Exploring Sustainable Transportation Attitudes and Stages of Change Using Survey and Geospatial Data in New England Campus Commuters

by Tat Fu, Norbert Mundorf, Colleen A. Redding, Leslie Brick, Andrea Paiva, and James Prochaska

This paper presents findings of a two-campus project designed to assess alternative/sustainable transportation (AT), which is defined as commuting via non-SOVs (single occupancy vehicles) such as transit, carpooling, walking, or biking. One of the objectives was to test the application of a well-known behavior change model, the Transtheoretical Model of Change (TTM), to transportation behaviors. Additionally, geospatial analysis and visualization were applied using the TTM measures. The survey results show that commuting distances, transit connectivity, and status (i.e., students, staff, and faculty) affected commute modes and stages of readiness to use AT. Another important finding was that the survey data for AT replicated TTM relationship predictions between constructs and stages of change.

INTRODUCTION

Due to disruptions prompted by demographic patterns, aging infrastructure, climate change, and a growing culture that values sustainability, there has been considerable interest in encouraging sustainable transportation alternatives. This quest has not yet translated into substantive behavior change. In order to achieve widespread adoption of alternative, active, sustainable transportation (AT) choices, population-based changes in individuals' knowledge, attitudes, and behaviors are essential. AT choices are transit, carpooling, walking, biking and other means of commuting without using single occupancy vehicles (SOVs).

Transportation has been the fastest-growing source of U.S. greenhouse gas emissions since 1990, and it contributes approximately 27% of greenhouse gas emissions in the U.S. (EPA 2006). It is also a primary source of pollution, traffic congestion, injury, and premature death. Many approaches are capable of reducing greenhouse gas emissions from transportation, such as developing energy efficient vehicles and tax incentives to promote alternative fuel (e.g., electric, hybrid, and natural gas) vehicles. However, a key strategy is the reduction of SOV miles traveled by shifting transportation modes to walking, biking, transit, and carpool. This will significantly and directly reduce the use of gasoline and car emission by reducing the number of cars on the road. This work was designed to assess and promote readiness for AT. In this project, two comparable transportation surveys were conducted among students, staff, and faculty at the University of New Hampshire (UNH) and the University of Rhode Island (URI). Comparative examination of survey results showed the differential impact of commute distances, geographic information, status, and stage of readiness for AT on commute patterns.

Surveys were conducted at both UNH and URI to assess transportation topics such as transit ridership, commute patterns, satisfaction and awareness of transportation services, traffic demand model measures, and parking. The surveys incorporated key measures of the Transtheoretical Model (TTM) with the primary goal of identifying differences in commuting behaviors among different university constituencies (students, staff, and faculty). Given that students typically live closer to campuses, the authors hypothesized that students would be more likely to display pro-AT attitudes and behaviors compared to staff and faculty. This hypothesis was tied to the second research goal, which was to evaluate how geographical location affected commute behaviors. More specifically, the authors hypothesized that long commute distances discouraged the use of AT, and availability and proximity of public transportation infrastructure had a strong positive effect on AT usage.

The main contributions of this paper are to help promote the use of sustainable transportation by better understanding commuters' behaviors, attitudes, and their relationships to transit infrastructure and other location-based constraints. The study findings can be used by policy makers, school administrators, and city planners regarding transit infrastructure decisions. More specifically, attitudes, behaviors, and geographical information of commuters can be used to determine where and how to better allocate transportation resources and investment.

BACKGROUND

Transportation Modes

Transportation researchers and practitioners agree on the need to modify automobile transportation patterns—especially in urban areas, and during peak travel times. Also, resources to expand existing highways are severely limited—in fact, many states struggle to keep up maintenance of roads and bridges. A number of alternatives are being discussed. Travel Demand Management (TDM) experts point out that strategies, which "adjust roads and vehicles," have limited effectiveness as they often lead to increases in vehicle travel and associated problems (Litman 2015). Alternatively, addressing "market distortions" and, thus, influencing driver behavior may be a cost effective long-term strategy to reduce traffic congestion, crash risk, and pollution. Litman (2015) also points to several macro-economic trends, which also favor managing travel demand and promoting a shift to sustainable transportation alternatives, including rising costs of road construction, increased urbanization, aging demographics, consumer preferences, and environmental concerns.

Two recent articles in JTRF also address factors influencing Vehicle Miles Traveled (VMT). Woldeamanuel and Kent (2014) conducted an analysis of travel data in California and found that some key variables have remained as key factors (e.g. distance to work, population density), others gained significance compared with a decade earlier. In particular, commuting by public transit, and increasing public transit trips, as well as number of bike trips emerged as determinants of per capita VMT. McMullen and Eckstein (2013) studied 87 U.S. urban areas to analyze determinants of VMT. Among other findings, they found that the "per capita demand for VMT was … impacted by lane miles" (p. 5). They also found that fuel price and public transit use was negatively related to VMT. Overall, more western and larger urban areas were related to higher per capita VMT.

According to the Intergovernmental Panel on Climate Change (2013), transportation, especially by automobile, is one main contributor to greenhouse gas (GHG) emissions and the depletion of fossil fuel sources. Pacala and Socolow (2004) called for transportation related conservation strategies needed to mitigate climate change, pollution, congestion, and other problems. In addition, public health communities are increasingly concerned about the impact of sedentary lifestyles and energy balance. By reducing SOV usage, AT represents one effective way to simultaneously reduce GHG emissions and related threats, and increase physical activity (Dora 1999; Kwaśniewska et al. 2010; Woodcock, Banister, Edwards, Prentice, and Roberts 2007). Despite many synergistic benefits of sustainable transportation, nearly 90% of Americans still commute by driving alone.

Researchers have identified options to increase active transportation. A study commissioned by the American Public Health Association (2010) concluded that the near-complete dependence on automobile travel results in further costs of road construction and repair, continued urban sprawl and reduced walkability, less physical activity, health problems due to sedentary lifestyle, pollution and car crashes, and enormous long-term direct and indirect costs. Morency, Demers, and Polinquin (2014) found that converting short motorized trips to walking would allow 8.3% of their study population to increase physical activity levels, potentially improving weight management.

Underwood, Handy, Paternity, and Lee (2014) conducted a detailed interview study and concluded that biking was somewhat popular among American elementary school children, but tended to lose interest once they entered middle school. While numerous political, social, economic, structural, and cultural factors need to be considered in order to change the overreliance on SOV driving, communication strategies aimed at behavior change will provide critical engagement and incentives.

