THE ROLE OF BUS TRANSPORTATION IN REDUCING GREENHOUSE GAS (GHG) EMISSIONS

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PRESENTATION OVERVIEW

• Introduction
• Research objective, scope and methodology
• GHG emissions associated with transportation in Canada
• Present situation in the National Capital Region
• Mode choice strategy for reducing GHG emissions
• Energy and emission estimation for proposed scenarios
• Conclusions and recommendations
INTRODUCTION

Each Canadian produced 20 tonnes of GHG emissions in 1995

- Globally, the sea level has risen 4-10 inches
- Precipitation over land has increased by 1%
- Temperature could rise 1.6-6.3°F by 2100

RESEARCH OBJECTIVE AND SCOPE

• OBJECTIVE
  – To assess the role of bus transportation in reducing GHGs through the modal shift and new technology

• SCOPE
  – The NCR is used as case study
  – Diesel, hybrid and fuel cell buses
RESEARCH METHODOLOGY (I)

Visualization of the situation

Present situation in the Region
GHGs and global warming process

1986 and 1995 O-D Survey
Statistic Canada 1986, 1996
- Urban activity system
- Transportation systems

The Outaouais Region and some factors for the RMOC

Area of "first" running of TRANS model

TRANS model for travel demand modeling

Trip generation model

Trip distribution model

Modal split model

Trip assignment

1. Running of TRANS model per scenario

- Parking cost
- Fuel cost
- Transit fare
- Transit time
- New tech. buses

Changes in policy variables

Auto volume per link

Auto-persons switch to buses

Area of "second" running of TRANS model
Area of "second" running of TRANS model

2. Running of TRANS model per scenario:
   - Assignment of "background" traffic
   - Calculation of vehicle kilometers traveled and link-average speed

TRANS model for travel demand modeling

Trip generation model

Trip distribution model

Modal split model

Trip assignment

Traffic volume per link

Vehicle kilometers traveled and link-average speed

Area of post-processing
RESEARCH METHODOLOGY (III)

Area of post-processing

- Vehicle mix data for passenger vehicles per link type and characteristic area
- Fuel consumption equations by vehicle type
- GHG emission rate by type of vehicle and type of fuel (grams/liter of fuel)

Emission calculator

- Vehicle kilometers traveled per link by vehicle type
- Fuel consumption per link by vehicle type (liters)
- GHG emissions per link by vehicle type (grams)
- GHG emissions aggregated per link types and charact. areas

- VKM for autos, 80% of light trucks and transit buses
- Fuel consumption equations for average travel speed for arterials and highways
- GHG emissions expressed in CO₂ equivalents (grams)
- Results presented for: 8 link types and 8 characteristic areas in NCR
GHG EMISSIONS ASSOCIATED WITH TRANSPORTATION IN CANADA

GHG emissions in Canada per sector of activity

- 27% of transportation
- 17% Electric Power Generation
- 15% Industrial Processes
- 12% Industrial Fuels
- 21% Residential, Commercial & Other Fuels
- 8% Miscellaneous

- 42% of transportation related GHGs comes from automobiles
STUDY AREA: THE NATIONAL CAPITAL REGION
PRESENT SITUATION IN THE OUTAOUAIS REGION


- Persons/h.h. (2.85-2.59)
- Number of households increased by about 35%
- Trips/per./day (2.14-2.35)
- Inc./h.h. ($35122-$48324)
- Vehicles/h.h. (1.29-1.30)
Trips originated in the Outaouais Region during the 1986-1995 (24 hours)
Transit participation decreased from 11% to 6.2%

Transit and car participation in 1986
- Cars: 74%
- Other motorized and non motorized: 15%
- Transit: 11%

Transit and car participation in 1995
- Cars: 77.20%
- Other motorized and non motorized: 16.60%
- Transit: 6.20%
TRANS Model, EMME/2 Software

Level 1
Prepare and Review LUSE Data

Level 2
Prepare Networks and Network Attributes

Level 3
Trip Tables by Mode

Employed Labor Force Ratio → Trip Generation

Change in Peak Hour Factors → Peak Hour O-D

Change in Modal Attributes → Trip Distribution

Change in Modal Attributes → Modal Split

Trip Tables by Mode

Summarize Results by Screenline (optional)

Equilibrium Achieved?

