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Evaluating Public Transit As An Energy Conservation and Emission Reduction Strategy

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Abstract
This report investigates the role public transit improvements can play in conserving energy and reducing emissions. Critics argue that transit is an inefficient strategy since on average it uses almost as much energy per passenger-mile as driving, and more than some commercially available cars. However, this reflects the inefficiency of public transit services intended to provide basic mobility, which requires operation at times and locations with low demand. Public transit is more energy efficient on major urban corridors. Some transit improvements, such as bus lanes and faster loading, increase operating efficiency. High quality transit can leverage additional energy savings by stimulating transit-oriented development and by supporting other energy conservation strategies such as pricing reforms. High quality transit can provide other savings and benefits in addition to energy conservation and emission reductions. When these factors are considered, public transit service improvements often turn out to be cost effective emission reduction strategies, particularly if implemented as an integrated package with other transport and land use policy reforms.

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Introduction

Public transit (also called *public transportation* and *mass transit*) includes various services that provide mobility to the general public in shared vehicles, including shuttle vans, local and intercity buses, and passenger rail. This report investigates the role public transit can play in achieving energy conservation and emission reduction objectives.

Critics argue that public transit is an inefficient way to reduce fuel use and emissions, since overall average fuel consumption per passenger-mile is only modestly lower for transit travel than for average cars and higher than for efficient cars such as hybrids. They therefore argue that public transit improvements are less cost effective than strategies which encourage motorists to purchase more efficient and alternative fueled vehicles.

This type of analysis tends to overlook several factors:

- Transit's relatively low average fuel efficiency occurs because most service is designed primarily to provide basic mobility for non-drivers, and so operates at times and locations with low demand. On major urban routes with relatively high load factors (portion of capacity that is actually used), transit buses and trains are fuel efficient.
- The marginal energy cost of additional ridership (the additional fuel consumed if additional passengers use available vehicle capacity) is often very low. Policies that increase transit ridership on routes with excess capacity can increase energy efficiency.
- Some transit improvements, such as bus priority lanes and faster loading systems increase transit energy efficiency by reducing delays and stop-and-go operating conditions, as well as improving performance (passenger's travel speed and comfort).
- High quality transit tends to stimulate transit-oriented development, creating compact, multi-modal neighborhoods where residents tend to own fewer cars, drive less and rely more on walking, cycling and public transit. This provides significant additional energy savings and emission reductions.
- High quality public transit provides additional benefits besides energy savings and emission reductions, including congestion reductions, road and parking facility cost savings, consumer savings and affordability (savings for lower-income users), improved mobility for non-drivers, support for strategic land development objectives (i.e. reducing sprawl), and improved public fitness and health. These co-benefits should be considered when evaluating public transit cost efficiency.
- High quality public transit supports other energy conservation and emission reduction strategies, including transport pricing reforms and smart growth land use policies. For example, road pricing tends to be more politically acceptable and effective (a smaller price is needed to achieve a given vehicle travel reduction) on corridors with high quality transit services. Similarly, transit stations often provide a catalyst for creating compact, multi-modal neighborhoods.

More comprehensive analysis, which considers these factors, tends to support public transit improvements for energy conservation and emission reductions.

Evaluating Transit Energy Efficiency

For this analysis it is important to understand the different roles public transit plays in an efficient and equitable transport system. It is intended to achieve two different and sometimes conflicting goals: basic mobility and efficient urban transport, as summarized below.

Table 1 **Contrasting Transit Goals and Services**

Basic Mobility	Efficient Urban Transport
Broadly distributed services, including times and locations with low demand, and special mobility services such as demand response buses.	Service concentrated on busy routes, intended as an efficient substitute for driving in order to reduce traffic problems (traffic and parking congestion, energy consumption and pollution emissions)
Basic convenience and comfort. Users are transit dependent and so will use the service regardless.	Service must be competitive in convenience and comfort in order to attract travelers away from driving.
Mostly buses in mixed traffic.	Includes grade separated bus and rail services.
Serves lower-density development.	Intended to support and encourage transit-oriented development.
Tends to be energy inefficient (low fuel efficiency per passenger-mile).	Fuel efficient, and by supporting transit-oriented development it can leverage large additional per capita energy savings.

Public transit services can have two different and often conflicting goals.

As a result, it is inappropriate to criticize basic mobility services for being energy inefficient, since that requires operation at times and locations with low demand, leading to low load factors. Similarly, it is inappropriate to criticize efficient urban transport for favoring wealthy passengers and being regressive, since that requires superior service quality to attract discretionary travelers (people who would otherwise drive).

In practice, most North American transit services are intended primarily to provide basic mobility; only a few large urban areas offer high quality transit service that is competitive with automobile travel. As a result, North American transit services are overall not very energy efficient (energy consumption per passenger-mile), as indicated in Table 2. Under current conditions, U.S. transit vehicles consume about the same energy per passenger-mile as cars, although less than vans, light trucks and SUVs.