Sheepers et al. (2014) analyzed various incentives designed to promote active transportation as a way to encourage physical activity and reduce negative impacts of SOV transportation. Almost all studies in their analysis of published research found positive effects on (sustainable) mode shift from car use to active transportation. They categorized intervention tools as legal, economic, communicative (media, behavioral) or physical (e.g., bike rentals, improved facilities). Typically, more than one intervention tool was used, such as social marketing, individualized transportation plans, improved facilities, or financial incentives.

Transtheoretical Model

The Transtheoretical Model (TTM) has been recognized as one of the world's leading approaches to changing health behaviors. TTM has been successfully applied to more than 50 health behaviors (Hall and Rossi 2008), including smoking, diet, and exercise. Interventions based on the TTM have been successful at moving entire populations, including people who are not interested in moving toward change and in encouraging people to sustain long-term behavior changes (Noar, Benac, and Harris 2007; Krebs, Prochaska, and Rossi 2010; Prochaska, Redding, and Evers 2008). Smoking cessation is the most widely studied behavior change using the TTM, with measurement development research (Redding, Maddock, and Rossi 2006) leading to tailored intervention development and randomized trials evaluating the efficacy of TTM interventions (Prochaska, DiClemente, Velicer, and Rossi 1993; Velicer et al. 1999). Finally, TTM intervention efficacy with smoking cessation has also been replicated and extended in new populations and with multiple behavioral targets, including some studies by independent investigators (Hall et al. 2006; Hollis et al. 2005; Prochaska et al. 2001, 2004, 2005). This program of research for smoking cessation and other health behaviors provides direction and promise for TTM research applied to sustainable transportation. In order to systematically develop instruments and interventions to promote change in individual's transportation behavior, TTM and geospatial modeling were used to compare transportation choices and behaviors at two New England state universities with considerable variation in transportation infrastructure and travel patterns.

One key construct of the TTM is the *stage of change***.** Longitudinal studies have found that people move through a series of five stages when modifying behavior on their own or with the help of formal intervention (Prochaska and DiClemente 1983; Prochaska et al. 2008). In *precontemplation*, individuals may deny a problem and be resistant to change; they may be unaware of the negative consequences of their behavior, or have given up on change because they are demoralized. They are not intending to change in the foreseeable future. Individuals in *contemplation* are more likely to recognize the benefits of changing. However, they continue to overestimate the costs of changing and, therefore, are ambivalent and not yet ready. Individuals in *preparation* have decided to change soon, and have begun to take small steps toward that goal. People in *action* are overtly engaged in modifying their behavior and are working to prevent relapse. Those in *maintenance* have sustained change for at least six months and may not need to work as hard to prevent relapse as their behavior change becomes more habitual. The TTM improves the likelihood of behavior changes by tailoring or targeting interventions to each individual's *stage of change*. The TTM also includes constructs such as decisional balance and self-efficacy that have demonstrated systematic relationships with stages of change (Hall and Rossi 2008). Decisional balance, specifically, addresses individuals' evaluations of the costs of changing, and/or the cost savings of adopting a new behavior. These TTM constructs have been adapted and applied to sustainable transportation (Redding et al. 2015). Metaanalyses across a series of randomized trials including a range of different health behaviors have found that TTM tailored interventions are more effective than non-tailored interventions (Krebs et al. 2010; Noar et al. 2007).

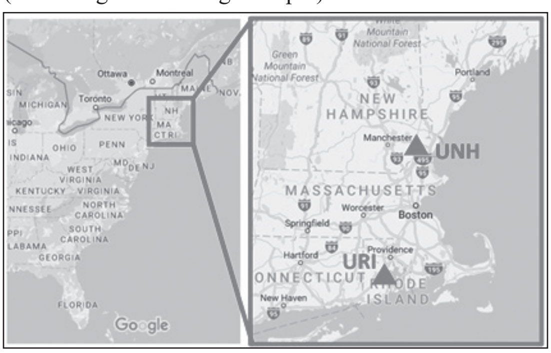
A TTM-based intervention study in the U.K. to increase active commuting among employees was effective. Mutrie et al. (2002) demonstrated that a TTM-based self-help intervention effectively helped those people who were either in the contemplation or preparation stages to initiate active commuting (walking or bicycle riding) to work.

Two Australian studies demonstrated the potential utility of TTM in reducing single occupancy vehicle (SOV) as a primary mode of transportation. Shannon et al. (2006) assessed the potential for change as well as barriers and motivators affecting transportation choices of 1,040 students and 1,170 staff at the University of Western Australia in Perth. A strong predictable relationship between stages of change for adopting active modes of transportation (walking, biking, public transit use) and pros and cons of change and self-efficacy (confidence in using active modes) was demonstrated. Students (46.8%) and staff (21.5%) engaged in "active modes" of transportation. Attitude and behavior patterns were more favorable compared with the U.S., but they also illustrated the potential for reaching out to those not yet engaged in active modes of transportation.

Rose (2008) utilized a software package, *TravelSmart,* to target 2,977 incoming students at Monash University, Australia, to encourage the use of AT modes and reduce SOV travel. Students received individually tailored travel information as well as various incentives. A single tailored intervention produced progress for those at each stage of change over the course of the school year.

UNH and URI Campuses

Figure 1: UNH and URI Locations
(base image from Google Map®)



UNH's main campus is located in Durham, NH (Figure 1), with 14,467 students and 3,577 staff and faculty. UNH has a good public transportation system and a well-established culture of sustainability. According to the 2007 UNH Transportation Report (UNH 2007), UNH Transit provided over one million transit trips to the surrounding community in 2006-2007, making UNH the largest transit system in the state and significantly reducing SOV miles traveled. Over 50% of off-campus students lived within walking distance of a UNH transit stop and only half of off-campus students commuted by driving alone. On the other hand, most staff and faculty commuted by SOVs.

There are three nearby towns (5-11 miles away) in the UNH Durham campus area— Dover, Newmarket, and Portsmouth. UNH Transit covers these towns with frequent schedules, providing convenient transportation alternatives to students, staff, and faculty living there. Rochester and Exeter are two other towns nearby (12-15 miles away) with limited transit options to the Durham campus. Manchester and Concord (35-40 miles away) are two urban centers housing many UNH commuters. Some UNH personnel also commute from Massachusetts and Maine.

