An additional factor that influences

desirability for walking is aesthetics. Hoehner et al.[33] reported that low walkability environments were more likely to be in poor shape with garbage and broken glass littered around the area. People living in these areas were 50-70% less likely to meet the physical recommendations through AT.[33]

Urban vs. Rural Environments

Urban environments exhibit higher AT use when compared to rural environments, at least partly due to low ratings for some of the built environment factors known to predict AT in rural areas (e.g. low connectivity, low residential density). A study by Scheepers et al.[27] discovered people living in an urban area were two times more likely to actively commute compared to those living in rural areas. Another study by Van Dyck et al.[40] found that urban adults were more likely to walk inside and outside of their neighborhood for transportation and bike inside their neighborhood for transportation. Individuals living in a urban environment reported 75 min/week more walking and 58 min/week more biking for transportation compared to rural individuals.[40] This study also found that urban individuals took about 800 steps more per day during the weekdays, and 600 steps more per day on the weekends compared to rural individuals. Scheepers et al.[27] argued that urban AT rates are higher because urban neighborhoods usually have high population density, lower distances between locations, and high connectivity. The authors continued to suggest that rural environments have a low population density and fewer facilities, resulting in less chances for AT use.[27] However, while studies comparing physical activity between urban and rural environments are available, not many studies comparing AT rates between urban and rural environments exist.

Summary

In summary, many studies have shown that the built environment has an impact on AT usage. Higher population and residential density, land-use mix, and street connectivity can create high walkability environments, greatly improving AT rates when compared with low walkability environments. When comparing urban and rural environments, urban environments have a higher usage of AT due to factors such as a higher population density and lower distances between destinations.

Table 3. AT and the built environment			
Article	Purpose	Method	Findings
Buehler 2011 – Determinants of transport mode choice: a comparison of Germany and the USA	To discover the factors that determine mode choice in Germany and USA	Use of two national travel surveys: the National Household Travel Survey in the USA and the Mobility in Germany Survey in Germany	1. Germany Odds of choosing bike over car are 46.7 times higher than USA Walking over car use are 4.6 times higher than USA High mix-land use = 7.9% decrease in driving, 4.1% increase in walking, 3.2% in cycling For 1 mile trips, 1000 people per km^2 = 1.23 greater odds of walking over driving **Positive correlates:** closer destination, high population densities, great mix-land use. **Negative correlates:** car ownership, drivers license, work & shopping trips, farther destinations 2. USA Living within 400 m of public transport = 4.5% more likely to use public transport compared to 1000 m away 1000 more people per km^2 = 16% more likely to choose public transport over car Mix land use = 1.6% decrease in driving, 1.7% increase in walking **Positive correlates:** closer destination, high population densities, great mix-land use. **Negative correlates:** car ownership (more likely to have more than 1 car, leading to even less use of AT), drivers license, work & shopping trips, being female, retired individuals, distance, lack of sidewalks and trails
Deforche 2010 – Perceived social and physical environment correlates of physical activity in	Determine if perceptions of social and physical environments are associated with AT and	Adolescents from 20 randomly selected schools in East- and West-Flanders, Belgium completed a questionnaire	1. **Correlates to AT** High land use, high street connectivity, attractive environments, high emotional satisfaction with neighborhood, better access to recreational facilities

adolescents and the moderating effect of self-efficacy	leisure physical activity and examine if the relationship is moderated by self-efficacy	during one of their class periods (N = 1,445).	
Frank 2006 - Many Pathways from Land Use to Health: Associations between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality	Determine if built environment associations with AT, time in vehicles, and amount of vehicle emissions produced	Used data from the Neighborhood Quality of Life Study and King County Land Use, Transportation, Air Quality and Health Study in Kind County Washington	1. **High Walkability neighborhoods** High land use mix, street connectivity, high residential density, and pedestrian-oriented retail People living in these neighborhoods used more AT, drove less, lower BMIs. 5% increase in walkability = 32.1% increase in minutes of AT and 4.7% increase in leisure PA
Frank 2010 – The development of a walkability index: application to the Neighborhood Quality of Life Study	Determine physical environment variables related to physical actively	Combined residential density, mixed used, intersection density, and retail floor area ratio into a Z-score sum and applied to areas in Seattle and Washington, D.C. Examined physical activity of residents in these areas with survey travel data from residents.	1. Found to be reliable. 2. High walkability high income and high walkability low income neighborhoods had higher levels of active travel compared to low walkability areas.
Frank 2010 – Carbonless footprints: Promoting health and climate stabilization through active transportation	Determine if neighborhood design strategies have positive benefits for health and climate change goals	Studied 10,148 people aged 16 and over living in 13 Atlanta, GA counties. Both high walkability and low walkability counties were sampled. Participants completed a 2-day travel survey	1. Net residential, intersection density, street connectivity, and transit accessibility are significant factors in predicting AT levels 2. **Low Walk/High Motorized Environment** Zero AT users 3. **Low Walk/Low Motorized Environment** Zero AT users 4. **High Walk/High Motorized Environment** AT users walked 0.48 miles/d and burned 27.35 kcals/d 5. **High Walk/Low Motorized**

			AT users walked 0.68 miles/d and burned 38.85 kcals/d (42% higher than HW/HM)
			6. Low walkability environments People living in neighborhood with low residential density, low intersection density, and low proximity to public transit are more likely to drive and spend more time in the car. **7. High walkability environments** People living in neighborhoods with high land use mix, high intersection density, high street connectivity, and higher proximity to public transport use more AT
Hankey 2012 – Health Impacts of the Built Environment: Within-Urban Variability in Physical Inactivity, Air Pollution, and Ischemic Heart Disease Mortality	Examine how built environment impacts air pollution and physical activity, and estimate health risks associated.	Examined a travel-survey, measured estimates of air pollution, literature estimates of ischemic heart disease caused by physical inactivity or air pollution, and geographic information system.	**1. Low walkability environment** Avg. 68 min/week of PA 12.5% nonsendentary individuals AT accounts for 20% of PA 51 IHD death/100,000/year **2. High walkability environment** Avg. 102 min/week of PA (50% higher) 24.9% nonsendentary individuals (50% higher) AT accounts for 50% of PA AT is 3.6x higher compared to low-walkability environment 44 IHD deaths/100,000/year
Hoehner 2005 – Perceived and Objective Environmental Measures and Physical Activity Among Urban Adults	To examine association between transportation and recreational physical activity and neighborhood environment in low and high walkability cities.	Sampled four locations (two in St. Louis, MO and two in Savannah, GA) that covered 4.5 square miles through phone survey of and neighborhood audits. Sample size was 1,053 people.	**1. Low-walkability environment (St. Louis)** 71% used AT in low income, 57.4 used in high income environment 21.9% met PA recommendation in low income environment, 14.4 in higher income environment **2. High-walkability environment (Savannah)** 82% used AT in low income, 55.4 used in high income environment

			35% met PA recommendation in low income environment, 15.2% in high income environment >\# of people using AT = 2-3x more likely to use AT **3. AT Correlations** **Positive:** High land use led to 2-3x more AT, short distances, presence of a trail, presence of bike lanes, presence of public transport stops **Negative:** sidewalks in bad shape, environment in bad shape (garbage, litter, broken glass) were 50%-70% less likely to meet PA recommendations through AT
Scheepers 2013 – Personal and Environmental Characteristics Associated with Choice of Active Transport Modes verses Care Use for Different Trip Purposes of Trips up to 7.5 Kilometers in The Netherlands	Analyze trip purposes and choice of AT vs. car transport modes for short distance trips among different age groups and explore influence of personal and neighborhood characteristics of these choices.	Used Data from Mobility Research Netherlands (annual household survey) from 2004-200 (N = 277,292, age 18+)	1. People in urban-centre area 2x more likely to actively commute than people in rural areas **2. Positive correlates of AT** high density, street connectivity, proximity to facilities **3. Negative correlates of AT** Low density, less facilities, long distance to facilities, less street connectivity
Van Dyck 2011 – Urban-Rural Differences in Physical Activity in Belgian Adults and the Importance of Psychosocial Factors	Examine the differences in physical activity between rural and urban Belgian adults and see if the relationship between psychosocial factors and PA is moderated by the environment	Selected 5 urban and 5 rural areas in Flanders Belgium and conducted in-home interviews using Neighborhood Physical Activity Questionnaire as well as had subjects wear a pedometer for 7 days and complete activity log	1. **Urban Environment** Reported 75 min/week more walking and 58 min/week more biking for AT than rural individuals Took 800 steps/d more than rural individuals during weekdays, 600 steps/d more on weekends 2. People in urban neighborhoods take more steps and report more AT. 3. Rural adults with high psychosocial scores perform more physical activities than those who don't.

Key

AT = Active Transportation
PA = Physical Activity
HW/HM = High Walk/High Motorized
IHD = Ischemic Heart Disease

Attitudes Toward Active Transportation

In addition to the built environment, there are individual and social characteristics associated with use of AT. Identifying and understanding specific psychosocial variables and attitudes associated with AT can be used to identify predictors as well as barriers to AT use. This section will cover how this data is collected and then summarize some of the psychosocial factors consistently associated with AT behavior.

Methods of Data Collection

Most research on the attitudes towards AT is collected via cross-sectional designs through the use of surveys, which limits conclusions to associations rather than cause and effect. Formats of surveys include both online and paper formats or a combination of both.[26,41-45] Recruitment efforts by researchers vary. In attempting to determine factors that that influenced adults' mode of transportation, Bopp et al.[41] recruited subject to take an online survey through a combination of emails to local employees, community listservs, and advertisements in other media such as the local newspaper. Additionally, the researchers also placed fliers around the study area employer buildings.[41] Handy and Yang[43] used a slightly different approach while surveying a sample of individuals in six bicycle friendly cities. The researchers created an online survey and then purchased a list of random addresses to send letters to invite individuals to take the survey. Postcards were sent as a reminder if the survey had not been accessed within a month and again a month later if there was still no response. Some researchers may choose to recruit on sight. McNeil et al.[45] approached adults to take a survey on factors influencing physical activity at the waiting room of a health center and then performed a follow up through a phone call. Panter et al.[28] recruited individuals to take a survey to determine predictors of

active commute by setting up recruitment stands in addition to advertisements and email listservs. All of these different approaches can have varying impacts on response rates and rates can range from not being able to be determined[44] to upwards of 70% in other cases.[28]

When assessing reason for commute, variables often assessed include demographics, commuting habits, psychosocial influences, and environmental influences using a combination of forced-choice and Likert scales.[26,41-43,46,47] Common demographic variables include gender, age, height, weight, education, employment status, and the amount of weekly physical activity. Commuting habits include anything that could affect the decision to commute (access to vehicles, etc.) as well as answering questions on the distance and time of commute, and mode of transportation.[26,41,46] Common psychosocial variables assessed for AT include self-efficacy, social support, benefits, barriers, and motivators.[26,28,41,48] To assess benefits, barriers, and motivators, researchers use either forced choice responses, or Likert scales. For example, in a study examining transportation sustainability at Kent State University, Kaplan[42] surveyed 668 students and provided a list of barriers. He quantified the importance of barriers by the percentage of participants that listed an item as a barrier. However in a study by Shannon et al.[47] assessing AT patterns by students at the University of Australia through a survey, participants were provided a list of 17 barriers and asked to indicate each barriers' importance via a 5-point Likert scale. When assessing self-efficacy or social support, Likert scales are almost exclusively used to determine an individual's agreement with a statement provided. However, survey questions to assess these can greatly differ among studies. Some studies may use one or two questions to score a variable, while others have

upwards to thirteen to fourteen questions that are used to compute a variable such as self-efficacy. For example, in Bopp et al.'s[41] study mentioned above, one item on the survey was used to determine a subject's level of self-efficacy for using active commute with a 5-point Likert scale. However, in a study by De Gues et al.[26] assessing variables that influence cycling for transportation among cyclists and non-cyclists, subjects indicated their level of agreement with 9 items using a 5-point Likert scale to determine a score for self-efficacy. The researchers further analyzed this by creating a score for internal self-efficacy (characteristics of the person influence self-efficacy[49]) and a score for external self-efficacy (action is not entirely contingent on the person[49], such as being able to cycle depending on the weather[26]). This heterogeneity in survey instruments can make it difficult to compare results related to self-efficacy, and other variables scored differently.

Summary

Data that examines why or why not individuals commute actively is primarily collected through cross-sectional designs via surveys. Recruitment of participants is handled in many ways such as email listservs, signs, and on-sight. Combinations of recruitment strategies are also possible. Variables examined include demographics, psychosocial, environmental, motivators and barriers. Both forced-choice and Likert-scales are employed, however the method used to quantify these can make comparison of studies difficult.

Individual Psychological Correlates of Active Transportation Behavior

Self-efficacy

Self-efficacy is the degree to which a person believes he/she has the power to perform a task or activity.[50] Researchers most often quantify self-efficacy through use of

survey questions. However, survey questions differ among studies. Some studies use one or two questions to determine self-efficacy, while others have upwards to thirteen to fourteen questions. This heterogeneity in survey instruments makes it difficult to compare results related to self-efficacy in studies.

With regard to physical activity, De Gues et al.,[26] McNeill et al.,[45] and Trost et al.[51] found self-efficacy to be one of the most consistent correlates of physical activity behavior (see Table 4). Low self-efficacy impairs an individual's ability to exercise. Bourdeaushuji and Sallis[52] argued that low levels of self-efficacy negatively influences an individual's ability to self-discipline themselves to participate in physical activity. Existing research supports this as Bopp et al.[41] used a 5-point Likert (1 being the lowest, 5 being the highest) to measure self-efficacy for AT and found that those that commuted by walking or biking averaged 4.08 and 4.11 respectively compared to 1.93 for drivers. De Gues et al.[26] used a 3-point Likert scale to measure internal and external self-efficacy. The researchers found that those who cycled to work reported stronger internal (1.79 vs. 1.52) and external (1.99 vs. 1.56) self-efficacy compared to non-cyclists. Another study by Deforche et al.[36] examined AT rates with self-efficacy as a mediator in high and low walkability environments. Their data showed that youth with high self-efficacy averaged 60 min/d of AT compared to 46 min/d by youth with low self-efficacy. The researchers also found that there was an interaction of self-efficacy with distance to local facilities (local shops, schools, etc.). Distance to these locations was negatively associated with youth with high self-efficacy, while it was positively associated with youth with low self-efficacy. The authors argued that high walkability environments are more important for youth with low self-efficacy.[36]

Economic Awareness

With regard to AT, economic awareness can be described as appreciating the value of the money saved by walking or biking instead of driving.[26,53] Bopp et al.[41] found that people who report higher rates of AT had higher economic awareness compared to those with lower rates. Scores on the 5-point Likert scale to measure economic awareness were higher for those who walked or biked to work, 3.81 and 3.98 respectively, compared to 2.06 for drivers. Another study by De Gues et al.[26] discovered that those that cycled to work were more likely to agree with the statement that "cycling is cheaper and better for the environment" compared to non-cyclists (4.48 vs. 4.21 on a 5-point Likert scale). Heinen et al.[54] further confirmed this by reporting cyclists were more likely to report that bicycling was cheaper than driving to work compared to non-cyclists. These studies suggest that interventions focused on convincing individuals that AT is cheaper than driving could be effective at increasing rates.

Environmental Awareness

Environmental awareness refers to the knowledge about the connection of AT to a decrease in greenhouse gas emissions and stress on the environment.[26,53] Heinen et al.[54] determined that those who cycled to work were more aware of the environmental benefits cycling to work has compared to non-cyclists. The researchers also found that environmental awareness mediated the barrier of distance for cycling. Those with higher levels of environmental awareness were more likely to cycle for transportation, even for long distances.[54] Li et al.[55] used an attitudinal market segmentation approach to determine that environmental awareness was positively associated with the perception of

commuting by bicycle. Goodman et al.[53] believes that individuals view AT as a "moral choice" due to the environmental benefits it provides.

Perception of Health Benefits

Those that believe that AT provides health benefits are more likely to use it. Heinen et al.[54] reported that those that cycle to work more strongly believed that this activity provided health benefits compared to those that commuted by driving. For every 1 point increase in agreement that bicycling to work resulted in direct benefits, participants were two times more likely to cycle to work. Bopp et al.[41] reported similar results in that those who walked or biked averaged 4.32 and 4.40 respectively on a 5 point scale related to belief of health benefits from AT compared to 3.44 for drivers. In the same survey, 61% of all respondents believed that walking or biking to work offered health benefits.

Individual Factors

The opinion of an individual on factors, such as time flexibility, comfort, and satisfaction with surroundings could impact AT rates. Panter et al.[28] found that individuals who believed destinations are within walking distance are 5.37 times more likely to walk and 1.52 times more likely to bike. The same study also found that those who agreed or strongly agreed that there was little traffic on the road were 1.17 times more likely to bike to work. The authors also reported that individuals who agreed or strongly agreed with the statement that it is "pleasant to walk" to work are 2.34 times more likely to bike to work.[28] Handy and Yang[56] conducted a study using a survey with a 5-point Likert scale asking participants if they believed biking to work was comfortable. For every 1-point increase, the odds of using AT by factor of eight, and two point

increase increased the odds by 16. The same study assessed if participants had a positive or negative attitude towards active commuting and found for every 1-point increase on positive attitude, participants were four times more likely to use AT.

<u>*Summary*</u>

In summary, some individual psychological correlates predict AT use. High degrees of self-efficacy, economic awareness, environmental awareness, and acknowledging health benefits are more likely in active commuters. Additionally, those who believe they are within walking and/or biking distance to their destination, are comfortable during their commute, and have a positive attitude towards AT are more likely to do so.

Social support association with active transportation behavior

Social support, described as the encouragement provided by family, friends, and significant others[26], is constantly found as a correlate of AT use. Modeling, referred to having other members in an individual's support system actively participate with the individual in an activity[26,53], is a subset of social support that is also strongly correlated with AT use. A study by Bopp et al.[41] found that those who walked or biked to work believed they received more social support from coworkers as evidenced by walkers averaging 2.15 and bikers averaging 2.07 on a 5-point Likert scale (1 being the lowest, 5 being the highest) compared to 1.90 for drivers. Another study by De Gues et al.[26] studying psychosocial differences between those that cycle to work and those that did not found that cyclists were significantly more likely to have social support, averaging 2.74 compared to 2.23 for non-cyclists on a 5-point Likert scale. The same study also found cyclists were significantly more likely to have relatives who cycled (modeling) with

cyclists averaging 2.95 compared to 2.50 for non-cyclists. A similar study by Campbell and Bopp[25] discovered that individuals with lower rates of active commuting perceived less active commuting by coworkers and lower coworker normative beliefs compared to those with higher rates of active commuting (1.47 vs 1.60 on 5-point scale and 8.58 vs. 9.15 on 20-point scale, respectively).

This evidence that social support is important, suggests particular interventions. For example, a supportive work social environment may increase the number of employees participating in AT.[25] McAuley et al.[57] believed this could be accomplished by having active commuters form buddy groups. Campbell and Bopp[25] also suggested that interventions focused on increasing modeling from spouses could further increase active commuting rates. This could be accomplished by having spouses walk children to and from school.[25] Another idea suggested by many researchers is to use worksite interventions to improve social support and therefore AT as a review by Conn et al.[58] reported that worksite interventions are effective at improving employee physical activity levels. Kaczynski et al.[44] and Campbell and Bopp[25] believe that interventions creating an active commuting-oriented culture could help individuals alter their modes of commute from vehicle use to walking or biking.

Summary

In summary, social support and modeling are important correlates to AT use. Both types of support have consistently been found in active commuters. Targeting these traits for interventions may increase the use of AT.

Perceived barriers to use of active transportation

Time Constraints

Barriers to AT include perceptions of time constraints including errands before and/or after work or school, lack of safety, and poor condition of facilities. A study by Banwell et al.[59] interviewed 50 obesity experts about their transportation choices. Two-thirds mentioned increasing car reliance and lack of time for physical activity as the main contributors to obesity. Many of the experts attributed this to the increased pressure put on people to do more with their time.[59] In the study by Bopp et al.[41] drivers averaged 4.07 on a 5-point Likert scale for perception of time constraints, compared to 2.38 and 2.48 for walkers and bikers respectively. In the same study, 67% of participants indicated that time constraints was a barrier to AT.[41] De Gues et al.[26] found that non-cyclists were more likely to report lack of time on a 5-point Likert scale as a reason for not actively commuting cyclists (cyclists = 1.96 vs. noncyclists = 2.60). The study also found that non-cyclists estimated it would take significantly longer to get to work by bike than cyclists; as non-cyclists estimated it would take 23.66 minutes compared to cyclists estimating 21.76 minutes. This was in spite of similar distances for the commute. When asking study participants how long they would spend active commuting, participants answered less than 15 minutes.[26] This indicates a need for a quick trip with a fixed schedule. However, the concern about excess time required for active commute may be misperceived. Li et al.[55] argued that bicycling to work made for a more flexible schedule with a more consistent duration than driving as a bicycle does not have a fixed departure time and rarely is delayed by traffic, thus saving time in some instances.

Safety

Another barrier to AT is a fear for an individual's safety. The U.S. Department of Transportation conducted a national survey to assess the attitudes of bicyclists and

pedestrians. Of the people who felt threatened for their safety while bicycling, 83% cited motorists as the main reason with 39% reporting that the drivers drove to close to bicyclists, 24% believing motorist drove too fast on the roads, 16% saying that motorists almost hit the bicyclists, 13% were cut off by motorists, and 12% felt threatened just by having motorists around.[60] Using a 5-point Likert scale, Bopp et al.[41] found that drivers had a greater concern about safety from traffic as a barrier as drivers averaged 3.82 on the scale compared to 2.68 and 3.07 for walkers and bikers respectively. The U.S. Department of Transportation also discovered that of people who feared for their safety, 43% of respondents also cited uneven roadway services as a reason.[60] In the study by De Gues et al.,[26] the researchers found that only 1 in 10 households were satisfied with the condition of the city's bicycle lanes. Fear of crime may also prevent individuals from actively commuting. Grow et al.[61] examined the neighborhood environments on AT in adolescents and found that fear of crime was negatively associated with AT. Sallis et al.[62] argued that crime in high walkability neighborhoods might discourage AT use, but believe more research is needed to confirm this.

Summary

In summary, time constraints are the most reported reason for not actively commuting. Issues related to time include believing a car is necessary to run errands before and/or after work or school, or concern that active commuting takes too much time. Perceived lack of safety is another important barrier that keeps many individuals from active commuting.

Personal Beliefs

Some research suggests that the differences in personal beliefs about bicycling should be used to tailor interventions. For example, Li et al.[55] segmented subjects into six groups based on their answers to a variety of questions determining attitudes about AT use via bicycle. Segment 1 did the least active commuting by bike with only 2.8%. Along with Segment 2, this group was considered "firm non-bicycle travelers" as they had a low need for a fixed schedule and had low environmental awareness. Segment six had the highest use of bicycling to work, 50.8%; this group of individuals had a strong need for a fixed schedule and had a high environmental awareness. Along with Segment 5, this group was considered "firm bicycle users" based on their attitude. Segments 3 and 4 were considered "potential bicycle users" as their responses to the survey indicated that the bicycle could fit into their daily commute. Li et al.[55] believed that specific interventions could be conducted for each group with the hope of converting more individuals to active commuters. For Segments 1 and 2, cycling environments would have to be built and/or improved with paths that provided a direct path from neighborhoods to work distracts. Segments 5 and 6 need more bike lanes or paths that connect to bicycling facilities with improved bicycle parking. Based on their environmental attitudes, interventions focusing on reducing vehicle emissions may also be effective.[55] The researchers did not offer specific interventions for Segments 3 and 4 but believed strategies did exist.

Summary

In summary, examining the specific traits of groups may be of use when developing specific interventions aiming to increase AT use. However, since few interventions have been conducted, this is still theoretical.

Limitations

Many of the studies performed to date have cross-sectional designs, which allow only correlations, not causation. Randomized controlled trials are needed to determine whether interventions designed to alter psychosocial and social variables are effective at altering AT behavior.

Table 4. AT and psychosocial influences

Article	Purpose	Methods	Findings
Aldred 2012 – Incompetent or Too Competent? Negotiating Everyday Cycling Identities in a Motor Dominated Society	Explain that modes of transport create disadvantaged and stigmatized social identities	Conducted and analyzed 55 narrative interviews of people who cycle in Cambridge or Hull (English cities)	1. Vehicle users believe cyclists don't follow and lack knowledge of rules of the road 2. Cyclists worry about being labeled "bad" or "incompetent" on roadways 3. Cyclists worry about safety from vehicles and assaults 4. Cyclists believe there are health benefits from cycling
Bopp 2012 – Active commuting influences among adults	Analyze influences of walking, biking, and driving in order to tailor interventions for promoting active commuting	Cross-sectional design that distributed a survey in Manhattan, Kansas in 2008 between August and December (N = 375. age 18+, working full or part-time)	1. <u>Walking</u> **Positive correlates:** self-efficacy, employment, >20 mins of travel time, parking difficulty **Negative correlates:** age, travel before/after work (61%), travel concerns, time constraints (67%) 2. <u>Biking</u> **Positive correlates:** male, working part-time, good weather
Bourdeaudhuij and Sallis 2002 – Relative Contribution of Psychosocial Variables to the Explanation of Physical Activity in Three Population-Based Adult Samples	Determine the contribution of 4 psychosocial variables (social, self-efficacy, perceived benefits, perceived barriers) in explain physical activity levels	Performed in person interviews on 3 different ages groups: 16-25, 35-45, and 50-65 for a total of 2,390 people	1. Social variables are the strongest predictors of PA levels 2. Self-efficacy is a predictor of PA levels 3. Psychological and health barriers are associated with less PA as age increases.
Campbell 2013 – Examination of the	Examine the relationship between social support and AT	Cross-sectional experiment in the mid-Atlantic region. An online survey was	1. Support of AT from business could increase AT levels

		distributed to employees at moderate to large businesses (N = 1,234)	2. Social support from significant and coworkers lead to higher AT levels
Relationship of Interpersonal Influences with Walking and Biking to Work			
De Gues 2008 – Psychosocial and environmental factors associated with cycling for transport among a working population	Examine psychosocial and environmental predictors of cycling for transportation between cyclists and non-cyclists	Cross-sectional design using a self-reported survey (N = 343, age 18-65) in Flanders, Belgium	1. **Cyclists** More social support, higher internal & external self-efficacy, economic and ecological advantages are more important, have facilities at workplace 2. **Non-cyclists** Lack of time and/or skills, estimated time of travel to be longer 3. **Predictors of cycling** Social support, high levels of external self-efficacy, ecological-economic awareness, facilities at workplace 4. **Barriers:** Lack or time/interest 5. Mean estimated-time people would spend traveling is <15 minutes.
Deforche 2010 – Perceived social and physical environment correlates of physical activity in adolescents and the moderating effect of self-efficacy	Determine if perceptions of social and physical environments are associated with AT and leisure physical activity and examine if the relationship is moderated by self-efficacy	1,445 adolescents from 20 randomly selected schools in East- and West-Flanders, Belgium completed a questionnaire during one of their class periods.	1. High self-efficacy was correlated with more AT and leisure physical activity 2. Modeling and social support was positively correlated with AT 3. AT contributed 60 min/d of PA in those with high self-efficacy, 46 min/d in those with low self-efficacy 4. Self-efficacy is a better predictor than BE variables

Goodman 2013 – Who uses new walking and cycling infrastructure and how? Longitudinal results from the UK iConnect study	Analyze patterns of using high quality, traffic-free walking and cycling routes over one and two year follow up times. Also wanted to determine the purposes for using the trails and predictors of use.	Distributed survey pacts one year and two years after implementation of new, high-quality trail (N =1,849 at year one, 1,510 at year two).	1. High levels of social support, modeling, and self-efficacy are more likely to cycle to work 2. AT is viewed as economic or moral choice for those that use it. 3. Path users are 5x more likely to bike than walk 4. 7% of users used trail for AT 5. Distance is a correlate (40% users who walked lived <1 km from path, 15% lived ≥4 km)
Handy and Yang 2015 – Factors Correlated with Bicycle Commuting: A Study in Six Small U.S. Cities	Determine the influence of physical environments and social environment of the workplace relative to the influence of sociodemographic characteristics and individual attitudes	Cross-sectional design examining behavior of residents in six communities (N = 965)	1. <u>Individual factors: Predict better than physical environment</u> 2. 1 point increase on comfortability increases odds of AT by factor of 8, 2 point increases odds to 16 3. 1 point increase on positive attitude = >4x more likely to use AT **Positive:** comfort, positive attitude towards cycling, **Negatives:** females, home-ownership, need car before or after work (errands), supervisor disproves 4. <u>Physical environment</u> **Positive:** No significant data **Negative:** Perceived low safety on streets, long distance.
Heinen 2011 – The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances	Examine the differences of attitudes between cyclists and non-cyclists and how attitude towards bicycle commuting influence its use.	Recruited people through an internet or hardcopy survey of large companies located in the Netherlands that have above average cycling commuting rates.	5. **Cyclists (compared to non-cyclists)** More likely to commute via bike if bike reports: Bike commuting has environmental benefits, relaxing, cheap, safe and healthy, high self-efficacy

			Each 1 point increase in "direct benefits" = >2x more likely to cycle 6. **Distance** As distance increases, positive attitudes toward bike commuting decrease, becomes a decision based on individual characteristics of a person Those that commute long distances have high "awareness"
Li 2013 – Bicycle commuting market analysis using attitudinal market segmentation approach	Identify attitudes towards commuting travels, segment bike-commuting market into segments based on attitudes, and analyze characteristics to develop policies to promote bike usage.	Household survey of randomly selected Nanjing, China residents.	1. Those that commute by bike value flexibility, a fixed schedule, view biking as environmentally friendly, are willing to bike. 2. Negative correlates are wanting to be comfortable, longer travel time 3. Interventions should be aimed at potential market switchers
Panter 2014 – Patterns and predictors of changes in active commuting over 12 months	Describe changes in AT and analyze the predictors of uptake and maintenance of AT and other commute patterns vs. vehicle commute	Analyzed Commuting and Health in Cambridge data: 1,164 adults 16 and older who lived within 30 km (18.6 miles) took a survey and another survey one year later.	1. **People that commute by walking** No children in household, convenient public transport, lack of parking at work, view walking to work as pleasant 2. **People that commute by bike value** Convenient cycle route, reliable bus service Switching to commute by AT gained 15-30 min/week of extra PA No children = 2.2x more likely to walk for transport

Key
AT = Active Transportation
PA = Physical Activity
BE = Built Environment

Active Transportation on College Campuses

College campuses and towns provide a unique opportunity for AT in that they have a high percentage of young adults and usually have off campus housing that is within a few miles of the campus.[8,63] This offers students and faculty/staff an opportunity to commute via walking or bicycling. In fact, some college towns have some of the highest rates of active commuting as the American Community Survey in 2014 found that 28.3% and 18.7% of people living in Davis, CA and Boulder, CO commuted via bicycling, respectfully.[19] Here we will describe the differences between students and faculty staff in relation to AT as well as the variables that affect the rates of these groups.