Table 2 **Average Fuel Consumption 2001** (BTS, Tables 1-29, 4-20, 4-23, 4-24)

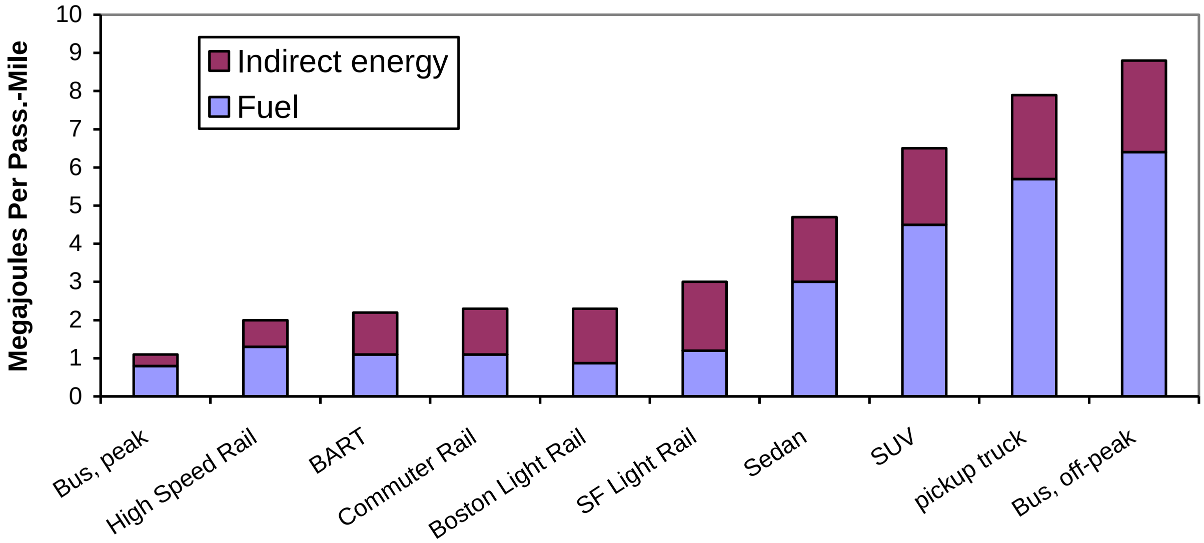
Vehicle Class	Average MPG	Mode	BTU/Pass. Mile
Passenger Cars	22.1	Car	3,578
Vans, Pickup Trucks, SUVs	17.6	Vans, Pickup Trucks, SUVs	4,495
Motorcycle	50	Aviation	4,000
Single Unit Truck	7.4	Transit, Bus	3,697
Combination Truck	5.3	Transit, Electric Light Rail	1,152
Buses	6.9	Intercity Rail, diesel	2,134
Hybrid Electric Bus (estimate)	14.0	Hybrid Electric Bus (estimate)	1,070

This table summarizes average fuel consumption per vehicle, and energy consumption per passenger-mile for various vehicle types. (BTU = British Thermal Units)

This efficiency is highly dependent on transit vehicle load factors. A bus with seven passengers is about twice as energy efficient as an average automobile, and a bus with 50 passengers is about ten times as energy efficient, as discussed later in this report. Rail transit systems tend to be about three times as energy efficient as diesel bus transit. New hybrid buses are about twice as energy efficient as current direct drive diesel. The marginal energy use of additional passengers using existing capacity is very low, so increasing transit service on corridors with high demand, or increasing incentives to use transit service can increase energy efficiency.

Chester and Horvath (2008) and Chester, et al. (2013) calculate lifecycle energy consumption and pollution emissions for various transport modes, including fuel used in their operation, and energy embodied in vehicle and facility construction and maintenance, as illustrated in Figure 1. Public transit typically uses less than half the energy of a sedan and a quarter of the energy of a SUV or light truck. These efficiencies vary depending on travel conditions. For example, during peak periods, when load factors are high, buses are the most energy efficient mode, but during off-peak, when load factors are low, buses are least efficient.

Figure 1 **Lifecycle Energy Consumption** (Chester and Horvath 2008)



This figure compares fuel and indirect energy (energy used in vehicle and facility construction and maintenance) for various transport modes.

Kimball, et al. (2013) evaluated the life-cycle energy and environmental impact assessment of the Phoenix light rail system, taking into account both direct impacts, and indirect impacts from more compact on embodied resources for vehicle and building production, and travel activity. The results indicate significant potential energy savings, and both local and global (greenhouse gas) emission reductions from more transit-oriented development, as well as economic and local livability benefits including increased affordability and urban redevelopment.

Energy Consumption Impacts

Public transport can affect total transport energy consumption in several ways, so there are several types of transit energy conservation and emission reduction strategies.

Some strategies increase public transit vehicle fuel efficiency (APTA 2009). Diesel bus fuel efficiency has increased over time so newer buses tend to be significantly more efficient than older buses, and some new buses have hybrid drive-trains that provide additional energy savings. Rail systems can be designed or upgraded with features such as regenerative braking and more efficient station lighting, heating and cooling systems.

Some strategies increase transit system operational efficiency, for example with grade separation and prioritization to reduce transit vehicle congestion delays, and prepaid fares and additional doors to speed loading and alighting. This reduces fuel consumption and other operating costs, and can attract more discretionary travelers.

