Greenhouse Gas Emission Baseline: Students, Faculty and Staff Commuting to the University of British Columbia

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October 28, 2003

EXECUTIVE SUMMARY

The purpose of this report is to establish a clear baseline of the greenhouse gas (GHG) emissions that are created by students, faculty and staff commuting to the University of British Columbia (UBC). The impetus for establishing a baseline is to sell GHG emission credits that are earned through the U-Pass. By establishing a baseline of GHG emissions in 2002, the year prior to the U-Pass, UBC can monitor the impact of U-Pass and determine if any credits are available for sale.

Whether or not credits are sold, the larger goal is to reduce GHG emission at UBC. The UBC Campus Sustainability Office is conducting a campus wide GHG emission monitoring and reduction program. This report will facilitate that program by quantifying the transportation GHG emission total.

Calculations are performed for the years 1997 and 2002 for students, faculty and staff commuting to UBC by vehicle and bus. Based on the calculations, in 1997 the total GHG emissions were 28,619 tons and in 2002 they were 30,544 tons for an increase of 6.73%, or 1,925 tons. The emission difference between taking the bus and driving alone is very significant: the average return trip to campus in the average single occupant vehicle for 2002 produces 9.56 kg of CO2e, while the same trip in a bus produces 1.02 kg per passenger. So, if the U-Pass usage rates are high, there could be a distinct change in recent trends and UBC may notice a significant decrease in GHG emissions in the future.

The calculations have been produced using available data, traffic counts and survey results in a manner that is easily reproducible. The report includes a thorough discussion of the calculation framework, an analysis of the results, suggestions for future calculations and a series of spreadsheets containing the complete calculation.

This report is intended to act as a baseline for future emission calculations therefore it is crucial that the calculations contained in this report are reproduced for the year 2003 and the subsequent years after that.

GREENHOUSE GAS EMISSION BASELINE:

FROM STUDENTS, FACULTY AND STAFF COMMUTING TO THE UNIVERSITY OF BRITISH COLUMBIA

INTRODUCTION

An international consensus has emerged that confirms our world is getting warmer (Government of Canada, 2003). The 1980's and 1990's were the two warmest decades in history, the ten warmest years on record have occurred in the last 15 years and the 20th century was the warmest in 600 years (Government of Canada, 2003). Climate change could have disastrous effects on the human population, and as such, major efforts are being made to curb the rate at which the climate is changing. In order to prevent, or at least slow the rate of climate change, attempts are being made to reduce the release of human produced greenhouse gas (GHG). GHG's are natural occurring and give the earth the heat retention that is needed to support human life on earth. However, human activity has increased the amount of GHG in the atmosphere skewing the natural balance and changing weather patterns around the world.

If the goal then is to reduce GHG emissions, where is the best place to start? According to Canada's Greenhouse Gas Inventory, for the year 2000, transportation is the largest single source of emissions in Canada. (table 1)

NATIONAL GHG EMISSION SECTORS: 2000	
GHG Emission Source	**Percent of National Total**
Transportation	36.76
Energy/Heat/Manufacturing/Construction	36.23
Fugitive/Industrial Processes/Agriculture/Waste	23.36

Table 1 (Government of Canada, 2000)

The University of British Columbia (UBC) is the second most traveled to destination within the city of Vancouver, with downtown being first. In 1997 the UBC TREK Program Centre was established with a mandate to "reduce single-occupant vehicle (SOV) trips and increase transit ridership by 20%" (UBC TREK, 2003). One of the primary objectives of the UBC TREK Program Centre has been to implement a U-Pass, which is, among other things, a student wide bus pass. 2003 is the first year that the U-Pass is provided at UBC. One of the benefits of U-Pass is an anticipated reduction in GHG emissions.

Major efforts to reduce GHG emissions are ongoing at local, national and international levels. The most publicized initiative to date has been the Kyoto Protocol, which is an attempt to commit individual countries to reduce their GHG emissions by a stated amount. Canada's Kyoto target is to reduce GHG emissions to 6 percent below 1990 levels between 2008 and 2012. In order to accomplish this goal the federal government will rely on three market-based instruments, in addition to a number of non-market actions. One of the three market-based instruments is International Emissions Trading (IET). The objective of IET is to achieve a global reduction in GHG emissions at a minimal cost with maximum flexibility(Government of Canada, 2003). Through IET those organizations with a low cost of reducing GHG emissions may sell their reductions to organizations with a high cost of reduction. The theory follows that the GHG emission reduction targets will be met and market forces will ensure that this is done at the lowest possible cost.

PURPOSE

The initial impetus for this project was to trade GHG emission reductions generated at UBC. Selling GHG emission credits would help finance emission reduction projects, help mitigate climate change and serve as an excellent learning opportunity for those involved in the project. Discussions have taken place with two interested buyers: GEMCo and BC Hydro and it is expected that discussions will continue and that UBC will attempt to conduct a trade in the future.

In order to trade emission reductions, it must first be proven that there is in fact a reduction in emissions over a given time. UBC does not currently measure the amount of GHG emissions generated from transportation; therefore, a calculation of GHG emissions over time must be done prior to a sale. The primary purpose of this project is to quantify the amount of GHG emissions before the U-Pass is implemented in order to establish a baseline of GHG emissions attributed to commuting to UBC. As of September 2003, UBC will be introducing the U-Pass, which among many things will provide each student with a three-zone bus pass. It is anticipated that a large proportion of students will switch from single occupant vehicle use to public transportation as a primary means of traveling to UBC. If this proves to be true there will be a significant reduction in the amount of GHG's produced from commuting to UBC. Following the introduction of U-Pass a second calculation will be made to quantify the amount of GHG emissions with U-Pass in place. At that point UBC will be able to isolate the amount of GHG emission reductions, which can be attributed to U-Pass. That amount of GHG emission reduction could then be sold to an interested buyer.

A more general purpose of this project is to learn about GHG emissions and more specifically about IET through a practical reduction project. UBC is attempting to become the "leading research university in Canada and one of the leading research universities in the world" (UBC, 2002). Climate change is a current issue that is threatening the future of humanity and is thus a very fitting university research topic. There is a large amount of uncertainty surrounding GHG emission reduction strategies, the trading of GHG credits, the impact of various TDM measures, administrative will to reduce GHG emissions and a number of other issues. By working through a practical GHG reduction project the goal is to shed some light on as many of these uncertainties surrounding GHG emission reduction strategies. This learning will take place over time and will involved many UBC students, faculty and staff members

While the GHG emissions generated by commuting to UBC are the largest single source of emissions, they are not the only source. The larger purpose behind this project is to reduce GHG emissions at a campus wide level, whereby the commuting total is but one of several calculations that contribute to a single total for the entire campus.

In the end, the purpose of this project is to reduce the amount of GHG emissions at UBC. One of the first steps in reducing GHG emissions is to know what the current level of emissions is. From there, measures can be taken to reduce the amount of GHG emissions that UBC produces.

EXPLANATION OF THE CALCULATION

INTRODUCTION

Calculating GHG emissions from a mobile source, such as transportation, is very complex. One of the difficulties is the large number of variables involved in the calculation. The most significant variables include: mode of transportation, emission coefficients, commuting population, distance traveled, number of trips and passengers per vehicle. In the case of UBC, some of these variables have been reliably quantified, whereas others factors have not. Therefore, several assumptions and estimations, which are explained in this report, have been made in order to complete the calculation. The framework for this calculation has been developed to make use of the available data.

When quantifying GHG emissions from a mobile source the end goal is to quantify how much fuel is combusted; to do so there are two established methods that may be used. One is to record the actual amount of fuel used per vehicle and the second is to model the fuel used per vehicle. The first method involves installing a chip or some other system that measures fuel consumption in every vehicle in the given population. The fuel total is then multiplied with an emission coefficient to produce the GHG emission total. The benefits of this method are the high degree of accuracy and the relative ease of producing the GHG emission total. On the downside, it is very costly, there are some privacy issues and only one aggregated total number is produced. The second method, modeling, uses all available and relevant data to estimate how much fuel is consumed by a given population. The benefits of modeling are the low cost and the ease at which detailed information can be produced for sections of the population. On the downside, modeling is not as reliable and the calculation can be very complex. Due to the fiscal constraints of this project and having access to completed surveys, data sets and traffic counts, modeling is the chosen method.

