Long Range Transit Plan

Appendix IV

Greenhouse Gas Emissions Analysis

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1. Introduction

Community Transit has made the conscious decision to improve transit service quality, efficiency and productivity in its service area and adapt transit services to the evolving needs of the communities it serves. To do this, it needs to effect change in land use and urban development practices along transit emphasis corridors, taking a leading role in coordinating and promoting denser and smarter development in the municipal jurisdictions that comprise its service area, and along strategic transportation corridors.

This technical memorandum is intended to pave the way for future estimates about the impacts that Community Transit's corridors approach will have on greenhouse gas emissions. The long range plans are not yet fully refined, and do not provide the exacting details about land use patterns, overall travel and system patronage needed to make specific estimates of greenhouse gas reductions. The memo does propose an approach that can be employed when making these estimates in the future.

Public transportation has the potential to significantly reduce greenhouse gas (GHG) emissions in the transportation sector, which makes about 28 percent of all GHG emissions in the U.S. overall and about 50% in Washington State. The major GHG benefits that are derived from public transportation are from reductions in overall vehicle-miles traveled (VMT) in urban areas. These savings are often called displaced VMT. They are mostly indirect impacts that come from changes in mode split, congestion relief, and the "land-use multiplier" effect.

Measuring the transit benefits to climate change from Community Transit or any single transit agency, for that matter, is not an easy task and requires thorough documentation and review of all emission sources. A thorough review of the methodology to account for transit emission debits and credits is included in this memorandum.

It is difficult for transit projects to be able to claim CO_2 benefits. Buses tend to be "dirty" from a CO_2 perspective, and the mode shift they create can be backfilled through induced demand. (Meaning that auto trips rise to their previous levels and congestion relief benefits are washed out by this new travel.) Recognizing these issues, transit projects have had the greatest success in reducing GHG emissions when they are combined with land-use and congestion management strategies. This paper documents current research in those areas.

2. Literature Review

This chapter provides an overview of four major studies that have been published very recently. Together, these studies represent the latest thinking about the impacts of public transportation on climate change. Their major message is that Community Transit is on the right track. Only through incentives to promote changes in land use (mixed-use) and urban development (more density) will transit be able to improve productivity, efficiency and accrue overall reductions in GHG emissions in the transportation system and the urban area.

Growing Cooler: The Evidence on Urban Development and Climate Change

Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Don Chen. ULI 2008

Conclusions: Innovations in vehicle and fuel technology will not save us, the key is reducing VMT, and only urban development change (densification) will facilitate VMT reduction.

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This study concludes that compact development has the potential to make a significant impact on VMT, and hence CO_2 emissions. Technological solutions on their own will not be enough to meet CO_2 emissions targets, since any gains in efficiency will be swamped by growth in VMT due to sprawl development trends.

"Growing Cooler" demonstrates that national CO_2 reduction targets cannot be met by advances in vehicle and fuel technology alone. The distances traveled by vehicles must also be sharply reduced to meet emissions goals. The study uses a three-legged stool analogy for the ways of reducing carbon emissions that includes:

- Vehicle fuel efficiency
- Carbon content of fuel
- Vehicle-miles traveled

Current official efforts are aimed almost exclusively at improving the first two legs. Any improvements in vehicle technology or cleaner fuels are likely to be offset by increases in VMT. Since 1980, VMT has grown three times faster than the population and almost twice as fast as the number of car registrations. Average commute times have been increasing and many Americans now spend longer time commuting than vacationing.

Why do we drive so much, why is it increasing so rapidly, how can we effectively and fairly reduce the amount we need to drive?

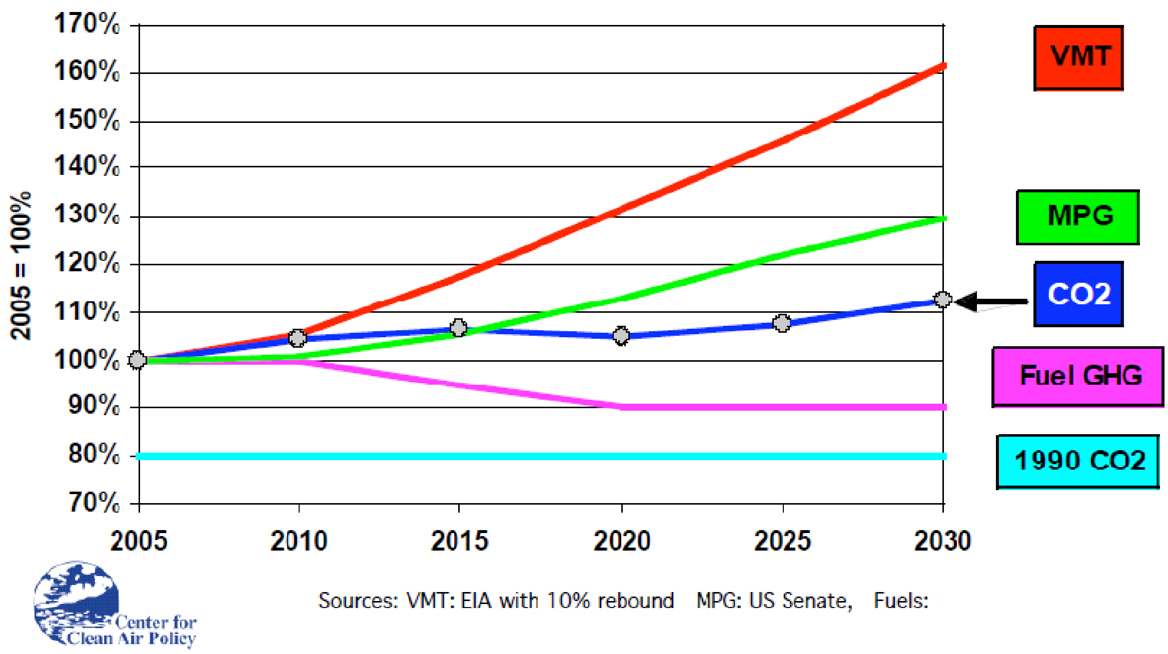
The growth in distances is due, in part, to urban planning – the built environment. Since WWII, planning has assumed that virtually all trips will take place by car, and hence many Americans are given little choice as to how to get around. As the built environment has become more car dependent, usage of other modes has dropped. Population growth accounts for only 25 percent of the growth in VMT.

Technological advances will be cancelled out by increased VMT

Whereas most pollutants can be controlled by in-vehicle technology – catalytic converters, advanced engine management – CO_2 is a direct product of combusting fossil fuels. There is currently no practical way to remove it from tailpipe emissions. As of today, the best way that individuals can reduce their CO_2 emissions is to drive less.

The average fuel economy of American cars has not changed for 15 years. Technological improvements have been fully offset by increases in the weight and power of vehicles. Even if new federal CAFE standards and state initiatives like California's low-carbon fuel initiative go into effect – the growth in emissions will be far in excess of the required cuts (40% increase relative to current levels, instead of a cut of 60-80% relative to 1990 levels). See Figure 1 below.

Figure 1: Projected Growth in CO2 Emissions from Cars and Light Trucks Assuming Stringent Nationwide Vehicle and Fuel Standards*



* The study concludes that, by 2030, total VMT will increase by more than 60%. The GHG impacts of this increase will be partially offset by increased fuel economy and lower carbon contents in the fuels being utilized. Even with these improvements, the increased number of miles driven will mean that CO_2 emissions from transportation will actually be greater in 2030 than they were in 2005.

Estimates of potential impact of smart growth on emissions

These same studies conclude that it is realistic to assume a 30 percent reduction in VMT when compact development occurs. Not counting the CO_2 impacts of the buildings themselves (things like the higher energy efficiency of attached housing); they conclude that transportation related CO_2 emissions could be reduced by 7 to 10 percent by 2050. This would be equivalent to a federal mileage standard of 32 mpg for the entire vehicle fleet.

Unlike new technologies – hybrids, biofuels, hydrogen – the "technology" of compact urban development already exists, and it is ready to use right now.

The impact of compact development on travel requirements

Compact community planning puts most things within walking and cycling distance. Where cars are needed, the trips are short. Compact planning makes transit viable and increases the profitability of neighborhood commercial districts over big box retail and strip commercial development.

Many different names have been given to dense community areas: "walkable communities", "TOD", "new urbanist neighborhoods", "mixed-use development." Infill and brownfield developments also play a part. There have been several studies looking at the relationship between sprawl and average daily miles driven. Larry Frank at the University of British Columbia found that households in the most walkable communities drove 26 percent less.

Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions

Cambridge Systematics, Inc. ULI 2009

Conclusions: transportation demand management (system operations, parking and congestion pricing) coupled with land use development management and investments in transit infrastructure will reduce VMT.

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Little research has taken a critical look at the full range of transportation measures that would influence the greenhouse gas emissions by reducing the amount of vehicle-miles traveled, reducing fuel consumption and improving the performance of the transportation system. The intent of the Moving Cooler study is to assess the potential effectiveness of a broad variety of transportation strategies that are intended to reduce greenhouse gas emissions.

The study concludes that transportation contributes roughly 28 percent of the United States' total GHG emissions, and transportation emissions have been growing faster than those of other sectors. In fact, between 1990 and 2006, growth in the U.S. transportation GHG emissions represented almost one-half (47%) of the increase in total U.S. GHGs. Success in reducing GHGs through transportation strategies will be critical to meeting national goals.

Transportation GHG emissions are the result of the interaction of four factors: vehicle fuel efficiency, the carbon content of fuel burned, the number of miles that vehicles travel, and the operational efficiency experienced during travel. The range of transportation strategies that can be used to reduce GHGs fall into four basic approaches:

- **Vehicle Technology**: improving the energy efficiency of the vehicle fleet
- **Fuel Technology**: reducing the carbon content of fuels through the use of alternative fuels (e.g. natural gas, biofuels, and hydrogen)
- **Travel Activity**: reducing the number of miles traveled by transportation vehicles or shifting those miles to more efficient modes of transportation
- **Vehicle and System Operations**: improving the efficiency of the transportation network so that a larger share of vehicle operations occur in favorable conditions, with respect to speed and smoothness of traffic flow, resulting in more fuel efficient operations

The focus of Moving Cooler is on strategies that fall within these last two approaches to reducing transportation GHGs. The individual strategies considered are grouped into nine categories, as follows:

- **Pricing and taxes**: taxing the cost of vehicle miles traveled and fuel consumption, and pricing local and regional facilities (congestion pricing) and economy wide pricing strategies (carbon pricing)
- **Land use and smart growth**: strategies that create more transportation efficient land use patterns, and by doing so reduce the need to make motor vehicle trips and reduce the average length of motor vehicle trips that are made
- **Non-motorized transportation**: strategies that encourage greater levels of walking and bicycling as alternatives to driving
- **Public transportation improvements**: expanding public transportation by subsidizing fares, increasing service and/or building new transit infrastructure (BRT, light rail, streetcars)
- **Ride-sharing, car-sharing and other commuting strategies**: strategies that expand services and provide incentives to travelers to choose transportation options other than driving alone
- **Regulatory strategies**: implement regulations that moderate vehicle travel or reduce speeds to achieve higher fuel efficiency
- **Operational and intelligent transportation system (ITS) strategies**: strategies to improve the operation of the transportation system to make better use of the existing capacity; strategies to also encourage more efficient driving
- **Capacity expansion and bottleneck relief**: expand highway capacity to reduce congestion and to improve the efficiency of travel
- **Multimodal freight movement strategies**: strategies to promote more efficient freight movement within and across modes

Findings: Combining Strategies to Reduce GHGs

The study concludes that an integrated multi-strategy approach – combining travel activity, local and regional pricing, operational and efficiency strategies – can contribute to significant GHG emission reductions. Implementation of a complete portfolio of Moving Cooler strategies without economy-wide pricing could achieve annual GHG emissions ranging from 4 to 18 percent and as high as a 24 percent reduction from the projected baseline levels in 2050. Such reductions would involve considerable – and in some cases major – changes to current transportation system and operations, travel behavior, land use patterns, and public policy and regulations.

The strategies that contribute the most to GHG reductions are local and regional pricing and regulatory strategies that increase the costs of single occupancy vehicle travel, regulatory strategies that reduce and enforce speed limits, educational strategies to encourage eco-driving behavior that achieves better fuel efficiency, land use and smart growth strategies that reduce travel distances, and multimodal strategies that expand travel options.

The analysis also shows that some combinations of strategies could create synergies that enhance the potential reductions of individual measures. In particular, land use changes combined with expanded transit services achieve stronger GHG reductions, than when only one option is implemented.

These results demonstrate that transportation agencies and other decision makers could create effective combinations of transportation strategies that provide high-quality transportation services, while achieving meaningful GHG emission reductions.

Public Transportation Role in Responding to Climate Change (Federal Transit Administration)

Federal Transit Administration. FTA 2009

Conclusions: Public transportation can play a significant role on climate change. Public transit (metro, light-rail, and bus) is many times cleaner than single-occupant vehicles on a passenger mile basis. Transit has the potential to reduce overall VMT, the major source of CO_2 emissions.

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This paper presents an analysis of national level data (National Transit Database, US Department of Energy and US Environmental Protection Agency) and frames it in a broader context. National level data show significant potential for greenhouse gas emission savings by use of public transportation, which offers a low emissions alternative to driving. Based on an examination of FTA's data and other academic, government, and industry sources, public transportation can reduce greenhouse gas emissions by:

- Providing a low emissions alternative to driving
- Facilitating compact land use development, reducing the need to travel long distances
- Minimizing the carbon footprint of transit operations and construction

Public transportation produces lower greenhouse gas emissions than autos

National averages demonstrate that public transportation produces significantly less greenhouse gas emissions per passenger mile than private vehicles (see Figure 2). Leading the way is heavy rail transit, such as subways and metros, which produce about 75 percent less in greenhouse gas emissions per passenger mile than an average single-occupancy vehicle (SOV). Light rail systems produce 57 percent less and bus transit produces 32 percent less. The environmental benefits of public transportation vary based on the number of passengers per vehicle, the efficiency of the bus or train, and the type of fuel used.

The number of riders greatly impacts transit's emissions savings.

Transit's emissions savings would be even greater with higher ridership levels; the more passengers that are riding a bus or train, the lower the emissions per passenger mile. For instance, U.S. bus transit, which has about a quarter of its seats occupied on average, experiences about 2 percent lower greenhouse gas emissions per passenger mile than the average U.S. single occupancy vehicle. The savings increases to 83 percent for a typical diesel transit bus when it is full with 40 passengers. The average 40-passenger diesel bus must carry a minimum of 7 passengers on board to be more efficient than the average single-occupancy vehicle. Similarly, the average heavy rail car would need to have at least 19 percent of seats full to exceed the efficiency of an automobile carrying an average passenger load.

Power sources and vehicle efficiency also impact transit's emissions.

Most rail transit systems are powered by electricity. Those relying on electricity from a low emissions source, such as hydroelectric, not surprisingly, have much lower emissions than those relying on coal power plants. Rail vehicles also vary in terms of energy efficiency due to weight and engineering factors.

Emissions from bus systems vary due to the use of low carbon fuels, more energy efficient vehicles, and different operating environments (such as frequent stops in denser urban areas). In terms of vehicle efficiency for instance, many transit agencies are replacing older diesel buses with new hybrid-electric buses, which consume 15 to 40 percent less fuel, and consequently produce 15 to 40 percent fewer carbon dioxide emissions.

Figure 2: Estimated CO_2 Emissions per Passenger Mile for Average and Full Occupancy

