



Exploring spatio-temporal commuting patterns in a university environment

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ABSTRACT

Universities in small towns are often located so that amenities, stores, activities and housing are concentrated within a short distance from campus. Given this compactness between origins and destinations, bicycling and walking should be ideal modes of transportation among a university population. This research seeks to explore the spatial, temporal and gender differences in transportation modal choice among student commuters with an objective of uncovering incentives to increase the use of non-motorized or public transportation to the campus. Findings point to the availability of lower-cost parking permits as an enabler of shorter distance car commutes, especially in the winter season. Male students are found to be more likely to switch commuting modes throughout the year while females are generally more likely to drive. Differences in commuting choice behavior between students with children, and traditional undergraduate and graduate students are also found. Policy implications of the stated preference survey are discussed.

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1. Introduction

As universities throughout the United States and the world strive to create sustainable campuses through a number of green initiatives, transportation can play a significant role in establishing not only a more sustainable campus, but also contribute to the overall sustainability of the university's city or town. This is especially true in smaller, university town settings where the campus serves as the major trip attractor for employees and students alike. Policies encouraging non-motorized and public transportation can have an immediate benefit to the local environment in terms of reduced air pollution, congestion, and public health, and in addition, changes in student travel behaviors can create longer term reductions in automobile dependence as those students move on to help shape future public policies and continue to make commuting choices throughout their adult lives (Shannon et al. 2006). Balsas (2003) has argued that university campuses represent a microcosm of society; places where norms and behaviors are shaped, and are hence an ideal setting for exploring policy initiatives targeted at reducing automobile dependence. Habits have been found to be a significant factor in the decision to use non-motorized transportation such as bicycling (Heinen et al., 2010), so shaping these at the onset of adulthood could help lead to longer-term increases in alternative transportation choices.

Several recent studies have examined student or university community mode choice decisions with the intention of identifying the potential for modal change. For example, Shannon et al. (2006) performed an online survey of commuting patterns and attitudes towards switching to active modes of an urban university population in Perth, Australia. The authors found travel time to be the most important barrier to change, and that potential policy measures include increased parking costs, improved bus and bicycling service, more student housing close to campus, and the implementation of a public bus pass to help shift transportation modes. In a very different setting of rural Thailand, Limanond et al. (2011) identify vehicle ownership as the largest factor associated with student mode choice decisions. From a US perspective, Toor and Havlick (2004) provide an overview of sustainable transportation case studies and issues with regard to planning and policies, while, Rodriguez and Joo (2004) found local topography and sidewalk availability to be significantly associated with the attractiveness of non-motorized transportation for university commuters.

In terms of policies aimed at decreasing automobile dependence among student commuters, subsidized parking on university campuses has received some attention in the literature as a catalyst for disproportional automobile use; these policies have been charged with unfairly rewarding drivers by reducing their true costs, while providing no rewards for bicyclists and walkers (Shoup, 1999).

As an alternative to driving, bicycling is often proposed as the most promising modal switch in a university setting given the often short distances separating off campus student housing and main campuses (Tolley, 1996). Bicycling offers the advantages of

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being both inexpensive and fast, while also reducing the ecological footprint of a university by emitting no air or noise pollution, and increasing the overall health of the student population, as active student commuting has been associated with increased overall physical activity as compared to drivers (Sisson and Tudor-Locke, 2008).

Transit-university partnerships are another policy initiative aimed at reducing student automobile dependency. These programs often feature unlimited transit access and have been common features of university transportation management plans since the late 1970s (Bond and Steiner, 2006; Brown et al., 2001). While an attractive option, these initiatives are not a guaranteed success as noted in Zolnik (2007), stakeholder coordination and planning of funding are critical to its ability to be both financially viable and to attract student commuters.

This small, but growing literature on campus commuting behaviors generally share a desire to aid in the development of policies that will encourage shifts from automobile commuting to alternative modes. Mode shift in individuals is not an easy task, but is partly a function of the scale of the transportation system and urban form of the surrounding area. It may be very difficult to change modes of transportation in suburban areas without a complete overhaul of the building and transportation infrastructure. However, in a small, compact, university town setting where the university is the major employer, and where destinations (home, services, stores, workplace) can be reached within a relatively short distance, automobile alternatives are a very plausible solution. Therefore, incentives identified by its residents to switch from a car to an alternative mode for in-town trips hold a promising potential for reducing automobile use, and in the long run to shape lifetime behaviors or preferences of students who will become the next generation of decision and policy makers.

The purpose of this paper is to explore the spatial and temporal patterns of student commuters in a small town, Moscow, Idaho, home of the University of Idaho, with the intention of identifying potential policy prescriptions for increasing alternative transportation usage among students. Given the weather-related effects on bicycling usage found in the literature (Nankervis, 1999), the temporal component of this study seeks to explore seasonal, climate-related changes in behavior. While the case study is specific to Moscow, numerous small, college-oriented towns exist throughout the United States, and so the findings may provide guidance for other such locations. The structure of the remainder of the paper is as follows, in Section 2 the survey and data collection method is described. In Section 3, survey responses are presented including spatial and a spatio-temporal visualization component,

while Section 4 evaluates policy implications followed by a conclusion in Section 5.

