A 2009 Mobile Source Emissions Inventory Of The University Of Central Florida

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A 2009 MOBILE SOURCE EMISSIONS INVENTORY OF THE UNIVERSITY OF CENTRAL FLORIDA

by

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ABSTRACT

This thesis reports on the results of a mobile source emissions inventory for the University of Central Florida (UCF). For a large urban university, the majority of volatile organic compounds (VOC), oxides of nitrogen (NO_x), and carbon dioxide (CO_2) emissions come from on-road sources: personal vehicles and campus shuttles carrying students, faculty, staff, and administrators to and from the university, as well as university business trips. In addition to emissions from daily commutes, non-road equipment such as lawnmowers, leaf blowers, small maintenance vehicles, and other such equipment utilized on campus contributes to a significant portion to the total emissions from the university. UCF has recently become the second largest university in the nation (with over 56,000 students enrolled in the fall 2010 semester), and contributes significantly to VOC, NO_x, and CO_2 emissions in Central Florida area. In this project, students, faculty, staff, and administrators were first surveyed to determine their commuting distances and frequencies. Information was also gathered on vehicle type, and age distribution of the personal vehicles of students, faculty, administration, and staff as well as their bus, car-pool, and alternate transportation usage. The EPA approved mobile source emissions model, Motor Vehicle Emissions Simulator (MOVES2010a), was used to calculate the emissions from on-road vehicles, and UCF fleet gasoline consumption records were used to calculate the emissions from non-road equipment and on campus UCF fleet vehicles. The results of the UCF mobile source emissions inventory are reported and compared to a recently completed emissions inventory for the entire three-county area in Central Florida.

I dedicate this to my nephew, Kaedyn, whose curiosity about the world is contagious. His passion for science is inspiring and reminds me to keep learning.

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I would like to thank The Department of Sustainability and Energy Management at UCF for their support of this research. More specifically I would like to thank David Norvell, for allowing me to work in conjunction with the university and to contribute to UCF's 2009 Carbon Dioxide Emissions Inventory. This financial support helped me to achieve my goal of earning my master's degree. Another thank you goes to my officemates for their support and laughs. Thank you Kurt, Wyatt, Mark, Jessica, and Steve, for your teamwork. Most importantly, I would also like to thank Dr. Cooper for his continued support and guidance throughout my graduate career. He has provided many valuable lessons, which I will bring to my future work in Environmental Engineering. I would also like to acknowledge Dr. Reed Perkins. Without his guidance at Queens University of Charlotte and his bravery in taking college students to Yap in The Federated States of Micronesia, I might never have understood the necessity of sustainability. Lastly, I would like to thank my family for always encouraging me and teaching me to never give up on my dreams.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

ACUPCC	American Colleges & Universities Presidents' Climate Commitment
ATV	all terrain vehicle
B20	biodiesel fuel
CAA	Clean Air Act
CH_4	methane
CO_2	carbon dioxide
$CO_{2,eq}$	carbon dioxide equivalent
DOE	U.S. Department of Energy
E10	gasohol
FL	Florida
GHG	greenhouse gases
HFCs	hydrofluorcarbons
HNO_2	nitrous acid
HNO_3	nitric acid
HPMS	Highway Performance Monitoring system
IPCC	Intergovernmental Panel on Climate Change
I/M	inspection & maintenance
MOVES	Motor Vehicle Emission Simulator
MPH	miles per hour
NGO	non-governmental organization
NMIM	National Mobile Inventory Model

NO	nitrogen oxide
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
O_3	ozone
OSO	Orange, Seminole & Osceola counties
PNNL	Pacific Northwest National Laboratory
Ppb	parts per billion
RFG	reformulated gasoline
RVP	reid vapor pressure
SUV	sport utility vehicle
UCF	University of Central Florida
UKDEFRA	United Kingdom Department for Environment, Food & Rural Affairs
ULSD	ultra-low sulfur off-road diesel fuel
UMD	University of Maryland: College Park Campus
U.S. EPA	United States Environmental Protection Agency
VHT	vehicle hours traveled
VMT	vehicle miles traveled
VOC	volatile organic compounds
WRI	World Research Institute

1. INTRODUCTION

Based on student population, UCF is now one of the largest universities in the nation, and therefore has the potential to significantly impact air resources in Central Florida. An emissions inventory was completed for UCF to quantify the university's contribution to air pollution emissions in our three-county region (Orange, Seminole and Osceola). An emission inventory is an important tool in managing air quality for any region because it gives managers and decision makers a good tool for identifying and focusing their efforts on large sources when trying to reduce emissions from various sources (U.S. Environmental Protection Agency, 2004).

UCF is a member of American Colleges & Universities Presidents' Climate Commitment (ACUPCC) and is committed to sustainable development, energy conservation, and reduction of emissions of global climate change gases. As a part the university's commitment to ACUPCC, an inventory of carbon dioxide (CO_2) emissions for 2009 for UCF main campus in Orlando, Florida (FL), was conducted. In addition to CO_2, volatile organic compounds (VOC) and nitrogen oxides (NO_x) were calculated. It is important to account for VOC and NO_x, because they are ozone precursors.

This Emissions Inventory for UCF is production-based and details emissions from mobile sources only. No point sources are located within the boundaries of the university (Santiago, March). A chilled water plant is located on campus, but utilizes electricity to cool the water. The mobile sources examined include the personal vehicles of students, faculty, administration, and staff; UCF shuttle buses; UCF fleet vehicles; campus non-road equipment (lawn and garden, other); and travel (airplane, car and train) by UCF personnel on UCF business.

In the emissions inventory for UCF, CO_2, VOC, and NO_x emissions were estimated using MOVES2010a (MOVES), the EPA's latest motor vehicle emissions simulator. To calculate CO_2 emissions from non-road sources and UCF fleet vehicles, emissions factors from the U.S. Department of Energy (Department of Energy), the U.S. EPA (Greenhouse Gas Protocol, 2009), and the U.K. Department for Environment, Food & Rural Affairs (Greenhouse Gas Protocol, 2009) were used, which are approved by the Intergovernmental Panel on Climate Change (IPCC).

1.1 Carbon Dioxide & Other Greenhouse Gases

Emissions from motor vehicles include four greenhouse gases: carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons. Motor vehicles are the second largest source of GHG emissions in the U.S. The major GHG emitted from motor vehicles is carbon dioxide. Carbon dioxide is a product of the combustion of any fuel containing carbon. Hydrofluorocarbons (HFCs), are used as coolants in a vehicle's air conditioning system, and contribute about 4.2% of motor vehicle GHG emissions. Methane and nitrous oxide, together contribute 1.9% of those GHG emissions from motor vehicles (McCarthy, 2010).

Whether the EPA has authority to regulate GHG's through the Clean Air Act (CAA) has been under consideration for more than a decade. During the Clinton administration, in 1998, the EPA general Counsel concluded that GHG were air pollutants within the definition of the term in the CAA. As a result of that finding, a group of 19 organizations petitioned the EPA to regulate GHG from motor vehicles under Section 202. This section grants the EPA Administrator broad authority, “to set ‘standards applicable to the emission of any air pollutant from any class or classes or new motor vehicles’ if in her judgment they cause or contribute to air pollution which ‘may reasonably be anticipated to endanger public health or welfare (McCarthy, 2010).

The EPA denied this petition in August 2003 under the Bush Administration. The denial was based on a new General Counsel memorandum that concluded the CAA does not grant EPA authority to regulate carbon dioxide and other GHG emissions based on climate change impacts. Massachusetts, 11 other states, and various organizations challenged this denial all the way to the Supreme Court. In April 2007, for the case Massachusetts v. EPA, the Supreme Court decided by a 5-4 vote that the EPA does have authority to regulate GHG emissions, since they are clearly air pollutants under the CAA definition of the term. Nearly one year later, the EPA under the Bush Administration issued a detailed information request, and an Advance Notice of Proposed Rulemaking (ANPR), on July 30, 2008. On April 17, 2009, in Federal Register 66496 under the Obama Administration did the EPA find that GHGs do endanger both public health and welfare and emissions from new motor vehicles contribute to that endangerment (McCarthy, 2010).

According to the IPCC greenhouse gases contribute to climate change and global warming. The IPCC states that climate change is expected to contribute to some air quality problems. More specifically, respiratory disorders may be exacerbated by warmer temperatures that would increase the frequency of ground level ozone and particulate air pollution. The Global Change Research Program, within the EPA's Office of Research and Development is investigating research on the effects of climate change on U.S. air quality.

1.2 Ozone

Ozone (O_3) is accumulated in the atmosphere through a series of complex reactions between VOC and NO_x, in the presence of heat and sunlight. O_3 is regulated by the U.S. Environmental Protection Agency. In 2008 the EPA set the current maximum allowable ozone level is 75 ppb (8-hour average), (U.S. Environmental Protection Agency, 2009).

Ozone is regulated because it is known to cause health problems in the general population. Studies have found that these health problems are linked to ground level ozone exposure. This exposure to ozone among the general population can lead to airway irritation, aggravation of asthma, wheezing and difficulty breathing during outdoor exercise and activity. Permanent lung damage can occur with repeated exposure to ground level ozone. In addition to its negative effects on human health, ozone can cause changes in plants and ecosystems. It likely increases susceptibility of plants to certain insects, diseases, competing species, harsh weather, and reduces forest growth and crop yields.

1.3 Nitrogen Oxides

Nitrogen oxides (NO_x) are a group of compounds released from car and truck engines, non-road mobile equipment, buses, and power plants. Nitrogen dioxide (NO_2), nitric acid (HNO_3), and nitrous acid (HNO_2) are considered NO_x. The starting point for this group of compounds is NO and NO_2. Formation of NO and NO_2 occurs from combustion of any fuel in air at high temperatures.

1.4 Volatile Organic Compounds

Volatile organic compounds (VOC) are carbon containing compounds that participate in atmospheric photochemical reactions. VOCs do not include carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, or ammonium carbonate. Volatile organic compounds can cause adverse health effects, such as headaches, respiratory problems and nausea. Their main problem is that they participate in the formation of ozone. VOC emissions come from sources such as consumer solvents, on-road vehicles, non-road equipment, industrial processes, dry cleaning facilities, and restaurants.

2. LITERATURE REVIEW

With the increase in awareness and prevention of global climate change, many organizations have been founded that focus on the reduction of greenhouse gases (GHGs). The percentages of GHGs that are reduced are dependent upon the results of an initial Greenhouse Gas Inventory that examines GHGs, mainly CO_2 equivalents ($CO_{2,eq}$) that contain CO_2, methane (CH_4), and nitrous oxide (N_2O)). In 2006, a study done by the EPA found that 96% of GHG emissions from motor vehicles were CO_2 equivalents (CO_2, nitrous oxide, and methane, and 4% were from the release of hydrofluorocarbons (HFCs) from motor vehicle air conditioning (McCarthy, 2010). It is important to note that N_2O and CH_4 emission from motor vehicles only account for 1.9% of GHG emissions, and consequently when reporting emissions results from mobile sources in tons of CO_2 or $CO_{2,eq}$, a 1.9% difference is negligible. Due to this reasoning, GHG emissions will only be reported as tons of CO_2.

While CO_2 emissions are examined for UCF, the methodology and terminology that is used in this paper differs from the methodology and terminology used in a typical Greenhouse Gas Inventory. The main focus of a GHG inventory is to quantify the GHG consumed by electrical and natural gas utilities. In a GHG inventory, the boundaries of what sources are considered are often left up to the organization completing the inventory. Most corporations and universities consider emissions from mobile sources as secondary and are often termed “indirect” or “optional” emissions.

The Climate Leaders GHG protocol, an EPA Industry-government partnership, prioritizes GHG emissions into two categories: core emissions and optional emissions. The World Research

Institute defines GHG emissions as Scope 1, 2, or 3 (Greenhouse Gas Protocol, 2009). When comparing the definitions between The Climate Leaders GHG Protocol and the World Research institute, Core emissions (Scope 1) are from the generation of electricity, heat, or steam, physical or chemical processing, and the transportation of materials, products, waste and employees. Any emissions from transport related activities are considered optional emissions (Scope 2 and 3) (U.S. Environmental Protection Agency, Climate Leaders, 2005).

2.1 ACUPCC

A growing number of colleges and universities are completing an emissions inventory in an effort to decrease their carbon footprint and increase sustainability. ACUPCC has signatures from presidents/chancellors from approximately 680 different universities, colleges, and community colleges throughout the United States (ACUPCC). A college or university that signs the ACUPCC agreement states they will (1) create an organizational structure to be responsible for leading the process, (2) implement at least two short-term 'tangible actions' to reduce greenhouse gas emissions, (3) complete an inventory of annual greenhouse gas emissions from campus operations, (4) create a *Climate Action Plan* that lays out a process for achieving climate neutrality in operations and integrating climate and sustainability into the educational experience for students, and (5) make the inventories, Climate Action Plans, and periodic progress reports publicly available through the ACUPCC Reporting System (ACUPCC). Each educational institution that is a part of the ACUPCC, is responsible for defining the boundaries and procedure for their emissions inventory.

The procedures and boundaries for various colleges varied greatly among the members of ACUPCC. Drexel University, in Philadelphia, Pennsylvania, hired Pennoni Associates Inc., a consulting engineering firm to complete an emissions inventory for their school. The boundaries of the inventory or Drexel University did not include emissions from faculty, staff, and student's daily commutes (Pennoni Associates Inc., 2009). The College of Holy Cross made assumptions on the number of commuter days, the number of persons per vehicle, and the average mileage per trip (College of Holy Cross, 2010). These assumptions along with the average miles per gallon of fuel use among the fleet were used to estimate the total number of gallons of fuel consumed. The total volume of fuel consumed was multiplied by emission factors to calculate total GHGs for the emissions inventory of The College of Holy Cross.

2.2 University of Maryland

The most comparable university emissions inventory that was found reported in the literature was for the University of Maryland: College Park Campus (UMD). UMD is a large urban university, and did a CO_2 emissions inventory for 2009. When comparing UCF to UMD it is noted that, for the fall 2009 semester, the total student population enrolled at UCF was 53,466 with a total campus population (including faculty, staff, administrators, and others) of 58,620, while the University of Maryland had 34,437 students and a total campus population of 43,577 (Office of Institutional Research, University of Central Florida). In the UMD study, several simplified assumptions about student travel behavior were made, whereas the UCF study, a detailed survey of student travel behavior was conducted. Two key assumptions made by the UMD researchers were: (1) that students commuted only 160 days/year and (2) that students made only one round trip per day. In the UMD study, each commuting student thus made only 160 round trips per year (University of Maryland).

2.3 Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory (PNNL) is one of the U.S. Department of Energy's (DOE's) ten national laboratories. PNNL completed its first GHG emissions inventory for the 2007 calendar year. The laboratory's approach to identifying emissions is based on the World Resources Institute's (WRI) publication: Hot Climate, Cool Commerce: A Service Sector Guide to GHG Management (Judd, 2009). The emissions factors used by PNNL are from GHG protocol, developed by WRI and the World Business Council for Sustainable Development. The GHG protocol is the international standard for corporate GHG inventory development; it is approved by The Climate Registry and the U.S. EPA's Climate Leaders (Judd, 2009).

Currently, PNNL has approximately 4,900 staff members that are distributed, "across the Richland campus, Sequim, Seattle, Portland, the Washington, DC metropolitan area, and other locations." An on-line survey was developed to gather data about PNNL employees. The survey was modeled after the GHG Protocol employee commute survey tool and distributed to employees. For each survey respondent a number of "commuting weeks" in the calendar year was estimated by using an average number of hours worked per year (minus vacation and holidays) (Judd, 2009). The number of hours worked did not include days worked from home, the average number of days spent on business travel, and any time on extended leave during the calendar year. The U.S. average fuel economy data for various vehicle types was used to calculate the total fuel consumption; a fuel specific emission factor was used to estimate the total GHG emissions.

3. SURVEY

3.1 Methodology

3.1.1 On-line Survey

A voluntary survey was conducted to gather data on travel behavior, distances, and frequency of trips (which affect vehicle miles traveled (VMT)), and the source type distribution of the personal vehicles of students, faculty, administration, and staff, and other information. The survey was conducted electronically using SurveyMonkey, which proved very easy to use for both the respondents and the researchers. SurveyMonkey is an online company that allows customers to gather information about market research, customer feedback, product planning and education/training through personalization of surveys (SurveyMonkey). The company keeps a record of each survey participant and the answers they selected. A weblink to this voluntary survey was emailed to graduate and undergraduate students, faculty, administration, and staff/other by the Office of Administration & Finance.

3.1.2 Survey Description

The survey was designed for ease of completion and limited the number of questions for each commuter group. Each survey participant was asked to identify his or her involvement with the university: Undergraduate Student, Administrative, Faculty, Staff, Graduate Student, other. The UCF population was asked to identify their specific involvement with the university because each group was predicted to have different commuting habits and locations within the central Florida area where they reside. From this question undergraduate students were asked whether they resided on-campus or off-campus. Undergraduate students who stated they lived on-campus were asked how they traveled from their residence hall to class: walk/bike, drive to a closer parking lot/garage, take the UCF Shuttle, other. After answering the previous question undergraduate on-campus residents were then directed to the end of the survey because the other questions in the survey were not applicable to them.

Survey participants who stated they were (1) undergraduate students that lived off-campus, (2) graduate students, (3) administration, (4) faculty, and (5) staff/other were asked to estimate the mileage they traveled from home to campus. Each was then asked to identify what type of vehicle he or she drove to the university: “car”, “small SUV/pick-up truck or minivan”, “large SUV/pick-up truck or large van”, “motorcycle, moped or similar”, “I don’t drive a vehicle to campus.” If a survey participant selected, “I don’t drive a vehicle to campus”, they were then asked what alternate transportation they utilized to commute to UCF (UCF Shuttle, Carpool, Lynx Bus, Bicycle, Walk) and were then directed to the end of the survey. This information was used to create a source type population for the university.

After survey respondents identified the type of vehicle used to commute to the university, they were asked to select the age of the vehicle from a dropdown menu from a range of 1979-2011 and whether the driver participated in a carpool. If “yes” was selected he or she was then asked the average number of times a week he or she participated in a carpool during the fall/spring semester and summer semester and how many persons were present in the vehicle. After answering questions about carpooling, survey participants and those who indicated they did not participate in a carpool were then asked “How many one-way trips (in your vehicle) from your residence to UCF main campus do you make each week during the

FALL/SPRING semester?" Participants were also asked the average time of day they typically arrived on campus and how long it took them to find a parking spot. The final question asked was whether he or she traveled to campus during the summer semester. If "yes" was selected, participants were asked the same three questions about how many one-way trips a week are made to campus, the time of arrival, and time spent searching for parking. If "no" was selected, they were taken directly to the end of the survey.

3.2 Survey Representation

The online survey was administered through SurveyMonkey. The company keeps record of each survey participant and the answers they selected. On January 4, 2011, the results were downloaded from Survey Monkey and analyzed through the use of Microsoft Excel and Microsoft Access. This final database contained a total of 3,034 respondents (202 administrative personnel, 202 faculty, 392 staff/other, 459 graduate students, and 1779 undergraduate students).

The UCF populations of undergraduate and graduate students, faculty, staff/other, and administration can be seen in Table 1, along with the percentage of survey respondents that completed the survey. It is important to note that a small portion of survey respondents (109) did not complete the survey, or exited the survey before completion. These respondents, along with statistical outliers (127), were not included when calculating the percent representation in Table 3-1 for each UCF group. As a result we were only able to analyze responses from 3,034 survey respondents. After contacting UCF's Residence Life Office, it was determined that essentially no graduate students lived on campus, and that about 22% of undergraduate students did reside on campus and therefore did not commute to the UCF main campus.

Within each of the five separate groups to be analyzed (administration, faculty, staff/other, graduate and undergraduate students), an average weekly mileage/vehicle miles traveled (VMT) was calculated. This average was determined separately for the summer term and the fall/spring terms. For each survey participant within a group who indicated they traveled to UCF in their personal vehicle, an estimated mileage driven from home to the university was determined as well as an average number of trips per week.