Shifting travel from automobile to transit tends to conserve energy. Net energy savings depend on transit's marginal energy consumption (the additional energy required by each additional passenger), which can be small if the transit system has excess capacity. Attracting discretionary travelers who would otherwise drive requires convenient, fast and comfortable transit service, plus support strategies such as commute trip reduction programs, more efficient road and parking pricing, and improved stop and station access.

Transit improvements can also increase urban transport energy efficiency by reducing traffic congestion and therefore automobile fuel consumption (ICF 2008). Urban traffic congestion tends to maintain equilibrium: delays increase to the point that some potential peak-period automobile travelers shift to other times, modes or destinations. Transit service quality affects the point of equilibrium: if service is relatively fast and comfortable, travelers will more readily reduce their driving. This generally requires grade separation and other quality features to attract discretionary travelers.

Transit improvements can allow some households to "shed" cars, that is, to own fewer vehicles. For example, if transit attracts commuters from automobiles, some of these households (perhaps one in ten) may avoid purchasing a second or third car, and a few may give up car ownership altogether. Since automobiles have high fixed and low variable costs, once households purchase a car they tend to increase their vehicle travel, so reductions in vehicle ownership tend to leverage additional automobile travel reductions and provide significant financial savings (Polzin, et al. 2008).

Transit improvements and supportive policies can also reduce total vehicle travel and energy use by stimulating transit-oriented development and supporting other energy conservation strategies such as efficient road and parking pricing. These help create communities where people tend to own fewer cars, drive less and rely more on alternative modes (APTA 2009; ICF 2010; Cervero and Arrington 2008; Gallivan, et al. 2015; Lem, Chami and Tucker 2011). This tends to leverage additional vehicle travel reductions. In a typical situation, each passenger-mile of high quality public transit reduces 3-9 automobile vehicle-miles, as indicated in Table 3.

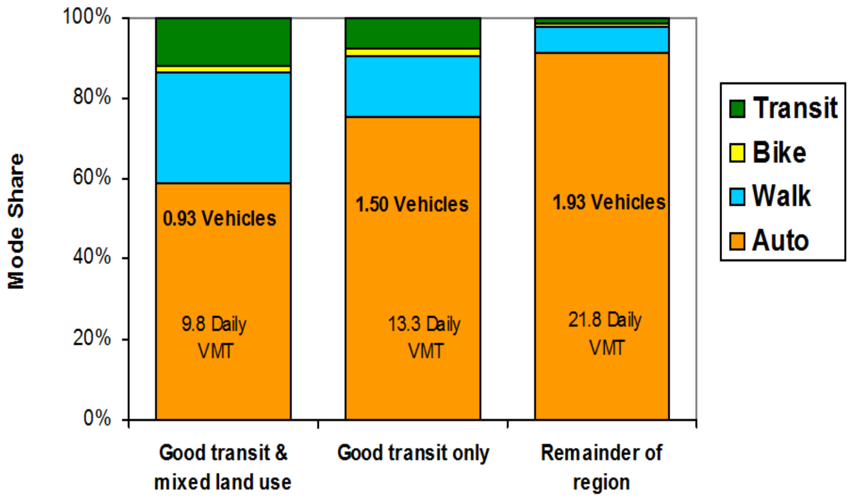
Table 3 **VMT Reductions Due to Transit Use** (Holtzclaw 2000; Litman 2004)

Study	Cities	Vehicle-Mile Reduction Per Transit Passenger-Mile	
		Older Systems	Newer Systems
Pushkarev-Zupan	NY, Chicago, Phil, SF, Boston, Cleveland	4	
Newman-Kenworthy	Boston, Chicago, NY, SF, DC	2.9	
Newman-Kenworthy	23 US, Canadian, Australian and European cities	3.6	
Holtzclaw 1991	San Francisco and Walnut Creek	8	4
Holtzclaw 1994	San Francisco and Walnut Creek	9	1.4
Litman 2004	50 largest U.S. cities.	4.4	
ICF 2008	U.S. cities	3-4	

This table summarizes results from several studies indicating that high quality public transit service can leverage automobile travel reductions by changing transport and land use patterns.

Described differently, high quality transit is more than simply a vehicle; it is an integrated system that includes compact, attractive stops and stations surrounded by compact and mixed-use development with reduced parking supply, good walking and cycling conditions, and more social acceptance of carfree living. Residents of transit-oriented developments tend to own 15-30% fewer vehicles, drive 20-40% fewer annual miles, and rely much more on walking, cycling and public transit than they would in automobile-dependent communities (Cervero and Arrington 2008). Bailey (2007) found that a typical household reduces its energy consumption and pollution emissions about 45% by shifting from automobile-dependent to transit-oriented development.

Figure 2 **TOD Impacts On Vehicle Ownership and Use** (Ohland and Poticha 2006)



Transit-oriented development residents tend to own fewer vehicles, drive less and use alternative modes more than in automobile-oriented communities.

"Daily VMT" indicates average daily vehicle miles traveled per capita.

