SUSTAINABLE URBAN TRANSPORTATION SYSTEMS

Evaluation of Greenhouse Gas Emissions

Prepared for:

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ABSTRACT

A greenhouse gas inventory was conducted for UIC commuters based on the results of a transportation commuter survey. The transportation commuter survey was used to determine the transportation activity data for UIC commuters. Commuters consisted of students, staff and faculty. The survey was used to determine the passenger miles traveled by UIC commuters for the following modes of transportation: driving (including carpooling), bus, light rail (CTA) and commuter rail (Metra). Emission factors for CO_2, CH_4 and N_2O were generated using the Campus Carbon Calculator™. The emissions factors were multiplied by the transportation activity data to determine the baseline greenhouse gas emissions inventory. After the baseline greenhouse gas emissions inventory was completed, three (3) mode shift alternatives were evaluated to predict the impact on greenhouse gas emissions resulting from a 30% mode-shift from driving to alternative modes of transportation.

The baseline GHG Inventory concluded that 43,221 metric tons of greenhouse gases as eCO_2 were emitted as a result of commuter travel to and from UIC by students, staff and faculty. Fifty-nine percent (59%) of the greenhouse gas emissions were related to driving. All of the mode-shift scenarios resulted in a reduction of greenhouse gas emissions. The best mode-shift alternative was the automobile to light rail scenario. Under this scenario, the GHG Inventory predicted that 37,691 metric tons of greenhouse gases would be emitted as a result of commuter travel to and from UIC by students, staff and faculty, which resulted in an overall 13% reduction in greenhouse gas emissions. Forty-eight percent (48%) of the greenhouse gas emissions were still related to automobile-oriented transportation. In both cases, ninety-eight percent (98%) of the emissions were as CO_2.

It was clear that the majority of commuter transportation-related greenhouse gas emissions were related to automobile-oriented transit under both the baseline scenario and the 30% mode-shift conditions. Therefore, it was concluded that decreasing automobile related transportation can help UIC reduce its overall carbon footprint and support sustainability.

Comprehensive transportation planning must occur in order to facilitate a reduction in automobile-oriented transportation. City planners and decision-makers must take measures to increase the viability of walking, cycling or public transit. These activities support sustainability through the reduction of automobile-oriented transportation by reducing per-capita resource consumption, traffic congestion, accidents, pollution, and land consumption. In addition, increasing travel options for non-drivers can help to reduce social inequity (Litman, 2005).

The commuter transportation survey was not specifically designed to provide the results that were obtained for this project. Therefore, the commuter transportation survey should be revised and reissued in the fall of 2009 and then conducted annually thereafter. The quality of the commuter transportation survey is paramount because all transportation emissions will be based on the results of the survey. It is the only way to measure transportation activity. Furthermore, the mode-shift analysis presented herein was based on a unilateral reallocation of 30% of automobile passenger miles to a single alternate mode. A mode-shift of automobile passenger miles would most likely be reallocated among multiple alternative modes of transportation. Transportation improvement options should be considered when revising the survey to receive input regarding the barriers to reducing automobile-oriented transportation.

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1.0 INTRODUCTION

1.1 Global Warming

Greenhouse gases are gases in the Earth's atmosphere that trap the sun's energy and heat the Earth's atmosphere. They include water vapor, carbon dioxide, methane, nitrous oxide and ozone (USEPA 2009). Greenhouse gases warm the atmosphere by efficiently absorbing thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. As a result of its warmth, the atmosphere also radiates thermal infrared in all directions, including downward to the Earth's surface.

The greenhouse gas effect is a naturally occurring phenomenon that helps protect life on Earth from the extreme temperatures in space. However, changes in human activities over the past century, such as rapid industrialization and deforestation, have resulted in increased greenhouse gases emissions into the Earth's atmosphere. These human-induced activities have resulted in enhanced greenhouse effect that has long been argued to adversely contribute to global climate change (i.e. global warming). According to the Chicago Climate Task Force, climate warming is already occurring in Chicago. Since 1980, the average temperature has risen by about 2.6°F, trees and plants flower earlier in the spring, frosts occur later in the fall, the amount of winter ice on Lake Michigan is decreasing and heavy rainstorms are increasing in frequency (CCAP, 2008).

It is estimated that the world's greenhouse gas emissions are over 25 billion metric tons. In 2007, the United States' total greenhouse gas emissions were over 7 billion metric tons, which had increased 17% from the 1990 emissions. In 2007, transportation activities accounted for 33% of emissions from fossil fuels, 60% of which was related to gasoline consumption from personal vehicle use. Transportation is the fastest-growing source of U.S. GHGs, accounting for 47 percent of the net increase in total U.S. emissions since 1990 (USEPA 2009).

As the financial, industrial, and cultural capital of the Midwest, Chicago is responsible for roughly 34.6 million metric tons of heat-trapping or "greenhouse" gases, in CO_2-equivalent terms. Adding in the six surrounding counties in the Chicago area increases this to about 103 million metric tons per year. This region accounts for nearly half the total emissions of the state of Illinois, with emissions greater than the state totals of more than 30 individual states (CCAP, 2008).

Scientists, leaders, politicians, businesses and communities have recognized that climate change is a serious issue. At the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992 (more commonly referred to as the Earth Summit), an international treaty was developed. This treaty, the United Nations Framework Convention on Climate Change, aimed to stabilize greenhouse gas emissions in the atmosphere to prevent global warming. This treaty did not set any limits on greenhouse gas emissions for individual nations or enforcement provisions; however, the treaty provided for "updates" that would set limits. That update or amendment is the Kyoto Protocol, which was adopted in December 1997 and entered in force on February 16, 2005. The Kyoto Protocol is a legally binding agreement under which industrialized countries will reduce their collective emissions of greenhouse gases by 5.2% compared to the year 1990. The United States signed the Kyoto Treaty on December 11, 1998, but as of January 14, 2009, it has not ratified the agreement (UNFCCC, 2009).

1.2 City of Chicago Climate Action Plan

The City of Chicago and over 930 other cities have signed the U.S. Conference of Mayors Climate Protection Agreement (USCM 2008). This Agreement committed cities to meet or beat the greenhouse gas emission reduction target suggested for the United States in the Kyoto Protocol, which was a 7% reduction from 1990 levels by 2012. In order to accomplish these objectives, the City has developed a Climate Action Plan. A Climate Action Plan is a list of strategies, goals and actions that will reduce greenhouse gas emissions. In September 2008, the City of Chicago's Climate Task Force released the *Chicago Climate Action Plan* (CCAP), which outlined the impacts global climate change may have on the Chicago region.

The CCAP stated that buildings and their associated energy use accounted for approximately 70% of all greenhouse gas emissions in Chicago while transportation accounted for 21%, mostly from the burning of fossil fuels, to operate vehicles, buses and trains (CCAP, 2008). The CCAP provided several Improved Transportation Options to reduce the transportation-related greenhouse gas emissions. Emphasized was the desire to invest more in transit, expand transit alternatives and promote transit-oriented development. The CCAP specified a goal of boosting transit ridership by 30% as a way to reduce transportation greenhouse gas emissions (CCAP, 2008).

