The influence of individual perceptions and bicycle infrastructure on the decision to bike

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ABSTRACT

This paper focuses on the opportunities and challenges presented to cyclists on and to the University of Maryland (UMD)-College Park Campus. A web-based survey is conducted to understand the travel patterns and the specific issues regarding the bicyclists. The survey included questions about the possible bicycle infrastructure improvements, policy and program innovations to assess the perceptions of the campus community on these changes. This paper discusses the findings of this survey to understand cyclists' travel patterns and identify their issues and concerns. Both non-bicycle commuters and bicycle commuters agreed that bicycle lanes, trails and paths would encourage them to ride a bike (or ride more often) to campus.

Discrete choice models are estimated to model the commuters' mode to campus. The findings of the models suggest that the people are more sensitive to time for non-motorized modes and females are less likely to ride a bicycle. The people who perceive walking and biking as a form of exercise and identify flexibility of departure time as an important factor in their mode choice are more likely to ride a bicycle. Those more likely to choose to drive an automobile to campus assume they do not have other options to commute to campus. Policies designed to promote the use of bicycle transportation on and to campus based on these findings are presented. The results of this paper will help the practitioners and campus transportation planners understand the reasons that prevent people from bicycling and evaluate the transportation improvements that may be considered to achieve bicycle friendly campuses.

1. INTRODUCTION

There is an increasing interest among colleges and universities to combat local congestion, reduce contributions to greenhouse gases, and provide leadership in sustainable development. The financial, environmental and spatial constraints are steering the decision makers to alternative approaches rather than building new transportation infrastructure *(1)*. These approaches include the TDM (Transportation Demand Management) strategies which provide disincentives for auto travel and incentives for alternative transportation modes. Bicycling is an important component of this framework.

Bicycles have low access costs, moderate travel speeds and provide flexibility in departure time compared to transit modes. They also bring many health benefits, help to protect the environment and improve the quality of life. This mode is often more visibly used in locations with college campuses, where these advantages appeal to younger and more cost conscious students, who tend to live near campus. However, in spite of these clear and well-known advantages over other modes of transportation, the percentage of bicycle trips remains low on many US campuses and administrators are struggling with how to promote and support more cycling to and around campuses *(1)*.

The aim of this study is to better understand the needs of bicyclists to be able to facilitate better bicycle planning. This will help in decreasing the automobile travel which causes congestion and pollution.

This paper analyzes the survey data collected by DOTS (Department of Transportation Services) and the authors on the transportation patterns of the commuters at the University of Maryland (UMD), with a specific emphasis on bicycling. The specific focus of this study is on the people living close to campus (within 5 miles) to understand the reason that keep them from cycling.

The rest of the paper is organized as follows. The following section gives a review of the existing studies. Section 3 presents the descriptive statistics of the UMD Campus Transportation Survey and the principal components analysis conducted to identify the interrelationships among the perceptions of the people on transportation characteristics. Section 4 presents the mode-choice models and the planning and policy implications of these models. The study ends with Section 5, the concluding comments.

2. BACKGROUND

Recent research efforts in the planning field revealed that land use and design policies can influence human behavior *(2-4)*. With this idea in mind, several researchers have explored the attitudes of bicyclists and non-bicyclists to various bicycling conditions *(5-10)*. While the needs of bicycle commuters on a campus setting may differ from the general population, it is still important to understand the factors associated with bicycle use in the larger cycling population and literature. This section provides a brief overview on the existing studies focusing on the cycling policies and conditions in different cities, factors affecting the commuter bicyclists' route choices and frequency of bicycling, and perceptions towards bicycling and facility improvements.

Pucher et al. *(5)* compare the policies implemented in European cities to US cities and suggest that with the right set of policies, bicycling in the US could increase dramatically. They emphasize the fact that German, Dutch, and Danish cities give cyclists priority on certain streets, intersections and routinely employ advanced green lights and traffic-calmed streets. Some European cities have dedicated car parking space to bike lanes or bike parking, to enable cycling and discourage auto use. The authors conclude that as long as car use remains cheap and transportation policy remains dominated by motorized modes, bicycles will continue to be used primarily for recreation and not for daily urban travel in US.

Another study by Pucher and Buehler *(6)* finds out that in spite of the colder climate, Canadians cycle more than Americans. The authors suggest that the higher urban densities and mixed-use development, shorter trip distances, lower incomes, higher costs of owning, driving and parking a car, safer cycling conditions, and more extensive cycling infrastructure and training programs in Canada are the reasons for higher bicycle mode shares. They argue that the cycling levels in US would significantly increase by adopting some of these policies.

