THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF GEOGRAPHY

ACCESSIBILITY, CLOSENESS AND DISTANCE: CATA TRANSPORTATION IN STATE COLLEGE, PENNSYLVANIA

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Spring 2012

A thesis submitted in partial
fulfillment of the requirements
for a baccalaureate degree
in Geography
with honors in Geography.

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Abstract

Since the Brundtland Commission released “Our Common Future” in the late 1980s, policy makers have been striving to create strategies that promote sustainable development, or “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN Documents, 1987). Public transportation is an aspect of sustainable development that could have significant effects on the environment and human life.

The Pennsylvania State University is home to approximately 44,000 undergraduate and graduate students with a fluctuating demand on the public transportation system (U.S. News, 2010). This thesis investigates students’ perceptions of the Centre Area Transportation Authority’s (CATA) bus system and their use of CATA in State College, Pennsylvania. These perceptions could reveal useful information for CATA’s accessibility strategies to make it an attractive solution for travel, thus gaining more public transportation use. This thesis will assess the accessibility and relative closeness of CATA bus stops to participants’ residences and participants’ perceptions of accessibility and closeness of this form of public transportation. Additionally, it will compare the distance judgments between males and females and their perceptions of accessibility. Past research has found significant differences between the judgment of distance by males and females, which potentially is related to the different ways males and females survey the physical world (Coluccia & Girogia, 2004). These findings could support reasons behind their varied public transportation behaviors.

The frequency of bus-use will be analyzed based on the distance between participants' residences and the closest bus stop, their perceptions of this distance and their ratings of accessibility and closeness. This thesis will use research based on individual questionnaires of student participants.

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1.0 Introduction

1.1 Literature Review

Transportation is an important part of every person's life, because humans have an inherent need to change spatial locations, in order to live. In return, mankind's mobility and transportation has effects on the economic and social foundations of society. With that said, different modes of transportation can have significantly different impacts on the environment (Murray, Davis, Stimson, & Ferreira, 1998). Walking and bicycling have lesser effects on the environment than automobiles and public transit, which dip into Earth's finite natural resources of fossil fuels. Although public and private transportation both consume fossil fuels, private transportation has the largest impact on the environment, according to Frank, Stone and Bachman (2000). Emissions, caused by transportation, account for more than half of the detrimental emissions released in major urban spaces (Frank, Stone Jr, & Bachman, 2000).

New urbanism is a novel aspect of neighborhood design, which aims to reduce the use of private transportation and increase other modes of transportation, such as walking, bicycling or public transit. This new paradigm focuses on people's behavioral choices for transportation. The results of different studies have shown that increased connectivity of neighborhoods, a variety of population densities, and the mixing of commercial and residential properties have varying effects on people's transportation choices. According to Crane and Crepeau's (1998) research in San Diego, California, neighborhood street patterns that are more connected and direct do not reduce people's automobile use (Crane & Crepeau, 1998). On the other hand, Frank, Devlin, Johnstone and van Loon found that adults that live in areas of increased connectivity and proximity to their destinations in Vancouver, British Columbia, are two to three times more likely to walk. In addition, neighborhood designs that include parks and open spaces have the ability to double the chances of active transport, or transportation that requires physical exertion, such as walking or bicycling (Frank, Stone Jr, & Bachman, 2000). This clash in findings leads readers to wonder if the effect of neighborhood design may be particular to the individual place, as a result of people's preferences and social norms of a specific area.

The use of public transportation may also be affected by travelers' enjoyment or utility of the trip. Paez and Whalen (2010) define utility of travel as the activity at the destination, activities during the trip and the enjoyment of travel itself. While many people think of a commute as a waste of time, Paez and Whalen suggest that activities during a trip and enjoyment of travel may have an effect on people's choices of travel at McMaster University in Ontario, Canada. They found that people are most receptive to policies that affect cost, especially car-users. Active travelers make the group that finds the most enjoyment from their commute, and the authors suggest that this daily commute may have positive impacts on health. A specific challenge they found for public transit was that travelers generally desire to reduce the time spent traveling by public transportation in comparison to active transport or automobile use (Paez & Whalen, 2010). Likewise, Carrus, Passafaro and Bonnes have found that individuals anticipate negative emotions with the use of public transportation (Carrus, Passafaro, & Bonnes, 2008). In contrast with the negative reactions to the time of commute associated with public transportation, travelers reacted positively to the good quality of shelters made for public transit. Both the positive and negative emotions associated with public transportation explain the reasons behind public transportation use and the frequency of this public transit use (Paez & Whalen, 2010).

The accessibility of public transportation is another aspect that affects the use of such systems. According to Curl, Nelson and Anable (2011), infrastructure accessibility can be delineated within three parameters: travel times, travel distances, frequency of bus services and congestion. These parameters lay the groundwork for people's understanding of infrastructure and its effect on their use of public transportation (Curl, Nelson, & Anable, 2011). While planning both private and public transportation systems, Murray and his colleagues (1998) found that the perceived accessibility of this transit is also heavily reliant on the purpose of specific travel, cost, temporal frequency and spatial dispersal of these trips. While there are many measures of accessibility, Murray and his colleagues specifically focused on accessibility in terms of spatial proximity. They found that, like other places, "the South East Queensland region is far from being able to provide the level of public transport service that it would like to." This inability to provide public transport is directed at populations that are predominantly rural and the public transport services are hardly capable of meeting these needs at a reasonably low cost. They suggest more creative solutions, such as "multiple fare taxi, a mini-bus on a flexible route or a conventional bus on an established route" (Murray, Davis, Stimson, & Ferreira, 1998).

Neighborhood design, utility and enjoyment of commutes and accessibility are all significant factors in the realm of public transportation. Frank and his colleagues (2000) found new urbanism can decrease private automobile use in Vancouver, Canada, while Crane and Crepeau (1998) found that new urbanism has not decreased private automobile use in San Diego, California. This variety in findings could suggest the success of new urbanism in a community is dependent on specific case studies. The utility that passengers experience while using public transportation explains the reasons for different transit decisions (Paez & Whalen, 2010). Positive or negative emotions associated with different transportation choices could ultimately affect public transportation ridership (Carrus, Passafaro, & Bonnes, 2008). Murray and his colleagues found the accessibility, in regards to spatial distance, declines with the density of populations (1998). New Urbanism neighborhood design, utility of transportation and accessibility are aspects of public transportation can be used to build a framework that explains some of the constraints of public transportation in the world.

1.2 Research Outline

The University Park campus of Penn State University is known by many as the large college town with an undergraduate and graduate student population of approximately 44,000 in the middle of rural central Pennsylvania (State College, Pennsylvania, 2011). With such a concentration of people, buildings and jobs in State College, the presence of a public transportation system is essential for many people. The CATA bus service offers seventeen fare routes, known as "Community Service," and four fare-free routes, called "Campus Service." According to the 2012 CATA Ridership Report, the 2011- 2012 ridership was a total of 3,802,498 for the "Campus Service" routes campus and a total of 3,202,431 for the "Community Service" routes (CATA, 2012).

Twenty-three percent of students at Penn State have their cars registered and parked on campus (U.S. News, 2010), which does not include the students who park their cars off-campus. The amount of student parking off campus could either have little effect or great effect on the public transportation use. In addition to CATA buses and CATA shuttle services, Penn State Transportation Services offer a shuttle for students and staff to travel around campus. This shuttle functions Monday through Friday from 7 AM to 6 PM and circulates at 15 minute intervals (Bittner, 2011). This shuttle service can be seen below in Figure 1.