Even at the regional level, which includes many automobile-oriented neighborhoods, residents of urban regions with high quality public transit tend to drive 5-15% fewer annual miles than residents of cities that only have basic quality transit (Litman 2004; Liu 2007). These regional impacts indicate that the effects are not just self-selection (households that drive less than average choosing transit-oriented communities), rather, high quality transit tends to reduce total vehicle travel.

Table 4 **Energy Consumption Mechanisms**

Mechanism	Typical Strategies	Scope and Magnitude
Transit vehicle consumption	Improve transit vehicle fuel efficiency. Newer diesel buses are significantly more efficient than older buses, and some use hybrid technologies or alternative fuels.	Transit vehicles consume a small portion of total transport fuel, so potential energy savings are small. However, they contribute a larger portion of local air pollution in some urban areas and so new technologies can help reduce this problem.
Transit operating efficiency	Increase loading efficiency through prepaid fares and multiple loading doors. Increase travel efficiency through grade separation and transit priority systems.	These measures can reduce transit vehicle energy consumption and by making transit service more time competitive, attract more riders.
Automobile travel substitution	Attract travelers who would otherwise drive to reduce automobile travel.	Moderate. Since less than 2% of total trips are by transit, doubling transit travel would, at best, reduce 2% of vehicle travel.
Congestion reductions	Grade separation, faster loading and bus pull-outs reduce delay to other traffic.	Probably small overall, but significant on a few routes.
Vehicle ownership effects	Transit service improvements and transit-oriented development, in conjunction with improvements to other alternative modes (walking, cycling, carsharing, taxi) and incentives such as unbundled residential parking (households only pay for the number of parking spaces they need).	This can have small to moderate effects, depending on the portion of total households that can reduce vehicle ownership, and the degree that transit improvements are implemented with other strategies.
Land use effects	Transit-oriented development, including high quality service, attractive stations, smart growth development policies, improvements to alternative modes, and efficient parking management.	Potentially very large. Residents of transit-oriented developments tend to drive 20-60% less than in automobile-oriented areas, and even at the regional levels travel reductions and energy savings of 5-15% can occur.

Public transit services can affect transport energy consumption in several ways. Most analyses only consider direct impacts (the first three categories) and ignore other, indirect ways that transit can reduce vehicle travel, fuel consumption and emissions, although they are potentially larger in magnitude.

These impacts are, of course, complex. They depend on demand for transit travel and transit-oriented development (which appears to be growing), and the degree that transit is implemented with support strategies such as walking and cycling improvements, more efficient parking management, and smart growth policies. In appropriate conditions, transit improvements can provide significant energy savings and emission reductions (CNT 2010; Davis and Hale 2007; NCTR 2011). ICF (2008) estimates that by reducing automobile travel and congestion, and stimulating more compact land use, public transport reduces about 37 million metric tons of CO_2 emissions annually.

Evaluating Transit Demand

A key factor in this analysis is the level of *transit demand*, that is, the amount that people would choose to use public transit under various conditions (Litman 2011). In most North American communities, most transit passengers are *transit dependent* (they cannot use an automobile for that trip). However, there is evidence that high quality (convenient, fast, comfortable) transit, such as light rail and express buses, often attracts a large number of discretionary travelers, as indicated in Table 5.

Current demographic and economic trends (aging population, rising fuel prices, increasing urbanization, changing consumer preferences, and increased health and environmental concerns, etc.) are increasing demand for high quality transit and transit-oriented development (Litman 2006). Although it is difficult to predict these effects, transit demand is likely to increase and be more sensitive to service quality and land use factors. This suggests that public transit improvements and support strategies can provide energy savings and emission reductions if they respond to these demands.

Table 5 **Demand Characteristics By Transit Mode** (CTS 2009)

Transit Service	Definition	Type of Rider	How Transit is Accessed	Trip Characteristics
Light-Rail Transit	Light rail between downtown and suburbs, with several stops	Mostly (62%) choice	Balanced between bus, walking, and park and ride	Home locations spread throughout the region; the average rider lives more than three miles from the line.
Express Bus	Express routes between downtown and suburbs	Primarily choice (84%)	About half park-and-ride (48%)	Home locations clustered at the line origin
Premium Express Bus	Express routes with coach buses	Almost exclusively choice (96%)	Mostly park and ride (62%)	Home locations clustered at the line origin
Local Bus	Serves urban and suburban areas with frequent stops	Mostly captive (52%)	Nearly all bus or walk (90%)	Home locations scattered along route; most riders live within a mile of the bus line

Rail transit and express bus services tend to attract many discretionary users.

Critics sometimes argue that the lower rates of automobile travel in transit-oriented neighborhoods largely reflects *self-selection* (those areas attract households that would drive less than average regardless of where they locate). Research indicates that self-selection occurs but only explains a minor portion of vehicle travel differences between transit- and automobile-oriented locations, and households do significantly reduce their vehicle travel when they move to transit-oriented neighborhoods (Cervero 2007). If latent demand exists for transit-oriented locations, failing to create sufficient supply forces some households and businesses to choose more automobile-dependent locations and drive more than they actually prefer (Reconnecting America 2004). If this is true, building more transit-oriented developments can provide significant energy savings and emission reductions.