The factors affecting the commuter bicyclists' route choices and frequency of bicycle trips have been a focus of several studies. According to the study by Stinson and Bhat *(7)* travel time is the most important factor on route choice. Presence of a bicycle facility (bike lane or separate path), the level of automobile traffic, and pavement or riding surface quality are also very important determinants. Another study by Stinson and Bhat *(8)* evaluates the factors that affect the frequency of bicycle use for a person's commute. They state that using a bicycle for non-work trips increases the frequency of commuting by bicycle to work; non-bicyclists either have misconceptions about the dangers of bicycling or lack convenient and safe route options for bicycling to work.

Tilahun et al. *(9)* take an interesting approach of valuing the bicycle facility improvements. They evaluate the individual preferences for different cycling environments by trading off a higher travel time as a cost incurred when choosing a better facility. Their findings reveal that the respondents were willing to travel up to 20 minutes more to switch from an unmarked on-road facility with side parking to an off-road bicycle trail, with smaller changes associated with less dramatic improvements.

While having bicycle lanes on streets improves the bicycling conditions, the discontinuities of on-street bicycle lanes cause discomfort for cyclists. Krizek and Roland *(10)* analyze the issues related to discontinuities of on-street bicycle lanes. They state that the discontinuities ending on the left side of the street, with increased distance of crossing intersections, having parking after the discontinuities, and wider width of the curb lane increase the level of discomfort.

Gatersleben and Appleton *(11)* analyze the perceptions and attitudes towards bicycling during the "stage of change": change from being a non-bicyclist to bicyclist. They state that as people start cycling, their attitudes towards cycling become more positive and their perceptions of various personal and external barriers change. This suggests that while majority of the people have never considered cycling, there is a group of people that could be persuaded to cycle and would like and continue cycling in the end.

While the studies mentioned above investigate the factors associated with bicycling over the general population, Balsas *(1)* states that a campus setting differs from the other urban areas with its unique population with younger and more active individuals, continuous movement of people throughout the day and irregular schedules. He also suggests that the campuses have the unique opportunity as the sustainable transportation policies applied on college campuses not only affect the campus itself but the travel behavior of the whole population. The travel behavior and environmental awareness adopted by the students will spread into the whole nation over time. This is why the campus transportation policies and decisions require more and in-depth analysis.

This paper adds to the existing literature by analyzing the transportation patterns at a campus setting (UMD-College Park), identifying the potential target groups of the population to increase bicycle mode share and incorporating the personal attitudes in mode choice modeling.

3. DATA and METHODS

This paper analyzes the UMD - Campus Transportation Survey data and draws recommendations based on the analysis results to achieve a higher bicycle mode share. UMD Campus is in the Washington, DC Metropolitan area, located on a 2.5 square-kilometers campus inside the DC beltway. Approximately 50,000 people attend and/or work at the University. Of this 50,000 people nearly 8% are faculty, 11% are staff, 23% are graduate students and 58% are undergraduate students *(12)*. Around 10,000 students live on campus with a large number of students living adjacent to the campus property in private housing.

The bicycle mode-share at UMD is low compared to other campuses in US. Several other campuses including the University of Wisconsin at Madison, University of Colorado at Boulder, University of California at Santa Barbara, Sanford University, University of California at Davis, University of Oregon at Eugene, and University of Washington at Seattle have higher bicycle and walking mode shares than UMD *(1)* .

Until recently, most campus transportation planning efforts and investments at UMD have focused primarily on motorized transportation. However, with the increasing concerns about congestion, parking, environmental damage and health concerns, the Department of Transportation Services (DOTS) started putting efforts into improving the bicycling conditions and encouraging the bicycle as a mode of transportation on, to and from the UMD campus.

3.1 UMD Campus Transportation Survey

UMD Campus Transportation Survey was designed and administered online to students, faculty and staff. A web-based survey was chosen because of the time and cost efficiency of administration, ease of posting the survey on the DOTS web-page and emailing the survey link to several list-serves. The survey was posted on the DOTS web-page on April 1, 2008 and was accessible for 20 days. A total of 1,627 responses were received and around 1,500 of these provided complete responses. The survey focused primarily on the bicycling issues on campus; however, it was promoted widely as a campus transportation survey in order to gather responses from a range of bicycle users and non-users.