1.3 University of Illinois at Chicago Climate Action Plan

Like the City of Chicago, The University of Illinois at Chicago (UIC) has committed to reduce its greenhouse gas emissions. On September 14, 2007, UIC became an inaugural signatory to the American College & University Presidents Climate Commitment (ACUPCC). As of March 2009, over 600 colleges and universities have made the commitment to achieve climate neutrality as soon as possible by initiating the development of a comprehensive Climate Action Plan. In addition, while the more comprehensive Climate Action Plan is being developed, these colleges and universities have also committed to initiate two or more tangible actions to reduce greenhouse gases, and to make the Climate Action Plan progress reports publicly available by providing them to the Association for the Advancement of Sustainability in Higher Education (AASHE).

As a result of this commitment, UIC has undertaken the effort to initiate the development of the UIC Climate Action Plan (UCAP). While the comprehensive UCAP is being developed, UIC has committed to initiate the following two (2) tangible actions to reduce greenhouse gases:

- Formalize the current practice that all new campus construction will be built to at least the U.S. Green Building Council's LEED Silver standard or equivalent.

- Encourage the use of and provide access to public transportation for all faculty, staff, students and visitors at our institution.

The UCAP outlines the steps that UIC needs to take to reduce its greenhouse gas emissions. However, the success of the UCAP depends not only on the efforts of the institution but by UIC's faculty, staff and students as well. Individual behaviors and actions are crucial to UIC reducing its carbon footprint (OS 2009).

1.4 Greenhouse Gas Inventory

One component of the UCAP was to complete a greenhouse gas inventory (GHG Inventory) for the entire UIC campus. A GHG Inventory is an accounting of greenhouse gas emissions associated with an entity or facility. For the UIC campus, greenhouse gas emissions have been generated through: on-campus energy production, purchased electricity, natural gas service to buildings, and transportation. The goal of a GHG Inventory was to establish a baseline level of GHG emissions from which reduction strategies can be developed.

1.5 Sustainable Transportation Planning

Sustainable transportation planning considers the overall long-term goals of society (Litman, 2005). Broadly considered, sustainable transportation planning includes environmental, social and economic issues. When considering greenhouse gas emission reduction strategies for transportation activities in terms of emissions, a more efficient and cleaner vehicle can reduce emissions on a per-mile basis; however, driving a cleaner vehicle does not mitigate congestion, road construction or parking costs, or the adverse impacts of urban sprawl. Therefore, it has been hypothesized that when all impacts are considered, sustainable transportation strategies that consider options to improve travel options, create more accessible land use patterns and reduce automobile travel are the most sustainable (Litman, 2005).

1.6 Project Objective

Given that transportation activities have been documented to be a significant source of greenhouse gas emissions, the first objective of this project was to complete a GHG Inventory on UIC commuter transportation emissions. Upon establishing a baseline GHG Inventory, three (3) hypothetical mode-shift scenarios were modeled. Consistent with the City of Chicago's goal to boost transit ridership by 30%, the hypothetical mode-shift scenarios evaluated the affects of a 30% mode-shift from automobile-oriented to transit-oriented modes of transportation. The results of the mode-shift evaluations were then compared to the baseline evaluation. This report has presented the methodology, data, results and conclusions of the analyses.

2.0 METHODOLOGY

2.1 Greenhouse Gas Inventory Analysis

2.1.1 Determine Transportation Activity Data

The first step in completing the transportation-related GHG Inventory was to determine the transportation activity data. The necessary transportation activity data were the passenger miles traveled by UIC commuters for each different transportation mode. UIC commuters included students, staff and faculty. The four (4) modes considered were: driving (including carpooling), bus (CTA and UIC Shuttle), light rail (CTA) and commuter rail (Metra).

A commuter transportation survey was conducted in the fall of 2008 by the UIC Office of Sustainability. The results of the survey were evaluated using the third party statistical software SPSS. The commuter survey was used to determine the total passenger miles traveled by UIC commuters for each mode. For a known population, the survey data were analyzed to determine the percent of the population that used each mode. Then, based on a known number of trips and the average trip distances, the passenger miles were determined for each mode.

2.1.2 Determine Transportation Emission Factors

Emission factors were generated by the Campus Carbon Calculator™. Emission factors within the Campus Carbon Calculator™ were based on government documents from the U.S. Department of Transportation, the U.S. Environmental Protection Agency, and the U.S. Department of Energy (CACP 2008). Three (3) greenhouse gases were investigated: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emission factors were determined in kg-pollutant per mile for each of the four (4) modes of transportation under consideration.

Automobile emission factors were based on an average fuel economy of 22.1 miles per gallon and a commuter vehicle mix of 62% cars. Bus emission factors were based on a normalized fuel efficiency of 39.67 miles per gallon per passenger. Light rail emission factors were based on 2.91 passenger miles / kWh. Commuter rail emission factors were based on 132.28 passenger miles per gallon of diesel.

The Campus Carbon Calculator™ provided emission factors that were indicative of a “pump-to-wheels” scenario. The “pump-to-wheels” scenario is limited to the combustion of the fossil fuel during transportation. This scenario does not consider any “upstream” impacts related to the mining, extraction and processing of the fuel. Because the Campus Carbon Calculator™ was designed to quantify an institution’s carbon footprint, the upstream greenhouse gas emissions were not considered.

2.1.3 Estimate Greenhouse Gas Inventory

Once the total passenger miles traveled for each mode were known, given the emission factors provided by the Campus Carbon Calculator™, the GHG Inventory was readily calculated. The GHG Inventory was determined for each transportation mode using the following general relationship.

Activity Data x Emission Factor = Emissions Inventory

2.2 Mode-Shift Impact Analyses

In order to evaluate the sustainability of reducing automobile-oriented transportation, three (3) mode-shift analyses from driving to public transportation were conducted using the City of Chicago’s goal of increasing ridership on public transit by 30%. To perform these analyses, 30% of the automobile-oriented passenger miles were reallocated to the alternative transportation modes. The corresponding GHG Inventories were then calculated using the Campus Carbon Calculator™ previously determined emission factors for CO_2, CH_4 and N_2O. One (1) important assumption was made in performing the mode-shift analyses:

- Alternative modes of transportation had the capacity for 30% increased ridership.

3.0 DATA

3.1 UIC Population Data

Faculty and student population data were needed for the analysis. These data were obtained from the UIC Office of Data Resources and Institutional Analysis (DRIA). The data were provided by semester. Fall Semester 2008 enrollment data were used to determine the number of students, faculty and staff for the analysis.

3.2 Commuter Survey Data

The primary source of data for this project was a transportation commuter survey. The survey was administered on-line by the UIC Office of Sustainability in the fall of 2008. The survey was intended to provide information on which mode(s) of transportation UIC commuters use to travel to campus. Moreover, the survey was intended to identify the average number of trips per year and the average trip distances for each mode(s). These results were used to estimate the total UIC commuter passenger miles for each transportation mode.

