World Impact of Transportation

"The science and public perception on the global costs and impacts of transportation"

An Interactive Qualifying Project Report
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of the
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ABSTRACT

It seems that the common public perception of transportation is that automobiles are damaging the environment and the best way to combat the rise in pollution is to take as many trips as possible on foot or using a bicycle. This would cut down on emissions and, therefore, save the planet. The theory explored in this report is that the common views on transportation are not entirely accurate and people don't always see the big picture. The main goal of this project is to investigate the out-of-pocket cost weighed against the global impact of various forms of transportation, namely, walking, riding bicycles, traditional cars, electric cars, etc. The end goal of this project is to find the most "efficient" transportation method in regards to environmental, and socioeconomic impact. This would also require surveying a sample group to get their input on the various aspects involved in transportation. This could include views on the environment, current transportation methods and willingness to change them. In the end the question that needs to be answered is: "Are we wrong in how we think about transportation?"

AUTHORSHIP

Abstract	EL
Introduction	MM,EL
Background and Literature Review	EL, MM
Procedure	EL,MM
Results	MM, EL
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INTRODUCTION

Context

Throughout the course of history, humans have developed many different methods of transportation. In the Early Neolithic Age (9500-3500 BCE) humans traveled by foot, carrying their belongings. Repeated travel over certain popular routes left the terrain flattened and cleared, creating natural “paths”. The discovery of the wheel around 3500 BCE and the travois, a precursor to the modern day cart, dramatically changed human travel. Livestock such as oxen, horses, and donkeys could be attached to a travois rigged with wheels which enabled people to travel further distances with more belongings. The earliest evidence of wheel-axle systems is believed by historians to be from the very beginning of the Early Bronze Age (3300-2200 BCE).[1]

As civilization advanced, travel and transportation requirements grew exponentially, and as a result, transportation technology developed rapidly to meet these growing needs. Dirt paths gave way to gravel and cobblestone, the predecessor to the modern road and highway. The Travois and the wheel led to horse drawn carriages, and eventually the modern automobile. The advent of the airplane allowed for faster and farther travel than ever before while the invention of trains and subways innovated what we know today as mass transit.

These developments in transportation methods greatly affected the development and advancement of the global community. Advancements in the ability to transport people and goods farther and more quickly has greatly impacted the political fabric of both Europe and America. Around 500 BCE the Romans began to construct local as well as long distance roads in order to connect their rapidly growing empire. At its peak the Roman Empire maintained over 350 roads covering upwards of 80,000 kilometers. This transportation infrastructure enabled the empire to move military resources and personnel as well as goods from the vast and distant territories it occupied and played a fundamental role in the rise and success of The Roman Empire and the diffusion of Roman culture into much of Europe, the Middle East, and North Africa.[2]

Similarly, advancements in transportation infrastructure played a major role in American expansion westward throughout the 19th century. Early pioneers and settlers who first ventured west traveled by foot or horse and carriage mostly following natural geographic trails and old native American traveling routes. However, the advent of the steam power locomotive connected

[1] Lay, Maxwell G., and James E. Vance. Ways of the World: A History of the World's Roads and of the Vehicles that Used Them. Rutgers university press, 1992.
[2] Fulford, Michael. "Territorial expansion and the Roman Empire." World Archaeology 23.3 (1992): 294-305.

western settlements to the eastern coast. Goods and products procured in the west could be moved back to the more developed eastern coast where they could be sold or exported. Materials needed to build cities and communities could also be sent in larger volumes to the west which played a key role in the development of more permanent and advanced cities and institutions on the west coast.[3]

In these examples as well as many others transportation was not only a product of societal and scientific advancements, but was fundamental in catalyzing this growth. Understanding how transportation has impacted our society in the past provides insight into how our present day transportation choices impact us as individuals as well as the national and global communities.

Today, there are many different methods of personal transportation available for use and consumers have many choices of how to travel from point A to point B. There are many factors that play into an individual's decision on which method to use as his/her primary mode of transportation including socio-economic status, geographic location, occupation and environmental impact among many others. Though these considerations play a large role in this decision, so too does personal choice. While some consumers may prefer the comfort of a personal automobile, others may place more of an emphasis on the environment and prefer to bike or walk.

ASSUMPTIONS

In order to calculate costs associated with travel and transportation methods, a number of assumptions and qualifications needed to be made. The subsections that follow outline the key assumptions made in order to quantify travel costs. Many of these assumptions draw from previous research, as well as statistics on average Americans compiled by the government.

Initial Purchase Cost

For this study, initial cost is defined as the cost of purchasing the equipment required to walk, bike or drive. For automobiles, the average purchase cost for a new car was taken from Kelley Blue Book to be $33,340.[4] It should be noted that only the price of new vehicles were

[3] Goldfield, David. "The American journey: A history of the United States." (2001).
[4] "New-car transaction prices rise steadily, up 2.6 percent in april 2015, according to Kelley Blue book." kbb.com. Kelley Blue Book | MediaRoom, 1 May 2015. Web. 17 Feb. 2016.

considered, while pre-owned and used car prices were not. The average lifespan of a car was also required and taken from Consumer Report to be 150,000 miles.[5]

The average cost of walking shoes as well as their average lifespan was acquired from Runner's World to be $70 and 500 miles respectively.[6] For biking, the purchase price of a bike according to Consumer Report is $465 with an average lifespan of 6,500 miles.[7] Depreciation and salvage value for this equipment was taken into account in the disposal and maintenance cost calculations.

Maintenance Costs

The cost of upkeep for automobiles was taken from the American Automobile Association, also known as AAA. According to AAA, the overall cost to buy and maintain a vehicle is $0.54 per mile. 5.06% of this cost is attributed directly to the operational expense of a vehicle. Due to the fact that fuel expenses were calculated separately in this study, $0.06 was removed to leave a value of $0.03 per mile for upkeep and insurance.[8]

For the upkeep cost of bikes and shoes, it was assumed that no repair costs are incurred and that the equipment is replaced instead of repaired. No insurance costs are incurred for walking or biking.

Disposal Costs

The disposal cost calculation represents the cost of disposing equipment required for each mode of transportation. For automobiles, it was assumed that at the end of their 150,000 mile lifespan, cars are sold at their salvage value. According to Edmund's, the average trade in values for vehicles with 150,000 miles is $1,000.[9] This value was used from the disposal cost of a vehicle and as such, the disposal cost is negative, representing a positive cash flow to the individual.

The disposal cost from bikes and walking shoes was calculated using average costs of trash disposal in the city of Worcester, Massachusetts. Resale or donation of the bikes or shoes was not considered.

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[5] Weisbaum, Herb. "What's the life expectancy of my car?" ConsumerMan. Consumer Report, 28 Mar. 2006. Web. 28 Jan. 2016.
[6] "Running shoe Q&A." runnersworld.com. Runner's World, 26 May 2015. Web. 25 Nov. 2016.
[7] "Bike buying guide." consumerreports.com. Consumer Reports, 19 Sept. 2016. Web. 24 Nov. 2015.
[8] "Annual cost to own and operate a vehicle falls to $8, 698, finds AAA | AAA newsRoom." aaa.com. AAA NewsRoom, 28 Apr. 2015. Web.
[9] Reed, Philip. "Using a Car's Key Mileage Figures To Buy or Sell." edmunds.com. Edmunds, 24 Apr. 2012. Web.

Fuel Costs

In order to calculate the value of energy requirements for driving, the average price of gasoline was taken from the US Energy Information Administration to be $2.84.[10] Additionally, the average combined highway and city fuel economy of motor vehicles in the US was reported by the Consumer Energy Center as 25 mpg.[11]

The energy required to fuel biking and walking was taken to be the additional calories required by the human body (in excess of the average person's resting metabolic rate) to power a bike or walk. Average caloric requirements for walking and biking were taken from the Michael Bluejay article published by the New York Times. According to Bluejay, on average walking requires 121.25 kcal/mile, while biking requires 49.25 kcal/mile.[12]

For the purpose of this study, the average cost of these calories was based upon Kip Andersen's documentary *Cowspiracy*. Andersen makes use of the average cost of a McDonald's cheeseburger to calculate a cost per calorie in the US. This method has been used in other areas of research and has been coined "the cheeseburger standard".[13] According to this technique, One McDonald's cheeseburger which contains 300 calories costs $1.22 in the US (Andersen 2014).

Valuing Time

The time a person spends traveling between two locations is dependent on the transportation method he/she employs. According to the Federal Office of Highway Policy Information, the average motor vehicle travels at 28.9 mph, while bikes travel at an average speed of 10.8 mph and walking 3.7 mph.[14] These averages were used in the calculation of the cost of time each method of transportation required. Additionally, the US Average Income of $26 per hour, taken from the US Census Bureau was utilized at a quantification of the value of the average American's time.

It is worth noting that in calculating the time value expense of walking or biking, exercise requirements should be taken into consideration. According to a study done by Penn State University with data collected in the US Census, the average American exercises 2 hours per

[10] "Gasoline and diesel fuel update - energy information administration." eia.gov. 15 Oct. 2015. Web
[11] Woodyard, Chris. "Average Gas Mileage of New Cars Rises in January." USA TODAY, 6 Feb. 2015. Web.
[12] Bluejay, Michael. "Bicycling wastes gas?" New York Times. Oct. 2013. Web.
[13] (Animals United Movement A.U.M., 2014)
[14] "2015 National Higway Statistics" Federal Office of Highway Policy Information 2015

week.[15] If an individual decides to walk or bike as a means of travel as well as to fulfill their exercise requirements, the time value expense must be adjusted. This assumes that the individual would spend 2 hours exercising per week regardless of whether they did so substituting driving with walking or biking. For the purpose of this study, it will be assumed that the first 2 hours of walking or biking does not carry a transportation cost. Time spent walking or biking beyond the first 2 hours each week however does have a cost associated with it.

Commute Mode Share

Commute mode share is the concept that many people, especially in built up areas such as large cities don't always use only one method of transportation on their daily commute. They use a combination of modes such as walking to a subway to get downtown or driving to a garage near their workplace and walking the final few blocks. Because so many people's commutes can have a variety of "modes" it is very difficult to narrow down and quantify the use of specific forms of transportation in commuting.