URI's main campus is located in South Kingstown, RI (Figure 1), with 16,294 students and 2,543 staff and faculty. The town has the third-largest commuter population among RI state employees—many of them URI staff and faculty. Underclassmen tend to live in campus housing. Most off-campus students live in Narragansett, often in winter rentals near beaches and coastal recreation areas. Due to zoning, there is very little off-campus student housing in South Kingstown, which means that a typical commute for off-campus students from Narragansett is between 5-8 miles, just beyond comfortable biking range. In-state commuters often travel from their homes throughout the state. Public transportation to URI is limited in availability and usage. Buses are operated by the Rhode Island Public Transportation Authority. Transit connectivity between URI and RI communities is limited: one bus line connects with the capital of Providence (30 miles away) and continues to the southern part of South Kingstown. Another line connects URI with its Bay Campus in Narragansett and the city of Newport (18 miles away). Buses run about hourly with limited evening service. Coordination with class schedules is very limited. The most suitable form of AT for most off-campus students would be carpooling. There is virtually no transit connectivity to the western and southwestern part of the state.

This collaboration between URI and UNH provided a unique opportunity to examine transportation behaviors and attitudes using the TTM. UNH has a good public transportation system and, in spite of a well-established culture of sustainability, faculty and staff are still reluctant to use AT. URI has limited public transportation connectivity and has only recently begun to embrace sustainability, so faculty, staff, and off-campus commuters are also reluctant to use AT. Examined using the TTM, this may mean that participants are at different stages of change for AT and/or that participants value the pros and cons of AT differently. It also means that external conditions for change are more favorable at UNH. Both campuses may require different tailoring of interventions. A comparative study has value in adapting this model to changing transportation behaviors.

METHOD

Sample and Recruitment

The target population consists of 14,469 UNH students, 3,577 UNH staff and faculty, 16,294 URI students and 2,543 URI staff and faculty studying and/or working at the main Durham (UNH) and South Kingston (URI) campuses. Visitors were also welcome to participate in the surveys. Both UNH's and URI's institutional review boards approved all procedures for compliance with human subjects' considerations. Data were collected in spring 2011 over a four-week period in April and May to minimize the impact of New England weather and holidays.

Both online and phone surveys were used at UNH, while online surveys only were used at URI. Online surveys were conducted using a popular online surveying website. UNH phone surveys were conducted through UNH's Survey Center targeting only staff and faculty. A list of staff and faculty office phone numbers were obtained from UNH's human resources department and the staff at the Survey Center called a random sample of these phone numbers to recruit a target sample of 400 participants. Phone surveys were much more costly compared with online surveys but they could target a specific group of participants. In prior UNH transportation surveys, staff and faculty were recruited using phone surveys, and the 2011 survey continued this recruitment method for longitudinal comparison purposes. The 2011 survey was URI's first campus-wide transportation survey, and resources were not available to conduct phone surveys.

Newsletters, email, and social media advertisements were the main recruiting methods for the online survey at UNH. Flyers were also posted throughout the UNH campus. Incentives were also used. UNH survey participants could win prizes while URI recruitment included emails and class announcements to participate in an anonymous, voluntary online survey. Several email announcements were sent to the campus community, and a link was posted on the campus website. In addition, departments approached their faculty and staff to encourage participation. Students were reached by web and email. In a number of classes, students received extra credit or research credit for survey participation.

Survey Description and Development

The UNH and URI 2011 transportation surveys were a collaboration between UNH and URI. Since 2001, UNH has regularly conducted campus-wide transportation surveys with the most recent prior data collected in 2007. The 2011 surveys were adapted based on this 2007 UNH Transportation Survey (UNH 2007) by adding TTM measures for AT (Redding et al. 2015). The goals of past surveys were to assess community attitudes regarding UNH's transportation system, campus mobility, and accessibility issues. Questions from past surveys were repeated to allow longitudinal comparisons. The 2011 surveys covered transportation topics such as transit ridership, commute patterns, satisfaction and awareness of transportation services, traffic demand model measures, and parking. The URI survey was adapted to reflect the uniqueness of the campus and transportation system. Comparable questions were included in both surveys to facilitate comparison between the two campuses.

Measures

Stages of Change for Alternative Transportation. Stages of change for AT was assessed using the following item, consistent with prior research (Redding et al. 2015): "Alternative transportation includes any way of getting to URI or UNH other than driving by yourself (single occupancy vehicle use). So walking, biking, public transportation (bus/subway/train) and carpooling are all means of Alternative Transportation." Then, participants chose one statement that best reflected their situation:

(1) I do not regularly use AT and I do not intend to start within the next six months (Precontemplation);
(2) I am thinking about using AT regularly within the next six months (Contemplation);
(3) I plan to use AT regularly within the next 30 days (Preparation);
(4) I use AT regularly and have been for less than six months (Action); or
(5) I use AT regularly and have for six months or more (Maintenance)

Decisional Balance for Alternative Transportation. A decisional balance measure assessing pros and cons of Alternative Transportation (AT) reported good measurement structure, assessed by principal components and structural equations modeling analyses (Redding, Maddock, and Rossi 2006), and replicated previously established relationships with stages of change in college students, staff, and faculty (Redding et al. 2015). More specifically, the pros (5-item $\alpha = .84$) and cons (5-item $\alpha = .77$) each showed a relatively high value for Cronbach's alpha, α, which is a measure of internal consistency (Cronbach 1951). SPSS 21 was used to calculate α as described in Redding et al. (2015). Pro items asked individuals to weight the importance of various AT benefits in their own decision making, including such potential benefits as saving money, being green, and improving their own and the planet's health. Along similar lines, con items asked participants to weight the importance of various downsides of AT in their own decision making, including such potential barriers as time, practicality, and difficulty.

Self-Efficacy for Alternative Transportation. A five-item self-efficacy scale ($\alpha = .82$ as computed in SPSS 21) also reported good measurement properties (Redding et al. 2006) and replicated hypothesized relationships with stages of change in college students, staff, and faculty (Redding et al. 2015). Self-efficacy items asked participants to rate how confident they were that they would use AT, even when challenges arose, such as when they were running late, it was inconvenient, or they were tired.

Geospatial Variables. Survey participants (off-campus residents) were asked to enter address information of their residence—the closest cross streets and zip codes. Such information is used to obtain geographic information such as longitudes and latitudes. Due to privacy concerns, only the closest cross streets of participants' residences were requested. Given that block sizes varies in different towns and individuals' variation in identifying the nearest cross streets, the authors acknowledge the inherent errors in this method of collecting geospatial information.

