CHBE 484: Term Report

Greenhouse Gas Emissions Analysis of Future UBC Transportation Options

Curtis Wan
Joyce Ying
Torrio Louie

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Summary:

This report analyzes the CO_2 emissions of UBC transportation in: 2007, 2020 based on the current transportation methods, the elimination of the U-Pass, the extension of the SkyTrain from Broadway to UBC, the effects of increasing promotion in carpooling, and the implementation of SkyTrain with increased carpooling.

From literature the carbon intensity of cars, conventional and trolley buses, and SkyTrains are found to be 286.0 g/CO_2, 1752.0 g/CO_2 and 53.0 g/CO_2 respectively. It is determined that the emissions for 2007 were 83646.07 tonnes CO_2 for cars and 2316.08 tonnes CO_2 for trolley and conventional buses traveling to UBC. If the transportation methods are unchanged from 2007 to 2020, the growth rate of the population (extrapolated to be 44.01%) will increase the carbon emissions from 85962.15 tonnes CO_2 to a total of 123796.74 tonnes CO_2. Thus 95428.59 tonnes of CO_2 will need to be eliminated in order to reduce the projected total carbon emissions of 2020 by 33% from 2007 levels. In addition, if the U-Pass program is removed, the total emissions will be further increased to 159985.57 tonnes of CO_2 per year, causing an 86.11% increase in emissions from 2007.

For the implementation of the SkyTrain to UBC, a low estimate of 20% is used to approximate the migration of people going to UBC from SOV, HOV and buses to the new SkyTrain. Since the SkyTrain travels along the same path as the 99 B-Line, the assumption is that all users of the 99 B-Line migrate to the SkyTrain. The high estimate of the migration to SkyTrain is assumed to be 40% of SOV, HOV and buses. The high and low emission levels for this scenario are estimated to be 73863.79 and 98462.94 g CO_2, respectively. The low estimate leads to an increase in emissions from 2007 by 14.54%, while the high estimate leads to a reduction in 2007 emissions by 14.07%. For the carpooling scenario, low and high estimates are determined to be 113449.40 g CO_2 and 103075.71 g CO_2. These results show an increase in emissions from 2007 by 31.98% and 19.91%.

The implementation of both SkyTrain and carpooling incentives by 2020 yields a carbon emission of 90187.99 g CO_2 and 61428.36 g CO_2 per year for high and low estimates respectively; which correspond to a 4.92% increase and a 28.54% decrease in emissions from 2007 values.

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Introduction:

As one of the world's top 40 universities, UBC's strategic vision for the 21st century, Trek 2010, is to "prepare students to become exceptional global citizens, promote the values of a civil and sustainable society, and conduct outstanding research to serve the people of British Columbia, Canada, and the world." (UBC, 2006) UBC is committed to enhance the learning experience for the students and to provide the best possible environment for the employees. For this reason, UBC has established Canada's first campus Sustainability Office in 1998.

Since UBC is a rapidly expanding community, the increasing demands for different transportation options are inevitable. With developing a fully sustainable campus as a core value, the amount of greenhouse gas emitted by the different modes of transportation poses as a main obstacle. This report analyzes future transportation trends by providing an overview of the future transportation scenarios and quantifying their respective greenhouse emissions. Social aspects of the different scenarios are also discussed in some detail.

For the report, the year of 2007 serves as the baseline year, and projections are made of 2020 campus population. The year 2020 is chosen because it is the projected year of completion for the anticipated Broadway corridor SkyTrain. In addition, the AMS Lighter Footprint Strategy aims to reduce greenhouse gas emissions by at least 33% from 2007 levels by 2020. Different scenarios are investigated, which are developed in accordance to UBC expansion plans and the changing behaviour of the commuters.

As the university expands, the question of whether we can develop a carbon neutral campus remains. This report is prepared for the Sustainability Office's SEEDS program, to support UBC's goal as a leader for promoting campus sustainability. Additional benefits include helping UBC Trek with planning future transportation options, and investigating the feasibility of implementing the Broadway corridor SkyTrain.