At the very beginning of the survey, the respondent is asked when he/she last rode a bicycle: (1)within the last week, (2) last month, (3) last year, (4) more than a year ago or (5) never. The responses were used to group the respondents as bicyclists (responses 1-3) and non-bicyclists (responses 4 and 5) and direct them to questions appropriately targeted for each group. The people who are identified as bicyclists may not necessarily have an observed commute pattern to campus by bicycle. They may be bicycling around their own neighborhood or for recreation rather than utilitarian travel, and not commuting to campus because of several reasons, such as long distances, the necessity of changing clothes, or other commitments (dropping off kids at school, other appointments etc.).

Because of space restrictions, the original survey instrument is not included in this paper. Interested readers can contact the authors to obtain it. Some of the core questions of the survey include:

- How many times a week do you commute to campus by: bicycle, on-foot, Shuttle-UM, other bus system, rail, and car?
- How far do you live from campus?
- How many minutes does it take you to get to campus by: bicycle, on foot, bus, car, and rail?
- What would encourage you ride a bicycle (or ride more often) on/to campus?
- What prevents you from riding a bicycle (or ride more often) on/to campus?
- Socio-demographic and residential location information
- Specific bicycle commute questions

The respondents who live less than 5 miles from campus and are identified as bicyclists by the self-reported assessment of the last time they rode a bicycle are considered as the *first target group* for increasing cycling activity on and around campus. The reason for this assessment is the fact that these people live within a reasonably short distance and already have the bicycling experience.

3. 2 Descriptive Statistics

Table 1 provides an overview of the survey respondents. The survey sample is representative of the campus population, with the percentages of faculty and graduate students being very close to the actual values, while staff members are over-represented (11% versus 23%) and undergraduate students (58% versus 43%) are under-represented. Almost all of the survey respondents have a driver's license. More than half of the survey respondents have campus parking permits, and again more than half own or have access to a bicycle. Two thirds of the survey respondents are female. Nearly 60% of the survey respondents have not ridden in more than a year and are considered to be non-bicyclists. The remaining 40%, who rode a bicycle within the last week, month or year are grouped as bicyclists.

TABLE 1 Descriptive statistics

	N	%
Status		
Faculty member	97	7.28
Graduate student	342	25.66
Staff	315	23.63
Undergraduate student	579	43.44
Location		
Off campus	1136	75.58
On campus	367	24.42
Miles from campus (for off-campus residents)		
Less than a mile	132	11.70
1-5 miles	315	27.93
5 to 10 miles	218	19.33
10 to 15 miles	161	14.27
More than 15 miles	302	26.77
The time the respondent last rode a bicycle		
More than a year ago & never	901	59.95
Within the last year, month, week	602	40.05
Have bicycle		
No	611	45.77
Yes	724	54.23
Have parking permit		
No	574	43.32
Yes	751	56.68
Have driving license		
No	87	6.52
Yes	1,247	93.48
Gender		
Male	418	31.45
Female	911	68.55
Individual age (mean value)		29.2

Table 2 summarizes the off-campus residents' mode choices to campus. The data are segmented based on the status (faculty, staff, undergraduate and graduate student) and the distance to campus. The results of the survey indicate that most of the off-campus residents commute to campus by car (65%).

TABLE 2 Mode to campus by distances and status (for off-campus residents)

	Bicycle	Shuttle-UM	Rail	Other bus	Walk	Car	Total N
	%	%	%	%	%	%	
Status							
Faculty	3.1	16.7	2.1	0.0	5.2	72.9	96
Staff	3.9	10.7	1.6	1.3	0.6	81.9	309
Undergraduate	6.3	22.4	0.7	1.5	12.9	56.3	272
Graduate	7.5	30.1	3.3	1.8	6.3	50.9	332
	5.1	20.2	2.0	1.3	6.4	65.0	1128
Distance							
<1 mile	9.8	32.6	0.0	0.0	38.6	18.9	132
1-5 miles	9.8	28.3	0.6	2.5	5.7	53.0	315
5 to 10 miles	1.4	24.8	4.1	0.9	0.0	68.8	218
10 to 15 miles	3.7	15.5	2.5	1.2	0.0	77.0	161
> 15 miles	1.7	5.6	2.3	1.0	1.0	88.4	302
Total	5.1	20.2	2.0	1.3	6.4	65.0	1128

The percentage of undergraduate and graduate students driving to campus (56% and 51% respectively) is less than faculty (73%) and staff (82%), but still high for a campus setting. Few faculty and staff rode their bicycles to campus.