There were 2,685 respondents to the survey. The survey allowed respondents to specify up to three (3) different Legs of a trip to UIC. For example, a respondent may have utilized two (2) modes of transportation if s/he drove to a train station and then rode a train into UIC. A copy of the survey questionnaire has been included in Appendix A.

The commuter transportation survey results were provided in a Microsoft excel worksheet. The data were first organized in excel and then imported into SPSS for statistical analyses. The first step involved deleting columns of unnecessary data. The second step involved assigning numerical values to respondents' verbal responses, such as to numerically identify the mode of transportation used for a particular Leg of a trip.

Then, all of the responses were separated by UIC role. Three roles were possible: Students, Faculty or Staff. This was accomplished by sorting the data by UIC role and then generating three new excel files, one for each UIC role. For example, the student survey data were created by deleting responses from faculty and staff. Similarly, the faculty survey data were created by deleting responses from students and staff. Finally, the staff survey data were created by deleting responses from students and faculty.

Once a separate data file had been created for each of the three populations, each excel file was then imported into SPSS for further investigation. The categories (columns of data) that were imported into SPSS were:

- Weeks (per year) traveling to UIC
- Days per week traveling to UIC
- Leg 1 Mode
- Trip Distance for Leg 1
- Leg 2 Mode
- Trip Distance for Leg 2
- Leg 3 Mode
- Trip Distance for Leg 3

Once these data were entered into SPSS, the data were then aggregated three (3) separate times for each group of UIC commuters (students, staff & faculty) using the Trip Leg as the break variable. Each Trip Leg involved seven (7) possible mode choices, represented by the following variables:

1. Driving
2. Carpooling
3. Metra (Commuter Rail)
4. CTA-El (Light Rail)
5. Bus
6. Walk
7. Bike

The student data set was first aggregated by using Trip Leg 1 as the Break Variable. The summary variables obtained through this aggregation were:

- Number of Student Respondents traveling Leg 1
- Mean weeks per year traveling to UIC
- Mean days per week traveling to UIC
- Average Trip Distance per mode during Leg 1

Data were then aggregated similarly for Trip Leg 2 and Trip Leg 3. However, the only summary variable obtained through these secondary aggregations was the average trip distance per mode. A dummy variable of '0' was used for Leg 2 and Leg 3 in the event that the student's trip had been completed after Leg 1. Values of '0' were then specified as missing upon aggregating data by Leg 2 and Leg 3 to determine average trip distances for each mode.

Percentages of students who used each mode were determined by first totaling the number of students using that mode for any Leg of their trip. That number was then divided by the total number of student responses to estimate the percentage of students that would use that mode. For example, out of a known number of 1,127 student responses, if 207 students used light rail as the transportation mode for the first Leg of their journey to UIC, 230 students used light rail as the transportation mode for the second Leg of their journey to UIC, and 62 students used light rail as the mode for the third Leg of their journey to UIC, the percent of students estimated to use light rail was (207+230+62)/1,127, or 44.3%.

The average trip distances per mode were determined by calculating the weighted average of the trip distances for multiple Trip Legs. For example, if the average trip distance was 8.47 miles for 207 students using light rail for the first Leg of their trip, 8.60 miles for 230 students using light rail for the second Leg of their trip, and 3.59 miles for 62 students using light rail for the third leg of their trip, the overall average trip distance was determined by taking the weighted average as illustrated below.

Avg. Trip Distance = [(207)(8.47)+(230)(8.60)+(62)(3.59)]/(207+230+62) = 7.92miles.

This process was repeated for the staff population and again for the faculty population.

3.3 Campus Carbon Calculator™

The Campus Carbon Calculator™ in a Microsoft excel workbook designed to facilitate conducting a greenhouse gas emissions inventory. It includes all six greenhouse gases specified by the Kyoto Protocol (CO_2, CH_4, N_2O, HFC, PFC and SF_6). The Campus Carbon Calculator uses standard methodologies codified by the GHG Protocol Initiative, and employed by corporations, the state of California, The Climate Registry, and other entities to account for greenhouse gas emissions, most notably, the World Resources Institute and the California Climate Action Registry (CACP, 2008).

4.0 GREENHOUSE GAS INVENTORY RESULTS

4.1 UIC Population Data

The population data obtained from DRIA has been summarized on the following Table 4.1. Faculty and staff were based on full-time equivalent (FTE). These data represent UIC enrollment data for fall 2008 (DRIA 2009).

Table 4.1

UIC Population Fall 2008	
Students Full Time	20,125
Students Part Time	5,000
Faculty	2,574
Staff	8,941

Based on the number of full and part time students listed above, the analysis student population was determined by summing the full-time students and half of the part-time students. Summer school students were not included in the analysis.

4.2 Mode Choice

Based on the statistical evaluation of the commuter survey data, the mode choice analysis for UIC commuters has been summarized on Table 4.2.

Table 4.2

Summary of Mode Choice						
UIC Role	Population	% Driving	% Carpool	% Light Rail	% Commuter Rail	% Bus
Students	22,625	32.4	5.0	44.3	24.0	47.0
Staff	8,941	53.2	9.7	24.1	30.8	26.0
Faculty	2,574	43.2	7.4	25.2	26.1	28.0

The average number of people per vehicle for commuters that carpooled was two (2). The above table indicates the percentages of each population that utilized each mode. For example, 53.2% of UIC staff drove to get to UIC. Of that 53.2%, 9.7% carpooled. Similarly, 47% of UIC students used the bus to get to UIC. The percentages summed for each column do not add up to 100% because commuters were allowed to use up to three (3) different modes of transportation for one trip to UIC. Copies of the SPSS aggregation case summaries have been included in Appendix B.

4.3 Transportation Activity Data

4.3.1 Student Activity Data

Based on the responses from students only, the average number of trips per week, the average number of weeks traveling to UIC per year, and the average trip distances (in miles) were determined through an aggregation using SPSS. The numbers of using each mode was determined by multiplying the appropriate percentage by the total population (22,625). Based on the number of trips, the student passenger miles were calculated for each mode. The results have been provided on Table 4.3 below.

Table 4.3

Student Summary of Miles Traveled per Mode (22,625 Students)						
Mode	%	Number of Students	Average Trips/Week	Average Weeks/Year	Average Miles/Trip	Passenger Miles
Driving	32.37	7,324	8	29	15	24,730,185
Carpooling	4.97	562	8	29	15	1,898,502
Bus	47.00	10,634	9	29	4	11,883,640
Light Rail	44.30	10,023	9	29	8	19,882,252
Commuter Rail	24.00	5,430	9	27	30	39,035,683

4.3.2 Staff Activity Data

The staff activity data, in passenger miles per mode, were calculated using output data from SPSS, and the results have been summarized on Table 4.4 below.