The geospatial variables were calculated with the self-reported closest cross streets of participants' residences. Given the uneven distribution of residence locations, the geospatial analyses are based on scattered points instead of uniformly spaced grid points. Spatial gaps, such as unpopulated regions, were automatically excluded as there are no survey data in these areas.

Statistical Analyses

First, demographic, site, and subgroup descriptive and transportation variables were examined systematically prior to geospatial analyses. All statistical analyses were conducted using SPSS 21. A three-way Multivariate Analysis of Variance (MANOVA) was conducted among off-campus participants to examine the effects of study site (UNH, URI), employment group (students, faculty/staff), and AT stage on three dependent variables: pros, cons, and self-efficacy. Subsequent follow-up ANOVAs were conducted to clarify interpretation (Tabachnick and Fidell 2013). To balance sample sizes across subgroups, the AT stages were collapsed into three groups (Precontemplation, Contemplation/Preparation, Action/Maintenance), and staff and faculty were combined into one group. All analyses summarize effect sizes using η^2 (eta-squared), an effect size measure, comparable to R^2 used for regression, that shows the proportion of variance accounted for by the effect being tested (Tabachnick and Fidell 2013). Effect size estimates, such as η^2, are interpreted using guidelines for small (.01), medium (.06), and large (.14) effects developed by Cohen (1988).

Geospatial Analyses

Two main types of geospatial analyses are presented. One is a simple representation of variables in a geographic format (i.e., on a map). Such representations can show concentrations of data points (e.g., public transit commuters living in towns with good public transportation options). Another analysis requires spatial averaging of variable values. The averages were calculated within a 2-mile × 2-mile area centered at participants' residences. A 2 × 2 $mile^2$ area is used because it covers a one-mile radius from the center point. Finer (e.g., 1 × 1 $mile^2$) or coarser (e.g., 3 × 3 $mile^2$) scales can be used to produce more localized or generalized spatial averages, respectively. Spatial averaging can help describe trends or patterns in different regions such as the average age of a town's residents. However, similar to most averaging methods, spatial averaging can be skewed by outliers, especially in regions with few responses.

RESULTS

Survey Sample

A total of 1,868 subjects participated in the UNH and URI transportation survey in spring 2011 (1,111 subjects at UNH and 757 at URI). Table 1 presents demographics of survey participants. There were more female participants than males in both surveys, and URI had a higher percentage of female participants than UNH. URI participants were younger with an average of 28.06 years old compared with the UNH average of 40.1 years old. This age difference partially reflected the fact that staff was the largest group (52%) at UNH while students comprised the largest group (66%) at URI. Participants who were both employed by the universities and taking courses were typically graduate students. At both UNH and URI, most participants were off-campus residents, living away from the Durham (84.5%) or Kingston campus (72%). Over 80% of participants self-identified as white on both campuses. AT stage distributions reveal that for both locations, the largest stage was precontemplation (66.8% for UNH and 62.9% for URI), but that stage was not distributed equally across sites, χ^2 (4) = 28.96, $p<0.0001$, $\phi=0.14$. Surprisingly, more UNH participants were in PC and C and fewer in M, compared with URI participants.

Table 1: SurveyDemographics by Site

	UNH		URI	
	N*	%	N*	%
Gender				
Male	465	43.6%	261	36.2%
Female	601	56.4%	459	63.8%
Age				
Mean	40.1		28.06	
Standard Deviation	15.6		13.7	
Range	18-98		18-74	
Status				
Student	310	27.9%	551	66.0%
Faculty	137	12.3%	87	10.4%
Staff	578	52.0%	136	16.3%
Employed and Taking Classes	67	6.0%	32	3.8%
Visitors or others	19	1.7%	29	3.5%
Residence				
On-campus residents	172	15.5%	212	28.0%
Off-campus residents	939	84.5%	545	72.0%
Ethnicity				
White	591	83.2%	646	89.7%
Black or African American	2	0.3%	22	3.1%
Asian	29	4.1%	11	1.5%
Hispanic Latino	8	1.1%	22	3.1%
Native Hawaiian or Other Pacific Islander	3	0.4%	1	0.1%
American Indian or Alaska Native	2	0.3%	3	0.4%
Other	75	10.6%	15	2.1%
AT Stage Distribution (Off-campus residents)				
Precontemplation (PC)	364	66.80%	573	62.90%
Contemplation (C)	91	16.70%	94	10.30%
Preparation (PR)	15	2.80%	45	4.90%
Action (A)	18	3.30%	34	3.70%
Maintenance (M)	57	10.50%	165	18.10%

* Slightly different *N*'s across categories reflect missing data

Commuting Modes

Figure 2 breaks down the main commuting modes at UNH and URI among students, staff and faculty. Students used AT much more often than staff and faculty at both campuses. At UNH, only 35% of students drove alone to school compared with faculty (74%) and staff (84%). All URI commuters used SOV at higher levels than UNH commuters. URI students commuted by SOVs at 53%, and URI faculty and staff were at 82% and 85%, respectively.

Students showed the largest between campus difference (18%) using AT among all statuses. At UNH, 31% of students walked or biked to school compared with 25% of URI students. Almost a quarter (24%) of UNH students rode university transit. In comparison, only 9% of URI students reported using university or public transit. On the other hand, URI students carpooled (13%) more frequently than UNH students (9%) did.

At UNH, significantly fewer faculty (74%) drove alone to campus compared with staff (84%). Meanwhile, comparable proportions of URI faculty and staff drove alone to work (82% of faculty and 85% of staff). UNH faculty (25%) used AT more often than their URI counterparts (17%). More UNH faculty walked, biked, and rode public transit than URI faculty. For staff, UNH (84%) and URI (85%) showed similar AT usage. UNH staff walked more and URI staff took public transit more often. At both campuses, faculty used AT more often than staff. This observation aligns with a previous study that found less education was associated with greater gasoline consumption (Liu 2007).