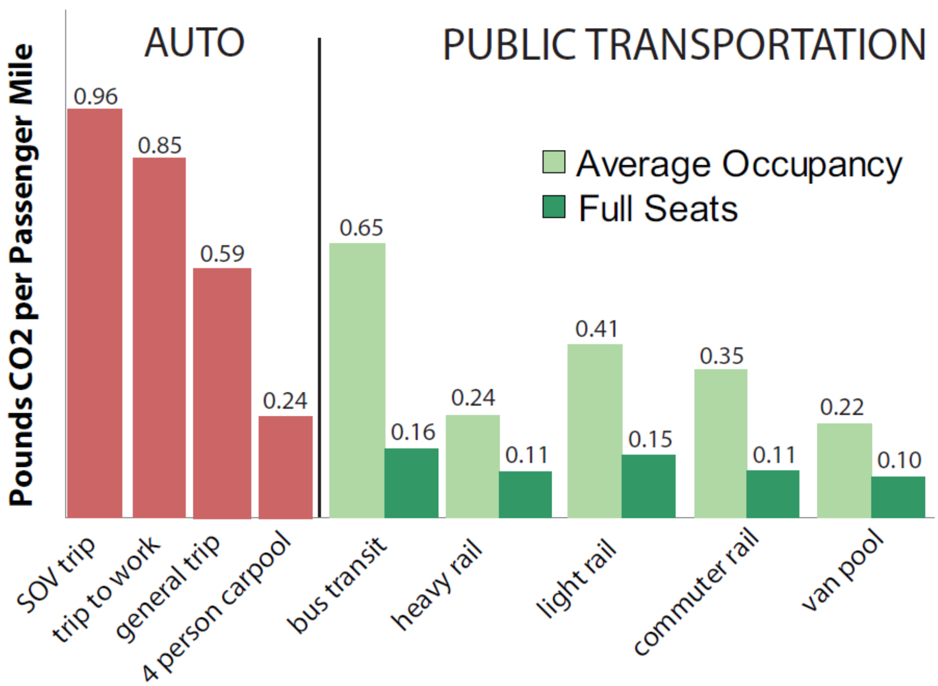
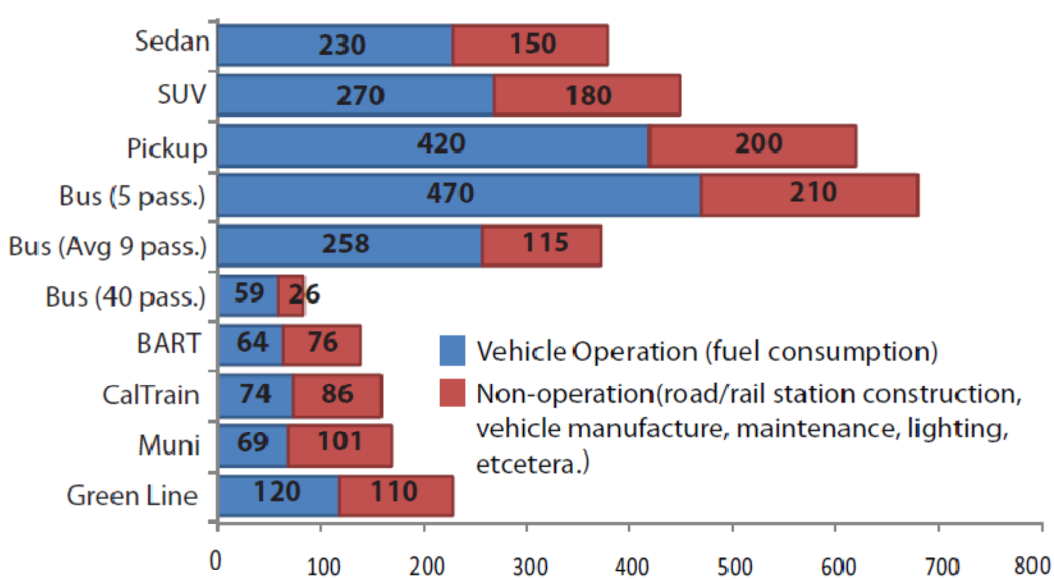


Figure 3: Greenhouse Gas Emissions from Full Life Cycle, including Operation, Construction and Maintenance



Taking lifecycle emissions into account also shows emissions savings from transit

Transit-based greenhouse gas emissions per passenger mile are significantly lower than those from driving, even taking emissions from construction into account, manufacture, and maintenance. Life cycle emissions include a full accounting of all emissions generated over the full life of a transportation system. This includes emissions from building the highway or rail system, manufacturing the vehicles, maintaining the infrastructure and vehicles, producing and using the fuel, and eventually disposing of the vehicles and infrastructure.

The researchers found that including full life cycle impacts increased greenhouse gas emissions estimates by as much as 70 percent for autos, 40 percent for buses, 150 percent for light rail, and 120 percent for heavy rail (see Figure 3 above). While including emissions from construction of infrastructure has a larger impact on rail transit than on automobiles, the results still show significant emissions savings from average occupancy rail and bus transit over average occupancy sedans, SUVs, and pickups.

Public transportation facilitates compact land use, which plays a role in greenhouse gas reductions

Public transportation reduces emissions by facilitating higher density development, which conserves land and decreases the distances people need to travel to reach destinations. In many cases, higher density development would be more difficult without the existence of public transportation because more land would need to be devoted to parking and travel lanes. By facilitating higher density development, public transportation can shrink the footprint of an urban area and reduce overall trip lengths. In addition, public transportation supports increased foot traffic, street-level retail, and mixed land uses that enable a shift from driving to walking and biking.

Public transportation can also facilitate trip chaining, such as combining dry-cleaning pick-up, shopping, and other errands on the way home from a station. Finally, households living close to public transportation tend to own fewer cars on average, as they may not need a car for commuting and other trips. A reduced number of cars per household leads to reduced car use, and driving may cease to be the habitual choice for every trip.

Multiple studies have quantified the relationship between public transportation, land use, and reduction in travel. The studies show that for every additional passenger mile traveled on public transportation, auto travel declines by 1.4 to 9 miles. In other words, in areas served by public transportation, even non-transit users drive less because destinations are closer together. A recent study used modeling to isolate just the effect of public transportation on driving patterns (rather than that effect combined with denser land use creating a need for improved public transportation). That study, conducted by consulting firm ICF and funded through the Transit Cooperative Research Program, found that each mile traveled on U.S. public transportation reduced driving by 1.9 miles.

It concluded that public transportation reduces U.S. travel by an estimated 102.2 billion vehicle-miles traveled (VMT) each year, or 3.4 percent of annual U.S. VMT. A study published by the Urban Land Institute found that within areas of compact development, driving is reduced 20 to 40 percent compared to average U.S. development patterns.

Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit (APTA)

American Public Transportation Association. APTA 2009

Conclusions: GHG emission reduction benefits from transit are only accrued when accounting for transit direct emissions (debit) and indirect emissions (credit). Transit major credits are mode split changes, congestion relief, and urban development changes.

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This document (issued in August 2009) provides guidance to transit agencies for quantifying their greenhouse gas emissions, including both emissions generated by transit and the potential reduction of emissions through efficiency and displacement. It lays out a standard methodology for transit agencies to report their greenhouse gas emissions in a transparent, consistent and cost-effective manner. It ensures that agencies can provide an accurate public record of their emissions; may help them comply with future state and federal legal requirements; and may help them gain credit for their “early actions” to reduce emissions.

Typology of Transit Greenhouse Gas Impacts

The impact of transit on greenhouse gas emissions can be divided into two categories, shown in Figure 4:

- **Emissions produced by transit**: This category accounts for the “debit side” of net transit emissions. The major element is mobile combustion — i.e., tailpipe emissions from transit vehicles or electricity use for rail agencies. It also includes stationary combustion, such as on-site furnaces and indirect emissions from electricity generation. These debits are calculated at the agency level.
- **Emissions displaced by transit**: This category accounts for the “credit side” of net transit emissions, through reduced emissions from private automobiles. These credits are calculated at the regional or national level. They can be divided into three subcategories:
  - Avoided car trips through mode shift from private automobiles to transit.
  - Congestion relief benefits through improved operating efficiency of private automobiles, including reduced idling and stop-and-go traffic.
  - The land-use multiplier, through transit enabling denser land-use patterns that promote shorter trips, walking and cycling, and reduced car use and ownership.

For purposes of greenhouse gas reporting, emissions displaced by transit would normally be considered optional (Scope 3, according to the terminology introduced on page 12). However, should an agency decide to report its emissions, APTA strongly encourages the inclusion of displaced emissions in order to provide the fullest picture of transit’s benefits.

Why Quantify Emissions?

There are several reasons why a transit agency might want to comprehensively quantify its greenhouse gas emissions:

- Communicating the benefits of transit
- Ensuring eligibility for new funding sources
- Reporting to carbon accounting and trading organizations

- Setting emissions targets in local/regional climate action plans
- Supporting internal efforts to reduce emissions

Scale

Another distinction is between average (i.e., ongoing or historical) impacts and marginal impacts from transit (Figure 5). Average impacts can be understood as the net impact of transit on present-day emissions. These are the benefits that have accrued from historical investments. Marginal impacts can be understood as the incremental change in emissions that result from a new project or policy change – for example, from implementing a new light rail or BRT line, or changing fare levels.