Table 4.4

Staff Summary of Miles Traveled per Mode (8,941 Staff)						
Mode	%	Number of Staff	Average Trips/Week	Average Weeks/Year	Average Miles/Trip	Passenger Miles
Driving	53.20	4,757	10	46	14	29,260,242
Carpooling	9.70	434	10	46	14	2,667,522
Bus	28.00	2,503	10	45	5	5,395,417
Light Rail	25.20	2,253	10	43	7	6,861,064
Commuter Rail	26.10	2,334	10	46	27	27,935,849

4.3.3 Faculty Activity Data

The faculty activity data, in passenger miles per mode, were calculated using output data from SPSS, and the results have been summarized on Table 4.5 below.

Table 4.5

Faculty Summary of Miles Traveled per Mode (2,574 Faculty)						
Mode	%	Number of Faculty	Average Trips/Week	Average Weeks/Year	Average Miles/Trip	Passenger Miles
Driving	43.20%	1,112	9	43	13	5,283,516
Carpooling	7.40%	95	9	43	13	452,523
Bus	26.00%	669	8	40	4	845,234
Light Rail	24.10%	620	9	43	7	1,562,817
Commuter Rail	30.80%	793	9	45	24	7,486,176

4.3.4 Overall UIC Commuter Activity Data

The travel activity data on Tables 4.3 through 4.5 was combined to represent the baseline transportation activity data for the entire population of UIC commuters. The baseline UIC commuter activity data has been summarized on Table 4.6.

Table 4.6

Summary of Transportation Activity Data				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	26,628,687	11,883,640	19,882,252	39,035,683
Faculty / Staff	37,663,803	6,240,652	8,423,881	35,422,025
Total	64,292,490	18,124,291	28,306,134	74,457,709

4.4 Emission Factors

Emission factors were obtained for the three (3) greenhouse gases under consideration, carbon dioxide, methane, and nitrous oxide. Based on the assumptions stated in Section 2.1.2, the emission factors output by the Campus Carbon Calculator have been summarized on Table 4.7.

Table 4.7

Summary of Emission Factors				
	kg / mile			
Compound	Driving	Bus	Light Rail	Commuter Rail
CO_2	0.393965246	0.25174798	0.116384097	0.124520585
CH_4	7.88043E-05	1.4293E-05	2.88314E-06	5.50078E-06
N_2O	2.71243E-05	6.4783E-06	2.05427E-06	2.80812E-06

4.5 Baseline Greenhouse Gas Emissions Inventory

The greenhouse gas emissions inventory was estimated by multiplying the transportation activity data (in passenger miles) for each mode by the appropriate emissions factor. The results of the greenhouse gas emissions inventory have been presented for each of the three (3) greenhouse gases under consideration in the following subsections.

4.5.1 Carbon Dioxide

Based on the emission factors and the total miles traveled per mode, the carbon dioxide emissions inventory was calculated and has been summarized on Table 4.8.

Table 4.8

Summary of CO_2 Emissions (kg)			
Mode	Activity Data	Emission Factor	CO_2 Emissions Inventory
Driving	64,292,490	3.94E-01	25,329,007
Bus	18,124,291	2.52E-01	4,562,754
Light Rail	28,306,134	1.16E-01	3,294,384
Commuter Rail	74,457,709	1.25E-01	9,271,517
Total CO_2 Emissions (kg)			42,457,662

4.5.2 Methane

Based on the emission factors and the total miles traveled per mode, the methane emissions inventory was calculated and has been summarized on Table 4.9.

Table 4.9

Summary of CH_4 Emissions (kg)			
Mode	Activity Data	Emission Factor	CH_4 Emissions Inventory
Driving	64,292,490	7.88E-05	5,067
Bus	18,124,291	1.43E-05	259
Light Rail	28,306,134	2.88E-06	82
Commuter Rail	74,457,709	5.50E-06	410
Total CH_4 Emissions (kg)			5,817

4.5.3 Nitrous Oxide

Based on the emission factors and the total miles traveled per mode, the nitrous oxide emissions inventory was calculated and has been summarized on Table 4.10.

Table 4.10

Summary of N_2O Emissions (kg)			
Mode	Activity Data	Emission Factor	N_2O Emissions Inventory
Driving	64,292,490	2.71E-05	1,744
Bus	18,124,291	6.48E-06	117
Light Rail	28,306,134	2.05E-06	58
Commuter Rail	74,457,709	2.81E-06	209
Total N_2O Emissions (kg)			2,129

4.5.4 Carbon Dioxide Equivalents

The emissions inventories for each greenhouse gas summarized in Tables 4.8 through 4.10 have been normalized to carbon dioxide equivalents (eCO_2). The raw emissions inventory for each compound was converted to carbon dioxide equivalents by multiplying the emissions by the global warming potential (GWP) factor for the 100-year time period. Methane emissions were multiplied by a factor of 23 because methane is 23 times more potent of a greenhouse gas than carbon dioxide. Similarly, nitrous oxide is 296 times more potent of a greenhouse gas than carbon dioxide. The baseline commuter transportation GHG Inventory totaled 43,221 metric tones of eCO_2. The carbon dioxide equivalent emissions have been tabulated by compound on Table 4.11, and by mode on Table 4.12 and Figure 1.

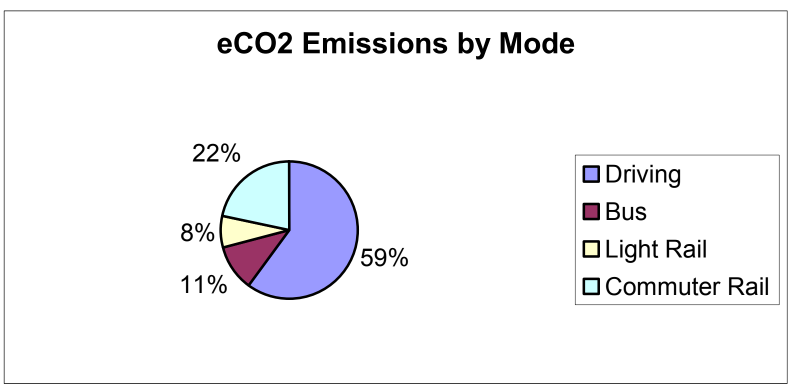
Table 4.11

Total Emissions Summary as CO_2 Equivalent				
Compound	Total Emissions (kg)	Global Warming Potential	CO_2 Equivalent (kg)	Metric Tons eCO_2
CO_2	42,457,662	1	42,457,662	42,458
CH_4	5,817	23	133,785	134
N_2O	2,129	296	630,047	630
Total CO_2 Equivalent Emissions (metric tonnes)				43,221

Table 4.12

Summary of eCO_2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	25,329,007	116,530	516,190	25,962
Bus	4,562,754	5,958	34,755	4,603
Light Rail	3,294,384	1,877	17,212	3,313
Commuter Rail	9,271,517	9,420	61,890	9,343
Total eCO_2 Emissions				43,221

Figure 1: Baseline eCO_2 Emissions by Mode.



For the baseline GHG Inventory, CO_2 itself accounted for approximately 98% of the greenhouse gas emissions. Automobile oriented transportation accounted for approximately 59% of UIC commuter transportation emissions. Commuter rail was the second leading emitter followed by bus, and light rail transit comprised the lowest percent of commuter transportation emissions.

