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Evaluating Public Transit Benefits and Costs

Best Practices Guidebook

2 January 2017

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Abstract

This guidebook describes how to create a comprehensive framework for evaluating the full impacts (benefits and costs) of a particular transit service or improvement. It identifies various categories of impacts and how to measure them. It discusses best practices for transit evaluation and identifies common errors that distort results. It discusses the travel impacts of various types of transit system changes and incentives. It describes ways to optimize transit benefits by increasing system efficiency, increasing ridership and creating more transit oriented land use patterns. It compares automobile and transit costs, and the advantages and disadvantages of bus and rail transit. It includes examples of transit evaluation, and provides extensive references. Many of the techniques in this guide can be used to evaluate other modes, such as ridesharing, cycling and walking.

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Executive Summary

Public transit (also called *public transport* or *mass transit*) includes various services that provide mobility to the general public, including buses, trains, ferries, shared taxi, and their variations. It can play important and unique roles in an efficient and equitable transport system by providing affordable basic mobility for non-drivers, efficient urban travel, and a catalyst for more efficient land use development. It can therefore have diverse impacts (benefits and costs), including many that are indirect and external (they affect people who do not currently use transit). Some result from the existence of the service, others from transit use, some from reduced automobile travel, and others from transit's ability to affect land use development patterns, as summarized in Table ES-1. Not all transit services have all of these impacts, but most have several.

Table ES-1 **Public Transport Benefits and Costs**

Category	Improved Transit Service	Increased Transit Travel	Reduced Automobile Travel	Transit-Oriented Development
Indicators	Service Quality (speed, reliability, comfort, safety, etc.)	Transit Ridership (passenger-miles or mode share)	Mode Shifts or Automobile Travel Reductions	Portion of Development With TOD Design Features
Benefits	• Improved convenience and comfort for existing users. • Equity benefits (since existing users tend to be disadvantaged). • Option value (the value of having an option for possible future use). • Improved operating efficiency (if service speed increases). • Improved security (reduced crime risk)	• Mobility benefits to new users. • Increased fare revenue. • Increased public fitness and health (by stimulating more walking or cycling trips). • Increased security as more non-criminals ride transit and wait at stops and stations.	• Reduced traffic congestion. • Road and parking facility cost savings. • Consumer savings. • Reduced chauffeuring burdens. • Increased traffic safety. • Energy conservation. • Air and noise pollution reductions.	• Additional vehicle travel reductions ("leverage effects"). • Improved accessibility, particularly for non-drivers. • Reduced crime risk. • More efficient development (reduced infrastructure costs). • Farmland and habitat preservation.
Costs	• Increased capital and operating costs, and therefore subsidies. • Land and road space. • Traffic congestion and accident risk imposed by transit vehicles.	• Transit vehicle crowding.	• Reduced automobile business activity.	• Various problems associated with more compact development.

Public transport can have various types of benefits and costs, many of which tend to be overlooked or undervalued in conventional transportation economic evaluation.

Conventional transport economic evaluation tends to overlook and undervalue many transit benefits. These evaluation practices originally developed to assess roadway improvements and focus primarily on vehicle travel speeds and operating costs. They do not generally quantify or monetize the benefits of basic mobility benefits, vehicle ownership and parking cost savings, or efficient land development benefits.

Public transit can also have significant costs, including facility costs, operating costs, and various external costs such as accident risk and pollution imposed on non-users. Many of these costs are fixed so transit services tend to experience scale economies (unit costs decline with increased use), resulting in low marginal costs.

These factors should be considered when evaluating public transit benefits and costs:

- Public transit can provide various types of impacts. Comprehensive evaluation should consider all significant benefits and costs.
- Many transit services (those that operate at times and places with low demand) exist mainly to provide basic mobility for non-drivers. Although relatively costly per trip, they are often cheaper than alternatives such as taxis and chauffeuring (drivers making special trip to carry non-drivers, which often requires empty return trip), or inadequate mobility for non-drivers.
- High quality (relatively fast, convenient, comfortable and integrated) transit can attract discretionary travelers who would otherwise drive, which reduces traffic problems including congestion, parking costs, accidents and pollution emissions. Transit that attracts discretionary travelers provides consumer welfare (surplus) benefits, since they would not change mode if they did not consider themselves better off overall.
- High quality transit can stimulate *transit-oriented development*, compact, multi-modal neighborhoods where residents tend to own fewer vehicles, drive less and rely more on alternative modes than in more automobile-oriented communities. This can leverage additional travel reductions and benefits (besides just the travel shifted to transit).
- Traffic congestion tends to maintain equilibrium: it increases until delays discourage additional peak-period vehicle trips. High quality, grade-separated transit can reduce traffic congestion costs by reducing the point of equilibrium, offering travelers an alternative to driving, and by supporting compact development which reduces travel distances.
- Highway expansion tends to induce additional vehicle travel which increases external costs such as downstream congestion, parking demand, traffic risk, barrier effects, and pollution emissions, costs that are avoided if travelers instead shift to public transit. These impacts should be considered when comparing roadway expansions with transit improvements.
- Transit travel time unit costs (dollars per hour or cents per minute) vary significantly depending on travel conditions and user preferences. Many travelers prefer high quality transit even if it takes longer than driving because they can work or rest.
- These impacts and benefits tend to increase if transit improvements are implemented with support strategies such as walking and cycling improvements, more compact development, transportation demand management programs, and efficient road and parking pricing.
- Since active transport (walking and cycling) and public transit are complements, transit travel tends to increase public fitness and health.
- Public transit services have three features that justify public support and underpricing: they help achieve social equity objectives, they experience scale economies, and they can reduce various external costs including traffic congestion, accident risk and pollution emissions.
- Current demographic and economic trends (aging population, rising fuel prices, urbanization, changing consumer preferences, increasing health and environmental concerns) are increasing demand for transit and transit-oriented development, and therefore their benefits.

Introduction

Public transit (also called *public transportation*, *public transport*, *mass transit* and *urban transit*) includes various transport services available to the general public including vanpools, buses, trains, ferries, and their variations. These services can play various roles in a modern transport system and provide various benefits, including direct benefits to users and indirect benefits that result if transit helps reduce automobile travel or create more compact. This guidebook describes how to evaluate the value to society of a particular transit service or change in service. It explains how to create a comprehensive evaluation framework that incorporates various categories of impacts (benefits and costs), and how to quantify these impacts. It discusses how to determine whether a particular public transit program is worthwhile, and how to optimize transit services to maximize benefits. This framework is suitable for evaluating other modes such as taxi and ridesharing.

There are many reasons to improve transit evaluation. Current transportation evaluation practices tend to overlook and undervalue many transit benefit categories. More comprehensive analysis includes more impacts and so is more accurate. This is not to suggest that every transit project is cost effective or that transit is always the best solution to every transport problems. However, transit improvements tend to provide significantly more value to society than conventional models indicate.