Students

Multiple studies have reported that college students are more likely to use AT than faculty or staff. For example, while examining AT rates at Kansas State University, Bopp et al.[4] reported that students walked to campus an average of 4.5 times/week and biked 0.9 times/week whereas faculty/staff walked 0.8 times/week and biked 0.5 times/week (see Table 5). This difference may be partly mediated by the fact that most college students, even those living off campus, live within walking and biking distance to campus.[4,8,64,65] The study at Kansas State University found that 71% of students lived within walking distance (defined as living within a 20 minute walk to campus), while 91% lived within biking distance (defined as living within a 20 minute bike ride to campus).[4] However, in spite of the fact that most students could use AT, typical AT rates are not ideal. For example, Fu et al.[63] found that 25-31% of students active commute at the University of New Hampshire and the University of Rhode Island. Those that use AT

have reported living 0.4-7 miles from campus[4,63,66] and report actively commuting 4-6.3 times/week.[4,64,65] Distance may be a variable influencing AT use by students as Ransdell et al.[65] found that for every one-mile increase in distance between a student's home and the Boise State campus led to a 26% decrease in active commuting levels. Furthermore, Handy and Yang[56] reported that people living in six college towns frequently reported distance as a reason to not using AT.

Physical Activity Levels

Physical activity is important for an individual's health, however, the typical rates of physical activity in college students are shockingly low. In a meta-analysis to determine physical activity in college students, Keating et al.[67] reported that 40-50% of college students are physically inactive. Active commuting can contribute a substantial proportion of total physical activity for college students. Sisson and Tudor-Locke[8] tracked students physical activity with accelerometers and a travel log for two days and found that students that actively commuted reported 59 min/d of physical activity from their transportation patterns. Accumulated over a five day span, these students were doing 295 minutes of physical activity, easily meeting and surpassing the recommendation of 150 minutes a week by The United States Department of Health and Human Services.[68] Thus physical activity from AT could help prevent students from developing negative health consequences.

Age

A student's age could influence their likelihood of actively commuting. Ransdell et al.[65] found that for every year increase in age of college students, likelihood of commuting by AT decreased by 5%. One reason for this may be that as students age they

may have to take on more responsibilities and duties outside of their school life.[64]

Lemieux and Godin[64] suggested that graduate students may have a family with young children that need to be taken care of. Family duties may arise before or after class, leading to an increase dependence on car use.[64]

Psychosocial Correlations

As mentioned previously, some studies find that attitudes and psychosocial variables are better predictors of AT than built environment variables.[4,64] College students with higher levels of self-efficacy and perceived behavioral control are more likely to actively commute.[4,64] Being comfortable during the commute has also been demonstrated to be a correlate. Handy and Yang[56] found that when students reported a 1-point increase on comfortability on a 5-point Likert scale, the likelihood of commuting by AT increased by a factor of 8. Subsequently, those that reported a 2-point increase were more likely to commute via AT by a factor of 16. Students who report a positive attitude towards active commuting are more likely to participate in this behavior. The same study by Handy and Yang[56] found that for every 1-point increase in positive attitudes reported on a Likert scale, students were more than four times likely to walk or bike for transportation.

Vehicle Use and Parking

Another reason students may be more likely to actively commute is their view on the costs and environmental implications of driving motorized vehicles. Shannon et al.,[66] Bopp et al.,[4] and Ransdell et al.[65] found that students using AT believe that driving and parking on campus is costly, as students will have to pay for gasoline and various parking passes in order to able to park their car on campus. Bopp et al.[4] further found that

students also were worried about the potential for traffic congestion while driving to campus and parking availability once they reached campus. Parking availability is a problem for colleges as the number of people with parking passes is much typically greater than the number of parking spaces on campus. For example, Shannon et al.[66] estimated that 4,137 students and 2,490 faculty/staff park their cars on campus at the University of Western Australia. However only 4,236 parking spaces, exist, making it difficult for faculty/staff and students to find parking spaces.[66] AT has the potential to relieve parking congestion as well as providing many other benefits. Having a more environmentally friendly attitude has also been correlated with higher AT rates. A study conducted by Bopp et al.[48] in the college town of Manhattan, Kansas found that students who reported having a higher eco-friendly attitude commuted four times a week, compared to one time a week for those scoring low on the scale. Individuals who valued the environment also had higher degrees of self-efficacy, which could be a reason for the higher AT rates of this group. The researchers suggest that having an environmentally friendly attitude could reduce the perceptions of barriers to active commuting both directly and indirectly (i.e. through higher self-efficacy, etc.).[48]

Summary

In summary, most college campuses and communities provide ample opportunities for students to actively commute to their destinations. Although AT rates are usually higher in college communities, the rates are still not ideal, with a large percentage of students not actively commuting when they live within walking and biking distance. Since this population is at risk for physical inactivity, promotion of AT could help students reach and surpass the physical activity recommendations. Attitudes towards

AT are better predictors than built environment barriers. Students typically value comfortability and those having a positive attitude towards walking and biking to campus are more likely to do so. Lack of ample parking spaces and fear of traffic congestion are other reasons for using AT. Additionally, having an eco-friendly attitude is also a predictor of AT use.

Faculty/Staff

AT use by faculty/staff at universities is often much lower than the rate of student use. As reported earlier, Bopp et al.[4] found students at Kansas State University reported actively commuting an average of 4.5 times/week and biked 0.9 times/week whereas faculty/staff walked 0.8 times/week and biked 0.5 times/week. Another study by Fu et al.[63] reported that 25% of students at the University of Rhode Island commuted via AT while only 17% of faculty used this mode of transportation. The same study also found that 31% of students at the University of New Hampshire used AT compared to 25% of faculty. Typically, faculty/staff live farther away from campus than students do, making commute via single-occupancy vehicles more likely.[56] An explanation for this may be that housing near campus is often made up of various apartments that attract more students due to lower cost of rent and closeness to campus.[66] Bopp et al.[4] argued that housing near college campuses is often unattractive to faculty/staff, as they often desire a single-family house in order to raise a family. Further evidence is provided by the fact that faculty/staff are older in age than most students and may have young children in their household,[64] which is a negative correlate of AT.[21] Additionally, barriers to AT could increase as distance away from campus increases (lack of path or sidewalks, increased

levels of traffic, etc.).[4] Finally, health problems are more likely to be a barrier to use of AT in older employees than in young college students.

Predictors of Use

While many of the predictors of AT for faculty/staff are similar to those observed for students, other predictors are different for faculty/staff. Just as for students, faculty/staff with high degrees of self-efficacy and a shorter distance to travel to campus are more likely to report actively commuting.[4] Bopp et al.[4] and Shannon et al.[66] reported that acknowledging the health benefits and environmental benefits provided by AT is a predictor for faculty/staff transportation behavior. Shannon et al.[66] also found that a feeling of enjoyment from actively commuting was a predictor for faculty/staff, but not for students. Faculty/staff may exhibit a "self-selection" effect where those that are interested in actively commuting will choose their place of living with the condition that the built environment supports it (safe routes exist, etc.).[56]

Summary

In summary, AT rates among faculty/staff are lower than students. One reason for this is that many faculty/staff live farther away from campus because housing located close to campus is not attractable to this group. Faculty/staff are also likely to have children in their household, adding another barrier to actively commuting. Those that do actively commute have a higher degree of self-efficacy, have a shorter distance to commute, and enjoy the activity.

Proposed Interventions for Colleges

Specific interventions on college campuses or communities have been proposed (although not tested) to increase levels of AT. Bopp et al.[4] suggested that increasing self-

efficacy by arranging educational classes on AT or bike safety to help improve skills and forming clubs associated with active commuting to increase social support may be of use. For those that value the environment, interventions that sell AT as a sustainable and environment friendly activity could increase rates.[4] Due to the high amount of single-occupancy vehicles used for commuting, Handy and Yang[56] and Kaplan[70] suggested that interventions aimed at discouraging drive, such as higher costs for parking at the workplace, might encourage AT use. Although social variables have been shown to better predict AT levels, Handy and Yang[56] and Bopp et al.[4] argue that in some instances, the built environment needs to be addressed in order to increase levels in college students. One suggestion is to increase land-use mix in order for faculty/staff and students to complete errands before or after class more easily and in a timely manner.[56] Addition of a pathway towards mixed land-use buildings could also support AT.[56] Kaplan[70] also added that repavement/pavement of roads/sidewalks, addition of bike racks, linking apartments and campus buildings by addition of a path, and a bike share program may influence rates. Shannon et al.'s[66] study asked participants to rate the likelihood that a specific intervention would encourage that individual to actively commute. The authors found the respondents identified many interventions that would increase AT such as a convenient public transportation system with a free to low fair price. Other interventions they claimed would increase active commuting were development of a path system, housing located closer to campus, a bicycle repair station, a class that taught users how to bike, and addition of bicycle lockers. Shannon et al.[66] also argued that providing information on the amount of time it would take to actively commute to locations could increase AT as participants overestimated the amount of time it would take to actively

commute between various locations by 45% while underestimating travel time by car by 16%. Interestingly, none of these authors has published a report or an evaluation of a campus intervention to improve rates of AT.

Summary

In summary, interventions to increase AT on college campuses have been proposed, but not tested. Interventions based on the evidence should consider increasing self-efficacy through classroom sessions, classes focusing on improving bicycle skills, discouraging driving by increasing parking costs, increase land-use mix, and renovation of infrastructure. In one study, developing pathways, locating housing closer to campus, providing bicycle repair stations, and adding bicycle lockers were suggested strategies to increase active commuting.

Limitations

Limitations to these studies exist. Many of the studies reported are cross-sectional in nature and use surveys with self-report to gather information. All confounding variables cannot be controlled for, thus causation cannot be determined. Additionally, interventions aimed at increasing active commuting must be performed to determine if these suggested strategies will improve AT rates.

Table 5. AT and college campuses/towns			
Article	**Purpose**	**Method**	**Findings**
Bopp 2011 – Active Commuting Patterns at a Large Midwestern College Campus	Examine patterns and factors that predict active commuting among students and faculty at a university campus using a social ecological framework	Cross-sectional using a survey sent through email listserves (N = 457 students and 441 faculty/staff).	1. **Students** Psychosocial factors better explained variance than environmental Walked 4.5 times/week; biked 0.9 times/week 71% live within walking distance, 91% bike distance 2. **Faculty/Staff** Psychosocial factors better explained variance than environmental Walked 0.9 times/week, biked 0.5 times/week 3. **Students (compared to faculty)** Greater self-efficacy, traffic congestion, safety from crime, parking availability, parking cost had greater influences on AT 4. **Predictors of students** Economic concerns, self-efficacy, time barriers, weather, parking availability, distance to campus 5. **Predictors of faculty** Perceived health benefits, self-efficacy, time barriers, terrain, distance to campus
Bopp 2011 – The relationship of eco-friendly attitudes with walking and biking to work	Examine how eco-friendly attitudes and other variables relate to active commuting	Participants recruited fill out online survey by emailing local employers, community listserves, links from local Web sites, and fliers to adults aged 18 or older living or working full or art time in Manhattan, Kansas.	1. Students with high eco-friendly attitude 4x more likely to use AT vs. students with low eco-friendly attitude. 2. Eco-friendly attitude correlated with higher self-efficacy
Fu 2012 – Promoting Behavior Change	Identify differences in commuting behavior between student and	Use of online and phone surveys on University of New Hampshire (UNH) and an	1. **URI** Students use AT 25% of time Students live closer to campus

Among Campus Commuters	faculty/staff on college campuses and show that geographic location affects commute behaviors.	online survey on University of Rhode Island (URI) covering transportation topics (N = 2008).	Faculty use AT 17% of time Avg. walking commute is 1 mile Avg. biking commute is 7 miles Single occupancy vehicles commute >15 miles 2. **UNH** Students use AT 31% of time Faculty use AT 25% of time Students live closer to campus Avg. walking commute is 1.25 mile Avg. biking commute is 4 miles Single occupancy vehicles commute is 17 miles 3. **Overall** Long commute is a negative correlate of AT Public infrastructure impacts AT
Handy and Yang 2015 – Factors Correlated with Bicycle Commuting: A Study in Six Small U.S. Cities	Determine the influence of physical environments and social environment of the workplace relative to the influence of sociodemographic characteristics and individual attitudes	Cross-sectional design examining behavior of residents in six communities. Mailed an invitation to a survey to 1500 random residents, which was then filled online (N = 965).	1. <u>Individual factors:</u> Predict better than physical environment 1 point increase on comfortability increases odds of AT by factor of 8, 2 point increases odds to 16 1 point increase on positive attitude = >4x more likely to use AT **Positive:** comfort, positive attitude towards cycling, **Negatives:** females, home-ownership, need car before or after work (errands), supervisor disproves 2. <u>Physical environment</u> **Positive:** No significant data **Negative:** Perceived low safety on streets, long distance.
Kaplan 2013 – Transportation sustainability at a university campus	Examine real-time AT activity, behavior and attitudes of students in regard to AT, and how infrastructure impact AT	Physically counted AT users at key campus locations with hand clicker for 18 total hours. Attitudes of students were measured through a survey	1. **Counts** Most AT users come from apartments right off campus 2. **Survey** 86% have access to a vehicle (of these, 86% had parking pass)

			60 % use SOV <4% use bicycle for AT 3. **Reported barriers to walking**: bad sidewalk conditions (17%), bad weather (51%), time (43%), Inconvenience (27%) 4. **Reported barriers to biking**: bad weather (40%), time (30%), busy streets (21%)safety concerns (19%), no parking (14%)
Lemieux and Godin 2009 – How well do cognitive and environmental variables predict active commuting?	Identify cognitive and environmental variables that predict AT, explain intent to adopt AT, predict behavior and intentions, and test if environmental variables moderate intention-behavior relation.	Questionnaire based on the theory of planned behavior, and environmental variables. A 2-week follow up was conducted with self-report data of AT (N = 130 undergraduate and graduate students)	1. Walked 6.3 times/week 2. Walking (66.9%) more popular than biking (10.8%) 3. Cognitive variables predicted AT better than environmental. 4. **Positive correlates** Intent, perceived behavioral control, habit, living in apartments, younger age 5. **Negative correlates** Distance, access to car, time barriers, single-family residence
Ransdell 2013 – Predictors of Cycling in College Students	Examine prevalence of cycling for transportation and recreation and identify predictors of cycling in non-traditional-aged college students attending a urban university	ACHA-NCHA II survey with extra questions about cycling behavior and predictors added (N = 949 Students)	1. Cycling for transportation: 47% used for 4x/week 2. Students in "healthy weight" 0.90x more likely to cycle 3. **Students who cycled for transportation regularly**: Female decreased cycling 0.61x Living off campus decreased likelihood 0.71x 4. 1-mile increase in traveling distance = decreased 0.26x likelihood to cycle
Shannon 2006 – Active commuting in a university setting: Assessing commuting habits and potential for modal change	Understand barriers and motivators leading to staff and student travel decisions and determine what could be done to decrease SOV usage	16 question survey based on Department of Environment's TravelSmart Workplace questionnaire (N = 485 students, 553 staff).	1. Travel time was the biggest barrier 2. Saving money is biggest motivator for students 3. Place of living impacts levels of AT 4. Increasing cost of parking and decreasing cost of public transit can increase AT levels

Sisson & Tudor-Locke 2007 – Comparison of cyclists' and motorists' utilitarian physical activity at an urban university	Compare distance from campus and mode of transport between cyclists and motorists	Participants wore Accelerometers and completed a travel log for two non-raining days (N = 50).	1. Cyclists = 59 min/d of AT, 85.7 min/d moderate/vigorous activity 2. Motorists = 30 min/d of AT, 50.3 min/d moderate/vigorous activity

Key
AT = Active Transportation
PA = Physical Activity
SOV = Single-Occupancy Vehicle

Active Transportation and Improved Air Quality

Vehicle emissions are a health hazard, contributing to excess morbidity and mortality, because of the fine particulate matter and ozone released by many sources.[71] While ranking the top 15 risk factors for the global burden of disease, The World Health Organization ranked air pollution 14th.[71,72] For high-income countries, air pollution was ranked as the 8th top risk factor. Caiazzo et al.[72] (see Table 6) found that the transportation sector was the largest contributor to particulate matter emissions and ozone related mortality. Furthermore, vehicles produce more greenhouse gases during their first few minutes of use due to the engine insufficiency, leading to a greater stress on the environment.[73] Here we will examine the health hazards of vehicle emissions and how AT has the potential to decrease these emissions.

Vehicle Emissions and Mortality

Exposure to air volatile organic compounds and pollution may increase incidence of mortality. In a study by Tsai et al.[71] examining the vehicle emissions and cardiovascular mortality in central Taiwan, air volatile organic compounds were found to be highly correlated with vehicle emission pollutants. Primary air pollutants that the vehicles emitted were nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter up to 10 micrometers in size (PM_{10}). The researchers found that exposure to NO_2, CO, and PM_{10} lead to a 3.5%, 2.7%, and 4.1% increase in cardiovascular mortality respectively.[71] Caiazzo et al.[72] found that the emissions from the transportation sector are estimated to cause about 53,000 $PM_{2.5}$ related deaths and 5,000 ozone related deaths per year. An eight year extended analysis of the Harvard Six Cities study (originally conducted in 1993 by Dockery et al. studying 8096 people in six Mid-Western cities for

14 to 16 years) estimated that each 10 ug/m^3 increase in $PM_{2.5}$ led to a 16% increase in all cause mortality, 28% increase in cardiopulmonary mortality, and a 27% increase in mortality from lung cancer.[74] Hankey et al.[37] studied the southern California region and estimated that the current levels of $PM_{2.5}$ exposure lead to 30 deaths per 100,000 people per year from ischemic heart disease. Another study by Gan et al.[75] examined the long-term exposure to traffic-related air pollution and the risk for coronary heart disease (CHD) hospitalization and mortality in Vancouver, British Columbia. The study found that long-term exposure to the carbon gas emitted by vehicles lead to a 4% increased risk for CHD hospitalizations and a 14% increased risk for CHD mortality. A special report conducted by a panel of experts from Health Effects Institute labeled the relation between vehicle emissions and all-cause and cardiovascular mortality as "suggestive but not efficient" due to the low number of studies on the subject[76], but did cite studies done by Hoffmann et al.[77,78] that associated coronary artery calcification with living near a busy roadway with large amounts of traffic. Additionally, the panel also noted that lung funtion measurements are lower in those who live in polluted areas compared to those living in less polluted areas.[76] The release of particulate matter into the air also has the potential to increase as the panel estimated that global sales of cars between 2005 and 2020 would increase by about 11 million.[76]

Summary

In summary, substantial pollutants are produced by motor vehicles and they have adverse health implications. The World Health Organization has recognized air pollution as a risk factor for disease worldwide. Studies have shown that exposure to these pollutants lead to an increased risk in disease and mortality.

Active Transportation and the Potential for Decreased Vehicle Emissions

Due to the negative health impacts from air pollution, it is important to find ways to decrease it. AT can provide at least a partial solution, as modeling studies have shown that actively commuting could greatly decrease gas emissions. A study by Grabow et al.[5] estimated the impact that replacing 50% of short trips (2.5 miles) made by vehicles with cycling in 11 large Midwestern metropolitan areas. The authors estimated that this behavior change would decrease CO_2 emissions by 3.9 billion pounds per year. Lindsay et al.[13] found similar results when they estimated that 55 tons of CO_2 emissions would be eliminated by replacing 5% of short trips (7 km or 3.2 miles) made by motor vehicles with bicycling in New Zealand. Another study by Xia et al.[79] estimated the health benefits and greenhouse gas reduction of replacing use of vehicles with cycling over various scenarios in Adelaide, South Australia. If cycling trips were to increase by 5%, the researchers estimated that 191,313 tons per year of CO_2 would not be emitted and that emissions of $PM_{2.5}$ would decrease by 8.5%. If cycling trips were to increase by 10%, 238,626 tons per year of CO_2 would not be emitted and there would be a 8.6% reduction in $PM_{2.5}$ emissions. A study by Rojas-Rueda et al.[80] was conducted to look at the implications of reducing trips made by car in several different scenarios in Barcelona, Spain. If 20% of car trips made inside Barcelona (trips starting and ending in Barcelona) were replaced by cycling and public transportation (each replaces 10%), the researchers estimated that CO_2 emissions would decrease by 21,391 tons and $PM_{2.5}$ would be reduced by 0.07 ug/m^3. Replacing 40% of car trips made inside Barcelona with cycling and public transport would yield even greater results, as 47,783 CO_2 emissions would be avoided and $PM_{2.5}$ would be reduced by 0.14 ug/m^3. The authors of this study also wanted to

examine scenarios involving trips made outside Barcelona, defined as a trip starting in Barcelona and ending outside of the city, or a trip starting outside of the city and ending in Barcelona.[80] If 20% of car trips made outside Barcelona were replaced by cycling and public transportation, 80,233 CO_2 emissions would be avoided along with a reduction of 0.14 ug/m^3 $PM_{2.5}$ emissions. Further reducing car trips made outside of Barcelona by 40% would equate to reduction of 160,467 tons of CO_2 emissions and a decrease of 0.26 ug/m^3 $PM_{2.5}$ emissions. The authors believe that the reductions are greater in trips made outside of Barcelona when compared with trips made inside Barcelona because travel distance is longer.

Summary

In summary, air pollution from the transportation sector negatively impacts public health; leading to premature all-cause mortality, cardiovascular disease, and lung cancer. Fortunately, AT may offer a solution as modeling studies estimate that AT can substantially decrease the amount of CO_2 and $PM_{2.5}$ emissions from motor vehicles.

Active Transportation and Potential for Decreased Premature Mortality

AT has the potential to decrease premature mortalities associated with air pollution exposure. The estimated reduction in emissions as well as the increase in physical activity modeled in these studies predicts reduction in mortality. For example, Grabow et al.[5] estimated that 608 deaths would have been avoided by replacing 50% of short vehicle trips by bicycling in 11 Midwestern metropolitan areas. Lindsay et al.[13] estimated that replacing 5% of short trips with bikes would result in 5.6 fewer deaths per year from the decrease in air pollution in all of New Zealand. Additionally, the researchers reported that replacing 30% of short trips with bikes would result in 33.9

fewer deaths per year. In Xia's et al.[79] study conducted in Adelaide, South Australia, the researchers found that a 5% increase in cycling trips would lead to the elimination of 5 premature deaths and 39 disability-adjusted live years gained. The study by Rojas-Rueda et al.[80] examining different traveling scenarios in Barcelona, Spain found similar results. Reducing car trips by 20% inside Barcelona would result in 5 deaths/year avoided and 1.14 days life gained due to decreased air pollution. Further reducing the car trips made inside Barcelona by 40% would decrease premature deaths by 10.03 deaths/year and increase days of life gained by 2.28. When estimating the impact of health from reduced air pollution by replacing 20% of car trips made outside of Barcelona, the researchers found that 9.06 premature deaths/year would be avoided along with 2.05 days of life gained. Reducing car trips made outside of Barcelona by 40% would lead to 18.15 premature deaths avoided and 4.11 day of life gained.

Summary

In summary, the greenhouse gases and particulate matter emitted by vehicles can lead to cardiovascular diseases and premature mortality. AT can counteract this by decreasing the amount of pollution emitted, leading to decreases in premature death, days living with a disease, and increases in life expectancy.

Limitations

A few limitations exist among the studies reported. Most studies are of a modeling design, meaning many of the outcomes are only estimates. However, these studies are consistent in suggesting that replacing short trips with walking and biking could lead to either greater decreases in gas and particulate matter and mortality rates.

Randomized controlled trials are needed to determine the exact numbers, but these would

be difficult to conduct.