Few past studies have taken into account mode sharing in commuting and utilitarian travel, resulting in inaccurate data in those areas. Anything that the public self-reports about their transportation habits should be taken with a grain of salt because many people will only report their most prominent mode in a mode-share situation. Because this is a complicated thing to measure objectively as a third party it will be overlooked in this report as well. It should be assumed, therefore, that many urban commute and utilitarian trips include at least a short leg using an unreported mode. [16]

GOALS AND OBJECTIVES

The ultimate goal of this project is to investigate the total costs of various forms of transportation, namely walking, biking, and automobiles, then weigh them against public perception of these costs. For the purpose of this research, the term "total costs" refer to out of pocket costs for vehicle purchase and maintenance as well as time value costs. Additionally, impacts to things such as the environment will also be taken into account when looking at the "total cost". For example, when examining the total cost of walking as a method of travel, we will not only be taking into account the lack of fuel and vehicle expenses as well as immediate

[15] Skerrett, Patrick J. "Americans lag on exercise - Harvard health." Exercise and Fitness. Harvard Health, 6 Oct. 2010. Web.
[16] (Littman, 2014)

emissions, but also other personal impacts such as the price of special shoes and clothing, and the requirement to consume extra calories.

In addition to analyzing these costs, research into public perception of personal transportation will be conducted for comparison. There are many sources from which the public bases its opinions on various forms of transportation, many of which offer partial or misleading information. Again using walking as an example, many believe walking is a very cheap alternative to owning and maintaining an automobile. However there are many costs associated with walking that many do not take into consideration; the cost of increased caloric intake required to provide energy, the costs of the physical strain walking puts on the body, and the value of the extra time it takes to walk just to name a few.

By understanding where public opinion is incorrect or incomplete, this research will shed light on ways in which consumers can be better informed before making a decision on which method they will use for their transportation needs.

The purpose and goals of this study can be summarized by the following objectives:

- ➢ Calculate the true costs associated with walking, running, biking and driving as means of transportation
- ➢ Obtain insight into university students' perceptions of transportation costs and how they factor into transportation related choices.
- ➢ Compare the calculated costs with these perceptions and identify gaps between them

BACKGROUND AND LITERATURE REVIEW

The topic of environmentally friendly transportation has been investigated in many ways by many high-profile authors and institutions as well as small-time writers such as IQP groups and bloggers. It has also been approached from many angles including specifically hybrid and electric cars or bicycling, or how what you choose affects not only the environment but your personal health and wallet.

Automotive Transportation

The automobile first made its start in the United States in 1784 when the government approved the first patent for an automatically powered vehicle belonging to Oliver Evans. The automobile was a significant improvement over the horse or oxen powered vehicles as it could travel farther and faster without the hassle of maintaining livestock. The automobile developed

rapidly in the United States. This development is due in large part to Henry Ford, considered by many to be the father of the modern personal automotive vehicle. Ford's goal was to produce an affordable car for the common American so that every household could have the power of the automobile in their driveway.

Ford's efforts paid off; as of 2013, over 90% of American households reported having at least one personal automobile.[17] The average annual cost of operating these vehicles is estimated by AAA to be $8,698.[18] With 117 million households in the US today, Americans are spending on average 900 billion dollars per year to operate their motor vehicles. This combined with the $40 Billion invested by the federal government into roads and highway systems makes the personal automotive industry a major entity in American society.

Human Powered Transportation

Human-powered transportation includes any mode of transportation which relies entirely on one's own body and energy to function. This category includes walking, running, bicycling, skateboarding, or any other similar method. For many people, this is the mode of transportation that makes the most sense for many reasons including fitness, saving money, and lowering their carbon footprint. On the other hand, some people don't have a need for a car or cannot afford to purchase one. A need for a car could be, for example, living in a rural area or having a long commute not covered by public transportation. When exploring the true impact of human-powered transportation one must look beyond the immediate reduction in carbon footprint; one must explore many different costs including calories burned and the cost of lost time. Because of the extra complications when it comes to calculating a cost per mile, not many people consider running or bicycling to be costly.

Pedestrian Modes

When one thinks of methods of commuting, walking and running don't immediately spring to mind, especially if one lives in a rural area or an area prone to harsh weather. On the other hand, when the trip in question is short – a mile for example – walking is an option that everyone considers. Surprisingly, though, the National Household Travel Survey (NHTS) found that in 2005 48% of reported utilitarian trips and 7% of commuting trips were made on foot. These numbers are far larger than the percentage of people using their bicycle.[19]

[17] "Transportation Energy Data Book" United States Department of Energy 2015.
[18] Annual cost to own and operate a vehicle falls to $8, 698, finds AAA | AAA newsRoom." aaa.com. AAA NewsRoom, 28 Apr. 2015. Web.
[19] Littman, T. (2014, September 10). Short and Sweet Analysis of Shorter Trips Using National Personal Travel Survey Data. Victoria B.C.: Victoria Transport Policy Institute. Retrieved from http://www.vtpi.org/short_sweet.pdf

Bicycling

The bicycle has long been regarded as the most efficient form of human locomotion. Since its invention in 19th century Europe it has remained a popular choice for both transportation and recreation, taking on many function-dictated forms. It can be shaped to handle roadways, trails, and recreation areas such as skate parks. When it comes to getting to work, in 2010, 53% of American commuters chose cycling.[20] And many more people, mostly young people who cannot drive, use their bicycle for unreported utilitarian and neighborhood trips.

Because the bicycle is popular with young people and for short distances, it remains somewhat underreported and, like walking, it is often used as recreation or exercise. The following literature reviews give an overview of a few of the approaches and conclusions that have been encountered through initial research.

Trent Hamm: Walking, Bicycling, Driving, and Cost-Effectiveness

Trent Hamm, a writer for the website The Simple Dollar who was inspired by a new grocery store built in his town, breaks down the costs associated with driving, walking, and biking as a means of getting to his own points A and B. While Hamm makes many assumptions, he does go very much in depth in regards to fuel, time spent, distance traveled, and whether he should get rid of his extra car or not. In the end, Hamm decides that:

> *"For me, the choice is a pretty clear one: for my purposes, biking around town for my usual errands makes a ton of sense. I can literally save money at a rate higher than minimum wage just by bicycling around town instead of driving – and that ignores the exercise benefit of doing so. If I assume each hour of biking replaces half an hour of other exercising, then using my bike around town saves both money and time."*

While he does eventually reach this conclusion, he decides not to give up either of his cars. This is a very interesting commentary on the personal attachment we, as drivers, have to our cars.

Michael Bluejay; Bicycling Wastes Gas?

The article, originally posted in the New York Times Blog, details the benefits of a vegetarian diet as it relates to how much fossil fuel is actually used by someone on foot or riding a bicycle according to their diet. Michael Bluejay claims that the difference between a normal

[20] American Association of State Highway and Transportation Officials. (2015). Bicycling and Walk Commuting . In Commuting in America 2013. American Association of State Highway and Transportation Officials.

American diet and a vegan diet correlates to a 50 percent savings in the consumption of fossil fuels. He also claims that:

> *"In fact, meat production is so wasteful that walking actually uses more fossil energy than driving a 35 mpg car, if you get your calories from the standard American diet."*

While this article is quite focused on the dietary aspect of energy use and reads as an advertisement for veganism, Bluejay has done a fair bit of research on the subject and presents his findings well. The way we aim to expand on his research is that we will delve deeper into what it costs in up-keep for each mode of transportation and what the public's opinion is. Because of some backlash received by Bluejay, we have access to a goldmine of public response to the topic already.

A Study on Hybrid Cars: Environmental Effects and Consumer Habits

A previous IQP studied the environmental benefits of hybrid cars over conventional cars and if they live up to the hype. They concluded that, while on the right track, the technology is not ready to provide the benefits promised. The cars themselves have not been particularly capable; meaning they have a lack of space or could not perform over rough roads or during snowstorms. Also, the infrastructure is not currently in place to cater to plug-in hybrids and it would take time and money to make plug-ins a reasonable option.[21]

Genevieve Giuliano; Car ownership, travel and land use: a comparison of the US and Great Britain

A research study conducted by Genevieve Giuliano and Joyce Dangay in 2006 examined how previous personal transportation studies took into account the factors that play a role in car ownership. Through studying research on personal transportation done in the United State and Great Britain, they came to the conclusion that there are many factors in addition to proximity to work that affect whether a given consumer will utilize a car as their primary method of transportation.[22] Things such as socioeconomic status, field of occupation, geographic location and climate, gas and oil prices, access to viable alternative transportation methods, and many other factors play a large role in whether an individual will own and use a car.

[21] (Michael Christian Beliveau, 2010)
[22] Giuliano, Genevieve, and J. Dargay. "Car Ownership, Travel and Land Use: The US and Great Britain." priceschool.usc.edu. 2006. Print.

PROCEDURE

Cost Categories

A large piece of this project will be data collection and analysis. In order to calculate various expenses related to a given method of transportation travel statistics and data will be gathered from a variety of sources including public and private transit associations, travel regulatory agencies, and previous academic research among others. This data is the foundation of the project, crucial in painting an accurate picture of transportation costs.

In addition to this data gathering, extensive research into data analysis techniques, in particular quantifying impacts to things such as the environment will be conducted. Previous research studies that have also sought to assign a monetary value to such impacts will be the primary source of this information. This study will seek to quantify transportation costs on a per mile basis between walking, biking, and driving.

The Victoria Transport Policy Institute (VTPI), an independent research institute which explores transportation problems and solutions in North America, publishes a variety of papers on many of the topics that are covered in this report.[23] One of the most valuable resources that VTPI offers is a thorough 500 page handbook on the methods they use to monetize the costs of transportation in their own research known as the *Transportation Cost and Benefit Analysis Techniques, Estimates and Implications.* The methods in this guidebook will be utilized throughout the analysis contained within this report.

The Transportation Cost and Benefit Analysis details 23 unique cost categories including vehicle ownership, or the initial cost of a vehicle, pollution, infrastructure, and waste. Each cost is given a description involving three key terms; internal or external, fixed or variable, and market of non-market. These can be applies to any aspect of any method of transportation. The following shows a representative breakdown of the VTPI's 23 cost categories which will be guiding the research in this report.