Figure 1: Map of Penn State's shuttle service on campus (Penn State, 2011)

I plan to analyze the relationship between students' perceptions of the physical world and their public transportation choices. I will produce statistical information of participants' perceptions of CATA bus services the actual distances from participants' residences to bus stops, the demographics of the participants and their frequency of bus-use. This information could be used to understand how spatial proximity actually affects bus-use and accessibility perceptions. These relationships could make people aware of their actual behaviors in comparison to their perceptions of their transportation behaviors. Additionally, it could assist CATA with its planning for both old and new bus stops and consider their clients' perceptions of the system's accessibility. Below are my research questions:

How do students' perceptions of the physical world play a role in their public transportation behaviors?

- Is there a difference between the ability to judge distances accurately between males and females? According to Coluccia and Louse (2004), males navigate their environments with Euclidean coordinates and numeric distances, while females navigate their environments primarily with landmarks. Do these differences in accuracy correspond to variations in the frequency of CATA bus-use? Is there a difference between perceived distance (from residence to closest bus stop) and actual distance for males and females?
- Do consistent misjudgments of distance between the residences to CATA bus stops affect the students' personal ridership? If participants consistently underestimate this distance, are they more likely to use CATA buses? If participants consistently overestimate this distance, are the less likely to use CATA buses? Murray and his colleagues found that the spatial accessibility to public transportation is not uniform, when comparing rural to urban areas (Murray, Davis, Stimson, & Ferreira, 1998) – do differences in spatial distance affect ridership? These variations in distance may have an effect on participant's perception of closeness and accessibility, as well.
- I plan to research Penn State students' perceptions of their "accessibility" and "closeness" to transportation. What are their perceptions of their residences' proximity or actual distance to CATA bus stops? If people consider the bus stop to be "very accessible" or "very close" to their residences, will they underestimate the distance between their residence and the bus stop? If participants consider the bus stop to be "not accessible" or "very far" from their residences, will they overestimate

the distance between their residence and the bus stop? Do they relate specific distances with the words "very far" and "very close" or "accessible" and "non-accessible" to their residences? Do these perceptions have relationships with uses of different transportation, such as cars?

1.3 CATA Map

The two sections of CATA's fixed bus routes system of campus and community services can be seen in the maps below (see Figure 2 and 3).

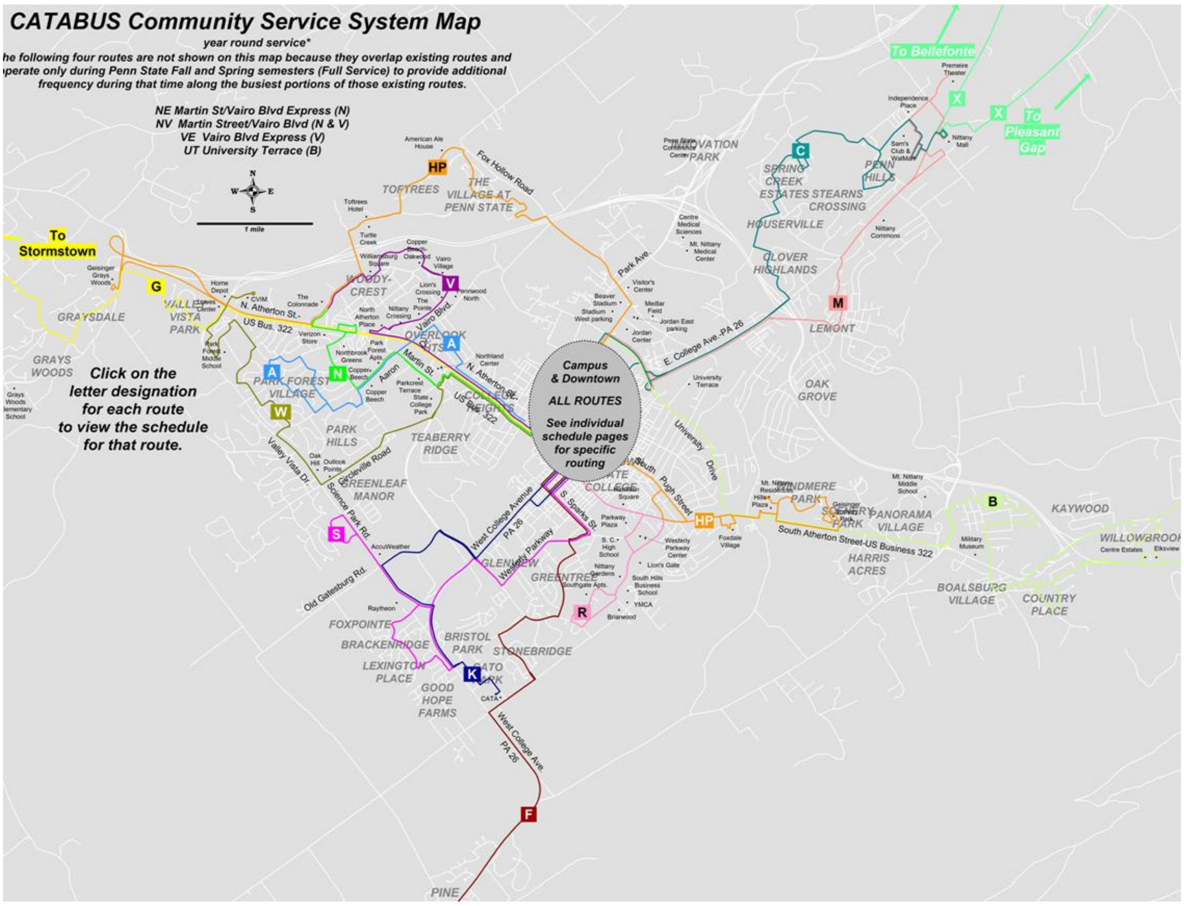


Figure 2: The map depicts the general "Community Service" bus routes of the Centre Area Transportation Authority's bus system. The grey oval obstructs the portion of the bus routes that run through the Pennsylvania State University's campus and on Beaver Avenue and College Avenue (CATA, 2012).