<table>
<thead>
<tr><th colspan="4">Table 6. AT as a means to improved air quality</th></tr>
<tr><th>Article</th><th>Purpose</th><th>Methods</th><th>Findings</th></tr>
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<td>Caiazzo 2013 – Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005</td>
<td>Evaluate premature deaths attributable to U.S. combustion emissions from multiple sectors</td>
<td>Used meteorology and air quality models to relate emissions to pollutant concentrations and used UK Committee on Medical Effects of Air Pollutants to evaluate health burdens from air pollution</td>
<td>1. Transportation sector emissions cause 53,000 $PM_{2.5}$ related deaths/year, 5,000 o-zone related deaths/year</td>
</tr>
<tr>
<td>Gan 2011 – Long-Term Exposure to Traffic-Related Air Pollution and the Risk of Coronary Heart Disease Hospitalization and Mortality</td>
<td>Identify if traffic-related air pollutants are responsible for increase risk of CHD and CHD mortality in in Vancouver, British Columbia</td>
<td>Examined a cohort study with 5-year exposure period for which mortality data was available for Metropolitan Vancouver residents.</td>
<td>1. Long-term exposure to carbon emitted by vehicles ($1.49\ 10^{-5}$/m) = 4% increase in CHD hospitalization and 14% increase in CHD mortality.</td>
</tr>
<tr>
<td>Grabow 2012 – Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States</td>
<td>Determine health, environment, and economy benefits for replacing 50% of short trips (<4km or 2.5 miles) by car with bikes in 11 large Midwestern cities</td>
<td>Used Community Multiscale Air Quality model, U.S. Environmental Protection Agency Benefits Mapping Analysis Program, World Health Organization Health Economic Assessment Tool to determine health, environment, and economic benefits of replacing 50% of <8 km (5miles) round trips with biking in the 11 cities.</td>
<td>1. Estimate a decrease of 608 deaths/year due to decrease in air pollution
2. Estimate decreasing CO_2 emissions by 3.9 billion pounds/year</td>
</tr>
<tr>
<td>Hankey 2012 - Health Impacts of the Build Environment: Within-Urban Variability in Physical Inactivity, Air Pollution, and Ischemic Heart Disease Mortality</td>
<td>To determine differences in urban form and how they relate to physical inactivity and air pollution to find health risks</td>
<td>Analyzed regional travel survey to determine physical activity and air pollution exposure for cities in Southern California</td>
<td>1. Air pollution contributes 30 deaths per 100,000 people/year from Ischemic Heart Disease.</td>
</tr>
<tr>
<td>Landen 2006 – Reduction in Fine</td>
<td>Follow up of Harvard Six Cities Study to evaluate robustness of previous</td>
<td>Used city-specific yearly mean PM 2.5 levels as a time-varying exposure to</td>
<td>1. Each 10 ug/m^3 increase in $PM_{2.5}$ = 16% increase in all-cause mortality,</td>
</tr>
</tbody>
</table>

Particulate Air Pollution and Mortality: Extended Follow-up of the Harvard Six Cities Study	findings and examine changes in $PM_{2.5}$ concentrations and mortality	determine the effect of exposure and mortality (N = 8,096).	28% increase in cardiopulmonary mortality, 27% increase in mortality from lung cancer
Lindsay 2011 - Moving urban trips from cars to bicycles: impact on health and emissions	Find the impact of replacing 5% of short trips (≤7km or ≤4.3 miles) made by vehicles with bicycles on health, and GHGs in New Zealand	Analyzed New Zealand Household Travel Survey for sample study (restricted to adults aged 18-64) and applied World Health Organization's Health Economic Assessment Tool to determine possible health benefits	1. Estimate 5.6 fewer death/year due to decrease in air pollution 2. Decrease CO_2 emissions by 50,000 tonnes/year (55 tons)
Rojas-Rueda 2012 – Replacing care trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study	Quantify health impacts of replacing use of car in metropolitan area of Barcelona by bikes and public transport	Examined current air pollution, traffic data, mortality, life expectancy and then estimated impacts alternative transportation could have across eight different scenarios.	1. **Reducing car trips by 20% inside Barcelona =** Reduce $PM_{2.5}$ by 0.07 ug/m^3, 5 deaths/year avoided, 1.14 days life gained, 21,391 CO_2 emissions/year avoided. 2. **Reducing car trips by 40% inside Barcelona =** Reduce $PM_{2.5}$ by 0.14 ug/m^3, 10.03 deaths/year avoided, 2.28 days life gained, 42,783 CO_2 emissions/year avoided. 3. **Reducing car trips by 20% outside Barcelona =** Reduce $PM_{2.5}$ by 0.13 ug/m^3, 9.06 deaths/year avoided, 2.05 days life gained, 80,233 CO_2 emissions/year avoided 4. **Reducing car trips by 40% outside Barcelona =** Reduce $PM_{2.5}$ by 0.26 ug/m^3, 18.15 deaths/year avoided, 4.11 days life

			gained, 160,467 CO_2 emissions/year avoided.
Tsai 2010 – Traffic-related air pollution and cardiovascular mortality in central Taiwan	Determine whether daily cardiovascular mortality was associated with traffic-related air pollutants in an urban environment	Examined mortality, hourly concentrations of air pollutants, hourly measures of volatile organic compounds in Taichung, China from January 1993 to December 2006	1. Volatile organic compounds are highly correlated with vehicle emission pollutants 2. Exposure to NO_2 = ~3.5% increase in CV mortality 3. Exposure to CO = ~2.7% increase in CV mortality 4. Exposure to PM_{10} = ~4.1% increase in CV mortality
Xia 2014 - Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia	Estimate health benefits and GHG reduction of replacing use of passenger vehicles with cycling	Estimated current health and air pollution for the year 2030. Then estimated impact of replacing 5% and 10% of trips made by vehicle with bicycling in Adelaide, South Australia	1. **5% increase in cycling trips** = 191,313 tons/year decrease in CO_2 emissions, 8.5% reduction of $PM_{2.5}$, 5 premature deaths eliminated, 39 disability-adjusted live years saved 2. **10% increase in cycling trips =** 238626 tons/year decrease in CO_2 emissions, 8.6% reduction of $PM_{2.5}$, 5 premature deaths eliminated, 39 disability-adjusted live years saved

Key
CHD = Coronary Heart Disease
GHG = Greenhouse gases
CV = Cardiovascular

Active Transportation and the Economy

In addition to providing health benefits, AT could also impact the economy. Here we will examine the different ways that AT can help individuals save money on gas, decrease health care costs throughout the nation, save cities money long-term, increase property values, and increase consumers' spending.

Active transportation and decreased spending on gasoline

AT may help decrease spending on gas, saving individuals money. In a study by Lindsay et al.[13] that estimated the benefits for replacing 5% of short trips with bicycling in New Zealand, the researchers estimated that each individual could expect to save $1,410-2,441 NSD ($900-1,558 USD) a year (see Table 7). Additionally, 22 million liters (5,811,785 gallons) of fuel would be saved leading to $37 million NZD ($23,622,650 million USD) in total fuel bills saved countrywide based on $4/gallon. The authors also mentioned that $222,412,000 NZD ($160,659,308 USD) in total fuel bills would be saved if 30% of short trips were replaced by cycling.

Health Care Costs

Physical inactivity results in increased expenditures on health care because of the association between inactivity and higher chronic disease risk. In a study by Carlson et al.[81] in 2015, the researchers estimated that inactivity (0 minutes of physical activity a week) and insufficient activity (less than 150 minutes of physical activity a week) makes up 11.1% of aggregate health care costs, amounting to $117 billion nationwide. At a more personal level, inactive adults are estimated to spend $1,437 more per year on health care compared to active adults (adults who meet the physical activity guidelines), while insufficient active adults are estimated to spend $713 more than active adults.[81]

However, AT has the potential to decrease the health care expenditures due to the co-benefits of increased physical activity and cleaner air. A study by Grabow et al.[5] examining the impact of replacing 50% of short trips with bicycling in Midwestern metropolitan areas estimated that $8.7 billion would be saved per year (2.5% of health care costs) due to the increased physical activity and decrease in greenhouse gas emissions.

Money Saved in Active Transportation Investment

Investing in AT can ultimately help cities save money. According to the American Road and Transportation Builders Association, a new two lane undivided road costs $2-3 million per mile in a rural area.[82] An urban area costs even more at $3-$5 million per mile. Maintenance of the road is also costly as a four-lane road is estimated to costs $1.25 million per mile. Investing in trials and infrastructure that can be used to AT is much cheaper than this. According to Wang et al.,[83] who examined the cost of construction and maintenance of five walking and biking trails in Lincoln, Nebraska, the total cost of construction was $90,982-2,366,927 depending on the surface, length, and if other characteristics were needed (bridges, etc.). Maintenance of a trail was also low, costing between $7,040-$26,183. Additionally, the annual cost per user of the trail was estimated to be $235 while the annual medical cost of inactivity was $622 per person. Bushell et al.[84] composed a report in 2013 that analyzed infrastructure costs for pedestrian and bicyclists around the United States. The researchers reported that average cost of building a bike lane is $133,170 per mile, while the average cost of a concrete sidewalk is $32 per linear foot. A paved multi-use trail is also much less than a road at an expense of $481,140 per mile.[84] Additionally, Garrett-Peltier[85] conducted a study

estimating the impacts of various transportation infrastructure projects in Baltimore, MD and found that pedestrian and bicycle infrastructure projects create 11-14 jobs per $1 million of spending compared to road infrastructure projects that create 7 jobs per $1 million of expenditures.

Active Transportation and Property Values

Having the ability to use AT increases the property value of residents and retail spaces. Krizek[86] conducted a study to determine how bicycle commuters value different travel environments and found that moving a home 400 meters closer to an off-street bicycle facility increases the value by $510. Karadeniz[87] examined the impact that the Little Miami Scenic Trail (a 74.9 mile paved trail running through Ohio) had on residential properties reported that a single-family residential property increased by $41,000 for every mile closer to the Trail. In an economic analysis of neighborhoods in Washington, D.C., the Brookings Institute reported that office and retail spaces that are located along better walkability areas rent for $6.92-8.88 more per ft^2 per year compared to spaces that are located in fair to average walkability.[88]

Increased Consumer Spending

Active commuters may spend more money at shops and restaurants that can be reached via AT. A study by Clifton et al.[89] examining how the built environment in the city of Portland impacts consumer spending by mode of travel found that bicyclists and pedestrians spend less money per trip to a restaurant, drinking establishments, and convenience stores located in cities compared to those who reach these places by driving. However, bicyclists and pedestrians make more trips per month to these establishments, ultimately spending more money at the commercial establishments than the car drivers.[89]

Summary

In summary, AT has many potential economic benefits at various levels, including the individual, community, and global level. Reduction in costs of maintaining and fueling a motor vehicle aid the individual while increases in physical activity and improved air quality may reduce health care expenses. Investing in AT infrastructure is much cheaper than investing in road infrastructure and also creates more jobs per $1 million spent compared to investing in road transportation. Property values increase as buildings become closer to trails and for locations located in highly walkability areas. Finally, active commuters in cities will spend more money per month at shops and restaurants than those reaching destinations by vehicle.

Table 7. AT as a means to an improved economy (personal and broader)			
Article	**Purpose**	**Methods**	**Findings**
Carlson 2015 – Inadequate physical activity and health care	Determine link between leisure-time aerobic physical activity and health care costs	Analyzed National Health Interview Survey (2004-2010) and Medical Expenditure Panel Survey (2006-2011) (N = 51,165).	1. Inactivity and insufficient activity accounted for 11.1% of aggregate health care costs ($117 billion)
Clifton 2013 – Examining Consumer Behavior and Travel Choices	Examine how built environment impacts non-work travel consumer spending by mode of travel	Collected different types of data at 89 different businesses throughout Portland metro region	1. Bicyclists and pedestrians spend less money per trip to a restaurant/convenience stores, but make more visits per month, spending more than car drivers.
Grabow 2012 – Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States	Determine health, environment, and economy benefits for replacing 50% of short trips (<4km or 2.5 miles) by car with bikes in 11 large Midwestern cities	Used Community Multiscale Air Quality model, U.S. Environmental Protection Agency Benefits Mapping Analysis Program, World Health Organization Health Economic Assessment Tool to determine health, environment, and economic benefits of replacing 50% of <8 km (5miles) round trips with biking in the 11 cities.	1. Estimate savings of >2.5 billion for short suburban bike trips 2. Estimate savings of 1.25 billion for short urban trips 3. Estimate 8.7 billion saved per year (2.5% of total cost of health care) on the increased AT and decrease in GHG emissions
Garrett-Peltier 2010 – Estimating the Employment Impacts of Pedestrian, Bicycle, and Road Infrastructure – Case Study: Baltimore	Estimate the employment impacts of various transportation projects in Baltimore, MD	Used an input-output model and project specific data provided by the City of Baltimore	1. 11-14 jobs are created from AT infrastructure projects per $1 million spent. 2. 7 jobs are created from road infrastructure projects per $1 million spent
Karadeniz 2008 – The Impact of the Little Miami Scenic	Analyze the impact of the Little Miami Scenic Trail on property values	Used the hedonic pricing technique along with Geographic Information Systems software	1. Single family residential properties increase by $41,000 every mile closer to

Trail on Single Family Residential Property Values			the Little Miami Scenic Trail
Krizek 2006 – Two Approaches to Valuing Some of Bicycles Facilities' Presumed Benefits: Propose a session for the 2007 National Planning Conference in the City of Brotherly Love	Understand how bicycle commuters value five different travel environments.	Used Adaptive Stated-preference survey that had video clips that represented conditions of different bicycle facilities.	1. Moving home 400 m closer to off-street bicycle facility increases value by $510
Lindsay 2011 - Moving urban trips from cars to bicycles: impact on health and emissions	Find the impact of replacing 5% of short trips (≤7km or ≤4.3 miles) made by vehicles with bicycles on health, and GHGs in New Zealand	Analyzed New Zealand Household Travel Survey for sample study (restricted to adults aged 18-64) and applied World Health Organization's Health Economic Assessment Tool to determine possible health benefits	1. Individuals can save $1410-$2441 NZD ($900-$1558 USD) a year by replacing 2. 22 million L (5811785 gallons) of fuel would be saved 3. $37 NZD ($23622650 USD) million in total fuel bills saved (based on $4/gallon)
Wang 2004 - Cost Analysis of Built Environment: The Case of Bike and Pedestrian Trials in Lincoln, Neb	Determine the annual cost of bike/walking trails in Lincoln, Neb.	Analyzed cost of construction and maintenance of 5 trails provided by Department of Parks and Recreation of Nebraska. Used 1998 Lincoln Recreational Trails Census data to determine number of users of trails	1. Total cost of construction between $90,982-$2,366,927 (adjusted for inflation) 2. Maintenance of trail is between $7,040 to $26,183 a year (adjusted for inflation)

Key
AT = Active transportation
GHG = Greenhouse gases

NZD = New Zealand Dollar
USD = United States Dolla

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Chapter 2:

Assessing Barriers and Motivators for Use of a Trail for Active Transportation in a College Town

Introduction

The U.S. Department of Health and Human Services developed the Physical Activity Guidelines (accumulating 150 minutes of moderate physical activity or 75 minutes of vigorous activity over the course of the week in at least 10 minute bouts[1]) to reduce the population prevalence of diseases such as cardiovascular disease.[2] However, it is estimated that up to a third of the world population is physically inactive (no reported physical activity[3]) and that close to 24% of the U.S. population is physically inactive[4], leading to an increased risk for diseases such as obesity and diabetes as well as their associated health care costs.[2,3,5]

Active Transportation (AT), defined here as walking or biking for transit[6], has been proposed as a partial solution to increase physical activity. Use of AT has been correlated with many health-related benefits such as lower BMIs, body fat and cardiovascular risk factors.[7-10] Vuori et al.[11] further showed that using AT for 10 weeks increased participants VO_{2max} by 4.5% and improved HDL cholesterol by up to 5%. However, despite the potential and reported benefits of AT, commuting via walking and biking remains low across the U.S. and has recently been estimated to be 3.4% of all commute trips.[12] However, the U.S. government is trying to improve upon this by setting goals to increase the proportion of trips of 1 miles or less via walking by 10% and increase proportion of trips of 5 miles or less via cycling by 3% as a part of the Healthy People 2020 initiative.[13]

Environmental and economic benefits have been associated with AT as well.[14-17] For example, Gabrow et al.[14] estimated that replacing 50% of short vehicle trips (≤ 2.5 miles) in 11 Midwestern metropolitan areas could result in $8.7 billion in health care savings due to increased physical activity and decreased greenhouse gas emissions.

College campuses may be good sites for attention to AT. Most universities discourage parking on campuses due to limited parking. Additionally, students attending college could be at risk for physical inactivity as a meta-analysis by Keating et al.[18] estimated that 40-50% of college students are physically inactive, increasing their risk for health-related problems. Studies across different universities have found that a vast majority of students live within walking and biking distance to campus.[6,19] AT by college students has been associated with reaching the physical activity recommendations as well. Sisson et al.[20] tracked college students who drove or cycled to campus with accelerometers at the University of Arizona and found that those that cycled had 85.7 minutes of physical activity a day, with 69% of that coming from AT; more activity than those who did not use active transportation to campus. Bopp et al.[21] identified "eco-friendly attitudes" as a predictor of the use of AT in participants of a survey of employed adults. Thus, the fact that active transportation is a mechanism to have a personal impact on the environment could be a motivating factor in college students.

In summary, replacing vehicle use with AT can improve health, decrease the economic burden from healthcare costs, and improve the environment. AT can also be used as a strategy to decrease traffic congestion at college campuses and increase physical activity in the student population. Although it is recognized that limited safe infrastructure can be a barrier to use of AT[22,23], there are many available trails and safe routes that are not fully used. Currently, research on examining the use of available safe conduits for AT by college students along with the motivators and barriers to use is limited. This is critical so that appropriate, tailored intervention strategies can be designed to increase the active use of available infrastructure by college students.

The purpose of this study was to determine the commuting habits and the reasons for and barriers to student use of a 1.9-mile trail for active commute that connected a major residential area to a large college university. The data collected can offer insight on the barriers to using trails for AT and help provide ideas for potential, appropriate interventions designed to increase AT via a trail, increasing physical activity and decreasing personal vehicle use in this population.

Methods

Design

This study, conducted in a rural college community, was made up of two parts: a cross-sectional questionnaire examining transportation commute behaviors and attitudes and a short-term longitudinal data collection of trail use by walkers and bikers collected over the period of survey completion. The focus of the study was a 1.9 mile, paved, free-from-traffic trail that connects an off-campus residential community to the university. The trail can be accessed through multiple entrances and connects to other trails in the surrounding area. When entering the trail from the residential area and traveling to the university, the trail ranges from a grade of 0.8% to 1.9%.[24] One side of the trail is a forest area with trees and a small creek while the other side is made up of farm land. A residential road separated by a median is adjacent to part of the trail for 0.9 miles and a residential highway passes over the trail via a bridge.

Longitudinal data collection on trail use was collected by two Chambers RadioBeam Bicycle-People (RBBP) counters. The RBBP uses a transmitter and receiver, one placed on each side of the trail.[25] A count was registered when the radio beam between the transmitter and receiver was broken. The device detected pedestrian and cyclists by using multiple radio frequencies. One set of counters was placed near the entrance of the trail from the residential community (Counter A) and the other was placed near the university entrance to the trail

(Counter B). There were several possible points of entrance and exits between the two counters so they are not expected to have identical counts. The counters have the potential to be inaccurate if individuals pass through the beam simultaneously when walking or biking side by side. To account for this, correction equations were developed by a research group[26] who had previously tracked trail traffic at this location by conducting field observations and comparing this to counter data during the same time periods. These correction equations were applied to all counter data except for counts of zero. The correction equation for pedestrian traffic is:[26]

$$y = 1.39x - 3.12$$

The correction equation for bicycle traffic is:[26]

$$y = 0.77x + 2.35$$

Additionally, weather data on the local area from the National Oceanic and Atmospheric Administration was downloaded for the study time frame to compare the maximum and minimum temperature and precipitation with the counter data. Data was collected through the mid-way point of the university's Spring Semester and for a small part of its Summer Semester. Because of this, data was split into two parts: Spring Semester (n=45) and Summer Semester Data (n=10). The data between sessions (n=10) was dropped since the university was not in session.

Cross-sectional data was collected via a 40-item online questionnaire (Qualtrics LLC, Provo, UT) that was developed based on a modification of items in surveys with good reliability used by other researchers.[27-30] The questionnaire was piloted by members of the research group and volunteers similar to test subjects who did not qualify for participation in the study. The variables assessed were chosen due to their relationship with AT and physical activity found in other studies.[27-31] Each questionnaire contained five parts: (i) demographics, (ii) commuting

behaviors, (iii) psychosocial correlates of AT, (iv) environmental attitudes, and (v) motivations and barriers to use the trail for AT. It was estimated that the questionnaire would take 10-15 minutes to complete and participants were instructed that they could leave questions unanswered. A copy of the online questionnaire is available in Appendix E.

The study was approved by the Institutional Review Board at Virginia Tech.

Participants

Recruitment of participants occurred from March 2016 – June 2016. Flyers were posted around the university (e.g. study areas, bulletin boards, etc.) and in the common areas of apartment buildings in the residential area of interest. In addition, the residential managers of the developments placed an ad in the community newsletter, sent an email to individuals signed up for the resident listerv, and posted information about the study on the community social media pages. Finally, the experimenters placed a sign with information about the study with a link and QR code to the questionnaire at the community entrance of the trail. Encouragement for completion of the survey included the option to enter their name into a drawing for a cash prize. Inclusion criteria for this study were: living in the residential area of interest, being 18 years of age or older, being able and well enough to walk or bike, having been in town for at least five of the past seven days when the questionnaire was completed, and be a student of the university. Participants were divided into two groups: Users (U) or Non-users (NU) of the trail for commute to the university. U were defined as those who answered "Yes" to completing at least one AT commute trip to/from campus from/to their residence via the trail within the past seven days. NU were defined as those who answered "No" to completing at least one AT commute trip to/from campus from/to their residence via the trail within the past seven days. Data collected

from those who met the study criteria, but identified as faculty/staff (n=10), were collected and

tables and figures created from these data are reported in the Appendix B.

Measures

RBBP Counters

Data from the RBBP counters were collected weekly for nine weeks during the period

that the survey was open for completion. Counters were checked every three days in order to

make sure they were functioning appropriately. The counters were used to determine the average

daily total traffic, the average pedestrian and bicycle traffic, hourly traffic patterns, and

weekend:weekday average daily count ratio. The weekend:weekday average daily count ratio

was used to examine if the trail had more of a commute pattern (defined as a ratio <1.0) or a

recreational pattern (defined as a ratio of >1.0) during the study period.[32]

Demographics

Participants were asked about their age, gender, height, weight, ethnicity/race, level of

education, the number of children in the household, income, type of residence, and length of stay

at their current residence based on questions asked by other researchers.[27-30] Subjects were also

asked to report their physical activity, how their health compared to others, and if they had been

diagnosed with a disease. A modification to the short-form International Physical Activity

Questionnaire[33] was used for participants to report their physical activity. The modification did

not include the questions about walking and sitting and was made in order for subjects to

quantify their moderate and vigorous physical activity for one week. This was used to compare

to the Department of Health and Human Service's Physical Activity Recommendations[1] and to

decrease the number of questions on the questionnaire. Forced-choice and check-all that apply

questions were utilized throughout this section, except for questions asking about participant's

age, height, weight, and physical activity level. Participants answered these by typing in their own responses.

Commuting Behaviors

Using forced-choice answers, participants were asked about their primary means of commute to campus, the number of trips they took per week to and from campus, the number of motor vehicles at their place of living, driver's license ownership, bicycle ownership, and university parking pass ownership. Subjects were also asked about their awareness of the trail connecting their community to campus, the number of trips taken to and from campus using the trail via walking and/or biking, and the commute time of these trips. Finally, to get a sense of their overall use of AT, participants were asked about the number of any AT trips taken and the commute time of those trips during that last two weeks.

Psychosocial Correlates

Participants were asked to report their attitude towards walking and biking using forced-choice answers by having them indicate their level of agreement with eight statements for walking and the same eight statements for biking using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The statements were used to determine how participants view walking and biking as far as their safety, enjoyment, value, and ease, among others. Overall mean attitude scores for walking and biking were created for each participant by taking the average score of their answers to the statements. Then, the mean of the score for each mode was averaged for an overall attitude score towards AT.

Participants were asked to indicate their perception of social support for the different modes of AT through forced-choice answers by having them indicate their level of agreement with seven statements for walking and the same seven for biking commute using a 5-point Likert

scale (1 = strongly disagree, 5 = strongly agree). The statements were used to determine if participants receive encouragement from family, friends, supervisors, and co-workers, among others. An overall walking social support and biking social support mean score were created for each participant by taking the average score participants assigned to each of the seven statements. Then, all answers to statements were averaged for an overall social support score for AT.

Environmental Attitudes

Participants were asked about their attitudes towards different environmental factors. This was determined by having participants indicate their level of agreement with eight statements using a 5-point Likert Scale (1 = strongly disagree, 5 = strongly agree). The statements were used to determine how participants view climate change and air pollution, among others, and determine if one group was more environmentally aware than the other. An overall environmental attitude score was computed for each participant by averaging scores assigned to each statement.

Motivation and Barriers

Participants were asked what may motivate them to increase their AT usage of the trail. For this question, participants were given 20 points to allocate towards a list of 13 answer choices. Between zero and five points were allowed to be given for any one item. A higher point allocation per item indicated a higher belief in the motivating power to change behavior. This set of questions was scored several ways. First, the total number of points assigned per response were tallied and then ranked in order from highest to lowest. Another ranking was calculated by tallying the number of people who allocated one point or more to each response. Finally, an overall ranking of motivators was determined by taking the average of these two rankings.

If participants were identified as a NU, an extra question appeared on the questionnaire that asked them to rank their top five reasons for not using the trail from a list of 21 options. Scoring was similar to the motivations, minus the point system. Responses were ranked by tallying the number of people who chose to rank a response in their top five. In the event of a tie (the same number of people chose to rank a response in their top five), the average ranking of the response was used as a tiebreaker.

Analysis

All counter and questionnaire analysis was done through SPSS 24.0 (IBM SPSS, Chicago, IL) software. The counters recorded the number of counts for the day in five minute increments and data was then aggregated into hourly counts. Data was censored if the total count data for a day was unavailable due to misalignment of the counters and for days where an event took place near the counter's locations. Independent T-tests were used to determine if total traffic, pedestrian traffic, and bicycle traffic differed between counters. Pearson Correlations were performed to examine the relationships between the average daily total, pedestrian, and bicycle traffic with weather data (maximum temperature, minimum temperature, and precipitation) for each counter. Due to the low number of Summer Semester data, weather correlations with these counts will be reported in Appendix A.

In regards to the questionnaire data, frequencies and descriptive statistics (Fisher's Exact Test) were used to describe the average responses with Tukey post hoc tests used to examine the differences between groups. Independent T-tests were used to examine the differences between groups for some demographic variables and commuting behaviors, and all psychosocial correlates and environmental awareness variables. For U, an Independent T-tests was used to determine if there was a difference between the number of walking and biking trips taken and if

there were differences in the time of commute between modes. Pearson Correlations were performed to examine relationships among demographic variables and psychosocial factors and environmental attitudes. All statistical significance values were set at $p < 0.05$.

Results

RBBP Counters

At Counter A, 82% of weekday pedestrian traffic and 88% of weekday bicycle traffic were valid (Table 1). Validity remained high for the weekend at this location as 92% of pedestrian traffic and 100% of bicycle traffic were kept. At Counter B, 97% of weekday pedestrian traffic and 100% of weekday bicycle traffic were valid. Validity remained high for the weekend at this location as 92% of pedestrian traffic and 100% of bicycle traffic were retained.

At Counter A, 100% of all weekend and weekday counts were valid. At Counter B, 63% of all weekday counts were kept (Table 2). Counter misalignment was found for all weekend days for Counter B and therefore no Summer Semester weekend data will be reported.

Trail Traffic

During the Spring Semester, over 520 individuals per day were counted on the trail during the weekday while over 440 individuals per day were counted during the weekend (Table 3). No differences were found between counters in regards to total traffic. Counter A had less pedestrian traffic during the weekday (300 ± 98 counts/day vs. 429 ± 160 counts/day; $t = -3.781$, $p < 0.001$) compared to Counter B. There was no difference in weekend pedestrian traffic between counters ($p < 0.614$). Counter A had more bicycle traffic during both the weekday (221 ± 65 counts/day vs. 162 ± 42 counts/day; $t = 4.240$, $p < 0.001$) and weekend (164 ± 51 counts/day vs. 124 ± 27 counts/day; $t = 2.432$, $p < 0.027$) compared to Counter B.

During the Summer Semester, over 420 individuals were counted per day on the trail during the weekday with no differences found between counters for total traffic (Table 4). During the weekend, 279 individuals per day were counted by Counter A, but comparison to weekend counts from Counter B cannot take place as no valid counts were obtained. Counter A had less weekday pedestrian traffic compared to Counter B (214 ± 41 counts/day vs. 282 ± 67 counts/day; $t = -2.295$, $p < 0.042$). However, Counter A did have more weekday bicycle traffic compared to Counter B (209 ± 37 counts/day vs. 144 ± 12 counts/day; $t = 4.531$, $p < 0.001$)

Hourly Traffic Patterns

The Spring Semester average weekday and weekend hourly traffic patterns are shown in Figures 1-4. During the weekday, peak morning traffic at Counter A was at 11:00am (32 counts/day) and peak afternoon total traffic was at 5:00pm (61 counts/day). During the weekend, peak morning traffic was found at 9:00am (21 counts/day) and peak afternoon traffic was at 5:00pm (55 counts/day). During the weekday, Counter B had peak morning total traffic at 9:00am (36 counts/day) and afternoon peak at 5:00pm (69 counts/day). Counter B had peak morning traffic at 11:00am (29 counts/day) and an afternoon peak at 5:00pm (45 counts/day).