[23] "Transportation Cost and Benefit Analysis Techniques, Estimates and Implications" [Second Edition] Todd Alexander Litman, E. D. 2015.Web

Cost	Description
Vehicle Ownership	Fixed costs of owning a vehicle.
Vehicle Operation	Variable vehicle costs, including fuel, oil, tires, tolls and short-term parking fees.
Operating Subsidies	Financial subsidies for public transit services.
Travel Time	The value of time used for travel.
Internal Crash	Crash costs borne directly by travelers.
External Crash	Crash costs a traveler imposes on others.
Internal Activity Benefits	Health benefits of active transportation to travelers (a cost where foregone).
External Activity Benefits	Health benefits of active transportation to society (a cost where foregone).
Internal Parking	Off-street residential parking and long-term leased parking paid by users.
External Parking	Off-street parking costs not borne directly by users.
Congestion	Congestion costs imposed on other road users.
Road Facilities	Roadway facility construction and operating expenses not paid by user fees.
Land Value	The value of land used in public road rights-of-way.
Traffic Services	Costs of providing traffic services such as traffic policing, and emergency services.
Transport Diversity	The value to society of a diverse transport system, particularly for non-drivers.
Air Pollution	Costs of vehicle air pollution emissions.
Greenhouse Gas Pollution	Lifecycle costs of greenhouse gases that contribute to climate change.
Noise	Costs of vehicle noise pollution emissions.
Resource Externalities	External costs of resource consumption, particularly petroleum.
Barrier Effect	Delays that roads and traffic cause to nonmotorized travel.
Land Use Impacts	Increased costs of sprawled, automobile-oriented land use.
Water Pollution	Water pollution and hydrologic impacts caused by transport facilities and vehicles.
Waste	External costs associated with disposal of vehicle wastes.

Figure 1: VTPI Cost Categories

Of the above categories described by the Victoria Transportation Policy Institute we have chosen to focus on the following:

- Vehicle Ownership
- Vehicle Operation
- Travel Time
- Air Pollution / Greenhouse Gas Pollution
- Waste

Material Costs

Initial Purchase

The most obvious cost to the consumer is, of course, the number on the price tag; this is also the simplest to calculate. Although it is an important number, acquiring a car or a pair of good running shoes is only the first step in one's relationship with that inanimate object which is why this and the following topic need to be looked at together.

Cost of Upkeep

After initially purchasing a car, bike or pair of walking shoes, there can be many costs associated with maintaining this equipment. These costs will be calculated on a per mile basis for each mode of transportation.

Automobile

A vehicle's cost comprises many different micro-costs distributed throughout the life of the car; these are often regularly scheduled and predictable such as filling the car with gas and changing the tires. Unpredictable or unscheduled costs can include brakes, spark-plugs, and emergency repairs. While the unscheduled costs can be a surprise they are things that need to be budgeted for, bringing the monthly cost of a vehicle far above the expected cost based on the monthly payment.

A hybrid or electric vehicle is slightly different. They need tires, brakes and emergency repairs just like a normal car, but need less gas or none at all. However, hybrid and electric cars are typically more expensive to buy than standard cars and they have a built-in defect. Once the batteries in one of these cars die they must be replaced which is a massively expensive event and buying an entirely new car could be a better, more cost effective solution depending on the age of the car. When considering the lack of gasoline for a plug-in hybrid or electric car one must also consider an added cost or inconvenience of finding or installing a charging station.

Bicycle

Bicycles are a very decent transition between the costs of automobile transportation and pedestrian transportation. On one hand the bicycle itself must be purchased and keeping it involves both foreseeable and unforeseeable costs. A bicycle will need new tires and regular repairs, but it also requires the rider to provide the power therefore shoes, specialty clothing, kilocalories burned and the health of the rider must be taken into account.

Pedestrian

Pedestrian modes of transportation include the costs of footwear, clothing and accessories, and food as foreseeable, scheduled costs. Unforeseeable costs are those relating to illness or injury. The largest cost, of course, is that of food. When it comes to cost per mile for fuel, walking and running are far less efficient than driving or cycling.

These considerations, specifically the cost to acquire, maintain and fuel a transportation method are placed into a "raw cost" category. These costs were calculated based on a combination of research on various retail websites and survey responses.

Disposal Costs

Once an individual is finished with this equipment, it needs to be discarded. The process of saying goodbye to something happens in two steps; first, you must remove the item from your property, and second someone must transport it to a facility where it will waste away or be recycled. That second step can also be broken down further in cases where there are companies hired to pick up and transport refuse while the government or another company controls the facilities. This study will take into account the costs related to discarding vehicles, walking, and biking equipment using typical disposal fees published by local governmental waste management bureaus.

Lost Time Costs

When it comes to the cost of getting from one place to another most people will only consider the previously mentioned costs; the costs of tangible items such as purchasing a car or filling it with gasoline. However, when one looks at the big picture there are many more issues associated with travel than out of pocket costs, emissions and waste disposal.

Chief among these less tangible costs is that of time. Like the old saying goes, *"time is money",* and the time required by various types of transportation is a major cost that must be considered. The time required to walk, bike or drive between locations is time dedicated solely to transportation. As such, it is time not being devoted to other productive tasks. Now think about the time it takes to travel to work, school, the store, or anywhere else that life may take you. How you choose to travel and the time commitment involved is a legitimate cost that will be quantified in this study. To do so average salaries will be used as a benchmark in order to quantify the value of an individual's time. This value will be factored by the average speed of walking, biking, and driving and compared using a reference commute.

Carbon Costs

Another cost that needs to be considered when looking at transportation is the impact different modes of transportation have on the environment. As earth becomes more populated, the health and sustainability of the environment is a primary concern. Different methods of transportation affect the environment differently. In order to quantify these impacts this study will consider to carbon emissions associated with walking, biking, and driving as well as the carbon emissions and resource consumption required to provide the extra caloric requirements from walking and biking.

Survey

In order to measure and collect data on public opinions and perceptions of transportation costs, a survey on the topic will be created and circulated. This survey will be created using Air University's Sampling and Surveying Handbook. This comprehensive guide will aid in providing structure and direction to the survey. A sample of the survey questions can be found in appendix A. The survey will be circulated solely to WPI students. As such, our findings will be tailored to the perceptions and opinions college students at this university have on personal transportation choices. This will add relevancy to our findings, as they represent the opinions of those individuals that will begin to enter the workforce within the next 4 years, and facing perhaps for the first time some of these transportation decisions. Assuming a student population of 4,500, a minimum of 94 individual responses to the survey will be required for a level of confidence of 95% and a standard deviation of 10.

RESULTS

The results came from a diverse collection of data from online sources including government websites, blogs, news articles and scientific journals. A certain amount of information used for calculations was also gathered from survey responses which will keep the resulting costs relevant to our focus group. For example, the survey revealed that the respondents paid an average of $70 for a good pair of walking shoes and $250 on a bicycle. The shoes would last around 500 miles and the bicycle would last between six months and a year and six months. These figures were also supported by such publications as Runner's World.

Initial Purchase

Automobile

The following data was used to calculate the per mile distributed cost of the initial cost of purchasing a new car.

Table 1: Initial Purchase, Automobile

Data	Value	Source
Avg. Price of Conventional Car	$33,340	Edmund's
Avg. Price of Hybrid Car	$37,987	Edmund's
Avg. Price of Electric Car	$40,840	Edmund's

Avg. Lifespan of a Car	150,000 (miles)	Consumer Report

To calculate the cost per mile of conventional, hybrid, and electric automobiles the average cost of each vehicle was divided by the average total mileage of a car to obtain an initial price per mile quantity. The results are as follows:

Table 2: Initial Cost Per Mile, Automobile

Car Type	Initial Cost per Mile
Conventional	$0.22
Hybrid	$0.25
Electric	$0.27

These values were added to the Initial Purchase/ Equipment field in the results table.

Walking/ Running

The following data was used to calculate the cost of shoe and equipment purchase on a per mile basis for both walk and running:

Table 3: Initial Purchase, walking/running

Data	Value	Source
Avg. Cost of Walking Shoe	$70	Runner's World
Avg. Cost of Running Shoe	$100	Runner's World
Avg. Lifespan of a Shoe	500 (miles)	Runner's World

The Average cost of each type of shoe was divided by the number of miles an individual can get out of the pair of shoes prior to needing to replace them. The results of the distributed per mile initial cost of walking and running are shown below and reside in the Initial Cost/Equipment field in the results table.

Table 4: Initial Cost Per Mile, Pedestrian

Type of Pedestrian Travel	Initial Cost per Mile
Walking	$0.14

Running	$0.20

Biking

The following served as the source data for calculating the per mile initial cost of purchasing a bicycle:

Table 5: Initial Purchase Cost, Bicycle

Data	**Value**	**Source**
Avg. Price of Bicycle	$465	Consumer Report
Avg. Lifespan of Bicycle	6,500 (miles)[24]	Bike Radar

To determine a per mile initial/equipment cost the average price of a bicycle was divided by the average lifespan of a bike. The following result can also be found in the results table under the Initial Cost/ Equipment field.

Table 6: Initial Cost Per Mile, Bicycle

Bicycling	$0.07 per mile

Cost of Upkeep

Automobile

In order to calculate the total cost of operating a car, maintenance costs had to be taken into account. To do this, the standard maintenance reimbursement paid by the federal government to its employees of $0.54 was used. However, this value takes into account many factors involved in vehicle operation. According to AAA, 5.06% of the operational costs of a vehicle come from maintenance. This equates to $0.03 per mile for maintenance and upkeep. Fuel which this study does separately from maintenance. As such, the $0.06 found to be the price per mile for gas (shown under “Fuel Costs” below) was subtracted. The maintenance costs among conventional, hybrid, and electric vehicles were assumed to be equivalent.

[24] *Though most bikes last much longer, according to Bike Radar, The costs required to continuously maintain and purchase replacement equipment is greater than that of the original purchase after 6,500 miles.*

Table 7: Upkeep Cost, Automobile

Automobile Upkeep Cost	$0.03 per mile

Walking, Running and Biking

For the purposes of this study it was assumed that the majority of individuals who utilize walking as a mode of transportation opt to replace walking/running shoes regularly. As such, initial purchase costs were calculated accordingly. For this reason, no upkeep costs are considered for walking and running.

In order to calculate the initial purchase cost of a bike, it was assumed that maintenance and upkeep costs reached the initial purchase price of the bike every 6,500 miles. As such, the initial purchase cost of a bike was calculated to assume replacement (or costs equivalent to replacement) every 6,500 miles. Therefore no additional upkeep cost for biking was included.

Disposal Cost

Automobile

Unlike bikes and shoes which are disposed of at a small cost to the consumer once the equipment has been replaced, most vehicles are traded in upon being replaced. Dealership often purchase old cars to resell as used or scrap for parts or metals. The average American car drives 12,000 miles per year and lasts 150,000 miles. This results in an average lifespan for a car of 12.5 years. According to Kelley Blue Book (KBB), the average trade in value of a 12.5 year old mid-sized vehicle with 150,000 miles is $2,354.

Table 8: Data Utilized

Data	Value	Source
Avg. Total Mileage	150,000 miles	Consumer Report
Avg. Annual Mileage	12,000 miles / year	AAA
Avg. Lifespan of a Car	12.5 years	Calculated
Average Trade in Value of 12.5 year old car with 150,000 miles	$2,354	Kelley Blue Book

Distributed over the total mileage of the car, this equates to $0.015 per mile. However, as this is value gained by the consumer trading in the vehicle, it appears in the results table as a negative cost of $0.015 per mile.