5.0 MODE-SHIFT ANALYSIS RESULTS

5.1 Automobile to Light Rail

The baseline transportation activity data were modified to simulate a 30% mode shift from driving to light rail. Therefore, the baseline automobile VMT (Table 4.6) were reduced by 30% and these passenger miles were reallocated to the light rail mode. Bus and commuter rail activity data remained unmodified from the baseline condition. The activity data representative of a 30% reduction in driving passenger miles and a commensurate 30% increase in light rail passenger miles has been summarized on Table 5.1.

Table 5.1

Summary of Transportation Activity Data (30% mode-shift)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	11,883,640	33,383,675	39,035,683
Faculty / Staff	26,364,662	6,240,652	14,210,205	35,422,025
Total	45,004,743	18,124,291	47,593,880	74,457,709

Emission factors for the mode-shift analysis were unmodified and reported on Table 4.7.

Following the previously described procedure of multiplying the transportation activity data by the emission factors, the GHG Inventories for CO_2, CH_4, and N_2O were recalculated using the activity data representative of a 30% mode-shift from automobile to light rail. The CO_2, CH_4, and N_2O emissions were again normalized into carbon dioxide equivalents (eCO_2) according to their respective global warming potential factors of 1, 23, and 296. The results of the normalized mode-shift GHG Inventory totaled 37,691 metric tones of eCO_2 as summarized on Table 5.2.

Table 5.2

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	4,562,754	5,958	34,755	4,603
Light Rail	5,539,171	3,156	28,940	5,571
Commuter Rail	9,271,517	9,420	61,890	9,343
Total eCO_2 Emissions				37,691

This mode-shift from automobile to light rail scenario represented a 13% reduction in greenhouse gas emissions from the baseline greenhouse gas emissions. Interim greenhouse gas inventory results for this scenario have been provided in Appendix C.

5.2 Automobile to Bus

The baseline transportation activity data were modified to simulate a 30% mode shift from driving to bus. Therefore, the baseline automobile VMT (Table 4.6) were reduced by 30% and these passenger miles were reallocated to the bus mode. Light rail and commuter rail activity data remained unmodified from the baseline condition. The activity data representative of a 30% reduction in driving passenger miles and a commensurate 30% increase in bus passenger miles has been summarized on Table 5.3.

Table 5.3

Summary of Transportation Activity Data (30% mode-shift to bus)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	24,420,676	19,882,252	39,035,683
Faculty / Staff	26,364,662	12,991,363	8,423,881	35,422,025
Total	45,004,743	37,412,039	28,306,133	74,457,709

Emission factors for the mode-shift analysis were unmodified and reported on Table 4.7.

Following the previously described procedure of multiplying the transportation activity data by the emission factors, the GHG Inventories for CO_2, CH_4, and N_2O were recalculated using the activity data representative of a 30% mode-shift from automobile to bus. The CO_2, CH_4, and N_2O emissions were again normalized into carbon dioxide equivalents (eCO_2) according to their respective global warming potential factors of 1, 23, and 296. The results of the normalized mode-shift GHG Inventory totaled 40,332 metric tones of eCO_2 as summarized on Table 5.4.

Table 5.4

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	9,418,405	12,299	71,741	9,502
Light Rail	3,294,384	1,877	17,212	3,313
Commuter Rail	9,271,517	9,420	61,890	9,343
Total eCO_2 Emissions				40,332

This mode-shift from automobile to bus scenario represented a 7% reduction in greenhouse gas emissions from the baseline greenhouse gas emissions. Interim greenhouse gas inventory results for this scenario have been provided in Appendix D.

5.3 Automobile to Commuter Rail

The baseline transportation activity data were modified to simulate a 30% mode shift from driving to commuter rail. Therefore, the baseline automobile VMT (Table 4.6) were reduced by 30% and these passenger miles were reallocated to the commuter rail mode. Light rail and bus activity data remained unmodified from the baseline condition. The activity data representative of a 30% reduction in driving passenger miles and a commensurate 30% increase in commuter rail passenger miles has been summarized on Table 5.5.

Table 5.5

Summary of Transportation Activity Data (30% mode-shift to commuter rail)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	11,883,640	19,882,252	49,065,311
Faculty / Staff	26,364,662	6,240,652	8,423,881	44,680,144
Total	45,004,743	18,124,292	28,306,133	93,745,455

Emission factors for the mode-shift analysis were unmodified and reported on Table 4.7.

Following the previously described procedure of multiplying the transportation activity data by the emission factors, the GHG Inventories for CO_2, CH_4, and N_2O were recalculated using the activity data representative of a 30% mode-shift from automobile to commuter rail. The CO_2, CH_4, and N_2O emissions were again normalized into carbon dioxide equivalents (eCO_2) according to their respective global warming potential factors of 1, 23, and 296. The results of the normalized mode-shift GHG Inventory totaled 37,853 metric tones of eCO_2 as summarized on Table 5.6.

Table 5.6

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	4,562,754	5,958	34,755	4,603
Light Rail	3,294,384	1,877	17,212	3,313
Commuter Rail	11,673,239	11,860	77,922	11,763
Total eCO_2 Emissions				37,853

This mode-shift from automobile to commuter rail scenario represented a 12% reduction in greenhouse gas emissions from the baseline greenhouse gas emissions. Interim greenhouse gas inventory results for this scenario have been provided in Appendix E.

5.4 Comparison of Mode-Shift Scenarios

All of the mode-shift scenarios modeled for this project resulted in an overall reduction in greenhouse gas emissions. Based on the percent reductions in greenhouse gas emissions, the best mode-shift alternative was from automobile to light rail. The second best mode-shift alternative was from automobile to commuter rail and the third best mode-shift alternative was from automobile to bus. The baseline scenario was outperformed by every mode-shift alternative. The results of the three (3) different mode-shift scenarios have been compared to the baseline condition on Table 5.7.

Table 5.7

Comparison of Mode-Shift Alternatives		
Mode-Shift Scenario	eCO_2 Emissions (Metric Tonnes)	Percent Reduction
Baseline	43,221	0%
Light Rail	37,691	13%
Bus	40,332	7%
Commuter Rail	37,853	12%

6.0 CONCLUSIONS

A greenhouse gas inventory was conducted for UIC commuters based on the results of a transportation commuter survey. The transportation commuter survey was used to determine the transportation activity data for UIC commuters. Commuters consisted of students, staff and faculty. The survey was used to determine the passenger miles traveled by UIC commuters for the following modes of transportation: driving (including carpooling), bus, light rail (CTA) and commuter rail (Metra). Emission factors for CO_2, CH_4 and N_2O were generated using the Campus Carbon Calculator^{TM}. The emissions factors were multiplied by the transportation activity data to determine the baseline greenhouse gas emissions inventory. After the baseline greenhouse gas emissions inventory was completed, three (3) mode shift alternatives were evaluated to predict the impact on greenhouse gas emissions resulting from a 30% mode-shift from driving to alternative modes of transportation.