The Summer Semester average weekday and weekend hourly traffic patterns are shown in Figures 5-8. During the weekday, peak morning traffic at Counter A occurred at both 8:00am and 9:00am (26 counts/day) and peak afternoon traffic was at 6:00pm (50 counts/day). During the weekend, peak morning traffic was at 10:00am (32 counts/day) and peak afternoon traffic was at 6:00pm (25 counts/day). At Counter B, weekday peak morning traffic was at 8:00am (31 counts/day) and peak afternoon traffic was at 12:00pm (48 counts/day). No traffic can be reported from Counter B during the weekend due to counter misalignment.

Weekend:weekday ratio

The Spring Semester weekend:weeday ratio (Figure 9) for Counter A revealed a weak commute pattern for pedestrians traffic (ratio = 0.96, 4% more traffic during the weekday) and commute use for bicycle traffic (ratio = 0.74, 26% more traffic during the weekday). The weekend:weekday ratio of Counter B revealed commute patterns for both pedestrian (ratio = 0.73, 27% more traffic during the weekday) and bicyclist traffic (ratio = 0.76, 24% more traffic during the weekday).

The Summer Semester weekend:weekday ratio (Figure 10) for Counter A revealed a commute pattern for pedestrian traffic (ratio = 0.76, 24% more traffic during the weekday) and a strong commute pattern for bicycle traffic (ratio = 0.56, 44% more traffic during the weekday). A weekend:weekday ratio for Counter B cannot be computed.

Traffic and Weather

During the Spring Semester, the average maximum temperature and precipitation during the study were 19 ± 6°C and 0.3 ± 0.5 cm respectively. The maximum temperature was found to have a positive, moderate correlation with total traffic during the weekday at Counter A ($r = 0.518$, $p < 0.006$) (Table 5). Further analysis revealed that this was also true for both weekday pedestrian ($r = 0.525$, $p < 0.005$) and weekday bicycle traffic ($r = 0.460$, $p < 0.012$) at this location. Precipitation had a negative, moderate correlation with total traffic at Counter B ($r = -0.408$; $p < 0.021$) but further analysis discovered that pedestrian traffic was only influenced at this location ($r = -0.365$, $p < 0.040$).

Survey Data

Overall, 89 individuals accessed the survey. Thirty-two people were dropped because they either did not meet the inclusion criteria or only answered the questions designed to

determine if they met the inclusion criteria, leaving all other questions blank. The final sample

consisted of 57 students, 32 of which were identified as U and 25 as NU.

Demographics

No significant differences in demographic variables assessed were found between groups

(Table 6). Most participants were in their young to mid-twenties with a normal BMI. Although

not significant, U were higher in males (57% of group), while NU had nonsignificantly higher

female representation (61% of group). Subjects were primarily Caucasian (78%) but 18%

reported as Asian, 2% as Native Hawaiian or other Pacific Islander, and 2% as "none of the

options" provided. Compared to the race/ethnicity enrollment for this university's Spring 2016

semester (64% Caucasian, 8% Asian, 0.1% Native Hawaiian or other Pacific Islander[34]), the

Asian participants in this study were over-represented while other ethnic groups were a lower

proportion. Most subjects (84%) reported being in good or excellent health while 20% of

participants identified being diagnosed with the following diseases: asthma or other respiratory

disease (7%), overweight or obesity (4%), hypertension (2%), mild depression (2%), anorexia

nervosa (2%), hypothyroidism (2%), and mood disorder (2%). A high majority of participants

(92%) reported meeting the CDC's aerobic physical activity guidelines. Both groups self-

reported an average of over 400 minutes of combined vigorous and moderate physical activity,

although there was a high variability in reported activity levels for both groups for both

intensities (vigorous activity: U = 112.0 ± 115.4 min/week, NU = 231.1 ± 238.4 min/week;

moderate activity: U = 330.9 ± 305.6, NU = 263.7 ± 289.8).

Few (12% of total participants) respondents reported that they had children in the

household. Among U, 53% had already completed their undergraduate degree or more education

while 63% of NU had completed some undergraduate degree work or less (63%), but this was

not different between groups. Eighty-eight percent of all responders reported earning ≤$20,000/year which is not surprising as this was a student population.

Nearly all participants lived in an apartment or condominium (96%) and at one of the apartment complexes in this neighborhood (95%). U were evenly made up of respondents who had lived at their residence for less than one year and respondents who had lived at their residence for a year or greater. NU had slightly more respondents who had lived at their residence for a year or greater (53%).

Commuting Behaviors

Commuting behaviors for U and NU are reported in Table 7. A significant difference was found between primary means of transportation between groups as 70% of U used AT or alternative transportation for commute while only 28% of NU used those primarily ($p < 0.004$). No significant differences were found for the number of trips taken to and from campus as each group took over 12 trips per week.

No significant differences were found for driver's license ownership or the number of motor vehicles at the residence. All NU reported having a driver's license while 97% of U owned one. Among U, an equal number of responders had either 0 or 1 motor vehicles at their residence, while NU had a slightly but nonsignificant higher percentage of respondents who had two or more vehicles at their residence (53%). Seventy percent of U owned a bicycle, while 47% of NU owned one, but this difference was not significant. Analysis showed a significant difference between groups for ownership of a parking pass for the university. U were less likely to own a parking pass compared to NU (U = 33% owned vs. NU = 68% owned, Fisher's Exact Test; $p<0.021$).

All U were aware of the trail while only 76% of NU knew of the trail, which was statistically significant (Fisher's Exact Test, p<0.005). U reported taking less walking trips compared to biking trips (2.5 ± 1.7 trips vs. $6.8\ 8 \pm 4$; t = -3.361, p < 0.006). For commute time, U reported that walking the trail took longer with an average of 36.7 ± 10.8 minutes than bicycle trips at 12.2 ± 3.5 minutes (t = -10.551, p < 0.001).

A significant difference was found for the number of any AT trips taken per week (including those using the trail) and for the commute time of these trips between groups. U took 7.4 ± 6.0 active trips/week while NU took 3.4 ± 3.2 active trips/week (t = 3.117; p<0.003). NU reported a shorter commute time (14.1 ± 5.9 minutes) for these trips compared to U (23.9 ± 14.6 minutes) (t = 3.183; p<0.003), which suggests that U were willing to walk farther distances than NU.

Psychosocial Correlates

The attitudes towards walking and biking are found in Figures 11 and 12, respectfully. While a difference in the overall attitude towards AT was not found between groups, a mild negative correlation was found for combined attitude score and their age (r = -0.285, p < 0.045). For walking, both groups had nonsignificant, favorable attitudes with a mean score of 4 or better on all factors. There was one factor rated lowest by both groups: believing that walking was "Time Saving." Each group rated this category about half of the other categories (U = 1.9 ± 1.0 vs. NU = 1.8 ± 0.7), but the groups were similar to each other.

The U group had a more favorable overall attitude of biking compared to NU (U = 3.9 ± 0.6 vs. NU = 3.6 ± 0.6, t = 2.105; p<0.041). U were also more likely to report that "Biking is safe" (U = 3.8 ± 1.1 vs. NU = 3.1 ± 1.2, t = 2.215; p<0.032 and "Biking is easy" (U = $3.8 \pm$

0.9, vs. NU = 2.8 ± 0.9, t = 4.082; p<0.000) compared to NU. Additionally, a mild negative

significant correlation was found between the age of participants and their overall bike attitude (r

= -0.360, p < .010).

The social support for modes of AT are found in Table 8. Participants did not report high

social support for modes of AT as no mean score for any individual item was greater than 3.1.

No differences were found between groups in any items for walking or biking social support.

The score for biking was slightly higher than their social support for walking but no difference

was found between groups.

Environmental Awareness

While a difference between groups in overall mean score (p< 0.140) for environmental

awareness was not found, there were some differences in specific items (Table 9). U more

strongly believed that "climate change is a serious problem" (U = 4.6 ± 0.7 vs. NU = 3.7 ± 1.1, t

= 3.520; t = 3.520 p<0.001) and that "bicycling or walking in place of car use is helpful to

protect the environment" (U = 4.7 ± 0.6 vs. NU = 4.2 ± 0.8, t = 2.584; p<0.013) compared to

NU. Their attitudes towards food-related environmental factors were not different between

groups. A mild negative correlation for overall environmental awareness was found for

participant's BMI (r = -0.329, p <0.023)

Motivation and Barriers

The reported motivators for AT use on the trail are reported in Table 10. For U, the top

three motivators to increase use of AT via the trail from first to third were to "be offered a cash

incentive (e.g. lower parking fee) for walking or biking rather than driving to" the university,

"increase in lighting along the trail", and "another person to cycle/walk with." The lowest ranked

included from eleventh to thirteenth "signs to show me where to go", "more specific information

about how long it takes to walk or bike to" the university, and "have a financial penalty for driving such as higher parking fees at" the university. For NU, the top three reported motivations to increase use of AT via the trail from first to third were "be offered cash incentive (e.g. lower parking fee) for walking or biking rather than driving to" the university, "signs to show me where to go", and a tie for third between "another person to cycle/walk with" and "increase connection with buses so I could ride bus one-way and walk/bike the other." This group's lowest ranked motivators from eleventh to thirteenth were "Better parking/storage for my bike", "Have financial penalty for driving such as higher parking fees at" the university, and "other."

NU were asked to rank their top five reasons for not using AT via the trail from a list of options provided. The top five reported barriers (Table 11) reported from first to fifth were that AT via the trail "takes too much time for commute", responders needed "to carry too many things", that the "weather makes it unreasonable", they worried they would "be sweaty when" they got to work, and that they needed "to do errands before/after work." The lowest barriers ranked included "I would be embarrassed", "the trail is unpleasant", "the surface of the trail is uneven", "inadequate places to park my bike at" the university, and "it is too dusty on the trail."

Discussion

The purpose of this study was to determine commuting habits and the reasons for and barriers to student of a 1.9-mile trail for active commute that connected a major residential area to a large college university. This can help provide potential interventions to increase the trail's use. This study showed that over 500 people are on the trail each day and is mostly associated with being used for commute purposes. The users of the trail had a better attitude toward biking and were more likely to see a connection between AT and the environment than those who did nott use the trail. Both U and NU participants also received little encouragement from their social

circles to use active commute. Primary barriers to use of the trail for active commute for NU were practical issues related to time and convenience. Both U and NU were motivated by financial incentives while trail improvements and signage were motivating for additional use by U and NU, respectively. These insights could be used to create tailored interventions to increase the use of AT to the university via the trail, increasing student's daily physical activity levels and reducing the negative consequences of personal vehicle use.

Counter Data

Data generated from the counters indicated regular use of that trail throughout the study duration. When separated by mode, more pedestrian traffic was found at Counter B during the weekday for both the Spring and Summer Semesters. This may be explained by the multiple entryways to access the trail with pedestrians entering the trail beyond Counter A from locations other than the study community. More bicycle traffic was found at Counter A during the weekday for both the Spring and Summer Semesters. This might be explained by the multiple routes that could be taken by cyclists entering the trail from the community going to destinations other than the university. At one intersection, users have the choice to continue towards the university, or access three other routes. Another potential reason for this greater cycle count on the counter near the community could be that students are using the trail for recreational purposes whereby they go through Counter A and return to the same counter without going through Counter B at all.

During the Spring Semester, the maximum temperature was found to have a moderate, positive influence on the total amount of traffic on the trail during the weekday at Counter A. Temperature has been shown to influence trail traffic as Wang et al.[35] tracked bicycle and pedestrians at six different locations in Minneapolis, MN using infrared counters while also

tracking weather data. The researchers reported that an increase of 1°C would increase trail traffic by 8.5%. Because temperature was only correlated with Counter A during the weekday, this could mean that the maximum temperature influenced whether people would use this part of the trail for recreational purposes. Users may have been more likely to make a loop as temperature increased, entering and returning to their residence from this location. Additionally, some may be deterred to active commute in the morning since the maximum temperature wouldn't be reached until later in the day. While surveying 64 students at three different universities in Australia, Nankervis[36] found that cyclists rated riding in the cold as more of a deterrent than riding in warmer conditions. Thus, individuals may not choose to active commute if they believe it is cold that morning. If this were the case, it may be beneficial to educate users on how they could reach campus through alternative transportation in the morning, and then active commute home later in the day.

Throughout the study duration, precipitation fell on 47% of the Spring Semester days and 60% of the Summer Semester days. During the Spring Semester, the amount of precipitation had a moderate negative influence on traffic during the weekday at Counter B. Further analysis showed that only weekday pedestrian traffic at this location was significantly associated with precipitation with a negative trend (nonsignificant) found for bicycle traffic. The decrease in traffic caused by precipitation is in agreement with other studies.[35,37-39] While tracking non-motorized traffic at 259 locations in Minneapolis, MN from 2007 to 2010, Hankey et al.[37] found that precipitation decreased pedestrian and bicycle traffic by 13.9% and 15.0% respectively. Another study by Lindsey et al.[16] measuring the use of five trails in Indianapolis, IN found that use decreased by almost 40% for each inch of precipitation above average. One reason why bicycle traffic was not significantly influenced in our study is that cycling commute took only an

average of ~12 minutes meaning cyclists would spend less time in the rain compared to walking the trail. While inclement weather leads to decreased non-motorized traffic, it may be that an individual's perception of the weather is the determining factor in deciding whether to use AT or not. Nankervis[36] compared weather data to the number of parked bikes on three different universities in Melborne, Australia while also surveying a sample of 64 students. He found that weather slightly affected the number of parked bikes on campus and that students listed many alternative options they could use in place of biking in inclement weather. However, 75% indicated they wouldn't change their mode of commute in inclement weather. From this, Nankervis[36] argued that the perception of the weather may be the deciding factor when determining if someone will commute via bicycle, rather than the actual weather itself. If this were true, at our location, educating residents on the strategies that could be used to active commute in inclement weather may help overcome that barrier.

Survey

In this study, U were more likely to use AT for other trips beyond commute on the trail as U took twice as many total trips via AT and spent 70% more minutes per week on active transport than NU. It is possible that the longer duration of AT per week in U is secondary to farther AT distances. Indeed, a high percentage of NU listed "the time it took to commute using AT" as a top reported barrier. This, with the shorter minutes per week of AT suggests that NU have a lower acceptable distance for AT.

We collected psychosocial and environmental variables in order to understand why students used or didn't use the trail. Interestingly, both groups reported a very favorable attitude towards walking with the exception of walking as "time-saving." Indeed, U reported that it took three times as long to walk the trail compared to biking and took over twice as many bicycling

trips to the university compared to walking trips as a result. Because of this commute time difference, biking may be the mode to encourage for those listing "takes too much time" as a barrier. The time it took to commute was also the top reported barrier by NU. Analysis of the 2001 and 2009 National Household Travel Survey revealed that the mean duration of walking trips in the U.S. was 16.4[40] and 14.9[41] minutes with an average distance of close to 0.7 miles for both surveys, less than half the distance of the trail we studied.[40,41] Even though attitudes towards walking were high among both groups, it may be that students perceive 1.9 miles as too long of a distance that involves too much time. Thus, the distance of this trail may be beyond what most people are willing to walk for commute. The goal proposed by Healthy People 2020 is to increase the amount of trips via walking that are 1 mile in length[42] and could further indicate that any trip over 1 mile is viewed as an unreasonable walking distance by Americans. Additionally, while the trail does bring students to the university, the trail length underestimates trip length since students may have additional walking required to get to their ultimate campus location. For these reasons, encouraging biking to campus may be the strategy for students concerned with the commute time it takes to walk.

NU were less likely to believe that bicycling was safe compared to U. This is in agreement with other studies involving bicycling for active commute.[27,43-46] NU may feel uneasy around vehicle traffic as a national survey by the U.S. Department of Transportation revealed that of cyclists that felt threatened during their last bicycle trip, 83% acknowledged motorists as the primary reason.[44] From this sample, 39% thought that vehicles were too close to the cyclists and 24% worried about how fast vehicles were moving.[44] Furthermore, Whannell et al.[47] surveyed students at a regional Australian university and found that perceived route safety was the biggest factor on determining if a student decided to use a bicycle to commute. It should be

noted that this trail is free from vehicle traffic, however it may be that NU are unaware of this as ~24% of them weren't aware of the trail's existence. Thus, interventions focused primarily on raising awareness of the trail and bicycling may have the biggest impact on an individual's choice to use any form of AT. Despite this, some NU may face vehicle traffic once exiting the trail, depending on their final destination. For these people, providing a sign on the road indicating motorists must share the lane may help increase perceived safety. Hess and Peterson[48] surveyed individuals to determine which type of sign would raise motorists' awareness of cyclists and perceptions of cyclists' safety. Participants indicated that the sign saying "Bicycles May Use Full Lane" was the most understood by individuals and increased the perception of the cyclist's safety compared to the other signs presented ("Share the Road" and sign indicating shared lane markings"). A sign like this could be placed around university roads, possibly increasing cyclists' perception of safety when traveling with vehicles. Changes to the physical environment, such as adding protected bike lanes, could also help separate cyclists from vehicle traffic and increase its use for commute. A report evaluating the impact of adding protected bike lanes in five large U.S. cities found that bicycle use increased anywhere from 21% to 171%.[49] Therefore adding bike lanes could make biking for commute more attractive to students.

In our study, NU believed cycling was more difficult compared to U. This could mean that being uncomfortable operating a bicycle may be a barrier to using AT via the trail. Citing lack of skills for cycling has been expressed by others.[50,51] An intervention involving bike lessons and education could be explored as a way to overcome concern about safety and ease to increase AT via this trail. Telfar et al.[52] evaluated the impact of a pilot program designed to increase bicycle skills and education for adults in Sydney, Australia. Participants reported higher confidence and knowledge of bicycle skills, increased non-cycling physical activity, and over

half continued to cycle during a 2-month follow-up. Additionally, non-cyclists before the program reported cycling for about 40 minutes a week after the intervention.[52] Interventions like these could be applied and increase self-efficacy and social support in NU, possibly creating a more positive attitude towards bicycling. This could be important as having a positive attitude towards biking was reported to influence its use for AT by Handy et al.[27] The researchers used a 3-point Likert scale to measure perception of biking comfort across six bicycle friendly cities and found for that every one point increase on the scale, participants were eight times more likely to use a bike for commute. Without a positive attitude towards cycling, individuals may not believe that active commute is an option since walking may be rejected due to length of commute. Interventions focused on making individuals more comfortable are likely to improve use of this trail for active commute.

Age was negatively associated with the participants' overall attitude towards biking. This is in agreement with other research at colleges and universities.[53,54] Ransdell et al.[54] assessed cycling prevalence at a large northwestern university and found that students were 0.05 times less likely to cycle for transportation for each year their age increased. Lemiuex and Godin[53] also studied 130 students at a university in Quebec and found that the older the students were, the less likely they were to use AT. It remains to be definitely determined why this trend is seen across the literature but mediating factors could be an increase in responsibilities, as suggested by Lemieux and Godin[53]; a busier lifestyle could rely more on car use and the time saved by using a car may be valued more than potential benefits of AT. An individual may have others in the household (children or significant other) that need attention. Our study does not shed light on this hypothesis since few (only 12%) reported that they had children in the household.

We did not find any differences in social support for active commute between groups. Most studies in the literature find that social support is related to use of active commute.[50,55,56] In a study done by Kaczynski et al.[57] on AT patterns among adults working full-time or part-time in Manhattan, KS, receiving more cultural social support (encouragement from their employer and/or perceiving coworkers using AT) was associated with an increased likelihood of using AT to work. De Gues et al.[50] found that adult cyclists in Flaunders, Belgium living <10 km (about 6.2 miles) from their workplace were more likely to report receiving social support for bicycle use compared to non-cyclists. Cyclists were more likely to receive social support from having a cycling partner and were more likely encouraged and accompanied by their significant others. However, the average age of the participants in those studies were much older (~40 year old)[50,57] as our study was made up of a physically active, college student population with an average age of 24. While the age of the populations differed compared to ours, social support was measured in comparable formats with a Likert scale and the scores for our study and the others are similar and generally low.[50,57] In this study, average scores for social support were below a 3 across all variables with one exception ("the university does things to encourage me to bike to campus" by NU). It could be that social support for using AT is so low for all individuals studied that it has no predictive value. However, both U and NU indicated the importance of social support by listing the need for a traveling partner as a motivator to use AT. Thus, improvement of social support for active commute on this trail may increase trail use and reduce driving to campus. Potential strategies to increase social support for AT use via this trail could include having a semesterly or monthly bike to class day to campus.[6,27] This could increase their experience, give them perspective on time required, and impact perceived social support for active commute. This may also stimulate students to consistently use AT as Rose and Manfurt[58] found that 27% of first

time participants in a Ride-to-Work Day in Victoria, Australia continued to bike to work five months after the event. In a review by Pucher et al.[59] it was reported that a 2008 Bike To Work Event in San Francisco caused bicycle counts to increase by 25.4% several weeks later compared to before the event. Also, Bopp et al.[6] suggested forming a club centered on using AT on a college campus to increase social support and acceptance. Adapting these interventions here could also increase the likelihood of an individual finding a travel partner, which may also influence perceived social support.

U were more aware of climate change as a problem and saw the value AT has a partial solution in reducing climate change compared to NU. This is in agreement with other research done on adults at college campuses and at the workplace.[21,50,60] While our study population was made up of college students, the importance of providing education on climate change and its connection with AT (reducing greenhouse gas emissions and other pollution) may be of interest. Bopp et al.[21] surveyed adults in the college town of Manhattan, Kansas and found that those with higher eco-friendly attitudes were four times more likely to use AT compared to those with low eco-friendly attitudes. The researchers also found that eco-friendly attitudes were associated with higher self-efficacy for AT and this could mean that environmentally friendly attitudes could motivate users to address any barriers related to AT such as poor bike skills.[21] Educating NU through classes or by providing handouts with information may be an option. For the latter, flyers could be placed in common areas of apartment complexes. Another suggestion would be to place information on the trail and potential benefits in any welcome packet that a new tenant receives since tenant turnover may be high at this community due to the student population.

Participants from both groups indicated that being offered a cash incentive would be their top reason for doing more active commute via the trail. Parking on college campuses is difficult

as the number of people attempting to park on campus is greater than the number of parking spots available. This is exemplified by Shannon et al.'s[61] study which estimated that 4,137 students and 2,490 staff tried to park on or near a university campus each day but only 4,236 parking spaces existed. Citing the potential frustrations of parking on campus (unable to find a parking spot, traffic congestion, etc.) has the potential to be used as a selling point to increase AT. Bopp et al.[21] reported that adults living in a college town were motivated to use AT more due to the costs associated with buying a parking pass and the traffic congestion in the morning and evenings. Additionally, difficulty parking was associated with more AT use in that study and another study done by Bopp et al.[6] that studied students and faculty/staff in a university setting. Educating participants on nullifying these frustrations through AT use via the trail and other motivators (such as saving money on gas) may be beneficial to increasing its use. However, Kaplan[43], in a study examining transport sustainability at Kent State University, noted that while students complain about campus parking, the ownership of a parking permit makes sustainable transportation a "matter of choice." In our study, about 70% of NU owned a parking pass; driving to campus may be important and convenient to this group. While the university offers a free transit system for travel to campus, driving to campus allows students to be unrestricted to the bus schedule, or the risk of a full bus. Making AT a necessity, instead of a choice may offer a solution. This could be achieved by limiting the number of parking permits given to students, forcing students to look into alternative options, such as AT. Another strategy to disincentivize driving is by increasing the fees for parking passes. Brockman and Fox[62] evaluated employees' transportation habits before and after a new transport plan was introduced at University of Bristol in the UK in 2000 through a travel survey. This new plan included reducing the number of parking spaces and conditions for acquiring permits as well as increasing parking fees, among

others improvements. From 1998 to 2007, it was found that these changes were associated with an increase of 11% and 5% of those regularly walking and biking to work, respectively, and decreased regular car use by 17%. Kaplan[43] surveyed students at Kent State University and found that increased parking fees would cause some to shift their transportation mode. Initiating interventions similar to these may result in more students opting to use AT, increasing physical activity, and decreasing car use. Additionally, if this intervention was explored, the announcement that changes to the parking system are going to be made may stimulate students to change their modes of transportation immediately in preparation for increased costs and decreased parking access.

U highly rated improving the lighting on the trail as something that would increase their use of active commute. College students may stay on campus past regular work-day hours in order to attend meetings or study groups, forcing them to travel in the dark, which may impact their feeling of safety. Wolch et al.[63] examined determinants of trail use for three trails in Chicago, Dallas, and Los Angeles and found that increasing perceived safeness of the trails would have the biggest influence on non-users to start using them and would result in close to an hour of increased use by current trail users. The addition of street lights could be added along the trail to provide better lighting and improve feelings of safety. Painter[64] examined the impact of improved lighting at three poorly lit and run down streets in London, England through intercept surveys and tracking crime and disorder incidents six weeks before and after the intervention. At two locations, 62% and 69% of interviewed people reported feeling safer after the lighting was improved. Reported crime and disorders was reduced by 77% and 82% respectively. At one location, when asked why users felt more safe, 83% cited the improved lighting.[64] The presence of streetlights may also influence trail usage in other ways as Reynolds et al.[65] examined

correlates of three different trails in Chicago, Dallas, and Los Angeles during daylight hours and found that the presence of streetlights was associated with more trail use. The researchers argued that presence of street lights influences the perception of the trail design, creating a more positive association with the trail.[65] Streetlights may be associated with aesthetics and help indicate that an area is well-maintained.[65] A recent review by Frost et al.[66] looking at the built environment's impact on physical activity in adults living in rural areas found that aesthetics was associated with increased physical activity and another study by Kirby et al.[67] found that aesthetics was associated with increased walking minutes per week. Thus, adding street lights could improve the attractiveness and perceived safety of the trail, stimulating people to use it.

In our study, a substantial proportion of NU indicated that they would like signs with directions on how to reach campus via the trail. A simple way to address this is to place signs that provide an overview of the trail with directions to and from the university at each entrance. Distance and time estimates could be included as 72% reported time as a barrier to commute and lack of time is often a top reported barrier to AT and physical activity.[21,43,50,53,55,68] Providing this information can be beneficial as Mutrie et al.[69] performed a study analyzing the effectiveness of a work site intervention where participants were given a packet of information that included maps with distances and time estimates to locations around the town of Glasgow, Scotland. The intervention group was 1.93 times more likely to increase their walking time to work and follow up focus groups revealed that the maps were "very useful."[69] Fredrick et al.[70] interviewed travelers at the Atlanta airport to determine why they rode the terminal train instead of walking to their departure gate. Almost 24% percent said they were unaware of walking as an option while about 14% rode the train because others did so. The research team then developed an intervention where signs were placed next to the trains with the estimated walk commute time to

each terminal, and found that walking to terminals increased by 10% in a 6-month follow up.[71]

Providing signage is also one of the least expensive interventions. For example, free signs can

be produced and downloaded from the "Walk [Your City]" website. The campaign is built on the

idea of placing signs with time estimates to central locations in towns and case studies done in

college towns have received positive feedback.[72] Simple interventions like these could be

incorporated for this trail, potentially stimulating its use for active commute.

Signs linking active commute using the trail with physical activity may also be effective

at motivating NU. A review by Sallis et al.[73] on environmental interventions to increase physical

activity found signs that were placed next to stairs encouraging their use over the escalators

doubled stair usage. Additionally, awareness of the trail should be raised as 24% of NU were

unaware of the trail and this could be done through a marketing campaign. Clark et al.[74] assessed

trail usage of ten trails after an intervention aiming to increase trail use: five received a

marketing campaign encouraging trail use; five received a marketing campaign and signage with

a trail map. Trail usage increased by 31% and 35% respectively (the increases were not

significantly different from one another).[74] The residential managers of the development could

aid in raising awareness through a marketing campaign and promote the trail on their website,

listservs, social media platforms, and advertise at any local events. Information designed to raise

awareness of existing bike programs/faculties that the university already offers could also be

included here.

Other barriers reported by NU include convenience issues such as the need to carry many

items, the weather, being sweaty, and errands before or after work. Most of these are in

agreement with other research done on AT at college campuses and elsewhere.[21,43,55,61] Helping

students problem solve may help them overcome their concerns. For example, a potential

intervention for those worried about carrying items while commuting could be to inform students where they could buy accessories for their bikes, such as bike rack carriers. Educating students on bringing small towels with them to wipe off sweat and where they can shower on campus could also be explored. To address the need to run errands, one long-term suggestion by Handy and Yang[27] includes creating additional pathways for active commuters to access other mix-land use buildings. Connection of the trail to other commercial buildings may allow students to run a few errands prior to or after class.