Methodology:

The methodology of calculating the greenhouse gas emissions are based upon dividing the various modes of commuting into the following categories: Single Occupancy Vehicles (SOV), High Occupancy Vehicles (HOV), transit, cycling, pedestrians, and others vehicles (including trucks). Of these options, only the SOV, HOV, and transit are taken into consideration as they are the only methods in which greenhouse gases are emitted. The category of other vehicles (including trucks) is not considered in this report, since it only corresponds to <1% of all travel to and from UBC (2007, Transportation Status Report). The greenhouse gas emissions used in this report are standardized using CO_2 as a reference substance.

For each of the commuting options, the greenhouse gas emissions are analyzed over the period of one school year, which includes both fall and winter sessions of classes. During this time, it is estimated that students will be commuting to school for about 33 weeks, which include 13 weeks of tuition involved, as well as additional projects/exams that may take place during the non-tuition time. This 33 week period also corresponds with the amount of weeks in which Translink has allocated for non-summer bus/skytrain schedules. Only weekdays are considered in each week, as there is no data available for weekend travel. The number of weekend commuters is also assumed insignificant to the amount of commuters to and from UBC during the weekdays. For each of the scenarios, the different commuting options will be compared based upon the CO_2 equivalent emissions per school year.

The average commuting distance to UBC is generated by analyzing the TREK 2007 Transportation Survey, where respondents have given feedback regarding their area of commute. Since the report only provides the originating municipalities of the commuters, an average distance from UBC to the various municipalities is generated using the on-line utility Google Maps.

In calculating the SOV and HOV vehicular emissions, the total amount of daily traffic volumes during the weekday is obtained from the TREK 2007 Transportation Status Report, and this value is simply multiplied by the average commuting distance to UBC and g CO_2 per kilometer factor. The emission value for both SOV's and HOV's is

286 g CO_2/km, which is adapted from the Energy Journal, in an article that focuses on the Fraser Valley (Poundenx & Merida, 2007). Multiplying the daily emission by 33 weeks/year and 5 days/week gives the result of gCO_2 equivalent/school year.

The transit emissions are generated in a similar manner. The total numbers of arrivals and departures of various routes to UBC are tabulated per weekday using TransLink's winter 2008/2009 schedule. Similarly, this number is then multiplied by 33 weeks/year and 5 days/week in order to give the total number of bus trips per school year. In order to determine the distance in which the bus travels, the utility Google Maps is used again to generate trip distance by tracing the bus route. The emissions values of 62 g CO_2/km and 1752 g CO_2/km are used for the trolley and diesel buses respectively (Poundenx & Merida, 2007). The resulting amount of greenhouse gas emissions in gCO_2 equivalent/school year is calculated by multiplying the total number of trips per year by bus distance, along with the emission factor, and an additional factor of 0.3. This additional factor pertains to allocate for UBC-specific trip, i.e. trips made specifically by UBC residents, students, and faculty, while excluding other bus users. An average factor of 0.3 is used as an average estimate, since 0.2 is considered a low estimate, while 0.4 is a high estimate (Fitzgerald, 2007).

In the future scenarios involving a hypothetical SkyTrain running through the Broadway corridor, data for the existing Millennium and Expo lines are used. The number of SkyTrains running per day, determined for each individual future scenario, is multiplied by the same factors of 33 weeks/year and 5 days/week to represent a school year. This value is then multiplied by the distance that the hypothetical line would take, which is simply the same distance the current 99 B-Line runs. The result is then multiplied by 53 g CO_2/km, the emission factor for the current SkyTrain (Poundenx & Merida, 2007).

Results and Discussion:

2007 Base Case Scenario:

It is of high importance to analyze the current emissions from (single occupancy, high occupancy) cars and (trolley, diesel) buses in order to accurately predict future emissions. The CO_2 emissions per kilometer and mean distance traveled per route are used to calculate the total emissions per year for different methods of transportation to UBC.

The CO_2 emissions per kilometer of conventional and trolley buses are found to be 1752.0 g CO_2/km and 62.0 g CO_2/km; while the emissions per kilometer for cars is 286 g CO_2/km (with diesel cars taking up 0.85% of the emissions and gasoline 99.15% of the CO_2 emissions). The average distance traveled per car is 17.69 km, while the distance traveled and number of trips traveled for various bus routes are tabulated in Table 1 below. The total emissions for cars and buses are calculated, and the results are shown in Table 2.