The explanation of the calculation will cover the following items: framework of the calculation, a look at the results of the calculation and future considerations.

FRAMEWORK

There are two stages to calculating the GHG emissions generated by students, faculty and staff commuting to UBC. Stage one, called commuting totals, determines how many kilometers are traveled by automobile and bus by UBC students, faculty and staff in one calendar year. Stage two, called emission totals, converts the kilometers traveled to GHG emissions. The basic framework is to multiply the total kilometers traveled by an emission factor, which produces the GHG emission total for all UBC commuters. The calculations are performed in a series of spreadsheets, which are grouped into the categories of commuting totals and emission totals and are included as appendix A through D.

For the purposes of this project the value in calculating the GHG emissions at UBC lies in the difference in GHG emissions over time as opposed to a one year total. Comparing the total emissions over time shows if GHG emissions are decreasing or increasing and at what rate. The years 1997 and 2002 are used in this calculation, primarily because data is available for both of those years. The data used has been collected between September and November and then extrapolated for the calendar year. Of future interest will be the change between 2002 and 2003, before and after the U-Pass. If UBC pursues selling GHG emission reduction credits, 2002 will be used as a baseline from which any decrease in GHG emissions will be available for sale.

STAGE ONE: COMMUTING TOTAL

The goal for the first component of this calculation is to determine the total bus and automobile kilometers traveled by UBC students, faculty and staff in one calendar year. In order to obtain the commuting total there are a number factors to consider. The first stage of calculating the commuting total is to collect all relevant data. There are two primary fields of data: first, is the UBC population numbers for students, faculty and staff; second, is the transportation mode split data. Table 2 lists all the information needed and the actual data for the year 2002.

2002 UBC Commuting Data

POPULATION	
Total FTE student population	32,456
On-campus student population	8,114
Total FTE faculty population	1,740
On-campus faculty population	168
Total FTE staff population	7,339
On-campus staff population	100
WORKING DAYS	
Student working days	180
Faculty working days	240
Staff working days	240

MODE SPLIT	
% of population who drive alone to UBC	42.6
% of population who carpool to UBC	25.6
% of population who bus to UBC	26.2
Average round trip commute distances to UBC	34.6 km

Table 2 (UBC Planning and Institutional Research, 2003)

UBC Population Data

The first step is to define the population. For this calculation we are concerned with UBC students, faculty and staff. The population data, displayed in table 2, was taken from the UBC Planning and Institutional Research (PAIR) web page (http://www.pair.ubc.ca/index.htm). PAIR provides basic population numbers from which further calculations and assumptions have been applied. In order to standardize the population numbers, full time equivalent (FTE) totals are used. PAIR provides student FTE population totals, which include both undergraduate and graduate students, from 1984 to present. However, faculty and staff population numbers are reported as full and part time; therefore a conversion was made to FTE. To convert part time to full time equivalent it was assumed that part time employees worked 20 hours per week and full time work 35 hours per week, which was confirmed with a UBC administrator. Therefore, it takes 1.75 part time employees to equal one FTE.

Another factor to consider is the number of students, faculty and staff living on campus. It is assumed that those who live on campus will not drive or take the bus to get to UBC and therefore they should be eliminated from the GHG emission calculation. According to the UBC web site, 25% of the student-population live on campus, assuming that this applies to full time students only, there were (25,037 x 0.25) 6259 students living on campus in 1997 and (28,103 x 0.25) 7026 in 2002. According to the Assistant Director, Residence Administration at UBC, the total number of UBC faculty and staff living on campus has remained constant between 1997 and 2003 at 268. This total of 268 is arbitrarily divided to assumed that 100 faculty and 168 staff live on-campus.

The term 'working days' is used to reflect the number of days that students, faculty and staff are commuting to UBC. For faculty and staff it is assumed, based on a telephone conversation with a UBC administrator, that both faculty and staff have an average of four weeks holidays per year. Therefore, faculty and staff are assumed to have 240 working days in one year (5 days a week times 48 weeks). However, there is some degree of uncertainty with this assumption. The actual number of working days could vary significantly over time with the increasing popularity of teleworking or a more senior faculty and staff profile.

Determining the working days for students is slightly more difficult and contains even more uncertainty. Table 3 displays the calculations that were used to determine the number of student working days.

Total Days at UBC per Student per Year				
Temporal Division	**Time Frame (weeks)**	**Adjustment Factor**	**Days per week**	**Days at UBC**
Full Classes	26	1	5	130
Summer Session	18	0.22	5	19.8
Exams	6	0.42	5	12.6
Reading Week	1	0.3	5	1.5
Vacation	1	0	5	0
Total	52			163.9

Table 3

The 'adjustment factor' in table 3 represents the percentage of students who are present during a specific time frame, where an adjustment factor of 1 infers that 100% of the student population is present. For the 26 weeks that class is in session it is assumed that 100% of the student population is at UBC 5 days a week, which in reality is not likely the case, but there is no reliable data to prove otherwise. However, to compensate for this and account for some truancy and illness, it is assumed that all students take a total of one week off as 'vacation', where they do not go to UBC at all and thus have an adjustment factor of 0 for that time frame. According to the UBC, (PAIR, 2003) enrollment in the summer session in FTE is approximately 22% of the regular school year, for an adjustment factor of 0.22. During the 6 weeks of exams it is assumed that students are at UBC roughly 42% of the time that they are there during regular class time (Hoffman and Chisholm, 2001). Finally, during reading week, it is arbitrarily assumed that students are on campus 30% as much as they are during regular class time. To determine the total numbers of day's students are at UBC the time frame (weeks) is multiplied by the adjustment factor, which is multiplied by 5 days per week. When all temporal divisions are added together the total number of student working days equals 163.6, which is rounded to 164.

There is no doubt a large amount of uncertainty with the assumption that students are at UBC 164 days per year. And furthermore, the student working day total has a significant impact on the overall total of GHG emissions. Considering that in 2002 there were 24,430 students living off campus who travel 34.6 km round trip to UBC, an increase in the student working day assumption by one day increases the total vehicle and bus kilometers traveled by nearly 1,000,000 km per year. That converts to an extra 183 tons of CO2e per year or 0.5% of the total GHG emissions for 2002. This uncertainty does pose a problem and decreases the reliability of the calculation. This is discussed further in the future considerations section.

Commuting Frequency

Once the population and working days have been defined the next step is to look at the commuting frequency. Commuting frequency is simply how many times students, faculty and staff commute to UBC in a given time period. As Dautremont-Smith (2002) states in his Guidelines for College-Level Greenhouse Gas Emissions Inventories, it would seem appropriate that people would commute once per, or a total of 10 one way trips per week. It is logical to assume that most people would prefer to only make one commuting round trip per day given the significant time and financial costs associated with each trip. Dr. Ken Denike (1998) a UBC geography professor, prepared a report about travel patterns to UBC and in his findings in 1997 the mean UBC commuter made 9.2 one way trips to UBC per week, or 1.84 per day, which is just slightly less than one round trip per day. This is slightly lower than Dautremont-Smith's assumption, but significantly closer than the findings of an Urban Systems report. According to Urban Systems, in 1997, the UBC population made 12.55 trips per week, or 2.52 per day. Further more, to calculate this trip frequency Urban Systems uses a total of 106,100 trips per day and a population of 42,300, which includes full and part time staff and students. Denike and Dautremont-Smith on the other hand both use FTE population numbers. By using FTE numbers with Urban Systems weekly trip total the commuting frequency raises to 17.67 trips per week, or 3.53 per day.