There are four general categories of transit improvements to consider:

- Increased service (more transit vehicle-miles)
- Improved service (more comfortable, convenient, reliable, etc.).
- Transit use incentives (lower fares, commuter financial incentives, marketing, etc.).
- Transit oriented development (land use patterns designed to support transit, including more compact, walkable, mixed development around transit stations and corridors).

Since transit service and automobile travel both impose significant costs (including indirect costs such as congestion, road wear and pollution emissions), improvements and incentives that increase transit load factors and attract travelers who would otherwise drive tend to provide large benefits. Described differently, there is little benefit to society from simply operating transit vehicles (excepting “option value” as described later); most benefits depend on how much transit is used, how well the service responds to users’ needs and preferences, the amount of automobile travel displaced, and the various savings and benefits that result (including reduced vehicle ownership and operating cost, avoided roadway and parking facility expansion, increased safety, etc.).

A challenge in developing this document is to maintain a balance between keeping it simple enough to be convenient to use while providing sufficient detail to address all possible situations. To achieve this, the document describes concepts and issues, and provides recommended evaluation techniques and default values, and offers numerous reference documents for additional technical detail.

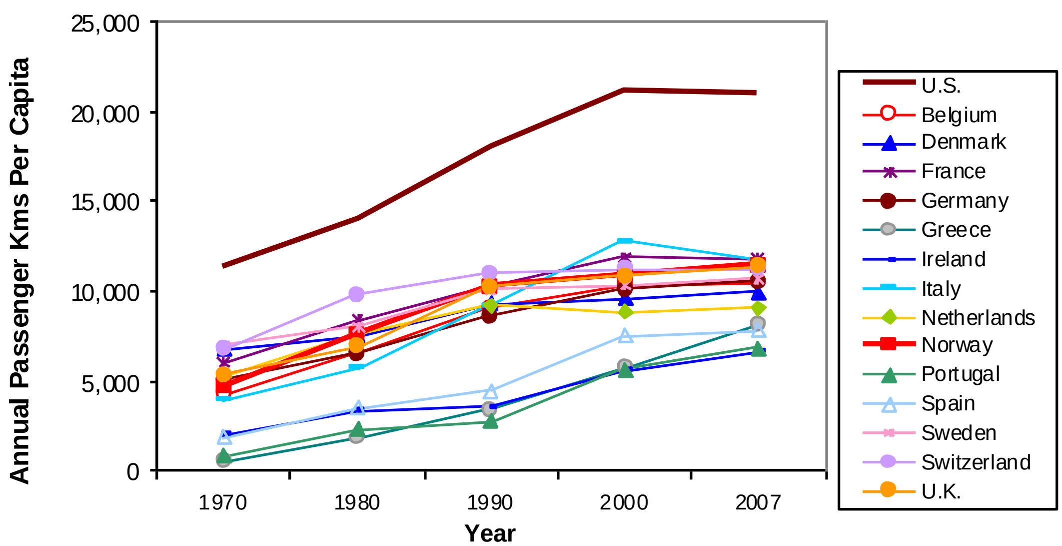
Public Transit's Role In An Efficient and Equitable Transportation System

During most of the last century automobile use (here *automobile* includes cars, light trucks, vans and SUVs and motorcycles) grew while public transit experienced a downward spiral of declining ridership, investment, and service quality, and more automobile oriented land use development. Critics argue that outside a few major cities there is little reason to expand transit service or encourage transit use (Cox 2000; Orski 2000; Balaker 2004), but current trends are increasing public transit's importance (Litman 2006; Puentes 2008):

- Aging population, rising fuel prices, increasing urbanization, increasing traffic congestion, rising roadway expansion costs, and changing consumer preferences and increasing health and environmental concerns are shifting travel demand from automobile to alternative modes.
- Many cities have recently experienced redevelopment and population growth, and some trends (smaller households, more elderly people, increased popularity of urban loft apartments, increased value placed on walkability, etc.) support increased urbanization.
- Many cities have reached a size and level of traffic demand that justifies more reliance on transit, including many areas previously classified as *suburban* that are becoming more urbanized, and so experience increased congestion, commercial clustering, land values and parking problems that make transit cost effective.
- There is a growing realization among transportation professionals and much of the general public that there is a value to having a more diverse transportation system.

Per capita motor vehicle travel peaked about the year 2000 in most OECD countries and has since declined slightly, as illustrated in Figure 1.

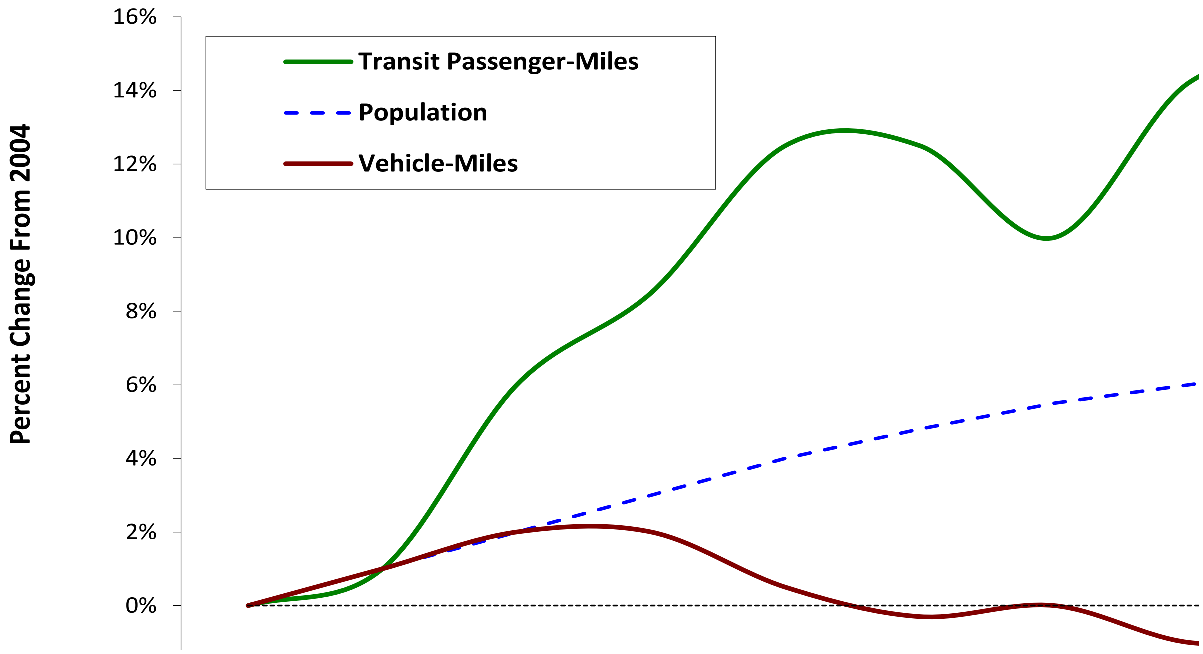
Figure 1 **International Vehicle Travel Trends** (Litman 2006)



Per capita vehicle travel grew rapidly between 1970 and 1990, but has since leveled off in most OECD countries, and is much lower in European countries than in the U.S.