Table 3-1: UCF Campus Population for 2009 and Survey Representation

	Spring 2009		Summer 2009		Fall 2009	
Group	*Campus Population*	*Survey Representation*	*Campus Population*	*Survey Representation*	*Campus Population*	*Survey Representation*
Administrative	282	66%	282	62%	278	67%
Faculty	1,771	10%	1,502	10%	1,727	10%
Staff/Other	3,015	10%	3,015	10%	2,971	10%
Graduate Students	7,212	4%	5,316	4%	8,246	4%
Undergraduate Commuter Students	31,997	3%	21,023	3%	34,956	3%
Undergraduate Non-Commuter Students	9,142	2%	6,006	3%	9,988	2%
TOTAL UCF POPULATION	53,418	4%	37,144	4%	58,620	3%

3.3 Survey Data Analysis

3.3.1 Source Type Population

Survey respondents were asked to identify what type of vehicle they drove to campus. Respondents were also able to select the option "I do not drive a vehicle to campus." From the survey analysis of the responses to this question several distributions were created that indicated the percentage of each source type, along with the option , "I do not drive a vehicle to campus." A source type distribution was created for each UCF group (5) for three semesters (spring, summer and fall), for a total of 15 distributions. The percentage distribution, seen in Table 3-2 was multiplied by the population of each UCF group for each semester to get a population of vehicles.

Table 3-2: Percentage Distribution for Source Type Population

UCF group	Percentage Distribution from Survey Responses					
	Motorcycle	**Passenger Car**	**Passenger Truck**	**Light Commercial Truck**	**"Don't Drive to UCF"**	**Total**
Administration	0.52	60.9	29.7	8.33	0.52	100
Faculty	1.04	62.0	28.1	5.21	3.65	100
Staff/Other	0.83	60.8	23.9	10.3	4.17	100
Graduate Students	1.01	67.6	18.8	4.05	8.45	100
Undergraduate Commuter Students	1.01	61.6	14.2	4.64	18.5	100
TOTAL UCF COMMUTER POPULATION	0.94	62.3	19.4	5.95	11.4	100

Table 3-3: Source Type Population for Spring 2009

UCF group	Spring Semester 2009				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	1	172	84	23	281
Faculty	18	1,098	498	92	1,706
Staff/Other	25	1,834	720	310	2,889
Graduate Students	73	4,873	1,364	292	6,603
Undergraduate Students	419	25,594	5,906	1,927	33,846
TOTAL UCF COMMUTER POPULATION	537	33,571	8,573	2,645	45,326

Table 3-4: Source Type Population for Summer 2009

UCF group	Summer Semester 2009				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	1	172	83	24	281
Faculty	16	931	422	78	1,447
Staff/Other	25	1,834	720	310	2,889
Graduate Students	54	3,595	1,006	216	4,867
Undergraduate Students	275	16,816	3,881	1,266	22,238
TOTAL UCF COMMUTER POPULATION	371	23,345	6,113	1,893	31,722

Table 3-5: Source Type Population for Fall 2009

UCF group	Fall Semester 2009				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	1	170	83	23	277
Faculty	18	1,070	486	90	1,664
Staff/Other	25	1,807	710	305	2,847
Graduate Students	84	5,572	1,560	334	7,594
Undergraduate Students	458	27,962	6,453	2,105	45,398
TOTAL UCF COMMUTER POPULATION	585	36,581	9,291	2,858	49,315

It is worth noting that for spring, summer, and fall semesters, the number of vehicles or source types for the Undergraduate students is greater than the population of Undergraduate commuter students. The explanation for this discrepancy is that the survey data used encompasses both commuter and non commuter undergraduate students. Undergraduate students who identified they lived on campus were required to answer the question "Since you live on campus, how do you travel from your residence hall to class?" The responses can be seen in the figure below. By using the survey data, with a greater number of vehicles than commuter students, those undergraduate students who reside on campus that drive to a closer parking lot or garage are included. It is better to be conservative rather than underestimate the population of vehicles on campus.

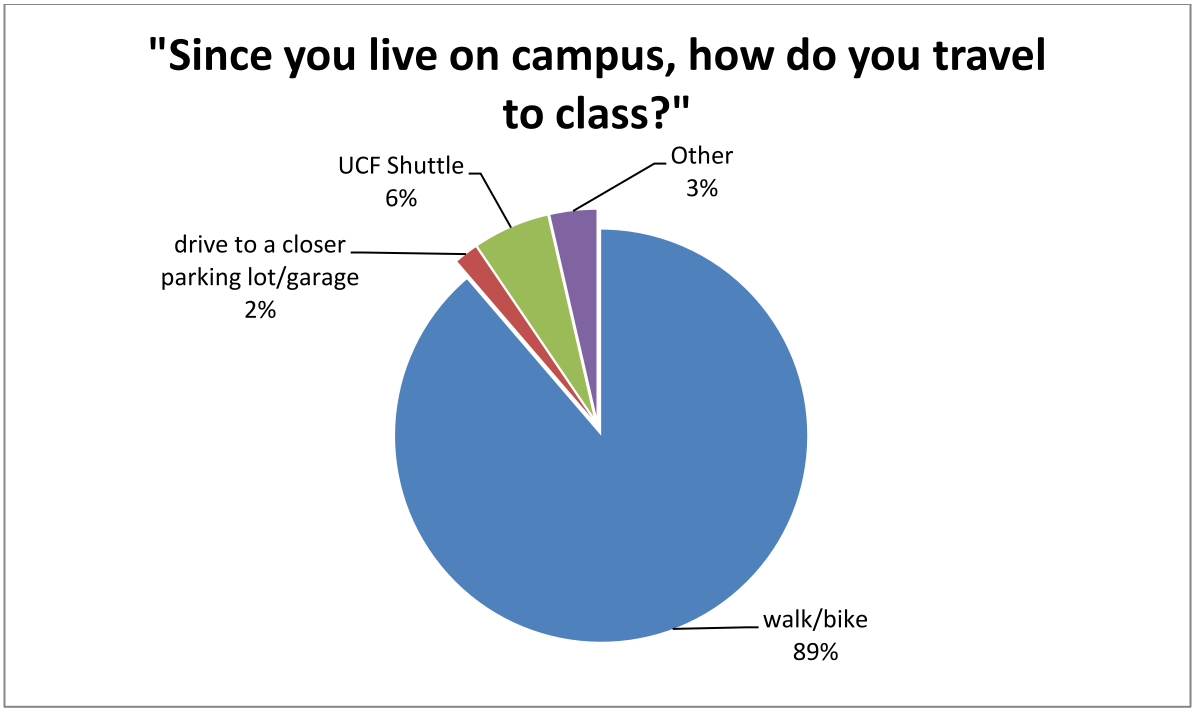

Figure 3-1: Percentage of Survey Responses from Undergraduate students who live on campus.

3.3.2 Vehicle Miles Traveled

From these data, an average weekly VMT was calculated for the fall, spring, and summer semesters because the populations of students changed significantly each semester. Included in this VMT is the estimated mileage driven while searching for a spot on campus. It is common to hear a student and/or visitor to complain that it took them over 30 minutes to park on campus. If such delays are common, that would cause an increase in emissions. It is common that while searching for parking, a vehicle would remain idle for a period of time while also being prone to sudden acceleration in the "hunt" for a spot. It is not uncommon that some students who prefer not to "hunt" for a spot will commute to campus at an earlier time and keep their car running, while either sleeping and/or studying in their personal vehicle. In Figures 3-2 and 3-3, a distribution of time spent searching for parking among the UCF commuter groups for the fall/spring and summer semesters was developed from survey responses.

For the fall/spring semester, as expected, the majority of administration, faculty and staff/other were able to park their vehicle in ‘2 minutes or less.’ Surprisingly, about 20 percent of Administration and Staff/other stated they ‘do not park on campus.’ It could be postulated that these administration and staff/other work in offices located off of Research Parkway, and are not required to purchase a parking permit for UCF main campus. The responses for graduate and undergraduate showed minimal variability between the different time intervals spent looking for parking. For graduate students, 21% chose ‘5 to 10 minutes,’ 19%: ‘3 to 5 minutes,’ and 15%: ’10 to 15’ minutes. For undergraduate students, 18% chose ‘5 to 10 minutes,’ 17%: ’10 to 15 minutes,’ and 15%: ‘3 to 5 minutes.’ 11% of both graduate and undergraduate students selected that it took them ’30 minutes or longer’ to find parking.

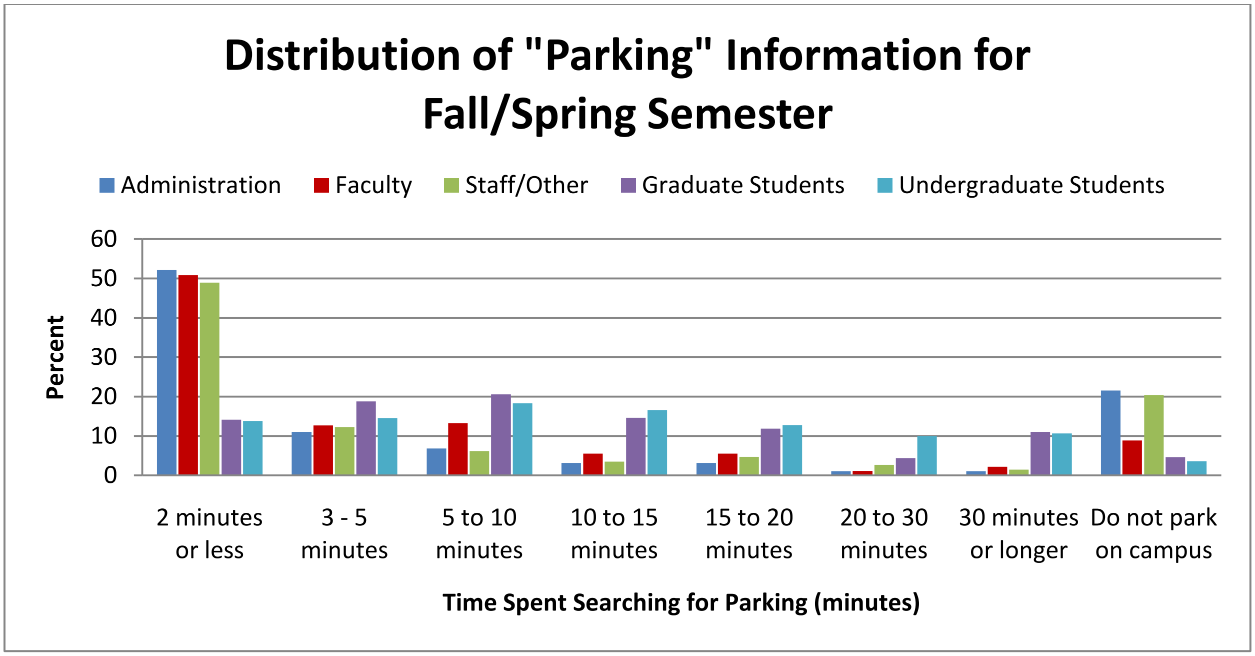

Figure 3-2: Percentage Distribution of Time Spent Searching for Parking for FALL/SPRING semesters on Campus

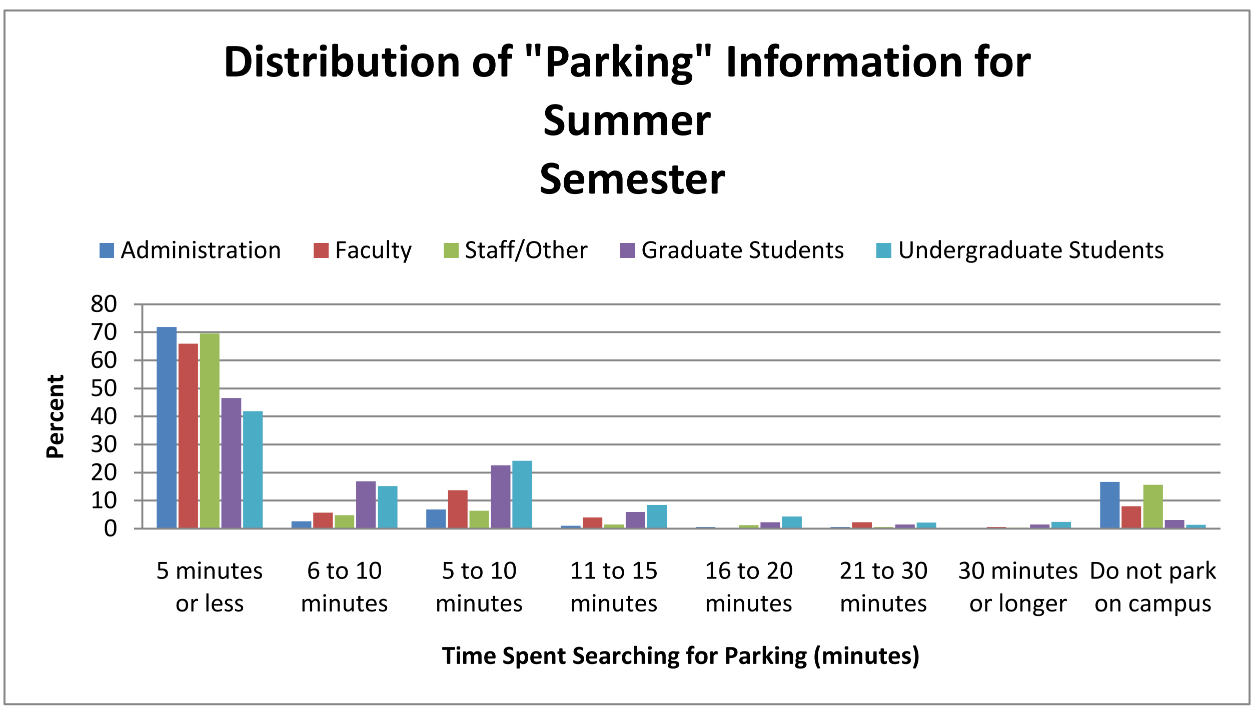

Figure 3-3: Percent Distribution of Time Spent Searching for Parking during the Summer Semester

The responses for the summer semester indicated, as expected, that parking is not difficult for any UCF group in the summer. The majority of administration, faculty, staff/other, graduate and undergraduate students selected that it took them ‘5 minutes or less’ to find parking. The UCF student commuter population decreased by about 2,000 graduate students and 10,000 undergraduate students between the spring and summer semester of 2009. This decrease is approximately 30% of the student commuter population, suggesting that if the university could decrease the student commuter population by about 30%, time spent and vehicle miles traveled searching for parking would greatly decrease.

In light of these UCF student habits, simply using the VMT from home to campus and back home again would not be accurate. The equations (Eq. 1 & 2) used to calculate the VMT for each survey respondent are seen below. Based on local observations, it was estimated that on average a vehicle travels at a speed of 7.5 mph while searching for parking at UCF.

$$\mathrm{VMT_{parking}} = \mathrm{t} \times \frac{7.5\ \mathrm{mph}}{60} \tag{3.1}$$

Where,

t = time spent looking for parking (minutes)

$$\left[\left(\frac{\mathrm{VMT}}{\mathrm{trip}} \times 2\right) + \left(\mathrm{VMT_{parking}}\right)\right] \times \frac{\mathrm{trips}}{\mathrm{week}} = \mathrm{VMT_{weekly}} \tag{3.2}$$

After using Microsoft Excel to tabulate a weekly VMT for each UCF group analyzed, the VMT per semester was tabulated. Even though the survey asked respondents to answer questions for the fall/spring semester as a combined time period, with knowledge of the actual populations on campus and the percentage of each the UCF groups represented in the survey, a statistically representative weekly VMT was found for each UCF group. This representative weekly VMT was then multiplied by the appropriate number of weeks in each semester.

Table 3-6: VMT of UCF Commuter Population

Group	Spring 2009 Mileage	Summer 2009 Mileage	Fall 2009 Mileage	2009 Annual Mileage
Administrative	662,592	487,476	614,768	1,764,836
Faculty	3,827,788	1,935,528	3,513,104	9,276,420
Staff/Other	7,879,891	5,148,276	7,308,144	20,336,311
Graduate Students	13,863,126	5,461,176	15,014,320	34,388,622
Undergraduate Commuter Students	73,435,954	24,508,464	75,509,856	173,472,274
UCF COMMUTER POPULATION	99,669,351	37,540,920	101,960,192	239,188,436

The VMT was compiled from survey data, and consequently statistical uncertainty exists. This uncertainty was estimated by calculating a margin of error using the following equation 3-3. In order to use this equation an overall analysis was completed of the VMT/week calculated from the survey responses from UCF Commuters. As previously stated, the VMT/wk was calculated from responses given from the UCF commuters, which included VMT driven while parking on campus for the fall/spring and/or summer semesters. The mean VMT per week for survey responses from the UCF commuters for the fall/spring semesters and summer semester was calculated. From these data points a standard deviation and margin of error were also tabulated.

Equation 3-1

$$e = z_{\alpha/2}\left(\frac{\sigma}{\sqrt{n}}\right) \quad (3.3)$$

Where,

$$e = margin\ of\ error$$

$$z_{\alpha/2} = 1.96\ (for\ 95\%\ confidence\ interval)$$

$$\sigma = standard\ deviation$$

$$n = sample\ population$$

For the fall/spring semesters a margin of error of ± 5 miles per week per commuter was calculated and ± 6 miles per week per person for the summer semester. In order to estimate the margin of error for each of the semesters the following equations were used.

$$e_{Fall} = \left(\pm 5\ \frac{miles/week}{commuter}\right) \times \left(\frac{16\ weeks}{fall\ semester}\right) \times (48{,}178\ commuters) \quad (3.4)$$

$$e_{Spring} = \left(\pm 5\ \frac{miles/week}{commuter}\right) \times \left(\frac{17\ weeks}{spring\ semester}\right) \times (44{,}277\ commuters) \quad (3.5)$$

$$e_{Summer} = \left(\pm 6\ \frac{miles/week}{commuter}\right) \times \left(\frac{12\ weeks}{summer\ semester}\right) \times (31{,}144\ commuters) \quad (3.6)$$

In summary, using a 95 % confidence interval, the commuter mileage for the fall semester had a margin of error of ± 3.8 million miles out of a total VMT of 102 million (3.9%). The margin of error was calculated for the spring 2009 semester was ± 3.8 million miles out of 100 million miles (3.7%); and the summer semester mileage had a margin of error of ± 2.2 million miles out of 38 million miles (6.0%).

Table 3-7: Percentage Distribution of VMT

UCF group	Percentage Distribution from Survey Responses				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	0.52	61.3	29.8	8.38	100
Faculty	1.08	64.3	29.2	5.41	100
Staff/Other	0.87	63.5	24.9	10.7	100
Graduate Students	1.11	73.8	20.7	4.43	100
Undergraduate Commuter Students	1.24	75.6	17.5	5.69	100
TOTAL UCF COMMUTER POPULATION	1.05	70.7	21.8	6.52	100

A separate distribution to create VMT for each source type and UCF commuter group was created from the survey responses. The separate distribution did not include the number of respondents that selected "I do not drive a vehicle to campus,' as this group of people are considered non commuters and would ultimately not contribute to VMT from the UCF commuter population. A percentage distribution was created for each UCF commuter group. This distribution was then multiplied by the weekly VMT for the appropriate UCF group and semester, and then multiplied by the number of weeks in that particular semester. The VMT for each commuter group for the spring, summer and fall semesters of 2009 can be seen in the following three tables.

Table 3-8: VMT by Source Type for Spring Semester 2009

UCF group	Vehicle Miles Traveled for Spring Semester 2009				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	3,469	405,881	197,737	55,505	662,592
Faculty	41,381	2,462,199	1,117,300	206,907	3,827,788
Staff/Other	68,521	5,002,018	1,964,263	845,090	7,879,891
Graduate Students	153,466	10,231,089	2,864,705	613,865	13,863,126
Undergraduate Commuter Students	908,861	55,531,396	12,814,938	4,180,760	73,435,954
TOTAL UCF COMMUTER POPULATION	1,175,699	78,632,583	18,958,942	5,902,127	99,669,351

Table 3-9: VMT by Source Type Population for Summer Semester 2009

UCF group	Vehicle Miles Traveled for Summer Semester 2009				
	Motorcycle	Passenger Car	Passenger Truck	Light Commercial Truck	Total
Administration	2,552	298,611	145,477	40,836	487,476
Faculty	20,925	1,245,015	564,965	104,323	1,935,528
Staff/Other	44,768	3,268,015	1,283,338	552,134	5,148,276
Graduate Students	60,456	4,030,388	1,128,509	241,82	5,461,176
Undergraduate Commuter Students	303,323	18,533,009	4,276,848	1,395,284	24,508,464
TOTAL UCF COMMUTER POPULATION	432,023	27,375,060	7,399,137	2,334,700	37,540,920

Table 3-10: VMT by Source Type Population for Fall Semester 2009

UCF group	Vehicle Miles Traveled for Fall Semester 2009				
	Motorcycle	**Passenger Car**	**Passenger Truck**	**Light Commercial Truck**	**Total**
Administration	3,219	376,586	183,465	51,499	614,768
Faculty	37,980	2,259,780	1,025,447	189,898	3,513,104
Staff/Other	63,677	4,648,386	1,825,394	785,344	7,322,800
Graduate Students	166,210	11,080,679	3,102,590	664,841	15,041,320
Undergraduate Commuter Students	934,528	57,099,656	13,176,844	4,298,828	75,509,856
TOTAL UCF COMMUTER POPULATION	1,205,485	75,455,784	19,310,085	5,988,838	101,960,192

4. UCF COMMUTER POPULATION

4.1 Background Information

The development of MOVES (Motor Vehicle Emissions Simulator) by the U.S. EPA's Office of Transportation and Air Quality was in response to recommendations by the National Academy of Science. It replaced the existing MOBILE 6.2 model as the EPA's official model for State Implementation Plans (SIPs) and regional conformity determinations (Beardsley, Dresser, Hillson, Koupail, & Wariia, 2010). The model can produce emissions inventories at the national, county and project level, as well as emission factors. In addition, MOVES may be customized for a specific hour, day (weekday or weekend), month or year (U.S. Environmental Protection Agency). It can be used for a GHG inventory, as it directly calculates atmospheric CO_2 and $CO_{2,eq}$, which include N_2O and CH_4.