Table 9: Average Cost of Disposal, Automobile

Average Disposal Cost of an Automobile	-$0.015 per mile

Walking, Running and Biking

In the case or Worcester, MA, a company called Waste Management handles the pickup and disposal of most of the city's refuse. In order to pay for their service and to encourage recycling, they will only pick up trash in yellow trash bags which are priced at $1.50 per bag. In addition, the city of Worcester gives each property a recycling bin. No recyclables will be picked up in yellow bags and no trash will be picked up in bins. This brings the cost per household to around $3 per week for trash pickup assuming a 4-person family. Of course, not everything you're done with can be put out on the curb. Shoes and clothing, if only gently used, can be placed into a collection bin for free, but such things as tires and waste oil must be dropped off at designated hazardous waste centers for another small fee.

According to worcesterma.gov, the current estimated population of Worcester, MA is around 182,596 people which means the income from trash bags should be around $136,947.00 per week. In addition, the city has outsourced bulk trash pickups to another company and the fee for hauling each item is between $19.00 and $65.00 depending on the size, type (burnable, hazards etc.) and whether or not they can be placed in a yellow bag. For clothing, foam and other burnable that will be discussed in this report the fee is either $19.00 bagged or $23.50 not in a bag. For the sake of simplicity the cost to discard these things will be:

Table 10: Disposal Costs, pedestrian

Shoes and clothing (assuming small amounts)	$1.50
Bicycle (assumed not in a trash bag)	$23.50

Runner's World recommends replacing running shoes every 300 – 500 miles while a question on Reddit.com asking casual runners how far they run in a week yielded an average of 20 miles per week. This means that the average casual runner, if following the guidelines in Runner's World, would need to replace their shoes every 15 – 25 weeks; about 3 – 6 months. According to Running USA in 2014 16,796,000 people in the US participated in and finished races less than marathon length. So if all of these people are buying shoes when they should be, potentially 33.6 – 67.2 million pairs of running shoes are being replaced yearly just by people who have participated in organized races.

Looking at just the sole of a running shoe, or most shoes for that matter, the insole is generally made of EVA (ethylene vinyl acetate) and the midsole is made up of polyurethane or polyurethane foam.[25] All three of the above cannot be completely recycled and, instead, are normally ground up and used in composite cushioning materials for carpeting which is generally where the recycling stops. Therefore, if a modern running shoe is as light as New Balance's $100 "Fresh Foam Zante" which weighs 7.6oz according to its website[26] and is mostly EVA and polyurethane foam, let's say 5oz of foam each, that's up to 20,995 tons of foam waste produced each year from casual running.

Assume that the number of casual runners in Worcester is proportional to the United States as a whole; the number of runners would be 9, 617 and would produce around 12 tons of waste yearly from shoes in just Worcester. In order to haul away 12 tons of shoes it would take 1,603 trash bags costing a total of $2,404.26 per year in this city alone. If we divide that cost among the runners we can add 25 cents to the yearly cost of running, which is only .00024 cents per mile, but it is a cost.

Fuel

Automobile

The follow data was compiled and used to calculate the average fuel costs per mile. The average national cost of gasoline over the past 10 years of $2.84 per gallon was used in order to account for fluctuations in gas and oil prices.

Table 11: Fuel Cost, average mpg

Data	Value	Source
Average Cost of Gasoline	$2.84	EIA
Average Fuel Efficiency (Conventional car)	25 mpg	Consumer Energy Center
Average Fuel Efficiency (Hybrid)	38 mpg	Consumer Energy Center

This equates to $0.11 per mile for conventional cars and $0.07 per mile for hybrid vehicles. To calculate a cost of fuel per mile for an electric car, the average cost of electricity generation (watts) and the average fuel efficiency of electric cars (miles per watt) were used.

[25] (Kolecki, 2015)
[26] www.newbalance.com/pd/fresh-foam-zante-v2/WZANT-V2.html

Table 12: Electricity Cost and Efficiency

Data	Values	Source
Average Electric generation Cost	$0.12 per kwh	NPR
Average Efficiency of Electric Cars	0.34 kwh per mile	Green Car Reports

This equates to $0.04 per mile in fuel costs for electric cars. The fuel costs for all the automobiles are summarized in the following table:

Table 13: Total Fuel Cost, automobile

Conventional	$0.11
Hybrid	$0.07
Electric	$0.04

Walking, Running and Biking

Looking at Bluejay's article about the efficiency of cycling, it is clear that diet greatly affects the efficiency of human-powered transportation. The following chart shows the difference that diet makes on efficiency. Michael Bluejay uses a combination of carbon emissions reports, food costs and kilocalorie use to calculate a miles-per-gallon equivalent for bicycling.

Table 14: MPG equivalent of diet

Diet	MPG equivalent
Omnivore	75
Vegetarian	102
Vegan	145

To calculate fuel cost the "cheeseburger standard" has been implemented and was chosen for an easy overlap with the impact of diet discussed later on. One McDonalds'™ cheeseburger contains 300 kilocalories and in the state of Massachusetts costs $1.22 which yields the following results:

Table 15: Caloric Requirements

Method	Average Caloric Requirements (kcal/mile)
Walking	121.25

Running	171.25
Biking	49.25

Table 16: Raw Cost Per Mile, pedestrian

Transportation Method	*Raw Cost Per Mile*
Walking	$0.485
Running	$0.685
Biking	$0.197

Lost Time Costs

. One can look at the cost of time objectively by breaking it down like in the following tables.

Table 17: Average Income

Average Individual Income (USD)	52,000	Google

Mode	Duration (minutes)	Distance (miles)	Speed (mph)
Motorcycle	24.6	12.1	29.5
Bike	20.9	3.8	10.8
Walk	15.6	1.0	3.7
Private Vehicle	22.9	12.1	28.9
Public Transit	53.0	10.2	11.4

Source: 2009 NHTS online tool, using variable TRVL_MIN, calculated for trips with both time and distance data. Private vehicle and public transit data from NHTS 2009 summary of travel trends

Figure 2: Commute distance, time and speed

Table 18: Time Costs

Mode	**Speed** (mph)	**Value of time** (USD / hour)	**Cost of time per mile** (USD / mile)
Driving	28.9	$26	$0.89
Bicycling	10.8	$26	$2.41m-$4.82
Running	7.5	$26	$3.47m-$6.94
Walking	3.7	$26	$7.03m-$14.06

In calculating time costs, exercise was taken into account. As mentioned previously, the average American gets 2 hours of exercise a week. As a result, the first two hours of walking or

biking would not incur a time cost as that time would have been spend exercising anyway. As a result, the table above expresses the cost of walking, running, and biking in terms of miles (m), and the cost of the first two "free" hours is subtracted.

Environment

Automobile

A major cost to the environment in terms of transportation is that of carbon emissions into the atmosphere. Gaseous carbon molecules, particularly carbon dioxide, create what is referred to as the greenhouse effect in the upper atmosphere in which energy from the sun enters the earth's atmosphere but cannot escape back out due to high volumes of these complex carbon molecules. This results in warming of the earth's atmosphere and surface. This phenomenon known as global warming is a major environmental concern.

Motor vehicles rely on combusting gasoline to create the energy required to power the vehicle forward. According to the International Energy Agency (IEA) the average mid-sized car will emit 6 tons of carbon per year. Assuming the average yearly mileage of a car of 12,000, that equates to 1 pound (0.0005 tons) of carbon per mile. The IEA estimates the average cost of carbon capture systems which remove carbon from the atmosphere to be $43 per ton of carbon removed. At this price that equates to $0.02 per mile in costs to the environment. This may appear small, but over the course of a single year this adds up to $258 in environment impact per car per year.

Table 19: Environmental Cost of Driving

Environmental Cost of Driving	$0.02 per mile

Walking and Biking

According to research done by Globe Scientists, 0.7kg of carbon is released into the atmosphere for every 2000 kcal consumed.[27] This means that the carbon emissions from walking and biking are tied to the amount of calories consumed to perform each activity. As mentioned previously, the cost of carbon capture systems is $43 per ton of carbon. Given the caloric requirements noted in a previous section the carbon costs of walking and biking are summarized as follows.

[27] "Carbon dioxide, part 2: Walk, drive a car, or ride a bike?" globe.gov. 21 Aug. 2008. Web

Table 20: Environmental Cost, pedestrian

Mode	Carbon Cost per Mile
Walking	$\$4.66 \times 10^{-6}$
Biking	$\$1.89 \times 10^{-6}$

Survey Results

An important part of the research for this project was to become familiar with how the public views transportation and the environment – specifically humanity's impact on global warming. The beliefs of the people matter greatly whether right or wrong and a look at the new generation of potential actors on the planet's health helps to determine how important it is to take a look at a picture that includes more than just gasoline and carbon emissions. A survey was constructed to examine the transportation habits and opinions of the WPI student body. It included 41 questions covering driving, walking, biking, the environment and safety and, while geared toward those with a driver's license and a vehicle of their own, collected useful data regardless.

Study Participants

The survey collected 161 responses from a student body of 6057 which is only around 2.6% of the student body but still a usable sample. 90 percent of survey participants have a driver's license and 68 percent reported living in a suburban area. The breakdown of actual age of participants is represented in the following figure.

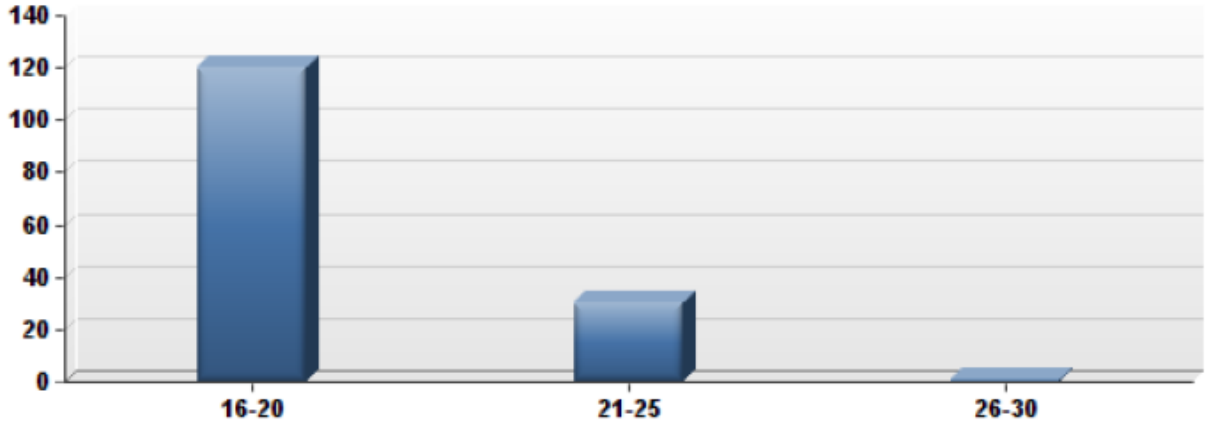

Figure 3: Survey Participants Age Breakdown

79 percent of participants reported that they were between the ages of 16 and 20 and only one student was in the 26-30 age range.