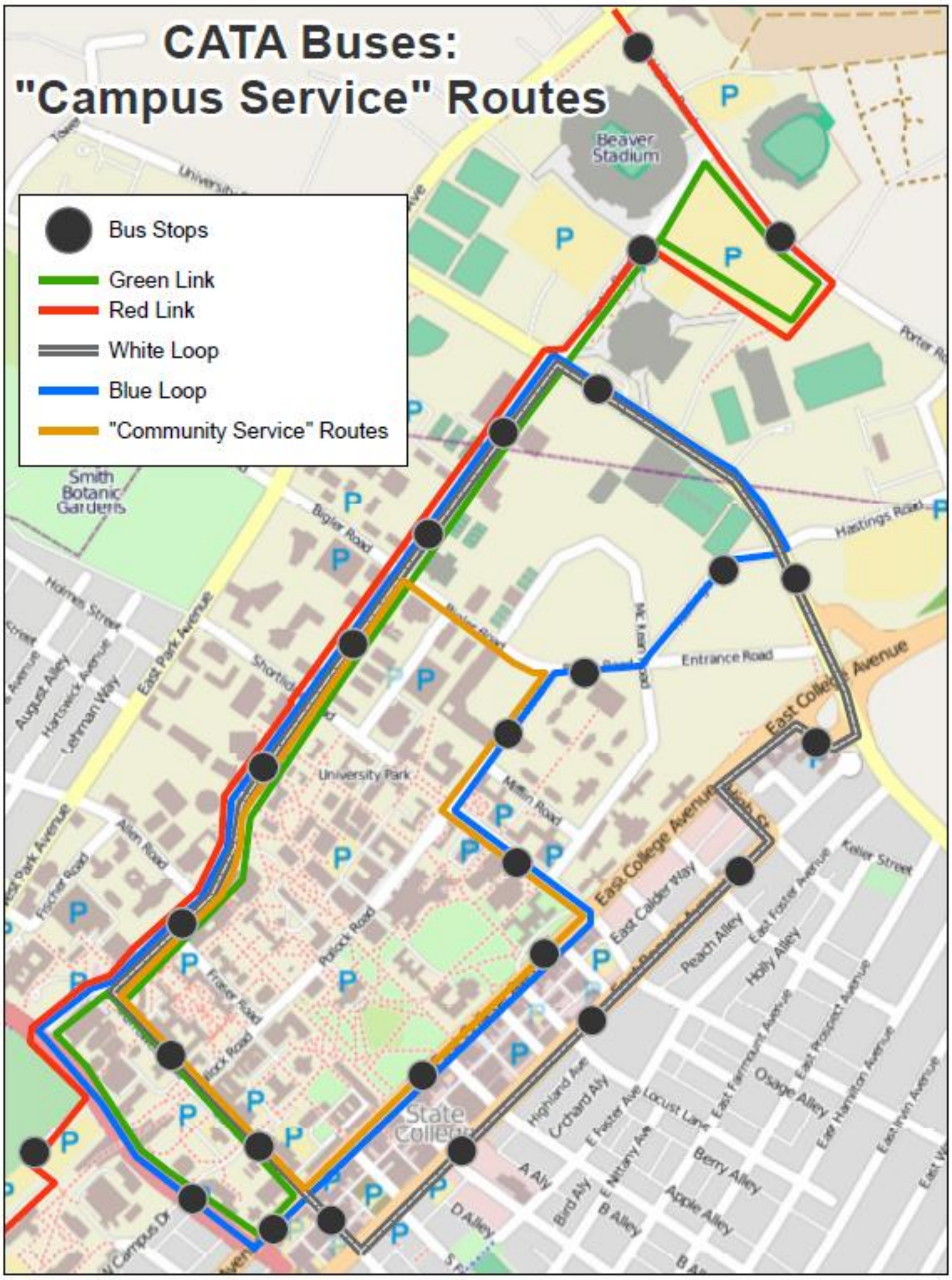


Figure 3: This map depicts the general "Campus Service" bus routes in green, red, grey and blue, and the "Community Service" routes in orange (CATA, 2012).

1.4 Methodology

In this research, students were asked to voluntarily answer a paper questionnaire (143 participants volunteered to answer the questionnaire), during a class period or during an extracurricular meeting. Of the 143 questionnaires returned, only 122 questionnaires were complete. Participants were asked ten questions, which were a mixture of multiple choice and open-ended questions, which can be seen in Appendix A.

- Categorize participants by their gender, male or female.
    - Determine if males and females use CATA buses at a different frequency.
    - Determine if males and females judge distance with the same accuracy.
    - Determine if males and females have different relationships between their error in distance judgment (error in judgment) and the actual distance.
- Categorize the participants' responses based on their frequency of bus use: "daily bus use," "2-5 times/week," "2-4 times/month," "1-3/semester" or "never." Of the many categorizations of time, I chose the following as a result of discussion in a human factors geography class under Dr. Alexander Klippel. The "daily" and "2-5/week" represent regular bus-uses; the "2-4/month" and "1-3/semester" represent infrequent bus-uses; the "never" response represents non-existent bus-use.
    - Determine if there is a correlation between bus-use frequency and the ratings of accessibility and the ratings of closeness.
    - Determine if there is a correlation between bus-use frequency and distance judgment (error in judgment).
    - Determine if there is a correlation between perceived distance and actual distance within the different categories of bus-use frequency.

- Categorize the participants into their ratings of accessibility of CATA buses (1: not accessible; 5: very accessible) and then into their ratings of closeness from their residences to the closest CATA bus stop (1: very far; 5: very close).
    - Determine if ratings of accessibility and closeness have relationships with distance judgment (error in judgment).
    - Determine if ratings of accessibility and closeness have relationships with the use of other transportation, such as cars.
    - Determine if ratings of accessibility and closeness have relationships with the actual distance between participants' residences and the closest bus stops.

1.5 Vocabulary

In this thesis, a specific terminology was used to describe different aspects of the data, which can be confusing. Because of this, the present section is devoted to the definition of vocabulary used throughout this thesis.

<u>Bus-use frequency</u>: describes how often or infrequently a participant uses the CATA bus system. This answer was a multiple choice answer, used to describe participants' use of buses for the Fall 2011 semester, because overall use usually changes from semester to semester depending on jobs, classes or other extraneous circumstances. Responses could be: "daily," "2-5/week," "1-3/month," "2-4/semester" or "never," which represent regular, infrequent and non-existent bus-use.

<u>Accessibility rating</u>: participants were asked to rate how accessible they believed the CATA bus system was, in general. The scale ranged from 1 to 5, where 1 was considered the "least accessible" and 5 was considered the "most accessible."

Closeness rating: participants were asked to rate how close they believed the CATA bus stops were to their places of residence. The scale ranged from 1 to 5, where 1 was considered the "very far" and 5 was considered the "very close."

Actual distance: describes the distance (in meters) from the participant's house to the closest CATA bus stop to their place of residence.

Perceived distance: this term describes the distance (in meters) perceived by the participants. Participants were asked to write down the distance from their residence to the closest bus stop that could be converted into meters. Responses, which were answered in minutes or street blocks, would be omitted from the distance comparisons.

Distance Judgment: this term describes the difference between the perceived distance and the actual distance (in meters). A positive number shows that the distance between the bus stop and their residence is perceived as farther than reality. A negative number shows that the distance between the bus stop and their residence is perceived closer than reality. If the number is zero, it means that the perceived distance and the actual distance are equal, which means that the participants' perceptions are consistent with reality. This also reveals that the closer the number is to zero, the more accurate the judgment was.

2.0 Results

In total, this research had 122 participants: 68 female participants and 54 male participants. Because some of the participants omitted questions, did not provide complete answers or answered questions with multiple responses, the numbers may change between different categories.

3.0 Gender: Male and Female

3.1 Gender and Distance Judgment

Table 1: Gender and Mean Distance Judgment		
Gender	Mean Distance Judgment* (meters)	Standard Deviation
Male	**-18.4**	**40.83**
Female	**-58.7**	**64.7**

Table 1: Table shows gender and distance judgment in meters. This table was based 37 males and 54 females, which did not including outliers (*).