Table 1: Distance Traveled to UBC by Buses

Bus Number	Bus Trips	Distance Traveled (km)
4	70	5.16
9	44	5.46
17	108	4.71
25	97	6.99
41	129	5.7
43	30	5.7
44	39	3.6
49	70	6.87
84	94	4.11
99	219	3.99
258	4	6.42
480	55	8.64

Table 2: Total Carbon Emissions (tonnes/school year)			
Method of Transportation	Occupancy/Route	One Way into UBC (tonnes/school year)	Round trip (tonnes/school year)
Car	SOV	33141.21	66282.41
	HOV	8681.83	17363.65
Bus	4	2.91	7.39
	9	1.94	4.92
	17	4.10	10.41
	25	154.43	392.01
	41	167.47	425.12
	43	38.95	98.87
	44	31.98	81.17
	49	109.53	278.04
	84	87.99	223.37
	99	199.02	505.20
	258	5.85	14.85
	480	108.23	274.74

The total emissions for vehicles into and out of UBC are 83646.07 metric tonnes/school year, whereas the total emissions per school year for buses are 2316.08 tonnes. As seen above, the emissions for single and high occupancy vehicles are significantly higher than that of buses. Thus, there is an opportunity to significantly reduce emissions via reduction of emissions from cars.

Since the cars take up 97% of the total emissions from transportation to UBC, any emission reduction plans must specifically target the group of people driving to UBC. Through negative reinforcement and positive punishment, initiatives such as reducing parking locations, increasing parking distance from UBC, setting tolls upon entering UBC premises via SOV and increasing parking fees can all combat the behavioural tendencies to travel by way of cars. Negative reinforcement occurs when an unpleasant stimulus is removed upon proper completion of a task. In the case of reduction in parking locations, it will cause frustration every time a person goes to park, thus every time a person does not drive to school, they do not experience the frustration of searching for a parking space. Similarly, with increasing parking distance, one must walk further to arrive to UBC, while those taking the bus will gain the convenience of being relatively close to their destination.

Tolls are a form of positive punishment because every time a person drives, they are given an adverse stimulus (a fee in this case). This toll will take into consideration an even broader range of drivers than increasing parking fees. This is because there are drivers that come to UBC simply to drop off or pick up a student / children and do not park, thus the toll will act as a disincentive, which in turn reduces carbon emissions. The feasibility of a toll may be low due to societal reasons and traffic issues; however, it is possible that future studies can evaluate different alternatives to reducing the behaviour of dropping people off, which occurs quite frequently. This option may become feasible in the future depending on advancement on technologies.

2020 Base Case Scenario:

In the base case scenario for 2020, the variable affecting emissions is limited to population growth because there is not enough time to cause revolutionary changes in the emissions of specific vehicles, thus the emissions per kilometer would remain constant. As the development, transition and public acceptance of fuel cell based systems will likely take longer than 13 years (the time span of the current report), the technological advance component is assumed negligible.

Based on the 2007 Transportation Status Report, the following data is extracted:

Table 3: Annual Daytime Population Growth at UBC		
Year	1997	2007
Population	42300	56000

As observed in Table 3, a population growth of 32.4% occurred over a span of 10 years. Therefore, the assumption made in this report is that there is an increase of 32.4% every 10 years in the population of UBC. One further assumption is that the ratio of people to buses or cars remains the same, whereby the number of buses and cars increase over the time span to cover for the population growth. This is because commuting habits tend to remain the same unless incentives such as additional transportation methods are implemented.

The emissions calculated from the assumptions are shown in Table 4 below:

Table 4: Comparison of Predicted Emissions from 2007 to 2020		
Method of Transportation	2007 (tonnes/school year)	2020 (tonnes/school year)
SOVS:	6.63E+04	9.55E+04
HOVS:	1.74E+04	2.50E+04
Transit:	2.32E+03	3.34E+03
Total:	8.60E+04	1.24E+05

This shows that an approximate 44.01% increase in carbon dioxide emissions can be expected from the population growth alone. With the AMS goal of a reduction of 33% from 2007 levels by 2020, the emissions from population growth will be a significant challenge for UBC. A total of 37834.59 tonnes of CO_2 need to be reduced per school year in order to get the emission levels back to 2007, and another 57594 tonnes of CO_2 per school year to reduce emissions further to 66% of 2007 levels.

