

# FOUNDATIONAL RESEARCH BULLETIN

SUSTAINABILITY BY  
DESIGN  
*Methodology document*

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## Methodology

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### Average Trip Length

Average trip lengths for all the transportation modes included in the bulletin were not available from a single source therefore the following sources were used:

American Public Transportation Association: Public Transportation Fact Book, Washington, DC, June, 2008.

Hu, P., Reuscher, T., 2004. 2001 NHTS Summary of Travel Trends, Washington, DC. IBI Group, 2002. Maricopa Association of Governments High-Capacity Transit Plan, May 2002

Setty, Michael D., Leroy W. Demery Jr. 2005. Beware of Rail Transit Oversell: A publictransit.us Occasional Paper. Publictransit.us

Translink, 2003. Bus Rapid Transit Evaluation Study. Prepared by IBI Group for Translink. Available online: [http://www.translink.bc.ca/files/polls\\_surveys/b\\_line/98B-LineBRT\\_EvalStudy.pdf](http://www.translink.bc.ca/files/polls_surveys/b_line/98B-LineBRT_EvalStudy.pdf)

TSI Consultants, 2001. Richmond/Airport – Vancouver Rapid Transit Project: Technical Appendix.

### Carbon Emissions per Passenger-Mile

The following equation was used to calculate carbon emissions per passenger-mile:

$$\frac{\text{Energy consumed per mile (kWh/mile)} \times \text{Carbon emissions per unit of energy (gCeq/kWh)}}{\text{Typical Passenger Capacity}}$$

Step 1: Calculating energy consumed per mile for each transportation mode was determined from the following sources:

Ministry of the Environment and Water (Budapest). 2003. Ecologically beneficial vehicular traffic. Institute of Transport Sciences Ltd.

Strickland, James. 2008. Energy Efficiency of different modes of transportation. Available online: <http://strickland.ca/efficiency>

## Step 2: Calculating carbon emissions per unit of energy by energy source

### GHG Emissions from Electricity Generation

For fossil fuels the total rate of emission is the sum of stack emissions during fuel combustion and releases from up- and down-stream activities of chains. Typically, GHG emissions from power plant construction and decommissioning, and contributions from power lines connecting the plant to the grid are negligibly small. For example, only 1% of the overall GHG emission can be attributed to plant construction and decommissioning. For nuclear power and renewable fuels, there are no GHG emissions at the point of generation, but there are atmospheric releases during fuel mining, preparation and transport, plant construction and decommissioning, manufacturing of equipment and decay of organic matter.

#### Electricity Production Chain GHG emissions

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Coal: 2005-20 Technology: 50-55% conversion efficiency	206 gCeq/kWh
Natural Gas: 2005-20 Technology: 60-65% conversion efficiency	106 gCeq/kWh
Solar PV: 2010-20 Technology	8.2 gCeq/kWh
Hydroelectric: Reservoir (Canada)	4.4 gCeq/kWh
Biomass: low	8.4 gCeq/kWh
Wind: Coast (30% capacity, UK)	2.5 gCeq/kWh

Source: Spadaro et al. 2000

### GHG Emissions from Gasoline and Diesel Combustion

One of the primary determinants of carbon dioxide emissions from mobile sources is the amount of carbon in the fuel. The values used here (2,421 grams for gasoline, and 2,778 grams for diesel) do not specifically address the impact of fuel additives such as ethanol.

Combustion	GHG Emissions
One gallon of gasoline	8,788 g/gallon Burning 1 g. gasoline generates 33.6 kWh = 262 gC/kWh
One gallon of diesel	10,084 grams/gallon Burning 1 g.diesel generates 138,690 Btu 138,690 Btu = 40.6 kWh = 253 gC/kWh

Sources: EPA, 2005. Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel. EPA420-F-05-001 February 2005; Strickland, James. 2008. Energy Efficiency of different modes of transportation. Available online: <http://strickland.ca/efficiency>

### Step 3: Calculating Typical Passenger Occupancy

Maximum occupancy was determined based on manufacturer specifications for all modes.

Typical occupancy for private automobiles is specified as the average vehicle occupancy for work trips.

Source: Bureau of Transportation Statistics. 2001. Highlights of the 2001 National Household Travel Survey. Research and Innovation Technology Administration

Typical occupancy for public transit was based on actual ridership data provided by the Toronto Transit Commission.

Source: TCC, 2007. Ridership and cost statistics for bus and streetcar routes 2006-2007. Toronto Transit Commission.