Along with the increase in customization of the MOVES model, the requirements for input information increases. When using MOBILE 6.2, the previous EPA approved model, to create an inventory, an extensive amount of post processing is required by the user. MOBILE 6.2 an emissions factor in grams/vehicle-mile, which must be used in post processing calculations to find emissions based on the number of vehicle miles traveled. In contrast, MOVES requires little post-processing by the user because the model completes those calculations required find a final value for total emissions. As a result MOVES requires the user input a large amount of information into the model (pre-processing). For the UCF Emission Inventory, a large amount of information specific to the UCF population was required by MOVES. The model was run using the "custom domain" option within the County Domain/Scale. Within the MOVES model a custom domain is defined as a geographic area that may consist of multiple counties, parts of counties, or combinations of counties and partial counties that can be described using a single set of inputs. A summary of local input data required can be found in Table 4-1 (U.S. Environmental Protection Agency, 2004).

Table 4-1: Required Inputs for Custom Domain in MOVES

Local Inputs for MOVES	
Age Distribution	Age fractions of fleet by age and source type
Avg. Speed Distribution	Speed distribution by road type, hour and source type
Fuel Supply	Market share of fuel blends
Fuel Formulation	Composition of fuel blends (RVP[*], sulfur, oxygenates, etc.)
Meteorology	Temperature and humidity inputs
Ramp Fraction	Fraction of freeway VHT[*] occurring on ramps
Road Type Distribution	Fraction of source type VMT on different road types
Source Type Population	Number of local vehicles operating in the area
Vehicle Type VMT	Total VMT by HPMS[*] vehicle class
Month VMT Fraction	Allocation factors to distribute annual VMT by month, day type (weekday vs. weekend), and hour
Day VMT Fraction	
Hour VMT Fraction	
I/M Programs	Description of I/M[*] programs, if any
Zone Road Activity	Allocates Source Hours Operating on each road type to zones

* RVP = Reid Vapor Pressure; VHT = Vehicle Hours Traveled; HPMS = Highway Performance Monitoring System; I/M Programs = Inspection and Maintenance Programs.

4.2 MOVES Methodology

The emissions from the personal vehicles of the UCF commuter population was calculated by running MOVES using the "Custom Domain" option within the County

Domain/Scale. The “Custom Domain” option creates a generic county for which there are no data available in the default database (U.S. Environmental Protection Agency). To utilize this customized option within the model, fifteen separate databases were created for spring, summer, and fall semesters of the 2009 calendar year. The fifteen databases consisted of five different databases to represent each UCF commuter population (Administration, Faculty, Staff/Other, Graduate and Undergraduate students) for each of the three different semesters of 2009. While the fifteen databases utilized the same ‘age distribution,’ ‘average speed distribution,’ ‘fuel formulation,’ ‘ramp fraction,’ and ‘road type distribution,’ other inputs were unique to each of the semesters, and to each of the UCF commuter groups. The MOVES default databases were used for the ‘average speed distribution,’ ‘fuel formulation’, ‘ramp fraction,’ and ‘road type distribution.’

While, using the “custom domain” option, a user cannot use default data within the MOVES database. To supply the UCF databases with MOVES default data, a Run Specification file was created at the county domain/scale for Orange County, FL, for 2009 for all road types and certain source types (motorcycle, passenger car, passenger truck, and light commercial truck). From the “County Data Manager,” default data was exported from the MOVES database. The exported data was then transferred into input files used to create the databases for the UCF Emission Inventory. Since, UCF is located within Orange County, FL, the default data from MOVES does not differ from data that would be supplied by the user for this inventory.

4.2.1 Age Distribution

In order to create an 'age distribution,' for UCF, information was supplied from the Parking & Transportation office. In order to purchase a parking permit, the purchaser is required to supply the model year of his or her vehicle; from this information a vehicle age distribution profile was created. The input file for 'age distribution' must provide a fraction of vehicles for each source type for each model year for the past 30 years (1979 – 2009). Originally, the 'age distribution' was to be formed from survey data. However, after realizing actual data could be gathered from the purchasing records of parking permits, it was used in place of the survey results. The vehicle age information was also thought to be more representative, as it also includes the vehicle age of purchasers of daily/visitor parking passes.

4.2.2 Fuel (Formulation and Supply)

MOVES requires two input tables for information regarding fuel: 'fuelformulation' and 'fuelsupply'. These two tables interact to define the fuels used in the area being modeled. The 'fuelformulation' table defines attributes of each fuel while 'fuelsupply' table identifies the fuel formulations used in an area and each fuel's respective market share values. MOVES has default gasoline and diesel fuel formulation and supply information for every county-year-month combination available. The default fuel information was developed from NMIM County Database and RFG Fuel Surveys for years up to 2005, and from the Energy Information Administration's Annual Energy Outlook from 2007, which projected fuel usage for 2012. Values for fuel properties between 2005 and 2012 were interpolated in order to achieve a consistent trend. The Default information for Orange County, FL for 2009 was used to supply the ‘fuelformulation’ and ‘fuelsupply’ input tables for UCF. Since, the MOVES database is supplied with region specific market share values for fuel blends the default data were used.

4.2.3 Average Speed Distribution

MOVES utilizes 16 different “speed bins” that describe the average driving speed on all road types. Input data is needed for average speed data specific to vehicle type, road type, and time of day/type of day. The user must enter the fraction of driving time in each speed bin for each hour/day type, vehicle type, road type, and average speed. The two day types considered in MOVES are week days and weekend days. The fractions entered must sum to one for each combination of vehicle type, road type and hour/day type specified. For the average speed distribution for UCF, the default input values were exported from the MOVES database for Orange County, FL. Table 4-2 lists the 16 speed bins and what range of speeds they represent.

4.2.4 Ramp Fraction

The term ‘ramp fraction’ is used to describe the fraction of ramp driving time on selected road types. Only if freeways and interstates, limited access road types, are to be modeled with MOVES does the program require this data to be entered. For Inventory calculations, such as the UCF inventory, MOVES automatically applies the default value of 8%. This default value was used in the UCF Emissions inventory

Table 4-2: Average Speed Bins used in MOVES

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc
1	2.5	speed < 2.5mph
2	5	2.5mph <= speed < 7.5mph
3	10	7.5mph <= speed < 12.5mph
4	15	12.5mph <= speed < 17.5mph
5	20	17.5mph <= speed <22.5mph
6	25	22.5mph <= speed < 27.5mph
7	30	27.5mph <= speed < 32.5mph
8	35	32.5mph <= speed < 37.5mph
9	40	37.5mph <= speed < 42.5mph
10	45	42.5mph <= speed < 47.5mph
11	50	47.5mph <= speed < 52.5mph
12	55	52.5mph <= speed < 57.5mph
13	60	57.5mph <= speed < 62.5mph
14	65	62.5mph <= speed < 67.5mph
15	70	67.5mph <= speed < 72.5mph
16	75	72.5mph <= speed

4.2.5 Road Type Distribution

MOVES requires data relating to the vehicle miles traveled by road type (roadtypeVMTfraction). The fraction of VMT by road type can vary from area to area and can have a significant impact on overall emissions from mobile sources. For each source (vehicle) type, the 'Road Type Distribution' table stores the distribution of VMT by road type. Each road type from the MOVES model is considered for the UCF emissions Inventory: Off-network, Rural Restricted Access, Rural Unrestricted Access, Urban Restricted Access, and Urban Unrestricted Access. Off-network describes locations where the predominant vehicle activity is vehicle starts, parking, and idling, i.e. parking lots, truck stops, rest areas, etc. Rural Restricted Access represents rural highways that can only be accessed by an on-ramp, Rural Unrestricted Access represents other rural roads (arterials, connectors, and local streets). Urban Restricted Access and Unrestricted Access represent urban highways and other urban roads.

Table 4-3: Road Type Distribution Input File for MOVES

sourceTypeID	roadTypeID	roadTypeVMTFraction
11	1	0
11	2	0
11	3	0.069172358
11	4	0.25541591
11	5	0.675411732
21	1	0
21	2	0
21	3	0.069172358
21	4	0.25541591
21	5	0.675411732
31	1	0
31	2	0
31	3	0.069172358
31	4	0.25541591
31	5	0.675411732
32	1	0
32	2	0
32	3	0.069172358
32	4	0.25541591
32	5	0.675411732

* The values for roadTypeVMTFraction were provided from the MOVES 2010a database,

4.2.6 Meteorological Data

Local temperature and humidity input are required for analysis with MOVES. Ambient temperature is a key factor in estimating emissions rates for on-road vehicles. Relative humidity is important for estimating NO_x emissions. A temperature in degrees Farenheit and relative humidity in percent are necessary for each hour that is to be modeled. The MOVES default 'meteorological' data, temperature and relative humidity, for Orange County, FL, were consistent with outside sources, and were also supplied to the UCF databases. The default MOVES information is based on 20 year averages from the National Climatic Data Center for the years 1971 to 2000. In addition to temperature and relative humidity, sea level pressure in inches of mercury must be entered. Sea level pressure is only required by MOVES for the "custom domain" option (U.S. Environmental Protection Agency, 2009).

4.2.7 Source Type Population and Vehicle Type VMT

Other information that must be entered into the UCF databases is particular to each UCF group analyzed for the spring, summer and fall semester of 2009. This information includes 'source type population' and 'vehicle type VMT.' These input files were supplied with data gathered from survey analysis. 'Source type population' information is the amount of vehicles of each source type. The source types that were included in this database are motorcycles, passenger cars, passenger trucks, and light commercial trucks. 'Vehicle type VMT' is the VMT sorted by HPMS vehicle class. HPMS vehicle classes identify vehicle types in a different manner than source types. For the inventory, the source types, passenger trucks and light commercial trucks were identified as one HPMS class, 'Other 2-axle-4 tire vehicles.' For motorcycles and passenger cars there is an equivalent HPMS vehicle class for each.

Information for both the 'source type population' and 'vehicle type VMT' was supplied from survey analysis. The results were entered into the 'source type population' input files. The data used to supply the input files can be seen in the tables below. Like the 'vehicle type VMT' distribution, the 'source type population' varied with each UCF commuter group for the spring, summer and fall semesters.

After the input information was compiled and entered into Excel files, a Run Specification file was created in MOVES for each of the fifteen databases. Each database was populated by uploading Excel Files containing input information into the MOVES graphical user interface (GUI). After the Run Specification file was populated with the appropriate database, the model was run and emissions were calculated. After each MOVES run, the results were exported from the MySQL output database files.

4.3 MOVES Results

4.3.1 Emissions from UCF Commuters

Overall the administration, faculty, staff/other and students produced 123,000 tons of CO_2, 247 tons of NO_x, and 213 tons of VOC. These results can be seen in Table 16. Between 68-71% of the emissions from commuters to UCF came from undergraduate students, and between 15-19% from graduate students. This is comparable with the percentage of VMT between the commuter populations at the university.

Like the percentage of emissions from students commuting in personal vehicles, 72% of VMT came from undergraduate students and 15% from graduate students. Again, in keeping with their contribution to emissions from UCF Commuters, administration at UCF only drove 1% of VMT, Faculty about 4% and staff/other contributed to 9% of VMT from the commuter population.

Table 4-4: Emissions from UCF Commuter Groups

UCF Group	CO_2, tons/year	NOx, tons/year	VOC, tons/year
Administrative	945	1.88	1.44
Faculty	4,902	9.77	8.16
Staff/Other	10,757	20.81	15.46
Graduate Student	18,179	44.05	40.13
Undergraduate Students	87,875	170.85	148.21
TOTAL	122,659	247	213

5. UCF SHUTTLE SERVICES

5.1 Background

UCF has an active and growing student shuttle bus service. It not only shuttles students to and from campus from nearby apartment complexes, but the service also runs shuttles to both the Rosen College of Hospitality Management campus in southwest Orlando, as well as the Health Sciences Campus at Lake Nona campus located south of the airport. The shuttles that transport students to and from student living facilities and UCF main campus are also in service on UCF College Football game days (5 hours before game and 2 hours after the game). On-campus shuttles (Black & Gold Line) transport students around campus to the most populated and important buildings and facilities. Another option for students who commute to campus is the “Park & Ride” shuttle, that runs from the Orlando Tech Center off Research Park to the Health Center (Lot C3), and Lot E8 to Burnett Honors College (Lot H2) , by the UCF Brighthouse Networks Stadium.

American Coach Lines keeps record of the number of riders, the miles driven, and the gallons of diesel fuel consumed for every month of the year. The information supplied by for this data can be found in Table 5-1.

Table 5-1: UCF Shuttle Information

2009 Shuttle Data			
Month	**Riders**	**Bus Mileage**	**Gallons of Diesel**
January	187,276	109,720	13,659
February	204,556	120,158	17,222
March	166,469	102,058	14,259
April	198,875	111,258	16,316
May	50,531	70,512	9,323
June	83,203	105,814	17,684
July	102,667	105,927	16,543
August	118,206	80,681	11,744
September	319,708	118,023	21,323
October	301,727	131,070	25,212
November	205,110	108,426	15,480
December	94,228	59,466	7,029
Totals	**2,032,556**	**1,223,113**	**187,047**

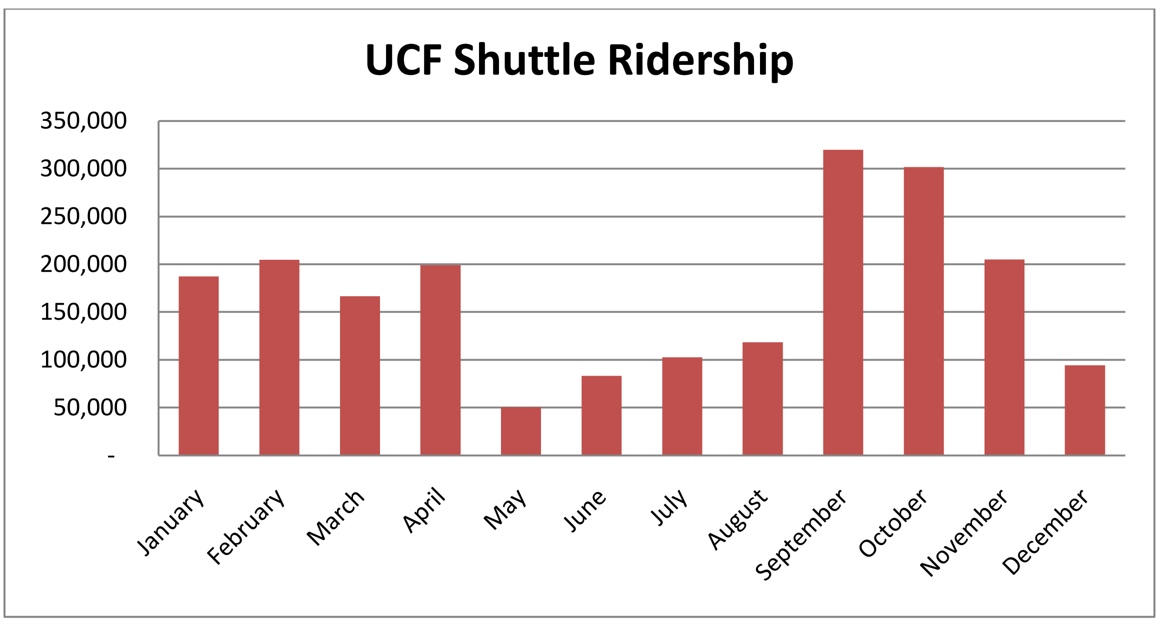

Figure 5-1: UCF Shuttle RIdership by Month

5.2 Methodology

In order to calculate CO_2 emissions from the UCF shuttle service, an emission factor from the U.S. Department of energy was used. The amount of CO_2 emitted from the campus shuttles was estimated by multiplying the number of gallons of diesel fuel consumed by the DOE emission factor.

$$gallons\ of\ Diesel\ Fuel \times \frac{10.15\ kg\ CO_2}{gallon\ of\ Diesel\ Fuel} = kg\ CO_2 \quad (5.1)$$

It was of interest to calculate the NO_x and VOC emissions from the UCF Shuttles in order to compare results with the 2008 Central Florida Emissions Inventory. Therefore, MOBILE6 emissions factors were used. Unlike the emission factors to calculate CO_2, MOBILE6 EFs are mileage based. Since mileage data was provided for the UCF shuttle service, MOBILE 6 emission factors were used. Equations 5-2 & 5-3 display the EFs and method used to estimate NO_x and VOC emissions from the UCF Campus Shuttles.

$$Number\ of\ Miles\ Driven \times \left(\frac{17.306\ g\ NO_x}{Mile}\right)_{Diesel\ Bus} = g\ NO_x \quad (5.2)$$

$$Number\ of\ Miles\ Driven \times \left(\frac{0.68 g\ VOC}{Mile}\right)_{Diesel\ Bus} = g\ VOC \quad (5.3)$$

5.3 Results

In 2009, the UCF Campus Shuttle service emitted 2,000 tons of CO_2, 23 tons of NO_x, and 0.9 tons of VOC. American Coach Lines provided detailed information for every month of service in 2009, therefore emissions per month can be seen in the Table 5-2.

Table 5-2: Emissions for UCF Campus Shuttle Buses

Month	tons CO_2	tons of Nox	tons of VOC
January	153	2.09	0.08
February	195	2.22	0.09
March	159	1.95	0.08
April	182	2.12	0.08
May	104	1.35	0.05
June	198	2.02	0.08
July	185	2.02	0.08
August	131	1.54	0.06
September	239	2.25	0.09
October	282	2.50	0.10
November	173	2.07	0.08
December	79	1.13	0.04
Totals	2,081	23.27	0.92

5.4 Estimated CO_2 Savings from UCF Shuttle Services

The weighted average one-way distance traveled by the local shuttle buses was about 2.6 miles/trip. This average distance was taken as the average distance that would have been traveled by students in their cars, had the shuttle service not existed. For the equivalent student car trips to the main campus (with average one-way distance of 2.6 miles), there are often parking difficulties. Therefore, 10% of the average distance from local student apartments to campus (0.26 miles) was added to represent the extra distance driven (and time idling) while hunting for a parking spot. Using Google maps to estimate mileage, it was found that the one-way trip to Rosen College was 28.8 miles and the one-way trip to the Health Sciences Campus in Lake Nona is 23.5 miles. Extra distance was not added for parking at those sites.

American Coach Lines, the shuttle system, transported 2,032,556 student riders in 2009. Since, the number of student riders may vary between shuttle routes; we examined the number of one-way trips for each of the different shuttles instead of the student rides. Information on the various shuttle routes and corresponding mileage can be seen in Table 5-3. There were approximately 522,000 one way trips near campus, 1,700 trips to Rosen, and 2,500 trips to Lake Nona.

Table 5-3: Shuttle Route Information

UCF Destination	Number of (one-way) trips/year	Average trip length (miles/one-way trip)	Mileage per year
UCF Main Campus*	522,586	2.2	1,141,851
Rosen College	1,690	28.8	48,672
Health Sciences Campus (Lake Nona)	2,532	23.5	59,502
TOTAL	526,808		1,250,025

*Note: Shuttles whose destination is the UCF Main campus encompass shuttles from nearby campus living facilities including Football Gameday Shuttles, along with Park N Ride shuttles, and on-campus shuttle routes.