Transit and cities are now experiencing a renaissance. Since the mid-1990s transit ridership has increased faster than automobile travel, as indicated in Figure 2.

Figure 2 **Transit Versus Motor Vehicle Travel Trends** (APTA and FHWA Data)



Between 2004 and 2012 the U.S. population grew 6%, motor vehicle travel declined 1% and transit ridership increased 14%. These trends indicate changing travel demands: although few people want to give up automobile travel altogether, many would prefer to drive less and rely more on walking, cycling and public transit, provided they are convenient, comfortable and integrated.

Most communities now have well-developed automobile transport systems. Increasing automobile dependence creates a variety of problems, many of which public transit can help solve. Transit tends to be most effective in dense urban areas where automobile problems are greatest. As a result, when all impacts are considered, transit is often the most cost-effective way to improve transportation.

Table 1 **Transportation Problems Transit Helps Solve**

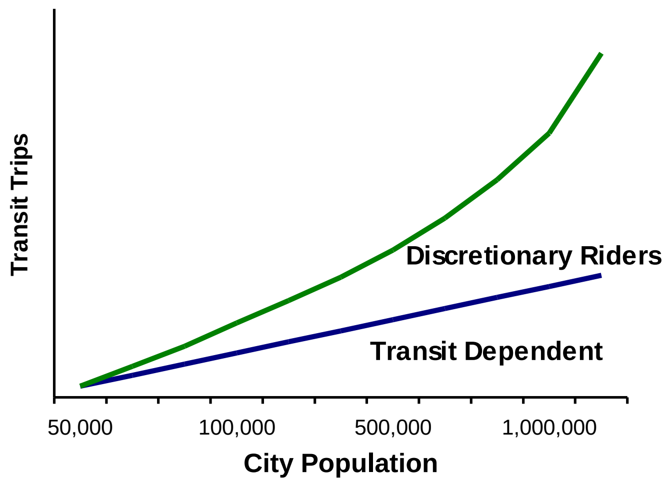
• Traffic congestion	• Automobile costs to consumers.
• Parking congestion	• Inadequate mobility for non-drivers
• Traffic accidents	• Excessive energy consumption
• Road and parking infrastructure costs.	• Pollution emissions

Public transit can help address a variety of transportation problems. Transit tends to be most effective along dense urban corridors where these problems are most intense.

There is also growing demand for housing in smart growth communities (Reconnecting America, 2004). The 2004 *American Community Survey* found that consumers place a high value on urban amenities such as shorter commute time and neighborhood walkability: 60% of prospective homebuyers surveyed reported that they prefer a neighborhood that offered a shorter commute, sidewalks and amenities like local shops, restaurants, libraries, schools and public transport over a more automobile-dependent community with larger lots but longer commutes and poorer walking conditions (Belden, Russonello and Stewart, 2004). This indicates that many people want to live less automobile-dependent lifestyles if given suitable options such as high quality transit services and walkable neighborhoods.

Transit becomes more important as cities grow. In smaller cities transit primarily serves *transportation disadvantaged* riders (people cannot use an automobile), typically representing 5-10% of the population, but as cities grow in size and density transit serves more *discretionary riders* (people who have the option of driving), and so provides more benefits by reducing traffic problems and supporting more efficient land use patterns.

Figure 2 **Transit Use By City Size**



As a city increases in size, transit ridership increases as more discretionary riders (people who have the option of traveling by automobile) use transit.

This does not mean that automobile travel will disappear and all travel will shift to public transit. However, at the margin (i.e., compared with their current travel patterns) many motorists would prefer to drive somewhat less and use alternatives more, provided they are convenient, comfortable and affordable. Satisfying this growing demand for alternative modes can provide a variety of benefits. When all impacts are considered, improving public transit is often the most cost-effective transportation improvement.

The Importance of Comprehensive Analysis

Economists and planners have developed various tools for evaluating the economic value of transport policies and projects. These were generally developed to evaluate a particular mode or objective. For example, highway investment models are designed to measure the value of road improvements, and emission reduction models are designed to prioritize emission reduction strategies. Because their scope is narrow, these tools are poor at evaluating multiple modes and objectives (NZTA 2010). For example, models designed to evaluate congestion reduction strategies often ignore emission impacts, and models designed to evaluate emission reductions often ignore congestion impacts. Many models ignore parking and vehicle ownership costs. Such "reductionist" models can lead to solutions to one problem that exacerbate others, and undervalue strategies that provide modest but multiple benefits, such as transit services.

Conventional transport evaluation models tend to undervalue public transit because they overlook many benefits, as summarized in Table 2. To their credit, many public officials realize that transit provides more benefits than their models indicate, and so support transit more than is justified by benefit/cost analysis, but this occurs despite rather than as a result of formal economic evaluation. Decision making would improve with better evaluation models that account for more impacts.

Table 2 **Conventional Analysis Scope** ("Comprehensive Evaluation" VTPI 2004)

Usually Considered	Often Overlooked
	Downstream congestion impacts
	Impacts on non-motorized travel
	Parking costs
	Vehicle ownership and mileage-based depreciation costs.
	Project construction traffic delays
	Generated traffic impacts
	Indirect environmental impacts
	Strategic land use impacts
Financial costs to governments	Transportation diversity value (e.g., mobility for non-drivers)
Vehicle operating costs (fuel, tolls, tire wear)	Equity impacts
Travel speed (reduced congestion delay)	Per-capita crash risk
Per-mile crash risk	Impacts on physical activity and public health
Project construction environmental impacts	Some travelers' preference for transit (lower travel time costs)

Conventional transportation planning tends to focus on a limited set of impacts. Some tend to be overlooked because they are relatively difficult to quantify (equity, indirect environmental impacts, crash risk), and others are ignored simply out of tradition (parking costs, long-term vehicle costs, construction delays). These omissions tend to undervalue transit improvements.

Recent research expands the range of impacts to consider in public transport evaluation (Cambridge Systematics 1999; Damuth 2008; ECONorthwest and PBQD 2002; HLB 2002; Gwee, Currie and Stanley 2011; Lewis and Williams 1999; MKI 2003; Nelson, et al. 2006; NZTA 2010; PTEG 2013; TRB 2000). This guide summarizes this research and describes how to apply more comprehensive evaluation in a particular situation.

Evaluation Best Practices

Economic Evaluation (also called *Appraisal* or *Analysis*) refers to methods to determine the value of a planning option to support decision making (Litman 2001). Economic evaluation involves quantifying and comparing the marginal (incremental) impacts (benefits and costs) of various options in a standardized format.