Figure 4: Typology of Greenhouse Gas Impacts

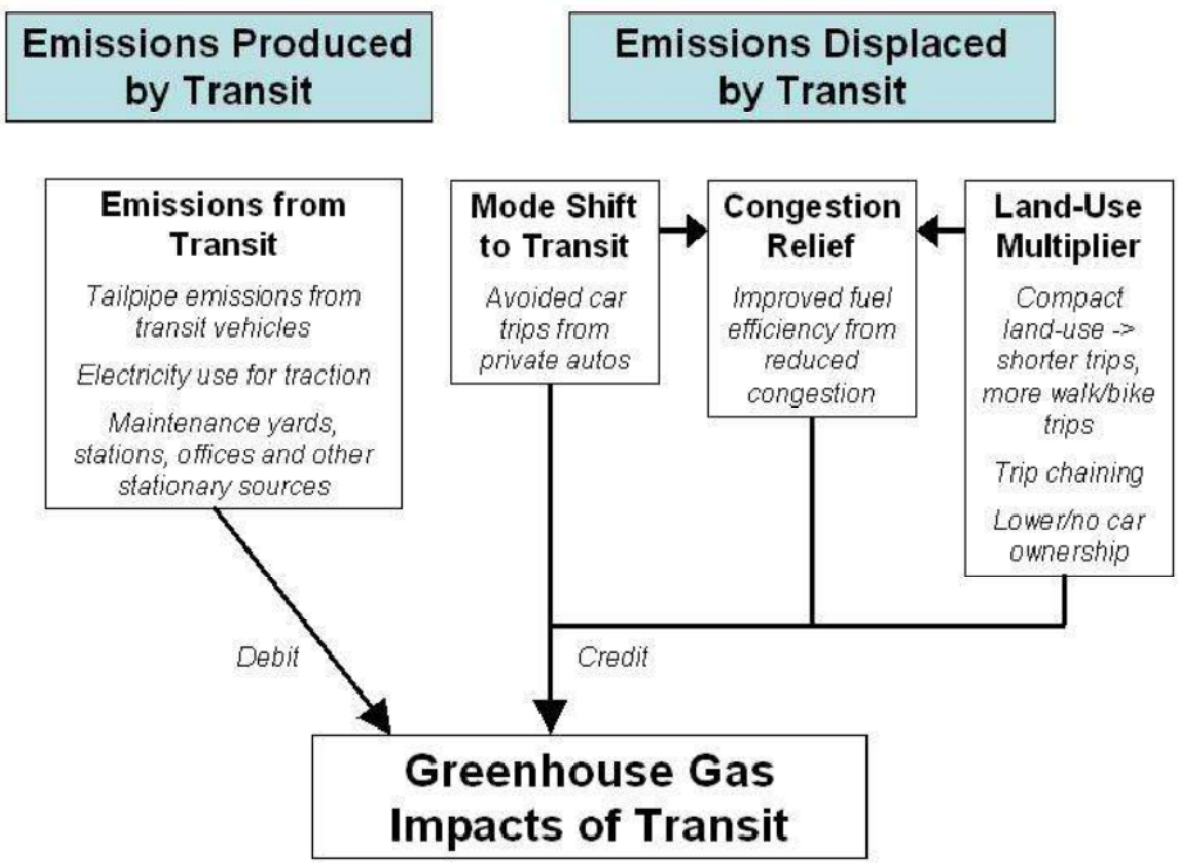
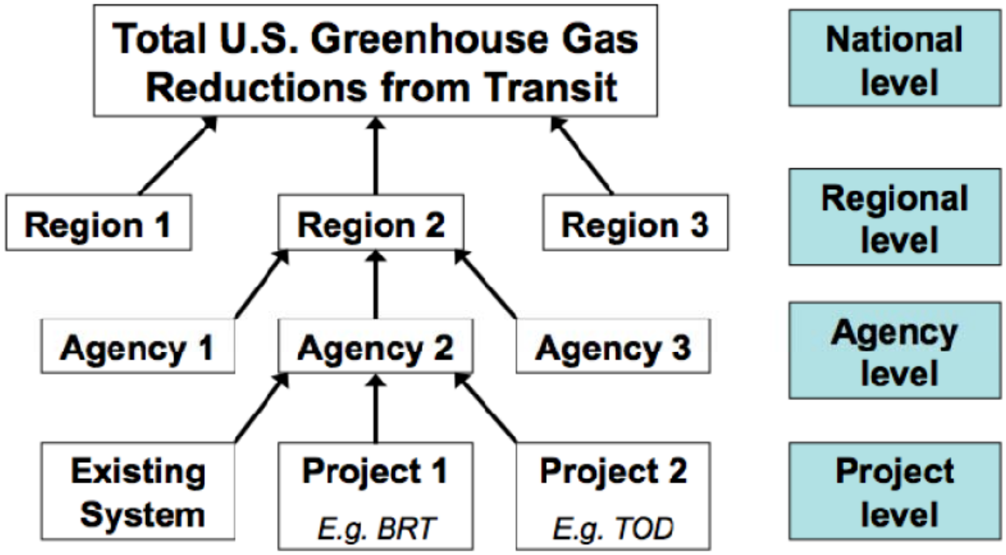


Figure 5: Scale of Greenhouse Gas Reductions from Transit



Emission Scopes

Emission inventory protocols such as those developed by The Climate Registry (2008) and World Resources Institute (2004) make a key distinction between three "scopes" of emissions:

- **Scope 1 – Direct Emissions**. This scope includes:
  - Stationary combustion from boilers and furnaces;
  - Mobile combustion in vehicles owned and controlled by the organization;
  - Physical or chemical processes; and
  - Fugitive sources such as methane leaks from refueling facilities, or leakage of SF6 from transformers or HFCs from air conditioning equipment.
- **Scope 2 – Indirect Emissions**. This scope includes purchased electricity, heating, cooling and steam.
- **Scope 3 – Optional**. This scope includes:
  - Displaced emissions from mode shift to transit, congestion relief and the land-use multiplier;
  - Transit access trips (e.g., to rail stations or park-and-ride facilities);
  - Employee commuting and business travel;
  - Life-cycle emissions from vehicle manufacture and disposal;
  - Upstream (well-to-tank) emissions from fuel extraction, refining and transportation; and
  - Waste disposal.

In practice, most emissions from transit operations fall under Scope 1 or under Scope 2 in the case of agencies that use electric traction power for rail or trolleybus propulsion. Most emissions from capital projects fall under Scope 3, as these will generally be reported under Scope 1 by another organization, such as the contractor and steel manufacturer. Scope 3 provides a mechanism for "double accounting without double counting." All displaced emissions (from mode shift, congestion relief and land use) fall under Scope 3. APTA encourages transit agencies to specify in purchased transportation and construction contracts the entity that will report specified emissions as Scope 1.

Should an agency decide to register its emissions with The Climate Registry, APTA strongly encourages the inclusion of displaced emissions under Scope 3. While this is optional from The Climate Registry's perspective, reporting displaced emissions from reduced private auto use provides the fullest picture of transit's net contribution to greenhouse gas reductions.

3. Estimating Transit's GHG Emissions

Reporting Scope 1 and 2 Emissions (mainly operational)

For funding and reporting purposes, transit agencies generally make a distinction between operations and capital projects. For the purposes of greenhouse gas reporting, however, a strict distinction between operational and capital project emissions is less helpful. It is difficult to separate Scope 1 and 2 emissions into an operations component and a capital component, as emissions will be aggregated in facilities where both types of activities are undertaken.[1]

Instead, transit agencies should distinguish between Scope 1 and 2 emissions and Scope 3 emissions. In general, operational emissions will fall under Scopes 1 and 2 and capital emissions under Scope 3 (see Figure 6 below).

Figure 6: Greenhouse Gas Emissions from Transit

Category of Emissions	Scopes[1]	Covered In	Credit/Debit
Operational emissions from transit fleets and stationary facilities	Scopes 1 and 2	Section 5	debit
Emissions from transit capital projects	mainly Scope 3	Section 5	debit
Displaced emissions from: - mode shift to transit - reduced congestion - land-use effects ("transit multiplier")	 Scope 3 Scope 3 Scope 3	 Section 6 Section 7 Section 8	 credit credit credit

1. See discussion of Scopes 1, 2 and 3 earlier in this section.

Gases to Be Reported

Emissions of all six greenhouse gases regulated under the Kyoto Protocol must be reported separately in metric tons of carbon dioxide equivalent (CO_2-e). These are shown in Figure 7, along with the standard Global Warming Potential (GWP) factors that are used to convert emissions to CO_2-e. Methane, for example, is 21 times more powerful as a greenhouse gas than carbon dioxide, and so one-twenty-first of a metric ton of methane is one metric ton of CO_2-e.

[1] Much of this is drawn from 'Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit,' American Public Transportation Association. 2009. See the previous chapter for a more complete description of the project.