Given the significant difference in findings between Denike and Urban Systems, who are both calculating commuting frequency for UBC in the same year, but use different methods, a closer look at their methods is needed before conclusions can be drawn. The full explanation of the data review can be found in the 'Future Considerations' section of this paper, under the title 'Review of Data Collection Procedures'. The result of looking at Urban Systems methods is that their commuting frequency calculations do not accurately represent the UBC population that is the focus of this report. Therefore, the commuting frequency is assumed to equal 9.2 trips per week, or 1.84 per day as found by Denike. Trip frequency data is not available for 2002, so 1997's frequencies are used for 2002.

Mode Split

Now that we know how many students, faculty and staff are commuting to UBC we need to know how they are getting there. This information is found in the second set of data used to calculate the commuting total, which called "mode split". "Mode split, or modal share, refers to the relative proportions of each travel mode used in a particular time period" (Urban Systems, 2003 p. 8). Urban Systems recorded mode split data for UBC for the time period between fall 1997 and the fall of 2002. (The report can be found at http://www.trek.ubc.ca). Again, the results from Urban Systems were compared to the results of Ken Denike in order to verify reliability. Unlike the commuting frequency values the mode split data is fairly consistent between Denike and Urban Systems. Urban Systems has been collecting UBC transportation data every year since 1997, whereas Ken Denike's last report was for 1997, and therefore Urban Systems' values for mode split should be used.

Each year since 1997, screen line, on-campus intersection, speed, volume, classification and bicycle and pedestrian counts are done throughout the university campus. Counts are used to determine how many people travel to UBC by single occupant vehicle, high occupant vehicle, public transit, bicycle, foot and sometimes motorcycle. This information is represented in person trips to the university both as aggregate numbers and percent of the total population.

There are two mode split categories that are required for the GHG emission calculation: automobile and bus. The automobile category is broken down further into the percentage of students, faculty and staff who drive alone and carpool. The mode split data collected by Urban Systems reports one number for the entire population therefore students, faculty and staff all have the same mode split numbers. Referring back to table 2 we can see that the most frequent mode of transportation is single occupant vehicle, which comprises 42.6% of the population in 2002, followed closely by bus and carpooling, respectively at 26.2% and 25.6%. Within the carpooling mode we know that 22.1% of the population commute in 2 person vehicles, 2.1% in 3 person vehicles and 1.5% in four or more person vehicles (Urban Systems, 2002).

One final bit of data, the average distance to UBC, is needed before the final commuting total calculation can be made. According to Hoffman and Chisholm (2001), the average commute distance to UBC is 17.3 km one way. To calculate this number, Hoffman and Chisholm used the postal codes from a transportation survey conducted in 2000 to group respondents in 21 centres. They then calculated the distance from each centre to UBC using GIS software. Without knowing specifically how Hoffman and Chisholm calculated the average trip distance and because their paper was not peer reviewed it is difficult to be confident in their numbers. Using trip frequency information from a 1997 survey that divided all commuters into 8 geographical commuting start points the average commuting distance to UBC is 14.6 km. At roughly 3,500,000 vehicle trips to and from campus per year a discrepancy of 2.6 km in trip distance translates into a difference of 18,200,000 km or 5,000 tons of CO2e emissions, which is the equivalent of 14% of the total GHG emissions in one year. Because there is not enough information to know which average trip distance is more accurate than the other it is assumed to be 17.3 km. Furthermore, there is no information that indicates a change in the average trip distance therefore it is assumed constant in both 1997 and 2002. Further work could be done to verify the correct distance, but more importantly, a constant framework should be developed to track the change in average commute distance over time. See appendix B for the spreadsheet containing commuting day and trip calculations.

Total Kilometers Traveled

Once the data has been collected the next stage is to determine how many vehicle and bus kilometers are traveled. This is done by the following multiplication:

Commuting Population x Commuting Days x Trip Frequency
x Mode Split x Trip Distance
= Kilometers Traveled

There are two different mode split categories that we are concerned with: automobile and bus. Within the automobile mode there are single occupant vehicles, 2 person vehicles, 3 person vehicles and 4+ person vehicles. Adding all four calculations together produces the total automobile kilometers traveled, which in 2002 was 107,894,986 km. There is just one mode split number to represent those who travel by bus. In 2002 the total kilometers traveled by bus was 2,582,776, which is assuming that there is an average of 20 students per bus (Hoffman and Chisholm, 2001). One thing that should be noted is that the mode split for students, faculty and staff are assumed to be equal. While the calculation spreadsheet separates students, faculty and staff the data does not break the mode split information among the same categories.

The final products of the Commuting Totals calculation are total automobile kilometers and total passenger bus kilometers for 1997 and 2002 (see appendix D). These numbers are then carried over to the second phase of the calculation, the emission totals, in order to calculate the final GHG emission total.

STAGE TWO: EMISSION TOTALS

Now that we have the total number of kilometers traveled by the UBC commuting population in one calendar year, we need to convert that number to GHG emissions, which is done by multiplying the total kilometers traveled by a GHG emission coefficient.

UBC Commuting Vehicle Fleet Profile

A spreadsheet was obtained through the Greater Vancouver Regional District (GVRD) titled Mobile Fuel Combustion Greenhouse Gas Emissions that contains emission coefficients for almost every mode of transporting either people or goods. The emission coefficient spreadsheet contains various emission factors according to the source of mobile combustion. All you need to know is what the fossil fuel is being combusted in, and the spreadsheet informs you what the emissions are per litre of fuel. Therefore, data must be collected on the UBC commuting vehicle fleet before the proper GHG emission coefficient can be selected. The two main factors impacting emission rates are the type and age of vehicle. UBC Parking Services does not have this information on file, but a UBC TREK staff member collected some data during the summer of 2002 about the make, model and year of a random sample of 30 vehicles. While this data is not statistically valid, it is the best available. The data indicates that in 2002 the average vehicle was 9 years old and 77 percent of the vehicles were light duty gas vehicles and 23 percent were light duty gas trucks. Due to the uncertainty of this data, the UBC vehicle fleet profile was compared to the fleet profile of British Columbia. According to a report prepared by the British Columbia Motor Vehicle Emissions Inspection and Maintenance

Program, commonly known as Air Care, the average age of vehicles in British Columbia is 8.55 years. It is reasonable to assume the average vehicle age in a university parking lot would be more than half a year older than the provincial average. However, looking at the mean vehicle age we see that the median vehicle age for the province of B.C. is 7 years, and the median vehicle age at UBC is 9.5, which is reasonable. There was no information quantifying the proportion of light duty gas vehicles to light duty gas trucks.

Since I was unable to locate data pertaining to 1997 I made the following assumptions. There is no reason to assume that the average vehicle age would be significantly different, and it was therefore kept at 9 years. However, with the recent increase in the popularity in sport utility vehicles (Stewart, S., Gourley,D., and Wong, J.,) I assumed there would have been a higher percentage of light duty gas vehicles in (90%) and fewer light duty gas trucks (10%) in 1997 as compared to 2002.

Emission Coefficients and Fuel Efficiency

In order to assign the proper emission coefficient to the UBC vehicle fleet, we need to look a little closer at how the coefficients are grouped. As mentioned earlier, the major determinants are the vehicle age and type. Vehicles are grouped into several categories based on the vehicle size; the three categories that we are dealing with are Light Duty Gas Vehicles (LDGV), Light Duty Gas Trucks (LDGT) and Heavy Duty Diesel Vehicles (HDDV), which are diesel busses. The significance of the vehicle age is that it correlates to the emission controls in place at the time the vehicle was built. Newer vehicles were subject to more strict emission controls and therefore have lower emission coefficients. Table 4 correlates vehicle age to emission control, emission coefficients and fuel consumption ratios:

Emission Coefficients and Fuel Consumption Ratios

Vehicle Category	Vehicle Age	Emission Standard	CO2 g/L of fuel	N2O g/L of fuel	CH4 g/L of fuel	Fuel Consumption Ratio L/100km
Light Duty	1994 and newer	Tier 1	2,360	0.12	0.26	10.0
Gas Vehicle	1980-1993	Tier 0	2,360	0.32	0.25	10.1
(LDGV)	1975-1979	Oxidation Catalyst	2,360	0.42	0.20	11.5
	1974 and older	Non-Catalyst	2,360	0.52	0.03	12.3
Light Duty	1994 and newer	Tier 1	2,360	0.22	0.41	14.2
Gas Truck	1980-1993	Tier 0	2,360	0.41	0.45	14.1
(LDGT)	1975-1979	Oxidation Catalyst	2,360	0.44	0.20	14.8
	1974 and older	Non-Catalyst	2,360	0.56	0.03	14.8
Heavy Duty	?	Advanced Control	2,730	0.12	0.10	30.0
Diesel Vehicles	?	Moderate Control	2,730	0.13	0.10	30.0
HDDV)	?	Uncontrolled	2,730	0.15	0.10	35.0

Table 4 (GVRD, 2003)

Looking at table 4 we can see that 1994, 1980 and 1974 are critical years in terms of emission standards. These three years signify when higher emission standards were applied. Therefore, in order to properly assign emission coefficients we need to determine how many vehicles were produced in each age category. Chart 1 displays the vehicle age distribution of the 30 sampled vehicles for the year 2002.