2. Data collection and study area

In an effort to decrease global emissions of greenhouse gases, the University of Idaho joined the American College and University Presidents' Climate Commitment in 2007. That same year, the University established a sustainability center to promote projects aimed at "greening the campus" by reducing its environmental footprint and creating a culture of sustainability among students, faculty and staff. Among several responsibilities to promote sustainability, the initial task of the center was to report greenhouse gases and the carbon footprint of the university population. In 2008, the center sought collaborative proposals that would help the University reach its climate change objectives, ultimately leading to the funding of a study on student travel behaviors, an effort led by University faculty, researchers, as well as town planners and community transportation advocates. Together, the team met to determine research questions that would help understand the rationale behind student mode choice, detect seasonal and geographic patterns of these choices, identify barriers to using non-motorized or public transportation, and finally, to help identify potential policy measures that would induce changes to alternative commuting modes.

2.1. Study area

The University of Idaho is located in the city of Moscow, Idaho and is the major employer of the town. The city has an area of 6.2 square miles, and according to the 2000 census had a population of 21,291 people. Most businesses and services are located in the center of city, but are also spread out along two major state highway roads (Fig. 1(a)). According to the U.S. Census 2000 survey of travel to work, 3.39% of residents bicycled to work while 20.5% walked; a slight decline from the previous decade when 4.78% of workers bicycled and 21.22% walked. These figures, however, do not capture student commuting statistics.

In 2006, the University employed 2974 people, of whom 696 were faculty members, 671 were lecturers and research assistants, and 852 were staff. A total of 11,739 students were enrolled in the University, of which approximately 20% were graduate students. The campus is located 8 miles east of another major University campus, Washington State University in Pullman, WA. A major shared-use path runs parallel to Highway 8, entering the

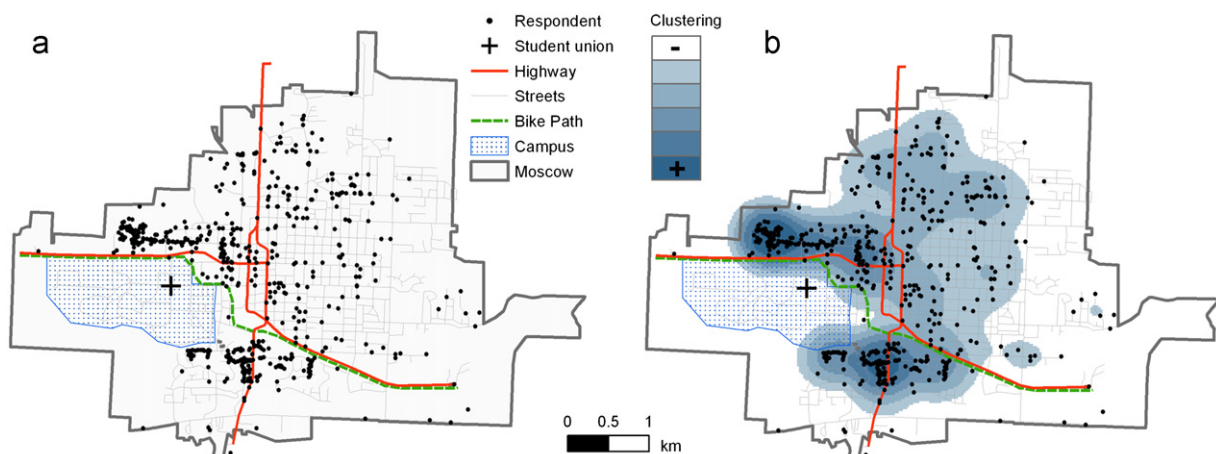


Fig. 1. Distribution of the survey respondents in (a) and associated spatial distribution in (b) by Kernel density estimation. The cross denotes the location of the student union from which network distance to each respondent was computed.

campus from the Northwest and leaving to the East. Due to its limited geographic extent and extensive presence of sidewalks, students living in the city of Moscow have different modal choices to reach campus. The University of Idaho campus is well connected to the center of town through two bike lanes on each side of the road, as well as sidewalks, which favor active commuting. In terms of public transportation, University students have free access to the city bus system which serves a total of 24 stops in the city over two routes (east and west). In addition, the routes connect to additional regional bus services to the city of Lewiston (South of Moscow), and Pullman, WA (Fig. 1(c)). Ridership statistics show an increase since boardings were recorded on those routes in 2004, with a total of 32,462 that year to 60,746 in 2006 and 104,635 in 2008.¹ In general, individuals living further away from town are more responsive to the service, while the majority of transit riders are non-student town residents.

2.2. Survey design

The survey was designed in collaboration with the Moscow Transportation Commission, city and university transportation planners, as well as the general public who were invited to participate and give feedback to the questionnaire. Questions in the survey were formulated with the aim at understanding which modes of transportation are used by students at different times of the year, their overall feelings about the current infrastructure and commuting environment, and to gain some insight on specific initiatives that would entice students to switch to non-motorized or public transportation from driving. Given the various stakeholders involved in the survey design, a stated preference or choice format was selected to provide respondents with a set of alternatives so that specific items could be evaluated. For example, in terms of barriers to bicycling, students were asked to select whether an increase in bicycle lanes would increase their probability of cycling (a city controlled item), or if the infrastructure on campus needed to be updated in terms of bicycle racks or covered shelters (University).