Since, American Coach Lines only provided information on the total student riders, instead of the number of riders per route, the previously mentioned weighted average trip length for the included routes of 2.86 miles (2.6 miles + 10%) was used. A CO_2 emission factor from the UCF commuter groups was calculated by taking the total emissions from the UCF commuters and dividing it by the total estimated mileage of UCF commuters. It was found to be 475 g CO_2/mile. Next, we assumed that when students travel by car, they average 1.2 students per car (note that this assumption is validated from student survey responses). The number of car trips avoided was calculated by dividing the total number of student rides on the shuttle (2 million) by the 1.2 students per car to get 1.69 million car trips avoided. The following equation was used to estimate the CO_2 emissions if the 1.69 million car trips were driven by student commuters.

$$\left(\frac{475\ g\ CO_2}{mile}\right) \times \left(\frac{2.86\ miles}{trip}\right) \times (1.69 \times 10^6\ trips) \times \left(\frac{ton}{907{,}000\ g}\right) = 2{,}537\ \frac{tons\ CO_2}{year} \quad (5.4)$$

Finally the CO_2 saved is found by subtracting the total CO_2 emissions from UCF shuttles (2091 tons) from 2,537 tons of CO_2. The CO_2 emissions averted by students riding the shuttle buses rather than drive in their own cars are about 446 tons a year. Table 5-4 presents those results.

Table 5-4: CO_2 Averted by UCF Shuttle Services

UCF Group	Data Entry	Units
No. of student rides on shuttle per year	2	million
No. of car trips avoided	1.69	million
Car-miles avoided/trip	2.86	miles
Emiss. of CO_2 /car-mile	475	grams/mile
Emiss. of CO_2 by cars	2,537	tons/year
CO_2 from UCF Shuttles	2,091	tons/year
CO_2 averted	446	tons/year

6. UCF FLEET, NON-ROAD VEHICLES, & MAINTENANCE EQUIPMENT

The University of Central Florida has an on-campus fuel pumping station. At this station, biodiesel fuel (B20), gasohol (E10), and ultra-low sulfur off-road diesel fuel (ULSD) are available. The UCF Fleet Vehicles and campus non-road equipment obtain fuel from this station. The UCF Fleet consists of total of 417 vehicles; 73 pick-up trucks, 54 Sport Utility Vehicles, 123 vans, 114 cars, 2 heavy trucks, and 53 other vehicles. Other vehicles include ambulances, non-road vehicles like golf carts, ATVs, four-wheelers, and electric cars. The total volume of gallons of fuel pumped from the on-campus station and gallons of fuel purchased for UCF Fleet vehicles was provided by the Department of Sustainability and Energy Management.

6.1 Methodology

The CO_2 emissions for both the UCF Fleet and non-road vehicles, and maintenance equipment were calculated using emission factors from the U.S. Department of Energy. The following equations list the emissions factors for the various fuels available at the pumping station.

$$154{,}460\ gallons\ of\ E10 \times \frac{7.978\ kg\ CO_2}{gallon\ of\ E10} \times \frac{ton\ CO_2}{907\ kg\ CO_2} = 1{,}359\ tons\ of\ CO_2 \tag{6.1}$$

$$10{,}324\ gallons\ of\ B20 \times \frac{8.115\ kg\ CO_2}{gallon\ of\ B20} \times \frac{ton\ CO_2}{907\ kg\ CO_2} = 92\ tons\ of\ CO_2 \tag{6.2}$$

$$815\ gallons\ of\ ULSD \times \frac{9.942\ kg\ CO_2}{gallon\ of\ ULSD} \times \frac{ton\ CO_2}{907\ kg\ CO_2} = 8.9\ tons\ of\ CO_2 \tag{6.3}$$

NO_x and VOC Emissions were only tabulated for on-road sources, using the same emissions factors from MOBILE6 used in the Central Florida Emissions Inventory. With knowledge that the

2009 combined miles per gallon ratio for cars and trucks is 21.1 mpg, and the gallons of fuel purchased, an approximate VMT can be calculated for Fleet Vehicles with purchased fuel records. It is estimated that from purchasing records, UCF Fleet vehicles drove about 3,300,000 miles, see Equation 6-4.

$$154{,}460\ gallons \times 21.1\ mpg = 3{,}256{,}106\ miles \tag{6.4}$$

From this estimated mileage and MOBILE 6 EFs the NO_x and VOC emissions can be calculated. These calculations can be seen in Equations 6-5 & 6-6. It is important to note that these emissions do not encompass UCF fleet vehicles, but only those vehicles for which fuel was purchased off campus.

$$3{,}256{,}106\ miles \times \frac{0.697\ g\ NO_x}{mile} \times \frac{ton\ NO_x}{907{,}000\ g\ NO_x} = 2.50\ tons\ NO_x \tag{6.5}$$

$$3{,}256{,}106\ miles \times \frac{0.936\ g\ VOC}{mile} \times \frac{ton\ VOC}{907{,}000\ g\ VOC} = 3.36\ tons\ VOC \tag{6.6}$$

6.2 Results

The following table summarizes the emissions results for the UCF Fleet Vehicles and maintenance equipment. The NO_x and VOC emissions from B20 (biodiesel) and ULSD (Ultra Low Sulfur Diesel) were about 0.09 tons and therefore not included in the results.

Table 6-1 Emissions from UCF Fleet Vehicles & Maintenance equipment

Source	tons of CO_2	tons of NOx	tons of VOC
UCF Fleet Vehicles			
E10 (gasohol)	1,359	2.50	3.36
B20 (biodiesel)	92		
Maintenance (non-road)			
Ultra low Sulfur Off road diesel	8.9		
TOTAL	1,460	2.50	3.36

**NOx and VOC emissions from B20 & ULSD are negligible (about 0.09 tons) and do not contribute to overall emissions.*

7. BUSINESS TRAVEL

7.1 Methodology

The CO_2 emissions from business travel were calculated using records for rental car, train, and airline mileage reported from the Office of Accounting. The emissions factors used in these calculations are from the U.S. EPA and the U.K. Department for Environment, Food & Rural Affairs (UK DEFRA), which are approved by the Intergovernmental Panel on Climate Change (IPCC) and other NGO's, such as the World Research Institute (Greenhouse Gas Protocol, 2009). NO_x and VOC emissions were not calculated for business travel. NO_x and VOC emissions are regional air pollutants and any emitted from business travel do not contribute to the local regional air pollution. Emissions Factors used for business travel are listed in Table 7-1.

Table 7-1: Emission Factors used for UCF Business Travel

Source	Emissions Factor
GHG Protocol	0.23 Kg CO_2/passenger mile (car)
UK DEFRA	0.163 kg CO_2/passenger mile (train)
	0.308 kg CO_2/passenger mile (airline)

7.2 Results

Table 7-2: Emissions from UCF Business Travel

UCF Business Travel for Calendar Year 2009						
	Car		Train		Airline	
Month	**Mileage**	**tons CO_2**	**Mileage**	**tons CO_2**	**Mileage**	**tons CO_2**
January	148,363	37.6	569	0.10	713,788	242
February	217,801	55.2	1,506	0.27	975,522	331
March	214,162	54.3	0	0.00	638,368	216
April	218,698	55.5	430	0.08	1,147,400	389
May	252,460	64.0	0	0.00	903,240	306
June	193,481	49.1	612	0.11	1,307,227	443
July	189,220	48.0	646	0.12	1,270,181	431
August	141,464	35.9	7,357	1.32	1,286,787	436
September	84,969	21.5	977	0.18	1,162,994	394
October	159,387	40.4	0	0.00	1,412,762	479
November	162,634	41.2	0	0.00	1,265,783	429
December	173,033	43.9	0	0.00	1,215,796	412
Total	2,155,672	547	12,097	2.17	13,299,848	4,509

8. DISCUSSION

The annual mobile source-related emissions inventory for the UCF main campus in Orlando, FL, for 2009 is summarized in Table 8-1. Both atmospheric CO2 and CO2,eq were modeled with MOVES and resulted in equal emissions for both pollutants. Again, as previously stated if N2O and CH4 were to be included in tons of CO2,eq there would be a negligible difference, if any, between tons of CO2 and CO2,eq. This negligible difference is due to the fact that only mobile sources were considered for the UCF Emissions Inventory because there are no point sources at the university.

Table 8-1: UCF Emissions Inventory for 2009

UCF Group	tons CO_2/yr	tons NOx/yr	tons VOC/yr
Administrative	945	1.88	1.44
Faculty	4,902	9.77	8.16
Staff/Other	10,757	20.8	15.5
Graduate Student	18,179	44.0	40.2
Undergraduate Students	87,875	171	149
UCF Shuttle	2,092	23.3	0.91
UCF Fleet Vehicles	1,451	2.50	3.36
Maintenance	8.93		
Business Travel			
Car	547		
Train	2.20		
Airline	4,509		
TOTAL	**131,269**	**273**	**218**

**NOx and VOC emissions from B20 & ULSD are negligible and do not contribute to overall emissions*

***NOx and VOC emissions from Business Travel do not contribute to the OSO regional air quality*

As can be seen in Table 8-1, UCF contributed about 131,000 tons of CO2 emissions, 272 tons of NOx emissions, and 217 tons of VOC emissions in 2009. About 80% of these emissions were due to students commuting to and from campus, and about 15% came from local commuting by faculty, staff, and administrators. A small amount came from university maintenance activities (mostly lawn and garden), and a large amount came from business-related airline travel, about 5,100 tons of CO2.

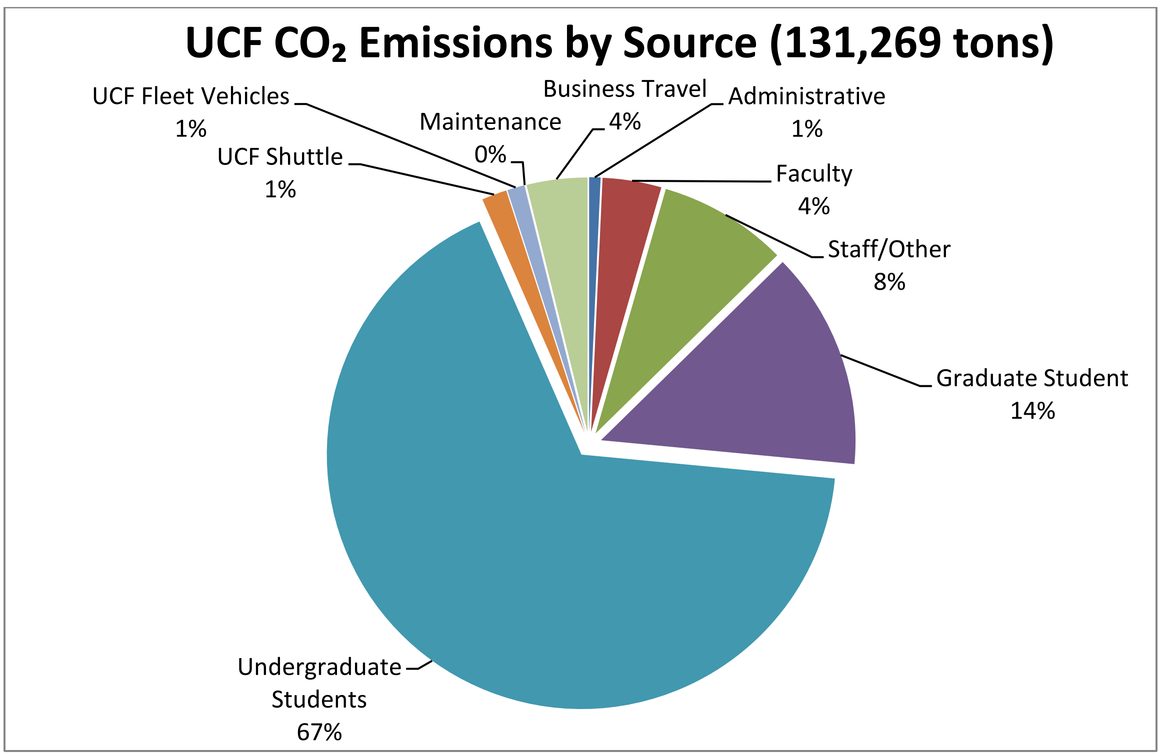

Figure 8-1: Carbon Dioxide Emissions by Source

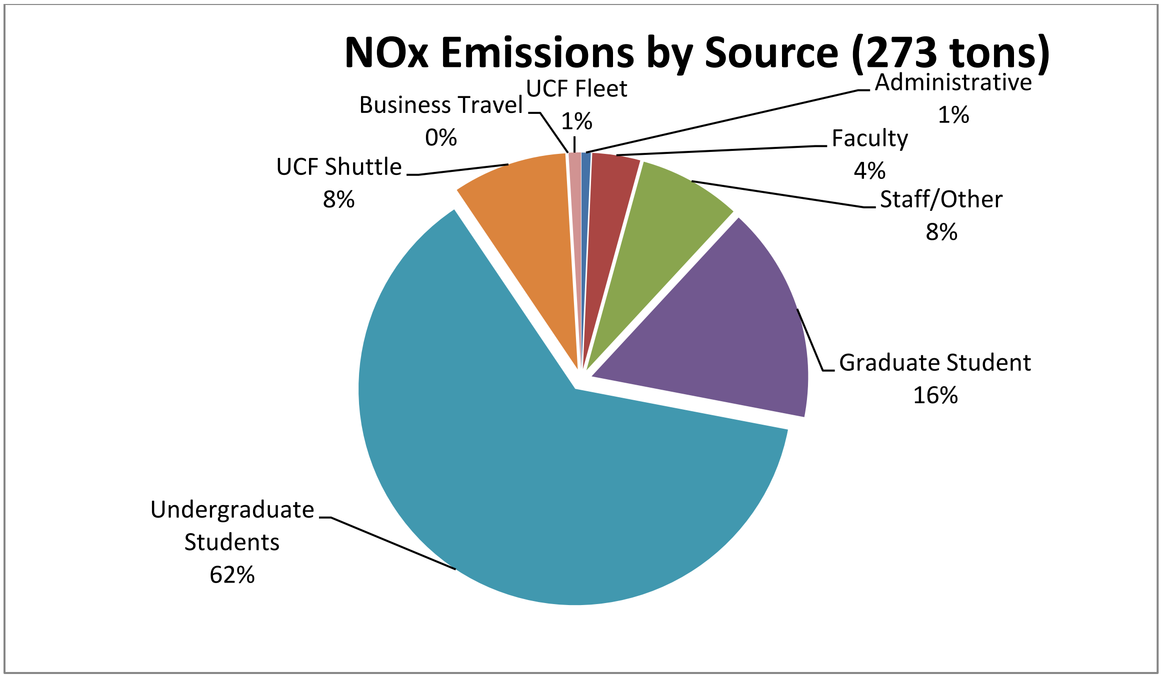

Figure 8-2: NOx Emissions by Source

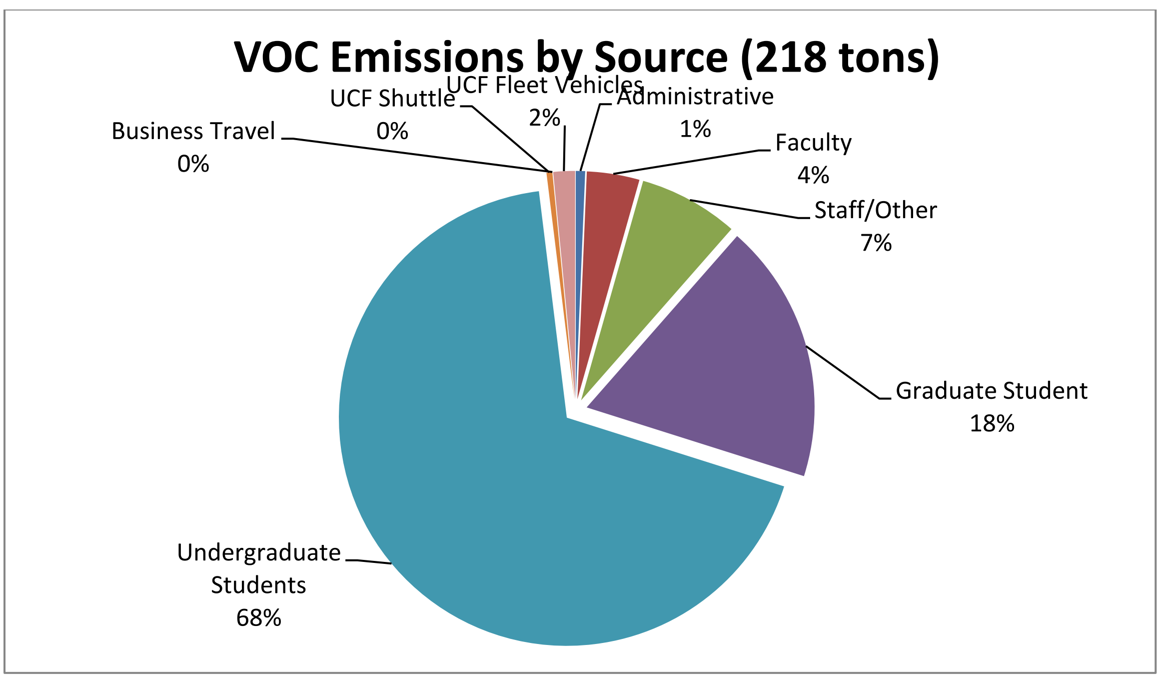

Figure 8-3: VOC Emissions by Source

8.1 Comparison With 2008 Central Florida Emissions Inventory

The final results of the UCF Emissions Inventory were compared to the 2008 Central Florida Emissions Inventory. Only the on-road and non-road mobile sources from Orange County were included in the table, so as to better compare results with the UCF 2009 Emissions Inventory without extraneous information. Again, there were no point and area source emissions from UCF. While the 2008 Central Florida Emissions Inventory did encompass a three county area, only the results from Orange County are listed in the Table 8-2, because that is the county in which UCF's main campus is located. The point and area sources for Central Florida in 2008 were tabulated but not included in the table. The Central Florida area includes Orange, Seminole, and Osceola counties. The point sources produced 1,901 tons of VOC, 10,987 tons of NO_x, and 8,267,199 tons of CO_2. The area source emissions consisted of 30,648 tons of VOC, 158 tons of NO_x and 147,153 tons of CO_2. Interestingly, the total on-road CO_2 emissions due to UCF is about 1.5-2% of the total CO_2 emissions from mobile sources for Orange County, FL, (Ross, 2011). Comparably, both NO_x and VOC emissions from UCF contributed to nearly 1% of the VOC and NO_x emissions from mobile sources for Orange County.

Table 8-2: Comparison between UCF & Central Florida Emissions Inventory

SOURCE	Central Florida Area - Orange County			University of Central Florida		
	VOC (tons/yr)	NOx (tons/yr)	CO_2 (tons/yr)	VOC (tons/yr)	NOx (tons/yr)	CO_2 (tons/yr)
On-road	15,304	24,487	8,185,289	220	275	126,749
Non-road	7,444	5,977	792,303			4,520
TOTALS	22,748	30,464	8,977,592	220	275	131,269

**NOx and VOC emissions from non-road sources within UCF are negligible (about .09 tons) and do not significantly contribute to overall emissions.*

***NOx and VOC emissions from UCF Business Travel do not contribute to the OSO regional air quality*

At first, it might seem surprising that the UCF commuter population would contribute such a large percentage (1.5-2%) of mobile source emissions for Orange County. However, the UCF populations of 59,000 people (students plus employees) are about 5 percent of the population of Orange County, which was estimated to be about 1.1 million in 2009(U.S. Census Bureau). Of course, there are a number of other factors besides population, such as commuter habits that influence the university's impact on local air pollution emissions. It is more appropriate to consider VMT. The total estimated mileage driven from the personal vehicles of the UCF commuter population and business travel (car) was 1.5-2 percent of the total vehicle miles traveled in Orange County for 2009.

A college/university is a unique environment and is unlike most other commuter populations. Generally, the 'workforce' travels from home to work and from work to home at the end of the day. However, this is not the case for university students. Only administration and staff/other follow a typical commuter pattern, while some faculty follow a pattern that more closely resembles that of the student population. This makes sense, because faculty teaches the classes that students attend. In fact, from survey results, students were shown to travel consistently throughout the day to and from campus from about 6:00 am to 5:00 pm. Classes are offered throughout the day, from 7:30 am to 7:00 pm. As a result, classic commuting assumptions cannot be used to predict travel patterns of college students. Figure 8-4 was constructed from survey data; it shows a percent distribution of arrival times for the different UCF commuter groups. Administration and staff/other generally arrived on campus between 6:00 and 10:00 am. Faculty generally followed the same pattern, but varied slightly more than administration and staff/other, because some faculty only teaches night classes.