When judging distance, females and males responded as expected, or their responses corresponded with other studies. When excluding outliers, male judgment of distance is more accurate than female judgment of distance. The average distance judgment for males was -18.4 meters, while the average distance judgment for females was -58.7 meters. This difference is statistically significant. As Levene's Test for Equality of Variances shows that equal variances cannot be assumed, I used a corrected t-value and degrees of freedom, $t(88.51) = 3.646$; $p < 0.001$. Both males and females, on average, perceived the bus stops to be closer to their residences than reality, but, on average, males estimated distance more precisely than females, which can be seen in Table 1. These findings coincide with a review written by Coluccia and Louse (2004). In their review, the authors argue that males are more accurate when judging distance because of the different strategies used. Males tend to use survey strategies that include Euclidean parameters with cardinal directions and metric distances, while female participants tend to use landmarks and relative direction words. These differences in spatial abilities and surveying capabilities are attributed to biological, psychological and environmental factors (Coluccia & Girogia, 2004). Although spatial abilities may contribute to behaviors, my research does not support distance judgment as an indicator of bus-use frequency behaviors. Females consistently underestimated the distance between their residence and the closest bus stop, hence they may be more inclined to use these CATA buses more frequently than males. As reported in section 3.2, a significant relationship was not found between bus-use frequency and gender, which calls for more research.

3.2 Gender and Bus-use Frequency

The table below shows the difference between male and female bus-use frequency.

Table 2:
Gender and Bus-use Frequency

Bus-use Frequency	Male Participants	Female Participants	Total Participants
Daily	13 (24.1%)	10 (14.7%)	23 (18.8%)
2-5/Week	17 (31.5%)	24 (35.3%)	41 (33.6%)
1-3/Month	10 (18.5%)	20 (29.4%)	30 (24.6%)
2-4/Semester	9 (16.6%)	10 (14.7%)	19 (15.6%)
Never	5 (9.3%)	4 (5.9%)	9 (7.4%)
Total	54 (100%)	68 (100%)	122 (100%)

Table 2: This table depicts male and female bus-use frequency with both the raw number of

participants in each category and percentage in each category.

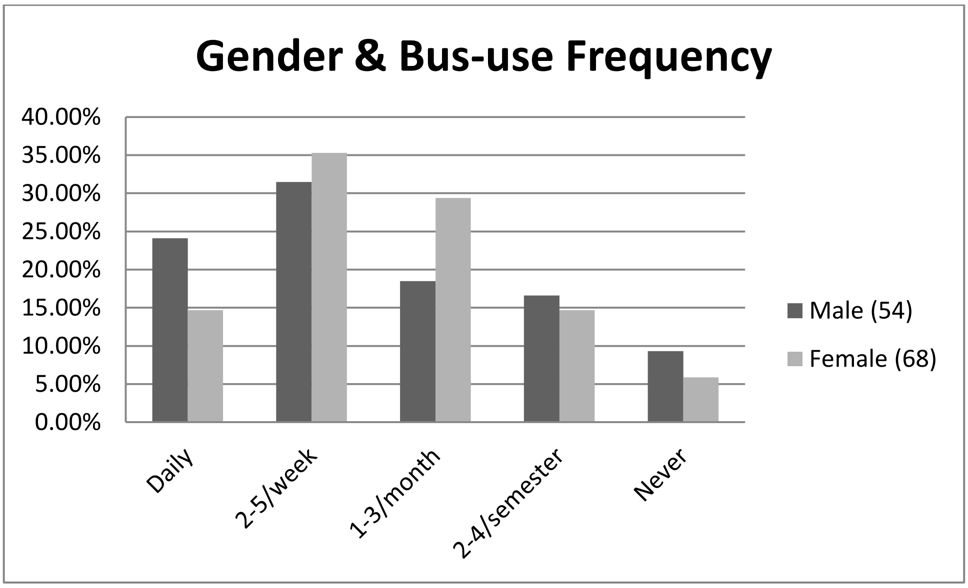
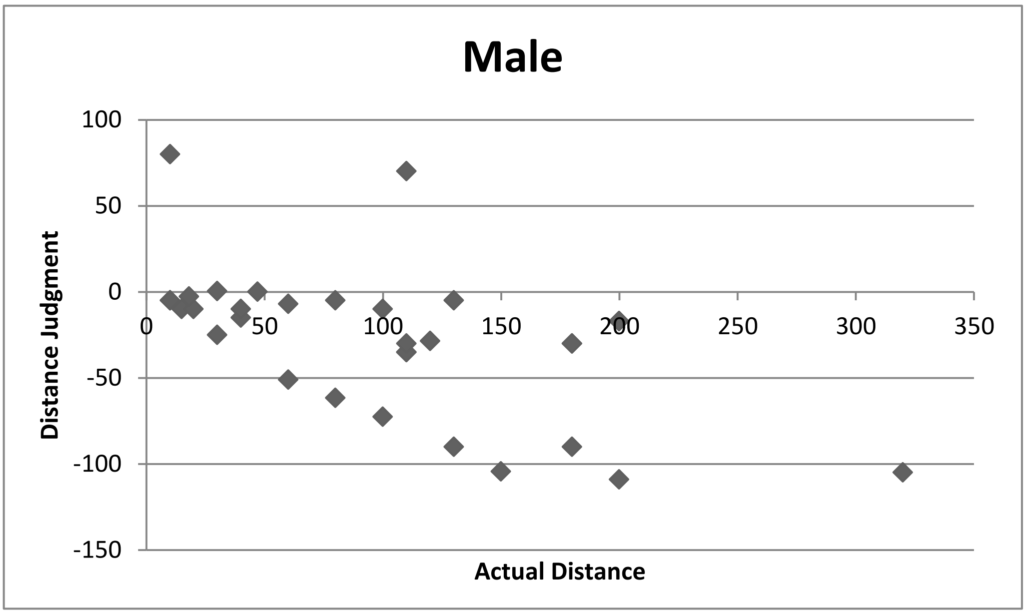


Figure 4: Chart of percentage of participants based on Gender and bus-use frequency.

Both the table and bar chart reveal that both genders generally use CATA buses in a comparable manner: the most common bus-use frequency is 2-5 times per week, while the least common response was “never.” For daily bus-use, the percentage of male participants was almost 10% more than female participants. In the category of “1-3/month,” female participants answered 29.4% and only 18.5% of males, which is over a 10% difference. Using a Chi-square test, these findings were not found significant, χ (4) = 8.145, $p > 0.05$. Therefore, bus-use frequency is not significantly different between males and females across the different frequencies. Another Chi-square test performed for bus-use frequency and total participants was found significant, χ (4) = 23.574, $p < 0.001$. This establishes that there are significant differences between the frequency of CATA bus-use and the number of participants in these specified five categories of bus-use frequency.

3.3 Gender and the comparison between Distance Judgment & Actual Distance

The figure below illustrates participants' Distance Judgment (error) on the vertical axis with the Actual Distance on the horizontal axis for males and females.