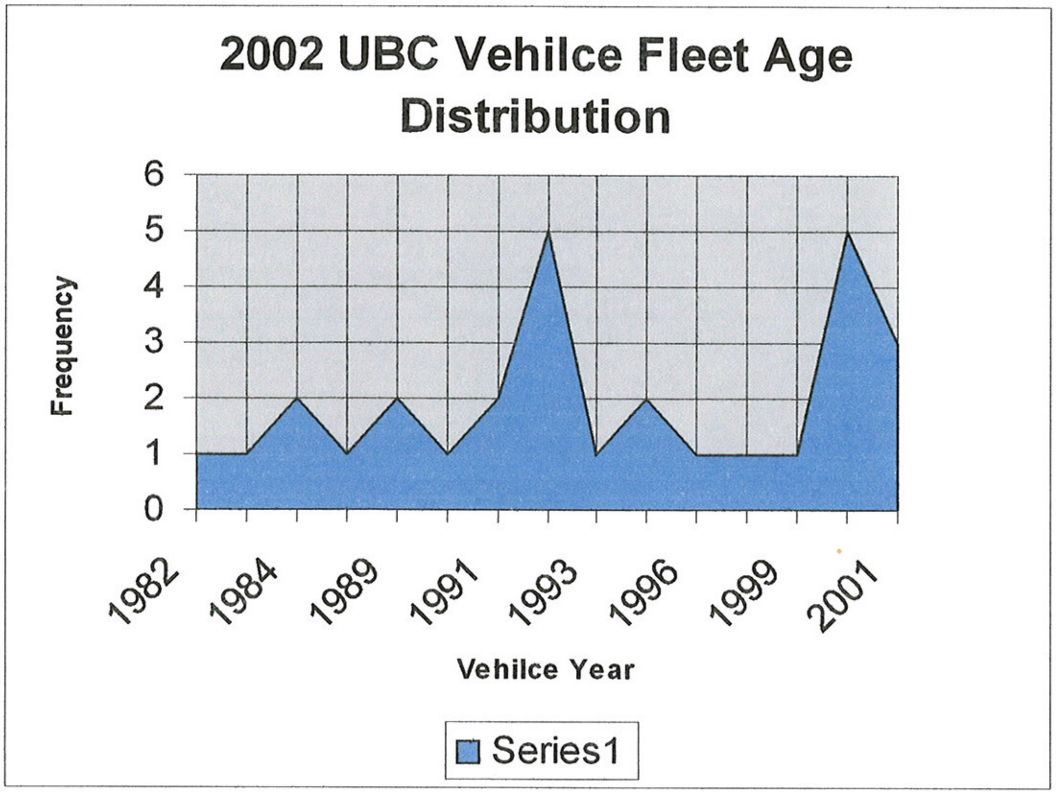


Chart 1

For the UBC sample, taken in the summer of 2002, the median vehicle age was 9.5 years. Since there is no vehicle fleet profile for 1997 the 2002 fleet distribution is applied to 1997, where the median vehicle age remains 9.5 years. Based on the vehicle fleet age distribution for 2002 we know that 56% of the vehicles were produced between 1982 and 1994 and the remaining 44% were produced after 1994. By applying the same distribution pattern for 1997 we know that 16% of the vehicles were produced between 1977 and 1980, 57% were produced between 1980 and 1994 and the remaining 27% were produced after 1994. Now that we have a more detailed break down of the vehicle age we can apply the appropriate emission coefficients.

Translink, the bus service provider for Vancouver, uses both diesel and electric trolley busses for service to UBC. According to Hoffman and Chisholm (2001), 71.3% of those trips are done on the diesel busses and the remaining 28.7% of the bus trips are conducted on electric trolleys. According to popular air quality planning procedure (Ergudenler,

2002) electric trolley busses are considered to be emission free. While this may or may not be true, depending on how the electricity is produced and how you measure mobile emissions, it is assumed to be the case here. Therefore, calculations are only performed for 71.3% of the bus trips that are diesel and the rest are considered to have zero emissions. The age of the average bus is unknown, several attempts to obtain this information have failed, so the assumption has been made that all the diesel busses have advanced emission control.

Another component must be factored in before the GHG emission coefficient is used: fuel efficiency. The GHG emission coefficients calculate emissions in grams per liter of fuel combusted. Therefore, fuel efficiency factors are added to the equation based on vehicle type and year. This information is contained in the GVRD Mobile Fuel Combustion Greenhouse Gas Emissions spreadsheet and is highlighted in chart 1.

Units

Finally, before the calculation is completed a standard unit must be chosen. There are three GHG's that are produced from the combustion of fossil fuel: carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4). Calculations are made to account for all three of these GHG's in the UBC commuting total, but they are then converted to a common unit called CO2 equivalent (CO2e). CO2e is widely accepted as the common method of reporting more than one GHG (Government of Canada, 2003). CO2e uses CO2 as the base unit from which the global warming potential (GWP) of other gasses are compared to. Figure 5 lists the GWP for carbon dioxide, nitrous oxide and methane according to the Intergovernmental Panel on Climate Change.

CO2 Equivalent Conversion Factors

Gas	GWP
Carbon Dioxide (CO2)	1
Nitrous Oxide (N2O)	21
Methane (CH4)	310

Figure 5 (Government of Canada , 2003)

From figure 5 we can see that one unit of methane has 310 times the global warming potential as one equal unit of carbon dioxide. Using CO2e allows one single number to be produced that represents the total GHG emissions generated by the UBC commuting fleet.

Emission Total Equation

Now that all the relevant data has been collected the final calculation, shown below, can be made. Refer to appendix E for the spreadsheet containing the calculation.

Total Kilometers Traveled (J) x Percent Total Fleet (D) / Fuel Consumption Ratio (E) /100 x GHG Emission Coefficient (G) /1000 x Global Warming Coefficient (I) = GHG Emission Generated by the UBC Commuting Fleet (K & M)

To begin, total kilometers traveled (J) is multiplied by the percent of total fleet (D), which produces the number of kilometers traveled by a specific mode of transportation. The next step is to convert number of kilometers traveled to fuel consumed, which is done by dividing the product by the fuel consumption ratio (E). To keep the units the same the fuel consumption ratio is divided by 100 to convert litres per 100km to litres per km. From there the emission coefficient (G) is factored in, which is divided by 1000 to convert grams per litre to kilograms per litre. Next, the global warming potential (I) is used to convert various emissions to CO2e. The result is the GHG emissions (K&M) generated by one section of the UBC commuting fleet. When all the sections are added together we have one number that represents the total amount of GHG produced by students, faculty and staff who commute to the UBC campus.

RESULTS

Based on the calculations performed in this report the students faculty and staff that commute to UBC produced 30,544 tons of CO2e in 2002 and 28,619 tons in 1997. Now what does that mean? And perhaps more importantly, what are the main factors that contribute to that total?