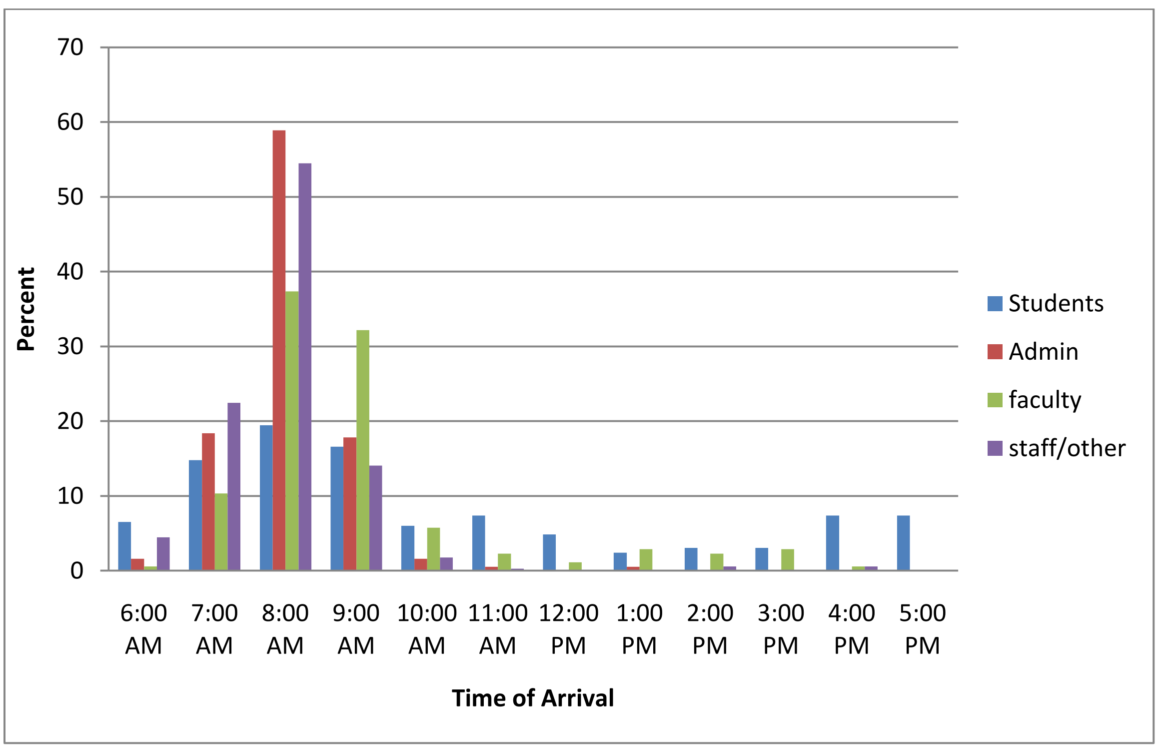

Figure 8-4: Percent Distribution of Arrival Times for UCF Commuter Population

8.2 Comparison with University of Maryland

A growing number of colleges and universities are completing an emissions inventory in an effort to decrease their carbon footprint and increase sustainability. ACUPCC has signatures from presidents/chancellors from approximately 680 different universities, colleges, and community colleges throughout the United States (ACUPCC). From the UCF emissions inventory it is evident that a survey was necessary to produce accurate data representing the university's population. After this study was completed, it was found that a previously completed inventory for UCF may have underestimated CO_2 emissions from transportation by a factor of 3 due to inaccurate assumptions used to estimate the VMT driven by student commuters (University of Central Florida, 2009). This proves that surveying a population is the better method to estimate VMT (and therefore emissions) for a university or even a corporation.

The UCF inventory was also compared with some studies recently completed by other universities. UCF emits larger amounts of CO_2 than most other universities. This is due mostly to the fact that UCF has a very large student population compared with other universities (UCF is now the second largest university in the country based on student population). Also, UCF has a higher percentage of commuter students than many other universities, and many students travel far distances within our service area. Furthermore, several of the universities did not include calculations for the summer semester, whereas UCF has an active summer program, and its emissions in summer were included in our study.

A comparable university emissions inventory that we found reported in the literature was for the University of Maryland: College Park Campus (UMD). UMD is a large urban university, and did a CO_2 emissions inventory for 2009. For the fall 2009 semester, the total student population enrolled at UCF was 53,466 with a total campus population (including faculty, staff, administrators, and others) of 58,620, while the University of Maryland had 34,437 students and a total campus population of 43,577(University of Maryland, 2009). A comparison of the 2009 CO_2 emissions between UCF and UMD is presented in Table 8-3.

Table 8-3: Comparison of 2009 CO_2 Emissions Inventory for UCF and UMD

Group	University of Central Florida Total tons CO_2/yr	University of Maryland Total tons CO_2/yr
Faculty/Staff Commuting	15,659	20,175
Student Commuting	106,054	21,566
Shuttle	2,092	2,218
University Fleet Vehicles	1,451	4,486
Total	**125,256**	**48,446**

As seen in Table 8-3, while the emissions from faculty/staff commuting and the student shuttle buses are almost identical, student-related emissions from UCF are much higher than at UMD. The large difference between UCF and UMD student commuting emissions likely is due to (1) the larger UCF population, (2) the greater percent of commuters at UCF, (3) the fact that summer semester travel was not included for the UMD study, (4) the use of MOVES in the UCF study versus using a gasoline consumption model for student travel in the UMD study, and (5) the fact that in the UMD study, several simplified assumptions about student travel behavior were made, whereas the UCF study, a detailed survey of student travel behavior was conducted. The University of Maryland study estimated that the total miles driven by student commuters for the Fall and Spring 2009 semesters was 106,099,010 (University of Maryland), while the miles driven by the UCF student commuter population was much larger for the same semesters at 177,823,256 miles, respectively. Furthermore, UCF students traveled an additional, 37,540,920 miles in the summer 2009 semester.

In addition to total CO_2 emissions, the student emissions rate per capita was calculated for UCF and for UMD. The annual student commuting emissions were added to the shuttle emissions, and the total was divided by the total fall semester student population for each school. The per capita student emissions rate was about 0.6 tons per UMD student and about 1.8 tons per UCF student, or three times as high. The difference in the per capita emissions rates for UCF and UMD seems to be quite large, but perhaps can be explained by three key assumptions in the UMD study. Those assumptions made by the UMD researchers were: (1) that students commuted only 160 days/year, (2) that students made only one round trip per day and (3) summer semester was not counted. In the UMD study, each commuting student thus made only 160 round trips per year (University of Maryland, 2009). In the UCF study, based on actual survey responses, we found that a significant number of students made more than one round trip per day. When dividing the total number of trips made per year (including summers) by the total fall enrollment, UCF students averaged about 250 round trips per year.

It is noted that university fleet vehicle emissions are significantly higher for UMD than for UCF. The university fleet for UMD includes equipment for the UMD golf course, building and landscape services, agricultural equipment, dining services equipment, and others (University of Maryland, 2009). The UCF fleet includes lawn & garden equipment, maintenance equipment, and department/college vehicles. The University of Central Florida fleet does not provide maintenance for a golf course nor includes dining services equipment; this is most likely the cause of the difference in CO_2 emissions for the university fleet between UCF and UMD.

With a growing awareness of climate change, it is has become popular among different organizations, corporations and colleges/universities to estimate their sustainability by focusing on energy management from a GHG Inventory. Most of these methods are consumption based and categorize emissions from transportation as “optional” or “indirect.” However, from both the Central Florida, and UCF Emissions Inventories the largest producers of VOC, NO_x, and CO_2 were from on-road mobile sources. Also, a GHG inventory neglects to quantify VOCs and NO_x, which are precursors to ozone. Ozone is strictly regulated by the EPA. In fact, the Central Florida region is in danger of becoming ozone non-attainment (Ross, 2011). It is also expected that the current EPA ozone standard of 75 ppb will be lowered to roughly 65 ppb in July 2011.

9. CONCLUSIONS & RECOMMENDATIONS

For the 2009 Mobile Source Emissions Inventory for UCF, the recent EPA mobile source emissions model (MOVES2010a) was used to generate the CO_2 , VOC, and NO_x emissions from on-road vehicles for the UCF commuter population. Mileage-based emission factors from MOBILE6 were used to calculate VOC and NO_x emissions from on-road vehicles. Fuel-use-based emission factors for CO_2 were used for UCF Shuttles and non-road equipment. Mileage-based emission factors were used to estimate CO_2 emissions from business-related car, train and airline travel. Although it represented considerably more work than other approaches, the methodology of this study is thought to be more accurate and comprehensive than that used in past studies by other universities.

To assess an organization's contributions to local air pollution emissions, it is necessary to include VOCs, NO_x, as well as CO_2. The 2009 UCF Emissions Inventory was compared to a recently completed 2008 Emissions Inventory of Central Florida and in both studies mobile sources were found to emit the most VOC, NO_x and CO_2. In order to avoid assumptions that result in inaccurate data, surveying the population is a better procedure to gather the necessary information to compute an emission inventory.

9.1 UCF Commuters

The UCF Commuter population contributed 94% of CO_2, 91% of NO_x, and 98% of VOCs from UCF-related mobile sources. The student population was responsible for 80% of UCF emissions due to transportation. In summer semester of 2009 the student commuter population decreased by 30% compared with spring 2009. This reduction was enough to greatly reduce miles driven while searching for parking. Reducing the student population is not an option, but increasing the number of students per vehicle is a very viable option. As a result of increasing the number of riders per vehicle, the number of commuter vehicles decrease as well as emissions from those vehicles. The following sections list recommendations for the University of Central Florida to reduce overall emissions.

9.1.1 Implement Carpooling Programs

Before the start of the 2010-2011 Academic year, UCF began a "Zimride" carpooling program. Zimride is a nationwide carpooling service that caters to universities and businesses (Zimride). There were 543 active rides posted on December 1, 2010 for the UCF program. There is no accurate method for tracking ridership participation and consequently the emissions reduction achieved. The goal of this program is to connect UCF students, faculty, and staff with rides to and from campus as well as throughout the area. It is recommended that UCF continue and encourage implementation of the Zimride program for the university.

9.1.2 "Free" Transit for UCF Students

Another recommendation to reduce UCF emissions is an unlimited access program. A number of universities partner with the public transit system to provide unlimited access to students. Unlimited Access means that students are granted the right to ride public transit without paying a fare. The university, in this case, UCF, would pay LYNX an annual lump sum based on expected student ridership. The student must provide a valid student identification card to board the bus. Both Florida State University and the University of Florida currently offer this program. Universities that offer Unlimited Access range in size from 4,500 students

(Edmonds Community College) to 49,000 students (University of Texas) (Champion, 2010). It has been noted that after implementation of Universal Access program, no university has discontinued this program. When asked to comment as on the program, various campus officials have stated that the program reduces demand for parking, increases students' access to housing and employment, helps recruit and retain students, reduces cost of attending college, and increases transportation equity.

The university students would not be the only beneficiaries of such a program. The Local Transit authorities that participated in this program reported an increase in ridership, a guaranteed revenue stream, and improved overall transit service (Champion, 2010). At an average of $30 per student per year, and using the fall 2010 UCF student population of 56,000, LYNX could expect approximately $1,680,000 of additional funding if this program were implemented.

To estimate potential reduction in emissions, we used survey data. From the survey conducted in this study it was found the average undergraduate student commutes 14 miles per one way trip to UCF. From a survey of 35 universities that participate in an Unlimited Access program, the average number of rides provided by schools of comparable size to UCF was 2,221,000 rides (Brown, Hess, & Shoup, 2001). If implemented, this program could potentially decrease UCF emissions by 45.6 tons of VOC (21%), 29.1 tons of NO_x (11%), and 15,750 tons of CO_2 (12%). This equates to $74 per ton averted, see Equation 9-1.

$$Annual\ Cost = \frac{\$1{,}168{,}000}{(45.6+29.1+15{,}750)} = \$74/ton \qquad (9.1)$$

9.1.3 ZipCar

About 225 universities across North America use Zipcar, including the University of Florida, and the University of Miami. This recommendation is the leading car sharing network throughout the U.S., Canada, and the U.K. Zipcar estimates that each car that is shared within its network takes 15 to 20 privately owned vehicles off the road. It has been recently featured in the news media as a features story on *MSNBC: Your Business Learning from the Pros: Zipcar CEO Scott Griffith* and in featured articles of The Economist, TIME Magazine and The Washington Post (Zipcar, 2010). The Company's official policy in response to inquiries from students/researchers is to refer them to the Zipcar website.

At the University of Florida, students, faculty and staff may join the program for $35 a year. By joining, they get 24/7 access to Zipcars that are parked on campus. Hourly and Daily rates include gas, insurance and 24 hours roadside assistance. A reservation must be made by phone, the Zipcar website, or the application downloadable to an Iphone or Android cell phone (Zipcar, 2010).

As of January 2010, Zipcar announced a partnership with Zimride in order to expand car and ride sharing application for college campuses. A Zipcar-Zimride application allows students to share a ride by posting the date, time and destination. The algorithm finds and notifies users, and will now include the ability find and share a local Zipcar. This partnership is predicted to reduce congestion, parking demand and CO_2 emissions. This combined program is already in effect at UCLA, UC Santa Barbara, UC Santa Cruz, California State University, USC, The State

University of New Your (SUNY) Purchase, Minnesota, Stanford and University of Michigan (Zipcar, 2010).

According to the company's calculations, the implementation of Zipcar at universities reduce carbon emissions by nearly 56 million pounds (28,000 tons), which is the equivalent emissions of over 4,800 passenger vehicles. With Zimride already implemented at UCF, it seems that Zipcar would be an amenable option to reduce transportation emissions at the university.

APPENDIX A: SURVEY

UCF Sustainability Survey

UCF Sustainability Survey

We need your help so that UCF can be included among a select group of environmentally conscious colleges and universities. You can help by giving us information about your daily commute to UCF Main Campus. By participating in this survey, you will help the Department of Sustainability and Energy Management collect data that is imperative for UCF to accurately calculate its carbon footprint. Please donate a few minutes of your time. Thank you!

UCF Sustainability Survey

Basic Information we need...

1. What is your involvement with UCF?

- ◯ Faculty
- ◯ Administrative
- ◯ Staff
- ◯ Undergraduate Student
- ◯ Graduate Student
- ◯ Other

UCF Sustainability Survey

Residence

2. Do you live on campus?

- ☐ Yes
- ☐ No

Student Resident

3. Since you live on campus, how do you travel from your residence hall to class?

- ◯ walk/bike
- ◯ drive to a closer parking lot/garage
- ◯ UCF Shuttle
- ◯ Other

UCF Sustainability Survey

Distance Traveled

4. How far do you live from UCF main campus (in miles)?

- ◯ 0 to 2
- ◯ 3 to 5
- ◯ 6 to 8
- ◯ 9 to 12
- ◯ 12 to 15
- ◯ 16 to 20
- ◯ 21 to 25
- ◯ 26 to 30
- ◯ 31 to 40
- ◯ If more than 40, please specify mileage

5. What is the closest intersection to your home? (list street names, e.g. Rouse Road and University Blvd.)

Street 1

Street 2

UCF Sustainability Survey

Vehicle Information

6. What kind of vehicle do you drive to UCF Main Campus?

- ◯ Car
- ◯ Small SUV, small pick-up truck, or minivan
- ◯ Large SUV, large pick-up truck or large van
- ◯ Motorcycle, moped, or similar
- ◯ I don't drive a vehicle to campus

UCF Sustainability Survey

Year of Vehicle

7. What year is your vehicle?

	2011 - 1979
Year	

UCF Sustainability Survey

8. Do you 'Carpool' to UCF main campus?

- ◯ Yes
- ◯ No

UCF Sustainability Survey

Carpooling

9. On average, how many times a week do you carpool with another person/s to UCF during the FALL/SPRING Semester?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

10. On average, how many times a week do you carpool with another person/s to UCF during the SUMMER Semester?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

11. When you carpool, how many people (including you) travel in your vehicle to UCF main campus?

- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

UCF Sustainability Survey

Fall/Spring Semester

12. How many one way trips (in your vehicle) from your residence to UCF main campus do you make each week during the FALL/SPRING Semester?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7 to 8
- ◯ 9 to 10
- ◯ If 11 or more, please state how many trips.

13. What time of day do you typically arrive on campus during the FALL/SPRING Semester?

Hour

14. On Average, how long does it take you to find a parking spot on UCF main campus during the FALL/SPRING Semester?

- ◯ 2 minutes or less
- ◯ 3 - 5 minutes
- ◯ 5 - 10 minutes
- ◯ 10 - 15 minutes
- ◯ 15 - 20 minutes
- ◯ 20 - 30 minutes
- ◯ 30 minutes or longer
- ◯ I do not park on UCF Main campus

15. Do you travel to UCF Main Campus during the SUMMER Semester?

- ◯ Yes
- ◯ No

UCF Sustainability Survey

Summer Semester

16. How many one way trips (in your vehicle) from your home to UCF do you make each week during the SUMMER Semester?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7 to 8
- ◯ 9 to 10
- ◯ If 11 or more, please state how many trips.

17. What time of day do you typically arrive on campus during the SUMMER Semester?

Hour

18. On Average, how long does it take you to find a parking spot on UCF main campus during the SUMMER Semester?

- ◯ 5 minutes or less
- ◯ 6-10 minutes
- ◯ 11-15 minutes
- ◯ 16-20 minutes
- ◯ 21-30 minutes
- ◯ 30 minutes or longer
- ◯ I do not park on UCF Main Campus

Other Transportation

19. Since you checked "I don't drive a vehicle to campus," how do you travel to UCF Main campus?

- ◯ UCF Shuttle
- ◯ Carpool
- ◯ Lynx Bus
- ◯ Bicycle
- ◯ Walk

UCF Sustainability Survey

20. Thank you for participating! How much time did it take you to complete this survey?

- ◯ 0 to 2 minutes
- ◯ 2 to 4 minutes
- ◯ 4 to 7 minutes
- ◯ 7 to 10 minutes
- ◯ more than 10 minutes

APPENDIX B: SURVEY INFORMATION FLOW DIAGRAM

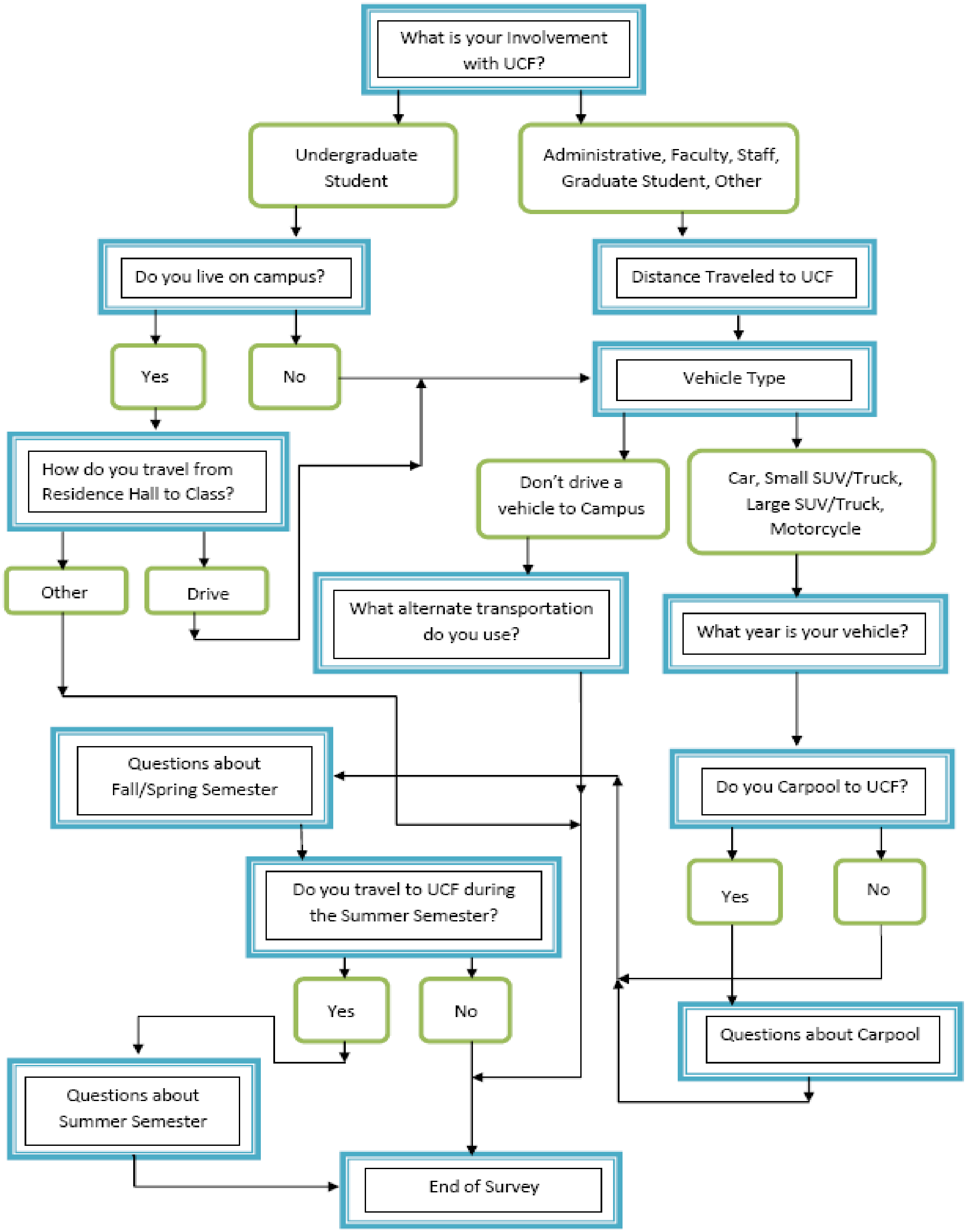

Figure B-1: Information Flow Diagram of Survey Questions and Reponses

APPENDIX C: SURVEY INTRODUCTION

UCF Sustainability Survey

UCF Sustainability Survey

We need your help so that UCF can be included among a select group of environmentally conscious colleges and universities. You can help by giving us information about your daily commute to UCF Main Campus. By participating in this survey, you will help the Department of Sustainability and Energy Management collect data that is imperative for UCF to accurately calculate its carbon footprint. Please donate a few minutes of your time. Thank you!