The baseline GHG Inventory concluded that 43,221 metric tons of greenhouse gases as eCO_2 were emitted as a result of commuter travel to and from UIC by students, staff and faculty. Fifty-nine percent (59%) of the greenhouse gas emissions were related to driving. All of the mode-shift scenarios resulted in a reduction of greenhouse gas emissions. The best mode-shift alternative was the automobile to light rail scenario. Under this scenario, the GHG Inventory predicted that 37,691 metric tons of greenhouse gases would be emitted as a result of commuter travel to and from UIC by students, staff and faculty, which resulted in an overall 13% reduction in greenhouse gas emissions. Forty-eight percent (48%) of the greenhouse gas emissions were still related to automobile-oriented transportation. In both cases, ninety-eight percent (98%) of the emissions were as CO_2.

It was clear that the majority of commuter transportation-related greenhouse gas emissions were related to automobile-oriented transit under both the baseline scenario and the 30% mode-shift conditions. Therefore, it was concluded that decreasing automobile related transportation can help UIC reduce its overall carbon footprint and support sustainability.

Comprehensive transportation planning must occur in order to facilitate a reduction in automobile-oriented transportation. City planners and decision-makers must take measures to increase the viability of walking, cycling or public transit. These activities support sustainability through the reduction of automobile-oriented transportation by reducing per-capita resource consumption, traffic congestion, accidents, pollution, and land consumption. In addition, increasing travel options for non-drivers can help to reduce social inequity (Litman, 2005).

The commuter transportation survey was not specifically designed to provide the results that were obtained for this project. Therefore, the commuter transportation survey should be revised and reissued in the fall of 2009 and then conducted annually thereafter. The quality of the commuter transportation survey is paramount because all transportation emissions will be based on the results of the survey. It is the only way to measure transportation activity. Furthermore, the mode-shift analysis presented herein was based on a unilateral reallocation of 30% of automobile passenger miles to a single alternate mode. A mode-shift of automobile passenger miles would most likely be reallocated among multiple alternative modes of transportation. Transportation improvement options should be considered when revising the survey to receive input regarding the barriers to reducing automobile-oriented transportation.

7.0 REFERENCES

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APPENDIX A

Commuter Survey Questionnaire

1	**What is the zip code of your residence while you work or attend classes at UIC?**
2	**When commuting to UIC, where do you usually go?**
3	**What is your primary role at UIC?**
4	**Do you use the U-pass for commuting to and from campus?**
5	**During the past year, approximately how many weeks did you travel to campus? (Note: summer session is 4 or 8 weeks; fall and spring semesters are 16 weeks)**
6	**In a typical week, how many days do you commute to campus?**
7	**In a typical week, during the periods when you are on campus, what time are you on campus?**
8	**Think about your commute from home to campus, most days, during the past year. The first mode of transport you use when you leave your residence is:**
9	**If you carpool, how many people are in the vehicle?**
10	**Approximately how many miles do you travel to get to UIC in this mode of transportation?**
11	**Do you use a second mode of transportation to continue your trip to UIC? (e.g. use commuter shuttle from Metra station)**
12	**The second mode of transport you use during your commute to UIC is:**
13	**If you carpool, how many people are in the vehicle?**
14	**Approximately how many miles do you travel in this mode of transportation?**
15	**Do you use a third mode of transportation, to continue your travels?**
16	**The third mode of transport you use during your commute to UIC is: (e.g. walking from Metra Station)**
17	**Approximately how many miles do you travel to get to UIC in this mode of transportation?**
18	**During the past year approximately how many times have you commuted to and around campus via bicycle?**
19	**I would commute to and around campus on a bike more often if (check all that apply):**
20	**If you use a car to get to UIC, what are the major barriers that prevent you from taking public transportation to campus? (Select up to 3 responses)**
21	**In the past year, did you travel by Amtrak train for university purposes? (including academic activities, sports activities, study abroad programs, etc)**
22	**Approximately how many trips did you take via Amtrak rail for university purposes in the past year? (please answer question 7 also)**
23	**Approximately how far did you travel via Amtrak rail for university purposes, in total, during the past year?**
24	**In the past year did you travel by air for university purposes (including academic activities, sports activities, study abroad programs, etc)**
25	**How many flights were less than four hours in length?**
26	**How many flights were more than four hours in length?**

APPENDIX B

SPSS Case Summaries

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Summarize

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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
WEEKSTOUIC_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
DAYSPERWEEK_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
MODE1MILES_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
N_BREAK * MODE 1	7	100.0%	0	.0%	7	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				WEEKSTOUIC_mean	DAYSPERWEEK_mean	MODE1 MILES_mean	N_BREAK
MODE 1	1	1		28.95	4.02	14.41	291
		Total	N	1	1	1	1
	2	1		27.13	4.13	11.70	53
		Total	N	1	1	1	1
	3	1		29.26	4.28	8.47	207
		Total	N	1	1	1	1
	4	1		27.32	4.39	29.57	142
		Total	N	1	1	1	1
	5	1		29.00	4.54	5.46	267
		Total	N	1	1	1	1
	6	1		31.19	4.66	2.88	90
		Total	N	1	1	1	1
	7	1		29.99	4.64	1.98	177
		Total	N	1	1	1	1
	Total	N		7	7	7	7

a. Limited to first 100 cases.

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Summarize

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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE2MILES_mean * MODE 2	7	77.8%	2	22.2%	9	100.0%
N_BREAK * MODE 2	7	77.8%	2	22.2%	9	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE2 MILES_mean	N_BREAK
MODE 2	.			17.26	18
	1	1		17.26	18
		Total	N	1	1
	2	1		11.92	3
		Total	N	1	1
	3	1		8.60	230
		Total	N	1	1
	4	1		29.92	123
		Total	N	1	1
	5	1		3.49	178
		Total	N	1	1
	6	1		9.22	11
		Total	N	1	1
	7	1		1.98	35
		Total	N	1	1
	Total	N		7	7

a. Limited to first 100 cases.

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  /MISSING=VARIABLE
  /CELLS=COUNT .
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Summarize

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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE3MILES_mean * MODE 3	5	83.3%	1	16.7%	6	100.0%
N_BREAK * MODE 3	5	83.3%	1	16.7%	6	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE3 MILES_mean	N_BREAK
MODE 3	-1			3.59	62
	3	1		3.59	62
		Total	N	1	1
	4	1		40.42	6
		Total	N	1	1
	5	1		2.42	85
		Total	N	1	1
	6	1		2.00	1
		Total	N	1	1
	7	1		.75	57
		Total	N	1	1
	Total	N		5	5

a. Limited to first 100 cases.