Evaluating the public health impact of suggested interventions in this section is beyond the scope of this paper. However, strategic planning through an implementation framework is recommended to ensure the internal and external validity of the best-fit interventions. This could be done by using the RE-AIM framework (R = reach, E = effectiveness, A = adoption, I = implementation, M = maintenance).[75] This framework would allow for the identification of potential stakeholders in this community, what agencies are responsible for implementing any suggested interventions, and determine what funding is needed to implement and maintain interventions.[76] Currently, focusing on reach should be the main priority. For example, in this residential community the turnover rate of the residents is likely to be high in a college town, and data collection on students may need to be on-going in order to address new concerns by new tenants. A potential stakeholder to create a relationship with could be residential management. Raising their awareness of issues we found could be beneficial in enlisting their participation.[76] This could be down by sharing what we found in our survey and convey how addressing student's concerns about the trail could benefit them (i.e. have more students apply to live in their neighborhoods). Furthermore, this relationship may allow us to address any problems management has in regards subsequent data collection and develop alternative methods to ease

their concerns and capture this information. This would be beneficial in that it could help determine how to obtain a representative sample of the residents and create a larger sample size. This would also allow for management to provide feedback on any suggested interventions as well.

Although important information was determined from our study, some limitations exist. Our study was a cross-sectional design and relied on self-report measures allowing for over or under reporting for different variables. The low sample size is also modest meaning that our findings may not extend to the total population of the residential area or the university. Since participants were allowed to leave questions blank, some outcomes had sample size than others. Due to our modest sample, no regression model was computed and therefore we are not able to determine weighting of variables on their influence for using AT. Despite these limitations, much of the research related to AT on college campuses addresses attitudes towards all AT use while this study focused on active commute using a specific trail that has ideal characteristics for active transport to a large university campus. This allows for the development of tailored interventions to address students concerns who live in this community which could provide a greater likelihood of increasing trail use and physical activity. The data generated may also be able to be applied to other universities that have an existing trail suitable for active transportation.

Conclusions

Active transportation research on college campuses has been focused on the attitudes towards it use as a whole and not on attitudes towards routes that are conducive towards its use. This study adds to the literature by determining the use, motivators, and barriers towards active commute on a specific, user-friendly trail, that connects a student population to their university.

This is needed to determine potential specific interventions for increasing active commute. Overall, non-users may less positive attitudes towards biking for commute while users may use active commute because they were more likely to see the value in active transportation as a partial solution to climate change. Both groups were interested in finding a travel buddy to commute with while those using the trail were interested in trail improvements and non-users were interested in more information about the trail and estimated time of commute. Based on this information, many interventions can be proposed to address barriers and further motivate students to use the trail to commute to the university, such as a "bike to class day", adding signage with trail information, and improving trail lighting. Steps, such as involving residential management, could be taken in order to help ensure the success of any intervention that is implemented. The findings here may be able to applied to similar universities that have trails connecting residential areas to campus and add to the existing body of research on active transportation use. Future research could include placing the counters on the trail for a full academic calendar year in order to determine how season and climate change affect its use. Interventions mentioned could also be developed and applied. The counters could be used to provide an objective measurement on trail use before and after in addition to other follow-up surveys.

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Figure 1. Counter A weekday average hourly traffic pattern from last seven weeks of spring semester
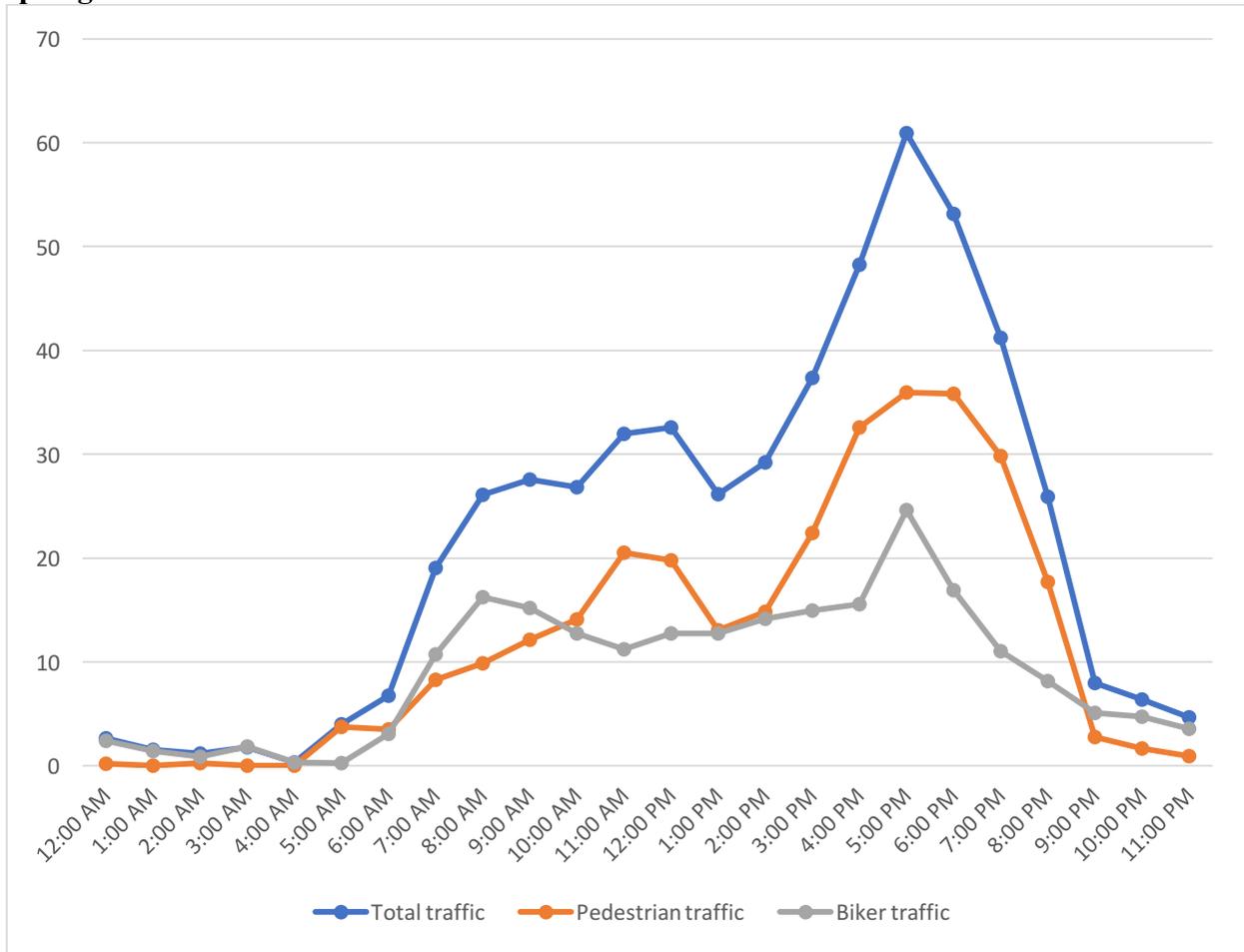
Figure 2. Counter A weekend average hourly traffic pattern from last seven weeks of spring semester
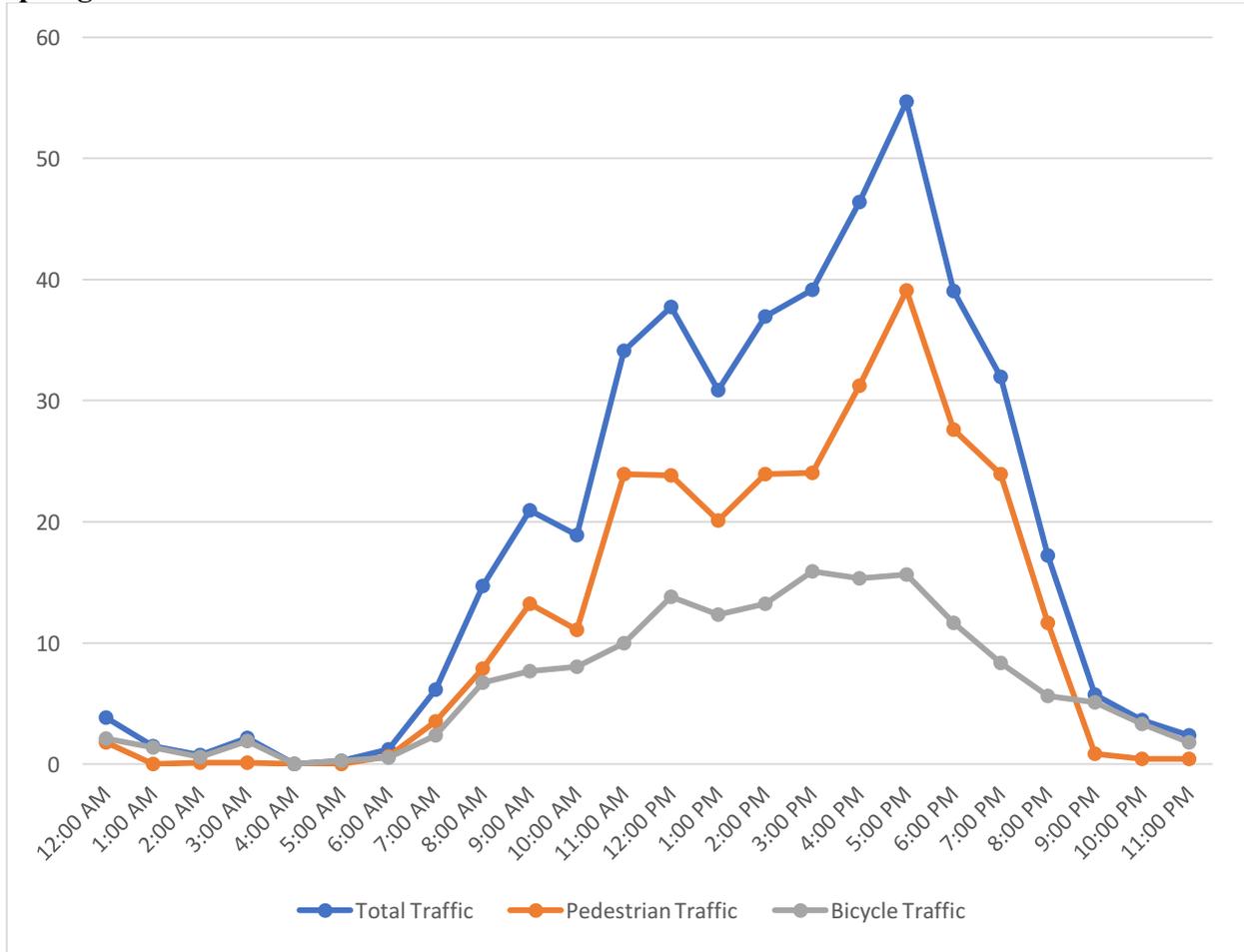
Figure 3. Counter B weekday average hourly traffic pattern from last seven weeks of spring semester
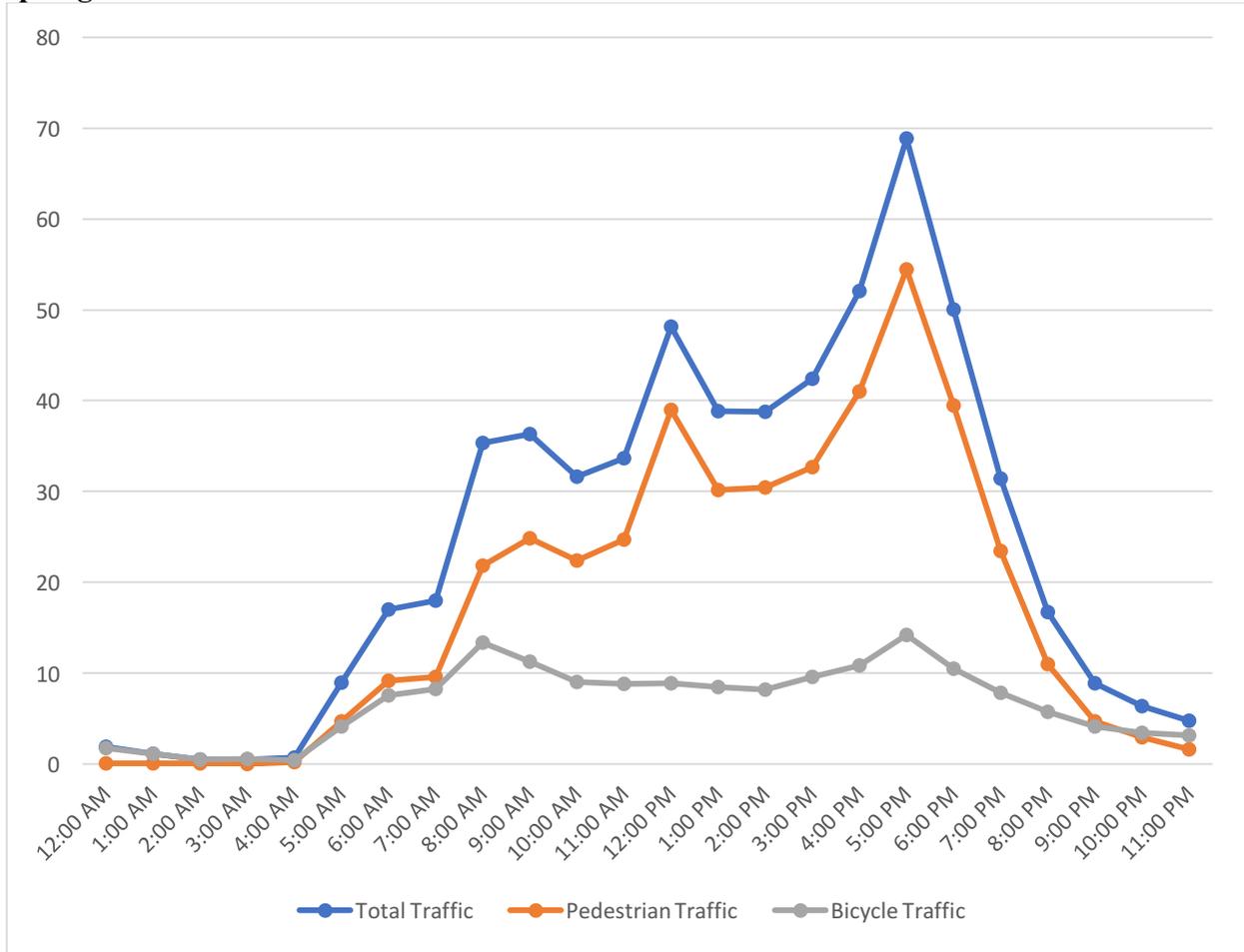
Figure 4. Counter B weekend average hourly traffic pattern from last seven weeks of spring semester
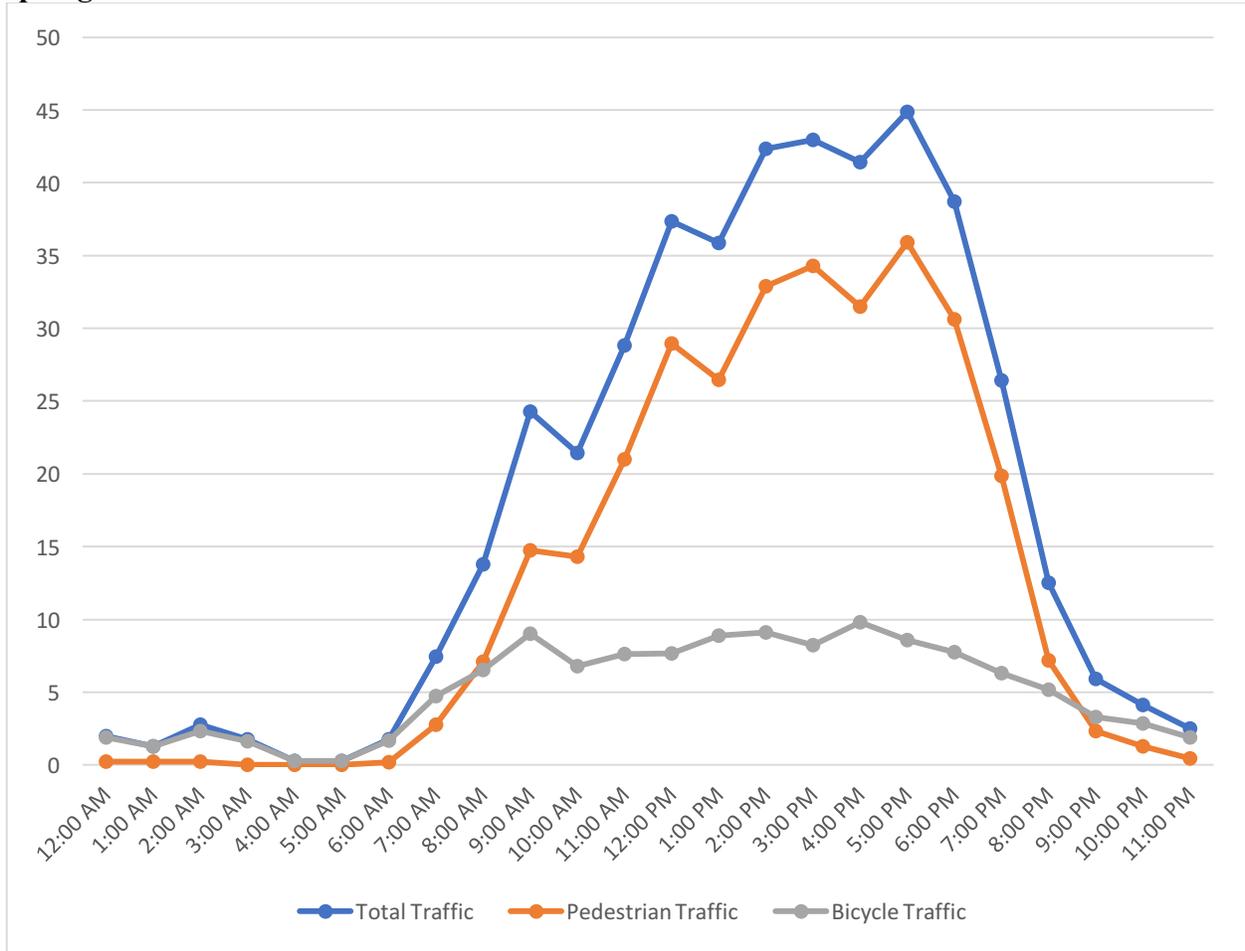
Figure 5. Counter A weekday average hourly traffic pattern from first ten days of summer semester
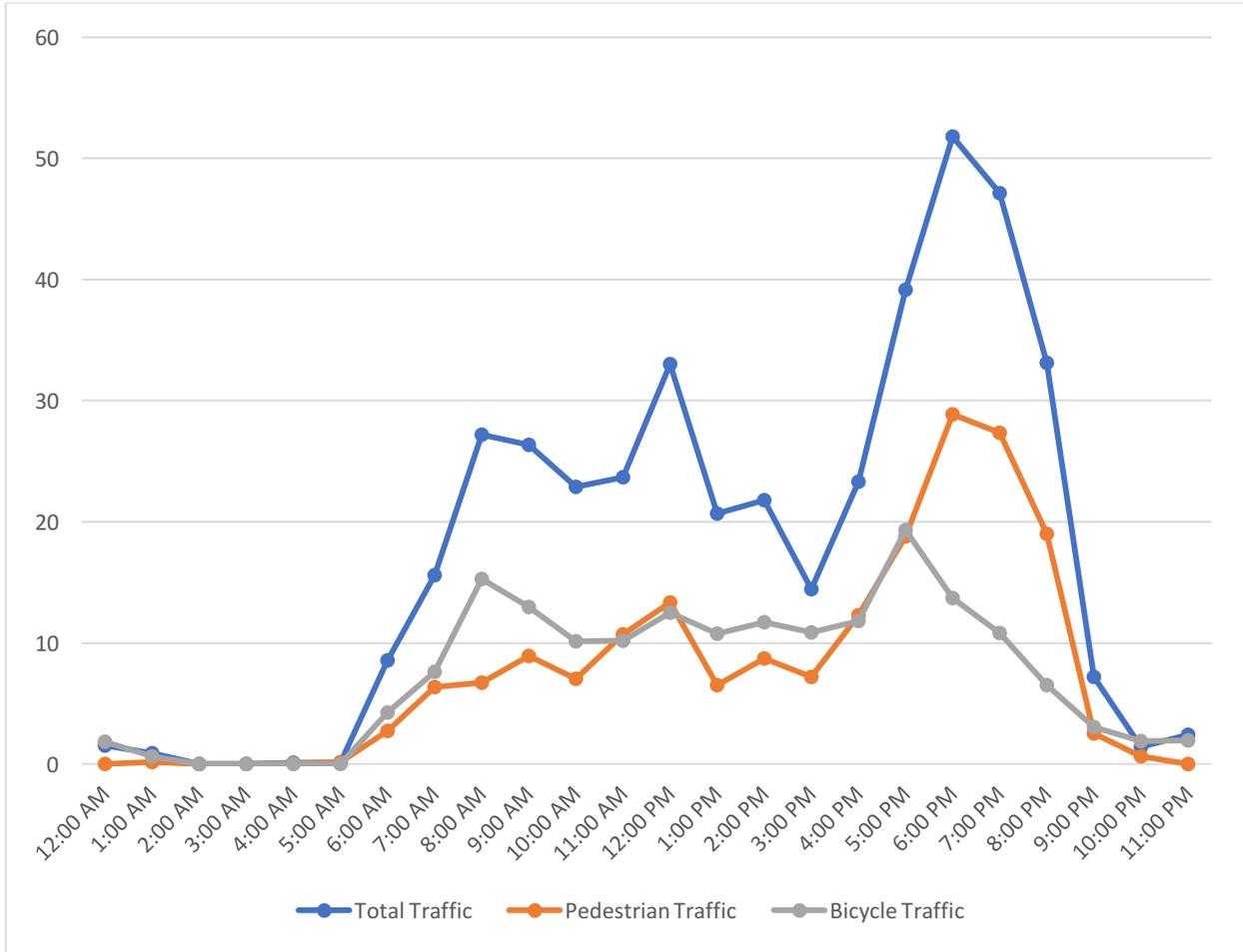
Figure 6. Counter A weekend average hourly traffic pattern from first ten days of summer semester
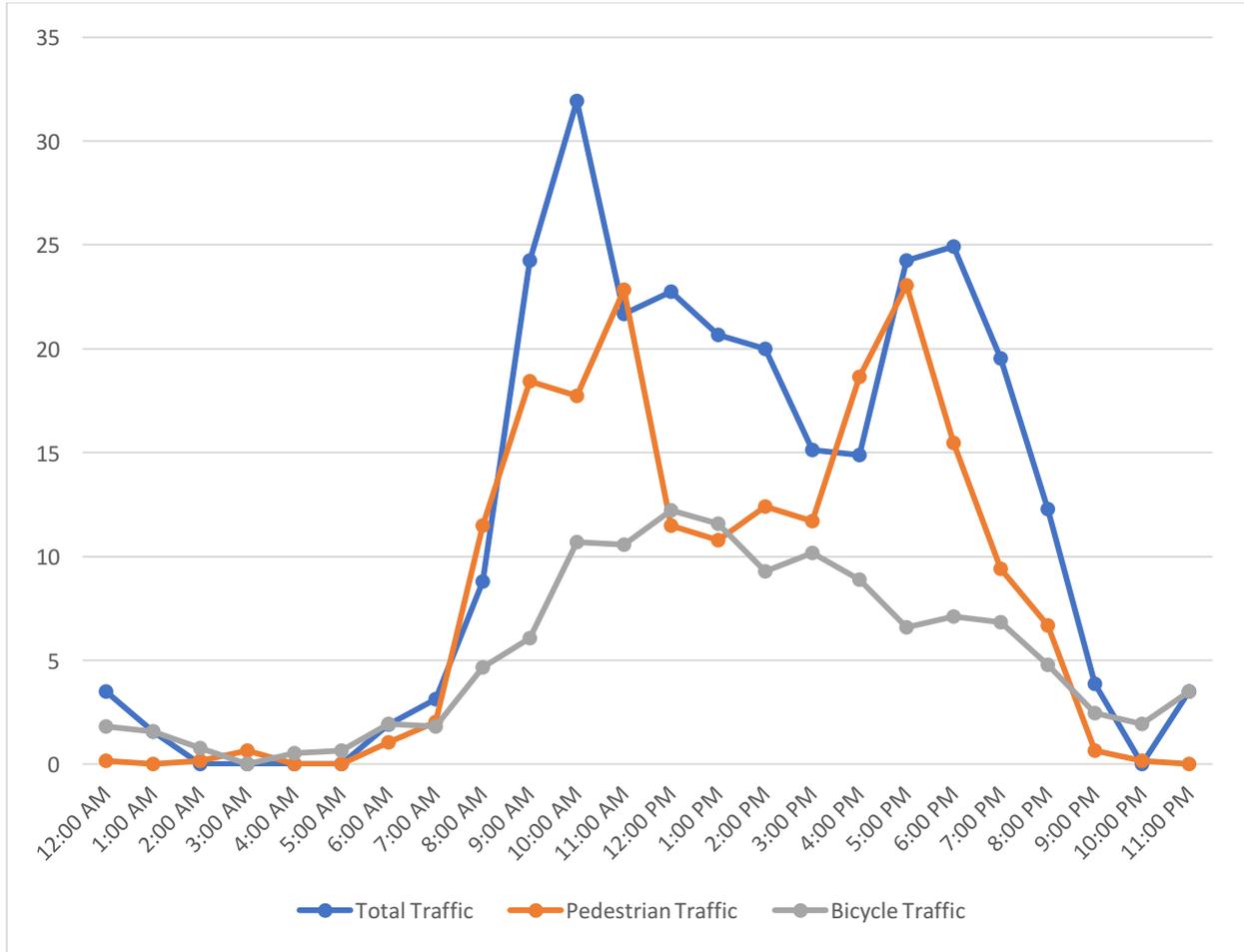
Figure 7. Counter B weekday average hourly traffic pattern from first ten days of summer semester
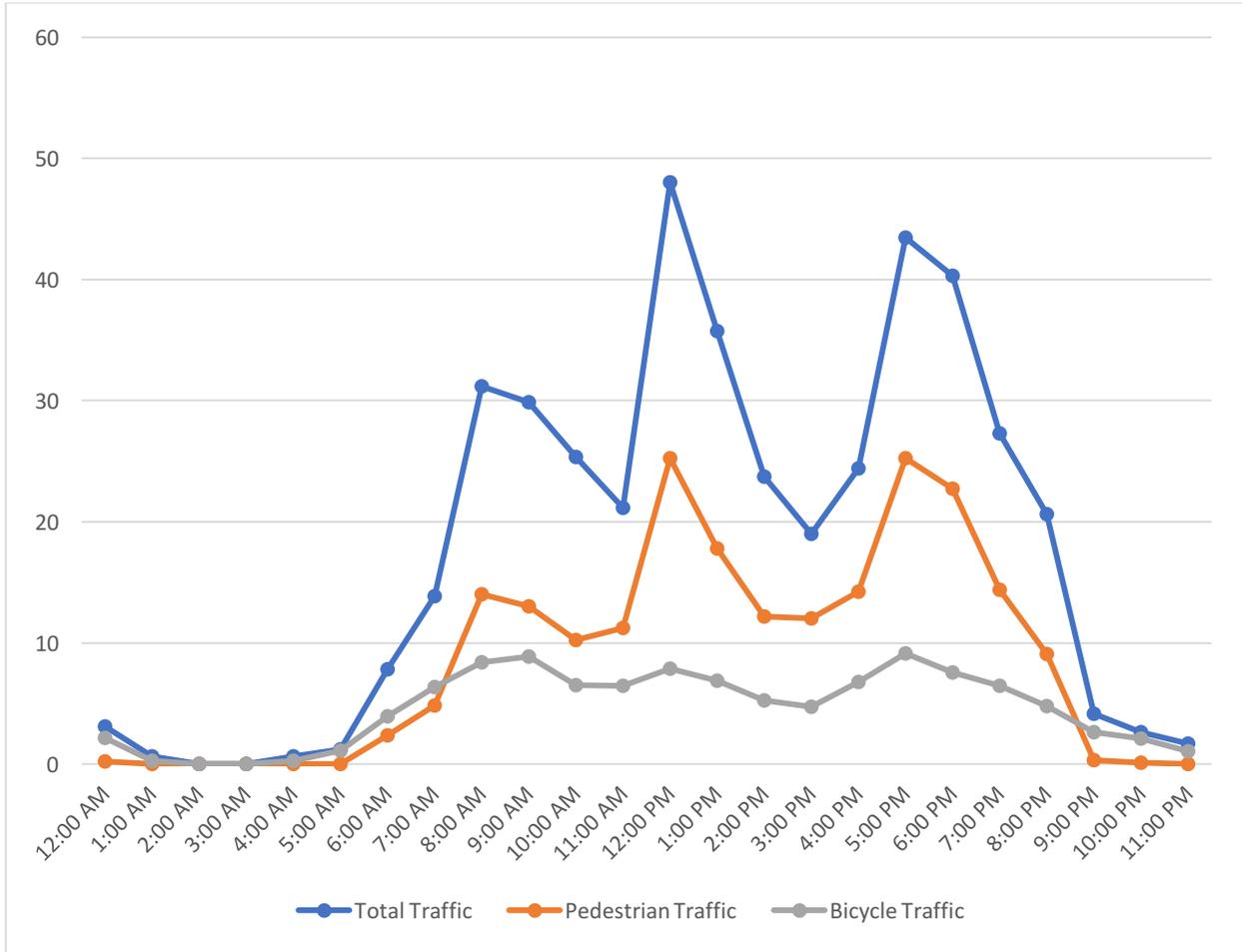
Figure 8. Weekend:weekday average adjusted ratio from last seven weeks of spring semester
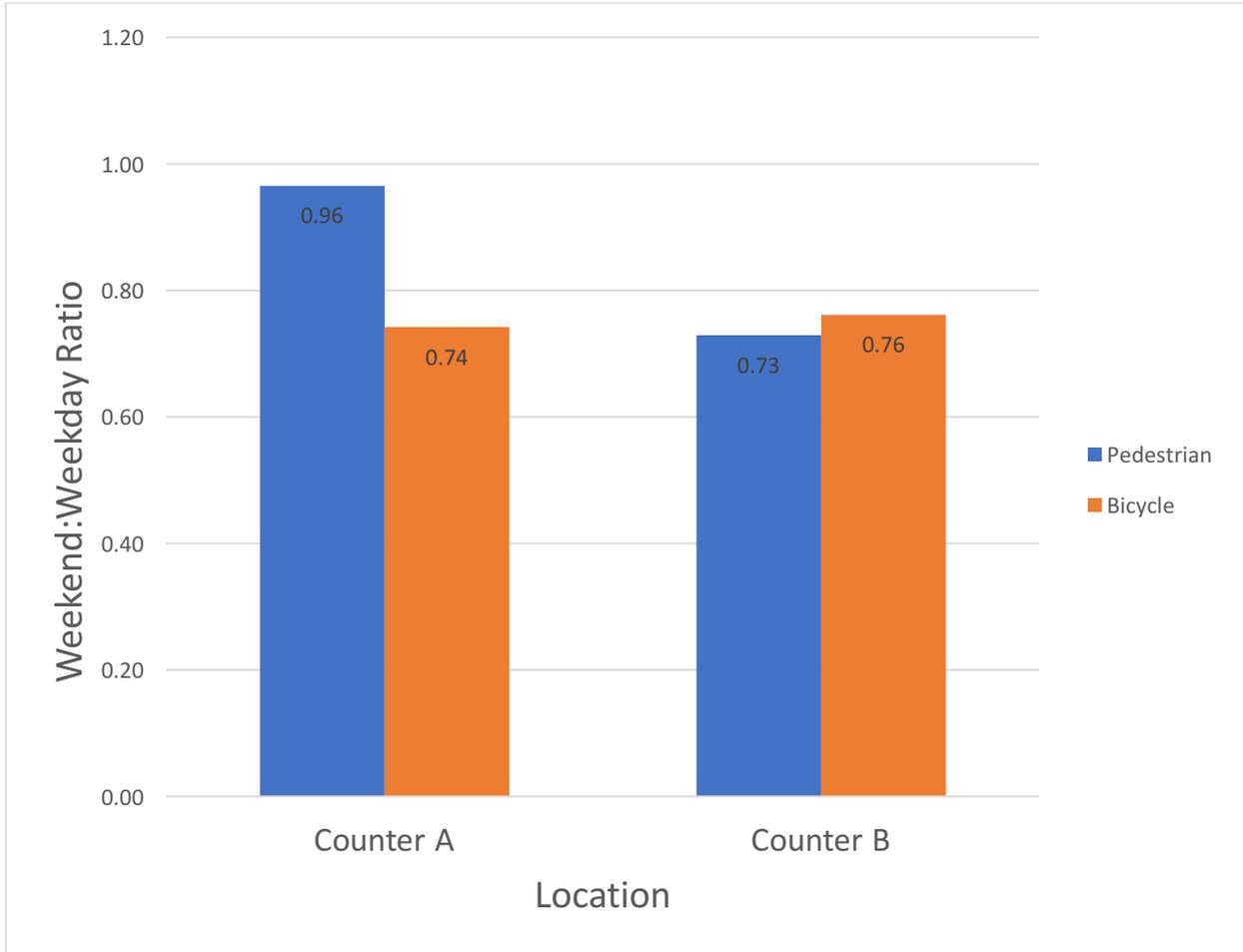
Figure 9. Weekend:weekday average adjusted ratio from first ten days of summer semester
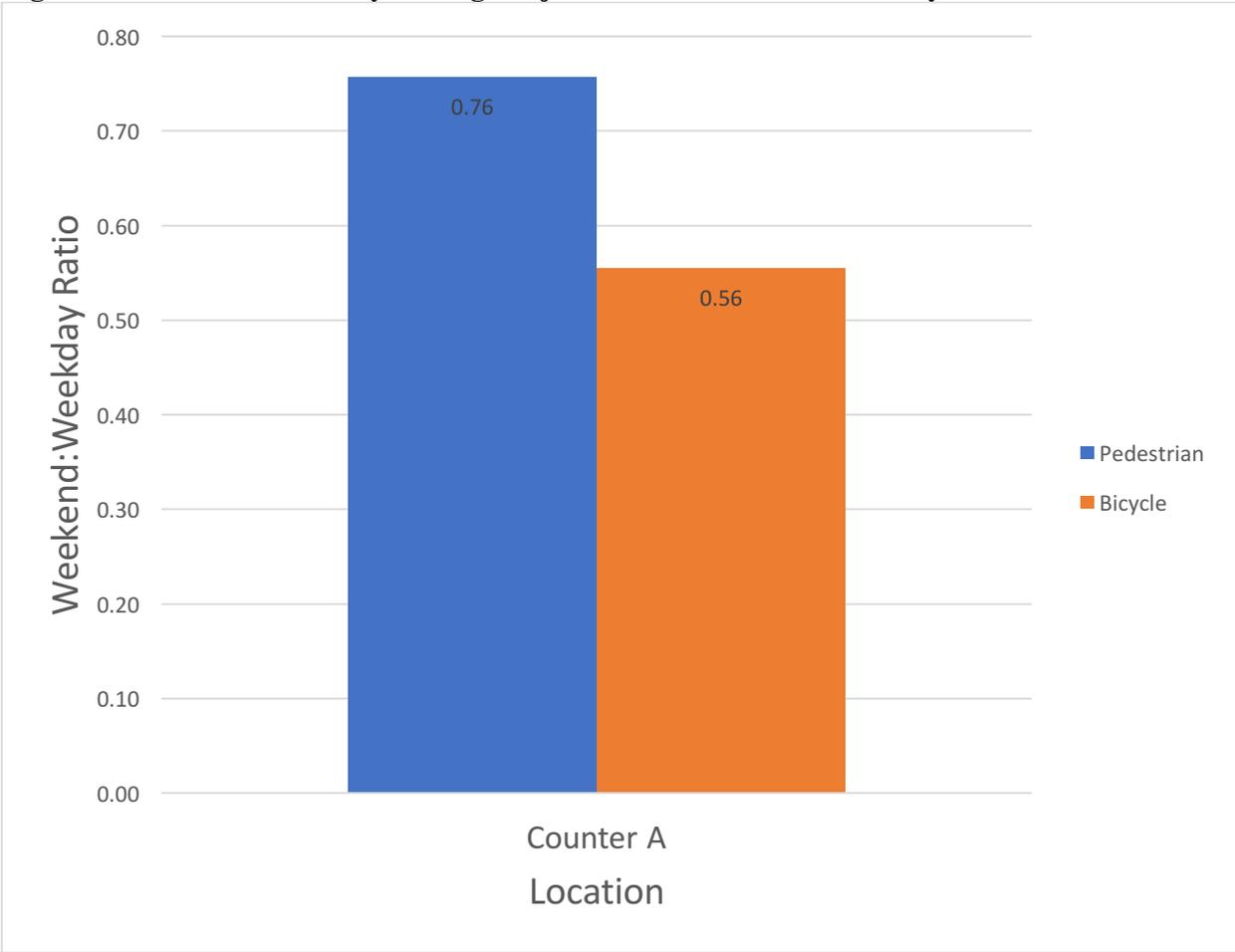
Figure 10. Attitude towards walking between groups
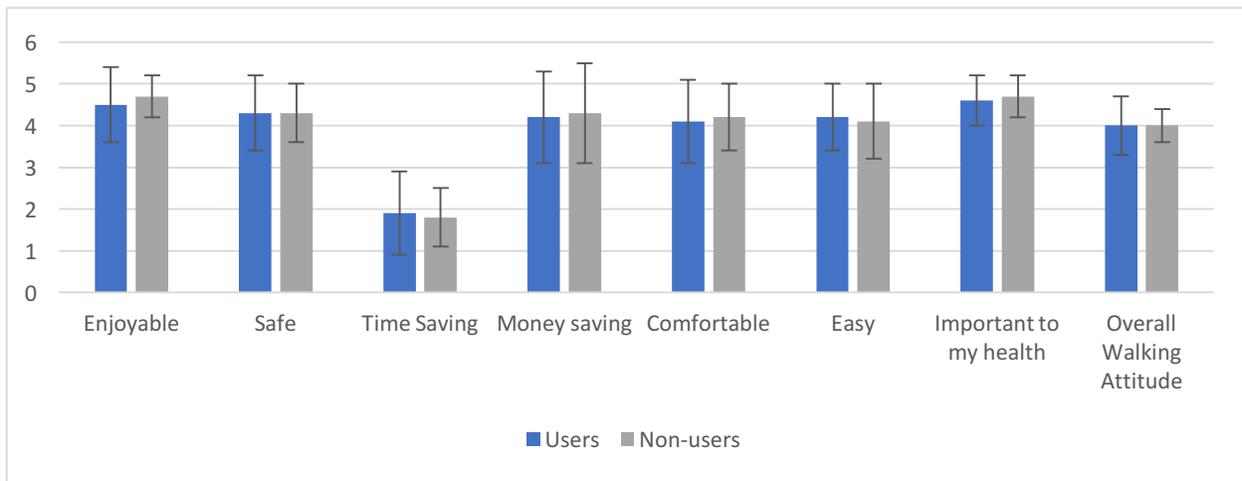
None of the factors was significantly different between U and NU on a 5-point scale (p<0.05; 1 = strongly disagree, 5 = strongly agree)