Evaluating Transit Benefits

Public transit can provide a variety of economic, social and environmental benefits (Abley, Durdin and Douglass 2010; Litman 2011). Many of these benefits depend on the degree to which public transit reduces automobile travel, and so requires a combination of high quality services (typically grade-separated rail or bus [they have their own lane or track and so are not delayed by traffic congestion], comfortable vehicles and attractive stations), ridership incentives (such as efficient road and parking pricing), and transit-oriented land use development policies.

Conventional transport economic evaluation tends to overlook or undervalue many of these benefits, as summarized in the table below. Traditional evaluation (i.e., benefit/cost analysis) only quantifies user travel time savings (for example, if grade-separated transit increases transit travel speeds), but ignores most other impacts and benefits, including leverage effects if high quality transit is a catalyst for more compact, multi-modal land use development.

Table 6 **Transit Benefits** (Litman 2011)

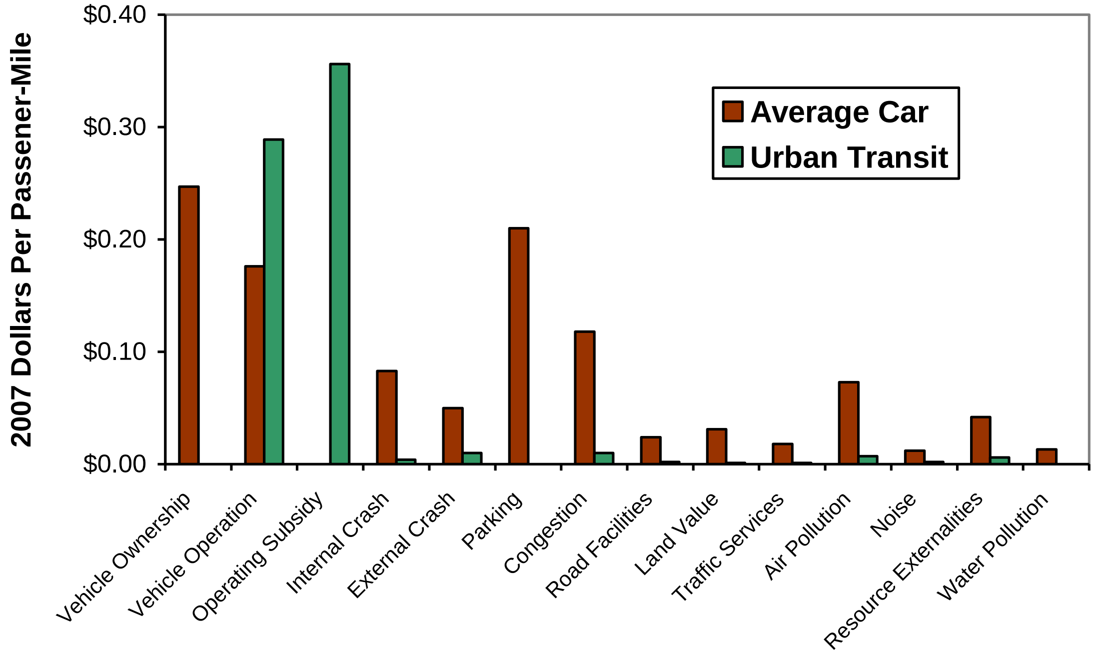
Benefits	Description	Considered?
User benefits	Increased convenience, speed and comfort to users from transit service improvements	Generally only increased speed
Congestion Reduction	Reduced traffic congestion	Direct but not indirect
Facility cost savings	Reduced road and parking facility costs	Generally not
Consumer savings	Reduced consumer transportation costs, including reduced vehicle operating and ownership costs	Operating costs, but not ownership costs
Transport diversity	Improved transport options, particularly for non-drives	Sometimes
Road safety	Reduced per capita traffic crash rates	Direct but not indirect
Environmental quality	Reduced pollution emissions and habitat degradation	Direct but not indirect
Efficient land use	More compact development, reduced sprawl	Sometimes
Economic development	Increased productivity and agglomeration efficiencies	Direct but not indirect
Community cohesion	Positive interactions among people in a community	Generally not
Public health	Increased physical activity (particularly walking)	Generally not

"Indirect benefits" are benefits that result if quality transit reduces per capita vehicle ownership and use.

It is possible to apply more comprehensive transit impact and benefit analysis (Litman 2011; Smith, Veryand and Kilvington 2009). Various studies have quantified and monetized (measured in monetary units) various transport costs and benefits (Litman 2009; Maibach, et al. 2008). Some are relatively easy to calculate, including vehicle costs, transit subsidies, and roadway costs, and there is growing research on parking, accident, and pollution costs (TC 2005-2008). Climate change emission cost values are based on estimated long-term control costs (future costs of reducing emissions), which are typically $20-50 per tonne (Litman 2009; Watkiss and Downing 2008).