2020 No – U-Pass Scenario:

Although the current U-Pass program has significantly reduced CO_2 emissions by preventing traffic congestion and lowering the cost of transportation to UBC, the elimination of the program is a potential scenario that needs consideration. It may be a possibility due to the required referendum for every fare increase. Although the cancellation of the U-Pass has relatively low probability, factors such as the potential of merging of the U-Pass program across multiple universities/colleges and rising monthly costs of U-Pass can result in a failing referendum. Translink's reputation and the dependency factor on the cooperation between UBC and Translink are also issues that affect the implementation of the program. In addition, this scenario is also a valid case for future reference beyond the year 2020.

The basis for the calculations of this scenario is that the percentage of commuters using transit to arrive at UBC remains similar to that of when the U-Pass was first implemented, since it is difficult to isolate growth rate for the total number of people using transit.

The predicted CO_2 emissions for 2020 without the U-Pass are shown in Table 5:

Table 5: Comparison of Predicted Emissions from 2007 to 2020 Without U-Pass

Method of Transportation	2007 (tonnes/school year) with U-Pass	2020 (tonnes/school year) without U-Pass
SOVS:	8.61E+04	1.24E+05
HOVS:	2.36E+04	3.41E+04
Transit:	1.36E+03	1.96E+03
Total:	1.11E+05	1.60E+05

The main observations are that the emissions from SOVS increased significantly in comparison to the year with the U-Pass in year 2020. Transit emissions increased slightly due to population growth, even though there was a loss of ridership on buses from the elimination of U-Pass. Comparing to the 2007 and 2020 base cases, this scenario has a predicted emission increase of 86.1% and 29.2%, respectively. The results suggest that it is definitely not an environmentally favorable scenario.

2020 SkyTrain Scenario:

In order to promote greater use of public transportation to UBC, the transit infrastructure will need to be expanded to meet the demand. The current situation is that many bus routes serving UBC are overcrowded, and their service can be unreliable as noted by the Vancouver-UBC Transit Plan (2005). This is where massive rapid transit can be implemented, with a Millennium Line SkyTrain extension from VCC-Clark continuing to UBC. This is one of the highlights in the Provincial Transit Plan announced in January 2008, which demonstrates the province's effort to double transit use in order to combat greenhouse gas emissions. Figure 1 illustrates the possible development of the transit network in the Lower Mainland.