As expected, the percentage of car commuters increases as the distance from home to campus increases. The percentages taking transit (other than Shuttle UM) and rail are significantly low among respondents. Shuttle-UM is the second most chosen mode (after cars) based on the survey respondents. It is interesting to note that 19% of the commute trips within one mile distance from campus are made by car. While this percentage is lower than that of the walking and Shuttle trips, it is still significantly high, given that the short distance.

The following table, Table 3 reveals an important issue. Most of the people, who are self-identified as bicyclists (based on their responses to the question regarding when they rode a bicycle) and live within 5 miles distance from the campus are not commuting to campus by bicycle. The dominant mode for the trips within the 5 miles from the campus is driving. This finding requires further exploration, as the people who already cycle for other purposes and live within the biking range from campus are the first potential target to promote bicycling.

TABLE 3 Modal Split (Respondents Living within 5 miles of the Campus)

	Bicyclists N=206 %	Non-bicyclists N=245 %	All N=451 %
Bicycle	19.9	0.0	9.1
Shuttle	23.3	35.1	29.7
Rail	0.0	0.8	0.4
Bus	1.5	2.9	2.2
Walk	15.0	15.9	15.5
Car	40.3	45.3	43.0

In order to analyze the factors that affect the bicycling patterns of these people in more detail, this population segment (people living less than 5 miles from campus) is further segmented into three groups. The groups are defined below.

- Group 1: Live less than 5 miles from campus and identified as ***non-bicyclist and do not own a bicycle (N=161).***
- Group 2: Live less than 5 miles from campus and identified as ***bicyclist (N=206).***
- Group 3: Live less than 5 miles from campus and identified as ***non-bicyclist but own a bicycle (N=59).***

The respondents were asked what prevents them from riding a bicycle and what would encourage them to ride a bicycle more often on/to campus. In these questions, the respondents were asked to choose the top five bicycle facility improvements for bicycling and top-three reasons that prevent them from bicycling. Table 4 shows the summary of these responses for the people living within 5 miles from the campus. The responses are analyzed based on the 3 population groups defined above. The top five rated bicycle facility improvements and the top three reasons are bolded for each group.

The people in groups 2 and 3 are considered as the people who might begin commuting by bicycle if their needs are accommodated. The results reveal that both bicyclists and non-bicyclists agree that dedicated bicycle lanes, trails and paths, more secure or covered bike parking would encourage them to ride more often. Only 26-28% of the non-bicyclist reported that they have no interest in bicycling. This reveals a significant opportunity: around 70% of the non-bicyclists may consider switching modes if a more bicycle-friendly environment is provided. The bicyclists and non-bicyclists who own bikes stated that a convenient space to change clothes and shower would encourage them to bicycle. The non-cyclists who own bikes rated a campus map showing bicycle routes as one of their top five choices. The bicyclists state that they would make use of a bicycle station on campus that provides repairs.

The reasons that keep people from bicycling tend to be similar for all three groups with the exception of the reason of not owning a bicycle for non-bicyclists. All three groups stated that they do not feel safe riding with vehicular traffic. They also stated that the lack of bicycle lanes and paths is a reason that prevents them from bicycling. In fact, these two factors are correlated. As the University and the surrounding communities start building bicycle paths or separating the bicycle lanes from the vehicular traffic, many of the concerns regarding the vehicular traffic will be addressed. The respondents did not rank the educational classes on bicycle riding and safety as one of their top incentives; however, these educational classes may actually help ease the concerns about feeling safe on the road. The people who are non-cyclists but own bikes are more concerned about crime compared to other groups. Bicyclists tend to find the lighting on and around campus insufficient.

These reasons and encouraging factors specific to the people living within 5 miles of the campus reveal important information on the needs of this population, who are the most promising target group for promoting bicycling on campus.

TABLE 4 Reasons That Prevent Bicycling and Bicycle Facility Improvements That Would Encourage Bicycling