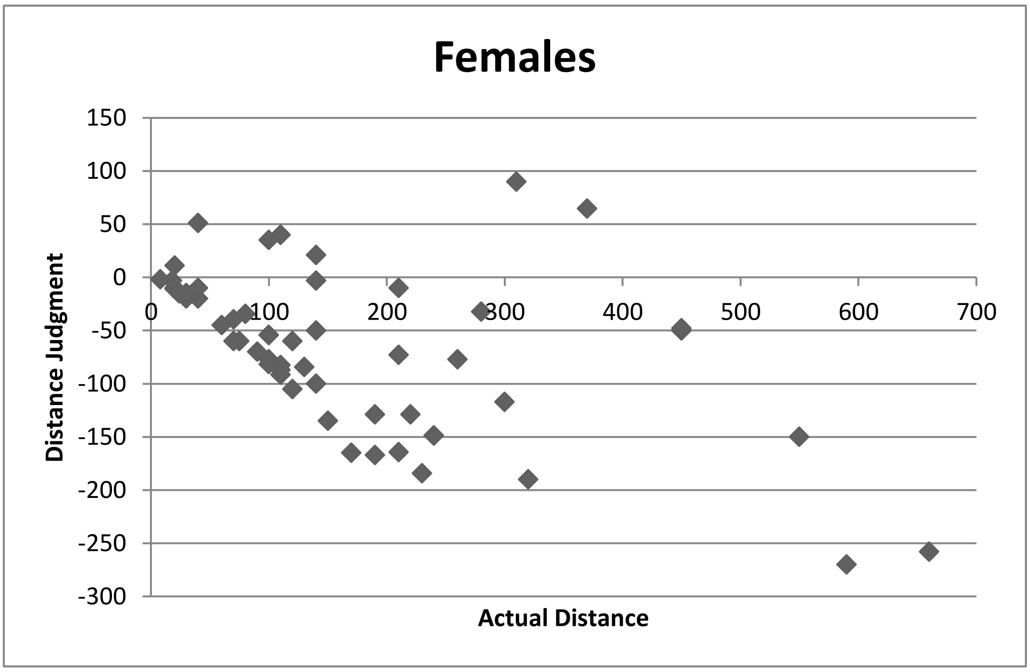


Figure 5: These graphs depict the Distance Judgment and Actual Distance in regards to gender, using the data of Distance Judgment without outliers.

Both male and female graphs illustrate negative trends in the relationship between Judged Distance and Actual Distance. This suggests that as the actual distance between a participant's residence and the closest bus stop increases, his/her ability to judge accurately declines. Furthermore, I used Pearson's r (correlation analysis) to describe the relationships between distance judgment and actual distance for both females and males. The correlation analysis for the 68 females surveyed reveals a weak negative correlation, $r\ -0.274$, p (two-tailed) < 0.05. For the 54 males surveyed, the Pearson's r data analysis revealed a strong negative correlation, $r\ -0.770$, p (two-tailed) < 0.01. When the actual distances of the female participants increased, the distance judgment (or error in judgment) became greater, but this trend occurred with a weak correlation. The strong correlation of male participants showed greater actual distances were paired with greater distance judgment (or greater error in judgment). Both the graphs and the Pearson's r analyses reinforce the previous findings that males and females perform differently in spatial tasks.

4.0 Bus-use Frequency

Bus-use frequency is an important aspect of this study, because it has important implications for the economic viability of CATA bus transportation. If students use these bus services more frequently, the more essential this form of transportation will become to the student community at the Pennsylvania State University.

4.1 Bus-use Frequency, Accessibility Ratings and Closeness Ratings

Table 3: Bus-use Frequency and Accessibility and Closeness Ratings		
Bus-use Frequency	Accessibility Rating	Closeness Rating
Daily	4.61	4.5
2-5/Week	4.34	4.39
1-3/Month	4.32	4.28
2-4/Semester	4.11	4.17
Never	3.67	4

Table 3: Table depicts categories of Bus-use Frequency and the averaged accessibility rating and closeness rating that correspond to each category.

Table 3 shows that participants who use CATA buses more frequently, on average, rate the accessibility as higher than the participants who use CATA buses less frequently. This pattern also occurs in the relationship between bus-use frequency and the closeness rating. The ratings of accessibility and closeness may be accurate indicators for students' CATA transportation behavior. Because of the similar patterns displayed by the accessibility ratings and the closeness ratings, these findings may suggest that participants may regard "accessibility" and "closeness" as similar or interchangeable, in regards to bus-use frequency. The researchers, Curl, Nelson and Anable (2011), described infrastructure accessibility within three parameters: travel times, travel distances, frequency of bus services or congestion; the inclusion of travel distances as a form of accessibility reinforces this relationship between perceived accessibility and perceived closeness (Curl, Nelson, & Anable, 2011). While the terms, "accessible" and "close" are linked, when regarding bus-use frequency, these terms do not always reveal coinciding results in other areas of the study, such as the results in section 5.1. Moreover, the results support the idea that students, who use transportation more frequently, are likely to perceive the CATA bus stops as more accessible or more close to their places of residences.

4.2 Bus-use Frequency and Distance Judgment

Initially, I believed that there could be a strong relationship between bus-use frequency and participants' ability to judge the distance between their residences and their bus stops. People, who use buses more often, may perceive the bus stops to be closer in distance (underestimate distance), while people, who use buses less often, would perceive the distance to be farther in distance (overestimate distance). Table 4 shows the data of the distances in meters.

Table 4:
Bus-use Frequency and Distance Categories

Bus-use Frequency	Average Perceived Distance [APD] (meters)	Average Actual Distance [AAD] (meters)	Distance Judgment* [APD-AAD] (meters)	Standard Deviation of Distance Judgment
Daily	**103.3**	**132**	**-28.7**	**78.7**
2-5/Week	**174.2**	**241.7**	**-67.5**	**108.7**
1-3/Month	**142**	**167.1**	**-25.1**	**78.5**
2-4/Semester	**164.4**	**198.8**	**-34.4**	**87.8**
Never	**102.9**	**126**	**-23.3**	**94.3**

Table 4: Table shows bus-use frequency and the averages of the perceived distance, the actual distance (meters) and the difference between perceived and actual (meters). This table was based on the Distance Judgment column not including outliers (*).

The data of Table 4 does not reveal any patterns. People who use the buses on 2-5/week were the least accurate (misjudged the distance by the largest margin), while the participants who never use CATA buses were the most accurate (misjudged by the smallest margin) in their judgments of distance. No relationship was found between the frequency of students' bus-use and their distance judgment from their residence to the closest bus stop.

4.3 Bus-use Frequency and the comparison of Actual Distance and Perceived Distance

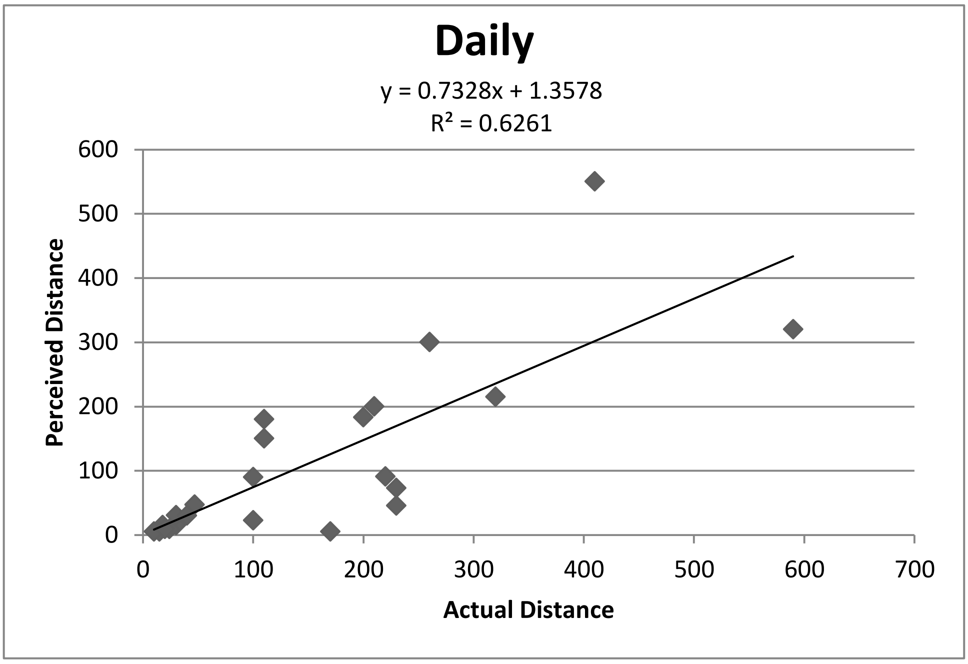


Figure 6: Daily bus-use and the relationship between perceived distance and actual distance.