Yes

Documentation

No

Level 1: Land Use Changes Loop

Level 2: Major Network Changes Loop

Level 3: Minor Network Changes Loop
MODE CHOICE STRATEGY FOR REDUCING GHG EMISSIONS

Mode split model - h.b.w. trip logit model

<table>
<thead>
<tr>
<th>Mode</th>
<th>Tra. cost</th>
<th>Tra. time</th>
<th>Veh./h.h.</th>
<th>Province</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto pers.</td>
<td>-0.8641</td>
<td>-0.0096</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-27.9)</td>
<td>(-2.14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit</td>
<td>*-0.8641</td>
<td>-0.0096</td>
<td>-1.738</td>
<td>-0.8367</td>
<td>0.9091</td>
</tr>
<tr>
<td></td>
<td>**(-27.9)</td>
<td>(-2.14)</td>
<td>(-15.6)</td>
<td>(-5.64)</td>
<td>(-5.41)</td>
</tr>
</tbody>
</table>

- Travel cost for auto increased (parking and fuel cost)
- Transit fare decreased by 10%
- Transit travel time decreased by 10% and 50%
- New technology buses (hybrid and fuel cell buses)
ENERGY AND EMISSION ESTIMATION

Link by link analysis (1995-2021)

1 EMME/2 MODELING => auto volume (cars)
   EMME/2 MACROS => link average speed, vkm

2 EMISSION CALCULATOR => fuel consumption and GHG emission estimation
ENERGY AND EMISSION ESTIMATION

Auto volume-1995 => link average speed, vkm
ENERGY AND EMISSION ESTIMATIONS

Calculation procedure

- Link average speed and vkm (for 9317 links)
- Fuel consumption (l/km)
  \[ \text{fuel consumption} \times \text{vkm} \times \text{GHG emission rate (g/l)} = \text{GHG emiss. per link (grams)} \]
- Results are aggregated per characteristic areas (core, urban, suburban and rural), and per link types (8 types)

\[ y = 4E-11x^5 - 1E-09x^4 - 2E-06x^3 + 0.0003x^2 - 0.0194x + 0.4428 \]
\[ R^2 = 0.9987 \]
GHG EMISSIONS IN THE NCR, 2021
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS (NCR)

- Base scenario: There will be 13.3% more GHGs in the National Capital Region in 2021 than in 1995.
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS (Outouais Region)

• Base scenario: There will be 8.7% less GHGs in the Outaouais Region in 2021 than in 1995

GHG EMISSIONS AND VEHICLE KILOMETERS TRAVELED IN OUTAOUAIS DURING PM PEAK HOUR - BASE SCENARIO 0

- Base scenario-GHGs (kg)
- VKT-autos
- VKT-light trucks
- VKT-transit
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

• Scenario 1 - parking cost increased by 10%
• 1495 auto persons (0.7%) in NCR switch to transit. As a result, GHGs are reduced by 1.7% in the Outaouais-1995

GHG EMISSIONS IN THE OUTAOUAIS REGION DURING PM PEAK HOUR
(SCENARIOS: BASE-PARKING COST INCREASED BY 10%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Base scenario</th>
<th>Parking cost increased by 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>130312</td>
<td>128103</td>
</tr>
<tr>
<td>2021</td>
<td>118996</td>
<td>117789</td>
</tr>
</tbody>
</table>
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

• Scenario 1: GHG emissions per characteristic areas-1995

<table>
<thead>
<tr>
<th>Area</th>
<th>GHG Emissions (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central core</td>
<td>14,158</td>
</tr>
<tr>
<td>Urban area</td>
<td>60,854</td>
</tr>
<tr>
<td>Suburban area</td>
<td>25,642</td>
</tr>
<tr>
<td>Rural area</td>
<td>29,658</td>
</tr>
</tbody>
</table>

GHG EMISSIONS PER CHARACTERISTIC AREA IN OUTAOUAIS REGION DURING PM PEAK HOUR IN 1995 (SCENRIOS: BASE-PARKING COST INCREASED BY 10%)
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 2 - parking cost increased by 50%
- 7114 auto persons (3.1%) in NCR switch to transit. As a result, GHGs are reduced by 5.9% in the Outaouais-1995
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

• Scenario 3 - parking cost increased by 100%
• 11436 auto persons (5%) in NCR switch to transit. As a result, GHGs are reduced by 9.5% in the Outaouais-1995
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 4 - fuel cost increased 1.0% above inflation rate
- 1928 auto persons (0.6%) in NCR switch to transit. As a result, GHGs are reduced by 1.2% in the Outaouais-2021

GHG EMISSIONS IN OUTAOUAIS DURING PM PEAK HOUR
(SCENARIOS: BASE-FUEL COST INCREASED 1% ABOVE INFLATION RATE)
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 5 - fuel cost increased 2.5% above inflation rate
- 6143 auto persons (1.8%) in NCR switch to transit. As a result, GHGs are reduced by 4.2% in the Outaouais-2021
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 6 - fuel cost increased 5.0% above inflation rate
- 19161 auto persons (5.7%) in NCR switch to transit. As a result, GHGs are reduced by 13% in the Outaouais-2021

GHG EMISSIONS IN OUTAOUAIS DURING PM PEAK HOUR
(SCENARIOS: BASE-FUEL COST INCREASED 5% ABOVE INFLATION RATE)
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

• Scenario 7 - transit fare decreased by 10%
• 949 auto persons (0.4%) in NCR switch to transit. As a result, GHGs are reduced by 0.6% in the Outaouais-1995 to 2021 period.
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 8 - total transit trip time decreased by 10%
- 1427 auto persons (0.6%) in NCR switch to transit. As a result, GHGs are reduced by 1.2% in the Outaouais-1995