NET GAIN IN GHG EMISSIONS

The most important conclusion from the calculation is that GHG emissions produced from commuting to UBC have increase between the years 1997 and 2002. Between the years 1997 and 2002, GHG emissions have increased by 6.73% for a total of 1,925 tons of CO2e. This is obviously not the direction that we would like to see the numbers going, but by looking a little closer there are a few positive trends.

The most influential upward pressure impacting the GHG commuting total is population growth. On average the UBC population grows by 2% per year. Therefore, in order to achieve a net reduction in GHG emissions, emissions have to decrease by more than 2% per year. The commuting population grew by 10% between 1997 and 2002, yet GHG emissions only grew by 6.73% over that same time period, which means that the per capita GHG emission rates are decreasing. This implies that some of the TDM efforts of the UBC TREK Program Centre are paying off and people who commute to UBC are using less ecologically taxing modes of transportation. While this is good news, in terms of trading GHG emission reductions, or meeting Kyoto standards, it is meaningless. Without an overall reduction in emissions there are no emission reductions available for sale.

CONTRIBUTING FACTORS

The results of this calculation reveal that there has been an increase in GHG emissions over time, but what about the future? One of the main purposes of the calculation is to establish a baseline to measure the impact of the U-Pass in terms of GHG reductions. In order to see what the future may hold, let's look at some of the major contributing factors and speculate what may change in the future, and see where some key leverage points to reduce GHG emissions are. To see what factors contribute to the GHG emission total, refer back to the parts the overall equation.

Total Kilometers Traveled (J) x Percent Total Fleet (D) / Fuel Consumption Ratio (E) /100 x GHG Emission Coefficient (G) /1000 x Global Warming Coefficient (I) = GHG Emission Generated by the UBC Commuting Fleet (K & M)

Total Kilometers Traveled (J)

Total kilometers traveled is a function of population, distance and people per vehicle; where, the fewer people, the shorter the distance and the more people per vehicle the better. Population is a factor that will likely always work against attempts to reduce GHG emissions. UBC wants to attract as many students as possible and will need to hire faculty and staff proportionally to student population growth, so in the future we should expect to see a constant rise in population at approximately 2% per year. However, the proportion of the population that lives on campus could increase in relation to the overall population, which would help decrease the amount of emissions. UBC is making some significant efforts to transform campus into a complete city, which would entice more students, faculty and staff to live on campus. This will help alleviate some of the upward pressure of population growth. Another factor that could reduce the impact of population growth is the rising popularity of teleworking and distance based learning. If students, faculty and staff choose to work at home they will not be commuting as frequently to UBC. This would be noticed in the 'working days' and the 'trip frequency' numbers. It is very likely that these numbers will decrease for students, faculty and staff.

The second factor is the average commute distance. Currently the average UBC student, faculty and staff member live approximately 17.3 kilometers from campus. There is some reason to believe that this distance will increase over time as the cost of living near UBC increases. The area surrounding UBC is unique in that there is not a lot of affordable housing. Most universities have a 'student ghetto' close to the school where students can find modestly priced accommodations for modest living. UBC however is surrounded by a large park and one of the most expensive neighbourhoods in the lower mainland. Vancouver has been recognized as one of the most desirable cities to live in the world and Vancouver was recently awarded the 2010 winter Olympics, both of which will further increase the cost of living as more people are drawn to the city. This will push lower income students further away from UBC in an attempt to find reasonably priced housing. Therefore, expect to see the average commute distance increase over time.

The third factor in the Kilometers Traveled component of the equation is people per vehicle. There has been a minimal decrease in single occupant vehicles commuting to UBC, but there has also been a corresponding decrease in the number of people carpooling. With the introduction of the U-Pass, UBC will likely see a complete shift in the mode split. The U-Pass attempts to increase the feasibility of transportation options, with a focus on decreasing single occupant vehicle trips. If successful this will have a very significant impact on the number of people per vehicle. Carpooling and transit use drastically reduce the number of trips to UBC and thus contribute to lowering the overall GHG emissions.

Percent of Total Fleet (D)

Percent of total fleet factors in mode split and vehicle type. Of these two factors the mode split has significantly more influence on the GHG emission total. Again, the U-Pass is going to have a dramatic impact on the future mode split, which will likely move the trends away from single occupant vehicle use and towards public transit. The emission difference between taking the bus and driving alone is significant: the average return trip to campus in the average vehicle for 2002 produces 9.56 kg of CO2e, while the same trip in a bus produces 1.02 kg per passenger. This dramatic difference displays how effective the U-Pass can be at reducing GHG emissions at UBC. Every person that switches from driving alone to campus to taking the bus will save (8.54x164) 1400 kg of CO2e per year. The amount of emission reductions that are realized over time will be heavily dependent on the success of the U-Pass.

The vehicle type refers to the vehicle type, light duty gas vehicle (LDGV) or light duty gas truck (LDGT), and the vehicle age. Light duty gas trucks have been very popular over the last few years and the trend is continuing. The emission levels of a LDGT is not that different than a LDGV, but the fuel consumption ratio is almost 50% less in a truck than a car, which makes the emissions per km significantly higher in a truck than a car. This trend therefore does not help reduce emissions, but over time vehicle emission standards are becoming tougher, which will help reduce emissions over time.

Fuel Consumption Ratio (E)

The fuel consumption ratios of the average automobile in Canada has been relatively constant over the years. This is in part due to the popularity of more powerful and larger vehicles that require larger, more fuel consuming engines. So, when fuel efficiency increases it is offset my larger, more fuel consuming engines. And perhaps the most significant reason is that the price of gasoline in Canada has actually risen less than inflation over the past 50 years (Statistics Canada, 2000). Therefore, there is no price incentive to reduce fuel consumption. But, this is likely to change in the near future.

The world supply of oil is currently at, or very near its peak and by the year 2050 there will be very minimal amounts of extractable oil remaining (Campbell, 1997). When the increasing scarcity of oil is factored into the market price of gasoline there will be a significant spike in price and this spike could come very soon. With the price of gasoline increasing there will be a strong demand for manufacturers to build more fuel-efficient vehicles. Furthermore, there will be incentive of price sensitive students to drive less, or carpool when they do drive.

There is no doubt that the price of gasoline will increase significantly and that that increase will dramatically decrease the amount of fuel consumed, but it is unknown exactly when this will happen.

The last two factors in the emission equation are GHG emission coefficient (G) and global warming potential (I). These factors do not have trends of their own, but are rather dependent on the other variables mentioned above.

FUTURE CONSIDERATIONS

The purpose of this calculation is to establish a GHG emissions baseline for students, faculty and staff commuting to UBC. The most important thing to consider in the future is to perform this calculation again. Performing this calculation in the future will enable UBC to monitor GHG emissions and evaluate various TDM measures as they relate to emission reductions. And, if there are reductions in GHG emissions, UBC will be able to sell those emission reductions as this calculation establishes a baseline total.

After preparing the calculation and analyzing the final product there are a few items that should be considered for future calculations. There are GHG's being emitted into the air when people commute to UBC, but UBC did not know to what extent. This calculation does not measure the actual emissions, but attempts to estimate what they are. Therefore, this model is only as good as the data that is entered into the model. Consequently, if there is some data that is unreliable the model is as unreliable as that data. Unfortunately, that is the case with this model: there is some degree of uncertainty with the final product because there is some uncertainty with the data. By critically looking at some of the uncertainty contained in the model future calculations may be made with greater certainty and precision.

There are four items that I will address in this section. First, is to question whether or not modeling is the appropriate method in the first place. Second, is to critically review the existing data collection procedures and third, is to look at what assumptions can be quantified in the future. The fourth section reviews how to use this model to calculate future emission totals.

TO MODEL OR NOT TO MODEL

At the very beginning of this report two methods of quantifying GHG emissions were mentioned, which are to physically measure the emissions or to model them. Modeling was chosen due to fiscal constraints. While modeling is cheap it does not produce the most accurate results. As mentioned above, modeling is an attempt to estimate what is really happening, it is not an actual measurement.