Figure C-1: Introduction of Survey

APPENDIX D: SURVEY RESPONSES & ANALYSIS

Table D-1: Survey Responses to Question One

What is your involvement with UCF?		
Answer Options	**Response Percent**	**Response Count**
Faculty	6.6%	202
Administrative	6.6%	202
Staff	12.1%	369
Undergraduate Student	58.7%	1788
Graduate Student	15.1%	460
Other	0.8%	23
	answered question	**3044**
	skipped question	**0**

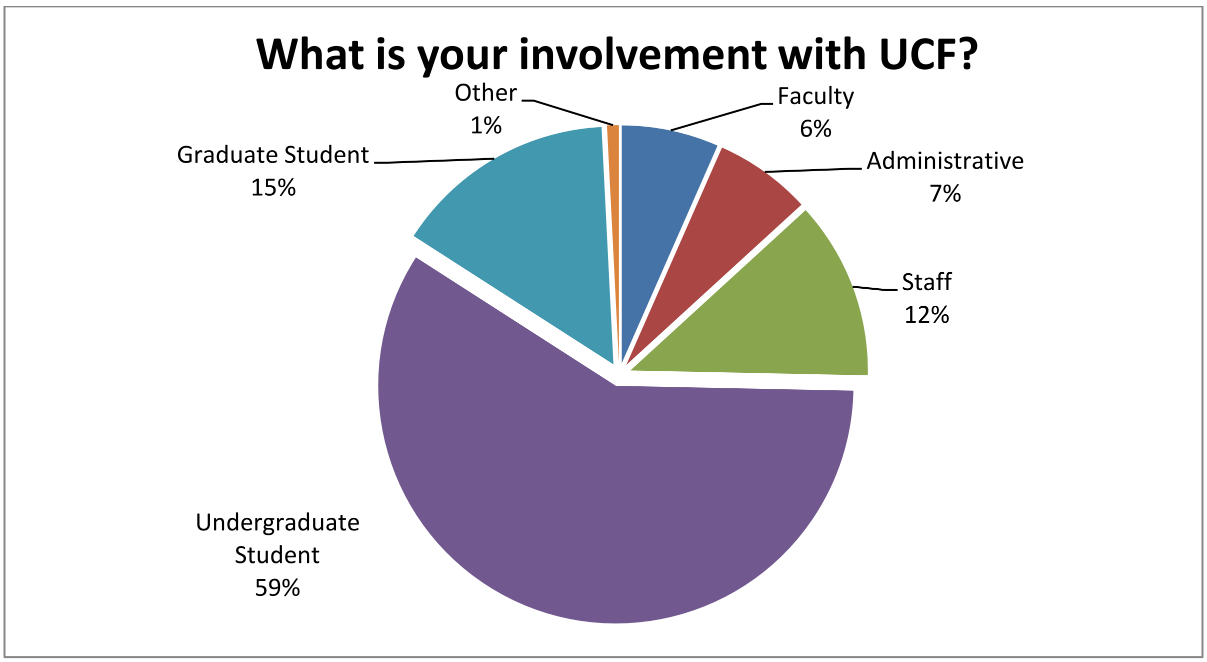

Figure D-1: Survey Respones to Question One

Table D-2: Survey Responses for Question Two (Only for Undergraduate Students)

Do you live on campus?		
Answer Options	**Response Percent**	**Response Count**
Yes	9.6%	171
No	90.6%	1618
	answered question	**1786**
	skipped question	**1258**

Table D-3: Survey Responses to Question Three (Only for Undergraduate Students)

Since you live on campus, how do you travel from your residence hall to class?		
Answer Options	**Response Percent**	**Response Count**
walk/bike	88.8%	150
drive to a closer parking lot/garage	1.8%	3
UCF Shuttle	5.9%	10
Other	3.6%	6
	answered question	**169**
	skipped question	**2875**

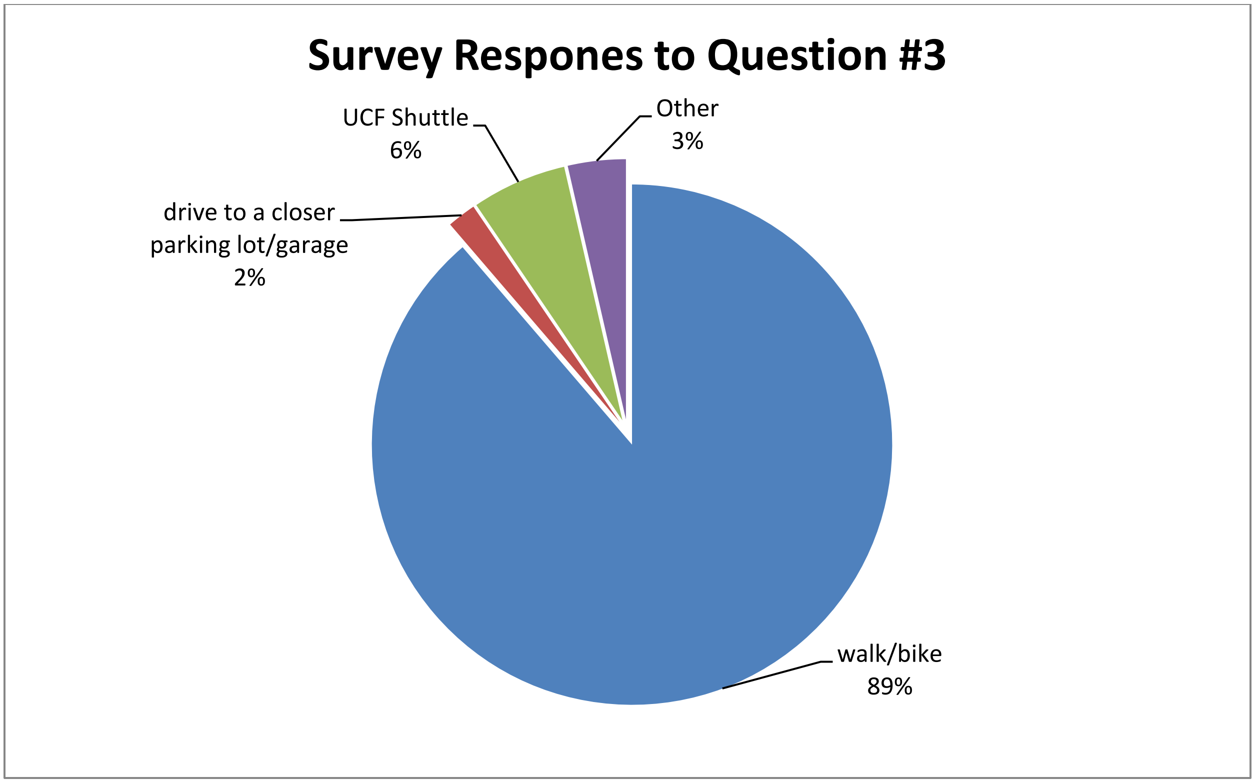

Figure D-2: Survey Responses to Question Three (Only for Undergraduate Students)

Table D-4: Survey Responses to Question Four (All Respondents Except Undergraduate Resident Students)

How far do you live from UCF main campus (in miles)?		
Answer Options	**Response Percent**	**Response Count**
0 to 2	17.6%	488
3 to 5	18.2%	506
6 to 8	13.4%	372
9 to 12	10.6%	294
12 to 15	7.3%	203
16 to 20	5.3%	147
21 to 25	5.6%	156
26 to 30	4.6%	128
31 to 40	8.2%	228
If more than 40, please specify mileage	9.1%	251
	answered question	**2773**
	skipped question	**271**

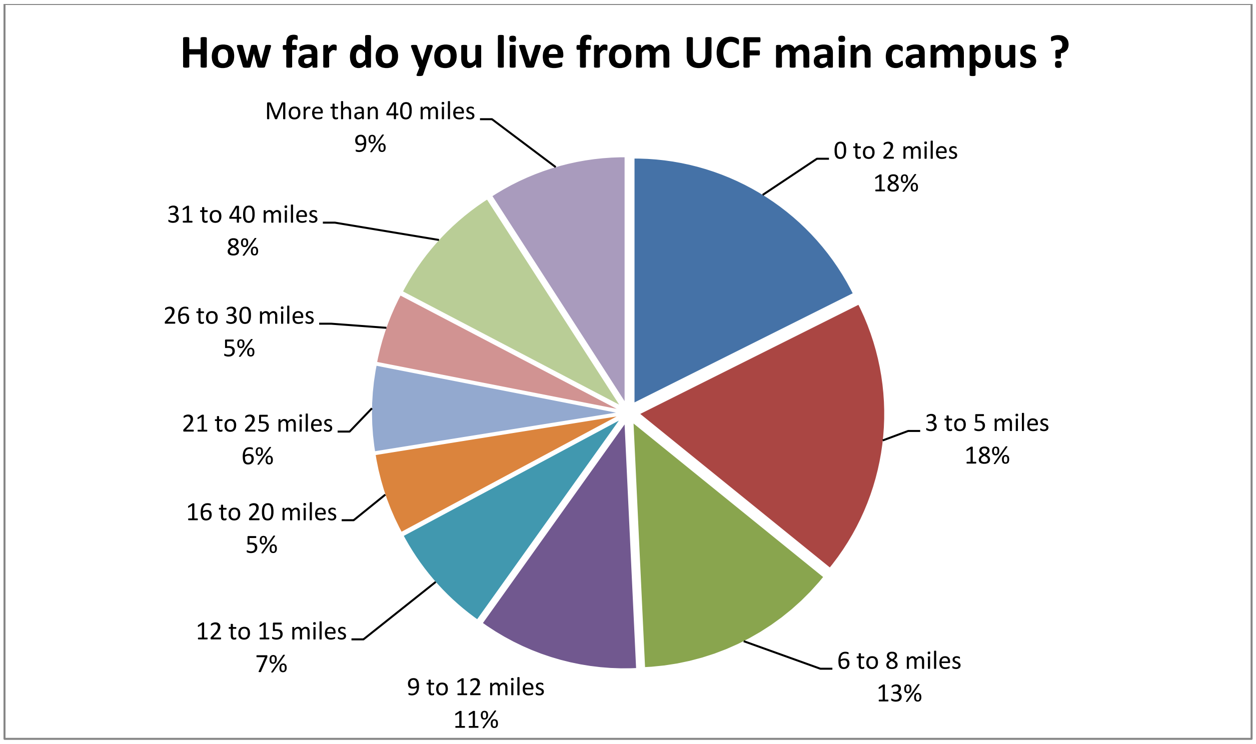

Figure D-3: Survey Responses to Question Four (All Respondents Except Undergraduate Resident Students)

Table D-5: Survey Responses to Question Five (All Respondents Except Undergraduate Resident Students)

What is the closest intersection to your home? (list street names, e.g. Rouse Road and University Blvd.)		
Answer Options	**Response Percent**	**Response Count**
Street 1	100.0%	2638
Street 2	86.6%	2285
	answered question	**2638**
	skipped question	**406**

Table D-6: Survey Responses to Question Six (All Respondents Except Undergraduate Resident Students)

What kind of vehicle do you drive to UCF Main Campus?		
Answer Options	**Response Percent**	**Response Count**
Car	63.9%	1769
Small SUV, small pick-up truck, or minivan	18.0%	497
Large SUV, large pick-up truck or large van	5.4%	150
Motorcycle, moped, or similar	0.9%	24
I don't drive a vehicle to campus	11.8%	328
	answered question	**2768**
	skipped question	**276**

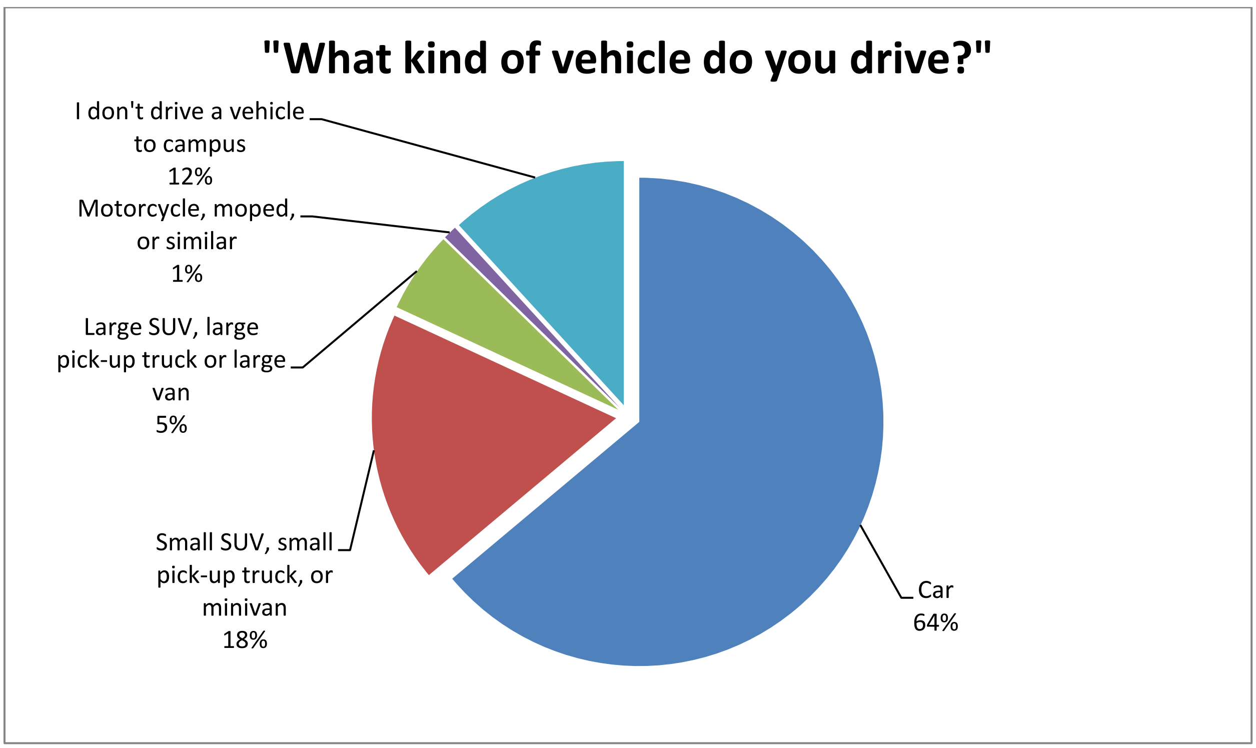

Figure D-4: Survey Responses to Question Six (All Respondents Except Undergraduate Resident Students)

Table D-7: Survey Responses to Question Seven (All Respondents that drove a vehicle to campus)

What year is your vehicle?	
2011 - 1979	
	Response Count
	2440
	Question Totals
answered question	**2440**
skipped question	**604**

Table D-8: Survey Responses to Question Eight (All Respondents that drove a vehicle to campus)

Do you 'Carpool' to UCF main campus?		
Answer Options	**Response Percent**	**Response Count**
Yes	9.6%	235
No	90.4%	2201
	answered question	**2436**
	skipped question	**608**

Table D-9: Survey Responses to Question Nine (All Respondents that participate in a Carpool)

On average, how many times a week do you carpool with another person/s to UCF during the FALL/SPRING Semester?		
Answer Options	**Response Percent**	**Response Count**
Zero	2.2%	5
Once a Week	17.7%	41
Twice a Week	37.5%	87
Three Times a Week	15.9%	37
4 Times a Week	6.0%	14
5 Times a Week	20.7%	48
	answered question	**232**
	skipped question	**2812**

Table D-10: Survey Responses to Question Ten (All Respondents that participate in a Carpool)

On average, how many times a week do you carpool with another person/s to UCF during the SUMMER Semester?		
Answer Options	**Response Percent**	**Response Count**
Zero	54.0%	122
Once a Week	7.5%	17
Twice a Week	9.3%	21
Three Times a Week	4.9%	11
4 Times a Week	6.6%	15
5 Times a Week	17.7%	40
	answered question	**226**
	skipped question	**2818**

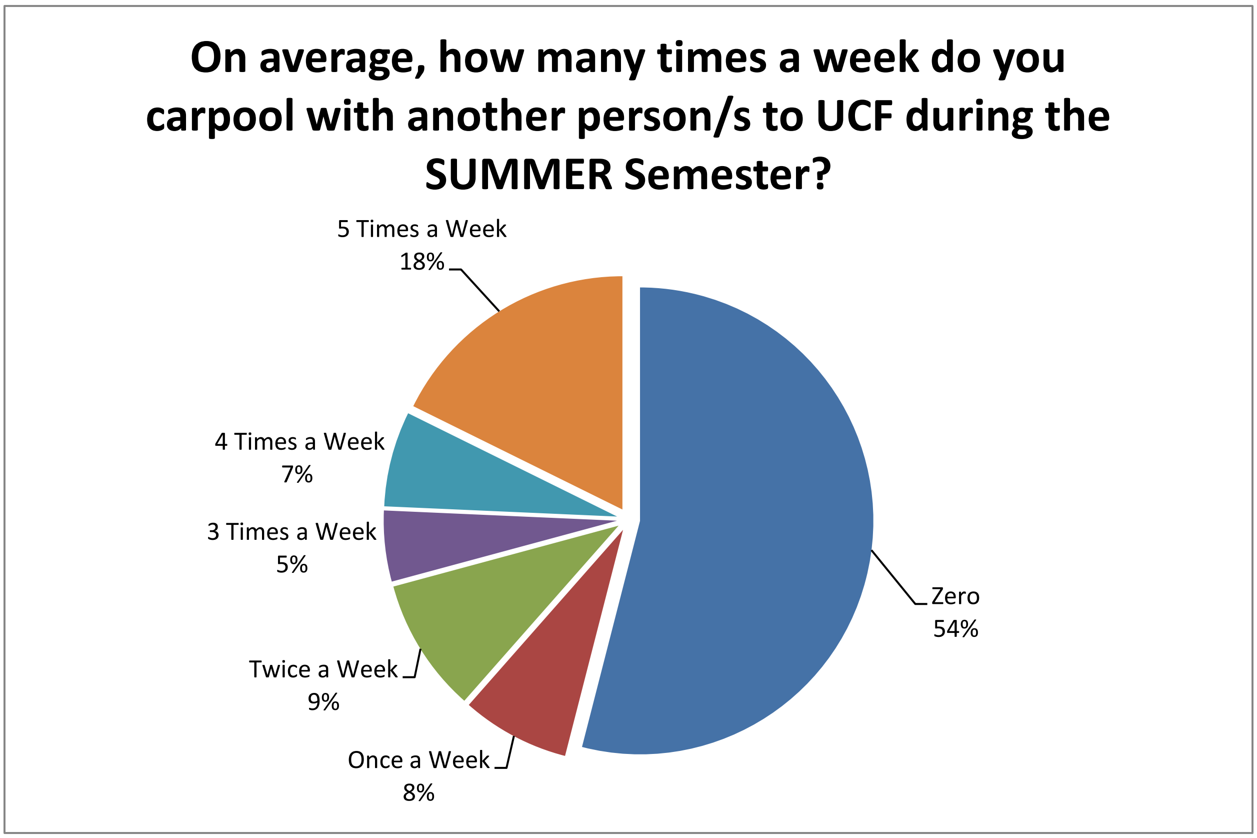

Figure D-5: Survey Responses to Question Ten (All Respondents that participate in a Carpool)