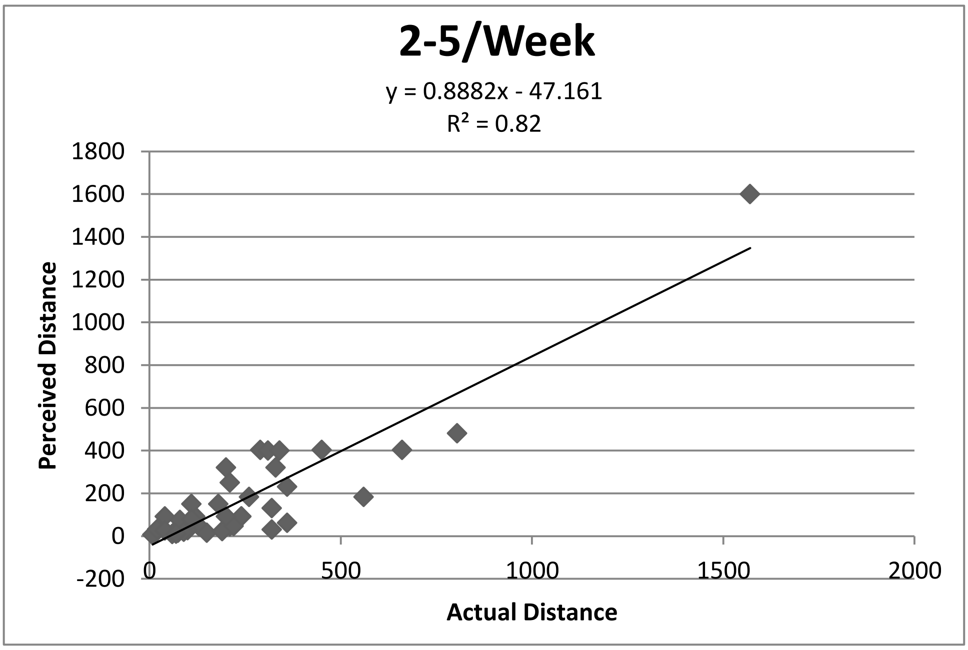


Figure 7: 2-5/week bus-use and the relationship between perceived distance and actual distance.

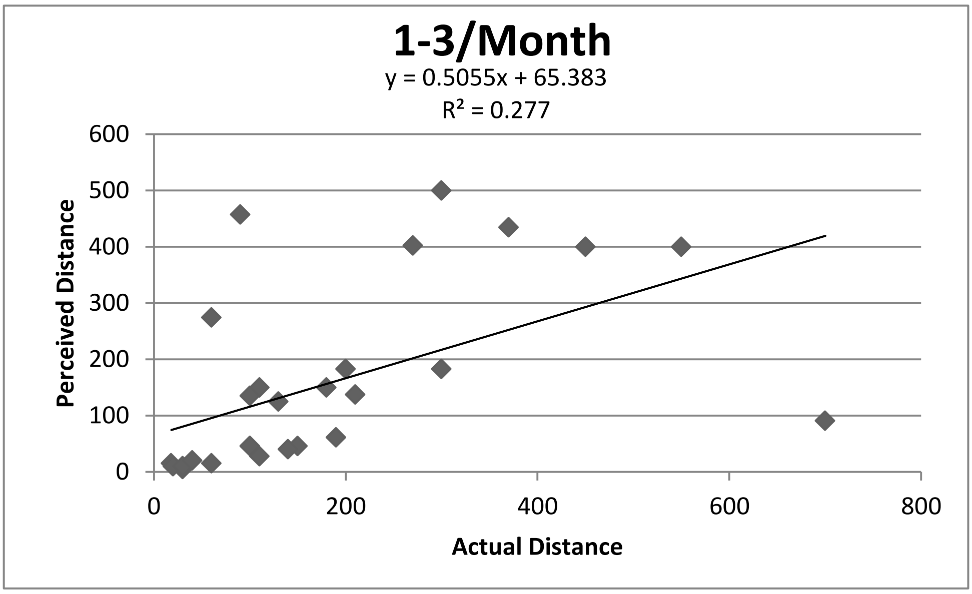


Figure 8: 1-3/month bus-use and the relationship between perceived distance and actual distance.

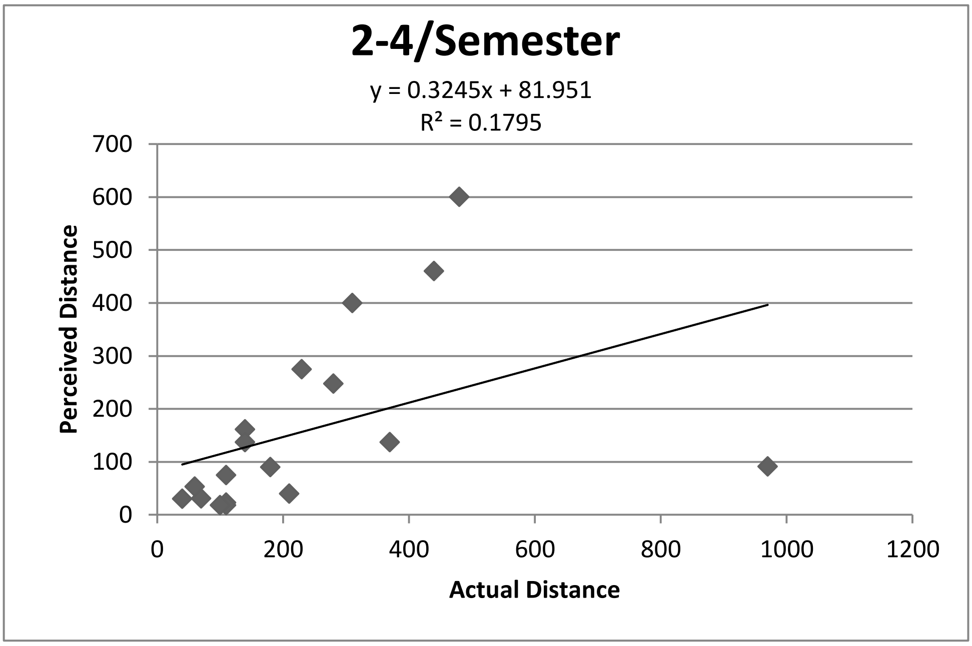


Figure 9: 2-4/semester bus-use and the relationship between perceived distance and actual distance.