Figure 11. Attitude towards biking between groups
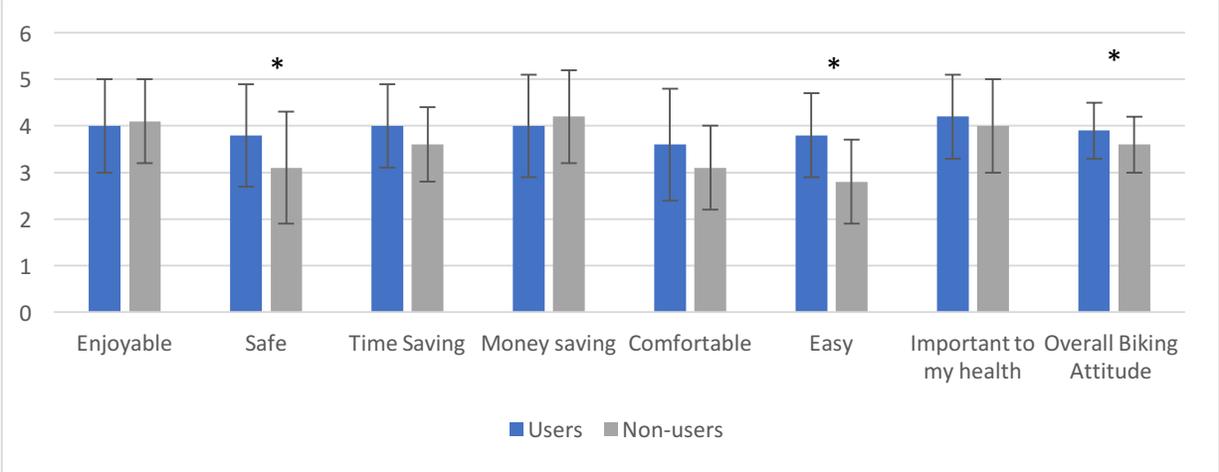
* indicates a significant difference between groups on a 5-point scale ($p<0.05$; 1 = strongly disagree, 5 = strongly agree)

Table 1. Percent valid count days from data collected during last seven weeks of spring semester (n = 45 days)

	Counter A		Counter B	
	# of Days Censored	Percent of Valid Counts	# of Days Censored	Percent of Valid Counts
Weekday (n=33)				
Pedestrian Traffic	6	82%	1	97%
Bicycle Traffic	4	88%	0	100%
Weekend (n=12)				
Pedestrian Traffic	1	92%	1	92%
Bicycle Traffic	0	100%	0	100%

Table 2. Percent valid count days (n=10) from data collected during first ten days of summer semester

	Counter A		Counter B	
	# of Days Censored	Percent of Valid Counts	# of Days Censored	Percent of Valid Counts
Weekday (n=8)				
Pedestrian Traffic	0	100%	3	63%
Bicycle Traffic	0	100%	3	63%
Weekend (n=2)				
Pedestrian Traffic	0	100%	2	0%
Bicycle Traffic	0	100%	2	0%

Table 3. Comparisons of traffic between counters from last seven weeks of the spring semester

	Counter A	Counter B	T-test value	p-value
Total Traffic				
Weekday	524 ± 161	593 ± 183	-1.536	<0.130
Weekend	450 ± 137	441 ± 118	0.172	<0.865
Pedestrian Traffic				
Weekday	**300 ± 98**	**429 ± 160**	**-3.781**	**< 0.001**
Weekend	290 ± 101.0	313 ± 110	0.512	< 0.614
Bicycle Traffic				
Weekday	**221 ± 65**	**162 ± 42**	**4.240**	**< 0.001**
Weekend	**164 ± 51**	**124 ± 27**	**2.432**	**< 0.027**

Values in bold are significant ($p < 0.05$).

Table 4. Comparison of traffic between counters from first ten days of the summer semester

	Counter A	Counter B	T-test Value	p-value
Total Traffic				
Weekday	423 ± 72	426 ± 77	-0.075	< 0.941
Weekend	279 ± 39	N/A	N/A	N/A
Pedestrian Traffic				
Weekday	**214 ± 41**	**282 ± 67**	**-2.295**	**< 0.042**
Weekend	162 ± 11	N/A	N/A	N/A
Bicycle Traffic				
Weekday	**209 ± 37**	**144 ± 12**	**4.531**	**< 0.001**
Weekend	116 ± 28	N/A	N/A	N/A

Values in bold are significant ($p < 0.05$).

Table 5. Correlations between traffic and weather for each counter during the last seven weeks of the spring semester

	Counter A	p-value	Counter B	p-value
Total Traffic				
Weekday				
Max Temp	**0.518**	**< 0.006**	0.213	< 0.242
Precipitation	-0.213	< 0.286	**-0.408**	**< 0.021**
Weekend				
Max Temp	0.344	< 0.300	0.052	< 0.879
Precipitation	0.221	< 0.514	0.002	< 0.996
Pedestrian Traffic				
Weekday				
Max Temp	**0.525**	**< 0.005**	0.252	< 0.164
Precipitation	-0.207	< 0.301	**-0.365**	**< 0.040**
Weekend				
Max Temp	0.226	<0.504	0.020	< 0.953
Precipitation	0.382	< 0.246	0.026	< 0.941
Bicycle Traffic				
Weekday				
Max Temp	**0.460**	**< 0.012**	-0.003	< 0.998
Precipitation	-0.180	< 0.351	-0.319	< 0.070
Weekend				
Max Temp	0.481	< 0.113	0.362	< 0.248
Precipitation	-0.186	< 0.562	-0.118	< 0.714

Values in bold are significant ($p < 0.05$).

Table 6. Demographics of sample (n=57)

Characteristics	Users (n=32)		Non-users (n=25)	
Age	24.3 ± 5.7		22.8 ± 4.9	
Male (%)	57		39	
Female (%)	43		61	
BMI	23.6 ± 3.8		23.7 ± 3.1	
Ethnicity (%)				
Caucasian	73		84	
Other	27		16	
Reported Health (%)				
Good or Excellent	80		89	
Fair or Poor	20		11	
Diagnosed with a disease (%)	Overweight or Obesity	4	Overweight or Obesity	5
	Mild Depression	4	Asthma or other respiratory disease	16
	Hypertension	4	Anorexia nervosa	5
	Hypothyroidism	4	Mood disorder	5
Meeting aerobic CDC's physical activity guidelines (%)				
Yes	93		89	
No	7		11	
Physical Activity (min/week)				
Vigorous Activity	112.0 ± 115.4		231.1 ± 238.4	
Moderate Activity	330.9 ± 305.6		263.7 ± 289.8	
Education (%)				
Completed some undergraduate degree work or less	47		63	
Completed undergraduate degree or more	53		37	
# of Children in the household (%)				
None	93		79	
One or more	7		21	
Income (%)				
≤$20,000/year	83		95	
>$20,000/year	17		5	
Location of living (%)				
Location A	97		92	
Other	3		8	
Type of Residence (% of total)				
Apartment or condominium	98		95	
Other	3		5	
Time at Residence (% of total)				
Less than one year	50		47	
1+ year	50		53	

None of the factors was significantly different between U and NU ($p < 0.05$)

Table 7. Commuting characteristics of sample

Characteristics	Users (n=32)	Non-users (n=25)
Primary means of transportation to VT (%)*		
Private Car	30	72
AT[a] or Alternative Transportation[b]	70	28
Total trips to campus/home from home/campus per week	12.5 ± 5.9	13.7 ± 7.5
Driver's License (%)		
Own	97	100
Do Not Own	3	0
# of Motor Vehicles at Residence (%)		
0-1	50	47
2+	50	53
Bike-Ownership (%)		
Yes	70	47
No	30	53
VT Parking Pass (%)*		
Own a Parking Pass	33	68
Do not own a parking pass	66	32
Awareness of Smithfield Plantation trail (%)*		
Yes	100	76
No	0	24
Any AT trips taken per week*	7.4 ± 6.0	3.4 ± 3.2
Commute time of any AT trips per week*	23.9 ± 14.6	14.1 ± 5.9

* indicates a significant difference between groups ($p<0.05$)
[a] AT refers to transit by walking/biking to the university
[b] alternative transportation refers to riding the bus to the university

Table 8. Social support for modes of AT between groups

Characteristics	Users (n=32)	Non-users (n=25)
Social Support		
Walk		
When I walk to the university, I almost always walk with at least one other person	2.1 ± 1.4	2.8 ± 1.4
Most people I know walk to the university	1.7 ± 1.1	1.4 ± 0.6
The university does things to encourage me to walk to campus	2.2 ± 1.3	2.3 ± 1.2
My supervisor/coworkers encourage walking to campus	2.4 ± 1.2	1.9 ± 1.2
My family/friends encourage walking to campus	2.7 ± 1.3	2.1 ± 1.1
Overall Social Support Walk	2.2 ± 0.9	2.1 ± 0.7
Bike		
When I bike to the university, I almost always bike to the university with at least one other person	1.7 ± 1.1	2.3 ± 1.0
Most people I know bike to the university	2.1 ± 1.1	1.8 ± 0.8
The university does things to encourage me to bike to campus	2.9 ± 1.3	3.1 ± 1.2
My supervisor/co-workers encourage biking to campus	2.6 ± 1.2	2.0 ± 1.0
My family/friends encourage biking to campus	2.8 ± 1.1	2.2 ± 1.2
Overall Bike Social Support	2.4 ± 0.8	2.3 ± 0.8
Overall Social Support for AT	2.3 ± 0.7	2.2 ± 0.7

None of the factors was significantly different between U and NU on a 5-point scale (p<0.05; 1 = strongly disagree, 5 = strongly agree)

Table 9. Environmental attitudes scores of U and NU

Characteristic	Users (n=32)	Non-users (n=25)
Environmental Attitudes		
Climate change is a serious problem*	4.6 ± 0.7	3.7 ± 1.1
Private cars are a major cause of air pollution	3.9 ± 0.9	3.7 ± 1.1
Bicycling or walking in place of car use is helpful to protect the environment*	4.7 ± 0.6	4.2 ± 0.8
Farmer/ranchers should use sustainable practices (e.g. less pesticides on crops, less antibiotics in animals)	4.2 ± 0.8	4.2 ± 0.8
I am willing to pay more for food that has been grown in a sustainable way	3.4 ± 1.2	3.1 ± 1.4
I am willing to eat less beef to help the environment	3.6 ± 1.5	3.2 ± 1.6
I try to buy local food to reduce the effect of transporting food on the environment	3.0 ± 1.1	3.3 ± 1.0
OVERALL ENVIRONMENTAL AWARENESS SCORE	3.9 ± 0.6	3.6 ± 0.7

* indicates a significant difference between groups on a 5-point scale ($p<0.05$; 1 = strongly disagree, 5 = strongly agree)

Table 10. Perception of changes that would motivate groups to change AT behavior.

What might encourage you to begin or do more walking or biking using the trail?	Total number of points given to each response[a]		Number of people who voted for each response[b]		Overall ranking of responses between groups[c]	
	Users	Non-Users	Users	Non-Users	Users	Non-Users
Another person to cycle/walk with	65	37	19	16	3	3 (Tie)
Signs to show me where to go	34	50	11	17	11	2
More specific information about how long it takes to walk or bike to the university	22	44	10	15	12	3 (Tie)
Increase in lighting along the trail	82	29	24	12	2	8
Increase in attractiveness of trail	50	24	17	9	5	9
Instruction on how to commute actively and handle challenges like weather	25	32	13	12	10	7
Confirmation that crime is low on trail	40	23	13	9	7 (Tie)	10
Call boxes for emergencies on trail	48	43	16	15	6	6
Be offered cash incentive (e.g. lower parking fee) for walking or biking rather than driving to the university	84	54	25	17	1	1
Have financial penalty for driving such as higher parking fees at the university	20	17	5	6	13	12
Increase connection with buses so I could ride bus one-way and walk/bike the other	36	37	13	16	9	3 (Tie)
Better parking/storage for my bike	64	20	19	9	4	11
Other	50	10	12	4	7 (Tie)	13

[a]= tally of the total number of points given by participants to option
[b]= tally of the total number of participants who assigned at least one point to option
[c]= Average ranking of option from ranking of [a] and [b]

Table 11. Top reported barriers by NU

	Number of participants that chose the response	Average ranking of response	Overall Ranking
Takes too much time for commute	18	2.2	1
I need to carry too many things	18	2.6	2
Weather makes it unreasonable	13	3	3
I worry I will be sweaty when I get to work	12	2.6	4
I need to do errands before/after work	12	3.3	5
The trail needs better lighting	8	3.8	6
I know about it but can't find it	6	2.7	7
It is too hard to change clothes at work	5	2.8	8
I am worried I might be hit by a car	5	3.6	9
I don't know about it	4	2.8	10
I am worried about crime and being mugged	4	3	11
I am not physically fit or healthy enough to do it	4	3.5	12
I don't like to be physically active	4	3.8	13
I don't have the energy	4	4.3	14
Other	3	1.3	15
Inadequate storage for my bike at my residence	3	2.7	16
It is too dusty on this trail	3	3	17 (Tie)
Inadequate places to park my bike at the university	3	3	17 (Tie)
The surface of the trail is uneven	3	3.7	19
The trail is unpleasant	3	4	20
I would be embarrassed	2	4.5	21

Appendix A:

Additional Counter Data Figures and Tables

Counter A weekday hourly traffic patterns as a percentage from last seven weeks of spring semester
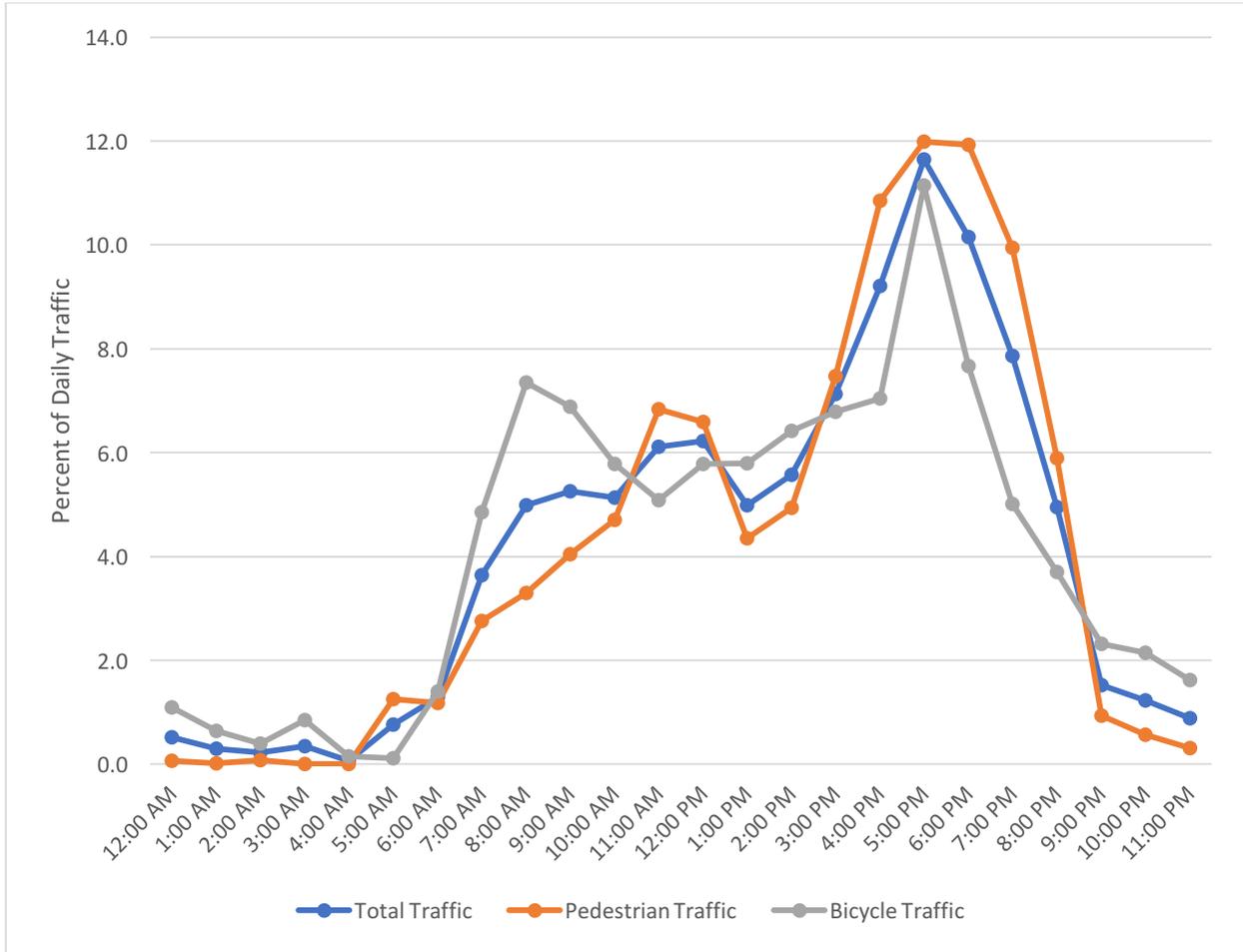
Counter A weekend hourly traffic patterns as a percent from last seven weeks of the spring semester
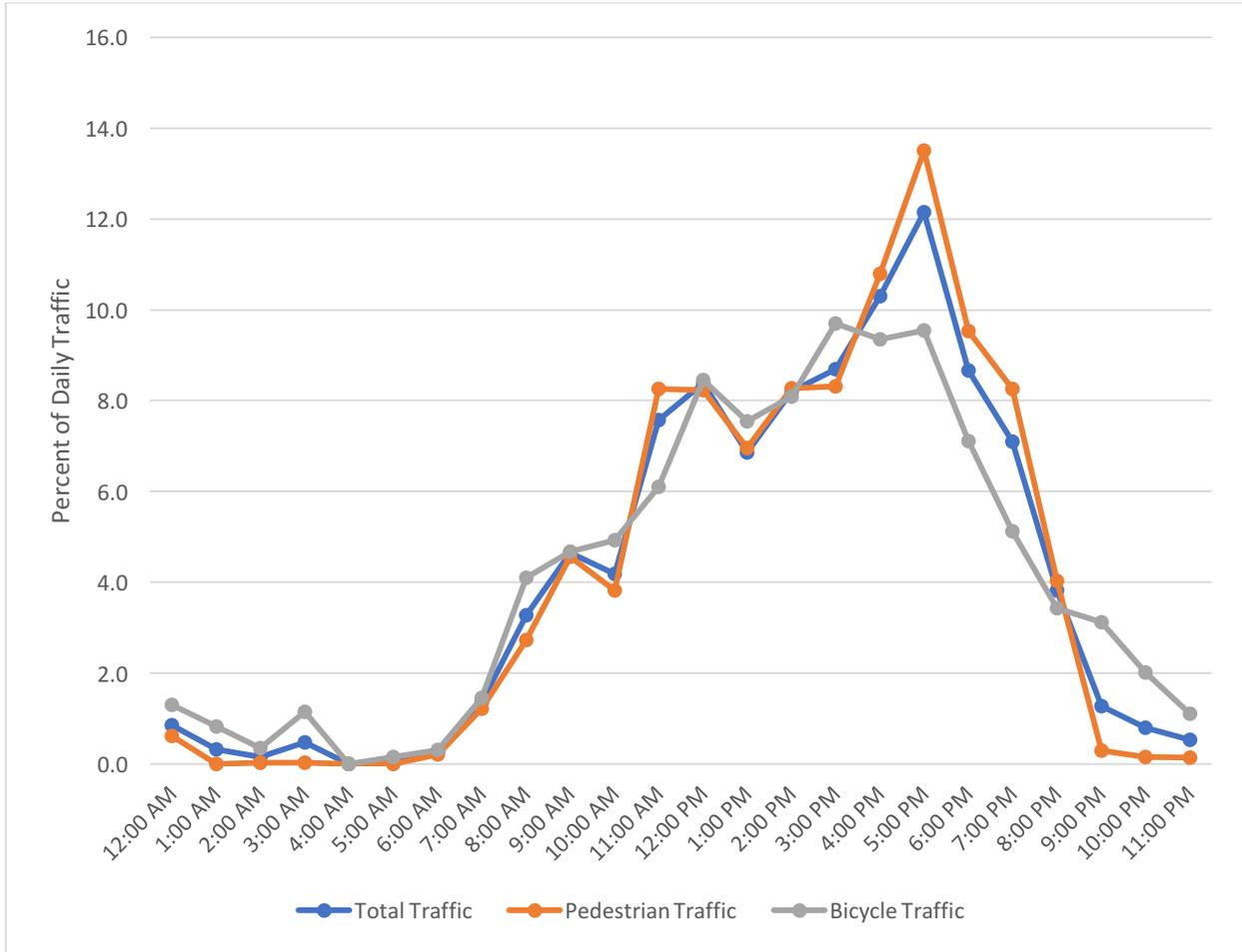
Counter B weekday hourly traffic patterns as a percent from the last seven weeks of the spring semester
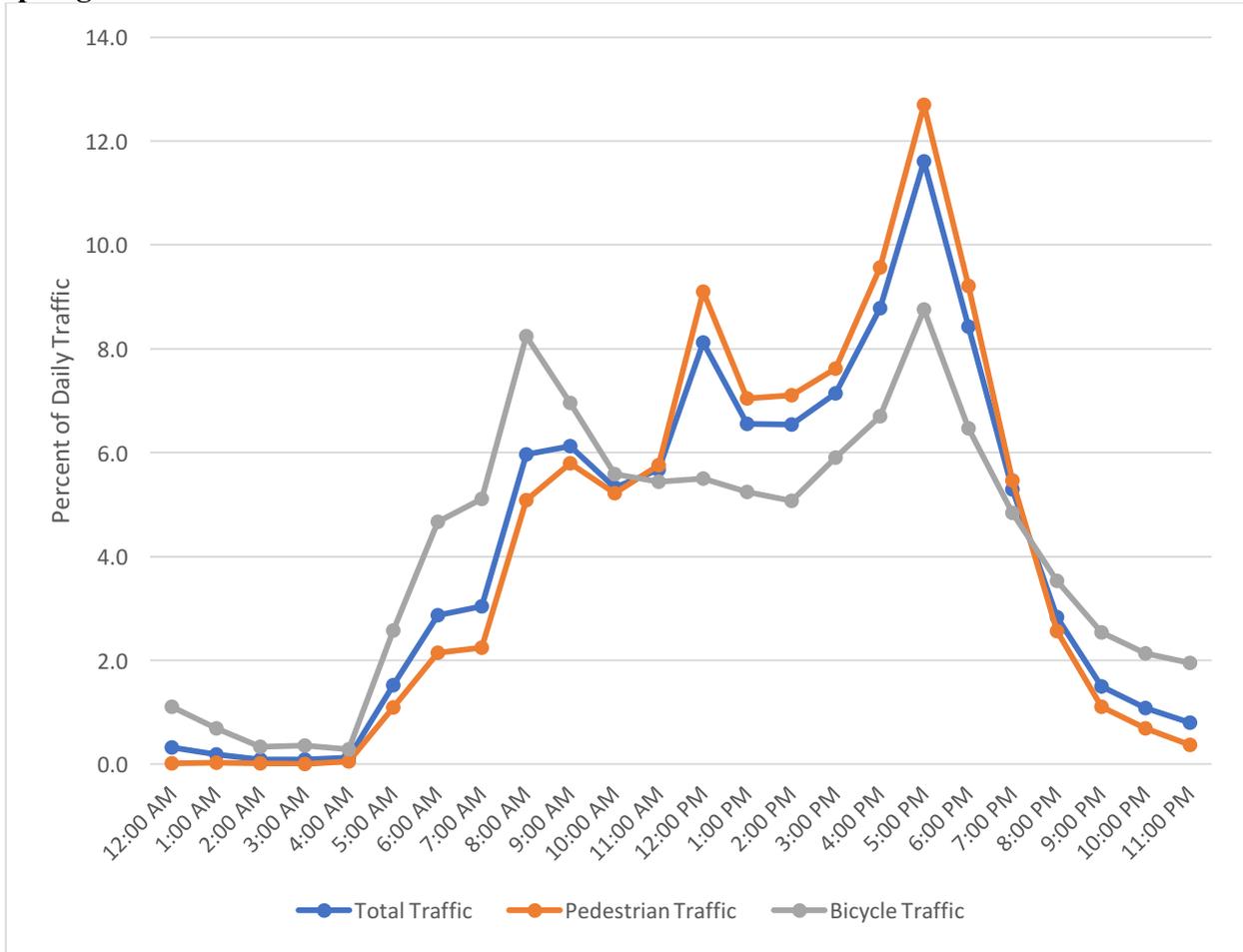
Counter B weekend hourly traffic patterns as a percent from the last seven weeks of the spring semester
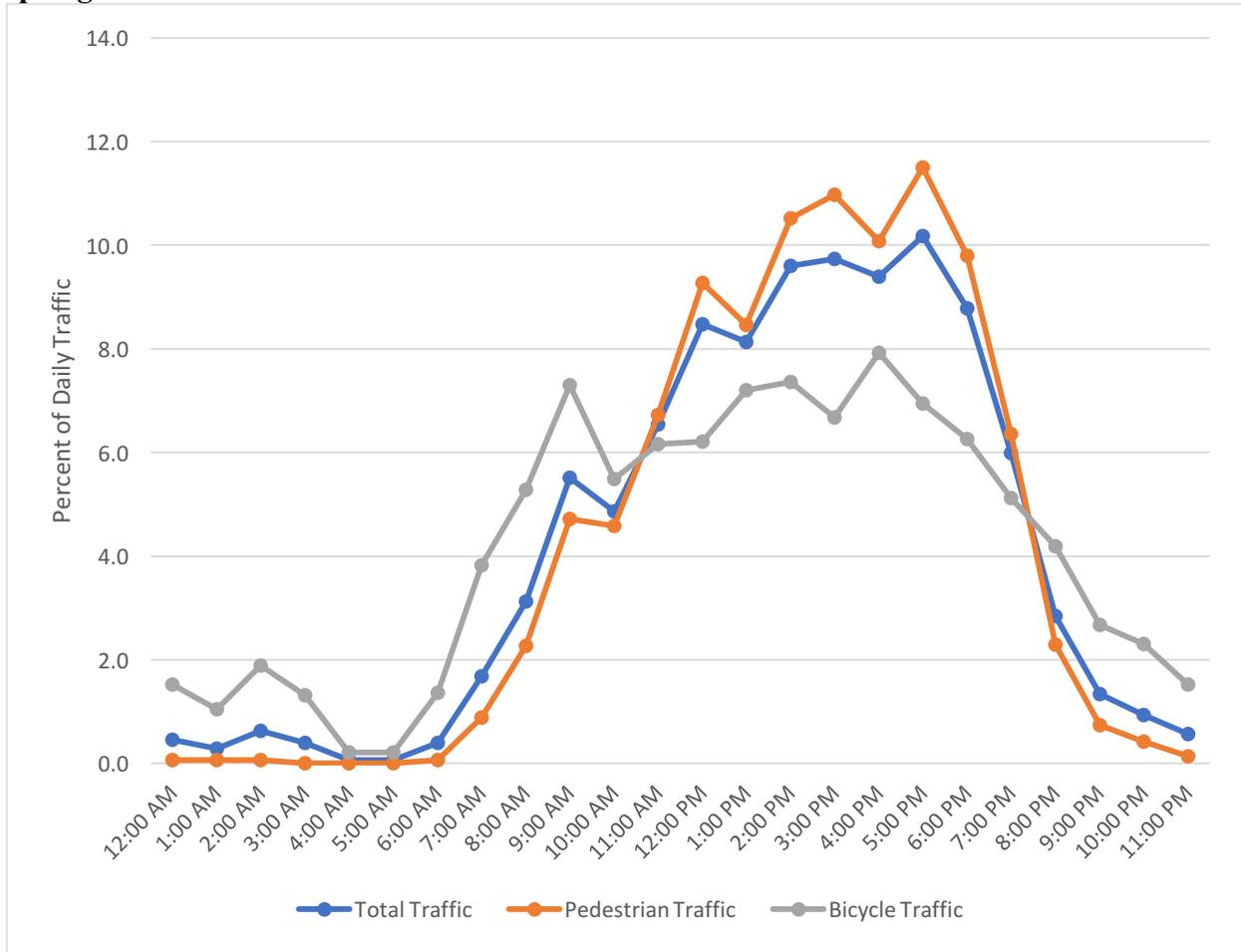
Counter A weekday hourly traffic patterns as a percent from first ten days of the summer semester
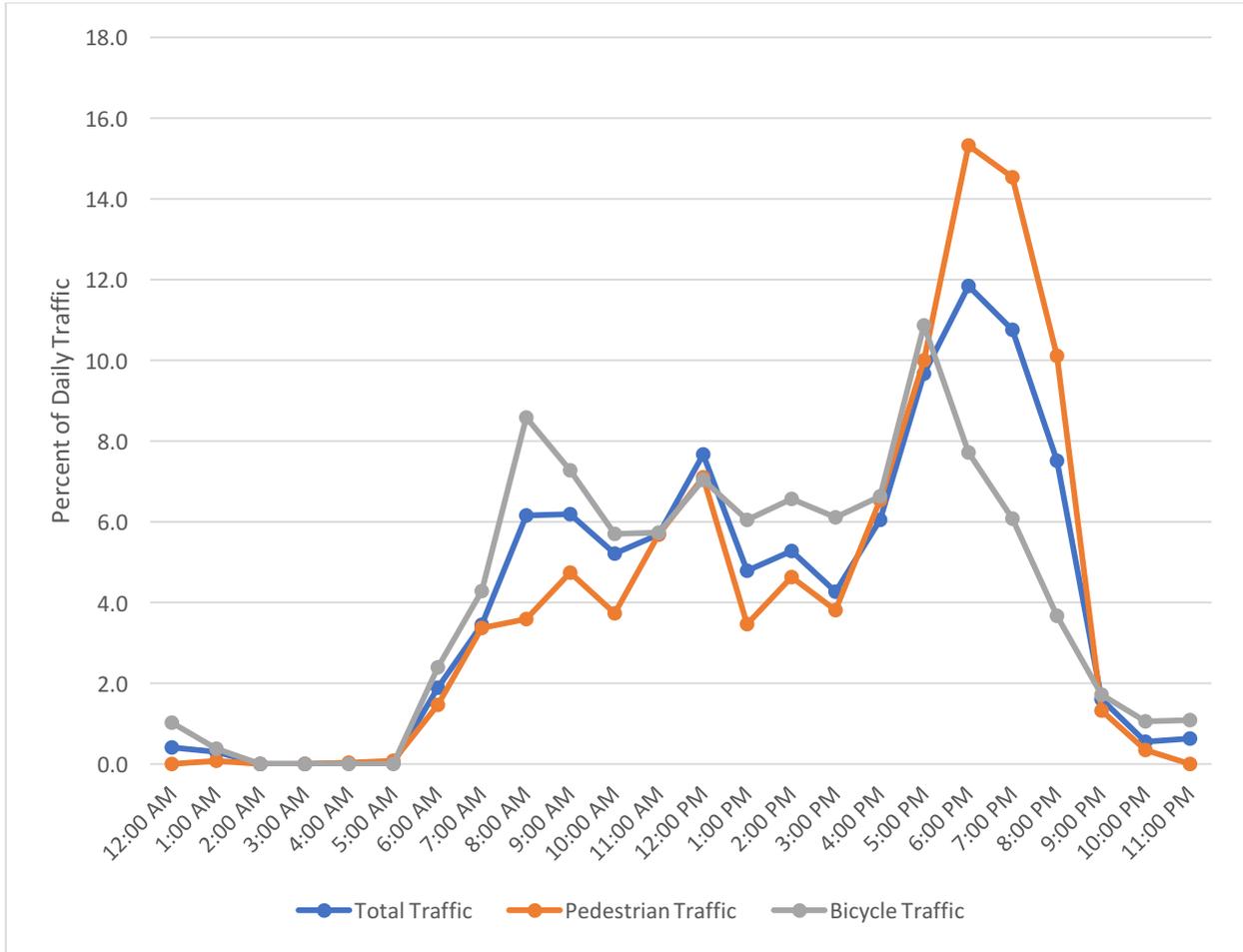
Counter A weekend hourly traffic pattern as a percent from first ten days of the summer semester
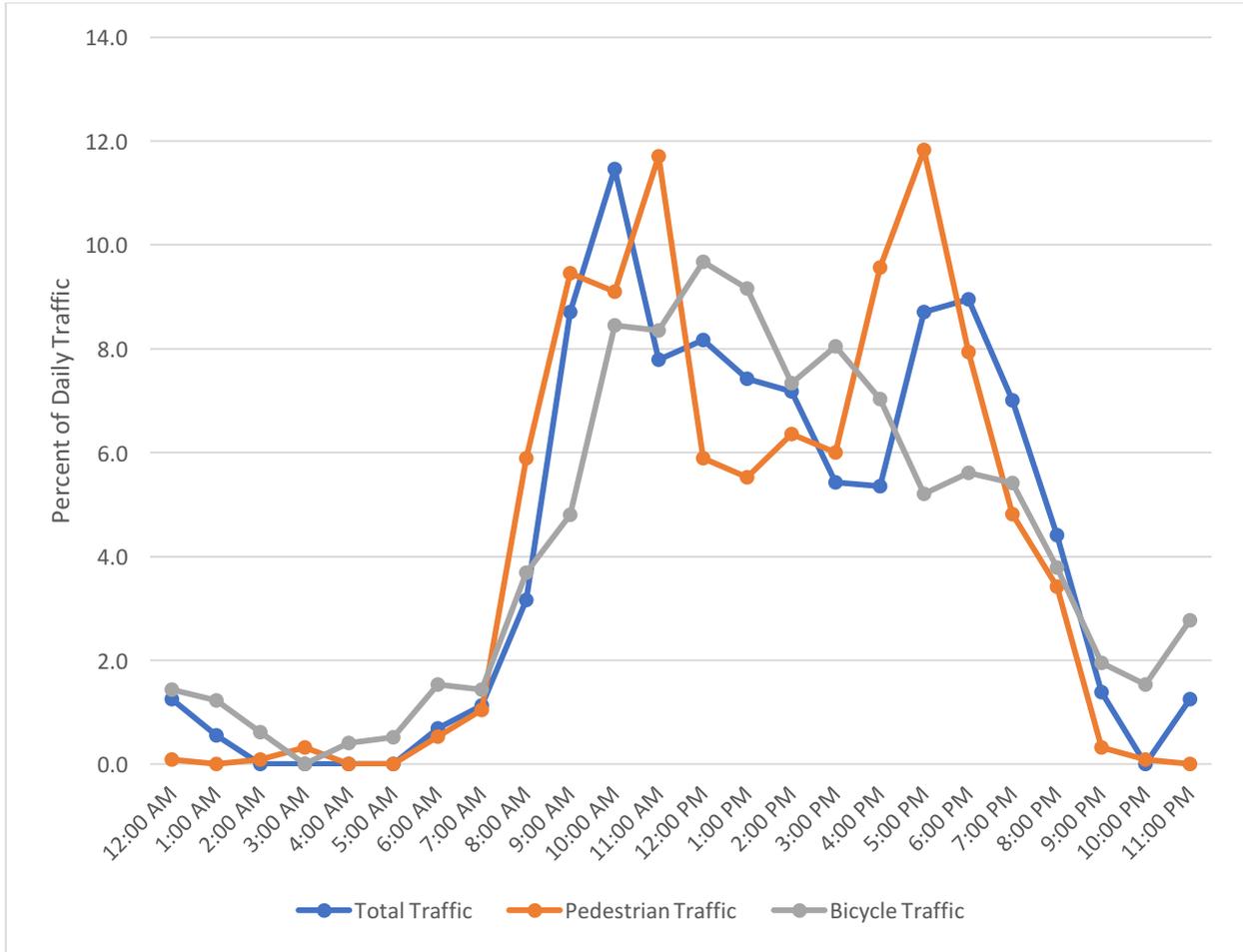
Counter B weekday traffic as a percent from the first ten days of the summer semester

Legend: Total Traffic, Pedestrian Traffic, Bicycle Traffic
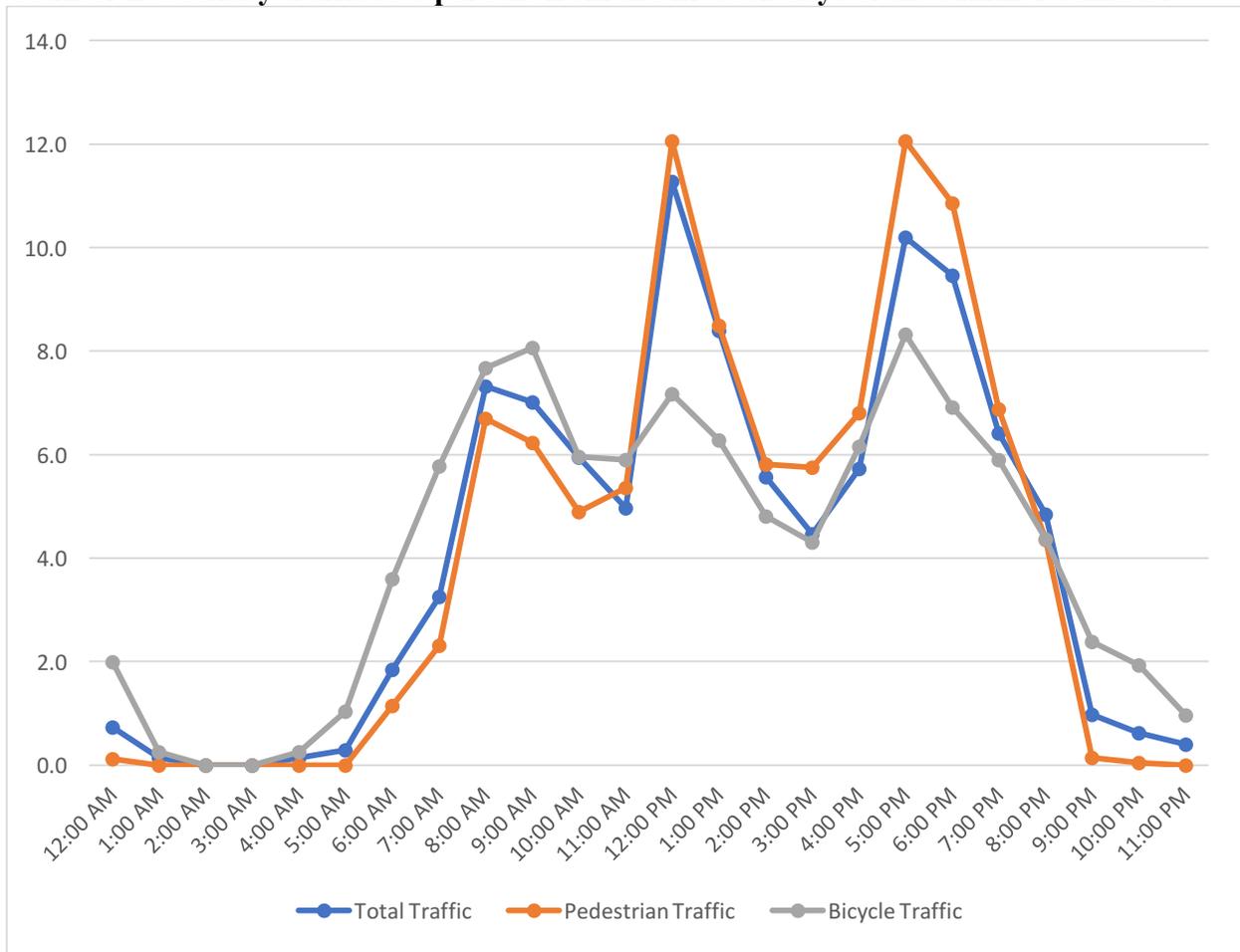
Mode share of trail usage

	Counts collected during Spring Semester		Counts collected during Summer Semester	
	Counter A	Counter B	Counter A	Counter B
Weekday %				
Pedestrian	57.4	72.3	50.4	70.9
Cyclist	42.6	27.7	49.6	29.1
Weekend %				
Pedestrian	65.6	65.6	58.3	N/A
Cyclist	34.4	34.4	41.7	N/A

Correlations between traffic and weather for each counter from first ten days of the summer semester

	Counter A	p-value	Counter B	p-value
Total Traffic				
Weekday				
Max Temp	-0.264	0.527	-0.379	0.530
Precipitation	**-0.794**	**0.019**	-0.740	0.153
Weekend				
Max Temp	N/A	N/A	N/A	N/A
Precipitation	N/A	N/A	N/A	N/A
Pedestrian Traffic				
Weekday				
Max Temp	-0.364	0.376	-0.411	0.492
Precipitation	**-0.900**	**0.002**	-0.751	0.144
Weekend				
Max Temp	N/A	N/A	N/A	N/A
Precipitation	N/A	N/A	N/A	N/A
Bicycle Traffic				
Weekday				
Max Temp	-0.119	0.778	-0.151	0.809
Precipitation	-0.558	0.151	-0.530	0.358
Weekend				
Max Temp	**1.000**	**0.01**	N/A	N/A
Precipitation	N/A	N/A	N/A	N/A

Values bolded are significant ($p < 0.05$)

Appendix B:

All Faculty/Staff Survey Data Figures and Tables

Attitude towards walking between group for faculty/staff
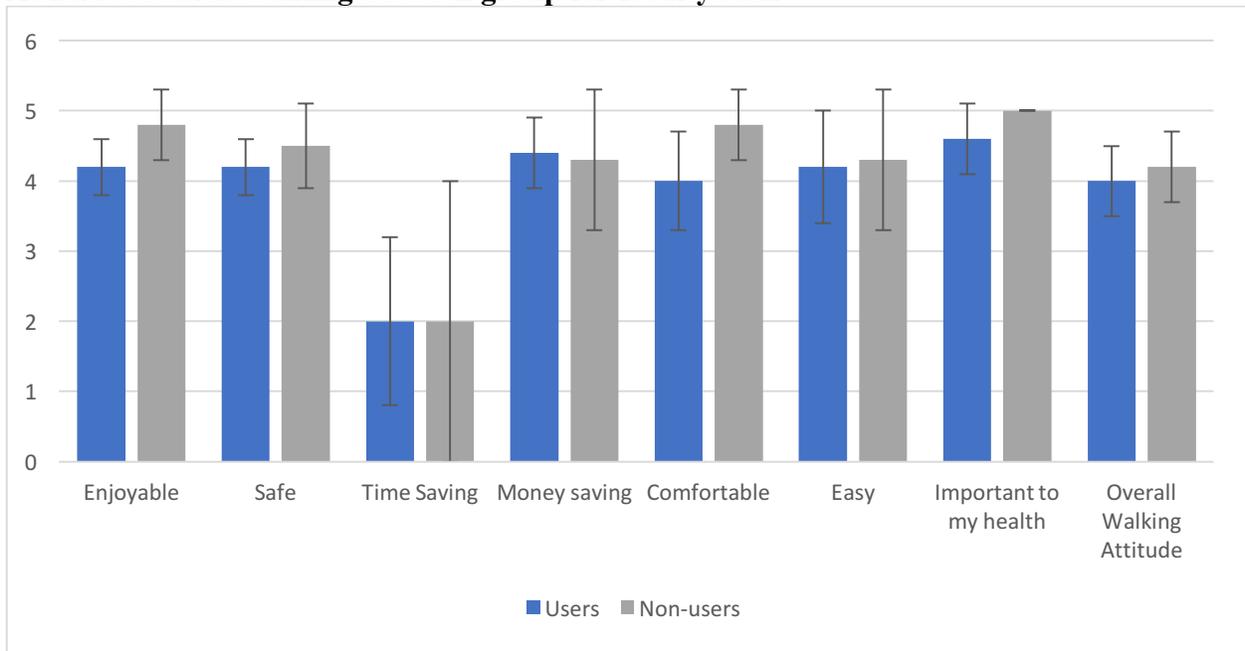
Attitude towards biking between groups for faculty/staff
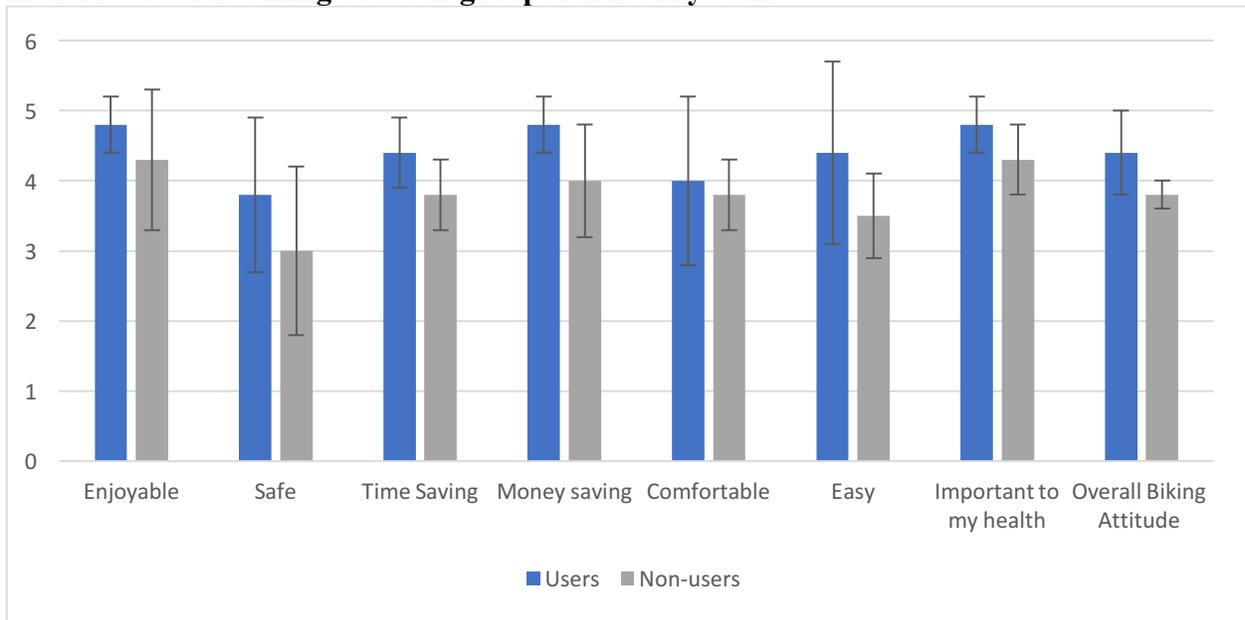
Demographics of faculty/staff sample (n= 10)