Figure 2: Main Commute Modes by Status

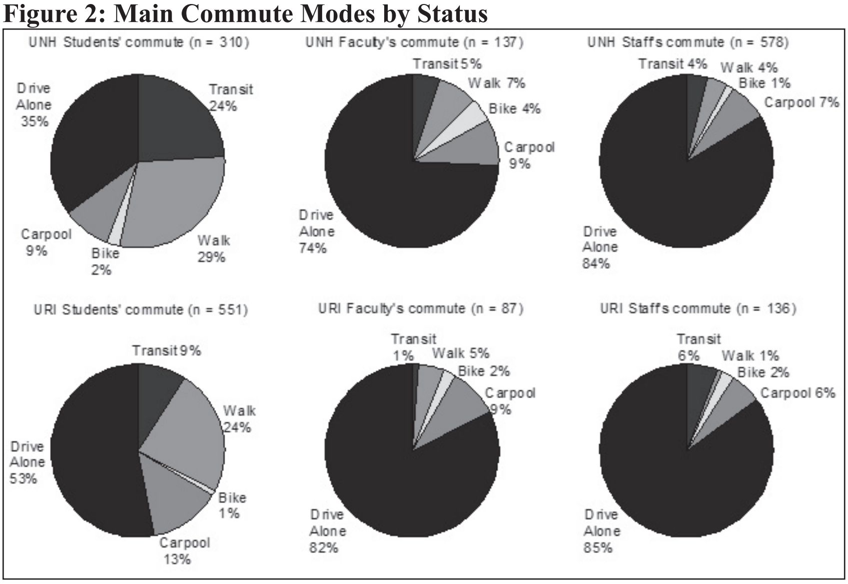


Figure 3 illustrates the average commute distances by off-campus student, faculty, and staff residents at UNH and URI. At UNH, students lived closest to campus followed by faculty and staff, who lived the farthest. At URI, students also lived the closest to campus while faculty and staff lived similar distances from campus. Across all subgroups, UNH commuters lived closer to campus compared with URI commuters.

Figure 3: Off-campus Residents' Commute Distances by Site

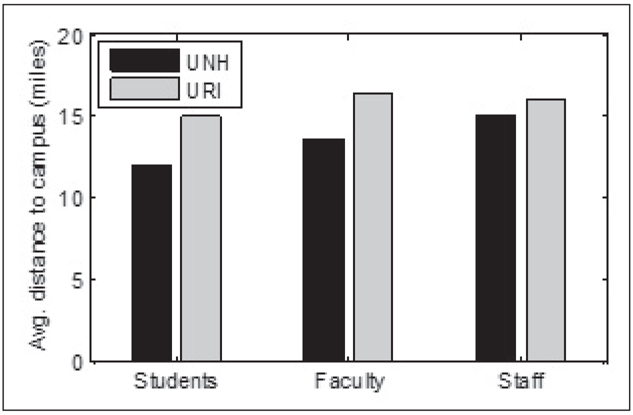


Figure 4: Off-campus Residents' Main Commute Modes and Average Commute Distances

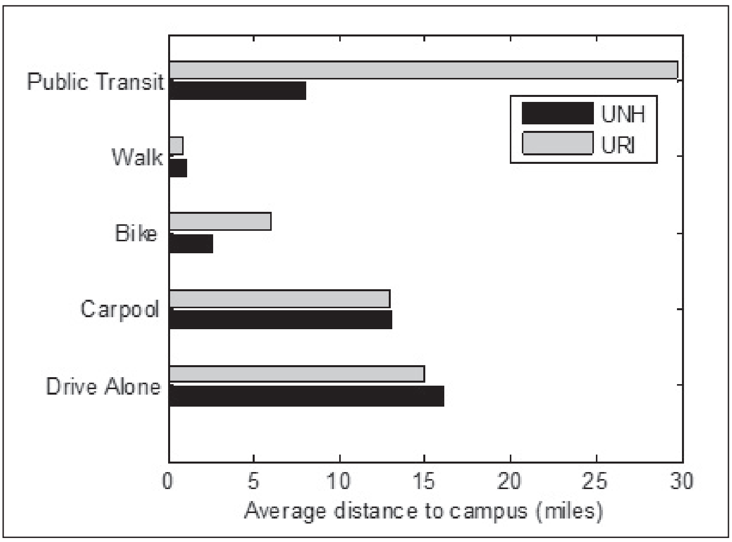
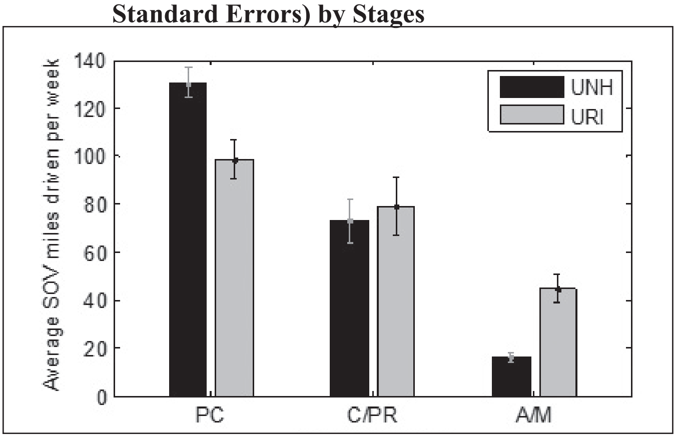


Figure 5: Average Weekly SOV Miles Driven (with Standard Errors) by Stages



We hypothesized that commute distances had an impact on commuting choices. In Figure 4, main commute modes were compared to commute distances for UNH and URI, respectively. At both UNH and URI, average commute distances followed similar trends for four commute modes: SOV, carpooling, biking, and walking. Among these four modes, SOV commuters live the farthest from campus, followed by carpooling and biking commuters. Walking commuters live the shortest distances from both campuses. UNH and URI commuters who used public transit had different commute distances. The average commute distance of UNH's "Public Transit" mode was in between "Bike" and "Carpool" distances. At URI, commuters who rode public transit had the longest commute distance at 27.5 miles.

Geographical Locations

To examine the relationships between AT stages of change, site (UNH, URI), and SOV miles driven, we conducted a two-way (by site and stage) ANOVA on average weekly SOV miles driven and graphed weekly SOV miles driven by both site and stage (see Figure 5). This ANOVA found a small significant site by stage interaction (F (2,972) = 7.70, p<.001, η^2=.015, a significant medium-to-large sized main effect for stage, (F (2,972) =53.06, p<.001, η^2 = .088, but no significant main effect for site. Figure 5 shows how many SOV miles were driven in an average week by all Stage groups at both sites (UNH, URI). Figure 5 also shows that, for participants in PC, UNH participants drove more SOV miles per week, while for participants in A/M, URI participants drove more SOV miles.