Figure 3 illustrates estimated automobile and public transit costs per passenger-mile under urban-peak conditions. Air pollution is a relatively modest cost overall, averaging about 7¢ per automobile passenger-mile, and about 1¢ per transit passenger-mile, which is less than 10% of the total costs of each mode. This indicates that it would not be cost effective to reduce emissions in ways that increase other costs (for example, if fuel efficiency requirements significantly increases total vehicle travel and therefore congestion, parking and accident costs), but emission reduction strategies become far more cost effective if they also reduce these other costs (for example, if public transit improvements also reduce congestion, parking costs, consumer costs and accidents). This emphasizes the importance of using comprehensive analysis that considers all significant impacts, including changes in indirect costs and benefits.

Figure 3 **Estimated Urban-Peak Auto and Transit Costs** (Based On Litman 2009)



This figure compares the various costs of automobile and public transit travel under urban-peak conditions. Overall, air pollution (of which climate change emissions are about a third of the total) are a relatively modest cost, representing less than 10% of the total costs of each mode.

This analysis does not explicitly account for *equity value* (benefits to physically, economically and socially disadvantaged people) and *option value* (the value of maintaining an option for possible future use), although this is possible by assigning a value to improved mobility options that are affordable and serve non-drivers ("Transportation Diversity," Litman 2009). Most transit service improvements and transit-oriented developments can help achieve these objectives. Equity and option value benefits can therefore be considered additional co-benefits of using transit improvements as a climate change emission reduction strategy.

Strategies To Increase Transit Benefits

Transit service benefits tend to increase if implemented with support strategies that increase efficiency and attract more riders, such as those described below. More information is available in the *Online TDM Encyclopedia* (www.vtpi.org/tdm), and Hidalgo and Carrigan (2010).

Transit Priority

There are various ways to help transit vehicles avoid congestion delays and travel faster, including managed lanes (special lanes for buses and other high occupancy vehicles, such as carpools), traffic signal preemption (giving transit vehicles priority through intersections), and faster loading systems (such as prepaid transit fares, so drivers are not required to sell tickets to boarding passengers). These strategies increase operating efficiency (since transit vehicles can carry more passengers in a given period of time) and make transit more competitive with automobile travel.

Impacts: Transit priority provides direct benefits to current transit users, and will typically shift 4-30% of current automobile trips to transit or vanpools, depending on conditions. The greater the time savings, the more mode shifting typically occurs.

Parking Management

Parking management can be an effective way to increase transit use. Parking management includes "parking cash out" (employees who receive free parking have the option of choosing cash or a transit subsidy instead), "unbundling" (building renters only pay for the amount of parking they actually want), and more flexible parking requirements that allow developers to supply less parking where appropriate.

Travel Impacts: Parking pricing is one of the most effective ways to reduce automobile travel and encourage transit use. Cost-based parking pricing (parking fees set to recover parking facility costs) typically reduces affected automobile travel 10-30%, with higher rates in areas with high quality public transit services.

Commute Trip Reduction Programs

Commute Trip Reduction (CTR) programs give commuters resources and incentives to reduce their automobile trips. CTR programs typically include some of the following:

- Commuter Financial Incentives (Parking Cash Out and Transit Allowances).
- Rideshare Matching.
- Parking Management.
- Alternative Scheduling (Flextime and Compressed Work Weeks).
- Telework (for suitable activities).
- Guaranteed Ride Home.
- Walking and Cycling Encouragement.

Travel Impacts: Worksites with CTR programs that lack financial incentives typically experience 5-15% reductions in commute trips. Programs that include financial incentives (such as transit subsidies or parking cash out) can achieve 20-40% reductions.

Campus and School Transport Management Programs

Campus Transport Management programs are coordinated efforts to improve transportation options and reduce trips at colleges, universities and other campus facilities. This often includes free or significantly discounted transit passes to students and sometimes staff (called a "UPASS").

Travel Impacts: Comprehensive campus transportation management programs can reduce automobile trips by 10-30% and increase transit ridership 30-100%.

User Information and Marketing

Improved user information, schedules, maps and wayfinding, real-time transit vehicle arrival information, market surveys and other marketing strategies to better understand transit demands (particularly the factors that would cause travelers to shift from driving to transit) and promote transit use.

Travel Impacts: Given adequate resources, marketing programs can often increase use of alternative modes by 10-25% and reduce automobile use by 5-15%. About a third of the reduced automobile trips typically shift to public transit.

Nonmotorized Improvements

Nonmotorized modes (walking and cycling) are important travel modes in their own right and provide access to public transit. Nonmotorized improvements can leverage shifts to transit. There are various ways to further improve and encourage nonmotorized transport:

- Improve sidewalks, crosswalks, paths and bikelanes.
- Correct specific roadway hazards to nonmotorized transport.
- Traffic calming to control automobile traffic in particular areas.
- Bicycle parking and storage.
- Address pedestrians and cyclist security concerns.

Travel Impacts: In many situations inadequate nonmotorized travel conditions are a major constraint to transit travel, so nonmotorized improvements may increase transit ridership 10-50% over what would otherwise occur.

Transit Oriented Development

Transit Oriented Development (TOD) refers to communities designed to maximize access by public transit, with clustered development and good walking and cycling conditions.