Characteristics	Users (n=5)	Non-users (n=5)
Age	43.8 ± 16.7	42.8 ± 10.3
Male (%)	80	50
Female (%)	20	50
BMI	24.6 ± 3.1	23.4 ± 0.8
Ethnicity (%)		
Caucasian	100	75
Other	0	25
Reported Health (%)		
Excellent	60	50
Good	40	50
Diagnosed with a disease (%)		
Overweight or Obesity	20	0
Hypertension	20	0
Asthma or other respiratory disease	20	0
Meeting aerobic CDC's physical activity guidelines (%)		
Yes	100	75
No	0	25
Physical Activity (min/week)		
Vigorous Activity	258.0 ± 109.9	177.5 ± 181.2
Moderate Activity	624.0 ± 841.4	213.8 ± 209.4
Education (%)		
Completed undergraduate degree	20	25
Some graduate school or finished graduate/professional degree	80	75
# of Children in the household (%)		
None	60	50
One or more	40	50
Income (%)		
≤$59,999/year	20	100
≥$60,000/year	80	0
Location of living (%)		
Location A	40	40
Other	60	60
Type of Residence (% of total)		
Single-family detached house	60	75
Apartment or condominium	40	25
Time at Residence (% of total)		
<5 years	20	25
≥5 years	80	75

None of the factors was significantly different between U and NU ($p < 0.05$)

Commuting characteristics of faculty/staff sample

Characteristics	Users (n=5)	Non-users (n=5)
Primary means of transportation to VT (%)		
Private Car	20	60
Bus or AT	80	40
Total trips to campus/home from home/campus per week	10.2 ± 3.3	11.2 ± 5.8
Driver's License (%)		
Own	100	100
Do Not Own	0	0
# of Motor Vehicles at Residence (%)		
< 2	40	0
≥2	60	4
Bike-Ownership (%)		
Yes	100	75
No	0	25
VT Parking Pass (%)		
Own a Parking Pass	60	66
Do not own a parking pass	40	33
Awareness of Smithfield Plantation trail (%)		
Yes	100	100
No	0	0
Any AT trips taken per week*	12.2 ± 6.9	3 ± 1.6
Commute time of any AT trips per week	16.6 ± 2.3	25.0 ± 15.8

None of the factors was significantly different between U and NU ($p < 0.05$)

Social support for modes of AT between groups for faculty/staff

Characteristics	Users (n=5)	Non-users (n=5)
Social Support		
Walk		
When I walk to the university, I almost always walk with at least one other person	2.0 ± 1.0	2.8 ± 2.1
Most people I know walk to the university	1.2 ± 0.4	1.3 ± 0.5
The university does things to encourage me to walk to campus	2.0 ± 1.4	2.8 ± 1.0
My supervisor/coworkers encourage walking to campus	2.4 ± 0.9	2.8 ± 1.3
My family/friends encourage walking to campus	2.4 ± 1.1	3.0 ± 1.6
Overall Social Support Walk	2.0 ± 0.7	2.5 ± 1.1
Bike		
When I bike to the university, I almost always bike to the university with at least one other person	1.0 ± 0.0	1.5 ± 1.0
Most people I know bike to the university	1.8 ± 0.8	1.5 ± 0.6
The university does things to encourage me to bike to campus	2.4 ± 1.5	2.3 ± 1.3
My supervisor/co-workers encourage biking to campus	2.6 ± 1.1	2.5 ± 1.3
My family/friends encourage biking to campus	3.8 ± 1.1	3.0 ± 1.8
Overall Bike Social Support	2.3 ± 0.6	2.2 ± 0.8
Overall Social Support for AT	2.2 ± 0.6	2.3 ± 1.0

None of the factors was significantly different between U and NU on a 5-point scale ($p < 0.05$; 1 = strongly disagree, 5 = strongly agree)

Environmental attitudes scores of U and NU for faculty/staff

Characteristic	Users (n=5)	Non-users (n=5)
Environmental Attitudes		
Climate change is a serious problem	4.8 ± 0.4	4.8 ± 0.5
Private cars are a major cause of air pollution	4.6 ± 0.5	3.8 ± 1.0
Bicycling or walking in place of car use is helpful to protect the environment	4.8 ± 0.4	4.3 ± 1.0
Farmer/ranchers should use sustainable practices (e.g. less pesticides on crops, less antibiotics in animals)	2.8 ± 1.6	4.3 ± 0.5
I am willing to pay more for food that has been grown in a sustainable way	3.4 ± 1.3	3.3 ± 1.7
I am willing to eat less beef to help the environment	2.4 ± 1.5	3.5 ± 1.3
I try to buy local food to reduce the effect of transporting food on the environment	3.0 ± 0.7	3.0 ± 1.8
OVERALL ENVIRONMENTAL AWARENESS SCORE	3.7 ± 0.7	3.8 ± 1.0

None of the factors was significantly different between U and NU on a 5-point scale ($p < 0.05$; 1 = strongly disagree, 5 = strongly agree)

Perception of changes that would motivate groups to change AT behavior for faculty/staff.

What might encourage you to begin or do more walking or biking using the trail?	Total number of points given to each response[a]		Number of people who voted for each response[b]		Overall ranking of responses between groups[c]	
	Users	Non-Users	Users	Non-Users	Users	Non-Users
Another person to cycle/walk with	2	0	1	0	10	11 (Tie)
Signs to show me where to go	0	0	0	0	12 (Tie)	11 (Tie)
More specific information about how long it takes to walk or bike to the university	0	2	0	1	12 (Tie)	9 (Tie)
Increase in lighting along the trail	15	10	3	2	3	3 (Tie)
Increase in attractiveness of trail	10	14	2	3	5 (Tie)	1
Instruction on how to commute actively and handle challenges like weather	5	2	1	1	9	9 (Tie)
Confirmation that crime is low on trail	1	5	1	1	11	7 (Tie)
Call boxes for emergencies on trail	9	12	2	3	7	2
Be offered cash incentive (e.g. lower parking fee) for walking or biking rather than driving to the university	17	10	4	2	1	3 (Tie)
Have financial penalty for driving such as higher parking fees at the university	4	0	2	0	8	11 (Tie)
Increase connection with buses so I could ride bus one-way and walk/bike the other	12	10	3	2	4	3 (Tie)
Better parking/storage for my bike	15	5	4	1	2	7 (Tie)
Other	10	10	2	2	5 (Tie)	3 (Tie)

[a]= tally of the total number of points given by participants to option
[b]= tally of the total number of participants who assigned at least one point to option
[c]= Average ranking of option from ranking of [a] and [b]

Top reported barriers by non-users for faculty/staff

	Number of participants that chose the response	Average ranking of response	Overall Ranking
I don't know about it	0	N/A	11 (Tie)
I know about it but can't find it	0	N/A	11 (Tie)
Takes too much time for commute	3	2.3	1 (Tie)
I don't have the energy	1	4	10
I am worried about crime and being mugged	0	N/A	11 (Tie)
I am worried I might be hit by a car	0	N/A	11 (Tie)
I am not physically fit or healthy enough to do it	0	N/A	11 (Tie)
I would be embarrassed	0	N/A	11 (Tie)
Weather makes it unreasonable	3	2.3	1 (Tie)
I don't like to be physically active	0	N/A	11 (Tie)
I worry I will be sweaty when I get to work	2	3	5 (Tie)
I need to carry too many things	3	3.3	3
I need to do errands before/after work	1	2	8
It is too hard to change clothes at work	2	2.5	4
The trail is unpleasant	0	N/A	11 (Tie)
The surface of the trail is uneven	0	N/A	11 (Tie)
The trail needs better lighting	1	3	9
It is too dusty on this trail	2	3	5 (Tie)
Inadequate storage for my bike at my residence	0	N/A	11 (Tie)
Inadequate places to park my bike at Virginia Tech	0	N/A	11 (Tie)
Other	2	5	7

Appendix C:

Institutional Review Board Acceptance Form

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

VirginiaTech

MEMORANDUM

DATE: March 22, 2016

TO: Janet Rankin, Timmy FitzPatrick, Steven C Hankey

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Assessing Use and Correlates to Active Commute with a Trail Connecting a Rural Neighborhood to a College Campus

IRB NUMBER: 16-242

Effective March 22, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Exempt, under 45 CFR 46.110 category(ies) 2**
Protocol Approval Date: **March 22, 2016**
Protocol Expiration Date: **N/A**
Continuing Review Due Date*: **N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix D:

Recruitment Flyers and Signs

1. Version 1 of flyer used for recruitment

Individuals are invited to participate in a research study by the **Department of Human Nutrition, Foods, and Exercise and the Department of Urban Affairs and Planning at Virginia Tech**

Purpose
- Study the use of the Smithfield Plantation Trail (connects Hethwood to Virginia Tech) for commuting with walking or bicycling by students and faculty/staff at Virginia Tech.

Involves
- Completing a 15 minute anonymous survey designed to assess
    - Transportation habits
    - Reasons and attitudes of transport decisions
    - Overall physical activity
    - Descriptive information (age, height, body weight, etc.)

When?
- Access to the survey will stay open until the end of April 2016

Eligibility Requirements
- Be a student, faculty, or staff at Virginia Tech
- Must be 18 years of age or older
- Be a resident of Hethwood
    - Chowning Place
    - Foxridge Apartment Homes
    - Haymarket Square
    - Mission Hills
    - Pilgrims Point
    - Stroubles Mill
- Be healthy and able to walk or bike

Access the survey at https://goo.gl/frmAA9 or scan the QR code above. Contact transportationVT@gmail.com with any questions or concerns. Participants can be entered into a drawing for $200. Odds of winning are expected to be about 1 in 200 depending on how many individuals participate.

2. Version 2 of flyer used for recruitment

Participants are invited to participate in a research study aiming to assess transportation habits in students and faculty/staff at Virginia Tech.

Sponsored by the Department of Human Nutrition, Foods, and Exercise and the Department of Urban Affairs and Planning at Virginia Tech

If you:
- Are a student, faculty, or staff at Virginia Tech
- Are 18 years of age or older
- Are a resident of Hethwood
  - Chowning Place
  - Foxridge, Apartment Homes
  - Haymarket Square
  - Mission Hills
  - Pilgrims Point
  - Stroubles Mill
- Are healthy and able to walk or bike

You may qualify for this study!

If you qualify for this study, you will be eligible to take an anonymous 15 minute online survey to learn about your:
- Transportation habits
- Reasons and attitudes for transport decisions
- Overall physical activity
- Descriptive Information (age, height, body weight, etc.)

Access the survey at https://goo.gl/frmAA9 or scan the QR code above!
Contact transportationVT@gmail.com if you have any questions!

Participate for a chance to win $200. Odds of winning are expected to be about 1 in 200 depending on how many individuals participate.

Transportation Study
Survey: https://goo.gl/frmAA9
Questions: transportationVT@gmail.com

Transportation Study
Survey: https://goo.gl/frmAA9
Questions: transportationVT@gmail.com

Transportation Study
Survey: https://goo.gl/frmAA9
Questions: transportationVT@gmail.com

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Questions: transportationVT@gmail.com

Transportation Study
Survey: https://goo.gl/frmAA9
Questions: transportationVT@gmail.com

Transportation Study
Survey: https://goo.gl/frmAA9
Questions: transportationVT@gmail.com

3. Sign that was placed at the entrance to the trail from the residential community

Research Study on Transportation Habits

Virginia Tech departments of Human Nutrition, Foods, and Exercise;
Urban Affairs & Planning

Complete 15-minute anonymous survey if you are:
- 18 or older
- Student, Staff, Faculty of Virginia Tech
- Resident of Hethwood

Questions about:
- Transportation habits
- Reasons & attitudes for transportation decisions
- Overall physical activity
- Descriptive information (age, weight, etc.)

How?
- Survey accessed at https://goo.gl/frmAA9 or scan the QR code above on your phone!

Chance to win $200 if complete survey (chance ~1 out of 200).
Contact transportationVT@gmail.com **about any questions or concerns!**

Appendix E:

Copy of Online Survey

Researchers from the department of Human Nutrition, Foods, and Exercise and the department of Urban Affairs and Planning at Virginia Tech are studying the use of the Smithfield Plantation Trail (connects Hethwood to Virginia Tech) for commuting with walking or bicycling.

The following survey is designed to learn about your transportation habits and attitudes including use of this trail. The survey may help our understanding of improvements or programs that could increase use of the trail.   Responses will be used for a student's Master's Thesis and is expected to be submitted for presentation at a conference and publication in a professional journal.

In order to qualify for this study, you will need to:
1. Be a resident of Hethwood (Chowning Place, Foxridge Apartment Homes, Haymarket Square, Mission Hills, Pilgrims Point, Stroubles Mill)
2. Be 18 years of age or older
3. Be able and well enough to walk or bike
4. Have been in town most of last week
5. Be a student/staff/faculty at Virginia Tech.

This survey will take about 15 minutes to complete. Please answer each question to the best of your knowledge.

The survey includes questions about your transportation habits, reasons and attitudes for your transport decisions, your overall physical activity habits, and descriptive information about you such as the community you live in (to clarify whether you are eligible to participate) body weight and height, income, race, and age.

You will not be paid to complete this survey but you will have the option to submit an email address at the end of the survey to enter a drawing for a $200 prize. The winner will be chosen by the end of May and contacted using the email provided. Odds of winning are expected to be about 1 in 200 depending on how many individuals participate.

Email will be stored separately from survey responses so that your responses remain anonymous.

Your participation in this study is voluntary. You may leave any question unanswered and there is no penalty for not answering every question. You may quit the survey at any time by closing out the survey.   By clicking the next button and completing the survey, you are indicating that you provide consent to be part of this study.

1. How old are you?

[BLANK] years

2. Please indicate which community you live in:

       Chowning Place
       Foxridge Apartments
       Haymarket Square
       Mission Hills
       Pilgrims Point
       Stroubles Mill
       None of the above

3. Indicate which of the following currently applies to you (choose only one, your primary role):
       Virginia Tech (VT) student
       VT faculty
       VT staff
       None of the above

4. How many days were you out of town over the last 7 days?
       None
       1
       2
       3
       4
       5
       6
       7

Logic, decision point:
If #1 lists an age ≥18 AND #2 selects any community in Hethwood area AND #3 is anything except "none of the above" AND #4 is "2", "1" or "0", the individual is eligible and will be provided with remaining questions.
If at least one of the above excludes their eligibility, they will not receive more questions and the following message will be shown

"Thanks for your interest in this study. Unfortunately you do not qualify based on your responses."

5. How many trips did you travel between your residence and the Virginia Tech campus over the last 7 days (including for work, classes, food, recreation, etc.)? For example, travel from your home to campus is one trip. Returning home from campus would be another trip.

       FILL IN blank

6. Indicate your <u>primary</u> (used for the majority of trips) means of getting between VT and your residence within the last 7 days.

    Private car
    Car/minibus pool
    Bus
    Motorcycle
    Bike
    Walk

7. Are you aware of the trail (Smithfield Plantation Trail, highlighted in yellow) that connects the Hethwood neighborhood to VT campus? (The Smithfield Plantation Trail is the paved path that runs along Stroubles Creek and Smithfield Plantation Road, connecting the edge of Hethwood to the edge of the Virginia Tech campus at the Duck Pond.)
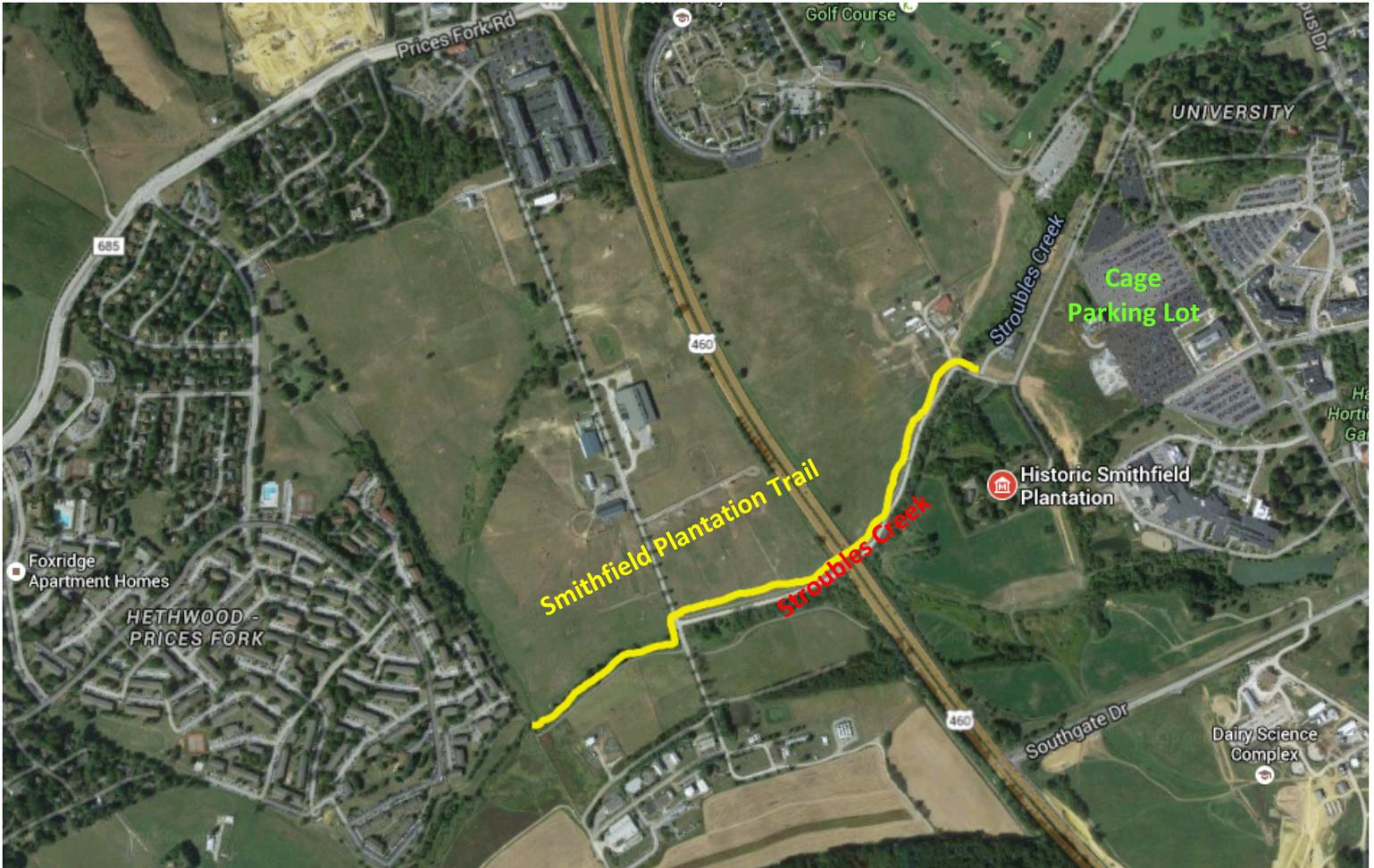
    Yes
    No

8. Over the last 7 days, have you <u>walked</u> at least once as part of getting to or from Virginia Tech and your residence?

     Yes
     No

If no, skip to Q 11

9. How many trips when you <u>walked</u> between Virginia Tech and your residence did you <u>use the Smithfield Plantation Trail</u>? (1 one- way trip counts as 1 trip)

     [BLANK] trips

10. When you <u>walked using the Smithfield Plantation Trail</u> from your residence, how many minutes, on average, did it take between your residence and Virginia Tech?

     [BLANK] minutes

11. Over the last 7 days, have you <u>biked</u> at least once as part of getting to or from Virginia Tech and your residence?

If no, skip to Q 15, unless answer to Q 8 was no also then skip to Q 14.

12. How many trips when you <u>biked</u> between Virginia Tech and your residence did you <u>use the Smithfield Plantation Trail</u>? (1 one- way trip counts as 1 trip)

     [BLANK] trips

13. If you <u>biked using the Smithfield Plantation Trail</u> from your residence, how many minutes, on average, did it take between your residence and Virginia Tech?

     [BLANK] minutes

Question 14 only appears if answers to Q 8 and Q 11 were both "No"

14. If you did not <u>bike or walk</u> to or from campus using the Smithfield Plantation Trail during the last 2 weeks, <u>rank the top five reasons</u> for this from the choices below. 1 = top reason, 2 next to top, through 5.

     I don't know about it
     I know about it but can't find it
     The surface of the trail is uneven
     I need to do errands before/after work
     I am worried about crime and being mugged
     Takes too much time for commute
     I don't have the energy

I am worried I might be hit by car or bicycle
The trail is unpleasant
I would be embarrassed
I am not physically fit or healthy enough to do it
Weather makes it unreasonable
I don't like to be physically active
I need to carry too many things
It is too hard to change clothes at work
I worry I will be sweaty when I get to work
The trail needs better lighting
It is too dusty on this trail
Inadequate storage for my bike at my residence
Inadequate places to park my bike at Virginia Tech
Other _____

15. We are interested in knowing what, if anything, might encourage you to begin or do more walking or biking to work using the Smithfield Plantation Trail. You have a total of 20 stars to allocate to the following items. You can give between one and five stars for any one item below. Allocate your stars according to what would motivate you to walk or bike to and from the Virginia Tech campus and your residence:

Another person to cycle/walk with
More specific information about how long it takes to walk or bike to Virginia Tech
Increase in lighting along trail
Signs to show me where to go
Increase in attractiveness of trail
Instruction on how to commute actively and handle challenges like weather
Confirmation that crime is low on trail
Be offered cash incentive (e.g. lower parking fee) for walking or biking rather than driving to Virginia Tech
Call boxes for emergencies on trail
Have financial penalty for driving such as higher parking fees at Virginia Tech
Increase connection with busses so I could ride bus one- way and walk/bike the other
Better parking/storage for my bike
Other _____

16. This question refers to any trips you have taken by walking or biking, including those using Smithfield Plantation Trail. Over the last 7 days, how many trips did you walk or bicycle for at least 10 minutes continuously to get to or from places (i.e. for transport to store, errand, visit friends or family, etc.)?

[BLANK] trips

17. How many minutes did the typical walk or bike for transport trip, described above, take?

[BLANK] minutes

18. Respond to your agreement with the following statements from 1-5 with 1 = strongly disagree and 5 = strongly agree

When I walk, to Virginia Tech, I almost always <u>walk</u> with at least one other person
Most people I know <u>walk</u> to Virginia Tech
Virginia Tech does things to encourage me to <u>walk </u>to campus
My supervisor/co-workers encourage <u>walking</u> to campus
My family/friends encourage <u>walking</u> to campus
When I bike to Virginia Tech, I almost always <u>bike </u>to Virginia Tech with at least one other person
Most people I know <u>bike</u> to Virginia Tech
Virginia Tech does things to encourage me to <u>bike</u> to campus
My supervisor/co-workers encourage <u>biking</u> to campus
My family/friends encourage <u>biking</u> to campus

19. Respond with a number indicating how much you agree with the following statements by indicating a number between 1 and 5. (1 = "strongly disagree" 5 = "strongly agree")

Walking is enjoyable
Walking is safe
Walking is time saving
Walking is money saving
Walking is comfortable
Walking is easy
Walking is important to my health

Biking is enjoyable
Biking is safe
Biking is time saving
Biking is money saving
Biking is comfortable
Biking is easy
Biking is important to my health

20. Indicate your opinion on a scale of 1 (strongly disagree) to 5 (strongly agree) for the following statements:

Climate change is a serious problem
Private cars are a major cause of air pollution
Bicycling or walking in place of car use is helpful to protect the environment
Farmers/ranchers should use sustainable practices (e.g. less pesticides on crops, less antibiotics in animals)
I am willing to pay more for food that has been grown in sustainable way
I am willing to eat less beef to help the environment
I try to buy local food to reduce the effect of transporting food on the environment

Use the following definitions for your answers to the next four questions:

> Vigorous = hard physical effort that makes you breath much harder than normal, such as jogging or running and bicycling on a steep hill or terrain, vigorous weight lifting, vigorous sports

> Moderate = moderate physical effort, including walking at a brisk pace (e.g. with pets, to class, work, the store, and/or for pleasure), cycling at moderate pace (5-9 mph), moderate exercise class, moderate weight lifting, casual sports

21. During the last 7 days, how many days did you do vigorous physical activities for at least 10 minutes at a time?

    [BLANK] days

22. How much time did you usually spend on one of those days doing vigorous physical activities

    [BLANK] hours and [BLANK] minutes per day

23. During last 7 days, how many days did you do moderate physical activities for at least 10 minutes at a time?

    [BLANK] days

24. Time spent doing moderate physical activity on one of those days?

    [BLANK] hours and [BLANK] minutes per day

25. What is your height in feet and inches?

    [BLANK] feet [BLANK] inches

26. What is your current body weight in pounds?

    [BLANK] pounds

27. What is your gender?
    Male
    Female

28. What is the highest level of education you have completed?
    Did not finish high school
    High school diploma or GED
    Some college

Undergraduate college degree
Some graduate school
Graduate or professional degree

29. What is your primary ethnicity/race?
African American/Black
American Indian or Alaskan native
Asian
Hispanic or Latino
Native Hawaiian or other Pacific Islander
White
None of the above

30. Indicate your annual gross income from last year:
$\leq$ \$20,000/year
20,000-39,999
40,000-59,999
60,000-79,999
80,000-99,999
100,000-119,999
$\geq$ 120,000

31. Which of the following best describes your current residence?
Single- family detached house
Apartment or condominium
Mobile home

32. How long have you been living at your current residence?
Less than one year
1 to <2 years
2 to < 5 years
5 or more years

33. How many children under the age of 18 years old live in your household?
None
One or more

34. Do you have a current US Divers license?
Yes
No

35. How many working motor vehicles are there in your household (e.g. cars, trucks, motorcycles)?
None
One
Two

Three
Four

36. Do you have access to at least one working bicycle?
    Yes
    No

37. Which of the following do you own?
    Commuter (off-campus) Parking Permit
    Graduate Student Parking Permit
    Carpool Commuter/Graduate Student Parking Permit
    Faculty/Staff Parking Permit
    Carpool Faculty/Staff Parking Permit
    Bike, Bus, & Walk (BB&W) Permit
    I do not own a Virginia Tech Parking Permit

38. In general, compared to other persons your age, how would you rate your health?
    Excellent
    Good
    Fair
    Poor

39. Indicate all of the following you have been diagnosed with:
    Heart Disease
    Hypertension
    Stroke
    Diabetes
    Overweight or obese
    Asthma or other respiratory disease
    Cancer
    Osteoporosis (thin bones)
    Disability (physical or mental that restricts your ability to walk)
    Other _____
    None of the above

40. You have reached the end of the survey. If you would like to enter your email for a chance to win the $200 prize, please enter your email below. Your email will only be used to contact you if you win the drawing. Odds of winning are expected to be about 1 in 200 depending on how many individuals participate. If you would not like to enter the drawing, leave this answer blank.

    [Blank] email