Economic evaluation applies an *evaluation framework* that specifies the basic structure of the analysis. This identifies the following ("TDM Evaluation," VTPI 2004):

- *Evaluation method*, such as cost-effectiveness, benefit-cost, lifecycle cost analysis, etc.
- *Evaluation criteria*, which are the impacts to be considered in analysis. Impacts can be defined in terms of *problems*, or their opposite, *objectives* (for example, if congestion is a problem then congestion reduction is an objective), and in terms of *costs* and *benefits* (for example, congestion reduction benefits are measured based on congestion costs reduced).
- *Modeling techniques*, which predict how a policy change or program will affect travel behavior and land use patterns.
- *Base Case*, meaning what would happen without the policy or program.
- *Comparison units*, such as net present value, benefit/cost ratio, or cost per lane-mile, vehicle-mile, passenger-mile, incremental peak-period trip, etc.
- *Base year and discount rate*, which indicates how costs are adjusted to reflect the time value of money.
- *Perspective and scope*, such as the geographic range of impacts to consider.
- *Dealing with uncertainty*, such as use of sensitivity analysis or other statistical tests.
- *How results are presented*, so that the results of different evaluations can be compared.

It is important to carefully define the questions and options to be considered (Moreland, et al. 2011). A transit evaluation may consider whether a particular transit investment is cost effective (benefits exceed costs), which of several transit options provides the greatest net benefits, whether a transit improvement provides more value than a highway improvement, and how to optimize transit service benefits, and how the benefits and costs of a transportation option are distributed. It is generally best to evaluate several options, which may include a base case (what happens if no change is implemented), and various roadway improvements, transit improvements, and support strategies. Transit options might include small, medium and large service improvements, plus transit improvements combined with various support strategies such as ridership incentives and transit-oriented development. All quantified values and calculations should be incorporated into a clearly-organized spreadsheet, which allows various options and assumptions to be tested and adjusted.

Some benefits and costs have a mirror-image relationship; a cost increase can be considered a reduction in benefits, and a reduction in benefits can be considered an increase in costs. For example, reduced accidents can be defined as increased road safety, and reduced congestion delays can be described as an increase in mobility.

Transit system costs tend to be relatively easy to determine, since most show up in government agency budgets. The main challenge is therefore to identify all incremental benefits. The scope of impacts considered when evaluating public transport policies and projects varies significantly between jurisdictions (Gwee, Currie and Stanley 2008). Some impacts are difficult to monetize (measure in monetary units) with available analysis tools and data. Such impacts should be quantified as much as possible and described. For example, it may be impractical to place a dollar value on transit equity benefits, but it may be possible to predict the number and type of additional trips made by transportation disadvantaged people, and to discuss the implications of this additional mobility on their ability to access basic services, education and employment.

Analysis should reflect *net*, *marginal* impacts. For example, net pollution reductions are the reduced automobile emissions minus any additional transit vehicle emissions. Marginal (incremental) impacts are sometimes difficult to determine. A 10% increase in transit passenger-miles does not necessarily increase transit costs by 10% if additional ridership occurs when the system has excess capacity.

Total impacts include both direct and indirect effects. Direct impacts result from increased mobility provided by transit, and reduced automobile use when people shift from driving to transit. Indirect impacts result when a major transit improvement provides a catalyst for more accessible land use patterns and a more diverse transport system that result in additional reductions in automobile travel. This *leverage effect* is discussed later. Analysis that only considers direct impacts and uses a short-term perspective tends to undervalue transit, particularly rail transit.

Some impacts can be considered in multiple categories, so it is important to avoid double-counting. For example, productivity gains from more accessible land use can be counted as land use benefits or economic benefits, but not both.

Some impacts are economic transfers rather than net gains. It is important to identify their full effects. For example, from a local perspective, federal grants can be considered a economic gain, since the money originates from elsewhere, but at a national level these are economic transfers, resources shifted from one area to another. Similarly, taxes and fares are economic transfers, costs to those who pay and benefits to those who receive the revenue. Both types of impacts should be considered in economic evaluation.

In general, it is best to calculate all impacts, including those that are indirect, long-term and affecting other jurisdictions, and identify their distribution by category, time, location and group. For example, a transit improvement might provide $10 million dollars in total net benefits, of which $6 million is direct and $4 million is indirect, $4 million occurs within the first 5 years, $6 million accrues within the local jurisdiction, and $2 accrues to lower-income people.

Evaluating Transit Service Quality

Service quality refers to how transit is perceived by users. AARP (2005); Dhinghi (2011); Hale (2011); Kenworthy (2008); Kittleson & Associates (2013); Litman (2008 and 2014); Marsden and Bonsall (2006); Stradling, et al. (2007); TRB (2010); Tomer, et al. (2011); and Tumlin, et al. (2005) provide guidance on evaluating transit service quality from various perspectives, including:

- *Availability* (when and where transit service is available), and *coverage* (the portion of a geographic area, or the portion of common destinations in a community, located within reasonable distance of transit service.
- *Frequency* (how many trips are made each hour or day).
- *Travel speed* (absolute and relative to automobile travel).
- *Reliability* (how frequently service follows published schedules).
- *Integration* (ease of transferring within the transit system and with other travel modes).
- *Price structure* and *payment options*.
- User *comfort* and *security*, including riding on, walking to, and waiting for transit.
- *Accessibility* (ease of reaching transit stations and stops, particularly by walking).
- *Universal design* (ability to accommodate diverse users including people with disabilities, baggage, inability to understand local languages, etc.).
- *Affordability* (user costs relative to their income and other travel options).
- *Information* (ease of obtaining information about transit services).
- *Aesthetics* (appearance of transit vehicles, stations, waiting areas and documents).
- *Amenity* (extra features and services that enhance user comfort and enjoyment).

Levinger and McGehee (2008) recommend that planners optimize the following factors to improve transit services and attract new riders:

1. *Ease.* Is the system or product easy to use? What difficulties do new users face? Transit example: Are your timetables legible and easily decipherable, even by inexperienced users? Are transfers convenient?
2. *Effectiveness.* How well does the system help users complete a task? Does the product serve its purpose well? Transit example: Do routes operate on time and on predictable schedules? Can passengers make their desired trips in a reasonable time?
3. *Comfort.* Do users feel safe, secure, and relaxed when using a product? Does use ever cause discomfort? Transit example: Do stops, stations and vehicles and vehicles always feel safe and secure? Do seats accommodate passengers of different sizes and abilities?
4. *Aesthetics.* Simply, does the product appeal to users? Is it visually and tactilely appealing? How does using the system affect all five senses? Transit examples: Are vehicles clean, outside and inside? Do the vehicles' temperature, fabrics, and hand-holds feel good? Are there any unpleasant smells, glaring lights, or blaring audio systems?

Transit service quality (travel speed, comfort, affordability, etc.) can be quantified using Level-of-Service (LOS) rating, which can be compared with other modes, particularly automobile travel, for various conditions and users (TRB 2011; Rickert 2006). A section later in this report discuss how to evaluate the value of transit travel time and compare it with other modes, taking into account user convenience and comfort.