Figure 7: Typical Sources for Transit Agencies

Gas	Typical Sources for Transit Agencies	GWP
Carbon dioxide (CO_2)	Gasoline and diesel combustion Combustion at stationary sources, e.g. maintenance yards Electricity purchases	1
Methane (CH_4)	Gasoline and diesel combustion Fugitive emissions of natural gas	21
Nitrous oxide (N_2O)	Gasoline and diesel combustion	310
Hydrofluorocarbons (HFCs)	Leakage of refrigerants	Varies[1]
Perfluorocarbons (PFCs)	Leakage of refrigerants	Varies[1]
Sulfur hexafluoride (SF_6)	Leakage from electrical equipment	23,900

1. Varies by specific gas. See Appendix B of The Climate Registry General Reporting Protocol.

All emissions must be quantified. However, up to 5 percent of emissions may be reported using simplified methods that provide an upper-bound (i.e., conservative) estimate. This may be appropriate where the costs of data collection are disproportionate to the quantity of emissions. For most transit agencies, some types of non-mobile source emissions are likely to fall under this 5 percent threshold and be eligible for simplified methods. Figure 8 below, provides examples from agencies that have reported emissions to the California Climate Action Registry. For example, emissions from mobile sources and purchased electricity account for 97 percent or more of emissions in these two cases.

Figure 8: Typical Sources of Emissions

Source	Scope	Santa Barbara MTD		AC Transit (California)	
		Metric Tons CO_2-e	Percentage	Metric Tons CO_2-e	Percentage
Mobile combustion	1	5,687	95%	64,379	93%
Stationary combustion	1	27	0.5%	1,965	3%
Process emissions	1	0	0%	0	0%
Fugitive emissions	1	1	0%	0	0%
Purchased electricity	2	264	4%	2,568	4%
Purchased steam	2	0	0%	0	0%
Purchased heating and cooling	2	0	0%	0	0%
Total		5,979	100%	68,912	100%

Source: Public reports submitted to the California Climate Action Registry

Organizational Boundaries

The Climate Registry provides three options for defining the organizational boundary (based on World Resources Institute 2004):

- **Equity Share**: Emissions from operations in which an organization has an economic interest in proportion to the equity share (usually defined by percentage ownership). If the equity share approach is used, either financial or operational control also must be used.

- **Financial Control**: All emissions from operations over which the organization has control over financial policies and an interest in economic benefits, or for which it bears the financial risks.
- **Operational Control**: All emissions from operations over which the organization has full authority to introduce and implement operating policies. In this instance, the agency must also provide a list of entities in which it has an ownership interest but does not have control.

APTA strongly recommends that transit agencies use the operational control method to report their emissions. This provides the most appropriate match with their emissions and is also the regulatory approach being considered in some states, including California. In many cases, organizational boundaries involve a gray area, and definitions of operational and financial control are subject to interpretation. In almost all cases, however, the following rule should apply: If a transit agency reports data on a service to the National Transit Database, it should be considered to have operational control over these emissions. This is a particularly important point for Community Transit. As an operator of Sound Transit services, care must be taken to avoid double reporting of GHG emissions resulting from Sound Transit contracted operations. This is particularly true if both Community Transit and Sound Transit elect to report GHG emissions to a climate action registry in the future.

Performance Metrics

Performance metrics are optional under The Climate Registry protocol. However, in order to facilitate benchmarking of transit agencies, this standard requires the following metrics to be reported for each National Transit Database modal category, and for the agency as a whole:

- **Emissions per Vehicle Mile** (revenue service plus deadhead segments): This primarily measures vehicle efficiency and will be sensitive to efforts to purchase lower-emission vehicles or to switch to lower-carbon fuels.
- **Emissions per Revenue Vehicle Hour**: This is another measure of operational efficiency, but will take into account efforts to reduce deadheading. It also takes into account congestion, which will depress performance on emissions per vehicle mile.
- **Emissions per Passenger Mile**: This takes into account service productivity and will reward increases in ridership and load factors.

Data on vehicle miles, revenue vehicle hours and passenger miles by mode for an agency can be found on National Transit Database. The reporting structure is shown in Figure 9. It is anticipated that these metrics will form part of the APTA Sustainability Commitment, currently in a pilot phase.

Figure 9: Required Performance Metrics

Mode	Emissions (E)	Vehicle miles (VM)		Revenue Vehicle Hours (RH)		Passenger miles (PM)	
		Total	E/VM	Total	E/RH	Total	E/PM
Bus	E_b	VM_b	E_b/VM_b	RH_b	E_b/RH_b	PM_b	E_b/PM_b
Light rail	E_{LR}	VM_{LR}	E_{LR}/VM_{LR}	RH_{LR}	E_{LR}/RH_{LR}	PM_{LR}	E_{LR}/PM_{LR}
[repeat for other NTD modes]							
Nonrevenue	E_{NR}						
Stationary sources	$E_{stationary}$						
Total[1]	E_{tot}	VM_{tot}	E_{tot}/VM_{tot}	RH_{tot}	E_{tot}/RH_{tot}	PM_{tot}	E_{tot}/P_{tot}

1. Including emissions from stationary sources.

Quantifying Emissions

There are five types of emission sources, as follows:

- Direct emissions from stationary combustion (e.g., on-site furnaces)
- Direct emissions from mobile combustion
- Indirect emissions from electricity use
- Other indirect emissions (e.g., steam purchases)
- Fugitive emissions (e.g., refrigerant leaks)

Direct Emissions from Stationary Combustion

In general, data on direct emissions from stationary combustion will not be available through NTD reporting. Agencies should determine annual fuel use by reading individual meters or by using fuel receipts or purchase records together with data on changes in stocks. Emissions must be calculated separately for each facility. Refer to Chapter 12 of The Climate Registry protocol for detailed directions and default emission factors. Emissions for each fuel type (A, B, etc.) are calculated using the following formulas:

Total Annual Fuel A Consumption = Annual fuel purchases – Annual fuel sales + Fuel stock at beginning of year – Fuel stock at end of year

- Fuel A CO_2 Emissions = Fuel consumed × CO_2 emission factor / 1,000
- Fuel A N_2O Emissions = Fuel consumed × N_2O emission factor / 1,000,000
- Fuel A CH_4 Emissions = Fuel consumed × CH_4 emission factor / 1,000,000

Direct Emissions from Mobile Combustion

Typical sources of mobile combustions for transit agencies include Revenue Vehicles and Non-Revenue Vehicles. This category includes vehicles fueled by natural gas and biofuels, but not electric traction where the electricity is generated off-site (and is thus classified as Scope 2).

When actual fuel use, fuel carbon content and heat content data are available, emissions for each fuel type (A, B, etc.) are calculated using the following formulas:

Total Annual Fuel A Consumption = Annual fuel purchases + Fuel stock at beginning of year – Fuel stock at end of year

- Fuel A CO_2 emissions = Heat content × Carbon content × % oxidized × 44 / 12 / 1,000
- Fuel A N_2O emissions = Annual distance driven × N_2O emission factor / 1,000,000
- Fuel A CH_4 emissions = Annual distance driven × CH_4 emission factor / 1,000,000

Note that N_2O and CH_4 emission factors must be included for all mobile sources. For diesel vehicles, these will be negligible, but for compressed natural gas vehicles, CH_4 emissions may be significant, due to incomplete combustion.

For locomotives, N_2O and CH_4 emissions are calculated based on fuel consumption rather than distance driven.

For purchased transportation services, transit agencies must obtain the relevant data from the contract operator.

Indirect Emissions from Electricity Use

Electricity use must be quantified for each NTD mode and for each facility. Electricity use for traction is reported on NTD Form R-30. Non-traction electricity use (such as for office buildings) is not reported to NTD, and monthly electric bills or meter records should be the primary source.

For leased premises where meter records or bills may not be available, electricity use can be estimated through information on total building area, space used by the agency, total building electricity use and building occupancy rate.

For transit agencies using electric traction that purchase power directly from a specific source, generator-specific emission factors may be used. Other transit agencies should use eGRID region-specific emission factors, provided in The Climate Registry protocol Chapter 14.

Other Indirect Emissions

These types of emissions include electricity, steam, heating or cooling purchases from a cogeneration plant, or a conventional boiler not owned by the agency. Refer to Chapter 15 of The Climate Registry protocol.

Fugitive Emissions

Typical sources of fugitive emissions for transit agencies include the following:

- Leakage from natural gas fueling facilities (although agencies may have automatic shutoff mechanisms that reduce this leakage to zero)
- Leakage from air conditioning systems in buildings and stations (note that not all refrigerants are greenhouse gases – refer to Appendix B of The Climate Registry protocol)
- Leakage from vehicle air conditioning systems (note that not all refrigerants are greenhouse gases – refer to Appendix B of The Climate Registry protocol)
- Leakage from fire extinguishers
- Leakage from electrical systems such as transformers (SF_6)

The Climate Registry protocol provides guidance on estimating fugitive emissions of HFCs and PFCs from air conditioning and refrigeration systems – e.g., air conditioning units on transit vehicles. Agencies that service their own units should have data on the quantity of refrigerants purchased and/or used. Other can use simplified estimation methods, provided that total emissions estimated using simplified methods do not exceed 5 percent of an organization's inventory.