Unfortunately the following statistic is not representative of the WPI student population. The male to female ratio of students at WPI is 67 percent male and 33 percent female but the survey participants were 44 percent male and 56 percent female. But when viewed in a larger scope, it can be said to be representative of any given population.

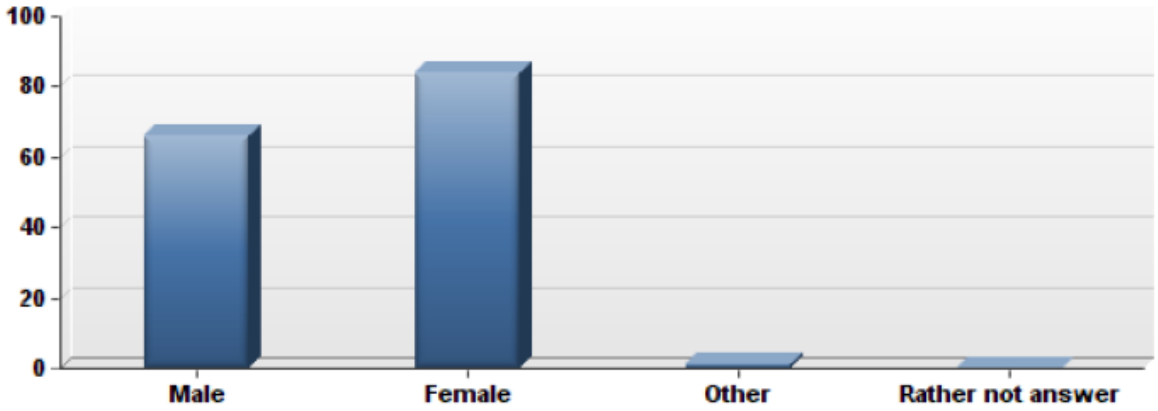

Figure 4: Survey Participants Gender Breakdown

Furthermore, 59% of responses came from underclassmen (21% freshman, 38% sophomore) while 40% came from upperclassman (37% juniors, 3% seniors) and 2% from graduate students. The average self-reported household income bracket from which the responders came from was $50,000-$125,000 per year. 68% of the survey population claimed to come from a suburban area, 20% from urban areas, and 13% from rural locations. 90% of responders claimed to possess a valid driver's license.

Results

The detailed results and findings of the survey can be found in appendix B.

Results and Finding Summary

The total costs of each method of transportation examined are summarized in the following table:

Table 21: Total costs

Costs per Mile	Conventional Vehicle	Hybrid Vehicle	Electric Vehicle	Bicycling	Running	Walking
Initial Purchase/ Equipment	$0.22	$0.25	$0.27	$0.04	$0.20	$0.14
Energy (Gasoline / Kilocalories)	$0.11	$0.07	$0.04	$0.16	$0.47	$0.31
Maintenance	$0.03	$0.03	$0.03	n/a	n/a	n.a
Disposal	-$0.02	-$0.02	-$0.02	0.0188	0.00024	0.00024
Material Costs	$0.34	$0.33	$0.32	$0.22	$0.67	$0.45
Time-Money	$0.89	$0.89	$0.89	$2.41	$3.47	$7.03
Environmental Costs	$0.02	$0.01	n/a	1.89×10^{-6}	n/a	4.66×10^{-6}
Human and Societal Costs	$0.91	$0.90	$0.89	$2.41	$3.47	$7.03
Total Cost Per Mile	**$1.25**	**$1.23**	**$1.21**	**$2.63**	**$4.14**	**$7.48**

DISCUSSION

Material Costs

According to our results, when considering only material costs, biking is the cheapest method of transportation at $0.22 /mile, 10 cents less than the next cheapest option of driving an electric car. Meanwhile, running was the most expensive method at $0.67, nearly triple that of biking. The major difference in cost for these methods in terms of material costs came from the difference in fuel costs. Cars utilizing gasoline or electricity paid much less for fuel than walking or biking. This is due to the cheap price of gasoline and cars getting increasingly better fuel efficiency.

Biking, while more than driving still had significantly cheaper fuel costs than running or walking. This is due to the fact that biking is more efficient than walking or running as less calories are burned in order to walk or run a similar distance. The cost of calories and the human body's

natural inefficiency to turn calories consumed into energy inflates the fuel cost for walking and running and as such make driving and biking more cost effective in terms of material costs. To be exact, the material costs of walking are 132% that of driving and 204% that of biking.

Intangible Costs

Where the cost difference between the various methods of transportation became most apparently was in the lost-time costs. Driving is significantly quicker than biking or walking. As such the lost time cost for driving was many times smaller than that of walking or biking. Time costs played the largest factor in determining the overall cost of each method of transportation.

These values were calculated on a per mile basis. When considering a given travel distance significantly small enough as to make the difference in lost time cost between driving and walking negligible as well as fuel required, walking, driving and biking have very similar costs. This is important to note as our results are best applied to moderate travel distances and does not work well for distance of either extreme.

Something else to note is an assumption made in the calculation of environmental costs. It was assumed that walking and biking did not have an environmental impact cost. However, the more walking and biking is utilized over driving, the more caloric fuel an individual requires. Producing such fuel comes at an environment cost.

It has long been believed that vehicle emissions are the number one cause of climate change, belching 4.75 metric tons of CO_2 into the air per car yearly according to the EPA. Taking into account that according to what Dr. Richard Oppenlander claims in his book, *Comfortably Unaware,* the maximum sustainable CO_2 level is around 565 gigatons, it is predicted that we will reach it by the year 2030 only by raising animals.

Of course, this is only half of the story, literally. World Watch Report stated in 2009 that 51% of greenhouse gasses are produced by agriculture; this includes CO_2, methane and nitrogen. Animal agriculture produces upwards of 32 million tons of CO_2 and nearly 55 trillion gallons of methane per year. Methane is an incredibly dangerous and underestimated emission which is 25-100 times more destructive and has a global warming potential more than 86 times that of CO_2 over a 20 year timeframe according to an article in Science Magazine. In addition to methane and CO_2, livestock is responsible for 65% of all nitrous oxide emissions which has a warming potential 296 times higher than carbon dioxide and can remain in the atmosphere for 150 years.[28]

[28] (Animals United Movement A.U.M., 2014)

Survey and Popular Opinion

Survey Data was collect from a total of 151 WPI students. Of these students 79% are between 16 and 20 years of age, while 21% are 21 or older. 44% of students surveyed self-identified as male and 56% as female. 59% of responses came from underclassmen (21% freshman, 38% sophomore) while 40% came from upperclassman (37% juniors, 3% seniors) and 2% from graduate students. The average self-reported household income bracket from which the responders came from was $50,000-$125,000 per year. 68% of the survey population claimed to come from a suburban area, 20% from urban areas, and 13% from rural locations. 90% of responders claimed to possess a valid driver's license.

It is important to understand and take into account the unique living situations these responders have as full time students. According to data published by US World and News Report, 50% of all WPI students, 50% live in on-campus housing, while the other 50% live in off campus accommodations. Of the latter, almost all live within 2 miles of the WPI campus. As such, the average WPI student spends less time traveling the shorter commute than the national average of 26 minutes per day for adults in the U.S as published by the Population Reference Bureau. Additionally, most students are still considered dependent adults. They often rely on their family to financially assist them and many do not have a job. These important influences affect the decisions the responders makes about personal transportation and cannot be overlooked.

From the data collected, a number of trends can be discerned. The responses received make it clear that students are not very conscious of their transportation habits and choices. Additionally, while students seem to have an idea of the impact of their choices (particularly in regards to safety and the environment). However, while aware of these impacts, transportation choices were most heavily influenced by an individual's access to a car, distance required to travel, and the purpose of the trip.

34% of those surveyed claimed to own a car they either pay for themselves or have the expenses paid for them. 51% said they drove a car belonging to someone else, and 15% claimed to have no access to a motor vehicle. When asked what would influence them to opt to walk or bike, 50% said they would do so as a cheaper alternative to driving, and 44% said they would do so because of a lack of access to a car. When asked to rank what factors would contribute the most when shopping for a new car, initial cost and fuel efficiency were the most highly ranked with 58% of those surveyed placing ranking them in the top two most influential factors. These responses make it clear that the students view using a car for transportation as a more expensive option which is limited by an individual's ability to afford it. Walking and biking are seen as cheaper

alternatives to using a car. Interestingly however, the majority of responders had difficultly assessing the costs associated with owning and operating a motor vehicle. When asked how much, on average, maintenance and upkeep cost per year, 74% answered $500 or less per year. This is significantly different than the annual report published by AAA, which calculated the average annual cost to operate a motor vehicle in 2015 to be $8,698. Similarly when asked how much gasoline costs per week, 40% of responders estimated less than $20 per week, while 39% claimed to not know the costs required for gasoline. According to the U.S Energy Information Administration, American's spend $37 per week on average for gasoline, almost double the estimate made by many of the survey responders. From this data it appears that students view utilizing a car for transportation as the most expensive option however are under informed as to the actual costs involved with this method of personal transportation.

While responders struggled to accurately estimate how expensive car ownership is, the results indicate that they have a fairly decent understanding of the impacts associated with choosing to drive a car. 80% of responders said they believe climate change is an immediate threat to the environment. 66% of those surveyed claimed they believed that if more people chose to walk or bike instead of drive, the effects of climate change could be slowed, and 65% believed an increase in hybrid and electric cars would have the same effect. However, only 48% of students said they would be likely to change their transportation methods due to environmental concerns. This speaks to the fact that while most students know the harmful impact driving may have on the environment, their transportation decisions are not heavily influence by it.

Similarly, responders claimed that driving was the safest mode of transportation around their local neighborhood. 67% believed driving was safer than walking or biking. When asked what they felt could increase the safety of driving, many responded with answers pertaining to the ability, prowess and education of drivers on the road. Many responders claimed they believed self-driving vehicles would help to increase vehicle safety. This indicates that the safety risks associated with driving are perceived to stem from human error and are inherent to the act of operating a vehicle. When asked the same question about walking or biking, most responses related to physical surroundings such as improved street and sidewalk lighting, more crosswalks and pedestrian path, etc. Those surveyed believed the act of driving to be inherently more risky while viewing the risks associated with walking or biking as being a product of the physical environment in which walk as opposed to the act itself.