Travel time maps use *isochrones* (lines of constant time) to indicate the time needed to travel from an origin to various destinations (Lightfoot and Steinberg 2006; Tomer, et al. 2011). For example, areas within one hour may be colored a dark red, within two hours a lighter red, within three hours a dark orange, and within four hours a light orange. Maps can indicate and compare travel times by different modes, for example, different colors or maps for automobile and public transit travel. Some maps show door-to-door transit travel times throughout an area, including walking, waiting and in-vehicle time (Cheng and Agrawal 2010; Shah and Adhvaryu 2016). Owen and Levinson (2014) measure home-to-work door-to-door travel times by walking-cycling-transit for 46 of the 50 largest metropolitan areas in the United States.

Table 3 compares factors considered in various transit service quality indices. Newer indices tend to be more comprehensive, and therefore more accurate at evaluating service quality and predicting the effects of changes in transit service and accessibility.

Table 3 **Transit Indices Compared** (Fu, Saccomanno and Xin 2005)

Indices	Studies	Performance Factors	Transit Availability?	Comfort and Convenience?	Travel Demand?
Local Index of Transit Availability	Rood 1997	Frequency; capacity; route coverage	Yes	No	No
Public Transport Accessibility	Hillman,	Frequency; service coverage	Yes	No	No
Mass Transit Indicators	Hale, 2011	Transit supply, travel impacts, land use, cost efficiency	Yes	No	Yes
Transit Level of Service Indicator	Kittelson & Ass. and URS 2001	Coverage; frequency; span; population; jobs	Yes	No	Yes
Transit Service Accessibility Index	Polzin et al. 2002	Coverage; span; frequency; travel demand	Yes	No	Total trips
Mobility Index	Galindez and Mireles-Cordov 1999	Travel speed; average vehicle occupancy	No	Yes	No
Service Quality Index	Hensher et al. 2001	13 variables (travel time; frequency, etc.)	Yes	No	Yes
Transit Service Indicator (TSI)	Fu, Saccomanno and Xin 2005	Frequency; coverage; walk, wait, transfer, and ride travel time.	Yes	Yes	Yes

This table compares indices used to evaluate transit service quality and predict service change impacts.

Travel Impacts

The benefits of a transit service or improvement are affected its travel impacts. The table below indicates the effects of various types of transit improvements. For example, some improvements provide basic mobility or increase affordability. Some are particularly effective at attracting motorists and reducing automobile travel.

Table 4 **Travel Impacts of Various Transit Improvements** (VTPI 2004)

Type of Transit Improvement	Improves Service Quality	Increases Affordability	Provides Basic Mobility	Reduces Auto Travel
Additional routes, expanded coverage, increased service frequency and hours of operation.	✓		✓	✓
Lower fares, increased public subsidies.		✓	✓	✓
More special mobility services.		✓	✓	
Commute Trip Reduction programs, Commuter Financial Incentives, and other TDM Programs that encourage alternative mode use.		✓		✓
HOV Priority.	✓			✓
Comfort improvements, such as better seats and bus shelters.	✓			✓
Transit Oriented Development and Smart Growth, that result in land use patterns more suitable for transit transportation.	✓			✓
Pedestrian and Cycling Improvements that improve access around transit stops.	✓		✓	✓
Improved rider information and Marketing programs.	✓			✓
Improved Security.	✓		✓	✓
Targeted services, such as express commuter buses, and services to Special Events.	✓			✓
Universal Design (accommodating people with disabilities)	✓		✓	
Park & Ride facilities.	✓			✓
Bike and Transit Integration (bike racks on buses, bike routes and Bicycle Parking at transit stops).	✓		✓	✓

This table summarizes the travel impacts of various types of transit improvements. Some improve conditions or reduce costs for existing riders, others cause shifts from automobile to transit.

User benefits result from improved convenience, speed, comfort or financial savings to travelers who would use transit even without those improvements. For example, if transit priority measures increase transit speeds, current users benefit from travel time savings. Similarly, bus shelters, improved security at transit stations, reduced fares, and other types of service improvements provide benefits to current transit users.

Mobility benefits result from the additional mobility provided by a transportation service, particularly to people who are physically, economically or socially disadvantaged. These benefits are affected by the types of additional trips served. For example, transit services that provide *basic mobility*, such as access to medical services, essential shopping, education or employment opportunities, can be considered to provide greater benefits than more luxury trips, such as recreational travel ("Basic Mobility," VTPI 2004).

Efficiency benefits result when transit reduces the costs of traffic congestion, road and parking facilities, accidents and pollution emissions. These benefits depend on the amount and type of automobile traffic reduced. For example, transit services provide extra benefits if they reduce urban-peak automobile trips, rather than off-peak or rural trips, because urban-peak automobile travel tends to impose the greatest congestion, parking and pollution costs. Table 5 compares mobility and efficiency objectives.

Table 5 **Comparing Mobility and Efficiency Objectives**

	Mobility	Efficiency
Objective	Increase mobility by non-drivers.	Reduce costs such as congestion and pollution.
How evaluated.	Quality of mobility options available, particularly for disadvantaged people.	Compared with the same trips made by automobile.
Service distribution and coverage.	Structured to provide the greatest possible coverage, including service at times and places where demand is low.	Focused on urban-peak travel conditions where congestion, facility costs and pollution are worst.
Service quality.	Service may be basic (i.e., bus rather than rail), but it must be comprehensive and affordable.	Intended to attract discretionary riders with premium quality service (e.g., rail rather than bus), Park & Ride, and express services.
Fare structure.	Affordable to disadvantaged people.	Attractive to commuters.

Public transit has various objectives that sometimes conflict.

These benefits tend to be greatest when transit serve people who face the greatest mobility constraints, such as wheelchair users and people with very low incomes (Litman and Rickert 2005). Special effort may be made to identify these users in ridership surveys and passenger profiles, evaluation of vehicle design features such as the portion of vehicles and terminals that accommodate people with disabilities (including the quality of pedestrian access in the area), and user surveys that include special features to determine the problems that disadvantaged people face using transit services.

To help analyze travel impacts it is useful to determine *mode substitution* factors, that is, the change in automobile trips resulting from a change in transit trips, and vice versa. For example, when reduced fares increase bus ridership, typically 10-50% substitute for an automobile trip; other trips shift from nonmotorized modes, vehicle passengers (which may involve a *rideshare* trip that would occur anyway; as opposed to a *chauffeured* trip in which a driver makes a special trip), or induced travel. Conversely, when disincentives such as road or parking fees cause automobile trips to decline, generally 20-60% shift to transit, depending on conditions. Ewing, Tian and Spain (2014); Pratt (1999); Kuzmyak, Weinberger and Levinson (2003), and TRL (2004) provide information on the mode shifts that typically result from various types of incentives.

According to travel surveys (APTA 2007, p. 8), more than half of transit passengers report that if transit service were unavailable they would travel by automobile, either as a driver or passenger in a private automobile or taxi (a portion of passenger trips would be *ridesharing*, using an otherwise empty seat without increasing vehicle mileage, while others would be *chauffeured trips* that do increase vehicle travel).