The stages of change for AT were also plotted geographically (Figures 6 and 7 for UNH and URI respectively). Each square in the figures represents the average value of the stages in a 2-mile × 2-mile area with a value of 1 for the *Precontemplation* (P) stage, 2 for *Contemplation* (C), 3 for *Preparation* (PR), 4 for *Action* (A), and 5 for *Maintenance* (M). A high average stage value indicates higher levels of readiness to use AT by the residents living in this square area; a low average stage value reflects residents' lower levels of readiness for using AT.

At UNH (Figure 6), the stage values were the highest (in A) in Durham, close to campus, reflecting that the many residents in this area were actively using AT. In the three nearby towns (Dover, Portsmouth, and Newmarket) that are covered by UNH transit, the stage values were also high. Portsmouth and Newmarket commuters were mainly in P while Dover was slightly earlier, typically in C/PR. For other nearby towns without university transit coverage, residents at Rochester had higher stage values (slightly above C) compared with Exeter (PC/C). Manchester and Concord residents were mostly in P. Generally, areas far away from campus had earlier average stage levels. However, certain less populated areas had relatively high average stage values despite being far from campus; this is likely due to the small number of data points in these areas.

At URI (Figure 7), there were four towns with average stage values well above PR: Kingston, Providence, Newport, and South Kingstown. All four towns had similar average stage values in between C and PR. Providence residents had the highest stage values. South Kingstown was separated into two regions with different stage values. The east part of South Kingstown was in PC/C while the west part was closer to PR. There were individual areas with M values but they consist of single data points. Similar to UNH, sparsely populated areas that were far away from campus had lower average stage values.

Multivariate Analysis of Variance of TTM Constructs

To compare attitudes toward AT and AT efficacy across campus sites and faculty/staff/student subgroups at different stages of change, a three-way MANOVA among off-campus participants examined the effects of site (UNH, URI), employment status (student, faculty/staff), and AT stage (precontemplation, contemplation/preparation, and action/maintenance) on three TTM dependent variables: AT pros, AT cons, and AT self-efficacy. Standardizing dependent variable scores allowed

Figure 6: UNH AT Stages by Locations (Off-campus Residents Only); Notation: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), Maintenance (M); Base Image from Google Earth®

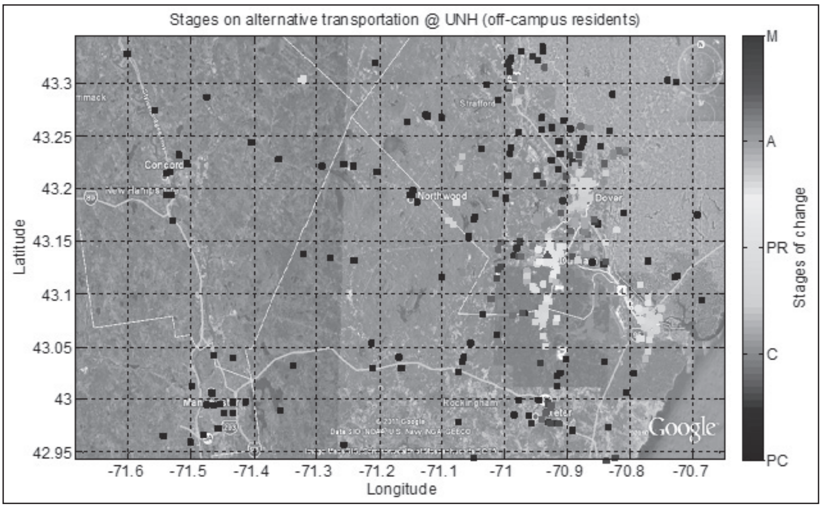
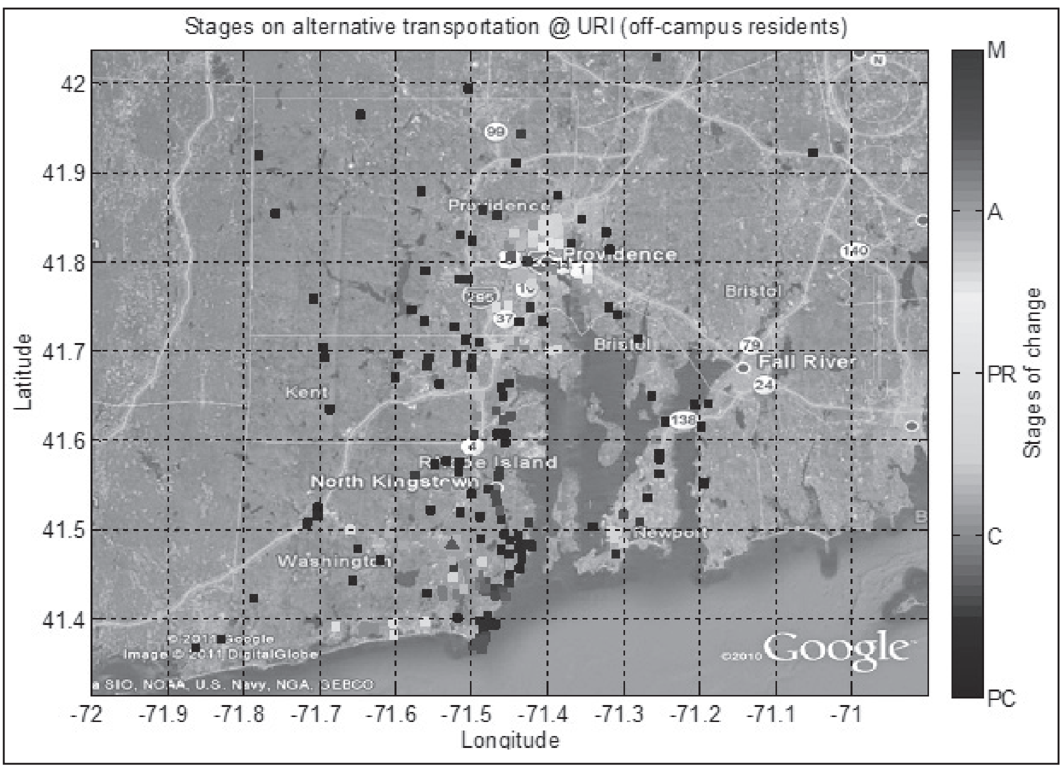