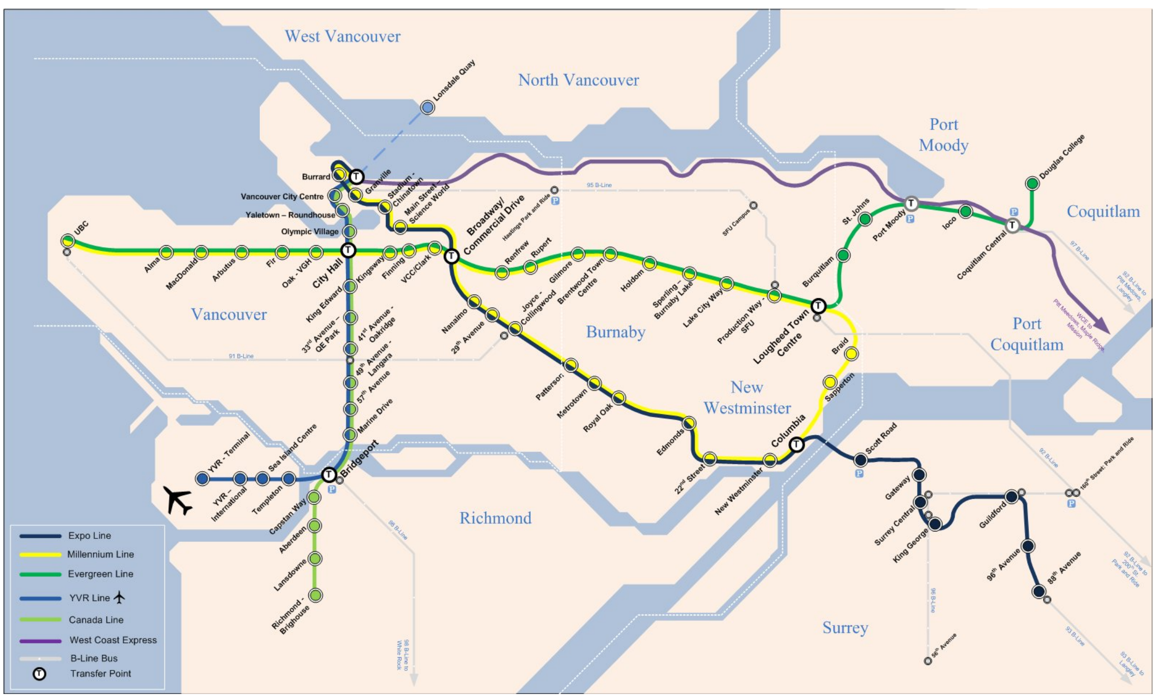

Figure 1: Potential SkyTrain Routes

The environmental impact of implementing the new SkyTrain routes will be tremendous, and the effect can be shown by comparing its carbon emission with that of the buses. The current SkyTrain technology emits 53 g CO_2/km, as opposed to 1752 g CO_2/km for diesel buses (Poudenx & Merida 2007). In addition, the SkyTrain has an even greater capacity than double-car buses. Upon implementation of the SkyTrain, the 99 B-Line bus route can be eliminated immediately.

During rush hour, the SkyTrain is able to travel over twice as fast as the current 99 B-Line, as the average service speed of a SkyTrain is 43.5 km/h, while an average rush hour commute within Vancouver by a light-duty vehicle is estimated at less than 20 km/h (Poudenx & Merida 2007). Thus it is anticipated that with the increased travel capacity of the SkyTrain, along with a shorter travel time, that many current drivers of SOV's and HOV's, as well as other bus users will switch to the SkyTrain system. From previous experience, as soon as a transportation option with an increased capacity becomes available, it will be filled immediately (Jolly, C., personal communication, March 27, 2008). A notable example of this is the implementation of the U-Pass incentive, where transit ridership has increased by 63% with the subsidized transit passes (U-Pass Final Report, 2005).

In order to calculate the potential CO_2 reduction, a low and high estimate are used to predict the percentage of bus, SOV, and HOV users will migrate to the SkyTrain system. These estimates are determined to be 20% and 40%. To calculate the new amount of CO_2 produced per school year, the calculations are conducted by taking the 2020 Base Case Scenario, along with the current CO_2 emission results of the different transportation modes, and reducing either 20 or 40% from their corresponding values. In addition, the 99 B-line is completely replaced with the SkyTrain. To determine the amount of CO_2 that the SkyTrain emits, the amount of Skytrains trips required is calculated. This is equal to the amount of traffic displaced by the SkyTrain from other transportation modes, divided by 300, which is an average capacity of the current SkyTrain. The length of the SkyTrain corridor and the CO2 emission factor then multiplies this result, which is equivalent to the total CO_2 emissions during a school year. The following Table 6 summarizes the results for 20% and 40% migration from other transportation options.

Table 6: 2020 SkyTrain Scenario Comparing 20% and 40% Migration From Other Transportation Options		
	2020 Scenario with 20% SkyTrain Migration (tonnes/School year)	2020 Scenario with 40% SkyTrain Migration (tonnes/School year)
SOV	7.64E+04	5.73E+04
HOV	2.00E+04	1.50E+04
Transit	2.09E+03	1.56E+03
SkyTrain	7.60E+00	2.23E+01
Total:	9.85E+04	7.39E+04

2020 Increased Carpooling Scenario:

According to the base case calculations, SOV generates the most carbon emissions among the different transportation methods. In order to reduce emission, carpooling should be promoted. Incentive programs can be set up by the university and government officials, which may range from special HOV lanes to reduced parking costs for HOV. Perhaps UBC can implement a system similar to that of the Emory University in Atlanta, Georgia, which offers reserved parking spaces for HOV and special rates for parking. In addition, its participants receive a "Value Pass," allowing them to drive alone 12 times per year (USEPA, 2001). Several important disincentives that limit the carpooling population include the carpooling schedule, commitments before and after the trips, and increased commute times allocated for picking up, waiting for, or dropping off partners.