The survey was divided into four sections. Section 1 consisted of 16 general questions (for instance major, gender, car ownership), Section 2 asked the frequency each student chose different modes of transportation throughout the year, recording temporal variations in commuting patterns. Section 3 consisted of 11 questions on automobile transportation (e.g. type of car, parking, reasons to drive a vehicle). Section 4 focused on alternative transportation with 18 questions on bicycling, walking, carpooling or bus commuting (bike ownership, external conditions affecting biking, distance students willing to walk to a bus stop to cite a few). The commuting environment was assessed in Section 5 with 6 questions on factors regarding infrastructure, traffic, safety, and topography that may impact mode choice decisions. Finally, at the end of the questionnaire, students were asked to map their house location and when possible, the most common route to campus, and to indicate places perceived as being dangerous for walking or bicycling, thus capturing a geographic component to their responses. Surveys typically took 10 to 15 min to complete.

2.3. Survey execution

Surveys were stratified among 42 classes in various departments and colleges to get a heterogeneous distribution of degree majors. Although it was our intention to conduct the survey earlier during the Spring 2008, delays in the IRB process caused the survey to be carried out in the last two weeks of April. To that

regard, there is a concern that results could have slightly been influenced by the weather (see Shannon et al. 2006 for a thorough discussion). Finally, the price of gas in April 2008 was at a high of almost \$4/gallon (EPA, 2008), and so this may have also influenced the number of walking and biking commuters.

2.4. Spatial database

The data were encoded in a database during the summer and fall of 2008, with each response containing a unique identifier, represented as a row, while answers to questions were encoded in the attribute column. A GIS layer indicating student place of residence was prepared, linking the database and the map through a unique identifier. A total of 1056 surveys were executed covering 89 different majors. Given that one of the objectives was to observe temporal trends in the data, respondents were asked about the frequency of selecting a particular mode each day of the week, and then for each season. The probability of modal usage is computed per week, for instance if a student traveled by car five days out of the week to the University, the probability of that mode would be 1, and zero for the other modes. If a student came three days a week to school and drove all these three days, the same rule applies. If a student carpooled two days a week, and walked the remaining three days, his probability of carpooling is 0.4, and walking 0.6, respectively.

3. Results

Although 1056 surveys were encoded, in a post-filtering process we discarded 489 surveys due to incorrect or incomplete information. In addition, if the place of residence was not indicated on the map, the sample was removed, resulting in a final sample size of 567 respondents. Frequencies by various groups of students are summarized in Table 1 indicating that the majority of students who participated in the survey were undergraduate and male.

Fig. 1(a) and (b) map the location of residence for the 567 respondents and associated spatial distribution by a Kernel density function, respectively. (The Kernel bandwidth of 500 m is selected based on the maximum clustering distance between points, a procedure suggested by Delmelle et al. (2011)).² While there is a stronger concentration of respondents to the North and Southeast of the University due to the presence of several student housing complexes, the remaining respondents are uniformly spread across town. Fig. 2 summarizes the density distribution of survey respondents with network distance to the university. For each respondent, we computed the network distance from their place of residence as indicated on the survey to the campus student union, a centrally located building on campus, by means of Network Analyst (ArcGIS, ESRI, Redlands CA). The upper plot pools all the respondents together, while the lower plot breaks down the density by group (male, female, undergraduate, and graduate students). According to the figures, most students live within 2500 m of the university, and undergraduate students live even closer, the majority within 1500 m of campus, or close to one mile. Female respondents on average live slightly closer than male students.

¹ Personal discussion with Tom LaPointe, executive director of Moscow Valley Public Transit (2009).

² See also Kamruzzaman et al. (2011) on the use of GIS to visualize student travel behavior.

Table 1
Number of valid responses per standing, gender and marital status.

	Standing*	Gender*		Marital status*		Children+	
		Male	Female	Married	Single	No. children	One or more
Freshman:	33	10	23	4	29	30	2
Sophomore:	106	56	50	14	92	96	10
Junior:	157	82	75	16	141	150	7
Senior:	234	142	92	35	199	214	20
Graduate/law:	35	24	11	11	24	30	5
Total	565	314	251	80	485	520	44

(*2, +3 students declined to enter this information).

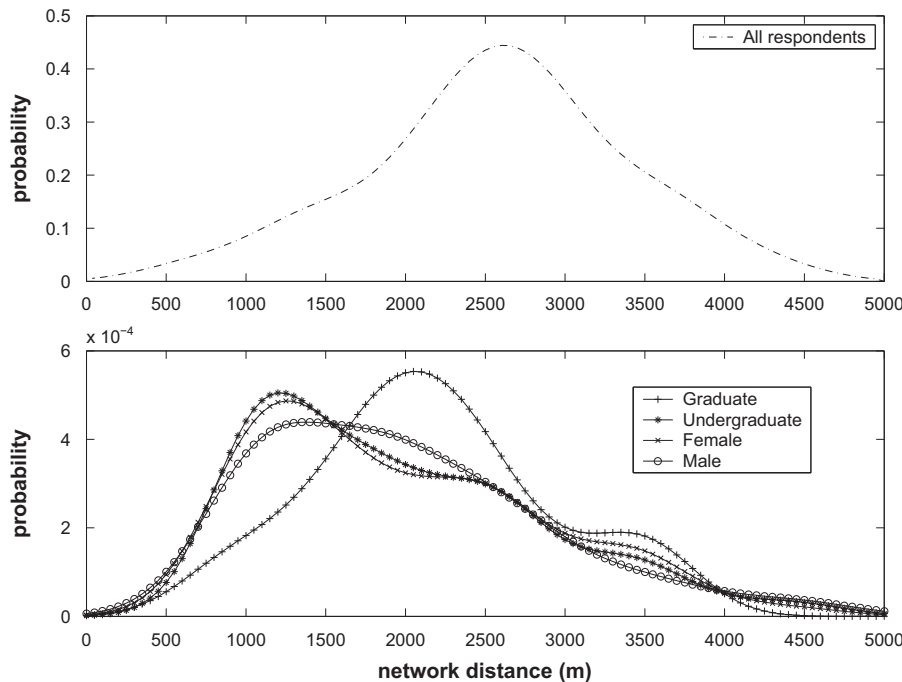


Fig. 2. Probability density function of survey respondents with distance to the University.