Perhaps the most telling trend found throughout the survey data relates to the ability of those surveyed to accurately assess their choices of personal transportation. Much of the data

collected regarding the types of transportation and the frequency in which the individual utilized them was inconsistent and in some cases contradictory. For example, survey question 7 asked the responder to describe their transportation activities and how often they opted to drive, walk or bike. 49% of those surveyed answered that they "tend to drive everywhere". However, when asked in question 10 how often they drive, 53% answered that they drive no more than 2-3 times per month and only 15% claimed to drive on a daily basis. Additionally, 68% of students claimed they would elect to walk to the corner store in their neighborhood (< 1 mile) and 6% claimed they would bike. These numbers are far larger than expected given the responses to question 7.

These inconsistencies indicate that those surveyed struggled to take into account the entirety of their transportation usage. For example, 41% claimed they would definitely drive when making a 5 mile trip. This number is much more consistent with the 44% from question 7. This might be a result of responders not taking into account shorter distances the travel throughout the day such as walking to and from classes. This may also indicate a larger trend in which those surveyed did not consider the use of a motor vehicle to make shorter trips. This might be due to environmental stigmas in which driving a shorter distance that can be easily walked is seen as unnecessarily wasteful and harmful to the environment. In addition, WPI operates a pedestrian only campus in which all but two roads are closed to vehicle traffic. This makes it difficult and time consuming as students must find parking in an off campus lot or on a surrounding street making driving to and from campus hard, and in some cases just as long or even longer than walking or biking.

APPLYING RESULTS

The results of this study can be applied to real life situations in order to estimate the costs of transportation methods for a given trip. To illustrate this, consider an individual with a 2.5 mile commute to work. The results of this study can be used to calculate the cost of this commute. The table below shows the calculations using found values. This type of analysis can assist individuals in determining which mode of transportation is best for a given trip by providing them a more sound understanding to the costs associated with each.

Table 22: Total costs applied

Costs per Trip	Conventional Vehicle	Bicycling	Walking
Initial Purchase/ Equipment	$0.55	$0.10	$0.35

Energy (Gasoline / Kilocalories)	$0.28	$0.40	$0.78
Maintenance	$0.08	n/a	n.a
Disposal	($0.05)	0.05	0.0006
Material Costs	$0.86	$0.55	$1.13
Time-Money	$2.22	$6.03	$17.58
Environmental Costs	$0.05	n/a	n/a
Human and Societal Costs	$2.27	$6.03	$17.58
Total Cost Per Trip	**$3.13**	**$6.58**	**$18.71**

Material Costs:			
Weekly	$8.60	$5.50	$11.31
annual	$430.00	$275.00	$565.30
Time Value:			
Weekly	$22.20	$60.30	$175.80
Annual	$1,110.00	$3,015.00	$8,790.00
Total:			
Weekly	$31.30	$65.80	$187.11
Annual	$1,565.00	$3,290.00	$9,355.30

CONCLUSION

The purpose of this study was to calculate real life costs of various methods of transportation and compare these costs to the perceptions university students have of them. Through the utilization of many statistical and data analysis techniques, this study successfully calculated per mile costs of each method of transportation. By calculating a dollar value of each cost per mile, costs of different natures such as material costs and time costs were able to be fit together to determine an overall cost for walking, biking and driving. Through the data collected from the students sampled in the survey, general trends in the perceptions and motivational factors behind transportation choices were identified. Lastly, these perceptions were compared to the real costs calculated.

Research into what consumers perceive costs of transportation choices to be is of crucial importance in improving our transportation system as a whole. To further the work done in this study, future research could be conducted into how best to educate consumers on the costs their transportation choices carry. More educated consumers will have a better understanding of the factors that play into transportation costs. This will enable them not only to lower their personal costs, but also seek out and spur new innovative ideas and technologies that will further help to make transportation cheaper, more environmentally friendly, and more efficient.

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APPENDIX B: SURVEY QUESTIONS

Abstract and Definitions

It seems that the common public perception of transportation is that automobiles are damaging the environment and the best way to combat the rise in pollution is to take as many trips as possible on foot or using a bicycle. This would cut down on emissions and, therefore, save the planet. But how accurate is this view? And how closely does it reflect the public's actual opinion? Through this survey it is hoped that a picture will form representing the views of college students on environmental and economic costs of transportation. The ultimate goal of combining the responses from this survey with research being done on the topics of automobiles, walking, running and bicycling is to attempt to answer the question: “Are we wrong in how we think about transportation?”

A few definitions provided below will help you more accurately respond to the following questions.

1. Global warming refers to the recent and ongoing rise in global average temperature near earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere.

2. Climate change refers to any significant change in the measures of climate lasting for an extended period of time.

3. Neighborhood: This will be considered within 1 or so miles of one’s home and it is assumed that the reason for the trip would not involve transporting more than the person or persons taking the trip.

4. Utilitarian: This will be considered a trip between 1 and 10 miles for a specific purpose such as running errands or going to school.

5. Commute: A commute is considered a trip between 10 and 50 miles for the purpose of getting to work or school.

1. What is your age range?

16--20

21--25

26--30

2. Gender identity?

Male

Female

Other

Rather not answer

3. What year in school are you, or how much have you completed?

College Freshman

College Sophomore

College Junior

College Senior

Graduate School

Other

4. What is the income bracket of your household?

up to $13,500 per year

$13,500 - $50,000 per year

$50,000-$125,000 per year

over $125,000 per year

5. Would you describe your location (where you travel the most or your permanent address) as:

Urban

Suburban

Rural

6. Do you have a driver's license?

Yes

No

7. Of the following, how would you describe your transportation activities (choose all that apply)

I tend to drive everywhere

I ride a bicycle

I walk when I can

I run when I can

I drive, but I also enjoy walking, running, or cycling as fitness/pleasure

Other

8. Do you own a motor vehicle?

Yes, and pay all expenses

Yes, and pay some expenses

No, but I drive a car owned by someone else

No

9. Which best describes the car(s) you drive? (choose all that apply)

Compact car (ex. Toyota Yaris)

Mid-size car (ex. Toyota Corolla)

Full-size car (ex. Toyota Camry)

SUV

Pickup

Other

10. How often do you drive?

Never

Less than Once a Month

Once a Month

2-3 Times a Month

Once a Week

2-3 Times a Week

Daily

11. How far is your regular commute?

0

< 5 miles

5-10 miles

10-20 miles

> 20 miles

12. Rate the following on how much each would influence your decision when buying a car, 1 being most important and 7 being least.

Age of the car

Look of the car

Fuel efficiency

Initial cost

Size, need more room

Size, need something smaller

12. How much do you pay per week for gas?

<20$

20-30$

30-50$

50-100$

100+

I don't know / don't pay for gas

13. Please estimate how much you pay per year for upkeep to your car.

<$200

$200-$500

$500-$1000

$1000-$2000

>$2000

14. Why do you walk, run or bike? (Choose all that apply)

It's healthy

No other means of transportation

It's fun

It's inexpensive

14. You normally walk, run or bike to: (choose all that apply)

School

Work

The store

Other

15. Do you buy special equipment (shoes, clothing etc.) because you walk/bike?

Yes

No

16. What have you bought in the past specifically for walking, running, or bike riding? (Choose all that apply)

Shoes

Clothing

Accessories such as Fitbit

Acc. such as water bottle

Upgraded equipment

17. Rate the following by the frequency of activity by mile.

Most - Least

Walk

Run

Bike

Walk

18. How often do you buy new walking or running shoes?

Once a year

Once every six months

Once every 3 months

More often

Less often

19. Please estimate how many miles a pair of walking or running shoes will last for you.

<200 miles

200 - 300 miles

300 - 500 miles

500 - 1000 miles

>1000 miles

Don’t know

20. How much do you pay for walking or running shoes?

<$25

$25-$40

$40-$60

$60-$100

>$100

21. If you own a bicycle, how much did it cost?

<$200

$200-$500

$500-$1000

>$1000

Don't own a bicycle

22. How often does it need new tires/other repairs?

Very few years

Yearly

Every few months

23. Which do you feel is the safest option for neighborhood trips?

Safest - least safe

Driving

Walking, Running

Bicycling

24. Which do you feel is the safest option for utilitarian or longer trips?

Safest - Least Safe

Driving

Walking, Running

Bicycling

25. If each were safer would you do it more often?

Yes Probably Not No

Driving

Walking, Running

Bicycling

26. What, if anything, do you think would make driving safer?

27. What, if anything, do you think would make running and walking safer?
28. What, if anything, do you think would make riding a bicycle safer?
29. If you were to visit the corner store within your neighborhood would you be most likely to:
30. You're going to school or work which is only about 5 miles away and it's a beautiful day. Do you... (Choose all that apply)

Walk

Bike

Drive

Other

Maybe walk or run

Maybe bike

Definitely walk or run

Definitely bike

Maybe drive

Definitely drive

Other

31. Do you think that Global Warming is an immediate threat?
32. How much of an impact do you think humans have on current climate conditions?
33. Please rate the following modes of transportation on the basis of how environmentally friendly you think they are.

Driving an electric vehicle

Driving a hybrid vehicle

Driving a conventional vehicle

Bicycling

Walking or running

34. What's your opinion of hybrid cars?
35. How about fully electric cars?
36. If more people walked or biked to work/school we could slow climate change.

Strongly Disagree

Disagree

Neither Agree nor Disagree

Agree

Strongly Agree

37. If more people drove hybrid/electric rather than conventional cars we could slow climate change.

Strongly Disagree

Disagree

Neither Agree nor Disagree

Agree

Strongly Agree

38. How likely are you to change your method of transportation for the good of the environment at this point?

Very Unlikely

Unlikely

Somewhat Unlikely

Somewhat Likely

Likely

Very Likely

39. How likely would you be to change your method of transportation for the good of the environment if presented with a credible argument?

Very Unlikely

Unlikely

Somewhat Unlikely

Somewhat Likely

Likely

Very Likely

APPENDIX C: SURVEY RESULTS

My Report Last Modified: 02/23/2016
1.
What is your age range?
Answer Bar Response %
1 16-20 120 79%
2 21-25 30 20%
3 26-30 1 1%
Total 151
Statistic Value
Min Value 1
Max Value 3
Mean 1.21
Variance 0.18
Standard Deviation 0.43
Total Responses 151
2.