Travel Impacts: Residents of TODs typically reduce automobile travel 20-60% compared with conventional, automobile-oriented development. Impacts depend on specific design features, and other geographic and demographic factors.

Synergistic Impacts

Many of these support strategies are important energy conservation and emission reduction strategies in their own right. They both support and are supported by high quality public transit.

For example, both economic theory and empirical evidence indicate that efficient road and parking pricing become more effective (a smaller fee is required to achieve a given reduction in vehicle travel and therefore energy use and emissions) and more politically acceptable if implemented in conjunction with public transit improvements which give travelers an attractive alternative to driving. This is a reflection of the smaller incremental cost to travelers (less consumer surplus loss) when they shift from driving to high quality public transit, and a direct financial benefit to motorists on roadways with congestion pricing.

One major road pricing study, called the *Traffic Choices Study*, found that the elasticity of Seattle-area home-to-work vehicle trips is approximately -0.04 (a 10% price increase causes automobile commute trips to decline 0.4%), but increases four-fold to -0.16 (a 10% price increase causes automobile commute trips to decline 1.6%) for workers in areas with the 10% best transit service (PSRC 2008). Similarly, the *Oregon Road User Fee Pilot Program*, which rewarded motorists for avoiding congested conditions, found that households in denser, mixed use, transit-accessible neighborhoods reduced their peak-hour and overall travel significantly more than comparable households in automobile dependent suburbs, and that congestion pricing increased the value of more accessible and multi-modal locations (Guo, et al. 2011).

Similarly, smart growth policies, which create more compact, multi-modal communities both support and are supported by high quality public transit. Rail and bus rapid transit projects are often used as a catalyst for smart growth policies. Municipal governments often reduce parking requirements and apply more parking management strategies in areas with high quality public transit. Residents of area with these attributes, in turn, are more likely to reduce their vehicle ownership and use, and rely on alternative modes, than if public transit is provided in areas with automobile-oriented land use patterns.

In other words, public transit tends to have synergistic effects with other emission reduction strategies (their impacts and benefits are larger when implemented together than if implemented alone). As a result, integrated programs that include a combination of public transit improvements, pricing reforms, mobility management programs, and land use reforms are often the most successful and cost effective way to conserve energy and reduce emissions.

Evaluating Criticisms

Critics claim that public transit improvements are an inefficient way to conserve energy and reduce emissions. For example, O'Toole (2008) compares average fuel efficient for various transport modes, including cars, light trucks, bus and rail transit. He concludes that, "Considering rail transit's poor track record, persuading 1 percent of auto owners to purchase a car that gets 30 to 40 miles per gallon or better the next time they buy a car will do more to reduce energy consumption and CO_2 emissions than building rail transit. Only minimal incentives might be needed to achieve this, making such incentives far more cost effective than building rail transit."

Moore, Staley and Poole (2010) argue that public transit can attract too small a share of total travel to provide significant energy savings (assuming 50% transit ridership growth would typically reduce automobile commuting just 1-3 percentage points in most urban areas). They assume that the primary ways to attract new riders is to eliminate fares (estimated to cost $1,398 per ton of CO_2 emissions reduced) or expand service (estimated to cost $4,257 per ton of CO_2 emissions reduced), which are much higher than many other emission reduction strategies.

The study, *Policy Options for Reducing Oil Consumption and Greenhouse-Gas Emissions from the U. S. Transportation Sector*, by Harvard University's John F. Kennedy School of Government (Gallagher, et al. 2007), does not mention public transit improvements or incentives at all. A major study of climate change emission reduction strategies, McKinsey (2007) excludes public transit improvements from its analysis, based on the assumption that reducing vehicle travel reduces consumer utility.

These criticisms overlook several important factors (Litman 2005). High quality public transit tends to leverage additional vehicle-travel reductions and energy savings, and support other energy conservation strategies. Transit provides other significant savings and benefits. When all impacts and benefits are considered, public transit improvements are often cost effective. Table 7 summarizes these criticisms and responses.

There are, of course, constraints on public transit's ability to provide cost effective energy savings and emission reductions. Public transit only conserves energy if it reduces automobile travel and stimulates more compact development. As a result, to be effective transit must operate efficiently where there is sufficient demand, and be implemented with support strategies such as pricing reforms and smart growth policies.

Table 7 **Transit Criticisms** (Litman 2011)

Criticism	Response
Public transit carries too small a portion of travel to provide significant impacts and benefits.	High quality public transit and transit oriented development can have a large leverage effect: each transit passenger-mile can reduce 2-10 automobile vehicle-miles.
On average, U.S. public transit is not very energy efficient, only slightly more efficient than car travel and less than a hybrid car.	The marginal energy costs of additional transit travel can be small, and with its leverage effects, high quality public transit can provide large energy savings.
North Americans prefer driving. Most users are transit dependent. There is little demand for transit by discretionary travelers.	High quality (convenient, fast, comfortable) transit can attract people out of cars. On some routes more than half of riders are discretionary travelers.
Public transit, especially urban rail, has high costs per passenger-mile.	High quality transit operates on major urban corridors where any form of transport is costly. Under those conditions transit is often cheaper than automobile travel, considering total vehicle, road and parking costs.
Public transit travel has increased little in recent years despite "massive" investments.	Transit spending is small compared with total road and parking expenditures, and about half is designed to provide basic mobility rather than reduce driving. Where high quality public transit is provided and integrated with support strategies, ridership often increases substantially.
Public transit is costly, requiring large subsidies.	High quality public transit provides many co-benefits, and its subsidies are often smaller than total road and parking subsidies required for urban-peak driving.