This degree of uncertainty, presented with modeling, was discussed with Aldyen Donnely of GEMCo, an interested GHG emission offset buyer. According to GEMCo's procedure, they will agree on a price per ton of CO2e and then discount that price based on the method of accounting. Due to the inherent uncertainty in modeling, GEMCo would likely discount the price by 30%, so if UBC agreed to sell one ton of CO2e for $10, they would only receive $7 if modeling is the chosen method of accounting. However, according to GEMCo, if UBC was to implement a system that measures fuel consumption GEMCo would pay the full price.

There are a few ways to measure, as opposed to model, the actual amount of GHG emissions. The most reliable is to install a computer chip in every car that travels to UBC. This chip would contain the vehicle information needed to determine the appropriate emission coefficient and it would measure the amount of fuel consumed over the course of the year. The information would then be downloaded to a data based and a simple multiplication would produce the total emissions produced by every trip taken by UBC students, faculty and staff. Notice that with this method it is not possible to distinguish between trips to UBC and trips with other destinations. This does pose a problem if UBC wants to know the emissions generated by commuting to UBC, but that could be alleviated by combining measurements with transportation survey results to try and isolate UBC trips. However, if the main purpose is to sell GHG emission reductions this does not pose a problem because GEMCo stated that they will purchase reductions with any trip as the destination, not only those trips with UBC as the destination, since the U-Pass can be used for any trip destination.

While the reliability of this measurement would be very good there are some other issues to consider. Privacy is a major problem. I am not sure how willing UBC students, faculty and staff would be to have a computer chip monitor their driving patterns. Cost is also another issue. Is the added cost worth getting more reliable data? Say for example that the 2002 emissions are reduced by 20% due to the U-Pass and that the going price is $10 per ton of CO2e. With a measuring system in place UBC could potentially earn $62,000, compared to $43,000 if modeling was used. Could a measuring system be put in place for less than $19,000? Further research is needed to look into the specifics of the cost and benefits of changing from modeling to measuring, but at this point I would suggest continuing with modeling.

REVIEW OF DATA COLLECTION PROCEDURES

The data used in this model has been collected from a variety of sources, some of which have been subject to standard statistical tests and others, which have not. In this section I will review the data collection methods used by Urban Systems.

UBC has committed to conducting a comprehensive transportation data collection and monitoring program as stated in the UBC Official Community Plan and the GVRD/UBC Memorandum of Understanding (Urban Systems, 2001). The data collection program, performed by Urban Systems, began in 1997 with the formation of the UBC TREK Program Centre. While the purpose of the data collection is to access the effectiveness of the UBC TREK Program Centre, the data is also very useful for this calculation. However, when looking over the data collection methods it is evident that the focus is not on producing precise numbers, but rather generalities that reveal trends (Urban Systems, 2002).

The annual data collection program collects data over a fairly short period of time. The counts typically occur in either October or November and are performed from anywhere between 8 hours to 24 hours a day for one week. The results are then extrapolated for the entire year. "Because the travel data are only collected over a short period of time each year, these daily fluctuations can be expected to account for variations in travel numbers of 5% to 10%" (Urban Systems, 2002). This is a fairly large degree of uncertainty that could drastically impact the GHG emission totals. The following quote is taken from Urban System, which is the company that performs that data analysis for UBC:

> As noted elsewhere in this report, traffic volumes can be expected to fluctuate on a daily basis by as much as 10%, and can be expected to fluctuate on a seasonal basis as well. The annual data collection program is only conducted over a period of one to two weeks each year, and some of the count activities are conducted over only a one-day period. Although this is sufficient to reliably estimate changes in travel patterns over time, the inherent variability in the data limits its usefulness for detailed analysis of localized traffic conditions. What is needed for more detailed analysis is traffic data collected over lengthier periods of time. The most cost-effective way to collect traffic data over long periods of time is to use a permanent automatic counter. UBC may wish to consider installing one or more permanent count stations in key locations on campus. A permanent count station is a traffic data recorder connected to a detector loop placed permanently within the pavement of each lane on a roadway. Permanent count stations can be incorporated into actuated traffic signals at little additional cost. Permanent count stations are used by several municipalities and are used throughout B.C. on provincial highways. Data collected from one or more permanent count stations at UBC could be used to calibrate and expand traffic data collected through the annual data collection program to represent a full year's worth of data. A fairly easy way to mitigate this problem is to conduct the counts over a longer period of time and at internals throughout the year. The more counts that are done the more representative the data will be." (2000)

Using permanent automatic counters appears to be an easy and cheap solution to a very significant problem. However, this also brings up another potential problem with the current and future counting procedures. With either manual of automated traffic counts there is no way to be certain that all of the traffic counted is in fact UBC students, faculty or staff. The UBC campus houses several buildings and attractions that attract other people (meaning not UBC students, faculty and staff) to campus. The hospital, anthropology museum and wreck beach are just a few of the more popular destinations. Urban Systems addresses this issue, but claims that it is not a significant factor.

> It should be noted however, that although the screen lines have been adjusted to capture only traffic that is related to UBC, the volumes recorded invariably include a small number of non-UBC trips to destinations such as Wreck Beach. As the annual counts are conducted in October and November, it is estimated that very few trips to this destination are still occurring, and therefore have little effect on the overall volumes recorded. (2003)

While Urban Systems denounces the impact of non-UBC related trips there is no supportive evidence given to estimate the impact that these trips have on the total trip number. When the traffic counts of Urban Systems are compared with the UBC Transportation survey results a large discrepancy is noticed. There is a significant difference in the commuting frequencies as determined by Ken Denike and Urban Systems: however, mode split data is fairly consistent between the two as the figure below indicates.

Data	**Ken Denike**	**Urban Systems**
Commuting Frequencies (1997, FTE population) • Per day	1.84	3.53
• Per week	9.2	16.67
Mode Split Data (1997) • SOV	42.3%	43.4%
• HOV	32.8%	34.0%
• Transit	20.5%	17.9%

Figure 6 (taken from Urban Systems, 2002 and Denike 1998)

Looking at the discrepancies in Figure 6 it is apparent that Urban Systems may be counting a significant number of trips that should not be attributed as UBC commuters. This is suspected because the mode split data, which is relative to travel choice, not total trip numbers is fairly consistent between Urban Systems and Denike, however, commuting frequencies, which is dependant on trip numbers are not consistent. With a FTE population in 1997 of roughly 30,000 students, faculty and staff Urban Systems is counting ((3.53*30,000)-(1.84*30,000)) 50,000 more person trips per day than Denike is accounting for through survey results. That is a large discrepancy.

A possible cause of this discrepancy could be the location of count stations. The figure below is a map indicating screen line count stations in blue, highlighted in dark gray is a residential area. This residential area contains both UBC student, faculty and staff housing as well as market housing. Count stations are located at all of the major exit roads from this residential area. It is possible that Urban Systems' count data includes more than UBC commuters due to the proximity of this area to the count stations.