Gender identity?
Answer Bar Response %
1 Male 66 44%
2 Female 84 56%
3 Other 1 1%
4 Rather not answer 0 0%
Total 151
Statistic Value
Min Value 1
Max Value 3
Mean 1.57
Variance 0.26
Standard Deviation 0.51
Total Responses 151
3.

What year in school are you, or how much have you completed?
Answer Bar Response %
2 College Freshman 32 21%
3 College Sophomore 57 38%
4 College Junior 56 37%
5 College Senior 4 3%
6 Graduate School 1 1%

7 Other 1 1%
Total 151
Statistic Value
Min Value 2
Max Value 7
Mean 3.26
Variance 0.79
Standard Deviation 0.89
Total Responses 151
4.

What is the income bracket of your household?
Answer Bar Response %
1 up to $13,500 per year 7 5%
2 $13,500 - $50,000 per year 30 20%
3 $50,000-$125,000 per year 62 42%
4 over $125,000 per year 49 33%
Total 148
Statistic Value
Min Value 1
Max Value 4
Mean 3.03
Variance 0.73
Standard Deviation 0.85
Total Responses 148
5.

Would you describe your location (where you travel the most or your permanent address) as?
Answer Bar Response %
1 Urban 30 20%
2 Suburban 102 68%
3 Rural 19 13%
Total 151
Statistic Value
Min Value 1
Max Value 3
Mean 1.93
Variance 0.32
Standard Deviation 0.57
Total Responses 151
6.

Do you have a driver's license?
Answer Bar Response %
1 Yes 136 90%
2 No 15 10%

Total 151
Statistic Value
Min Value 1
Max Value 2
Mean 1.10
Variance 0.09
Standard Deviation 0.30
Total Responses 151
7.

Of the following, how would you describe your transportation activities (choose all that apply)
Answer Bar Response %
1 I tend to drive everywhere 73 49%
2 I ride a bicycle 12 8%
3 I walk when I can 76 51%
4 I run when I can 5 3%
5 I drive, but I also enjoy walking, running, or cycling as fitness/pleasure 60 40%
6 Other 4 3%
Statistic Value
Min Value 1
Max Value 6
Total Responses 150
8.

Do you own a motor vehicle?
Answer Bar Response %
1 Yes, and pay all expenses 10 7%
2 Yes, and pay some expenses 37 27%
3 No, but I drive a car owned by someone else 69 51%
4 No 20 15%
Total 136
Statistic Value
Min Value 1
Max Value 4
Mean 2.73
Variance 0.64
Standard Deviation 0.80
Total Responses 136
9.

Which best describes the car(s) you drive? (Choose all that apply)
Answer Bar Response %
1 Compact car (ex. Toyota Yaris) 21 17%
2 Mid-size car (ex. Toyota Corolla) 49 39%
3 Full-size car (ex. Toyota Camry) 22 18%
4 SUV 22 18%

5 Van 10 8%
6 Pickup 5 4%
7 Other 11 9%
Statistic Value
Min Value 1
Max Value 7
Total Responses 125
10.

How often do you drive?
Answer Bar Response %
1 Never 13 10%
2 Less than Once a Month 24 18%
3 Once a Month 13 10%
4 2-3 Times a Month 22 16%
5 Once a Week 13 10%
6 2-3 Times a Week 30 22%
7 Daily 21 15%
Total 136
Statistic Value
Min Value 1
Max Value 7
Mean 4.26
Variance 3.99
Standard Deviation 2.00
Total Responses 136
11.

How far is your regular commute?
Answer Bar Response %
2 52 49%
3 5-10 miles 23 22%
4 10-20 miles 22 21%
5 > 20 miles 9 8%
Total 106
Statistic Value
Min Value 2
Max Value 5
Mean 2.89
Variance 1.03
Standard Deviation 1.02
Total Responses 106
12.

Rate the following on how much each would influence your decision when buying a car, 1 being most important and 7 being least.

Question 1 2 3 4 5 6 Total Responses Mean
1 Age of the car 15 27 36 27 15 14 134 3.31
2 Look of the car 5 21 39 34 19 15 133 3.65
3 Fuel efficiency 31 45 13 17 17 11 134 2.83
4 Initial cost 51 29 7 7 16 24 134 2.85
5 Size, need more room 11 19 32 30 25 16 133 3.65
6 Size, need something smaller 15 21 31 31 19 16 133 3.50

Statistic	Age of the car	Look of the car	Fuel efficiency	Initial cost	Size, need more room	Size, need something smaller
Min Value	1	1	1	1	1	1
Max Value	6	6	6	6	6	6
Mean	3.31	3.65	2.83	2.85	3.65	3.50
Variance	2.16	1.75	2.62	3.89	2.12	2.27
Standard Deviation	1.47	1.32	1.62	1.97	1.46	1.51
Total Responses	134	133	134	134	133	133

13.

How much do you pay per week for gas?
Answer Bar Response %
1 53 40%
2 20-30$ 23 17%
3 30-50$ 6 4%
4 50-100$ 0 0%
5 100+ 0 0%
6 I don't know / don't pay for gas 52 39%
Total 134

Statistic	Value
Min Value	1
Max Value	6
Mean	3.20
Variance	5.24
Standard Deviation	2.29
Total Responses	134

14.

Please estimate how much you pay per year for upkeep to your car.
Answer Bar Response %
1 46 35%
2 $200-$500 51 39%
3 $500-$1000 26 20%
4 $1000-$2000 6 5%
5 >$2000 2 2%
Total 131

Statistic	Value
Min Value	1

Max Value 5
Mean 1.98
Variance 0.88
Standard Deviation 0.94
Total Responses 131
15.

Why do you walk, run or bike? (Choose all that apply)
Answer Bar Response %
1 It's healthy 88 67%
2 No other means of transportation 57 44%
3 It's fun 51 39%
4 It's inexpensive 65 50%
Statistic Value
Min Value 1
Max Value 4
Total Responses 131
16.

You normally walk, run or bike to: (choose all that apply)
Answer Bar Response %
1 School 96 74%
2 Work 22 17%
3 The store 68 53%
4 Other 52 40%
Statistic Value
Min Value 1
Max Value 4
Total Responses 129
17.

Which do you feel is the safest option for utilitarian or longer trips?
Question Safest - Least Safe Total Responses Mean
1 Driving 117 4 1 122 1.05
2 Walking, Running 4 24 90 118 2.73
3 Bicycling 4 71 44 119 2.34
Statistic Driving Walking, Running Bicycling
Min Value 1 1 1
Max Value 3 3 3
Mean 1.05 2.73 2.34
Variance 0.06 0.27 0.29
Standard Deviation 0.25 0.52 0.54
Total Responses 122 118 119
18.

Do you buy special equipment (shoes, clothing etc.) because you walk/bike?

Answer Bar Response %
1 Yes 34 26%
2 No 97 74%
Total 131
Statistic Value
Min Value 1
Max Value 2
Mean 1.74
Variance 0.19
Standard Deviation 0.44
Total Responses 131
19.

What have you bought in the past specifically for walking, running, or bike riding? (Choose all that apply)
Answer Bar Response %
1 Shoes 76 76%
2 Clothing 46 46%
3 Accessories such as Fitbit 14 14%
4 Acc. such as water bottle 52 52%
5 Upgraded equipment 9 9%
Statistic Value
Min Value 1
Max Value 5
Total Responses 100
20.

Rate the following by the frequency of activity by mile.
Question Most - Least Total Responses Mean
1 Walk 100 28 5 133 1.29
2 Run 22 52 59 133 2.28
3 Bike 13 32 87 132 2.56
Statistic Walk Run Bike
Min Value 1 1 1
Max Value 3 3 3
Mean 1.29 2.28 2.56
Variance 0.28 0.54 0.45
Standard Deviation 0.53 0.73 0.67
Total Responses 133 133 132
21.

How often do you buy new walking or running shoes?
Answer Bar Response %
1 Once a year 49 37%
2 Once every six months 30 23%
3 Once every 3 months 4 3%

4 More often 0 0%
5 Less often 48 37%
Total 131
Statistic Value
Min Value 1
Max Value 5
Mean 2.76
Variance 3.16
Standard Deviation 1.78
Total Responses 131
22.

Please estimate how many miles a pair of walking or running shoes will last for you.
Answer Bar Response %
4 5 8%
5 200 - 300 miles 14 22%
6 300 - 500 miles 27 43%
7 500 - 1000 miles 9 14%
8 >1000 miles 8 13%
Total 63
Statistic Value
Min Value 4
Max Value 8
Mean 6.02
Variance 1.21
Standard Deviation 1.10
Total Responses 63
23.

How likely would you be to change your method of transportation for the good of the environment if presented with a credible argument?
Answer Bar Response %
1 Very Unlikely 8 7%
2 Unlikely 12 11%
3 Somewhat Unlikely 20 18%
4 Somewhat Likely 32 28%
5 Likely 28 25%
6 Very Likely 13 12%
Total 113
Statistic Value
Min Value 1
Max Value 6
Mean 3.88
Variance 1.95
Standard Deviation 1.40

Total Responses 113
24.

How much do you pay for walking or running shoes?
Answer Bar Response %
1 9 7%
2 $25-$40 23 18%
3 $40-$60 46 36%
4 $60-$100 38 29%
5 >$100 13 10%
Total 129
Statistic Value
Min Value 1
Max Value 5
Mean 3.18
Variance 1.13
Standard Deviation 1.06
Total Responses 129
25.

Do you think that Global Warming is an immediate threat?
Answer Bar Response %
1 Definitely yes 65 57%
2 Probably yes 26 23%
3 Maybe 14 12%
4 Probably not 6 5%
5 Definitely not 4 3%
Total 115
Statistic Value
Min Value 1
Max Value 5
Mean 1.77
Variance 1.16
Standard Deviation 1.08
Total Responses 115
26.

Please rate the following modes of transportation on the basis of how environmentally friendly you think they are.
Question Poor Fair Good Very Good Excellent Total Responses Mean
9 Driving an electric vehicle 3 18 38 41 14 114 13.39
10 Driving a hybrid vehicle 3 32 51 27 1 114 12.92
11 Driving a conventional vehicle 58 41 13 1 1 114 11.65
12 Bicycling 0 1 7 25 81 114 14.63
13 Walking or running 0 1 4 15 94 114 14.77

Statistic driving an electric vehicle driving a hybrid vehicle driving a conventional vehicle Bicycling Walking or running
Min Value 11 11 11 12 12
Max Value 15 15 15 15 15
Mean 13.39 12.92 11.65 14.63 14.77
Variance 0.97 0.66 0.62 0.41 0.30
Standard Deviation 0.98 0.81 0.79 0.64 0.55
Total Responses 114 114 114 114 114
27.