	Group 1 N=161	Group 2 N=206	Group 3 N=59
Improvements that would encourage bicycling	%	%	%
A bicycle station on campus providing repairs	14.3	22.3	11.9
A campus map showing bicycle routes	21.6	24.8	**28.8**
A convenient place to shower/ change clothes	16.3	**31.6**	**28.8**
Better lighting around campus for traveling	22.0	**38.8**	25.4
Better lighting on campus for traveling	15.9	18.4	16.9
Dedicated bike lanes on campus	**33.5**	**49.5**	**42.4**
Dedicated bike lanes to/from campus	**38.4**	**66.0**	**44.1**
Educational classes on bicycle riding and safety	3.3	4.4	1.7
Greater enforcement of traffic laws to protect cyclists	11.4	22.8	18.6
Trails and pathways separated from the roadways	**35.9**	**48.5**	**47.5**
Living closer to campus.	13.9	22.8	13.6
More convenient bike parking.	**25.3**	24.3	**35.6**
More police patrol to ensure safety.	13.9	13.1	16.9
More secure or covered bike parking.	**26.9**	**40.8**	**30.5**
Nothing, I have no interest in biking.	**25.7**	-	18.6
Prohibiting car traffic in some or all campus roads.	16.3	20.9	13.6
Reasons that prevent bicycling	%	%	%
I am not interested in biking.	26.1	-	28.8
I am worried about possible mechanical problems	3.3	8.7	8.5
I can not bike because of a physical or mental impairment	4.1	-	5.1
I do not feel safe about the possibility of crime.	19.6	20.4	28.8
I do not feel safe about the vehicular traffic.	**47.8**	**45.1**	**64.4**
I do not know how to bike.	5.3	-	-
I do not own a bicycle.	**65.7**	-	-
I need to change clothes/ carry things.	**45.3**	**54.4**	**57.6**
Lack of bike lanes/ paths/ trails.	25.7	**41.3**	**37.3**
Lack of proper lighting.	4.5	16.5	5.1
The lack of adequate bicycle parking.	6.1	14.1	11.9

3. 3 Attitudes towards Transportation and Principal Components Analysis (PCA)

The survey respondents were asked to choose the response (strongly agree, agree, disagree, strongly disagree) that reflects their attitudes regarding several transportation characteristics. Table 5 summarized their responses.

TABLE 5 Attitudes Regarding Travel Characteristics

	Strongly disagree %	Disagree %	Agree %	Strongly agree %	N/A %
The cost of gasoline affects my decision about how to travel on/to campus.	14.1	24.5	32.1	19.3	10.0
Congestion on campus is a serious problem.	1.3	13.3	45.4	36.8	3.2
I have many options about how I travel on/to campus.	14.2	33.8	39.7	9.7	2.6
There is adequate and convenient bike parking on campus.	5.6	29.7	25.9	2.9	35.8
I think that walking and biking provide me the opportunity to exercise.	2.3	2.5	41.4	48.6	5.2
Extreme weather conditions make me reconsider my travel mode to campus.	8.1	17.8	35.0	32.3	6.7
I feel safe walking on campus after dark.	26.2	38.6	27.2	3.0	4.9
I feel safe biking on campus after dark.	17.8	26.1	17.4	2.5	36.3
The cost of car parking is high on campus.	2.3	7.5	27.7	55.1	7.5
I think that the flexibility of departure time is an important factor in my travel decisions.	1.9	4.5	44.0	44.3	5.2

The majority of all of the respondents feel unsafe about walking and bicycling on campus after dark. This result is consistent with the reasons given about what keeps people from bicycling and the facility improvements necessary to encourage them. As reported in Section 3.1 several respondents are worried about the possibility of crime and would consider cycling if better lighting is provided on and around campus. It is interesting to see that more than 80% of the survey respondents think that the cost of parking automobiles is high on the UMD Campus. However, a comprehensive online research through the web-sites of many universities reveals that the parking rates at the UMD campus (particularly the student rates) are one of the lowest rates in US (annual student parking permit rate is $213 at UMD for the 2008-2009 academic year, whereas it is $687 at Cornell, $456 at UC-Davis, $432 at UC-Santa Barbara and $465 at Northwestern University). More than 80% of the respondents think that automobile congestion is a serious problem on campus. Around half of the respondents reveal that their travel behavior is affected by the cost of gasoline. Nearly 88% percent of the respondents find the flexibility of departure time as an important factor in their travel decisions.

As the public's attitudes towards transportation characteristics are very important, the authors decided to integrate these in the mode choice modeling. However, several of the attitudes turned out to be correlated with one another and the number of variables to be included in the model increase significantly, decreasing the degrees of freedom. Therefore, a Principle Components Analysis (PCA) is conducted to explore the interrelationships among these attitudes and to define new combined indicators of individual type based on their attitudes.

PCA is an exploratory analysis that may be useful in gaining a better understanding of the interrelationships among the variables. PCA is a method of transforming the original variables into new, uncorrelated variables. The new variables are called the "principal components". The principal components may be used in the analysis instead of the original variables to represent the interrelationships and eliminate the correlations. The component scores can be calculated for each individual and used as a new variable for further analysis *(13)*.