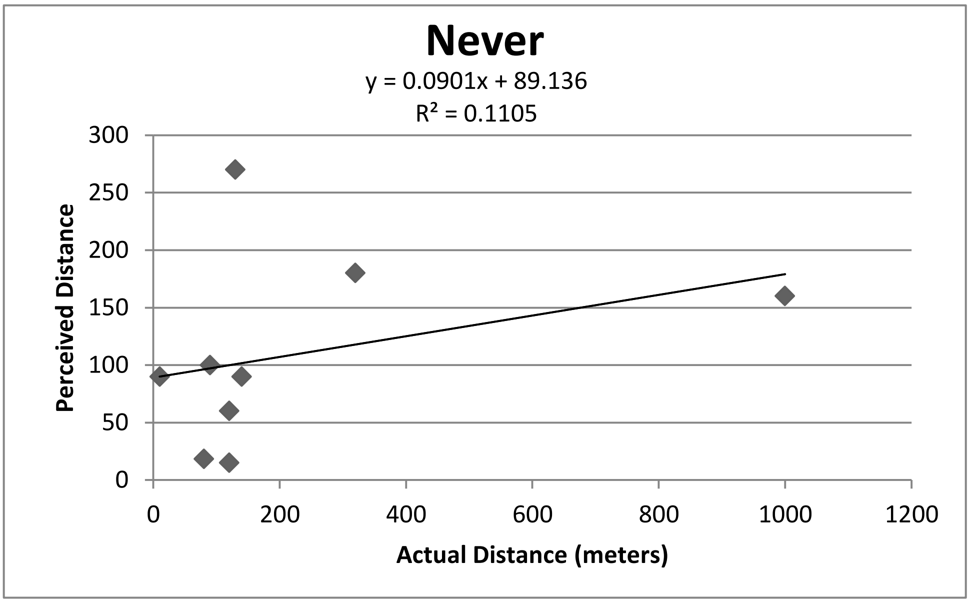


Figure 10: The bus-use of "Never" and the relationship between perceived distance and actual distance.

Figures 6- 10 show the relationship between actual distance and perceived distance. The R^2 values determine the accuracy of the regression equation in their prediction of the variables; the R^2 values are the highest (most accurate) of the two highest bus use frequencies. These values decline for the "1-3/semester," "2-4/month" and "Never" graphs. The diminishing accuracy for the last three regression equations suggests that students, who use the bus irregularly or never use the bus, are less precisely predicted than those of the categories of "daily" and "2-5/week" bus users. Additionally, a Pearson's r data analysis for each graph shows that the actual distance and perceived distance have varying correlations between bus-use frequency groups. Daily bus-use had a strong positive correlation, r 0.791, p (two-tailed) < 0.01; participants who answered 2-5/week also had a strong positive correlation, r 0.906, p (two-tailed) < 0.01. The Pearson's R analysis of participants who answered 1-3/month revealed a moderate positive correlation, r 0.526, p (two-tailed) < 0.01. Similarly, participants, who answered 2-4/semester and never, have moderate positive correlations, r 0.424, p (two-tailed) < 0.05 and r 0.332, p (two-tailed) < 0.05. While these results are not consistently strong correlations across the board, the results show there are strong correlations between actual distance and perceived distance for the groups of bus-use participants that use the bus most often (daily and weekly),while only moderate correlations were found between the last three groups of participants that use the bus irregularly or never.

5.0 Accessibility Ratings and Closeness Ratings

5.1 Accessibility Ratings, Closeness Ratings & Distance Judgment

Another part of this research related accessibility ratings and closeness ratings with the distance judgment. Initially, I believed that people who consider the bus stop to be "very accessible" or "very close" to their residences would underestimate the distance between their residence and the bus stop; this perception of distance would be smaller than the actual distance, making the distance judgment a negative number. Along this line of thinking, the participants, who consider the bus stop to be "not accessible" or "very far" from their residences, would overestimate the distance between their residence and the bus stop. The perceived distance would be larger than the actual distance, making the distance judgment a positive number. Table 5 and Table 6 show distance judgment in relation to accessibility and closeness ratings.

Table 5: Accessibility Ratings and Distance Judgment		
Rating of Accessibility	Distance Judgment (meters)	Number of Participants
1	**13.33**	**3**
2	**-69.46**	**5**
3	**-81.77**	**14**
4	**-72.35**	**28**
5	**-52.86**	**69**

Table 5: Table shows accessibility ratings and the averages of the distance judgment, which is the difference between the perceived distance and the actual distance (in meters). These results are based on 119 participants instead of the original 122, because some omitted this question.

Table 5 does not show a clear trend of increased accuracy in the ability to judge distance for high ratings of accessibility, but does have some interesting aspects. First, 69 participants of 119 rated the accessibility of CATA as a "5," while only 3 participants rated the accessibility as a "1." The participants, who rated CATA as having the lowest accessibility, on average, overestimated the distance, but were the most accurate. Assessments of accuracy are possible because distance judgments that receive a zero indicate that their perceived distance was equal to their actual distance. Therefore, if the absolute value for distance judgment is closer to zero, this value is more accurate than larger absolute values. Participants, who rated CATA as being highly accessible, on average underestimated the distance and were the second most accurate in distance judgment.

Table 6: Closeness Ratings and Distance Judgment		
Rating of Closeness	Distance Judgment (meters)	Number of Participants
1	**140**	**1**
2	**-69.86**	**5**
3	**-70.39**	**13**
4	**-80.48**	**33**
5	**-44.50**	**63**

Table 6: Table shows closeness ratings and the averages of the distance judgment, which is the difference between the perceived distance and the actual distance (in meters). These results are based on 115 participants instead of the original 122, because some omitted this question.

A clear pattern was not revealed by the Table 6. For 63 of 115 participants, the closeness of CATA was rated as a "5," while only 1 participant rated the closeness as a "1." The participant, who rated CATA bus stops as the farthest, overestimated the distance. This participant commutes to campus and uses the CATA system daily from the commuter parking lot. He rated the CATA bus stop located closest to his house, though he never uses that specific stop, which may not make his response an accurate representation of all students who rate CATA closeness as a "1." The participants who rated CATA as the closest, on average underestimated the distance and were the most accurate in distance judgment.

5.2 Accessibility Ratings, Closeness Ratings & Access to other transport

The accessibility ratings and closeness ratings did reveal a pattern for the participants' access to other transport, such as cars.

Table 7: Accessibility Ratings and Car Access		
Rating of Accessibility	Participant with car/ total participants in category	% of participants with access to car
1	**3/3**	**(100%)**
2	**4/5**	**(80%)**
3	**9/14**	**(64%)**
4	**14/28**	**(50%)**
5	**32/69**	**(46%)**

Table 7: Table shows accessibility ratings and the participants' access to other modes of transportation, specifically cars. These results are based on 119 participants instead of the original 122, because some omitted this question.

Table 8: Closeness Ratings and Car Access		
Rating of Closeness	Participant with car/ total participants in category	% of participants with access to car
1	**1/1**	**(100%)**
2	**4/5**	**(80%)**
3	**8/13**	**(61%)**
4	**16/33**	**(48%)**
5	**27/63**	**(42%)**

Table 8: Table shows closeness ratings and the participants' access to other modes of transportation, specifically cars. These results are based on 115 participants instead of the original 122, because some omitted this question.