3.1. Travel mode characteristics

In this section, general statistics regarding the commuting choices and the characteristics of respondents are reported as well as the stated factors impacting choice decisions, selected from a given set of alternatives, or recorded separately in an 'other' category.

In order to assess temporal variation in mode choice, students were asked to indicate the number of times each mode was used in a given week, for two month time periods. Therefore, to gain a general understanding on mode choice, the probability of selecting a mode for each individual is computed based on all responses. Seasonal differences are discussed in the next subsection. Table 2 summarizes modal choice probabilities for the entire year. In 40% of the cases, walking is found to be the dominant mode of transportation, followed by driving and biking. We did not find significant differences between males and females for walking or using the bus as the main mode of commuting. However, we did find that females are more likely to drive to campus or carpool, consistent with Rodriguez and Joo (2004), and that male students are more likely to bike to campus than females. In comparison to undergraduate students, graduates are less likely to use their car to commute to campus, and more likely to walk or bike.

The relationship between owning a bicycle and selecting bicycling as a mode of transportation is also explored. Table 3

Table 2
Modal choice probabilities.

	Car	Carpool	Bike	Walk	Bus	Drive and walk ^a
Male	0.332	0.053	0.141	0.396	0.029	0.039
Female	0.376	0.083	0.085	0.380	0.030	0.041
Freshman	0.380	0.084	0.054	0.448	0.007	0.019
Sophomore	0.346	0.074	0.096	0.357	0.060	0.051
Junior	0.360	0.084	0.106	0.386	0.028	0.027
Senior	0.353	0.048	0.128	0.391	0.021	0.047
Graduate/law	0.272	0.072	0.189	0.400	0.017	0.036

^a Drive and walk indicates that a student drives and parks somewhere off campus and walks from that location to campus.

below shows the breakdown of students in relation to bicycle ownership. Although bike ownership among males and females is similar, we observe a significant difference among the two groups for selecting that mode of transportation (*t*-test rejected, $p=.0077$). These findings are consistent with the bicycle commuting literature which points to an overall dominance of male bicycle commuters as compared to females, although the reason for this difference is not always well understood (Heinen et al., 2010). Overall, bicycle ownership is highest for graduate students, the group most likely to bike to campus.

In order to assess the relationship between mode choice and distance to campus, cumulative distribution plots showing the

Table 3
Bike ownership among different groups of students.

	Male	Female	Freshman	Sophomore	Junior	Senior	Grad.
Owens	118	103	17	44	64	86	10
Does not own	197	149	16	62	93	148	25
%	0.63	0.59	0.48	0.58	0.59	0.63	0.71

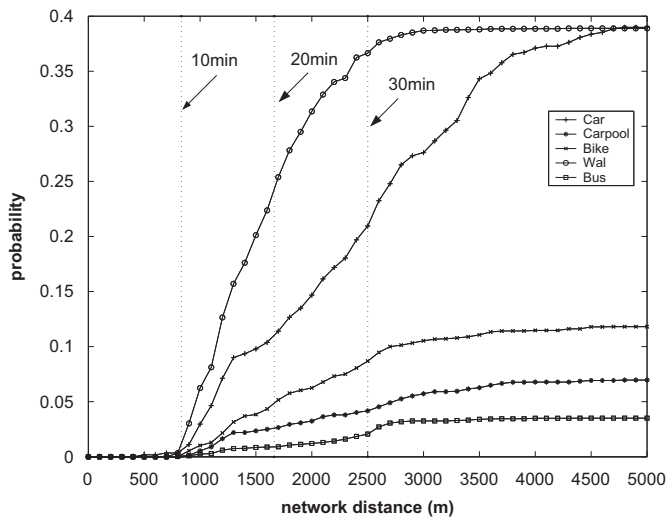


Fig. 3. Cumulative distribution per mode of transportation with distance to campus. The curve with crosses denote automobile commuting. Vertical lines represent walking time to campus.

probability of each mode with distance from campus to student residence are shown in Fig. 3 (walking time are indicated by vertical lines). Car usage and walking are the two dominant modes of transportation, and there is a strong propensity for walking to be the main mode of transportation up to 2500 m (30 min) where the curve flattens out. Car usage strongly increases between 10 and 15 min walking time and then gradually increases beyond 1250 m (or 15 min walk).

Aside from distance and gender, differences in mode choice decisions are shown in the family composition of students, a consideration often overlooked in considering student behavior; non-traditional students often have additional time-use constraints and obligations that may impact mode choice, and typically do not reside in nearby student housing complexes. The number of children has a significant and positive simple correlation with the probability of driving (0.305, $p=.04$), a negative correlation walking (-0.23 , $p<.001$) and slightly significant negative correlation with biking (-0.2298 , $p=.13$). The influence of household structure and gender in shaping mode choice decisions is not unique to students as these trends also appear in general mode choice to work studies (Commins and Nolan, 2011), but it should be taken into consideration when designing campus transportation policies.