Indirect Travel Impacts

In addition to direct travel impacts, transit improvements can affect travel indirectly by helping to create more multi-modal, accessible communities where people tend to own fewer cars and drive less than would otherwise occur, called *transit oriented development* (APTA 2009; Evans and Pratt 2007; Kenworthy 2008; Liu 2007). Where this occurs, each transit passenger-mile represents a reduction of 3 to 6 automobile vehicle-miles (Gallivan, et al. 2015; Holtzclaw 2000; ICF 2008 and 2010; Lem, Chami and Tucker 2011; Litman 2004a). Wedderburn (2013) found that, on average, each additional daily transit trip by driving age (18+ years) residents increases daily walking by 0.95 trips and 1.21 kilometers (in addition to the walking trips to access public transport), and reduces two daily car driver trips and 45km driven. The table below summarizes these impacts.

Table 6 **VMT Reductions Due to Transit Use** (Holtzclaw 2000; ICF 2010; Litman 2004a)

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 much more than a vehicle; it is an integrated system that includes compact, high quality stops and stations surrounded by compact and mixed-use development, good walking and cycling conditions, good taxi services, reduced parking supply, and more social acceptance of carfree living. Public transit projects often serve as a catalyst for this type of *transit-oriented development* (TOD). Where these features exist, residents own significantly fewer automobiles, drive less, and rely more on a combination of alternative modes (walking, cycling, ridesharing, public transit, taxi and delivery services).

Residents of transit-oriented developments tend to own about half as many vehicles, generate half as many vehicle trips, and rely on walking, cycling and public transit much more than in automobile-dependent communities (Arrington and Sloop 2009). 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, in which households that are constrained in their ability to drive choose transit-oriented neighborhoods, they indicate that high quality transit actually reduces total vehicle travel.

All of these features should be considered when planning for high quality public transit, and various impacts (compact development, reduced vehicle ownership and use, increased walking, reduced parking costs) should be considered potential results of high quality public transit.

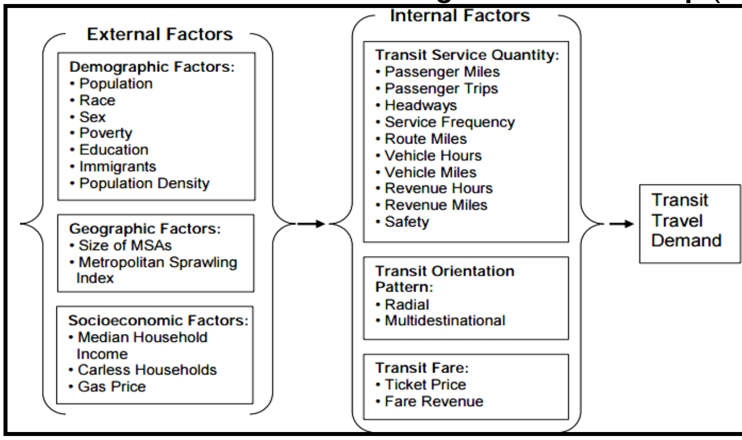
This does not mean that every transit improvement has all of these impacts. Basic bus service, or a rail line designed for park-and-ride suburban commuters may fail to significantly change transportation or land use patterns. Significant transit improvements integrated with supportive land use policies and incentives to reduce automobile use are generally needed to cause significant reductions. Rail transit tends to have the greatest impact on per-capita vehicle travel because it tends to have the nicest stations and therefore the greatest land use impacts. Busways impacts are generally smaller, but can still be significant if implemented in conjunction with other supportive policies. As a result, bus service improvements generally provide significant benefits compared with expanding highways and parking facilities, but not smaller benefits than provided by rail transit improvements, particularly over the long-run. As a result, debates between bus and rail transit generally boil down to a tradeoff between lower initial costs but smaller long-term benefits of bus, versus higher initial costs but larger potential long-term benefits of rail. These issues are discussed in the "Rail Versus Bus Transit" section of this report.

Transit Improvements Help Reduce Vehicle Ownership and Use (www.translink.bc.ca)
Despite strong population and economic growth, the city of Vancouver recorded a small decline in the number of registered automobiles, and a reduction in downtown automobile trips in 2004. Small reductions in growth rates were also recorded in nearby suburbs. Experts conclude that this results from increased transit services and a growing preference for urban living. Says expert David Baxter, "There are some fundamental changes going on. It's increasingly possible to live in Vancouver without a motor vehicle." Transit ridership rose 9.5% compared to last year, and was 24.6% higher than 2002. Bus trips increased 11.1%, and rail trips increased 5.4%. A customer survey found that 42% of SkyTrain riders, 49% of West Coast Express riders, 35% on the 99B bus route and 25% on the 98B route previously commuted by car. "The numbers show that demand for public transit continues to grow in response to significant service expansion."

Transit Demand

Travel demand refers to the number and types of trips people would make under particular conditions. Various demographic, geographic and economic factors affect transit demand as summarized in the following table.

Table 7 **Factors Affecting Transit Ridership** (Alam, Nixon and Zhang 2015)



Many factors affect transit travel demand.

For example, a particular transit route might attract 5,000 daily riders under current conditions; 6,000 if more employers offered subsidized transit passes; 7,000 if a local college has a U-Pass program; 8,000 if service quality improves; 9,000 if Park & Ride, pedestrian and bicycle access improved; and 10,000 if parking prices increase.

For more information on transit demand see Alam, Nixon and Zhang 2015; Kittleson & Associates 2013; TRL 2004; McCollom and Pratt 2004; Thompson, et al. 2012; Currie 2005; Bruun 2007; CTS 2009a; Taylor, et al. 2009; Abt Associates 2010; Greer and van Campen 2011; Walker 2012 and 2015; Wang 2011; Chen and Naylor 2011; and Xie 2012. The *Transit Performance Monitoring System* (TPMS) uses a standardized survey to evaluate transit use (FTA 2002). Iacono, Krizek and El-Geneidy (2008) discuss how trip distance affects transit demand. CTOD (2009) describes methods for improving transit demand models. Brown and Thompson (2009) identify various service design factors that affect transit ridership. Litman (2005c) discusses how demographic and economic trends are increasing demands for alternative modes, including public transit. Karash, et al. (2008) use marketing analysis tools to evaluate factors that can influence transit ridership.

Most urban regions have models that predict how various transport system changes affect travel patterns. However, such models are poor at measuring factors such as rider comfort and pedestrian accessibility, and so tend to understate the benefits of many transit improvements and incentives ("Modeling Improvements," VTPI 2002). Travel impacts of transit encouragement strategies can be evaluated by comparing the generalized costs (travel time and incremental expenses per trip) of transit and driving to calculate a *transit competitiveness ratio* (Casello 2007). The higher this ratio the relatively less attractive is transit compared with driving. Because travelers have diverse needs and preferences, some will choose transit even if the transit competitive ratio is relatively high, so models must be calibrated and adjusted to reflect specific conditions.