Reporting Scope 3 Emissions (mainly capital)

Most emissions from transit capital projects will fall under Scope 3. These emissions are optional to report under The Climate Registry protocol, as they will generally fall under Scope 1 of another organization (e.g., the contractor). However, for benchmarking purposes and in the interest of providing information that is as complete as possible, it can be useful to estimate these emissions.

Emissions should be reported for dedicated transit facilities only, such as stations, intermodal facilities and physically separated rights-of-way (including resurfacing of a separated right-of-way for exclusive use by bus rapid transit). Emissions from general roadway resurfacing projects, street lighting, etc. should be accounted for in the inventory of the respective local government entity (e.g., a county streets department), based on operational control.

Mode Shift to Transit

This section provides guidance on methodologies to calculate the mode shift impacts of transit on greenhouse gas emissions. Together with congestion relief and the land-use multiplier (discussed in the following two sections), mode shift to transit leads to “displaced emissions” as private automobile travel is reduced. There are three major methodological approaches to estimating the mode shift effect on an agency level:

- The use of regional travel demand models,
- Evidence from “natural experiments”
- Applying a mode shift factor to data on transit passenger mileage.

The APTA guidance recommends the third approach. However, the first two approaches are discussed briefly for the sake of completeness.

Regional Models

This approach uses county or regional travel demand models, typically maintained by metropolitan planning organizations (MPOs). The principle is simple: remove the transit system from the model and calculate vehicle miles traveled and greenhouse gas emissions. Regional models allow the complexities of feedback effects to be calculated. These include changes in destinations and trip lengths, as well as mode shift to a range of travel alternatives. There are several problems with this approach, however:

- Regional travel demand models are unlikely to be calibrated to address fundamental changes in transit availability.
- MPOs, where such models are normally housed, vary widely in their technical sophistication and in the availability of staff time to conduct such analyses.
- Some models may not deal well with suppressed trips that follow the elimination of a transit service (particularly important where transit has a social role).
- Results for different agencies may not be comparable, as modeling methodologies vary among regions. These discrepancies may grow as some regions switch to activity-based models.

Natural Experiments

The second methodological option takes advantage of natural experiments in which the transit system ceases to operate for a period of time. Normally, this would happen through industrial action – e.g., the New York City MTA strike of December 2005, the Los Angeles MTA strike of October/November 2003, or the BART strike of 1997.

The impacts of some of these strikes have been studied in detail. In Los Angeles, a small increase in traffic cut freeway travel speeds by up to 20 percent (Lo and Hall 2006). However, strikes are unsuitable to provide estimates of transit emissions benefits for several reasons:

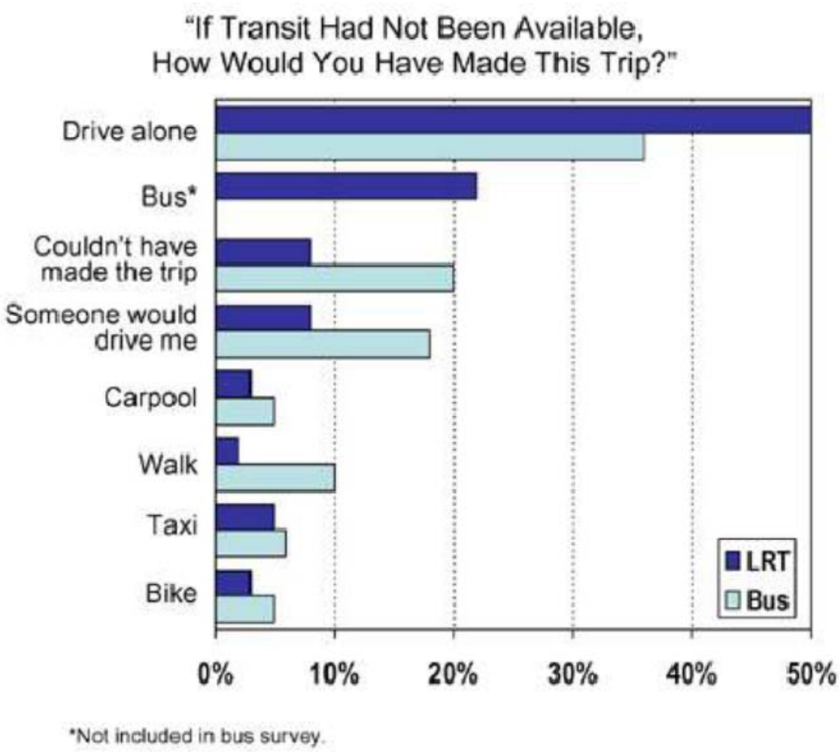
- They cannot provide consistent data across all U.S. transit agencies.
- Short-term adaptations for a strike (e.g., working at home or using taxis) may be infeasible as a longer-term response.
- Some strikes are not complete – some staff may work normally, and other transit service providers in a region (e.g., the municipal operators in Los Angeles) may be unaffected.

Applying a Mode Shift Factor

The recommended approach is to apply a mode shift factor (the ratio of transit passenger miles to displaced private auto miles) to data on passenger mileage. For example, if an agency reports 1,000,000 passenger miles in a given year to the National Transit Database and calculates a mode shift factor of 0.6, it would estimate displaced mileage at 600,000. This can then be converted to CO_2-e using a suitable emissions factor. The mode shift factor does not include changes to trip lengths or transit-induced shifts to walking and biking; these are considered in the "land-use multiplier."

An estimate of the mode shift factor can be derived from logical inference. For example, it might be assumed that individuals with no driver's license will not shift to private autos. However, there are few clear-cut cases (e.g., these individuals might obtain a ride from a friend or household member). This suggests that stated choice surveys are the most appropriate measure. In many cases, transit agencies already ask this question as part of regular rider surveys. Figure 10 shows the results from the Metropolitan Council (Twin Cities) survey.

Figure 10: Public Transit User Sample Survey



Source: http://www2.metrocouncil.org/directions/transit/transit2007/surveyMar07p2.htm

The following are the main challenges with interpreting such data:

- Long-term responses may differ from short-term (e.g., people might eventually move or purchase a vehicle). An additional question on auto ownership can be used to factor in these longer-term adjustments.
- Methods used to estimate transit passenger miles have some variability among transit agencies. Community Transit estimates transit ridership using manual surveys of passenger boarding activity to generate a stratified random sample to estimate unlinked

trips and annual passenger miles. Over the next few years, the agency will move to a full census of ridership measured by automatic passenger counter technology. Other transit agencies may use other technologies and methods to estimate passenger miles.

- Roadway infrastructure may not be able to accommodate all trips that would shift to private autos, suggesting either that trips may be suppressed or that infrastructure would respond (i.e., highways would be expanded).
- Trip lengths may differ between transit and auto (e.g., if an auto route provides a more direct path). Since individuals generally choose destination and mode simultaneously, trip lengths likely would lengthen in the absence of transit. However, this effect is calculated as part of the land-use multiplier. For purposes of calculating mode shift impacts, equal trip lengths by transit and auto are assumed.

Estimating the Mode Shift Factor Impact on Emissions

This section provides detailed guidance for a transit agency to calculate its mode shift factor and to estimate its mode shift impact on emissions. It provides different methods to enable agencies to select the most appropriate way to determine a mode shift parameter, based on available data, staff resources and the degree of precision required. The following procedure should be used:

- **Step 1: Quantify Passenger Miles**. Passenger miles by mode can be found on National Transit Database. The assumption is that one passenger mile on transit is equivalent to one passenger mile in a private auto.
- **Step 2: Calculate Mode Shift Factor**. Alternative methods for estimating the mode shift factor are listed below:
  - Model based
  - Survey based
  - Default by Agency Type
- **Step 3: Calculate VMT Displacement**. For each mode, multiply passenger miles by the mode shift factor.
- **Step 4: Estimate Average Fuel Economy for Displaced VMT**. Fuel economy will vary between regions depending on the composition of the vehicle fleet and degree of congestion in each region. Three methodological approaches to accounting for these regional differences, are proposed in decreasing order of specificity and sophistication:
  - Use a regionally specific factor published by the MPO
  - Use the speed adjustment formula from the TTI Urban Mobility Report
  - Use the national default value for fleet fuel economy from EPA
- **Step 5: Convert to CO_2-equivalent**. If regional or state-specific data are available on emission factors, these may be used. Otherwise, use the following default values:
  - CO_2 emissions: 8.81 kilograms CO_2/gallon of gasoline
  - N_2O emissions: 0.0069 grams N_2O/mile; 1 metric ton N_2O to 310 metric tons CO_2-e
  - CH_4 emissions: 0.0147 grams CH_4/mile; 1 metric ton CH_4 to 21 metric tons CO_2-e

Congestion Relief

This section outlines methodologies to calculate the congestion reduction benefits of transit. As discussed in the previous section, increased transit use can reduce private automobile travel, displacing emissions. Mode shift to transit also has the potential to displace additional emissions caused by traffic congestion. In other words, as more passengers choose transit and private auto travel declines, cars and trucks will consume less fuel from idling in traffic. Under certain VMT growth scenarios, especially in urban areas already facing substantial congestion, these reductions may be significant.