Although only 39% of car commuters gave specifics as to why they use their vehicles as main mode of transportation to commute to campus, 42% of them identified weather conditions as a motivating factor, 31% cited time management issues, and 20% revealed that distance to campus was a significant factor. A regression analysis on all respondents indicated that parking was the dominant positive variable associated with the probability of driving to campus (t -value=11.72) revealing that owning a permit increases car usage by 36%.

In terms of bicycling or walking, respondents were asked to evaluate the importance of topography, traffic conditions, and safety on their stated choice behaviors. An approximately equivalent number of males and females cited the size or number of cars on the roads as influential impedance on their decision to walk or bike (25.4% female, and 23.1% males). Gender differences were found on the stated impact of topography on mode choice decisions; in response to the effect of local topography on mode choice decisions, 12.3% of females stated it greatly impacted their decisions, while 48.8% said it somewhat affected their choice (compared to 5.4% and 37.14% of male respondents to the same question). Female bicycle commuters also expressed a greater concern for safety when bicycling as 67.5% of them stated that they felt either 'somewhat safe' or 'not safe' while cycling with the current infrastructure (compared to 51.7% for males). No clear spatial pattern in these responses was found; in other words, there were no locations that had an especially high number of commuters who felt unsafe or affected by topography or local traffic.

3.2. Temporal patterns and visualization

Next, seasonal variations in commuting choices are assessed for each mode. Overall, the greatest seasonal shifts in stated commuting behaviors are exhibited in the months of September and October when weather conditions are most favorable towards non-motorized transportation with relatively warm, dry temperatures. During these months, car usage is at its minimum for both driving alone and carpooling, while bicycling reaches its peak for all groups of students (graduate, undergraduate, female, and male). Interestingly, walking for graduate students shows a sharp drop during the more temperate autumn months, at the exchange of bicycling. In fact, the likelihood for graduate students to walk in the summer months decreases from 41% in the spring to 33% in the summer, directly attributable to an increase in biking from 20% to 30%. However, when pooled together for all surveys, we did not observe major changes in walking probabilities between summer and winter months (accepting t -test hypothesis, $p=.3891$). For other groups, walking remains relatively constant and does not seem to be affected by variation in temperature or changes in weather pattern.

The observed variation in car usage between the warmer summer and autumn months is statistically significant (rejected t -test; $p=.0886$), but differs by gender. Male students are more likely to switch from automobile to other modes of transportation than female students who do not exhibit statistically different changes in behavior throughout the year (rejected t -test; $p=.099$ for males, accepted t -test; $p=.4725$ for females). Similarly, carpooling, the second lowest mode of transportation used overall, shows a statistically significant increase during the winter months from 6.5% to 10.5% (rejected t -test; $p=.0048$). Bus commuting probabilities remain extremely low, and is the least chosen mode of transportation by students throughout the entire year with a slight increase in the winter months, primarily by females (Fig. 4).

These seasonal variations in commuting illustrate that when weather conditions are favorable, alternative transportation mode choices are commonly used; however, when conditions become less favorable, students tend to switch to driving alone rather than to carpooling or riding the bus. This suggests that there is little cost disincentive towards driving.

3.3. Spatio-temporal visualization

In order to visualize both these spatial and temporal patterns, and to enable the wider dissemination of results to multiple

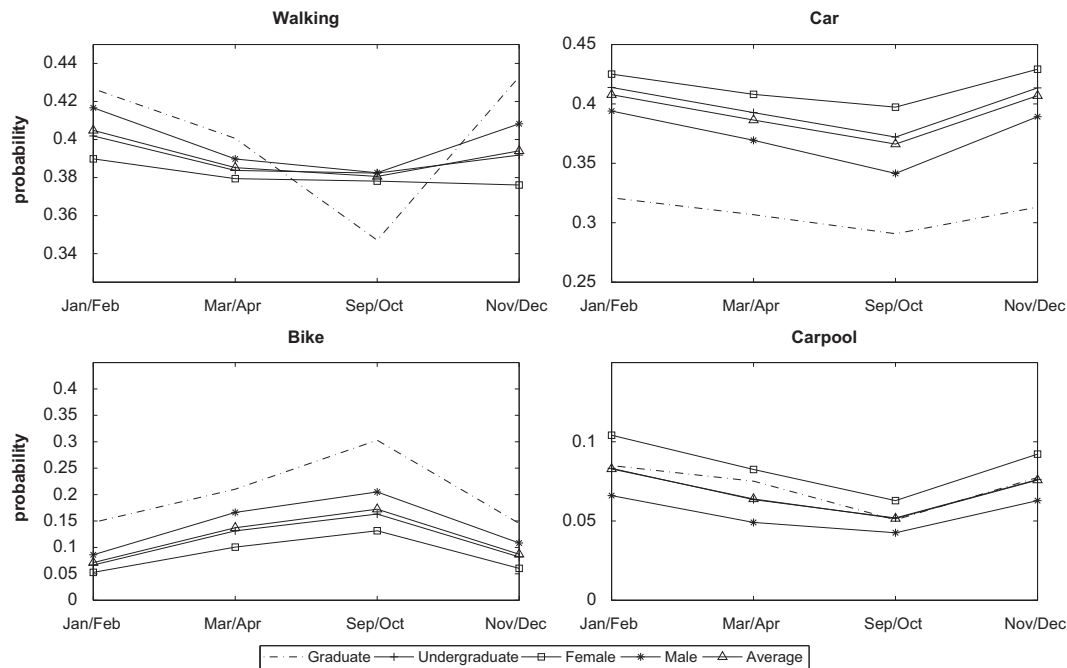


Fig. 4. Temporal variation in probability of walking, car usage, bicycling and carpooling for different student groups.