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DATASET CLOSE DataSet3.
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  /CELLS=COUNT .
```

Summarize

```
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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
WEEKSTOUIC_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
DAYSPERWEEK_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
MODE1MILES_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
N_BREAK * MODE 1	7	100.0%	0	.0%	7	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				WEEKSTOUIC_mean	DAYSPERWEEK_mean	MODE1 MILES_mean	N_BREAK
MODE 1	1	1		45.79	4.82	13.83	507
		Total	N	1	1	1	1
	2	1		46.79	4.79	12.76	111
		Total	N	1	1	1	1
	3	1		43.14	4.95	8.57	114
		Total	N	1	1	1	1
	4	1		46.11	4.86	27.19	168
		Total	N	1	1	1	1
	5	1		45.25	4.90	7.23	133
		Total	N	1	1	1	1
	6	1		46.12	5.00	3.90	41
		Total	N	1	1	1	1
	7	1		45.24	4.72	2.05	107
		Total	N	1	1	1	1
	Total	N		7	7	7	7

a. Limited to first 100 cases.

```
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Summarize

```
[DataSet5] E:\CME507\cme507 term project\staff.agg.mode2.sav
```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE2MILES_mean * MODE 2	7	77.8%	2	22.2%	9	100.0%
N_BREAK * MODE 2	7	77.8%	2	22.2%	9	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE2 MILES_mean	N_BREAK
MODE 2	.			21.17	7
	1	1		21.17	7
		Total	N	1	1
	2	1		20.50	3
		Total	N	1	1
	3	1		6.99	143
		Total	N	1	1
	4	1		26.30	138
		Total	N	1	1
	5	1		3.30	102
		Total	N	1	1
	6	1		5.79	7
		Total	N	1	1
	7	1		1.27	27
		Total	N	1	1
	Total	N		7	7

a. Limited to first 100 cases.

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```

Summarize

```
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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE3MILES_mean * MODE 3	5	83.3%	1	16.7%	6	100.0%
N_BREAK * MODE 3	5	83.3%	1	16.7%	6	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE3 MILES_mean	N_BREAK
MODE 3	-1			3.51	40
	3	1		3.51	40
		Total	N	1	1
	4	1		15.00	2
		Total	N	1	1
	5	1		3.22	96
		Total	N	1	1
	6	1		1.63	4
		Total	N	1	1
	7	1		.94	64
		Total	N	1	1
	Total	N		5	5

a. Limited to first 100 cases.

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DATASET ACTIVATE DataSet4.
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```

Summarize

```
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```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
WEEKSTOUIC_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
DAYSPERWEEK_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
MODE1MILES_mean * MODE 1	7	100.0%	0	.0%	7	100.0%
N_BREAK * MODE 1	7	100.0%	0	.0%	7	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				WEEKSTOUIC_mean	DAYSPERWEEK_mean	MODE1 MILES_mean	N_BREAK
MODE 1	1	1		43.02	4.25	12.82	130
		Total	N	1	1	1	1
	2	1		46.25	4.86	11.76	28
		Total	N	1	1	1	1
	3	1		43.42	4.33	7.17	43
		Total	N	1	1	1	1
	4	1		44.94	4.30	24.14	64
		Total	N	1	1	1	1
	5	1		40.48	4.16	4.30	31
		Total	N	1	1	1	1
	6	1		38.74	4.76	4.03	38
		Total	N	1	1	1	1
	7	1		42.23	4.56	1.26	43
		Total	N	1	1	1	1
	Total	N		7	7	7	7

a. Limited to first 100 cases.

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Summarize

```
[DataSet8] E:\CME507\cme507 term project\fac.agg.mode2.sav
```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE2MILES_mean * MODE 2	6	75.0%	2	25.0%	8	100.0%
N_BREAK * MODE 2	6	75.0%	2	25.0%	8	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE2 MILES_mean	N_BREAK
MODE 2	.			17.65	5
	1	1		17.65	5
		Total	N	1	1
	3	1		7.19	36
		Total	N	1	1
	4	1		24.78	51
		Total	N	1	1
	5	1		2.88	43
		Total	N	1	1
	6	1		10.50	5
		Total	N	1	1
	7	1		1.96	8
		Total	N	1	1
	Total	N		6	6

a. Limited to first 100 cases.

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  /MISSING=VARIABLE
  /CELLS=COUNT .
```

Summarize

```
[DataSet9] E:\CME507\cme507 term project\fac.agg.mode3.sav
```

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MODE3MILES_mean * MODE 3	5	83.3%	1	16.7%	6	100.0%
N_BREAK * MODE 3	5	83.3%	1	16.7%	6	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

				MODE3 MILES_mean	N_BREAK
MODE 3	-1			3.54	12
	3	1		3.54	12
		Total	N	1	1
	4	1		25.00	1
		Total	N	1	1
	5	1		4.59	24
		Total	N	1	1
	6	1		4.83	6
		Total	N	1	1
	7	1		1.03	29
		Total	N	1	1
	Total	N		5	5

a. Limited to first 100 cases.

```
DATASET ACTIVATE DataSet4.
DATASET CLOSE DataSet9.
DATASET ACTIVATE DataSet4.
DATASET CLOSE DataSet8.
DATASET ACTIVATE DataSet4.
DATASET CLOSE DataSet7.
DATASET ACTIVATE DataSet5.
DATASET CLOSE DataSet4.
```

APPENDIX C

Interim Results for 30% Mode-Shift from Automobile to Light Duty Rail

Appendix C: 30% Mode Shift from Automobile to Light Duty Rail

Table C.1

Summary of Transportation Activity Data (30% mode-shift to light rail)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	11,883,640	33,383,675	39,035,683
Faculty / Staff	26,364,662	6,240,652	14,210,205	35,422,025
Total	45,004,743	18,124,291	47,593,880	74,457,709

Table C.2

Summary of CO_2 Emissions (kg)			
Mode	Activity Data	Emission Factor	CO_2 Emissions Inventory
Driving	45,004,743	3.94E-01	17,730,305
Bus	18,124,291	2.52E-01	4,562,754
Light Rail	47,593,880	1.16E-01	5,539,171
Commuter Rail	74,457,709	1.25E-01	9,271,517
Total CO_2 Emissions (kg)			37,103,747

Table C.3

Summary of CH_4 Emissions (kg)			
Mode	Activity Data	Emission Factor	CH_4 Emissions Inventory
Driving	45,004,743	7.88E-05	3,547
Bus	18,124,291	1.43E-05	259
Light Rail	47,593,880	2.88E-06	137
Commuter Rail	74,457,709	5.50E-06	410
Total CH_4 Emissions (kg)			4,352

Table C.4

Summary of N_2O Emissions (kg)			
Mode	Activity Data	Emission Factor	N_2O Emissions Inventory
Driving	45,004,743	2.71E-05	1,221
Bus	18,124,291	6.48E-06	117
Light Rail	47,593,880	2.05E-06	98
Commuter Rail	74,457,709	2.81E-06	209
Total N_2O Emissions (kg)			1,645