### Capital Costs per Passenger-Mile

The general methodology for calculating the capital costs per passenger-mile for each mode was to determine the total capital costs associated with getting the system up and running (construction, vehicles etc.), determine an annualized cost and then divide this annualized cost by annual passenger-miles.

Sources for calculating capital cost per passenger-mile for private automobiles:

CAA. 2008. Driving Costs. Canadian Automobile Association

US Department of Transportation, 2006. Annual Vehicle Distance Traveled in Miles and Related Data – 2006. Federal Highway Administration, US Department of Transportation.

Source for calculating capital cost per passenger-mile for 40' diesel bus:

National Transit Database:  
Portland (1997-2006)  
Kenosha (1997-2006)  
St Louis (1996-2005)

Note: the NTD does not differentiate between normal bus service and BRT therefore cities chosen without BRT

Source for calculating capital cost per passenger-mile for articulated diesel bus [BRT capital costs vary significantly (from \$329 million/ mile for the Boston Silver Line bus tunnel to \$1 million/ mile for the Vancouver Broadway line). Here we have used the Vancouver line as an example of a mixed-traffic/curb bus lane]:

Translink, 2003. Bus Rapid Transit Evaluation Study. Prepared by IBI Group for Translink.

Source for calculating capital cost per passenger-mile for LRT:

National Transit Database:  
St Louis (1996-2005)

Note: the NTD does not differentiate between modern streetcar and LRT so city chosen without modern streetcar

Source for calculating capital cost per passenger-mile for Skytrain:

Translink, 2008. Evergreen Line Rapid Transit Project Business Case. Translink.

Source for calculating capital cost per passenger-mile for Trolleybus:

Brown, Kevin. 2001. The Benefits of Clean, Quiet, Emission-Free Transit Service: Promoting the Trolleybus in Vancouver. The TBus Group.

Translink. 2005. Vancouver & UBC Area Transit Plan 2005 - 2010: Draft Summary Report. Translink.

Source for calculating capital cost per passenger-mile for Modern streetcar:

Gloria Ohland and Shelley Poticha, Reconnecting America, Street Smart: Streetcars and Cities in the Twenty-First Century, 2006.

TCC, 2007. Ridership and cost statistics for bus and streetcar routes 2006-2007. Toronto Transit Commission.

## Operating Costs per Passenger-Mile

Data used to calculate the operating costs for private automobiles were gathered from:

CAA. 2008. Driving Costs. Canadian Automobile Association

LightRailNow, 2001. Cost per Passenger-Mile of an Urban Automobile. Available online: [http://www.lightrailnow.org/facts/fa\\_00016.htm](http://www.lightrailnow.org/facts/fa_00016.htm)

Data used to calculate the operating costs for diesel bus were gathered from:

National Transit Database

National (Aggregate 2006)

Portland

St. Louis

Kenosha

Data used to calculate the operating costs for articulated diesel bus were gathered from:

Vancouver 98 B-line: Translink, 2003. Bus Rapid Transit Evaluation Study. Prepared by IBI Group for Translink.

Boston Silver line (all): FTA, 2007. Silver Line Waterfront Bus Rapid Transit (BRT) 2007 Project Evaluation, Boston, Massachusetts. Federal Transit Administration, United States Department of Transportation.

Boston Silver line (Washington): FTA, 2005. Boston Silver Line Washington Street Bus Rapid Transit (BRT) Demonstration Project Evaluation. Federal Transit Administration, United States Department of Transportation.

LA Orange & Gold Line: Vincent, William and Lisa Callaghan, 2007. Preliminary Evaluation of the Metro Orange Line Bus Rapid Transit Project. Submitted to Transportation Research Board: April 2, 2007. Prepared by Breakthrough Technologies Institute (BTI).

Data used to calculate the operating costs for LRT were gathered from:

National Transit Database

Data used to calculate the operating costs for Skytrain were gathered from:

Translink, 2002. Cited in 'The Operating Cost Advantage of Driverless Systems. Magplane Technology Group of Companies. [www.magplane.com](http://www.magplane.com)

Literature used to determine operating costs for Trolleybus:

Brown, Kevin. 2001. The Benefits of Clean, Quiet, Emission-Free Transit Service: Promoting the Trolleybus in Vancouver. The TBus Group.

Rafter, D.O. 1995. The Electric Trolley Bus. Journal of the American Planning Association, 61 (1): 57-64.

Literature used to determine operating costs for Trolleybus:

Brown, Kevin. 2001. The Benefits of Clean, Quiet, Emission-Free Transit Service:

TCC, 2007. Ridership and cost statistics for bus and streetcar routes 2006-2007. Toronto Transit Commission.