Specific factors that affect transit ridership are discussed in more detail below.

Price Changes

The overall average Elasticity of transit ridership with respect to fares is -0.4, meaning that each 1.0% fare increase will reduce ridership by 0.4%, although this varies depending on various geographic, demographic and service factors (Hensher and King 1998; Pratt 1999; TRL 2004; Litman 2004). Transit dependent riders have lower elasticities than discretionary riders. Large cities tend to have a lower elasticity than small cities, and peak-hour travel is less elastic than off-peak. Commuter Financial Incentives, in which employers provide subsidized passes or cash to transit riders, can be effective at increasing ridership (www.commutercheck.com). Parking Pricing can significantly increase transit travel. Even a modest fee ($1-2 per day) often doubles transit commuting. The Trip Reduction Tables indicate the reduction in automobile trips that can be expected from various combinations of commuter financial incentives.

Table 8 **Transit Ridership Factors** (JHK 1995; Kain and Liu 1999)

Factor	Elasticity
Regional employment	0.25
Central city population	0.61
Service (transit vehicle mileage)	0.71
Fare price	-0.32
Wait time	-0.30
Travel time	-0.60
Headways	-0.20

This table shows elasticities of transit use with respect to various factors. For example, a 1% increase in regional employment is likely to increase transit ridership by 0.25%, while a 1% increase in fare prices will reduce ridership by 0.32%, all else being equal.

Service Quality

Pratt (1999) concludes that the elasticity of transit use with respect to transit service averages 0.5, meaning that each 1% increase in transit service frequency, vehicle mileage or operating hours increases ridership 0.5%, although this varies depending on service type, demographic and geographic factors. Elasticities of 1.0 can occur where service expands into suitable areas. Pratt finds the elasticity of transit use to service expansion (e.g. routes into new parts of a community) is typically 0.6 to 1.0, meaning that each 1% of additional service increases ridership by 0.6-1.0%. New bus services in a community typically achieve 3 to 5 annual rides per capita, with 0.8 to 1.2 passengers per bus-mile, with higher rates in some circumstances, such as university towns or suburbs with rail transit stations. Improved information, easy-to-remember schedules (for example, every half-hour), and more convenient transfers can increase transit use, particularly in areas where service is less frequent. Multiple regression analysis by Alam, Nixon and Zhang (2015) indicates that bus travel demand is transit supply, fares, average headways, service coverage and intensity, revenue hours, safety and gas prices.

Demographics

About 12% of U.S. residents use transit at least once during a two month period, and this is higher among certain groups (Polzin and Chu 1999). Ridership tends to be higher for:

- People who cannot drive (people with disabilities, youths, immigrants, etc.)
- People with low incomes.
- Residents of larger cities.
- Commuters to major commercial centers.
- High school, college and university students.
- Employees who are offered financial incentives.
- People who consider driving stressful.

The Transit Performance Monitoring System (TPMS) surveys provide information on transit ridership demographics (FTA 2002). Phase I and II surveys found the following:

- Most transit trips are made by lower-income household. Lower-income riders (less than $20,000 annual income in 2002) represent 63% of riders in small transit systems, 51% in medium size transit systems, and 41% of riders in large transit systems.
- Most transit trips are made by riders who use transit frequently. About 70% of trips are made by people who use transit at least five days each week. However, a large number of people use transit infrequently, so 70% of people who use transit during the last month use it less than five times a week.
- There is constant turnover of the transit user population. 38% of current transit trips are made by people who have relied on transit for less than one year, and 29% of transit trips are made by people who relied on transit one to four years.
- Work, school (including university and college) and shopping trips account for 75% of all trips.
- Overall, 33% of transit trips made by discretionary riders (people who have the option of driving a car). This increases to 36% in large transit systems.
- Walking is the most common form of access to transit stops. 6.2% of bus riders and 27% of rail riders drive to their transit stop. Nearly all transit trips end with a walking link.
- More than half (56%) of transit passengers report that if transit service were unavailable they would have traveled by automobile, either as a driver or passenger. Below is what respondents report they would do if transit service were unavailable:

Drive	23%
Ride with someone	22%
Taxi/Train	12%
Not make trip	21%
Walk	18%
Bicycle	4%

Table 9 shows responses to a national survey of why people use transit. This indicates that many users either cannot drive, but other factors also motivate transit use, including financial savings, avoiding the stress of driving, and environmental concerns.

Table 9 **Reasons for Using Public Transit** (CUTR 1998)

I Use Public Transit Because…	Portion of Respondents
It is the most convenient way for me.	82%
Costs less than driving.	78%
Do not have access to a car.	74%
Avoids stress of driving on congested roads.	74%
Is better for the environment.	72%
Avoids buying a car.	65%
I don’t drive or don’t like to drive.	60%
It is faster than a private vehicle.	43%
I can do something else	41%

Land Use Factors

Various land use factors affect transit use (“Land Use Impacts On Transport,” VTPI, 2004). Per capita transit ridership tends to increase with city size (see table below), population and employment density, and the quality of the pedestrian environment.

Table 10 **Portion of Residents Using Transit At Least Once A Month** (NPTS 1995)

City Size (Thousands)	Residents Riding Transit Monthly
Under 250	1.4%
250-499	5.4%
500-999	6.4%
1,000-2,999	10.0%
3,000+	21.0%
Nationwide	11.6%

One study found the elasticity of transit ridership with respect to residential densities to be +0.22 in U.S. urban conditions, meaning that each 1% increase in density increases transit ridership by 0.22% (PBQD 1996). Destination density (e.g., clustering of employment) tends to have a greater impact on transit ridership than residential density.

Per capita rail transit ridership rates tend to increase in an area with population density, commercial and governmental land uses, average income, bus service connectivity, distance to central station and service frequency (Chan and Miranda-Moreno 2011). Bento, et al, (2003) found that each 10% reduction in the distance between homes and the nearest transit stop reduces automobile commute mode split by 1.6 percentage points, and reduces total annual VMT by about 1%. Kuby, Barranda and Upchurch (2004) evaluate various transit station area factors that affect ridership. On average 100 jobs generate 2.3 daily boardings, 100 residents generate 9.3 boardings, 100 park-and-ride spaces generate 77 boardings, each bus generates 123 boardings, and an airport generates 913 boardings. These land use factors should generally be evaluated at a micro-scale (using small transport analysis zones) along a transit corridor or around a transit station.

Some people claim that at least 12 employees or residents (equivalent to about 6 housing units) per acre are needed to justify more than basic transit service, but other factors are as important as density. Strategies such as campus transport management, commute trip reduction programs and parking pricing can significantly increase transit ridership rates, and so justified quality transit services in areas with lower densities. For example, if a comprehensive commute trip reduction program doubles transit ridership rates, an employment center with 6 employees per acre would generate the same transit demand as an area with 12 employees per acre that lacks such a program.