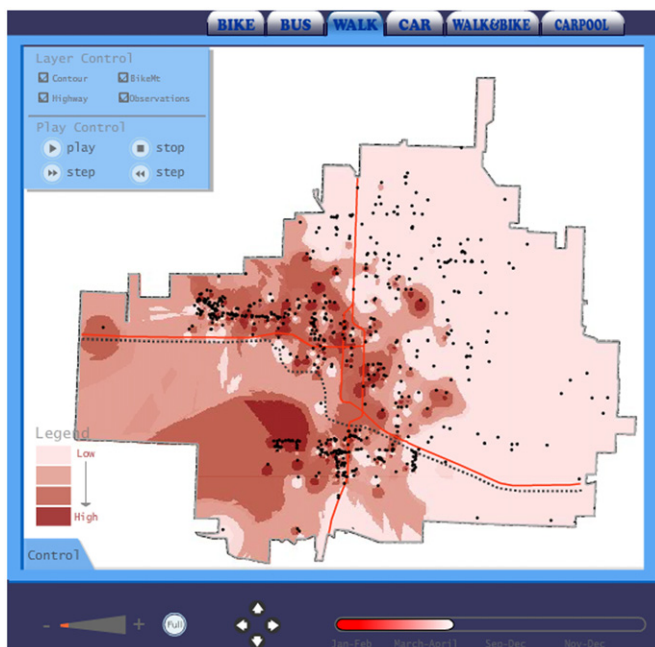


Fig. 5. Facilitating the visualization of spatio-temporal changes in modal choice, by means of a Flash-based online interface (Delmelle et al. 2010).

stakeholders, an online, flash-based animation is developed. This geovisualization technique is advantageous in that neither specialized GIS knowledge nor software is required, and it enables change over time visualization that would be difficult to see with static or paper maps.

The interface combines raster maps produced in the ArcGIS environment and vector data (Fig. 5, also available online³). User interaction is facilitated through the inclusion of buttons on the

interface (play controls, modal tab, zooming and panning). Maps for each mode at each of the four time seasons are included, while a built-in tweening process smoothes transition phases. For the purpose of simplicity, the sample was not subdivided into groups, as done in the previous sections (by males, females, graduate, and undergraduate). The probabilities of modal choice were interpolated from point observations using inverse distance in the ArcGIS environment and ranked from low to high.

Resulting maps show the seasonal and geographical pattern in modal choice previously discussed. The probability of using non-motorized transportation exhibits a distance decay function as students living in the close proximity of the University are likely to either use non-motorized modes of transportation, with the probability decreasing further from campus. Also, we observe greater variability in modal variation for students living in the close proximity of the university, as compared to those living further away, who demonstrate a more uniform choice distribution. Areas with high variability in commuting mode choices are those where policy measures may be most effective in altering student mode choice, as alternative transportation modes are shown to be feasible options, at least in terms of distance from campus. This visualization method should aid in pinpointing these specific locations and in directly targeting place-based initiatives.

3.4. Potential for change

In addition to mapping spatio-temporal patterns of mode choice decisions, students were queried on their willingness to switch modes of transportation given increases in the cost of driving such as increased parking fees on campus or increased gas prices. These two costs were selected given the literature's prior focus on parking, previously discussed, and because it represents a policy in which the University has control over and could potentially address. Gas prices on the other hand, are outside of the University's control, but given the rapidly rising prices at the time the survey was designed (\$3.46/gallon on April 21 2008 to \$3.54/gallon on May 5 2008, EPA, 2008), the committee wanted to

³ <http://geoeearth.uncc.edu/people/edelmelle/MoscowModalVariation.html> (flash player required)

know if prices continued to follow that trajectory, what changes could be expected.

Specifically, students currently holding parking permits were asked to identify the maximum price they would be willing to pay for a gallon of gas or for an annual parking permit before switching to an alternative mode. Overall, males exhibited a greater willingness to switch modes in response to rising parking permits as compared to females, while in response to gas prices, gender differences were minimal, both citing \$5.00 as a price where approximately 50% would switch modes. At higher prices females are slightly more willing to switch than males (Fig. 6). For parking fees among both groups, \$400 is identified as a price where 70% of participants would be willing to use an alternative mode to get to the university (Fig. 7). Approximately 50% of males reported that \$250 was the maximum fee they would be willing to pay per year, while half of female respondents identified \$300 to \$350 as the maximum price for a permit. Gender differences are also noticeable at the lower price range where males recorded a willingness to change starting at \$100 (19% of respondents).