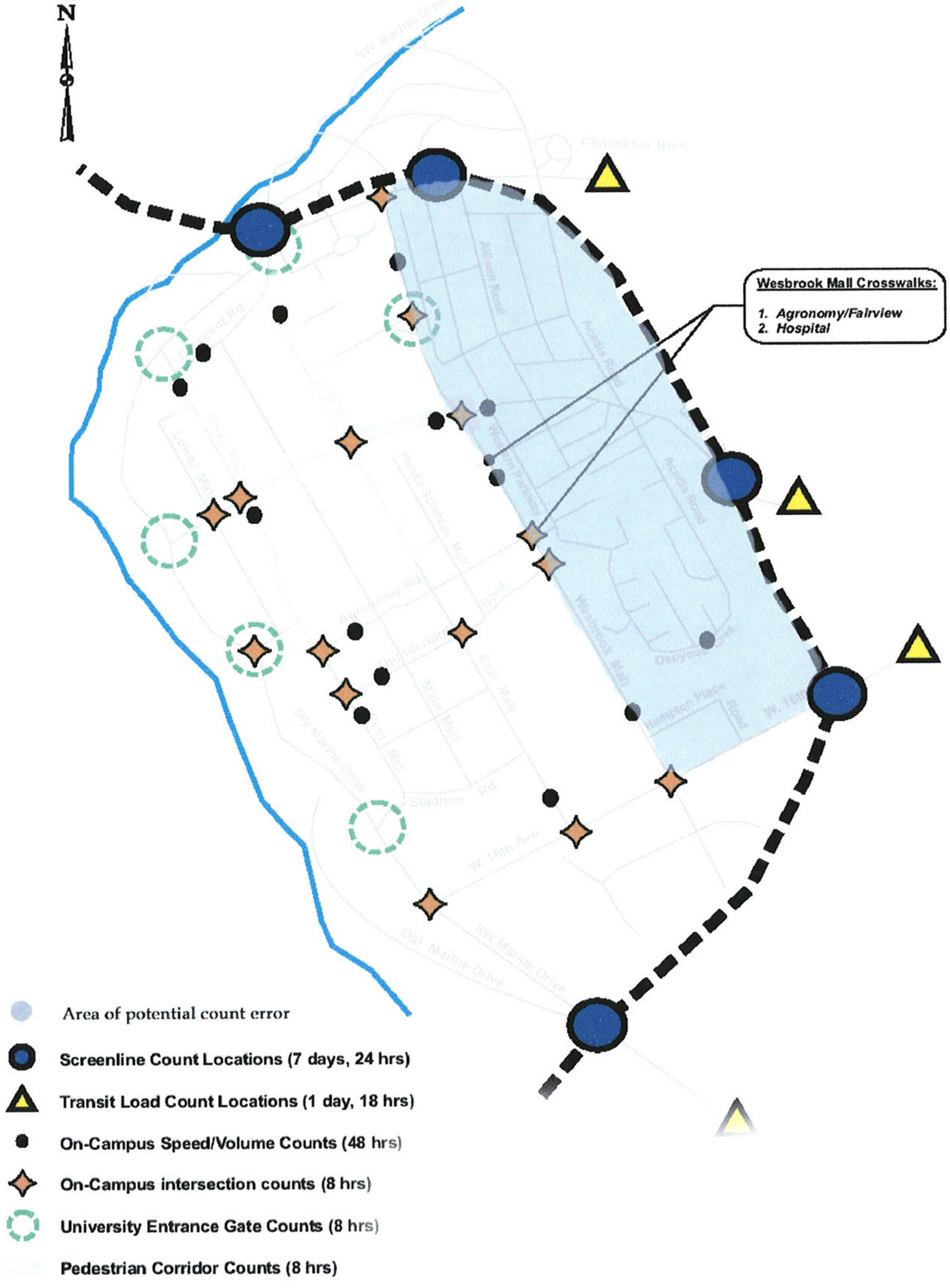


Figure 7 (altered from Urban Systems 2002)

The general problem is that the data collected is not intended for the specific purposes of this calculation, but rather to reveal general trends over time. However, with a few minor changes the data could be changed and thus be very useful for the GHG calculation.

FUTURE CALCULATIONS

Efforts have been made to prepare this calculation in manner that it is accurate and easily reproducible. In this final section considerations and information will be outlined for future GHG calculations.

CONSIDERATIONS

There are three things that I would suggest looking into for future calculations. One is to look at changing some of the data collection procedures; two, is to conduct surveys for working day factor; three, is collect more accurate vehicle fleet data.

As mentioned above, some of the data collected by Urban Systems is intended to reveal long-term trends and does not have the specificity that is required for calculating GHG emissions. To rectify this, one option is to consult with Urban Systems and try and meet the needs of both monitoring long-term trends and the specific information needed for this calculation. Option two, is conduct more frequent transportation surveys such as those conducted by Ken Denike.

The second suggestion pertains to quantifying assumptions made to produce the working day total. The working day total has a significant impact on the overall GHG emission total and it should therefore have more certainty to it. This could be easily achieved by conducting a small survey, or adding a few questions to existing surveys.

The third suggestion is to improve the reliability of the vehicle fleet data. The vehicle fleet data used in this calculation only had a sample size of 30, which is too small to rely on. Simply increasing the sample size and conducting the data collection during the school year, as opposed to the summer, would greatly enhance the reliability of this data.

INFORMATION

The purpose of this section is to provide a quick and easy reference chart for information that was used in this report and will be needed in future calculations.

Information	**Source**
UBC population data	http://www.pair.ubc.ca/
Mode split	• Urban Systems http://www.urban-systems.com/ • Report available at http://www.trek.ubc.ca/ • Ken Denike (604) 822-3077 kdenike@geog.ubc.ca
Fuel Consumption Ratio	• GVRD Ali Ergudenler, 604-436-6774 Ali.Ergudenler@gvrd.bc.ca

GHG Emission Coefficient	- Government of Canada http://www.climatechange.gc.ca/english/

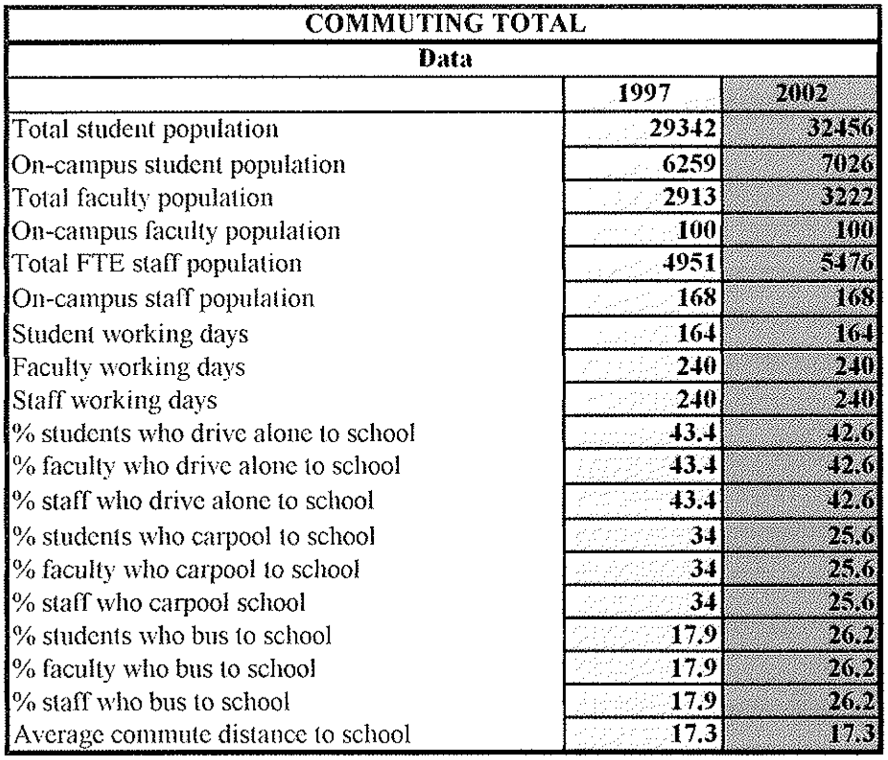
CONCLUSIONS

The calculations performed here are the first step in, what I hope, is a long process. The value of this calculation lie in future calculations and actions that are taken from there. Establishing a clear baseline of emissions is critical if UBC wishes to reduce GHG emissions for either the purposes of sale, or the general good of the region and the world.

There is good reason to believe that there will be a significant reduction in GHG emissions as a result of the U-Pass. The GHG savings from changing individual mode choice from SOV to bus are almost one and a half tons of CO2e per school year.