Table 6 shows the results of the PCA analysis: the number of underlying components, the % variance explained by each component and the loadings for each variable. Loadings which are larger than +0.40 or smaller than -0.40 are considered to be the most dominant variables in a given component. Although factor analysis rotation can be performed to obtain more easily interpreted components, the rotation had little to no effect on these results and therefore not performed.

Looking at the statistical results in Table 6, several surprisingly common features are evident in the PCA models.

TABLE 6 Principle Components Analysis, Factor Loading Results

	Component			
	1	**2**	**3**	**4**
Eigenvalues	2.337	1.549	1.048	0.899
% of variance	23.37	15.49	10.48	8.99
	Factor loadings			
The cost of gasoline affects my decision about how to travel on/to campus.	0.314	-0.202	-0.203	0.115
Congestion on campus is a serious problem.	0.299	-0.262	0.333	-0.085
I have many options about how I travel on/to campus.	0.301	0.166	**-0.572**	0.249
There is adequate and convenient bike parking on campus.	0.210	0.332	-0.216	**-0.801**
I think that walking and biking provide me the opportunity to exercise.	**0.403**	-0.085	0.119	-0.308
Extreme weather conditions make me reconsider my travel mode to campus.	**0.401**	-0.115	-0.344	0.243
I feel safe walking on campus after dark.	0.163	**0.558**	0.383	0.322
I feel safe biking on campus after dark.	0.246	**0.591**	0.126	0.100
The cost of car parking is high on campus.	0.328	-0.217	**0.410**	-0.010
I think that the flexibility of departure time is an important factor in my travel decisions.	**0.406**	-0.156	0.103	-0.090

The first factor clusters the people who perceive walking and bicycling as an opportunity to exercise, change their travel modes when extreme weather conditions occur and perceive flexibility of departure time as an important factor in mode choice together. The second factor is characterized by feeling safe walking and biking after dark. It is interesting that the people who think that they do not have many options to get to campus and the cost of car parking is high on campus cluster together (Factor 3). Factor 4 clusters the people who think the bicycle parking on campus is not adequate.

4. MODE CHOICE MODEL

Mode choice models are estimated to better evaluate the effects travel characteristics, socio-demographics and personal attitudes on mode choice to campus. The results of these models demonstrate the significant determinants of the decision to bicycle and based on these results decision-makers may draw recommendations on achieving a higher bicycle mode-share.

4.1 Methodology

The mode choice models in this study are estimated based on the discrete choice framework. Discrete choice models are based on the random utility theory, which assumes that the decision maker's preference for an alternative can be captured by the value of an index, called utility. It is assumed that the decision maker chooses the alternative that yields the highest utility.

The probability of any alternative *i* being selected from a choice set C_n is given by the following:

$$P(i \setminus C_n) = \Pr(U_{in} \geq U_{jn}), \forall j \in C_n, \qquad [1]$$

where, U is the utility of the given alternative.

Because the analyst has imperfect information about an individual's utility level, uncertainty is introduced into the utility equation *(14)*. Equation 2 represents the utility (U_{in}) of alternative *i* in the choice set C_n for decision-maker *n*.

$$U_{ni} = \beta_{ni} x_{ni} + \varepsilon_{ni} \qquad [2]$$

where, x_{ni} are observed variables that relate to the alternative and decision maker, β_{ni} is a vector of coefficients of these variables and ε_{ni} is the random component.

In this study, the choice set includes bicycling, walking, driving and taking public transit to campus. To model this decision, multinomial logit models are specified. The logit model arises from the assumption that the difference of the error terms is logistically distributed *(14)*. Under this assumption the choice probability for alternative *i* is given by:

$$P(i \setminus C_n) = \Pr(U_{in} \geq U_{jn}), \forall j \in C_n \qquad [3]$$

$$P_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \qquad [4]$$

4.2 Model Specification

The choice set in this study includes four choices and can be expressed as:

C_n= {bicycle, walk, public transportation, drive}

The variables included in the utility functions can be summarized as:

- *A group of individual characteristics*
  - Status (undergraduate, graduate, faculty, staff)
  - Gender (1; female, 0; male)
- *Variables related to the choice alternatives*
  - Time
  - Cost
- *Variables related to attitudes (factors from the PCA analysis)*
  - Principle Components 1,2,3 and 4

4.3 Model Results and Discussions

Table 7 presents the mode choice results to campus. The variables related to alternative specific characteristics (time and cost), individual characteristics and attitudes are added sequentially to the model and the log-likelihood ratio tests reveal that they all increase the explanatory power of the model significantly. Driving is set as the comparison case in the models.