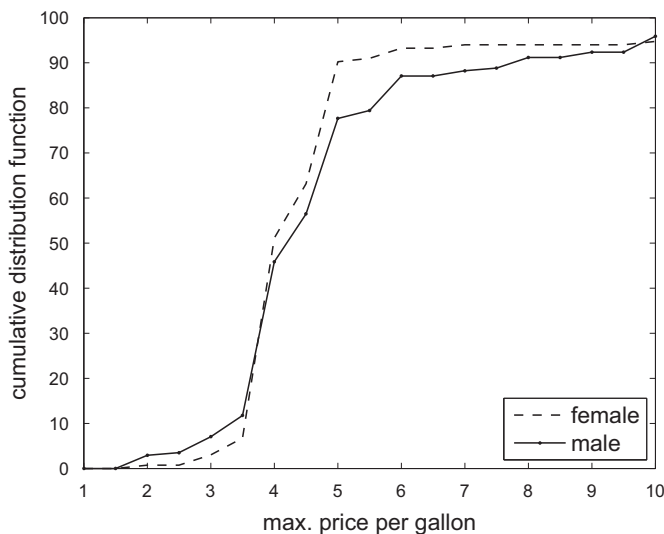


Fig. 6. Cumulative distribution of potential for modal change based on price for a gallon of gas, in \$.

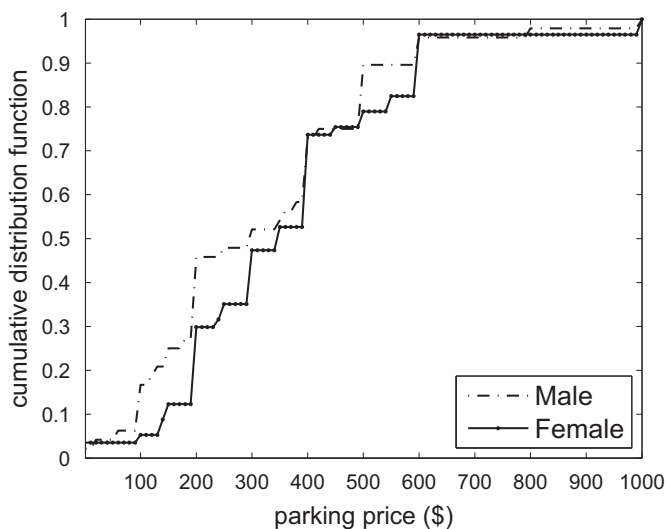


Fig. 7. Cumulative distribution of potential for modal change based on variation in parking price on campus, in \$ -all students pooled together.

In regards to campus parking prices, at the time the survey was performed, the minimum cost for a yearly permit was \$59 for the farthest lots (green/blue/magenta permits), \$131 for the next closest lots (red), and \$262 for the lots closest to campus (gold). Variation in the students' responses on their willingness to shift modes with rising parking fees were also exhibited by permit type held. Owners of a green, blue, magenta or purple parking tag ($n=69$) were very sensitive to a change in parking prices (median price for change was \$150/year) and 80% of those permit holders were not willing to pay more than \$200. For the red parking permit, more than half of the students ($n=58$) were willing to change if parking prices were to climb to \$300/year (median), and finally owners of the gold permit were generally much less willing to change modes (Fig. 8). We did not find significant evidence that willingness to change mode of transportation with increasing gas or parking price was related to distance from place of residence to campus.

Students were also asked to rank their preference for an alternate mode of transportation in response to rising prices. The results show that the majority of males would be willing to bike, although that was not the case for female students who were more responsive to either walking or carpooling than males (Table 4).

To evaluate the potential for increasing bus ridership, one question in the survey asked students how long they would walk to a bus stop if they were willing to switch to that mode of transportation (Fig. 9). Although the responses ($n=465$) did not reveal any differences in gender or standings, the percentage of students willing to walk 5 min or more was 35% and dropped to 10% for 10 min or more. The size of the city of Moscow and the proximity of the University for the majority of students (50% live within 30 min walk) are likely to affect the results as the total

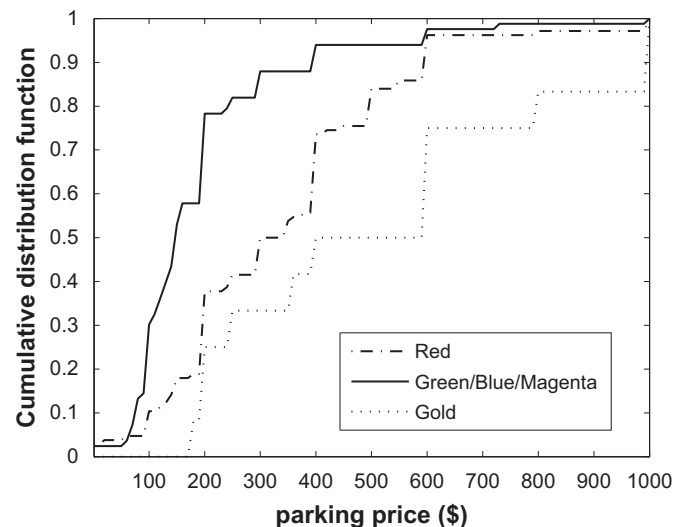


Fig. 8. Cumulative distribution of potential for modal change based on variation in parking price on campus, in \$, with different parking permits.

Table 4
Potential for modal change from car to alternative modes of transportation.