Jonathan Frantz prepared this report, for comments or questions please contact me at 604-787-3236 or jfrantz@shaw.ca

Apendix A



COMMUTING TOTAL		
Data		
	1997	2002
Total student population	**29342**	**32456**
On-campus student population	**6259**	**7026**
Total faculty population	**2913**	**3222**
On-campus faculty population	**100**	**100**
Total FTE staff population	**4951**	**5476**
On-campus staff population	**168**	**168**
Student working days	**164**	**164**
Faculty working days	**240**	**240**
Staff working days	**240**	**240**
% students who drive alone to school	**43.4**	**42.6**
% faculty who drive alone to school	**43.4**	**42.6**
% staff who drive alone to school	**43.4**	**42.6**
% students who carpool to school	**34**	**25.6**
% faculty who carpool to school	**34**	**25.6**
% staff who carpool school	**34**	**25.6**
% students who bus to school	**17.9**	**26.2**
% faculty who bus to school	**17.9**	**26.2**
% staff who bus to school	**17.9**	**26.2**
Average commute distance to school	**17.3**	**17.3**

Appendix B

COMMUTING TOTAL

Commuting Day and Trip Calculation

Year	Total Population	On-Campus Population	Commuting Population	Commuting Days	Commuting Day Total		Trip Frequency	Total Trips	
					1997	2002		1997	2002
	A	B	A-B=C	D	C*D=E	C*D=E	F	E*F=G	E*F=G
1997									
student	29,342	6,259	23,083	164	3,785,612		1.84	6,965,526	
faculty	2,913	100	2,813	240	675,087		1.84	1,242,161	
staff	4,951	168	4,783	240	1,147,825		1.84	2,111,998	
Total	**37,205**		**30,678**		**5,608,524**			**10,319,685**	
2002									
student	32,456	7,026	25,430	164		4,170,520	1.84		7,673,757
faculty	3,222	100	3,122	240		749,280	1.84		1,378,675
staff	5,476	168	5,308	240		1,273,920	1.84		2,344,013
Total	**41,154**		**33,860**			**6,193,720**			**11,396,445**

Appendix C

COMMUTING TOTALS								
Vehicle Trip Total								
	Total Trips	% Carpool					Total Automobile Trips	Total Bus Round Trips
		% drive alon	2 person	3 person	4+ person	% Bus		
	G	H	I	J	K	L	(G*H)+(G*I/2)+(G*J/3)+(G*K/4)=M	G*L=N
1997								
student	6,965,526	0.434	0.264	0.054	0.024	0.179	4,109,660	62,341
faculty	1,242,161	0.434	0.264	0.054	0.024	0.179	732,875	11,117
staff	2,111,998	0.434	0.264	0.054	0.024	0.179	1,246,079	18,902
Total	**10,319,685**						**6,088,614**	**92,361**
2002								
student	7,673,757	0.426	0.221	0.021	0.015	0.262	4,199,463	100,526
faculty	1,378,675	0.426	0.221	0.021	0.015	0.262	754,480	18,061
staff	2,344,013	0.426	0.221	0.021	0.015	0.262	1,282,761	30,707
Total	**11,396,445**						**6,236,704**	**149,293**

Appendix D

COMMUTING TOTAL			
Total Kilometers Traveled			
	Total Automobile Round Trips	Round trip Distance (km)	Total Automobile Kilometers
	M	O	M*O=P
1997	6,088,614	17.30	105,333,022
2002	6,236,704	17.30	107,894,986
	Total Bus Round Trips	Round trip Distance (km)	Total Passenger Bus Kilometers
	N	O	N*O=Q
1997	92,361	17.30	1,597,848
2002	149,293	17.30	2,582,776

Emissions source	Fleet Data				Fuel Consumption Ratio	Gas
	% Vehicle Type	Vehicle Age	% Vehicle Age	% of Total Fleet	L/100km	
	A	B	C	D	E	F
Non Mass Transit Commuters 1997						
						CO2
Light Duty Gas Vehicle	90	before 1980	16	14.4	11.5	N2O
						CH4
						CO2
Light Duty Gas Vehicle	90	1980 - 1994	57	51.3	10.1	N2O
						CH4
						CO2
Light Duty Gas Vehicle	90	after 1994	27	24.3	10	N2O
						CH4
						CO2
Light Duty Gas Trucks	10	before 1980	16	1.6	14.8	N2O
						CH4
						CO2
Light Duty Gas Trucks	10	1980 - 1994	57	5.7	14.1	N2O
						CH4
						CO2
Light Duty Gas Trucks	10	after 1994	27	2.7	14.2	N2O
						CH4
TOTAL						
Non Mass Transit Commuters 2012						
						CO2
Light Duty Gas Vehicle	77	1980 - 1994	56	43.12	10.1	N2O
						CH4
						CO2
Light Duty Gas Vehicle	77	after 1994	44	33.88	10	N2O
						CH4
						CO2
Light Duty Gas Trucks	23	1980 - 1994	56	12.88	14.1	N2O
						CH4
						CO2
Light Duty Gas Trucks	23	after 1994	44	10.12	14.2	N2O
						CH4
TOTAL						
Bus Commuters 1997						
						CO2
Diesel				71.3	30	N2O
						CH4
TOTAL						
Bus Commuters 2012						
						CO2
Diesel				71.3	30	N2O
						CH4
TOTAL						

EMISSION TOTALS							
Gas	Emissions Coefficient g/L fuel	Units	Global Warming Potential	1997		2002	
F	G	H	I	J	K	L	M
				km	CO2e	km	CO2e
CO2	2360	kg CO2 / km	1	105,333,022	4,116,583		
N2O	0.42	kg N2O /km	310	105,333,022	227,110		
CH4	0.2	kg CH4 / km	21	105,333,022	7,326		
CO2	2360	kg CO2 / km	1	105,333,022	12,879,983		
N2O	0.32	kg N2O /km	310	105,333,022	541,396		
CH4	0.25	kg CH4 / km	21	105,333,022	28,653		
CO2	2360	kg CO2 / km	1	105,333,022	6,040,638		
N2O	0.12	kg N2O /km	310	105,333,022	95,217		
CH4	0.26	kg CH4 / km	21	105,333,022	13,975		
CO2	2360	kg CO2 / km	1	105,333,022	588,651		
N2O	0.44	kg N2O /km	310	105,333,022	34,022		
CH4	0.2	kg CH4 / km	21	105,333,022	1,048		
CO2	2360	kg CO2 / km	1	105,333,022	1,997,885		
N2O	0.41	kg N2O /km	310	105,333,022	107,598		
CH4	0.45	kg CH4 / km	21	105,333,022	8,000		
CO2	2360	kg CO2 / km	1	105,333,022	953,078		
N2O	0.22	kg N2O /km	310	105,333,022	27,542		
CH4	0.41	kg CH4 / km	21	105,333,022	3,477		
				Total	27,672,183		
CO2	2360	kg CO2 / km	1			107,894,986	11,089,536
N2O	0.32	kg N2O /km	300			107,894,986	451,100
CH4	0.25	kg CH4 / km	21			107,894,986	24,670
CO2	2360	kg CO2 / km	1			107,894,986	8,626,938
N2O	0.12	kg N2O /km	300			107,894,986	131,597
CH4	0.26	kg CH4 / km	21			107,894,986	19,959
CO2	2360	kg CO2 / km	1			107,894,986	4,624,324
N2O	0.41	kg N2O /km	310			107,894,986	249,047
CH4	0.45	kg CH4 / km	21			107,894,986	18,517
CO2	2360	kg CO2 / km	1			107,894,986	3,659,166
N2O	0.22	kg N2O /km	310			107,894,986	105,744
CH4	0.41	kg CH4 / km	21			107,894,986	13,350
							29,013,948
				km	CO2e	km	CO2e
CO2	2730	kg CO2 / passenger km	1	1,597,848	933,059		
N2O	0.12	kg N2O/ passenger km	310	1,597,848	12,714		
CH4	0.1	kg CH4 / passenger km	21	1,597,848	718		
					946,491		
				km	CO2e	km	CO2e
CO2	2730	kg CO2 / passenger km	1			2,582,776	1,508,204
N2O	0.12	kg N2O/ passenger km	310			2,582,776	20,551
CH4	0.1	kg CH4 / passenger km	21			2,582,776	1,160
						Total	1,529,916

Final Results			
1997 Total CO2e kg	28,618,674	2002 Total CO2e kg	30,543,863
1997 Total CO2e Tons	28,619	2002 Total CO2e Tons	30,544
Percentage Increase	2002/1997=	1.0673	
Net Increase (Tons)	2002-1997	1,925	

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