The discussions are based upon Model 4, which is the most extensive model. While many non-significant variables are dropped from the analysis, some of them are kept in the models to be able to understand the direction of their effects and as these models are explanatory in nature. The cost and time coefficients are negative, which is an expected result; people will choose the mode which has the lower cost and the lower time when all else is equal.

The time coefficients for walking and bicycling are negative and significantly different (higher in magnitude) from the base case (car). This means that the people's decisions are more sensitive to time spent on non-motorized modes. Therefore, decreasing the time spent for bicycling will significantly increase the bicycle mode share. The probabilities calculated based on Model 4 reveal that decreasing the bicycle travel time by ***10 minutes*** will increase the probability of bicycling by approximately ***6 %.*** Other than living closer to campus, several other alternatives exist to decrease the travel time. These alternatives may be; designating some of the road facilities for bicyclists (as they are generally shorter than the trails), arranging the waiting time at certain intersections to favor the- non-motorized modes and providing better transit integration to promote transit and bicycle mode combinations.

TABLE 7 Mode Choice Model Results

	Model 1		Model 2		Model 3		Model 4	
Variable	Coef.	t stat	Coef.	t stat	Coef.	t stat	Coef.	t stat
ASC** –Bicycle	**-2.196**	**15.93**	**-1.648**	**4.99**	**-0.999**	**2.56**	**-1.605**	**3.67**
ASC** – Walk	**-1.765**	**13.78**	**0.719**	**1.96**	**1.109**	**2.25**	**1.062**	**2.13**
ASC** – Public	**-1.012**	**14.18**	**-1.148**	**4.52**	**-1.465**	**4.61**	**-1.513**	**4.73**
Time			**-0.034**	**4.39**	**-0.028**	**3.48**	**-0.026**	**3.21**
Time (Bike)			**-0.159**	**10.08**	**-0.155**	**9.37**	**-0.146**	**8.69**
Time (Walk)			**-0.173**	**11.32**	**-0.170**	**10.36**	**-0.169**	**10.28**
Time (Public)			**-0.085**	**12.05**	**-0.081**	**10.20**	**-0.079**	**9.72**
Cost			**-1.678**	**10.34**	**-1.536**	**9.21**	**-1.537**	**9.10**
Female (Bike)					**-1.011**	**3.51**	**-0.762**	**2.52**
Female (Walk)					-0.555	1.57	-0.471	1.31
Graduate student (Bike)					**0.694**	**2.31**	**0.672**	**2.16**
Graduate student (Walk)					0.475	1.31	0.480	1.32
Graduate student (Public)					**0.998**	**4.76**	**0.976**	**4.62**
Undergraduate student (Public)					0.237	1.01	0.261	1.11
Factor 1 (Bike)							**0.366**	**2.82**
Factor 2 (Bike)							**0.234**	**2.03**
Factor 2 (Walk)							0.177	1.32
Factor 2 (Public)							0.071	1.03
Factor 3 (Bike)							-0.139	1.21
Factor 3 (Public)							-0.098	1.14
Log likelihood (No coefficients)		-1570.6		-1570.6		-1570.6		-1570.6
Log likelihood (Constants only)		-1013.1		-1013.1		-1013.1		-1013.1
Log likelihood (At optimal)		-1013.1		-777.7		-695.2		-686.0
Number of observations		997		997		997		997

*Bolded coefficients are significant at the 95% level.
**ASC: Alternative specific constant (base case is driving).

The component scores calculated from the PCA analysis in Section 3.2 are incorporated in the analysis to understand the personal attitudes' impacts on mode choice. Factor 1 is associated with people who see walking and bicycling as an opportunity for exercise and perceive the flexibility of departure time as an important component in travel decisions. This factor (Factor 1) is significantly associated with bicycle mode choice. This implies that if the health benefits of bicycling are more broadly understood more people may start perceiving bicycling as an opportunity of exercise.

Factor 2 is associated with people who feel safe walking and biking on campus after dark. As expected this factor is significantly and positively associated with bicycling and walking. Feeling safe walking and bicycling after dark is also associated positively with public transportation (although not statistically significant at the 95% level). This indicates that as people feel safe walking and biking on campus after dark, they are more likely to walk, bicycle and use public transport.