How much of an impact do you think humans have on current climate conditions?
Answer Bar Response %
1 None 1 1%
2 Little 8 7%
3 Some 22 19%
4 A Lot 84 73%
Total 115
Statistic Value
Min Value 1
Max Value 4
Mean 3.64
Variance 0.42
Standard Deviation 0.65
Total Responses 115
28.

How likely are you to change your method of transportation for the good of the environment at this point?
Answer Bar Response %
16 Very Unlikely 17 15%
17 Unlikely 15 13%
18 Somewhat Unlikely 27 24%
19 Somewhat Likely 30 27%
20 Likely 19 17%
21 Very Likely 5 4%
Total 113
Statistic Value
Min Value 16
Max Value 21
Mean 18.30
Variance 2.00
Standard Deviation 1.41
Total Responses 113
29.

If more people walked or biked to work/school we could slow climate change.

Answer Bar Response %
1 Strongly Disagree 8 7%
2 Disagree 9 8%
3 Neither Agree nor Disagree 22 19%
4 Agree 58 50%
5 Strongly Agree 18 16%
Total 115
Statistic Value
Min Value 1
Max Value 5
Mean 3.60
Variance 1.14
Standard Deviation 1.07
Total Responses 115
30.

If you own a bicycle, how much did it cost?
Answer Bar Response %
1 36 28%
2 $200-$500 28 22%
3 $500-$1000 6 5%
4 >$1000 1 1%
5 Don't own a bicycle 59 45%
Total 130
Statistic Value
Min Value 1
Max Value 5
Mean 3.15
Variance 3.15
Standard Deviation 1.77
Total Responses 130
31.

How often does it need new tires/other repairs?
Answer Bar Response %
1 Every few years 66 83%
2 Yearly 8 10%
3 Every few months 6 8%
Total 80
Statistic Value
Min Value 1
Max Value 3
Mean 1.25
Variance 0.34
Standard Deviation 0.58

Total Responses 80
32.

Which do you feel is the safest option for neighborhood trips?

#	Question	Safest - Least safe			Total Responses	Mean
1	Driving	82	33	6	121	1.37
2	Walking, Running	51	36	35	122	1.87
3	Bicycling	27	62	32	121	2.04

Statistic	Driving	Walking, Running	Bicycling
Min Value	1	1	1
Max Value	3	3	3
Mean	1.37	1.87	2.04
Variance	0.34	0.69	0.49
Standard Deviation	0.58	0.83	0.70
Total Responses	121	122	121

33.

If each were safer would you do it more often?

#	Question	Yes	Probably	Not	No	Total Responses	Mean
1	Driving	47	28	21	25	121	2.20
2	Walking, Running	43	39	25	14	121	2.08
3	Bicycling	38	33	25	25	121	2.31

Statistic	Driving	Walking, Running	Bicycling
Min Value	1	1	1
Max Value	4	4	4
Mean	2.20	2.08	2.31
Variance	1.36	1.03	1.26
Standard Deviation	1.17	1.01	1.12
Total Responses	121	121	121

34.

If more people drove hybrid/electric rather than conventional cars we could slow climate change.

#	Answer	Bar	Response	%
1	Strongly Disagree		9	8%
2	Disagree		13	11%
3	Neither Agree nor Disagree		18	16%
4	Agree		62	54%
5	Strongly Agree		12	11%
	Total		114	

Statistic	Value
Min Value	1
Max Value	5
Mean	3.48
Variance	1.17
Standard Deviation	1.08
Total Responses	114

35.

What, if anything, do you think would make driving safer?
Text Response
less stupid people on the roads
Better Roads
Automatically disabling of texting
Better driving instruction and stricter license restrictions
Better drivers
Better traffic laws?
Honestly, my biggest problem is with glare.
You have the car frame to protect you in the event of an accident
Airbags
Collision prediction
-
No human drivers
Better communication among drivers
(In Worcester) clearer road signs/ intersections/ etc.
Knowing cars can't kill me
Better drivers education
Self-Driving cars
People driving better
People not drinking
Street Lighting
Living in a more remote area
Better collision prevention in cars, other drivers being better qualified, universal driving laws across state boundaries
Automated cars!
People not using their phones
Better enforcement of driving laws regarding drugs/alcohol
Less people drinking on the road
NA
Self Driving Cars
better drivers
automatically driven
fewer humans
Don't know.
Nothing
People being alert drivers
google cars
An AI doing the driving
Better road care in winter
Fewer stupid humans.
Better marked roads
Streets repair, and generally better drivers in MA

Not stupid drivers
Make sure streets signs visible
people actually paying attention
Fix all the giant potholes
Wider roads
Better drivers
Stricter laws that require better skills behind the wheel. Required seat belt wearing. Required to not text and drive.
better drivers
Higher the age of giving out licenses
People learning how to drive better
A drunk driver detector
Getting a drivers license
Less exposure

Telecommunications

Nothing
Statistic Value
Total Responses 55
36.

What, if anything, do you think would make running and walking safer?
Text Response
less stupid people on the roads
Cameras/Police
Removing cars from the road entirely
Walking lanes
The people
Depends on the neighborhood, and if the streets are well lit at night and are fairly open
More accessible sidewalks (year round)
Sidewalks
The area, wearing reflectors
Hidden cameras along the street
It really depends on the location.
Good sidewalk conditions, safe neighborhoods
Better lighting, no human drivers
Better Lit roads and sidewalks
More sidewalks and bike paths that are well-kept
More crosswalks
If people can't kill me
Better sidewalks
Sidewalks along all roads
Running or walking in safer areas
Safer route
Definitely more street lights

Not getting hit when people drive through crosswalks
Larger shoulders on streets/sidewalks everywhere
Better sidewalks and more street lights at night
Automated cars, or otherwise not needing to worry about motorized vehicle traffic.
Safety Clothing
More street lights, police surveillance, fewer bad people
Stay away from the streets
No street predators
Designated, connected paths
I don't think it's possible to make it safer
Better sidewalks/bike lanes
Being able to quickly get into contact with someone nearby if something goes wrong.
If people sucked less
Fewer cars
Proper sidewalks; less ice during winter
Not living in Worcester
Not being a woman alone at night
Being in groups
Google cars - to not hit people
Reflectors
Better lighting of paths. Sidewalks.
Fewer stupid humans.
Sidewalks where there aren't any
A lower crime/mugging rate in the area. Also being male.
Better sidewalks/more sidewalks
More sidewalks or lanes
Better sidewalks and street lights
More street lights
Have cars actually stop for pedestrians when legally required to
Wider roads
Wider roads

More lights on the streets.
Lighting, security?
Less creepy people
Wearing bright clothes
A smaller risk of predators.
Sidewalks everywhere that are always shoveled in the winter
Sidewalks
Better sidewalks and signals
Less accidents
I think it's a location issue
People who understand crosswalks
SIDEWALKS
Safer neighborhood

Statistic Value
Total Responses 66
37.

What, if anything, do you think would make riding a bicycle safer?
Text Response
More/better bike lanes, paths, etc.
More bike Lanes/Paths
Less stupid people on the roads
Better Paths Separate from Roads
Removing cars from the road entirely
Bike lanes
Falling and people
Less motor vehicle traffic
BIKE LANES!
Bike lanes/paths
Working breaks, bell, reflectors
Designated lane
-
Good road conditions with bike lanes
More bike lanes, no human drivers
Better bike accessories for night time
More bike paths and sidewalks that are well-kept, and clearly marked
Bike Lanes
If I was invincible or cars are made of clouds
Bike paths, bike lanes
Bike lanes, sidewalks, and helmets
People always wear helmets
Better roads
Making sure people don't go too far out when turning
Same as walking, additionally more reflective gear
Actual bike lanes on the street and cars that respect bikes on the street
Automated cars, or otherwise not needing to worry about motorized vehicle traffic.
Safety Clothing
More careful bikers and drivers
People must wear a helmet
Better rules and regulations
Designated, connected paths
Better protective equipment for bikes
Self-Driving Cars
Full body armor
Better drivers
Fewer cars/better plowed roads
Reduced bicycle theft
Not living in Worcester

Lights
Nothing, riding bikes is dangerous
Specific bike lanes not for cars or pedestrians in more places
Reflectors
Actual bike lanes.
See above.
Bike lanes
Knowing how to ride one
Street repair
Better bicycling paths
More sidewalks or lanes
Drivers being more attentive
More street lights
Having cars more aware of the bicycles around them

Wider roads
Wider roads
Requiring helmets to be worn.
Sidewalks, bike lanes
Bike lanes
Having a bike
Having a wider lane
Bike paths that aren't sidewalks or part of the road.
Bike lanes that people actually respect
Bike lanes
More bike lanes and better educated drivers.
I don't
More developed infrastructure
People who understand how bikes work on the road
Safer neighborhood
Statistic Value
Total Responses 68
38.

If you were to visit the corner store within your neighborhood would you be most likely to:
Answer Bar Response %
1 Walk 81 68%
2 Bike 7 6%
3 Drive 31 26%
4 Other 0 0%
Total 119
Statistic Value
Min Value 1
Max Value 3
Mean 1.58

Variance 0.77
Standard Deviation 0.88
Total Responses 119
39.

You're going to school or work which is only about 5 miles away and it's a beautiful day. Do you... (Choose all that apply)

#	Answer	Bar	Response	%
1	Maybe walk or run		34	29%
2	Maybe bike		37	31%
3	Definitely walk or run		9	8%
4	Definitely bike		7	6%
5	Maybe drive		39	33%
6	Definitely drive		49	41%
7	Other		4	3%

Statistic	Value
Min Value	1
Max Value	7
Total Responses	119

40.

What's your opinion of hybrid cars?

#	Answer	Bar	Response	%
1	Dislike Extremely		7	6%
2	Dislike Very Much		0	0%
3	Dislike Slightly		3	3%
4	Neither Like nor Dislike		40	35%
5	Like Slightly		27	23%
6	Like Very Much		31	27%
7	Like Extremely		7	6%
	Total		115	

Statistic	Value
Min Value	1
Max Value	7
Mean	4.75
Variance	1.89
Standard Deviation	1.38
Total Responses	115

41.

How about fully electric cars?

#	Answer	Bar	Response	%
1	Dislike Extremely		4	3%
2	Dislike Very Much		0	0%
3	Dislike Slightly		3	3%
4	Neither Like nor Dislike		29	25%

5 Like Slightly 28 24%
6 Like Very Much 32 28%
7 Like Extremely 19 17%
Total 115
Statistic Value
Min Value 1
Max Value 7
Mean 5.17
Variance 1.84
Standard Deviation 1.36
Total Responses 115