Table D-11: Survey Responses to Question Eleven (All Respondents that participate in a Carpool)

When you carpool, how many people (including you) travel in your vehicle to UCF main campus?		
Answer Options	**Response Percent**	**Response Count**
2	87.9%	204
3	9.9%	23
4	0.9%	2
5	1.3%	3
	answered question	**232**
	skipped question	**2812**

Table D-12: Survey Responses to Question Twelve (All Respondents that drive to campus)

How many one way trips (in your vehicle) from your residence to UCF main campus do you make each week during the FALL/SPRING Semester?		
Answer Options	**Response Percent**	**Response Count**
1	8.3%	197
2	12.7%	304
3	10.6%	252
4	13.2%	316
5	23.9%	571
6	8.2%	195
7 to 8	7.9%	189
9 to 10	12.0%	286
If 11 or more, please state how many trips.	3.1%	75
	answered question	**2385**
	skipped question	**659**

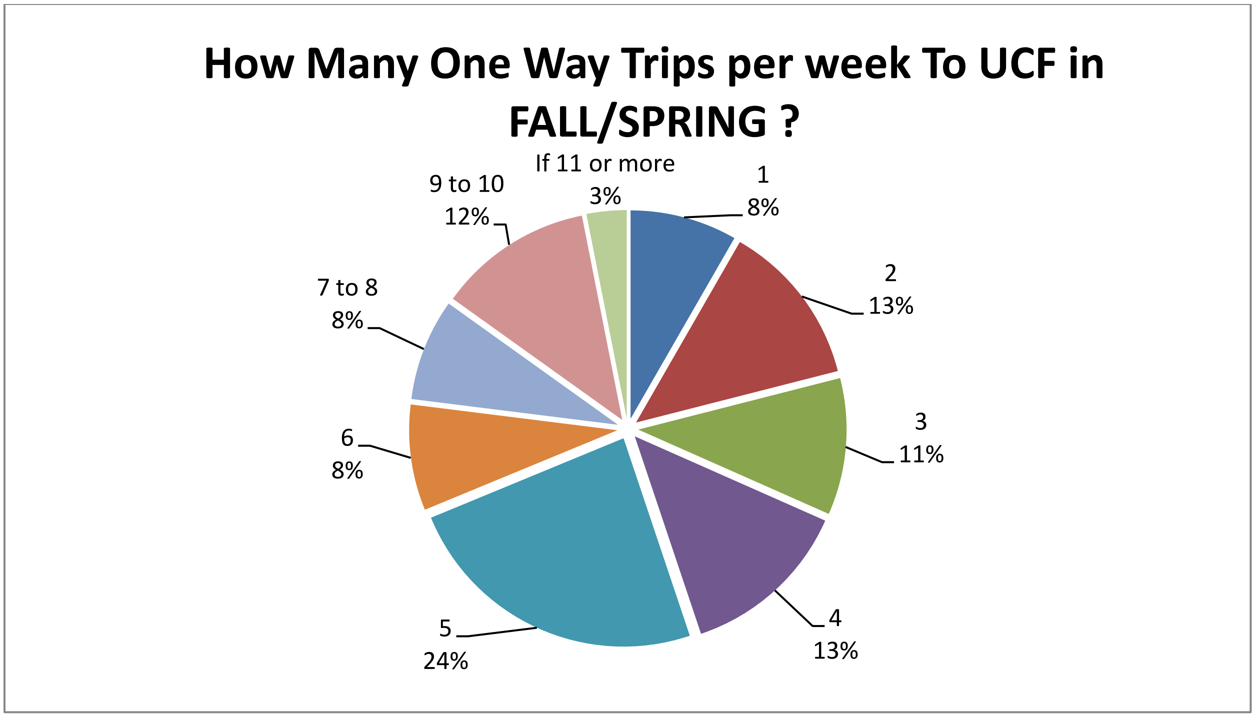

Figure D-6: Survey Responses to Question Twelve (All Respondents that drive to campus)

Table D-13: Survey Responses to Question Thirteen (All Respondents that drive to campus)

What time of day do you typically arrive on campus during the FALL/SPRING Semester?					
Answer Options	**6 AM**	**7 AM**	**8 AM**	**9 AM**	**10 AM**
	25	232	595	450	287
	11 AM	**12 PM**	**1 PM**	**2 PM**	**3 PM**
	103	123	85	46	55
	4 PM	**5 PM**	**6 PM**	**7 PM**	**8 PM**
	52	119	123	3	7
				9 PM	**10 PM**
				10	5
					Response Count
					2320
					Question Totals
				answered question	**2320**
				skipped question	**724**

Table D-14: Survey Responses to Question Fourteen (All Respondents that drive to campus)

On Average, how long does it take you to find a parking spot on UCF main campus during the FALL/SPRING Semester?		
Answer Options	**Response Percent**	**Response Count**
2 minutes or less	24.8%	591
3 - 5 minutes	14.5%	347
5 - 10 minutes	15.6%	373
10 - 15 minutes	12.4%	296
15 - 20 minutes	10.1%	241
20 - 30 minutes	6.6%	157
30 minutes or longer	8.0%	190
I do not park on UCF Main campus	8.0%	190
	answered question	**2385**
	skipped question	**659**

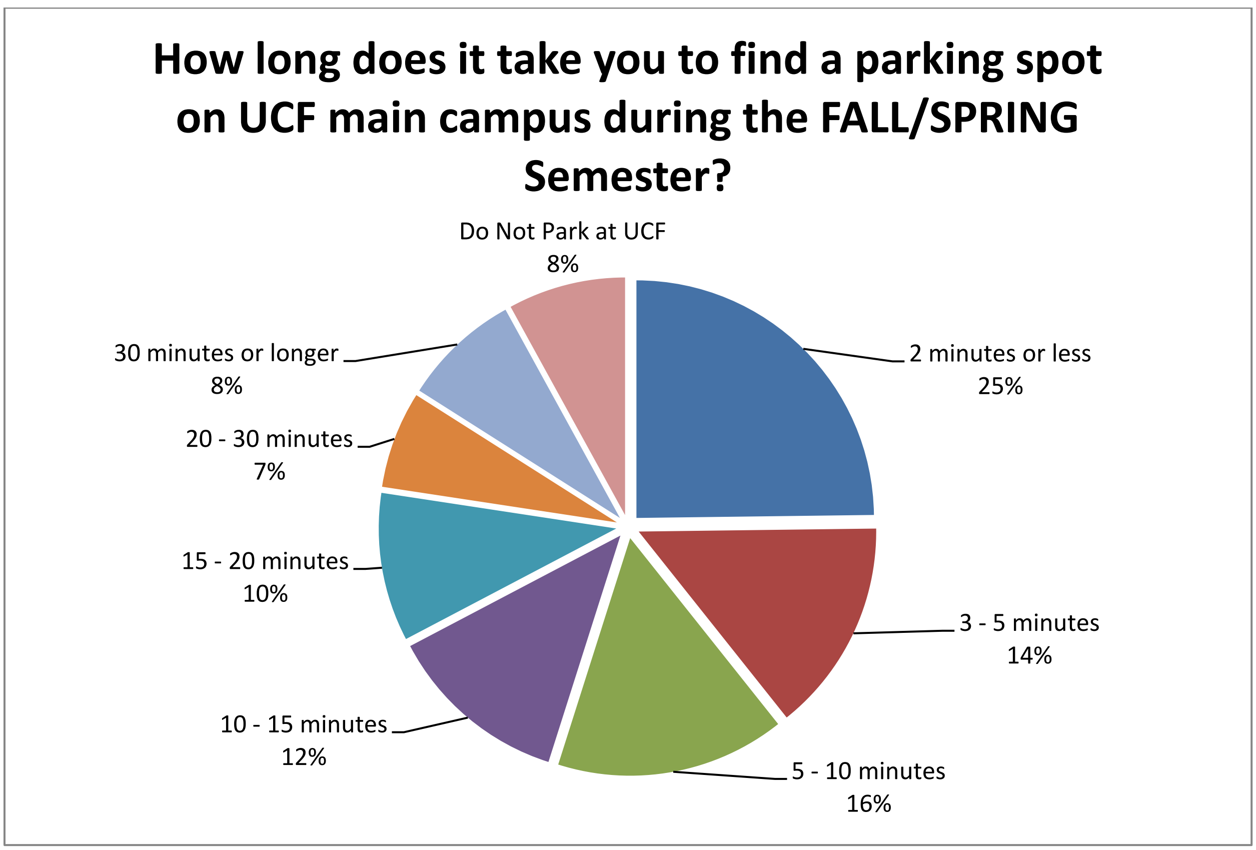

Figure D-7: Survey Responses to Question Fourteen (All Respondents that drive to campus)

Table D-15: Survey Responses to Question Fifteen (All Respondents that drive to campus)

Do you travel to UCF Main Campus during the SUMMER Semester?		
Answer Options	**Response Percent**	**Response Count**
Yes	69.5%	1654
No	30.5%	725
	answered question	**2379**
	skipped question	**665**

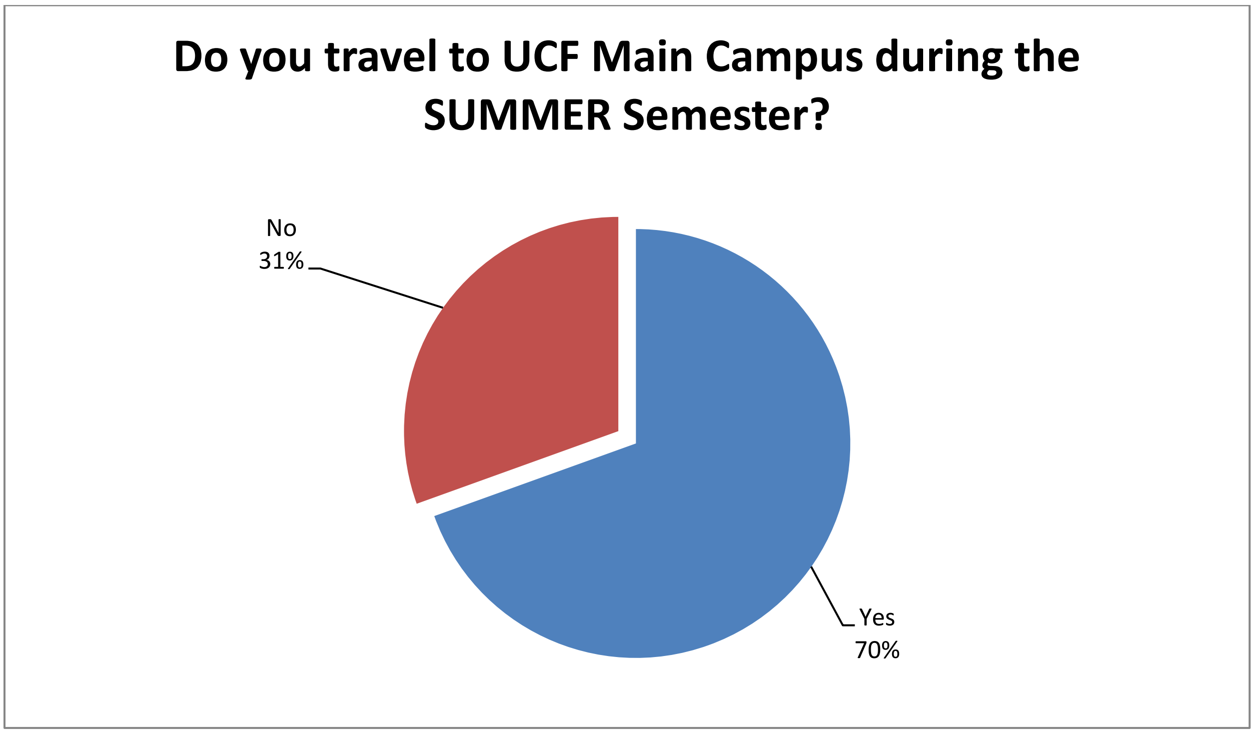

Figure D-8: Survey Responses to Question Fifteen (All Respondents that drive to campus)

Table D-16: Survey Responses to Question Sixteen (All Respondents that drive to campus during the Summer)

How many one way trips (in your vehicle) from your home to UCF do you make each week during the SUMMER Semester?		
Answer Options	**Response Percent**	**Response Count**
1	9.6%	159
2	13.2%	218
3	8.1%	133
4	18.8%	310
5	26.2%	431
6	4.2%	70
7 to 8	6.7%	110
9 to 10	11.2%	185
If 11 or more, please state how many trips.	1.9%	32
	answered question	**1648**
	skipped question	**1396**

Table D-17: Survey Responses to Question Seventeen (All Respondents that drive to campus during the Summer)

What time of day do you typically arrive on campus during the SUMMER Semester?					
Answer Options	**6 AM**	**7 AM**	**8 AM**	**9 AM**	**10 AM**
	18	139	433	299	208
	11 AM	**12 PM**	**1 PM**	**2 PM**	**3 PM**
	208	64	102	54	21
	4 PM	**5 PM**	**6 PM**	**7 PM**	**8 PM**
	39	84	89	2	8
				9 PM	**10 PM**
				6	1
					Response Count
					1600
					Question Totals
				answered question	**1600**
				skipped question	**1444**

Table D-18: Survey Responses to Question Eighteen (All Respondents that drive to campus during the Summer)

On Average, how long does it take you to find a parking spot on UCF main campus during the SUMMER Semester?		
Answer Options	**Response Percent**	**Response Count**
5 minutes or less	64.0%	1054
6-10 minutes	14.4%	237
11-15 minutes	7.0%	116
16-20 minutes	3.3%	55
21-30 minutes	2.1%	34
30 minutes or longer	1.8%	30
I do not park on UCF Main Campus	7.4%	122
	answered question	**1648**
	skipped question	**1396**

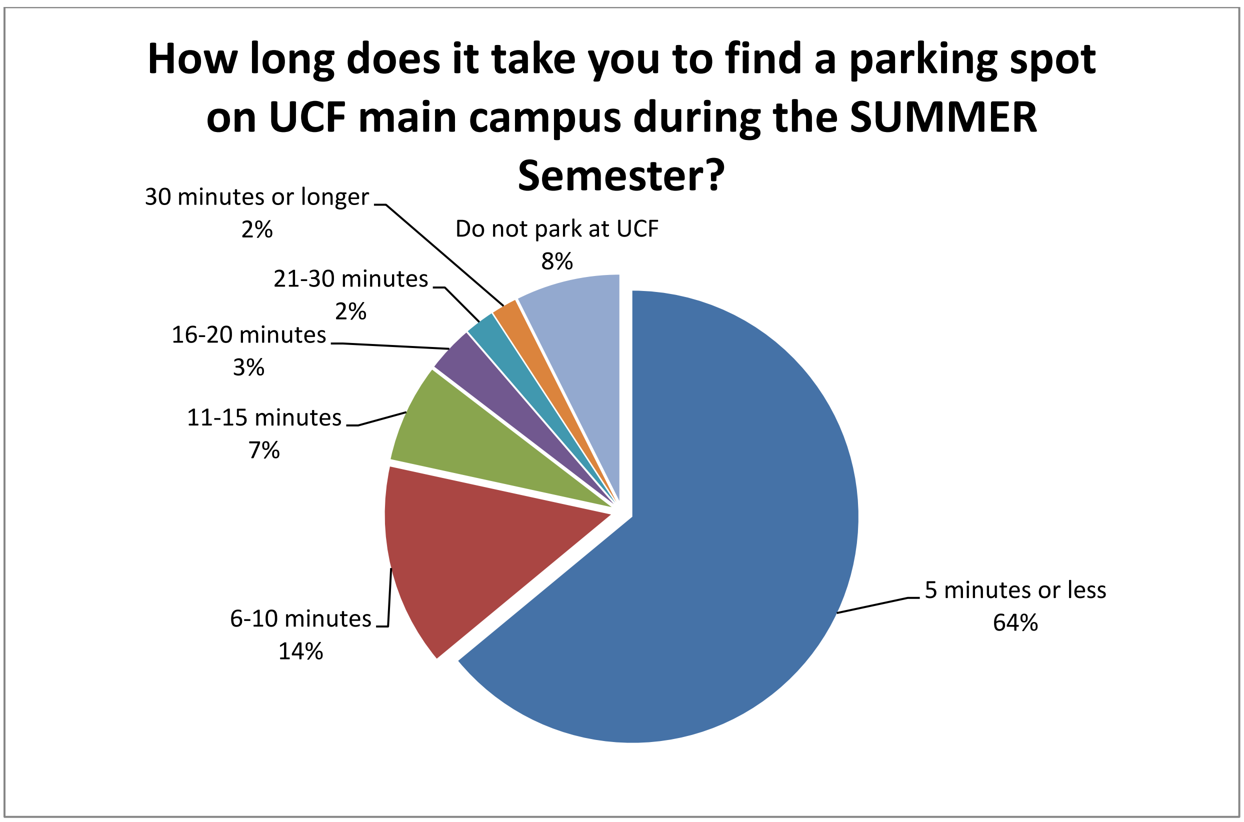

Figure D-9: Survey Responses to Question Eighteen (All Respondents that drive to campus during the Summer)

Table D-19: Survey Responses to Question Nineteen (All Respondents that do not drive to campus)

Since you checked "I don't drive a vehicle to campus," how do you travel to UCF Main campus?		
Answer Options	**Response Percent**	**Response Count**
UCF Shuttle	58.6%	205
Carpool	7.4%	26
Lynx Bus	6.3%	22
Bicycle	22.6%	79
Walk	5.1%	18
	answered question	**350**
	skipped question	**2694**

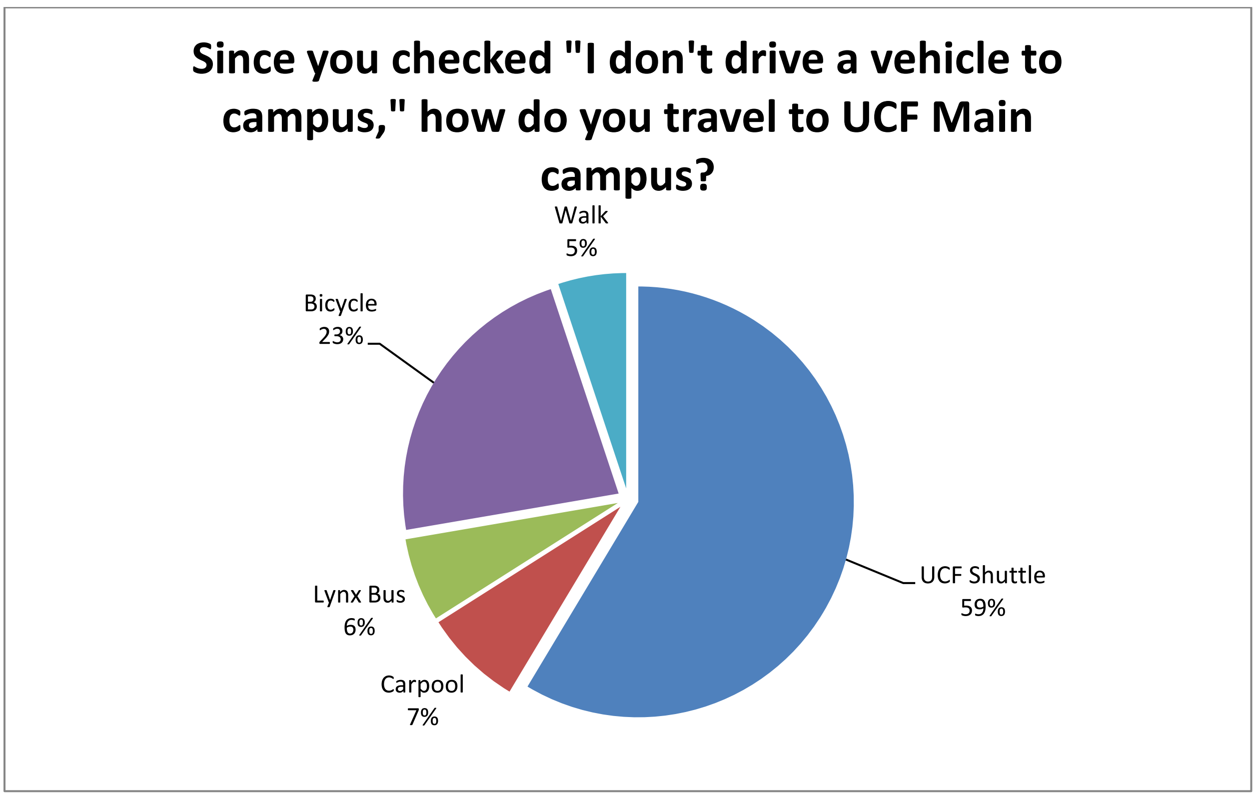

Figure D-10: Survey Responses to Question Nineteen (All Respondents that do not drive to campus)