	Male	Female
Biking	0.52	0.28
Walking	0.33	0.44
Carpooling	0.07	0.16
Bus service	0.08	0.12

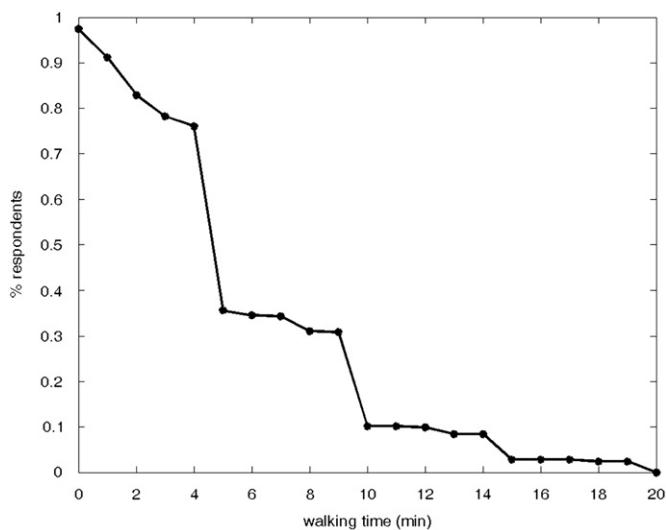


Fig. 9. Variation in the percentage of respondents with varying walking time to a bus service.

travel time by bus (walk to stop, wait, ride, walk to destination) will likely exceed the time needed to walk the same distance.

Students were also asked which improvements they would like to see in the bus transportation system in order for them to select it as an alternate mode of transportation. A total of 526 individuals responded that they would be willing to use the bus after some type of improvement. Approximately 53% of these respondents indicated that a more frequent bus service was needed (currently operating two busses per hour from 7 am to 5 pm). Nearly as many students identified that an evening service would increase their likelihood to switch mode of transportation, 49% of the students would like to see bus stops closer to their place of residence, and 35% reported that a weekend service was important.

4. Policy discussion

Given the compactness of a city like Moscow, Idaho featuring the University as a single, major traffic attractor, and the large majority of students residing within a few miles of the city, fostering a culture of non-motorized transportation certainly seems like a feasible endeavor. As with several other studies on student commuting choices, from a policy perspective, increasing the price of parking on campus seems to be a straightforward disincentive towards driving, and consequently, an incentive to switch modes. As compared to previous studies, however, this survey has shed light on how much change can be expected from increases of specific amounts. In this context, raising the parking permit fee to a minimum of \$200 per year can be expected to result in the largest decrease in driving to campus. Students currently holding the cheapest parking permit seemed most willing to forego purchasing a permit if the price were to rise. Many of the holders of this permit regularly alternate between bicycling or walking and driving depending on weather conditions. Caution, however, should be taken before simply raising on campus fees with the intention of creating a shift in commuting modes. As Toor and Havlick (2004) note, unintended consequences could include an increase in off-campus parking in surrounding streets, neighborhoods, or on the lots of local businesses, which may decrease the quality of life of residents in those locations. Ignoring the surrounding parking situation may undermine university efforts to increase non-motorized or

public transportation (Tolley, 1996). At a minimum, a coordinated effort between the city and University should take place to address the price of parking and parking policies in surrounding neighborhoods.

From an equity perspective, raising the cost for all commuters places an extra burden on those forced to commute by car because of more complex trip chaining travel behaviors due to family commitments or financial strains that force students to hold employment outside of school. Indeed differences in commuting mode choices were shown between traditional students and students with children and families at home. As the concept of sustainability includes a social dimension, the evaluation of a transportation policy should not ignore these factors, and perhaps a more in depth focus group for these potentially affected groups could help identify a solution to these issues. This equity issue is largely absent from the campus transportation sustainability literature, which is overwhelmingly targeted at environmental outcomes.

5. Conclusions

This study has examined spatial and temporal patterns student mode choices within a small, compact university town with the intention of identifying ways to decrease automobile dependence of students to the campus. Results illustrated large seasonable variations in commuting choice in which non-motorized modes are favored during the warmer autumn months, and a notable shift occurs in mode choice during the less temperate months. These results, in conjunction with the maps illustrating the spatial distribution of choices, indicate that non-motorized modes are feasible options for students, and even popular choices when the climate is favorable, however, the availability of low-cost campus parking permits give students the flexibility to switch modes throughout the year. Therefore, if the goal is to reduce overall car commuting, then a larger disincentive towards driving is necessary. In this case, doubling the minimum parking permit cost was identified as such a measure based on student stated choice behaviors. Holding a parking permit was found to be the greatest predictor of commuting by car, more so than distance to campus as was previously cited in the literature as the major incentive toward driving (Shannon et al., 2006). This measure is likely to be successful only if a coordinated effort between the city and University is enacted to ensure negative consequences are not experienced in surrounding neighborhoods, nor are efforts undermined by the availability of parking on nearby residential streets. Secondly, the University will need to address a social equity aspect of this policy so as to not place an extra financial burden on those forced to commute by car due to family or employment commitments. In this regard, a way to charge discounted parking fees to these groups will be necessary.

The study also found commuting choice differences between male and female students with females generally less receptive to non-motorized transportation, especially bicycling. Females also cited local topography and cycling safety to be greater issues in preventing the use of non-motorized transportation than males. Non-traditional students, or those with children, were also more likely to drive to campus.

In order to visualize the spatio-temporal mode choice patterns, a flash-based interface was developed which highlighted areas where there was a large amount of variability in commuting choices, and therefore pinpoint places where students may be most willing to change modes. Future research should use this technology to incorporate areas deemed unsafe or with poor infrastructure for bicycling and walking as indicated on survey respondent maps. This effort could help in decision making for

policy measures and ultimately lead to a safer transition away from car commuting.

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