Critics tend to ignore important factors when evaluating public transit. Considering all impacts and benefits, public transit improvements are often cost effective energy conservation strategies.

Best Practices

The following best practices use public transit as an energy conservation and emission reduction strategy.

- Focus transit improvements on major travel corridors where transit vehicles can maintain high load factors.
- To attract discretionary travelers (people who would otherwise drive) public transit must be convenient, relatively fast and reliable (compared with driving), comfortable, relatively affordable and socially acceptable. Transit improvements that help improve these amenities help reduce energy uses.
- Transit planners should consult potential users (people who currently drive but would consider using transit for a significant portion of travel) to determine the specific features and improvements that would affect their travel decisions. This can include amenities such as reduced crowding, improved user information (such as route, schedule and real time transit vehicle arrival information available by mobile telephone), more convenient fare payment options (such as electronic payment), refreshments and periodicals available at transit stops and stations, and on-board Wi-Fi services.
- Grade separation (bus lanes and rail transit on separate right-of-way) and strategies to increase loading and alighting speeds (such as prepaid fares and additional doors) can be used on major corridors to increase operating efficiency and attract discretionary travelers.
- Public transit improvements both support and are supported by other energy conservation and emission reduction strategies, including walking and cycling improvements, efficient road and parking pricing (including road tolls, parking fees, parking cash out and unbundling, distance-based vehicle insurance and registration fees, and increased fuel taxes), commute trip reduction programs, and smart growth land use policies. As much as possible, these strategies should be implemented as an integrated package.
- Transportation planning should endeavor to allow and encourage households to reduce their vehicle ownership, including improvements to alternative modes (walking, cycling, ridesharing, public transit, taxi, carsharing, delivery services and telecommunications), more efficient pricing (particularly parking cash out and unbundling), and transit-oriented development.
- Implement smart growth policies and transit-oriented development to integrate transit improvements with supportive land use development. As much as possible, residential development (particularly affordable housing) and commercial activities (particularly large employers) should be located near stops and stations that have high quality public transit, and this should be supported with walking and cycling improvements, mixed land use, and efficient parking management.
- Consider energy efficiency in all aspects of transit planning, including vehicle purchasing and deployment, vehicle maintenance, and driver training.

Conclusions

Appropriate public transit improvements provide cost effective energy savings and emission reductions. This generally requires high quality (convenient, fast, comfortable) service on major urban corridors, with suitable incentives to attract discretionary travelers, and land use policies that stimulate transit-oriented development. Incremental service improvements and support policies can also provide energy savings if they attract discretionary travelers and increase load factors.

Although public transit is on average only modestly more energy efficient than automobile travel, and less efficient than some commercially available cars, this reflects the relatively low load factors of transit services intended primarily to provide basic mobility. Transit services with high load factors are relatively energy efficient. Public transit improvements can provide significant energy savings and emission reductions by increasing operation efficiency, reducing traffic congestion, substituting for automobile travel, and leveraging additional vehicle travel reductions by stimulating more accessible community development. Residents of transit-oriented communities tend to drive significantly less than they would in conventional, automobile-oriented locations. Transit improvements support other energy conservation strategies, such as efficient road and parking pricing and smart growth development policies. Without high quality transit such strategies are less effective and less politically acceptable. Current demographic and economic trends are increasing demand for high quality public transit and transit-oriented development.

How transport is evaluated can affect the perceived value of public transit. Public transit improvements tend to provide a variety of benefits, many of which tend to be overlooked or undervalued in conventional transport project economic analysis. Energy savings and emission reductions are often smaller than other benefits such as road and parking facility cost savings, consumer savings and affordability, traffic safety and improved mobility for non-drivers. As a result, more comprehensive analysis tends to increase the overall cost effectiveness of public transit as an energy conservation and emission reduction strategy.

Current demographic and economic trends are increasing demand for public transit and transit-oriented development. Many of these transit improvements also benefit motorists by reducing their traffic and parking congestion, increasing safety and reducing chauffeuring burdens. As a result, the potential impacts and benefits of high quality public transit are likely to increase significantly in the future.

This does not mean that every transit improvement can provide large energy savings and emission reductions. Basic bus services and rail serving suburban park-and-ride commuters may provide minimal energy savings; they may be justified for other reasons, such as basic mobility for non-drivers or congestion reductions, but not for energy savings and emission reductions. However, high quality public transit, implemented with support strategies can cause significant automobile travel reductions, energy savings and emission reductions. When all impacts are considered, public transit improvements are often cost effective energy conservation and emission reduction strategies.

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