To the extent that public transportation gets drivers off the road, traffic volumes may decrease, and congestion will lessen. However, the relationship between displaced auto travel and congestion levels must be carefully considered. This document presents three methodological approaches to estimating transit's congestion reduction benefits at a regional level, ranging from greater to lesser specificity of data utilization. As such, these approaches are presented as tiers in order of recommendation, though not all approaches will be available to all agencies:

- Tier 1: Applying regional travel demand models.
- Tier 2: Extrapolating from data in the Urban Mobility Report.
- Tier 3: Applying a mode shift factor directly to data reported in the Texas Transportation Institute's (TTI) Urban Mobility Report.

Tier 1: Regional Modeling

This approach uses county or regional travel demand models, typically maintained by metropolitan planning organizations. Similar to the modeling approach for mode shift, the principle here is also simple: remove the transit system from the model, but then calculate vehicle-hours of delay and/or fuel consumed in congestion. From these results, calculate greenhouse gas emissions:

- **Advantages**: Regional travel demand models capture some of the complexity of the individual travel decisions that determine fuel consumption, and also reflect feedback effects within the transportation network. These include changes in route choice, destinations, vehicle occupancy, and trip lengths, based on a variety of factors, including congestion itself.
- **Disadvantages**: Extensive use of a regional travel demand model may require significant staff time and/or resources. MPOs, where such models are normally housed, vary widely in their technical sophistication and in the availability of staff time to conduct such analyses. Also, regional travel demand models are unlikely to be calibrated to address fundamental changes in transit availability, such as significant increases or decreases in system capacity.

Tier 2: Extrapolating from Urban Mobility Report Data

This approach extends the data available in the Urban Mobility Report to produce a metropolitan-wide estimate of fuel savings from public transportation service. This approach posits an exponential relationship between traffic density and congestion, where as auto VMT per lane-mile in a given region increases, so will congestion levels.

Transit agencies can use historical data from the Urban Mobility Report to model this correlation for their regions, estimate the additional auto VMT that would result if public transportation operations were to be discontinued, and produce a new estimate of excess fuel consumption.

Comparing this new estimate to the predicted congestion levels at current traffic density isolates the effect of transit.

There are four steps involved in the process to calculate GHG emissions impacts from congestion relief, these are:

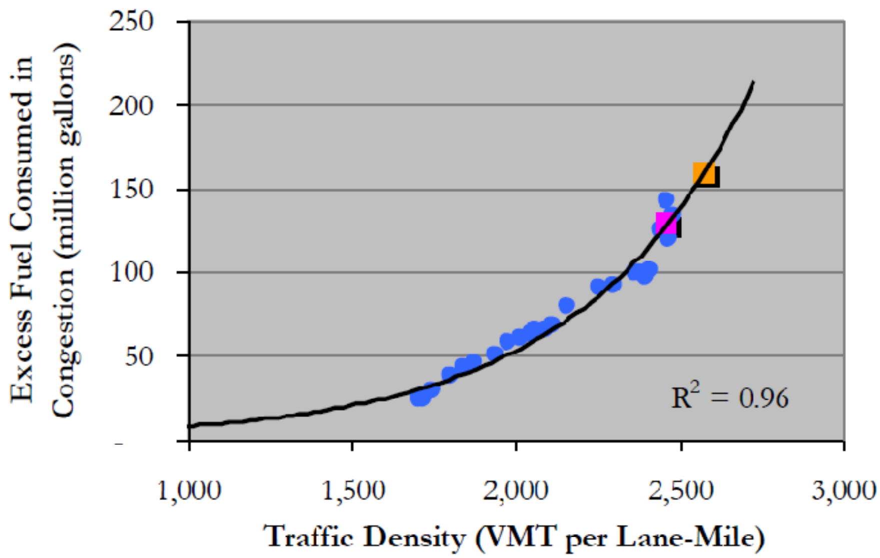
Step 1. Establish a Correlation between Traffic Density and Fuel Consumption

The correlation between traffic density and excess fuel consumption from congestion usually shows an exponential relationship, able to be modeled in a spreadsheet. Establish the following series, based on the Urban Mobility Report historical data for a given metropolitan area:

- Auto VMT = Freeway daily vehicle-miles of travel + Arterial daily vehicle-miles of travel
- Lane-miles = Freeway lane-miles + Arterial lane-miles
- Traffic density = Auto VMT / Lane-miles
- Excess fuel consumed in congestion (total gallons)

Figure 11 below, presents an example of this approach using data from the Chicago region, where blue circles are historical TTI data, and the two squares represent predicted excess fuel consumption with and without displaced auto VMT.

Figure 11: Correlation between Traffic Density and Excess Fuel Consumption



Step 2. Estimate Displaced Auto VMT

Use the mode shift factor as calculated in the preceding section, and apply to all transit passenger-miles in the region shown in the Urban Mobility Report. To be consistent with the relationship established with TTI data, passenger-miles from all transit service providers in the region should be included. This captures the comprehensive, cumulative effect of transit services in the region.

Step 3. Estimate Additional Fuel Consumption from Congestion

Add displaced auto VMT to current auto VMT, recalculate traffic density to include this displaced VMT, and then recalculate excess fuel from congestion using the equation established in Step 1. The difference between the fuel consumption predicted with and without this displaced auto VMT represents the fuel congestion benefit of transit.

Step 4. Convert Fuel Savings to Displaced Emissions

Use default emission factors to calculate displaced CO_2 emissions (regionally specific factors can again be substituted, if available). However, APTA recommends omitting emissions of N_2O and CH_4 for this step, since the exact relationship between vehicle congestion and emissions of these pollutants on a per-mile basis is unclear.

Advantages and Disadvantages of this Approach

The primary advantage to this approach is its closer compatibility with the mode shift methodology previously described, while requiring only moderate effort to complete. When agencies model the effect of discontinuing public transportation, this approach uses the same mode shift factor, ensuring that the resulting congestion benefits can be added to mode shift benefits for a particular region or agency.

Also, this approach models the exponential relationship between traffic volumes and congestion levels, which provides a more comprehensive view of the cumulative effect of public transportation services in an urban area. The disadvantages to this approach however are:

First, data is available for only 85 U.S. urban areas, and only at the metropolitan level. Agencies whose location is not one of the 85 urban areas in the report cannot readily use this approach. Agencies that do not represent all transit service in the metropolitan area will need to make several adjustments to divide metropolitan-level benefits among modes and agencies. This would be a major issue for Community Transit.

- Second, this approach must also rely on some assumptions, including that transit buses have a minimal effect on congestion now, so that their elimination would have no effect on congestion
- Third, the statistical relationship between traffic density and historical congestion as reported by TTI appears to be weaker in some cities, while quite strong in others.
- Fourth, this approach may underestimate the congestion impact of public transportation due to simplifying assumptions. The methodology assumes that displaced auto VMT is added to roadways in proportion to existing travel patterns by auto (current occupancy rate, spatial and temporal distribution, etc.), while transit use tends to be high in heavily congested corridors at peak travel times, where congestion relief benefits are also high.

Tier 3: Using Urban Mobility Report Data

The Texas Transportation Institute’s Urban Mobility Report, published annually, estimates the additional amount of fuel that would be consumed if public transportation operations were to be discontinued. As the simplest method to calculate transit’s congestion reduction benefits, this fuel use figure can be converted to displaced emissions following The Climate Registry’s Tier B methodology, using several assumptions and the mode shift factor calculated in previous sections. The mode shift factor estimation in this methodology incorporates regionally specific information about passengers’ next-best alternate mode, and average vehicle occupancy.