Table D-20: Survey Responses to Question Twenty (All Respondents)

Thank you for participating! How much time did it take you to complete this survey?		
Answer Options	**Response Percent**	**Response Count**
0 to 2 minutes	56.9%	1590
2 to 4 minutes	36.3%	1014
4 to 7 minutes	6.1%	170
7 to 10 minutes	0.5%	15
more than 10 minutes	0.3%	7
	answered question	**2796**
	skipped question	**248**

Figure D-11: Survey Responses to Question Twenty (All Respondents)

APPENDIX E: MOVES INPUT FILES

Table E-1: Age Distribution Fraction used for All Source Types and Semester

yearID	ageID	ageFraction
2009	0	0.08192
2009	1	0.08825
2009	2	0.09499
2009	3	0.09283
2009	4	0.08673
2009	5	0.08276
2009	6	0.08164
2009	7	0.07646
2009	8	0.07249
2009	9	0.04997
2009	10	0.04842
2009	11	0.03904
2009	12	0.02901
2009	13	0.02202
2009	14	0.01627
2009	15	0.01078
2009	16	0.00727
2009	17	0.00499
2009	18	0.00369
2009	19	0.00287
2009	20	0.00206
2009	21	0.00118
2009	22	0.00092
2009	23	0.00059
2009	24	0.00052
2009	25	0.00033
2009	26	0.00031
2009	27	0.00025
2009	28	0.00015
2009	29	0.00016
2009	30	0.00113

Table E-2: Ramp Fraction Input

roadTypeID	rampFraction
2	0.08
4	0.08

Table E-3: VMT fraction by Road Type for all Source Types

roadTypeID	**roadTypeVMTFraction**
Off-Network	0
Rural Restricted Access	0
Rural Unrestricted Access	0.069172358
Urban Restricted Access	0.25541591
Urban Unrestricted Access	0.675411732

Table E-4: Average Speed Distribution used for all Source Types on Rural Restricted Access Roads

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc	avgSpeedFraction
1	2.5	speed < 2.5mph	0
2	5	2.5mph <= speed < 7.5mph	0
3	10	7.5mph <= speed < 12.5mph	0
4	15	12.5mph <= speed < 17.5mph	0
5	20	17.5mph <= speed <22.5mph	0
6	25	22.5mph <= speed < 27.5mph	0
7	30	27.5mph <= speed < 32.5mph	0
8	35	32.5mph <= speed < 37.5mph	0
9	40	37.5mph <= speed < 42.5mph	0
10	45	42.5mph <= speed < 47.5mph	0
11	50	47.5mph <= speed < 52.5mph	0
12	55	52.5mph <= speed < 57.5mph	0.0091073
13	60	57.5mph <= speed < 62.5mph	0.0285067
14	65	62.5mph <= speed < 67.5mph	0.0988925
15	70	67.5mph <= speed < 72.5mph	0.248298
16	75	72.5mph <= speed	0.615196

Table E-5: Average Speed Distribution for all Source Types on Unrestricted Rural Access Roads

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc	avgSpeedFraction
1	2.5	speed < 2.5mph	0.00224224
2	5	2.5mph <= speed < 7.5mph	0.0107073
3	10	7.5mph <= speed < 12.5mph	0.0172897
4	15	12.5mph <= speed < 17.5mph	0.0388853
5	20	17.5mph <= speed <22.5mph	0.0468262
6	25	22.5mph <= speed < 27.5mph	0.0249236
7	30	27.5mph <= speed < 32.5mph	0.0427472
8	35	32.5mph <= speed < 37.5mph	0.0568322
9	40	37.5mph <= speed < 42.5mph	0.166133
10	45	42.5mph <= speed < 47.5mph	0.158276
11	50	47.5mph <= speed < 52.5mph	0.171038
12	55	52.5mph <= speed < 57.5mph	0.101443
13	60	57.5mph <= speed < 62.5mph	0.0827913
14	65	62.5mph <= speed < 67.5mph	0.0428538
15	70	67.5mph <= speed < 72.5mph	0.0277971
16	75	72.5mph <= speed	0.00921441

Table E-6: Avg. Speed Distribution for All Source Types on Restricted Urban Access Roads

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc	avgSpeedFraction
1	2.5	speed < 2.5mph	0
2	5	2.5mph <= speed < 7.5mph	0.01365
3	10	7.5mph <= speed < 12.5mph	0
4	15	12.5mph <= speed < 17.5mph	0
5	20	17.5mph <= speed <22.5mph	0
6	25	22.5mph <= speed < 27.5mph	0.0021
7	30	27.5mph <= speed < 32.5mph	0.02012
8	35	32.5mph <= speed < 37.5mph	0.01455
9	40	37.5mph <= speed < 42.5mph	0.02625
10	45	42.5mph <= speed < 47.5mph	0.02811
11	50	47.5mph <= speed < 52.5mph	0.28578
12	55	52.5mph <= speed < 57.5mph	0.12264
13	60	57.5mph <= speed < 62.5mph	0.46113
14	65	62.5mph <= speed < 67.5mph	0.02568
15	70	67.5mph <= speed < 72.5mph	0
16	75	72.5mph <= speed	0

Table E-7: Avg. Speed Distribution for All Source Types on Unrestricted Urban Access Roads

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc	avgSpeedFraction
1	2.5	speed < 2.5mph	0
2	5	2.5mph <= speed < 7.5mph	0
3	10	7.5mph <= speed < 12.5mph	0.182436
4	15	12.5mph <= speed < 17.5mph	0.251935
5	20	17.5mph <= speed <22.5mph	0.00800931
6	25	22.5mph <= speed < 27.5mph	0.0393225
7	30	27.5mph <= speed < 32.5mph	0.220652
8	35	32.5mph <= speed < 37.5mph	0.0606411
9	40	37.5mph <= speed < 42.5mph	0.16509
10	45	42.5mph <= speed < 47.5mph	0.0308381
11	50	47.5mph <= speed < 52.5mph	0.0302329
12	55	52.5mph <= speed < 57.5mph	0.00367659
13	60	57.5mph <= speed < 62.5mph	0.00704208
14	65	62.5mph <= speed < 67.5mph	0.000124438
15	70	67.5mph <= speed < 72.5mph	0
16	75	72.5mph <= speed	0

Table E-8: Fuel Supply Input File for Fll Semesters

countyID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
99001	2009	9	8129	0.428571	0.5
99001	2009	9	2727	0.571429	0.5
99001	2009	9	20043	1	0.5
99001	2009	10	8129	0.428571	0.5
99001	2009	10	2727	0.571429	0.5
99001	2009	10	20043	1	0.5
99001	2009	11	8129	0.428571	0.5
99001	2009	11	2727	0.571429	0.5
99001	2009	11	20043	1	0.5
99001	2009	12	8219	0.428571	0.5
99001	2009	12	2820	0.571429	0.5
99001	2009	12	20043	1	0.5[1]

[1] CountyID 99001 was assigned to UCF Custom Domain. MOVES requires an ID number to calculate emissions results.

Table E-9: Fuel Supply Input File for Spring Semester

countyID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
99001	2009	1	8219	0.428571	0.5
99001	2009	1	2820	0.571429	0.5
99001	2009	1	20043	1	0.5
99001	2009	2	8219	0.428571	0.5
99001	2009	2	2820	0.571429	0.5
99001	2009	2	20043	1	0.5
99001	2009	3	8129	0.428571	0.5
99001	2009	3	2727	0.571429	0.5
99001	2009	3	20043	1	0.5
99001	2009	4	8129	0.428571	0.5
99001	2009	4	2727	0.571429	0.5
99001	2009	4	20043	1	0.5

Table E-10: Fuel Supply Input File for Summer Semester

countyID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
99001	2009	5	8129	0.428571	0.5
99001	2009	5	2727	0.571429	0.5
99001	2009	5	20043	1	0.5
99001	2009	6	8129	0.428571	0.5
99001	2009	6	2727	0.571429	0.5
99001	2009	6	20043	1	0.5
99001	2009	7	8129	0.428571	0.5
99001	2009	7	2727	0.571429	0.5
99001	2009	7	20043	1	0.5

Table E-11: Meteorology Input File for Fall Semester

monthID	zoneID	hourID	temperature	relHumidity
9	990010	1	73.6	89.7
9	990010	2	72.8	91.3
9	990010	3	72.2	92.2
9	990010	4	71.8	92.8
9	990010	5	71.4	93.4
9	990010	6	71.2	93.1
9	990010	7	71.1	93.4
9	990010	8	72.2	92.5
9	990010	9	77.1	86
9	990010	10	81.7	77.8
9	990010	11	84.9	70.9
9	990010	12	87.3	65.7
9	990010	13	88.8	62.4
9	990010	14	89.4	61.1
9	990010	15	89.3	60.6
9	990010	16	88.1	61.9
9	990010	17	86.7	64.3
9	990010	18	84.8	67.4
9	990010	19	82	72.5
9	990010	20	78.9	78.1
9	990010	21	77.1	82.1
9	990010	22	75.8	84.5
9	990010	23	75	86.5
9	990010	24	74.2	88.3
10	990010	1	67.5	87.6
10	990010	2	66.7	89.1
10	990010	3	66.2	89.7
10	990010	4	65.6	90.4
10	990010	5	65.1	91
10	990010	6	64.8	91.3
10	990010	7	64.7	91.3
10	990010	8	65	91
10	990010	9	69.3	85.6
10	990010	10	74.5	76.4
10	990010	11	78.5	68.6
10	990010	12	81.2	63.2
10	990010	13	82.7	60

10	990010	14	83.6	58.1
10	990010	15	83.9	57.1
10	990010	16	83.4	57.6
10	990010	17	82.2	59.3
10	990010	18	79.9	62.8
10	990010	19	76.2	69.8
10	990010	20	73.3	75.5
10	990010	21	71.4	79.7
10	990010	22	70.1	82.4
10	990010	23	69.1	84.4
10	990010	24	68.2	86.1
11	990010	1	60.9	87.3
11	990010	2	60.1	88.2
11	990010	3	59.3	89.1
11	990010	4	58.7	89.7
11	990010	5	58.2	89.7
11	990010	6	57.9	90
11	990010	7	57.7	90.4
11	990010	8	57.4	90.7
11	990010	9	60.5	87.6
11	990010	10	66.1	78.7
11	990010	11	70.9	69.9
11	990010	12	74.3	63.7
11	990010	13	76.3	59.8
11	990010	14	77.6	57.1
11	990010	15	78	55.9
11	990010	16	77.7	56.1
11	990010	17	76.5	57.3
11	990010	18	73.9	61.8
11	990010	19	69.6	70
11	990010	20	66.9	75.5
11	990010	21	65	79.2
11	990010	22	63.6	82.3
11	990010	23	62.3	84.6
11	990010	24	61.4	85.8
12	990010	1	54.8	86
12	990010	2	53.9	86.9
12	990010	3	53.2	87.2
12	990010	4	52.6	87.8

12	990010	5	51.9	88.5
12	990010	6	51.5	88.8
12	990010	7	51.2	88.8
12	990010	8	50.9	88.7
12	990010	9	52.1	87.5
12	990010	10	57.1	81.2
12	990010	11	62.5	72.6
12	990010	12	67.1	65.1
12	990010	13	69.8	60.4
12	990010	14	71.5	57.4
12	990010	15	72.3	55.7
12	990010	16	72.3	55.3
12	990010	17	71.3	56.6
12	990010	18	68.8	60.7
12	990010	19	64.6	68.5
12	990010	20	61.7	74.4
12	990010	21	59.6	78.5
12	990010	22	58.1	81.3
12	990010	23	56.8	83
12	990010	24	55.7	84.5

Table E-12: Meteorology Input File For Spring Semester

monthID	zoneID	hourID	temperature	relHumidity
1	990010	1	52.4	84.3
1	990010	2	51.3	86.1
1	990010	3	50.4	86.7
1	990010	4	49.7	87.3
1	990010	5	49.3	87.7
1	990010	6	48.7	88
1	990010	7	48.6	87.6
1	990010	8	48.3	87.9
1	990010	9	49.1	87
1	990010	10	54.1	81.3
1	990010	11	59.6	72.1
1	990010	12	64.2	64.5
1	990010	13	67.4	59
1	990010	14	69.4	55.7
1	990010	15	70.5	53.9
1	990010	16	70.8	52.9
1	990010	17	70.1	53.4
1	990010	18	68.1	55.9
1	990010	19	63.8	62.8
1	990010	20	60.3	69.8
1	990010	21	57.7	74.3
1	990010	22	55.8	78.1
1	990010	23	54.3	81
1	990010	24	53.2	83.1
2	990010	1	53.9	83.4
2	990010	2	52.9	84.9
2	990010	3	52.1	86.2
2	990010	4	51.4	86.5
2	990010	5	50.7	87.4
2	990010	6	50.3	87.7
2	990010	7	49.8	88
2	990010	8	49.7	88
2	990010	9	51.5	86.5
2	990010	10	56.7	78.5
2	990010	11	62.1	68.4
2	990010	12	66.4	60.6
2	990010	13	69.5	55.7

2	990010	14	71.4	52.2
2	990010	15	72.5	50.3
2	990010	16	72.8	49.5
2	990010	17	72.4	49.8
2	990010	18	70.6	51.9
2	990010	19	67.1	57.3
2	990010	20	63.1	64.6
2	990010	21	60.1	70.8
2	990010	22	58.2	74.9
2	990010	23	56.5	78.5
2	990010	24	55.1	81.4
3	990010	1	58.5	82.8
3	990010	2	57.5	84.6
3	990010	3	56.6	86.4
3	990010	4	55.9	87.3
3	990010	5	55.2	88.6
3	990010	6	54.7	89.2
3	990010	7	54.4	88.9
3	990010	8	54.4	89.2
3	990010	9	58.5	84
3	990010	10	64	73.6
3	990010	11	68.8	64.1
3	990010	12	72.1	57.8
3	990010	13	74.6	52.9
3	990010	14	76.3	49.8
3	990010	15	77.3	48.2
3	990010	16	77.7	47.2
3	990010	17	77.2	47.6
3	990010	18	75.5	49.7
3	990010	19	72.4	54.5
3	990010	20	68.1	62.4
3	990010	21	65.1	68.5
3	990010	22	62.9	73.5
3	990010	23	61.3	77.2
3	990010	24	60	79.9
4	990010	1	63.1	82.2
4	990010	2	62	84.6
4	990010	3	61	86
4	990010	4	60.1	87.6

4	990010	5	59.4	88.8
4	990010	6	58.8	89.1
4	990010	7	58.7	89.1
4	990010	8	60.5	87.3
4	990010	9	66	78.4
4	990010	10	71.2	67.3
4	990010	11	74.8	59.4
4	990010	12	77.6	54.1
4	990010	13	79.7	50.5
4	990010	14	81	48.4
4	990010	15	81.9	46.8
4	990010	16	82	46.5
4	990010	17	81.2	47.4
4	990010	18	79.8	49.4
4	990010	19	77.2	53.1
4	990010	20	73.1	60
4	990010	21	69.8	67.3
4	990010	22	67.7	72.1
4	990010	23	65.9	76.5
4	990010	24	64.6	79.4

Table E-13: Meteorology Input for Summer Semester

monthID	zoneID	hourID	temperature	relHumidity
5	990010	1	72.2	86.8
5	990010	2	71.3	88.6
5	990010	3	70.5	90.3
5	990010	4	69.9	91.4
5	990010	5	69.4	92.3
5	990010	6	69.1	93.0
5	990010	7	69.1	93.2
5	990010	8	72.4	89.5
5	990010	9	77.4	80.9
5	990010	10	81.6	72.1
5	990010	11	84.8	65.3
5	990010	12	87.2	60.4
5	990010	13	88.7	57.1
5	990010	14	89.5	55.5
5	990010	15	89.6	54.9
5	990010	16	88.8	55.6
5	990010	17	87.5	57.6
5	990010	18	85.3	60.9
5	990010	19	83.1	64.6
5	990010	20	80.1	69.8
5	990010	21	77.3	75.3
5	990010	22	75.6	79.2
5	990010	23	74.3	82.3
5	990010	24	73.3	84.8
6	990010	1	73.3	87.9
6	990010	2	72.5	89.4
6	990010	3	71.7	91.2
6	990010	4	71.1	92.1
6	990010	5	70.7	92.8
6	990010	6	70.4	93.4
6	990010	7	70.5	93.7
6	990010	8	73.9	90.1
6	990010	9	78.7	81.9
6	990010	10	82.8	73.6
6	990010	11	86	67.1
6	990010	12	88.4	62.4
6	990010	13	89.7	59.5

6	990010	14	90.3	58.2
6	990010	15	90.2	57.8
6	990010	16	89.5	58.7
6	990010	17	88.4	60.1
6	990010	18	86.1	63.6
6	990010	19	83.8	67.5
6	990010	20	81	72.4
6	990010	21	78.2	77.5
6	990010	22	76.5	81.2
6	990010	23	75.3	83.9
6	990010	24	74.3	86.2
7	990010	1	74.5	88.6
7	990010	2	73.8	90.1
7	990010	3	73.1	91.6
7	990010	4	72.6	92.5
7	990010	5	72.2	93.1
7	990010	6	71.9	94.1
7	990010	7	71.9	94.1
7	990010	8	74.9	90.7
7	990010	9	79.9	82.8
7	990010	10	84.1	75
7	990010	11	87.3	68.1
7	990010	12	89.5	63.6
7	990010	13	91.1	60.3
7	990010	14	91.7	58.8
7	990010	15	91.3	58.7
7	990010	16	90.2	59.7
7	990010	17	88.1	63
7	990010	18	85.7	66.6
7	990010	19	83.8	69.6
7	990010	20	81.2	74.4
7	990010	21	78.7	79.4
7	990010	22	77.3	82.4
7	990010	23	76.2	85.1
7	990010	24	75.4	87.1

Table E-14: Monthly VMT Fraction for all Source Types for Fall Semester

monthID	monthVMTFraction
9	0.255339769
10	0.260874101
11	0.241914323
12	0.241871807

Table E-15: Monthly VMT Fraction for all Source Types in Spring Semester

monthID	monthVMTFraction
1	0.238194269
2	0.227201279
3	0.266372238
4	0.268232214

Table E-16: Monthly VMT Fraction for All Source Types for Summer Semester[2]

monthID	monthVMTFraction
5	0.32638181
6	0.329249402
7	0.344368788

[2] Monthly VMT Fraction in custom domain is used to split the total VMT entered among the different months selected by the user. It does not fraction a yearly VMT, but only the total VMT the user supplies for the particular Run Specification File.

Table E-17: Day VMT Fraction for all Source Types and Semesters

roadTypeID	dayID	dayVMTFraction
Off-Network	Weekend	0.137635
Off-Network	Weekdays	0.862365
Rural Restricted Access	Weekend	0.17882
Rural Restricted Access	Weekdays	0.82118
Rural Unrestricted Access	Weekend	0.17882
Rural Unrestricted Access	Weekdays	0.82118
Urban Restricted Access	Weekend	0.137635
Urban Restricted Access	Weekdays	0.862365
Urban Unrestricted Access	Weekend	0.137635
Urban Unrestricted Access	Weekdays	0.862365

Table E-18: Hourly VMT Fraction for Weekend Day for All Source Types and Semesters

hourID	hourVMTFraction
1	0.0214739
2	0.0144428
3	0.0109684
4	0.00749451
5	0.00683855
6	0.0103588
7	0.0184304
8	0.0268117
9	0.0363852
10	0.0475407
11	0.0574664
12	0.0650786
13	0.0713228
14	0.0714917
15	0.0717226
16	0.0720061
17	0.0711487
18	0.0678874
19	0.0617718
20	0.0516882
21	0.0428658
22	0.0380302
23	0.0322072
24	0.0245677

Table E-19: Hourly VMT Fraction for Week days for all Source Types and Semesters

hourID	hourVMTFraction
1	0.00986211
2	0.00627248
3	0.00505767
4	0.00466686
5	0.00699469
6	0.018494
7	0.0459565
8	0.0696444
9	0.0608279
10	0.0502862
11	0.0499351
12	0.0543654
13	0.0576462
14	0.0580319
15	0.0622554
16	0.0710049
17	0.0769725
18	0.077432
19	0.059783
20	0.0443923
21	0.0354458
22	0.031824
23	0.0249419
24	0.0179068

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