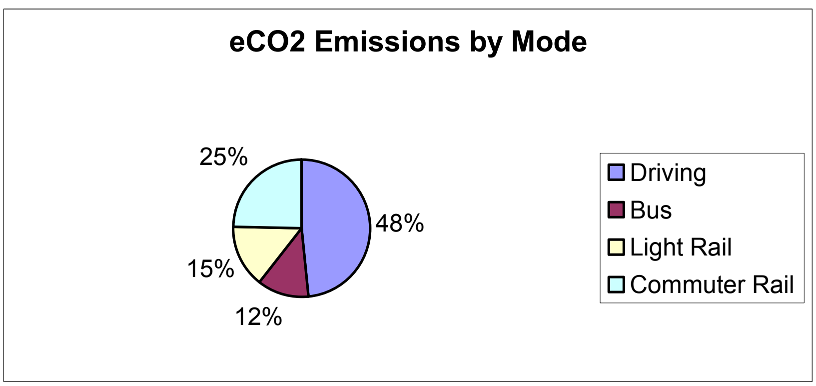
Table C.5

Total Emissions Summary as CO_2 Equivalent				
Compound	Total Emissions (kg)	Global Warming Potential	CO_2 Equivalent (kg)	Metric Tons eCO_2
CO_2	37,103,747	1	37,103,747	37,104
CH_4	4,352	23	100,105	100
N_2O	1,645	296	486,918	487
Total CO_2 Equivalent Emissions (metric tonnes)				37,691

Table C.6

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	4,562,754	5,958	34,755	4,603
Light Rail	5,539,171	3,156	28,940	5,571
Commuter Rail	9,271,517	9,420	61,890	9,343
Total eCO_2 Emissions				37,691

Figure C.1



APPENDIX D

Interim Results for 30% Mode-Shift from Automobile to Bus

Table D.1

Summary of Transportation Activity Data (30% mode-shift to bus)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	24,420,676	19,882,252	39,035,683
Faculty / Staff	26,364,662	12,991,363	8,423,881	35,422,025
Total	45,004,743	37,412,039	28,306,133	74,457,709

Table D.2

Summary of CO_2 Emissions (kg)			
Mode	Activity Data	Emission Factor	CO_2 Emissions Inventory
Driving	45,004,743	3.94E-01	17,730,305
Bus	37,412,039	2.52E-01	9,418,405
Light Rail	28,306,133	1.16E-01	3,294,384
Commuter Rail	74,457,709	1.25E-01	9,271,517
Total CO_2 Emissions (kg)			39,714,611

Table D.3

Summary of CH_4 Emissions (kg)			
Mode	Activity Data	Emission Factor	CH_4 Emissions Inventory
Driving	45,004,743	7.88E-05	3,547
Bus	37,412,039	1.43E-05	535
Light Rail	28,306,133	2.88E-06	82
Commuter Rail	74,457,709	5.50E-06	410
Total CH_4 Emissions (kg)			4,572

Table D.4

Summary of N_2O Emissions (kg)			
Mode	Activity Data	Emission Factor	N_2O Emissions Inventory
Driving	45,004,743	2.71E-05	1,221
Bus	37,412,039	6.48E-06	242
Light Rail	28,306,133	2.05E-06	58
Commuter Rail	74,457,709	2.81E-06	209
Total N_2O Emissions (kg)			1,730

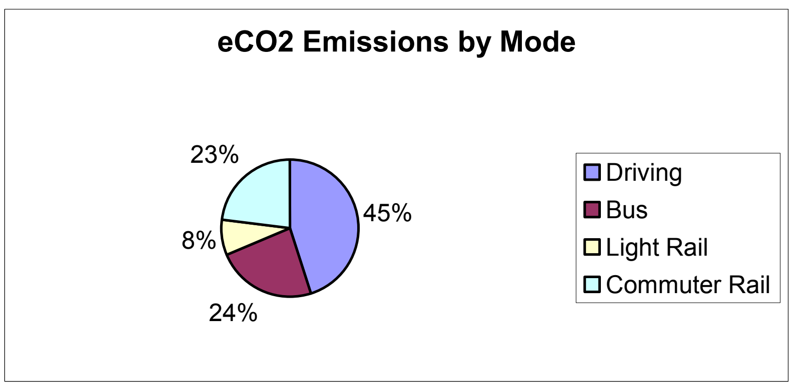
Table D.5

Total Emissions Summary as CO_2 Equivalent				
Compound	Total Emissions (kg)	Global Warming Potential	CO_2 Equivalent (kg)	Metric Tons eCO_2
CO_2	39,714,611	1	39,714,611	39,715
CH_4	4,572	23	105,167	105
N_2O	1,730	296	512,176	512
Total CO_2 Equivalent Emissions (metric tonnes)				40,332

Table D.6

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	9,418,405	12,299	71,741	9,502
Light Rail	3,294,384	1,877	17,212	3,313
Commuter Rail	9,271,517	9,420	61,890	9,343
Total eCO_2 Emissions				40,332

Figure D.1



APPENDIX E

Interim Results for 30% Mode-Shift from Automobile to Commuter Rail

Table E.1

Summary of Transportation Activity Data (30% mode-shift to commuter rail)				
Population	Passenger Miles Traveled			
	Driving	Bus	Light Rail	Commuter Rail
Students	18,640,081	11,883,640	19,882,252	49,065,311
Faculty / Staff	26,364,662	6,240,652	8,423,881	44,680,144
Total	45,004,743	18,124,292	28,306,133	93,745,455

Table E.2

Summary of CO_2 Emissions (kg)			
Mode	Activity Data	Emission Factor	CO_2 Emissions Inventory
Driving	45,004,743	3.94E-01	17,730,305
Bus	18,124,292	2.52E-01	4,562,754
Light Rail	28,306,133	1.16E-01	3,294,384
Commuter Rail	93,745,455	1.25E-01	11,673,239
Total CO_2 Emissions (kg)			37,260,681

Table E.3

Summary of CH_4 Emissions (kg)			
Mode	Activity Data	Emission Factor	CH_4 Emissions Inventory
Driving	45,004,743	7.88E-05	3,547
Bus	18,124,292	1.43E-05	259
Light Rail	28,306,133	2.88E-06	82
Commuter Rail	93,745,455	5.50E-06	516
Total CH_4 Emissions (kg)			4,403

Table E.4

Summary of N_2O Emissions (kg)			
Mode	Activity Data	Emission Factor	N_2O Emissions Inventory
Driving	45,004,743	2.71E-05	1,221
Bus	18,124,292	6.48E-06	117
Light Rail	28,306,133	2.05E-06	58
Commuter Rail	93,745,455	2.81E-06	263
Total N_2O Emissions (kg)			1,660

Table E.5

Total Emissions Summary as CO_2 Equivalent				
Compound	Total Emissions (kg)	Global Warming Potential	CO_2 Equivalent (kg)	Metric Tons eCO_2
CO_2	37,260,681	1	37,260,681	37,261
CH_4	4,403	23	101,267	101
N_2O	1,660	296	491,222	491
Total CO_2 Equivalent Emissions (metric tonnes)				37,853

Table E.6

Summary of eCO2 Emissions by Mode				
Mode	kg eCO_2 (CO_2)	kg eCO_2 (CH_4)	kg eCO_2 (N_2O)	eCO_2 (Metric Tons)
Driving	17,730,305	81,571	361,333	18,173
Bus	4,562,754	5,958	34,755	4,603
Light Rail	3,294,384	1,877	17,212	3,313
Commuter Rail	11,673,239	11,860	77,922	11,763
Total eCO_2 Emissions				37,853

Figure E.1