The patterns revealed by Table 7 and Table 8 show an inverse relationship of decreased access to other transportation coupled with an increase in the ratings of accuracy and closeness. Likewise, when the participants rated their residences as “far” or “not accessible,” a higher percentage of these participants had access to a car. Students may be obligated to own or rent a car when CATA buses are not easily accessible or not considered close or they may choose to live further from bus routes in less expensive areas, because they have access to a car. These descriptive patterns suggest that participants’ perceptions of accessibility and closeness relate to their transportation behaviors.

5.3 Accessibility Ratings, Closeness Ratings & Actual Distance

Table 9: Accessibility Ratings and Actual Distance			
Rating of Accessibility	Actual Distance (meters)	Standard Deviation	Number of Participants
1	**780**	**684.62**	**3**
2	**210**	**167.63**	**5**
3	**258.6**	**252.55**	**14**
4	**256.4**	**224.91**	**28**
5	**165.3**	**135.19**	**69**

Table 9: Table shows accessibility ratings and the actual distance between the participants’ residences and the closest bus stops to these residences.

While there are no consistent patterns between accessibility ratings and the actual distance, participants who rated CATA with the lowest accessibility, had more than double the distance between their residence and the closest bus stop, in comparison to the other categories of accessibility ratings. In addition, participants, who had the lowest actual distance, rated accessibility as the highest-ranking.

Table 10: Closeness Ratings and Actual Distance			
Rating of Closeness	Actual Distance (meters)	Standard Deviation	Number of Participants
1	**410**	**n/a**	**1**
2	**256**	**166.97**	**5**
3	**253.6**	**235.06**	**13**
4	**253.2**	**220.30**	**33**
5	**182.7**	**228.12**	**63**

Table 10: Table shows closeness ratings and the actual distance between the participants' residences and the closest bus stops to these residences. These results are based on 117 participants instead of the original 122, because some omitted this question.

The ratings of closeness and the actual distance reveal an inverse relationship: as the distance between residence and bus stop increases, the closeness ratings decreased in ranking. Participants' perceptions of closeness match with their corresponding distances in reality. This relationship may also suggest participants associate specific distances with non-specific vocabulary of distance. "Very far" described the closeness rating of 1, and the actual distances were greater than the higher closeness ratings. "Very close" described the closeness rating of 5, and the actual distances were smaller than all of the other distances of closeness ratings. The vocabulary words of "close" and "far" could have specific distances associated with them, in regards to public transportation, which could be an avenue for more research.

7.0 Conclusions

Males and females responded to judging the distance between their residence and closest bus stop as anticipated. Males were more accurate in judging metric distance, which corresponds to previous studies (Collucia & Girogia, 2004). The chi-square test indicated that bus-use frequency is not significantly different between males and females. The two variables of actual distance and distance judgment were determined to have negative correlations, according to the Pearson's r analysis: males had a strong negative correlation and females had a moderate negative correlation. This analysis suggests that for both male and female participants an increase in actual distance correlates with an increase in distance judgment (or increased error in judging distance).

Bus-use frequency is a response that is critical for both the economic viability of this public transportation system and environmental improvement through mass transit (Frank, Stone Jr, & Bachman, 2000). A relationship was found between accessibility and closeness ratings with bus-use frequency. When bus-use frequency increases, the ratings of accessibility and closeness also increase. Despite my initial beliefs that participants' perceptions of distance from their residences to the closest bus stops would affect their bus-use frequency, there was not a relationship found between these two variables. Lastly, a relationship was found between the variables of bus-use frequency, distance perception and actual distance. As the bus-use frequency decreases, the accuracy of the equations decreases, which suggests variability between responses increases. The relationship between actual distance and perceived distance is more accurate for participants, who use the bus more frequently (Daily and 2-5/week).

In regards to the ratings of accessibility and closeness and distance judgment, no clear correlations were discovered. On the other hand, accessibility and closeness ratings did have an inverse relationship to the variable of “access to other transportation,” specifically cars. As the rating of CATA transportation’s accessibility decreased, the percentage of participants who have access to cars increased. Likewise, as the rating of the closeness between CATA bus stops and participants’ residences decreased, participants’ access to cars increased. When the perception of accessibility and closeness are not considered high-ranking, students may be obligated to gain access to other means of transportation, such as cars, or if they already have access to cars, they may choose to live farther from campus to find cheaper housing. The ratings of accessibility and closeness could, in fact, be good indicators for revealing students’ access to other forms of transportation and proximity. There is also a relationship between the closeness ratings and actual distance. Participants, who have a farther distance to travel to arrive at a bus stop, did perceive the closeness as less or “very far.” Further research, could investigate specific distances and their relationships to words, such as “very close” and “very far.”

Because this research was performed with a paper questionnaire (see Appendix A), certain aspects of participants’ responses could not be controlled. For example, they were able to review their responses and change them, in order to make them consistent. In addition, the accessibility ratings and closeness ratings were both rated from 1 to 5, where 1 was the lowest rating and 5 was the highest rating. This similar assessment may have linked these two terms for participants, and may explain their fairly regular responses.

While there is room for improvement in the CATA bus system in State College, Pennsylvania, CATA has recently made dramatic changes to the system. Many buses have been completely replaced; these new buses are lower to the ground, which has improved the physical accessibility for the elderly and disabled, because smaller strides are required to enter the bus. In addition, they run more efficiently and less loudly (Lidgett, 2012). While I did not explicitly analyze neighborhood design, it may also affect student’s transportation choices. According to guidelines of “walkable neighborhoods” explained by Frank and colleagues, the campus and the immediate State College borough could be considered “walkable communities,” because they have more connective streets, more mixed land use and higher density (Frank, Stone Jr, & Bachman, 2000) than the rest of the areas that CATA buses service. The walkability along with free bus services makes the 600,000 more people that use the “Campus Service” routes rather than the “Community Service” routes, annually, not surprising. The advancements in technology, which improves comfort and utility, and neighborhood design do not necessarily address the spatial proximity and accessibility issues that this thesis discusses, but they are changes that have improved transportation quality for riders.

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Appendix

1. My sex is:
   a. Male
   b. Female

2. How often in the current semester do you use the CATA bus system at Penn State-University Park?
   a. Daily
   b. 2-5/week
   c. 1-3/month
   d. 2-4/semester
   e. Never

3. I have access to these types of transportation at my local residence in State College, PA:
   a. Car
   b. Bike
   c. Skateboard/scooter
   d. Motorbike/motorcycle

4. My street address is:____

5. Rate how "accessible" you feel the bus stop is to your residence:
   (1 = not accessible; 5 = very accessible)
   1 2 3 4 5

6. Estimate the distance between your personal residence and the closest CATA bus stop to your residence: (estimate in feet, yards, miles, meters or kilometers on the line below)

   ____

   When I walk to the closest CATA bus stop, I take a shortcut (i.e. you might cross through a parking lot or through a yard, instead of taking a route that follows a roadway)
   a. Yes
   b. No

   When I use this shortcut the distance, from my place of residence to the closest bus stop, is less; the shortcut distance is: (estimate in feet, yards, miles, meters or kilometers on the line below)

   ____

7. What bus route do you take from your residence? (i.e. "Blue Loop" or "Vairo Blvd")

   ____

8. Explain your route from your residence to the bus stop, using road names or landmarks: ____
____

9. Rate how "close" you feel the bus stop is to your residence:
(1 = very far; 5 = very close)
1 2 3 4 5

10. Please explain any extraneous circumstances that may affect the way you travel around State College, PA.
____
____

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