Figure 7: URI AT Stages by Locations (Off-campus Residents Only); Notation: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), Maintenance (M); Base Image from Google Earth®



for direct comparisons across constructs that may have different standard deviations (Hall and Rossi 2008), thus T-scores, similar to z-scores, standardize measures based on standard deviation units. Table 2 and Figure 8 present standardized (T-scores M=50, SD=10) mean scores by stage, site, and employment status for pros, cons, and self-efficacy. Comparable to the F-test statistic used for ANOVA, and similar to Wilk's Lambda, a test statistic used for MANOVA, Pillai's Trace test statistic was used for MANOVA significance testing here to adjust for a violation of homogeneity of covariance matrices. All three main effects (site, employment status, stage) achieved significance with no significant two-way or three-way interaction effects. Eta-squared (η^2) is a measure of effect size with established guidelines (Cohen 1988; Tabachnick and Fidell 2013). A small overall main effect was found for site, *Pillai's Trace* = .011, F (3, 1146) = 4.333, p = .005, η^2 = .011; a medium-to-large main effect was found for stage, *Pillai's Trace*=.190, F(6, 2294)=40.060, p<.001, η^2=.095; and finally, a small main effect was found for employment status, *Pillai's Trace* = .008, F (3, 1146) = 2.964, p = .031, η^2 = .008.

Table 2 and Figure 8 show mean T-score differences across all of these subgroups. Finally, three separate three-way follow-up ANOVAs examined each dependent variable one at a time: AT pros, cons, and self-efficacy by site, employment status, and stage to clarify multivariate findings reported above. To control for conducting multiple separate tests that would inflate the alpha level, a Bonferroni adjustment (α = .05 divided by 3 tests: α = .017 for each of three dependent variables) was used (Tabachnick and Fidell 2013). Significant small differences were found for the AT cons scale by site, F (1, 1158) = 12.074, p = .001, η^2=.010, with UNH scoring lower than URI. The small effect for employment status for AT pros approached significance, F (1, 1158) = 4.132, p = .042, η^2= .004, but after Bonferoni adjustment, was no longer significant. Significant medium-to-large differences were found for AT cons by stage, F (2, 1157) = 90.598, p < .001, η^2 = .136, with participants in A/M scoring lowest, followed by C/PR, and then PC; significant medium sized differences for AT pros by stage, F (2, 1157) = 28.762, p< .001, η^2=.048, with PC lower than A/M and C/PR; and medium-to-large differences for AT self-efficacy by stage, F (2, 1157) = 58.136, p < .001, η^2 = .092, with PC scoring lowest, followed by C/PR, and then A/M. In summary, these patterns of effects found (see Table 2 and Figure 8) for AT pros, AT cons, and AT self-efficacy across AT Stages of change were consistent across both UNH and URI sites, and across student and faculty/staff subgroups.

Figure 8: Means T-scores by Stage, Site, and Employment for TTM Measures; Notation: Precontemplation (PC), Contemplation/Preparation(C/PR), Action/Maintenance (A/M).

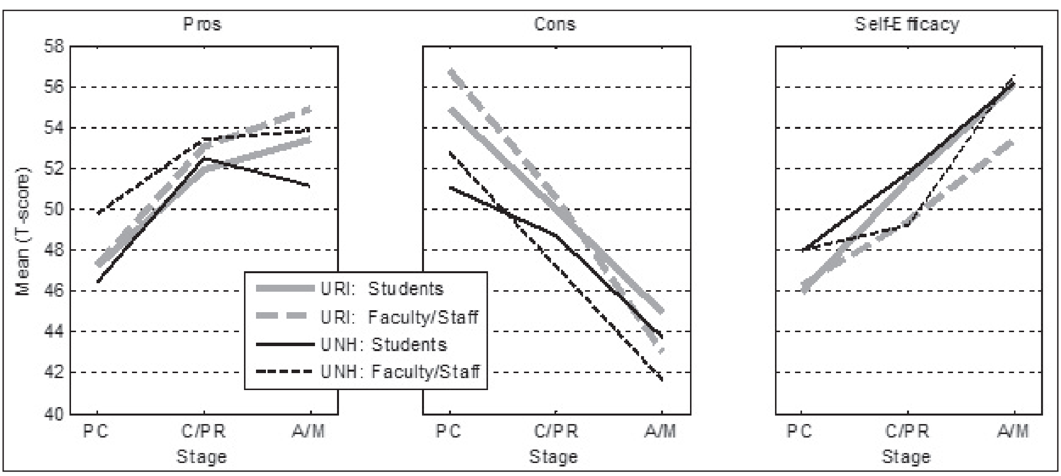


Table 2: Off-campus Students and Faculty/Staff Mean (SD) T-scores by Site and Stage; Notation: Precontemplation (PC), Contemplation/Preparation(C/PR), Action/Maintenance (A/M)

Study Location	Measure	Stage	Student			Staff/Faculty		
			Mean	SD	*N*	Mean	SD	*N*
URI	Pros	PC	47.25	8.90	201	47.30	11.93	96
		C/PR	51.95	8.11	59	53.06	10.04	27
		A/M	53.44	9.63	36	54.90	8.71	28
	Cons	PC	54.92	8.16	201	56.72	8.11	96
		C/PR	50.03	8.20	59	50.58	6.45	27
		A/M	44.97	11.71	36	43.01	10.64	28
	Self-Efficacy	PC	45.95	8.72	201	46.33	8.92	96
		C/PR	51.39	7.63	59	49.44	7.82	27
		A/M	56.08	11.57	36	53.43	9.05	28
UNH	Pros	PC	46.47	10.75	63	49.79	10.40	385
		C/PR	52.47	10.16	26	53.41	7.74	85
		A/M	51.15	10.48	69	53.86	9.14	85
	Cons	PC	51.07	7.86	63	52.80	9.01	385
		C/PR	48.71	9.32	26	47.24	9.33	85
		A/M	43.75	10.96	69	41.70	10.03	85
	Self-Efficacy	PC	47.93	9.42	63	48.00	8.83	385
		C/PR	51.77	9.65	26	49.22	8.16	85
		A/M	56.19	9.44	69	56.62	11.03	85

DISCUSSION

This integration of transportation and behavioral science research has demonstrated that both fields contribute important insights toward an improved understanding of transportation choices and ultimately the promotion of active, sustainable transportation. Commute distances and transportation infrastructure at both universities strongly influenced commute choices, attitudes, and readiness for alternative transportation (AT).