For this scenario, it is assumed that the carpooling population increases by 2020, providing incentive programs are well established for the HOV drivers. To calculate the potential CO_2 reduction, low and high estimates are incorporated to determine the percentage of SOV drivers that have converted to carpooling. For comparison, the ridership of transit remains the same, while the ridership of HOV increased by 20% and 40%. This range is chosen because previous studies have shown that commuting habits change when parking fees and transit incentives increase. In fact, the number of SOV has decreased by 34.43% when Bellevue, Washington, introduced a new transportation management plan to the city (Hansen, 2007). The results are tabulated as shown in the following Table 7:

Table 7: 2020 Carpooling Scenario Comparing 20% and 40% Migration From Other Transportation Options

	2020 with 20% increase in carpooling (tonnes / school year)	2020 with 40% increase in carpooling (tonnes / school year)
SOV	7.64E+04	5.73E+04
HOV	3.37E+04	4.25E+04
Transit	3.34E+03	3.34E+03
SkyTrain	0.00E+00	0.00E+00
Total:	1.13E+05	1.03E+05

From the above results, it is observed that an estimated increase of 40% in carpooling will generate more emissions in the HOV sector, but the overall carbon emission is less than the case with 20% carpooling. Neither the 20% nor the 40% case reduces carbon emission below the 2007 base level, but they are increased by 31.98% and 19.91%, respectively. This suggests that an increase of carpooling alone is not enough to meet the 33% reduction goal set by the AMS Lighter Footprint Strategy. However, if the population increase through 2007 to 2020 is considered, then the project carbon reduction for the 20% case and the 40% case are 8.36% and 16.74%, respectively. These results indicate that the implementation of incentive programs for carpooling can reduce greenhouse gas emissions, but should be carried out with other programs to increase transit ridership and decrease the use of SOV.

2020 Increased Carpooling + SkyTrain Scenario:

From the previous scenarios, results have shown that it is unrealistic to focus only on either one of the development of the SkyTrain or the promotion of HOV to reduce greenhouse gas emissions. As a result, this final scenario is designed to incorporate both a SkyTrain system and a well-established carpool incentive program. These factors will lead to an increase in SkyTrain and HOV ridership.

To calculate the potential CO_2 reduction, low and high estimates are incorporated to define the possible range of reduction. For the first case, it is assumed that by 2020, there is a 20% reduction in both buses and SOV's, and a 20% increase in HOV and SkyTrain ridership. For comparison, the second case is identical, except the percentage changes from 20 to 40%. The results are tabulated as shown in the following Table 8:

Table 8: 2020 SkyTrain & Carpooling Scenario Comparing 20% and 40% Migration From Other Transportation Options

	2020 20% skytrain + carpool (tonnes / school year)	2020 40% skytrain + carpool (tonnes / school year)
SOV	6.11E+04	3.44E+04
HOV	2.70E+04	2.55E+04
Transit	2.09E+03	1.56E+03
SkyTrain	1.05E+01	1.95E+01
Total:	9.02E+04	6.14E+04

The above table shows that for the second case, by increasing HOV and SkyTrain use by another 20%, the overall greenhouse gas emitted reduces by 31.89% from the first case. When compared to the 2007 baseline, the first case has an increased greenhouse gas emission of 4.92%. On the other hand, the second case shows a reduction of greenhouse gas emission of 28.54%. This shows that neither case satisfy the AMS goal to reduce greenhouse gas emission by 33%. The results suggest that it is unrealistic to have 33% reduction as a goal, since the second case already represent a high estimate of SkyTrain and HOV population. However, if the population growth from 2007 to 2020 is considered, the emission reductions from the two cases are actually 27.15% and 50.38%, respectively. These results support the idea that an addition of the SkyTrain system can greatly reduce greenhouse gas emissions. These results indicate that the implementation of a new travel mode, along with carpooling incentives, can greatly reduce greenhouse gas emissions.

Conclusion:

The main objective of this SEEDS report is to quantify the amount of CO_2 equivalent emissions, which originate from the different commuting options to UBC. Future scenarios are generated with respect to the year of 2020. The various scenarios have explored possibilities such as: the dissolution of U-Pass, increase in carpooling, and construction of a Broadway Corridor SkyTrain. A complete breakdown of the scenarios is demonstrated in the table below:

Table 9: % Reduction in CO2 Emissions of Future Scenarios from 2007 Base Case

	% Reduction from 2007 Base Case	% Reduction from 2020 Base Case
2007 Base Case	-	-
2020 Base Case	-44.01%	-
2020 w/o U-Pass	-86.11%	-29.23%
2020 w/ 20% SkyTrain Migration	-14.54%	20.46%
2020 w/ 40% SkyTrain Migration	14.07%	40.33%
2020 w/ 20% Increase in Carpooling	-31.98%	8.36%
2020 w/ 40% Increase in Carpooling	-19.91%	16.74%
2020 w/ 20% Skytrain Migration + Increase in Carpooling	-4.92%	27.15%
2020 w/ 40% Skytrain Migration + Increase in Carpooling	28.54%	50.38%