Factor 3 clusters the people who find the car parking costs on campus high and think that they do not have many options to get to campus. This factor is negatively associated with bicycling and public transportation which means that people who think they do not have many options are less likely to bicycle or take transit and more likely to drive. This could be interpreted as; if people are presented with other options, they may be inclined to give up driving. These alternatives may include providing additional shuttle services, constructing bicycle lanes, and improving the other bicycling facilities. In the short term, the existing bicycling opportunities on/around campus should be presented to the public; a campus map showing bicycle routes should be prepared and distributed and the public should be well-informed about their commuting options. The negative association of this factor (finding parking costs high on campus) with bicycling and public transportation may also be an indicator that mostly car drivers are troubled with the parking costs.

5. CONCLUSIONS

This study presents the bicycle facilities and policy innovations that would improve the bicycling conditions and increase the bicycle mode share on a campus setting. The empirical analysis is based on the Campus Transportation Survey conducted in April 2008 at UMD. The survey results reveal that many commute trips to campus are well within bicycling range in terms of distance, however because the transportation infrastructure on and around campus is automobile oriented, people drive their cars even for short distances.

Respondents of the UMD Transportation Survey cited the lack of bike lanes as the most important reason that keeps them from bicycling. This reveals the fact that a connected bicycle network is the backbone of a successful bicycle program and there is an immediate need to establish a bicycle network on campus consisting of bicycle lanes, routes and trails, connected to the surrounding residential areas.

The vehicular traffic on campus has a negative impact on biking. Many respondents stated that they do not feel safe about vehicular traffic. The campus authorities should put more effort into discouraging and using enforcement against the unsafe behaviors of car drivers. Locating "*Share the Road*" signs at the entrances and some key locations on campus may affect the perceptions of the drivers and remind them of the bicyclists. While the unsafe behaviors of drivers are penalized, the unsafe riding habits of the bicyclists should also be prevented (such as riding the wrong way, failing to stop at red lights, etc.) and the bicyclists should be educated regarding the rules of the road. Bicycle riding classes could be offered through the Police Department or the Department of Transportation Services. This will help creating a campus transportation system that bicyclists, pedestrians and drivers can safely operate.

The survey respondents (both non-bicyclists and bicyclists) stated that a campus map showing bicycle routes would encourage them to bicycle (or bike more in the case of bicyclists) to campus. Based on these responses, around 20% of the respondents may consider biking if a circulation map is provided. Currently, the UMD does not have any bicycle lanes on campus; however, bicycles lanes and trails exist in the surrounding neighborhoods. These facilities should be mapped clearly, with a list of close-by bicycle repair shops, as the possibility of mechanical problems is cited as one of the reasons that keep people from bicycling.

To promote non-motorized modes on and to campus, additional measures should be taken to increase security. The mode-choice models reveal a significant association with feeling safe and walking, biking and taking transit. Unfortunately, many survey respondents revealed that they are concerned about safety on campus, especially after dark. Increased security should be provided by increased police patrol, safety cameras and better lighting. As a matter of fact, lack of lighting was cited as one of the reasons that keep the respondents from cycling.

Consistent with the existing studies, the mode-choice model results indicate that time and cost of travel are important determinants of mode-choice. The findings of the models in this study particularly suggest that the people are more sensitive to time for non-motorized modes. This indicates that a significant increase in bicycling is expected with decreasing travel time. Some policies to decrease the bicycle travel time may be designating some of the road facilities for bicyclists (as they are generally shorter than the trails), decreasing the waiting time at certain intersections favoring the bicyclists and providing better transit integration reducing the commute time. The model shows that the mode choice is sensitive to cost, so any policy that increases the cost of driving would help reducing the number of car trips. One immediate policy could be increasing the car parking rates on campus. Enhancing the bicycling conditions should be complemented by restrictions on car use.

The policies discussed here should be implemented in an integrated manner. The campus authorities should start the less resource demanding policies as soon as possible, such as placing signs, increasing security and preparing a campus map. As the construction of bicycle lanes and paths are more time and resource consuming (and difficult to change once constructed), comprehensive planning should be undertaken before constructing these facilities so that a successful bicycle network can be developed. The bicycle network should be complemented with adequate bicycle parking facilities and signage.

The mode-choice models estimated in this study could be calibrated for other campuses and different policy scenarios with changes in travel time and cost, and personal attitudes could be tested to evaluate their overall impacts.

The findings of this study may be used by practitioners and campus transportation planners elsewhere to understand the reasons that prevent people from bicycling and evaluate the transportation improvements to be considered for implementation.

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