The results of UNH and URI's 2011 transportation surveys showed that students, staff and faculty displayed somewhat different commute behaviors at both universities. Figure 2 showed that students used AT more often than staff and faculty at both universities. This was largely due to the fact that students were more likely to live on campus. It is also possible that students' attitudes were more green compared with faculty/staff, although we did not find stronger endorsement of the pros of AT among students compared with faculty/staff (see Table 2). It is possible that we had a more select sample of faculty/staff with more green attitudes, given much higher numbers of and participation rates among students. Even among off-campus residents only, positive and negative attitudes toward AT were much more strongly related to the stage of change for AT than student/faculty/staff status or campus site. In fact, stage of readiness for AT accounted for about 8.8% of weekly SOV miles traveled and about 10% of the variance in attitudes and efficacy to use AT, and these results were consistent across students and faculty/staff groups, as well as across campuses. In fact, the relationships between AT stage and AT pros, cons, and self-efficacy replicated well across campus and student/faculty/staff subgroups in this study and replicated prior results as well (Redding et al. 2015). Campus did show a small effect on attitudes with participants at UNH rating the cons of AT lower than participants at URI. This may reflect the more facilitative transportation infrastructure and culture of sustainability at UNH compared with URI. At UNH, 41.5% of students lived on campus while only 2.5% of staff and faculty lived on campus. At URI, 29.4% of students lived on campus while almost no staff or faculty (0.6%) did. Even among off-campus residents, students tended to live closer to campus than staff and faculty (Figure 3). Given that there were more on-campus UNH student residents (Table 1), and UNH off-campus student residents lived closer to campus compared with URI students (Figure 3), Figure 2 also showed that more UNH students used AT than their URI counterparts did.

Commute behaviors were also different between staff and faculty as a function of commute distances. Figure 3 showed that at UNH, faculty lived closer to campus compared with staff, and more faculty used AT than did staff. At URI, faculty and staff lived at similar distances from campus, and there was only a very small difference (3%) between faculty and staff in using AT.

Figure 4 further supported the hypothesis that long commute distances discouraged AT usage. SOV commuters had the longest commutes (17 miles at UNH and 15 miles at URI) compared with all other commuters using AT. A single exception was the category of public transit commuters at URI. This exception was largely due to two popular public transit routes from Providence (30 miles away) and Newport (18 miles away) to URI. This showed that, in addition to commute distances, well placed public transportation infrastructure can support AT behaviors.

In UNH's nearby towns (Dover, Portsmouth, and Newmarket), there is an excellent UNH transit system and many residents commuted by transit. At URI, many Providence and Newport residents (mostly students) rode public transit to campus. Given that UNH transit is free to UNH commuters and its covered towns are relatively close (5-11 miles) to campus, more UNH commuters chose transit (24% of students and 4.8% of staff and faulty) compared with URI commuters (9% of students and 4.1% of staff and faulty). This presents an opportunity for URI in the future to improve its transit infrastructure.

The TTM measures also showed that commute distance and public transportation infrastructure influenced AT behaviors and attitudes. Figure 5 showed evidence of construct validation of the AT stages of change measure on commuting patterns; it showed that participants who were in later stages of change, that is, those practicing AT, drove fewer SOV miles at both campuses, as would be expected. This effect of stages of change on weekly SOV miles traveled appeared stronger at UNH given the steeper slope in Figure 5 for UNH compared with URI, where sustainability support and infrastructure is stronger. These conclusions confirmed our initial hypotheses and show how AT stage can be useful, especially when combined with other transportation measures, in future efforts to improve active and sustainable transportation. Figures 6 and 7 showed an overall trend of more readiness for AT at shorter commute distances on both campuses. These figures also displayed higher levels of AT stage when commuting from towns (Dover, Portsmouth, and Newmarket in NH and Providence and Newport at RI) with adequate public transportation infrastructure.

Finally, multivariate analyses on the entire sample found a significant relationship between AT stage and the three TTM constructs (AT pros, cons, and self-efficacy). These significant stage differences found were consistent with TTM theoretical predictions and replicated previous research findings across a range of health behaviors (Hall and Rossi 2008; Prochaska et al. 2008) and one previous study on transportation behaviors (Redding et al. 2015). Table 2 and Figure 8 show that participants in A/M scored lowest for cons but highest for self-efficacy, and participants in PC scored lower than C/PR and A/M for pros, lowest for self-efficacy, and highest for cons. Future research may find a better distribution of individuals across AT stage subgroups; small sample sizes in some subgroups limited our ability to compare all stage groups with sufficient power. Future studies should also examine longitudinal changes in AT attitudes and behaviors.

Conclusion and Future Work

Promotion of alternative, active modes of transportation (AT), such as walking, biking, carpooling, and public transit, can significantly improve sustainability on and off campus. There are many barriers for commuters to choose AT, such as long commute distances and inconvenient public transportation options. Understanding the commute behaviors and decision-making processes for choosing commuting modes is essential to effectively encourage AT. Transportation surveys conducted at two New England universities, UNH and URI, integrated behavioral and attitudinal measures—Transtheoretical Model (TTM)—and geographical information queries (e.g., residence locations) to assess AT stages of change, AT attitudes, and behaviors among students, staff, and faculty. At both campuses, students had the shortest commute distances and practiced AT more frequently compared with staff and faculty. Geographic locations strongly affected the use of AT and commuters' behaviors and attitudes toward AT. Consistent with TTM predictions, commuters living in towns with adequate university/public transit connectivity to the campuses showed the highest levels of readiness to use AT. Additionally, a strong negative relationship was found between increasing AT stages of change and decreased SOV miles traveled on both campuses (Figure 5), providing some validation of participants' reports of their stage of change. UNH participants rated the cons of AT as significantly lower compared with participants at URI, reflecting the better developed transportation infrastructure at UNH. At both universities, in students, staff, and faculty alike, attitudes and efficacy for AT were strongly related to stage of readiness for AT, consistent with TTM predictions and prior data. The assessment of commute patterns and behaviors shown in this paper is the first step in a program of research that aims to encourage AT behaviors in universities and, ultimately, communities.

Future work will develop and evaluate individual and policy interventions to promote AT based on commute patterns, behavioral models, and geographic information. The study findings should be made known to policy makers, school administrators, and city planners such that they can improve transit infrastructure (e.g., investment, recourse) to maximize its use. For example, new transit investments should be considered first in regions with higher readiness to adopt sustainable transportation.

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