### GHG EMISSIONS IN OUTAOUAIS DURING PM PEAK HOUR (SCENARIOS: BASE-TRANSIT TRIP TIME DECREASED BY 10%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Base scenario</th>
<th>Transit trip time decreased by 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>130312</td>
<td>128733</td>
</tr>
<tr>
<td>2021</td>
<td>118996</td>
<td>118172</td>
</tr>
</tbody>
</table>
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 9 - total transit trip time decreased by 50%
- 8228 auto persons (3.6%) in NCR switch to transit. As a result, GHGs are reduced by 3.5% in the Outaouais-1995

GHG EMISSIONS IN OUTAOUAIS DURING PM PEAK HOUR
(SCENARIOS: BASE-TRANSIT TRIP TIME DECREASED BY 50%)
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- **Scenario 10** - diesel electric hybrid buses in 2021
- There is no switching to transit; 0.5% less GHGs in the Outaouais in 2021 (36% less GHGs from transit)

![Graph showing GHG emissions comparison between base scenario and diesel-electric hybrid buses in 2021]

**GHG EMISSIONS FROM PASSENGER TRANSPORTATION IN OUTAOUAIS DURING PM PEAK HOUR (SCENARIOS: BASE-DIESEL ELECTRIC HYBRID BUSES INSTEAD OF DIESEL BUSES IN 2021)**

- **1995**
  - Base scenario: 130312 kg
  - Diesel-electric hybrid buses in 2021: 118996 kg

- **2021**
  - Base scenario: 118460 kg
  - Diesel-electric hybrid buses in 2021: 118460 kg
PROPOSED SCENARIOS FOR REDUCING GHG EMISSIONS

- Scenario 11 - fuel cell “Ballard” buses in 2021
- There is no switching to transit; 1.8% less GHGs in the Outaouais in 2021 (100% less GHGs from transit)
CONCLUSIONS AND RECOMMENDATIONS

• Bus transportation can play very important role in reducing GHG emissions. Increase in parking and fuel costs are very effective in terms of switching people to transit and reducing GHGs.

• Reduction of transit travel time is less effective than disincentives for the use of car. This scenario could be combined with other measures in order to reduce more GHGs. Decreasing transit fare has little effect.

• Hybrid buses produce 36% less GHGs than diesel buses, and fuel cell buses produce no emissions (the assumption is that hydrogen is produced from a regenerative process). The scenarios with these buses can be combined with other measures.

• There is a need for an analysis of all modes of transportation. Scenarios with increased fuel and parking costs should be further analyzed (eg. implication on business and the role of “park&ride” service).

• Land use should be planned with transportation and in favor of transit buses.
TIME FOR QUESTIONS
GHGs can be reduced through different parts of transportation system, including:

- Vehicles (fuel efficiency)
- Fuel (lower gas emission)
- Infrastructure (maintenance)
- Carriers (load factor)
- Changes in travel behavior as most promising measure
Concern over automobile emissions in household with at least one car (1992 survey)

- 71% of people think that more should be spent on transit
Slide in reserve: ENERGY AND EMISSION ESTIMATIONS

**Urban driving cycle**

<table>
<thead>
<tr>
<th>Time duration (seconds)</th>
<th>1.372</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (miles)</td>
<td>7.5</td>
</tr>
<tr>
<td>Avg. speed (mph)</td>
<td>19.5</td>
</tr>
<tr>
<td>Maximum speed (mph)</td>
<td>55.7</td>
</tr>
</tbody>
</table>

**GHG EMISSION RATE**

- **Autos** = 2490.5 (g/l)
- **Light trucks** = 2553.9 (g/l)
- **Buses** = 2763.8 (g/l)

**Highway driving cycle**
Slide in reserve: GHG EMISSIONS ON PORTAGE BRIDGE, PMPH, 2021

BASE NETWORK
USER DEFINED LOW DETAILED NETWORK

2103 2077 38.106 113.033 32743.826
2103 4300 30.261 595.832 181630.304
2104 1000 32.314 180.608 56760.786
2104 1017 32.115 310.906 92829.307
2104 2106 39.399 603.560 169344.960
2104 2432 12.212 1827.080 1048202.722
2105 6 44.165 139.287 38196.721
2105 2075 46.151 53.354 17211.721
2105 2076 36.529 207.284 59534.063
2105 2078 43.303 232.650 108465.557

2431 3530 37.730 140.510 41441.987
2432 154 10.763 190.945 112224.381
2433 2104 21.913 1421.874 533500.413
2433 2437 35.617 97.961 37999.428
2433 3580 26.325 260.721 88312.494
2433 3934 15.511 1201.220 621465.866
2433 2405 11.860 59.904 33910.433
2433 2411 11.211 10.006 10941.072
2433 2435 18.254 54.316 26651.295
2433 2494 12.312 5.930 42771.282

For Help, press F1

For Help, press F1
Slide in reserve: PRESENT SITUATION IN THE OUTAOUAIS REGION

STO (bus) ridership

Number of passengers

Year

Number of passengers