A regression analysis of the campus population shows a growth of 44.01% from 2007 to 2020. Since the 2020 base case is calculated with the assumption that mode shares of the different types of transportation remains the same, the CO_2 emissions will correspondingly go up by 44.01%, as evident in Table 9 above. The table also illustrates that the majority of the future scenarios reflects an increase in carbon emissions compared to the 2007 Base Case. However, when population growth is considered and the results are compared to the 2020 Base Case, most of the scenarios show a reduction in greenhouse gas emissions. There are only two future scenarios in which CO_2 emissions are actually decreased from the 2007 Base Case, which include the 2020 case w/ 40% SkyTrain migration with a reduction of 14.07%, and the 2020 case w/ 40% SkyTrain migration + increase in Carpooling has a reduction of 28.54%. Although this does not meet the AMS goal of reduction of 33% by 2020, there is only a 4.46% difference. Since the latter case already represent a high estimate of the SkyTrain and HOV population, it proves that it is unrealistic to set a goal at 33% reduction from 2007 base values.

However, as transportation is only a fraction of the greenhouse gas emissions from UBC, other changes in buildings and energy generation will affect the CO_2 emissions. Any advances on those technologies throughout the campus may be able to contribute to meeting the overall AMS target of 33% reduction by 2020.

The implementation of the SkyTrain infrastructure to UBC has a great potential to reduce the CO_2 emissions significantly, since it only emits a minimal amount of greenhouse gases. However, the best scenario will be combining this new SkyTrain with an increase in carpooling. The largest amount of emissions from commuting is generated by SOV's, and there will always be people that need to drive to UBC. Carpooling for this demographic is more feasible than converting them to transit users.

If UBC wishes to reach the goal of becoming a carbon-neutral campus, the implementation of the SkyTrain is certainly a beginning. By combining the SkyTrain infrastructure, carpooling incentives and the U-Pass program, UBC is one step closer to realizing the AMS Lighter Footprint Strategy.

Future Work:

The majority of the calculations carried out in this SEEDS report have had a multitude of assumptions and estimates. In order to create a more comprehensive analysis of CO_2 emissions of future transportation options to UBC, the following work can be performed to refine the calculations.

The main drawback of this report is that it only takes into account of the transportation emissions during operation. A more complete analysis should factor in production and disposal emissions, i.e. a full life-cycle analysis. This is especially important for the SkyTrain, since operation emissions are negligible, the amount of CO_2 emissions generated during construction can be significant. Sources of construction emissions include road blocks, traffic re-routes, and construction equipments. This is originally in the scope of this project, but it is written off due to time constraints, as a life-cycle analysis on the SkyTrain would warrant a SEEDS report by itself.

Another assumption involves advancing technology, which will be available in the year 2020. One of the main assumptions used throughout this report is that the emissions of CO_2 per distance travelled of cars, trolley and diesel buses, and SkyTrain remains constant. The basis of this assumption is that the internal combustion engine has a limited capacity left to improve on CO_2 emissions. However, research into detailing emerging technologies, such as fuel cells, hybrids, bio-diesel, and electric vehicles, which have potentials to emit lower carbon emissions, will further refine this report

A discussion of the University's role in course scheduling would be beneficial to this report as well. Altering the time that courses start in the morning, can potentially reduce emissions if it does not clash with the morning rush-hour commute by non-students. In addition, if the rush-hour traffic can be avoided, travel time to and from campus will decrease, which is also an incentive to taking public transit. Through the use of surveys and questionnaires, the impact on reducing CO_2 emissions by rescheduling course scheduling at UBC can be analyzed.

Another area in which further work can be conducted is to analyze how SOV users can be discouraged by UBC. One method would be to implement a flex parking pass, in which parking will be charged in the pay-as-you-go form, rather than charging a monthly fee. The current system promotes using one's personal vehicle as much as possible in order to get the most value out of the parking pass. A flex parking pass would encourage use of carpooling or transit. Encouraging greater use of transit can be done by implementing more B-Line services to UBC, as transit priority measures. These can come in the form of special bus lanes, traffic priority signals, and other measures.

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