To account for differences in mode shift factors between data sources, the TTI's data [that includes a mode shift factor] should be adjusted. Two steps are required in this calculation:

- **Step 1. TTI Fuel Savings Data**
- **Step 2. Convert TTI Fuel Savings Data to Displaced Emissions**: apply the mode shift factor determined before and use default emission factors to calculate displaced CO_2 emissions. APTA recommends omitting emissions of N_2O and CH_4, since the exact relationship between vehicle congestion and emissions of these pollutants on a per-mile basis is unclear.

CO_2 emission factors and average fuel economy values should be consistent with whatever is used in calculating mode shift. If available, agencies may use fuel economy data based on regional fleet characteristics.

Advantages and Disadvantages of this Approach

The primary advantage to this approach is its simplicity. Agencies can convert published figures into displaced emissions quickly and easily.

The primary disadvantage to this approach is that agencies that do not represent all transit service in the metropolitan area cannot claim the entire sum of benefits reported by TTI. A process by which to divide the metropolitan figure among modes or agencies is complex. This would be a major issue for Community Transit.

Also, this approach assumes that the TTI's congestion savings estimation methodology is broadly compatible with the mode shift factor. The Urban Mobility Report calculates congestion based on a relationship between traffic volumes and peak direction speed. This approach is conceptually consistent with displaced auto VMT, but applying a mode shift factor to these results is an approximation.

Issues with the Methodology

Quantifying the benefit of congestion relief provided by public transportation can be complex, and the techniques by which this benefit can be measured are being further refined. However, insofar as transit attracts some automobile traffic away from roadways, transit's effect on congestion levels may be potentially significant.

The Land-Use Multiplier

Together with mode shift and congestion relief (discussed in the previous two sections), the land-use multiplier leads to "displaced emissions" as private automobile travel is reduced. Unlike the prior two displacement areas, methodologies to measure the land use impacts of transit are evolving and local variables strongly influence how to measure these impacts. For this reason, this section presents alternate methodologies as guidelines and recommends that Transit Agencies use these methodologies or adapt other methodologies for their local circumstances.

What is the land-use multiplier?

The land-use multiplier accounts for the indirect impacts of transit on reducing vehicle travel. These impacts include the following:

- **Reduced trip lengths**: Higher-density development would, in many cases, not be possible without the existence of transit – for example, due to the need to provide more parking. By facilitating compact development in this way, transit can shrink the footprint of the urban area and reduce overall travel distances. In addition, residents often adjust to the availability of transit by moving closer to bus and rail corridors. This may be partly offset when the transit route structure forces travel by an indirect route, particularly when a suburb-to-suburb trip requires a transfer downtown.
- **Facilitation of bicycle and pedestrian travel**: As well as reducing trip lengths, the higher densities and mix of uses supported by transit enable mode shift from the private auto to walking and cycling. For example, pedestrian-oriented shops and services may not be economically viable without the density and foot traffic that transit supports.
- **Trip chaining**: Transit can facilitate the combination of trips into a single tour. For example, a commuter may pick up groceries or dry cleaning on the way home from the station.
- **Impacts through vehicle ownership**: Households living close to transit tend to own fewer vehicles, partly because a vehicle may not be needed for commuting, and partly because of the reduced availability and higher cost of parking. In turn, reduced vehicle availability leads to reduced auto use, and the private car may cease to become the habitual choice for every trip.

Evidence for the land-use multiplier

Disentangling these cause-and-effect relationships between transit and land use is a substantial methodological challenge. Some of the approaches taken, summarized in Figure 12, include the following:

- **Correlation of transit and auto travel**: These studies, beginning with Pushkarev and Zupan (1982), use the empirical observation that cities with high public transit use show far lower rates of auto travel than would be implied by the direct substitution of auto with transit trips. In a study of 32 global cities, Newman and Kenworthy (1999) estimate a land-use multiplier of between 5 and 7, meaning that for every extra passenger mile on transit per capita, vehicle miles per capita decline by five to seven miles.
- **Travel time budget analysis**: Neff (1996) uses travel time budget theory to analyze the substitution of transit travel for auto travel in U.S. urbanized areas. He concludes that every mile of transit travel replaces 5.4 to 7.5 miles of auto travel.
- **Structural equations modeling**: The most recent and sophisticated study, by ICF International for APTA, uses National Household Travel Survey data and structural

equations modeling (SEM). In contrast to earlier studies, which mainly identify correlations between auto and transit travel, SEM can help explain the extent to which transit causes denser, more walkable land-use patterns, and conversely the extent to which these land-use patterns create a need for improved transit service. This ICF study concludes (p. 12) that “the magnitude of the secondary effect is approximately twice as large as the primary effect of actual public transit trips,” giving a multiplier of 1.9.

- **Mixed Comparative Approach**: The New York Metropolitan Transportation Authority (MTA) has used several methodologies, including four step modeling, land use comparisons, and travel behavior analysis to estimate the land use impacts of transit. These studies produce a wide range of impacts depending on the area being evaluated and the method. The results from the MTA analyses range from 1.29 to 6.34.

Figure 12: Land-Use Multiplier Studies Summary

Study	Cities	Land-Use Multiplier[1]	Methodological Issues
Pushkarev & Zupan (1982)	U.S. metro areas with at least 2 million population	4	Correlation only; does not show causal relationship of transit.
Newman & Kenworthy (1999)	32 global cities	5 to 7	Correlation only; does not show causal relationship of transit.
Holtzclaw (2000)	Matched pairs in the San Francisco Bay Area	1.4 to 9	Correlation only; does not show causal relationship of transit.
Neff (1996)	U.S. urbanized areas	5.4 to 7.5	Assumes fixed travel time budgets.
Bailey et. al. (2008)	Entire U.S.	1.9	Accounts only for land-use effects *caused* by transit. The structural equations modeling used had relatively low explanatory power; may not be applicable to sub-national scales.
New York MTA (2009)	MTA Service Territory	1.29-6.34	Wide variation in results depending upon parameters selected.

Source: Partially based on Holtzclaw, 2000

1. Vehicle-mile reductions per passenger mile

Methodological Procedures

This guideline provides two methodologies for estimating the land-use multiplier: locally specific analysis and default approach using national data.

Methodology 1: Locally Specific Analysis

An agency with sufficient capacity can undertake an analysis using a number of tools which disentangle the relationship between transit service and land use patterns, based on the Mixed Comparative approach employed by MTA. These tools include the use of a four step model, statistical evaluation, and other types of GIS modeling.

Methodology 2: Default Approach Using National Data

An agency without the capacity to run a regional study as described in Methodology 1 may use the national default multiplier of 1.9 calculated by the ICF study (Bailey et al., 2008). This approach should be used only for sketch-planning applications or where there is another clear justification. This default should be considered a placeholder, pending future work to develop default emission factors that are disaggregated by size and type of region and transit system (for example, through further structural equation modeling work or a Delphi panel of expert opinions).

The calculation is as follows:

Emission reductions from land-use multiplier (metric tons per year) = Transit passenger miles / average vehicle occupancy (default 1.39) × Emissions per vehicle mile (default 0.436 kg) × 1.9 / 1000

Issues for Further Consideration

- While APTA encourages agencies to use the land-use multiplier to recognize the full impacts of transit on greenhouse gas emissions, this may not be appropriate for all agencies. In particular, the multiplier may be minimal for small transit providers in low-density suburban areas.
- The land-use multiplier is regionally specific rather than agency-specific. Given the complex interactions and data limitations, it is difficult to attribute the impacts to a particular agency where two or more operate in the same service area. This has the potential to be a major issue for Community Transit.
- Additional work is needed to define key parameters. The use of Methodology 1 to estimate GHG impacts provides a solid foundation for estimating GHG impacts. However, MTA's analysis shows that there is ambiguity in how key parameters (e.g., land use characterization, boundaries for high density and low density areas) should be estimated, primarily resulting from the lack of available data at levels that would allow a more accurate analysis.
- Land use multipliers are highly sensitive to the assumptions employed.
- Land use analysis is more applicable to small areas than large areas. Land use varies greatly within large areas. Because of this, it is difficult to make generalizations about land use within a large area.
- Given the gravity of land use implications for GHG emissions and the entangled relationship on trip making, mode choice, and transit availability, this subject will most certainly be pursed with vigor in coming years. The result will be a better overall understanding of the influence of transit on land use and GHG emissions, as well as the influence of land use on transit and GHG emissions. For Community Transit and this long range plan, these are major considerations and will require vigilance in monitoring of current research on the subject.

It is further suggested that Community Transit assume a leadership role in this issue at the regional level by forwarding the concept of GHG reporting through the structures of the PSRC. Given the regional nature of GHG gas emissions and overlapping transit providers, it might be most appropriate to report transit GHG emissions at a regional level rather than at individual agency levels.