Quality and Type of Transit
There is considerable debate concerning the differences in demand between bus and rail transit (see discussion of bus versus rail transit later). Rail transit is considered more comfortable and prestigious than buses, and so tends to attract more discretionary riders (travelers who would otherwise drive) within a service area (Pushkarev and Zupan 1977; CTS 2009a; Scherer and Dziekan 2012), but a bus network can reach more destinations, providing more comprehensive and direct coverage through a region, and so may attract more riders with a given level of investment (GAO 2001). Rail passengers appear willing to accept more crowded conditions than bus passengers (Demery and Higgins 2002).

Table 11 **Demand Characteristics By Transit Mode** (CTS 2009a)

Transit Service	Definition	Type of Rider	How Transit is Accessed	Trip Characteristics
Light-Rail Transit	Hiawatha Line from downtown Minneapolis to its southern suburbs	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	Connects suburban areas directly to downtowns	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 tends to attract more "choice" riders (discretionary transit users who could drive).

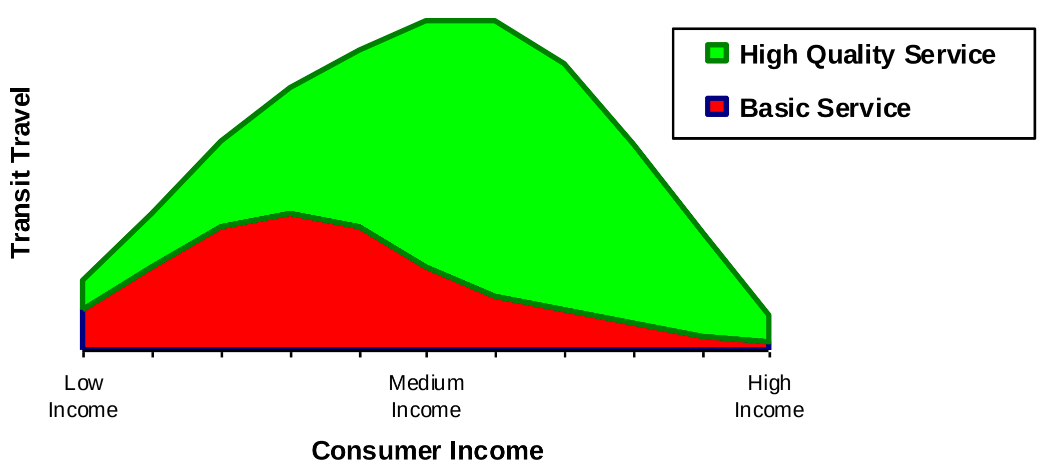
Cities with larger rail transit systems have significantly higher per capita transit ridership (Litman 2004a). Baum-Snow and Kahn (2005) found that in "old rail" cities (cities that have well-established rail transit systems in 1970) transit commuting declined from 30% in 1970 to 23% in 1990. In "new rail" cities (cities that build rail transit lines between 1970 and 1990), transit commuting declined from 8% to 6% during this period. In cities without rail, transit commuting declined from 5% to 2%. Transit use in all three samples remained relatively unchanged between 1990 and 2000. They conclude that rail transit does tend to increase total transit ridership if local land use is supportive.

New North American rail and BRT systems have attracted higher ridership than would be expected based on standard modeling of service frequency, travel speed and fare (Henry and Litman 2006; Hidalgo and Carrigan 2010). It is now common practice to apply up to a 12-minute in-vehicle travel time "bias constant" for high quality transit service (that is, the travel times for mode-split modeling purposes would be 12 minutes shorter for rail in comparison to conventional local bus service) due to factors such as more attractive vehicles and nicer stations (Kittleson & Associates 2007).

Various studies indicate that rail transit tends to reduce vehicle ownership and travel, and stimulate more walking and cycling activity (CTS 2009). Boarnet and Houston (2013) analyzed the impacts that a new light rail line had on travel activity by nearby households. Comparing before and after travel surveys (including GPS and accelerometer data) they found that households located within a half-mile of rail stations reduced their daily vehicle travel by 10 to 12 miles (about 30%) relative to comparable households located further away.

Demand for transit varies by service quality and income, as indicated in Figure 3. Demand for basic quality transit service (such as infrequent bus routes) tends to be greatest for lower-income people, and declines as incomes rise. Demand for higher-quality transit service (such as express commuter buses and frequent rail transit, with transit-oriented development) tends to increase with income, and is potentially much greater in total than for basic service, which is why cities with high quality transit tend to have much greater per capita ridership (APTA 2007, Table 13).

Figure 3 **Transit Demand By Income**



Demand for basic quality transit service (such as infrequent bus) is greatest by lower-income travelers and tends to decline with income. Demand for high quality transit increases with income and is potentially much larger in total.

Transit Impact Categories

This section describes various types of transit impacts (benefits and costs), and how they can be measured. For additional information on these impacts see Litman (2009).

Transit Expenditures

Most direct transit service costs can be obtained from transit agency budgets. Table 12 summarizes U.S. transit service expenses and revenues. Detailed information is available on individual transit agencies. Expenses are divided into *capital* (facilities, equipment and other durable goods) and *operation* (labor, fuel and maintenance). Some costs, such as Park&Ride lots, special roadway facilities such as bus pullouts, and increased road maintenance due to bus traffic may be borne by other government agencies.

Table 12 **2002 U.S. Public Transit Expenses and Revenues** (APTA 2003)

	Bus	Trolley Bus	Heavy Rail	Commuter Rail	Demand Response	Light Rail	Other	Totals
Capital Expenses (m)	$3,028	$188	$4,564	$2,371	$173	$1,723	$253	$12,301
Operating Expenses (m)	$12,586	$187	$4,268	$2,995	$1,636	$778	$457	$22,905
Total Expenses (m)	$15,613	$374	$8,832	$5,366	$1,809	$2,502	$710	$35,206
Average Fare Per Trip	$0.71	$0.51	$0.93	$3.50	$2.34	$0.67	$1.14	$0.92
Fare Revenues (m)	$3,731	$60	$2,493	$1,449	$185	$226	$132	$8,275
Subsidy (Total Exp. - Fares)	$11,882	$315	$6,339	$3,917	$1,624	$2,276	$577	$26,931
Vehicle Revenue Miles (m)	1,864	13	604	259	525	60	102	3,427
Passenger Miles (m)	19,527	188	13,663	9,450	651	1,432	1,034	45,944
Avg. Veh. Occupancy	10.5	14.1	22.6	36.5	1.2	23.9	10.1	13.4
Avg. Trip Distance (miles)	2.8	8.7	4.5	1.6	0.2	5.6	1.1	2.6
Unlinked Trips (m)	5,268	116	2,688	414	79	337	116	9,017
Total Expend. Per Pass. Mile	$0.80	$1.99	$0.65	$0.57	$2.78	$1.75	$0.69	$0.77
Fare Rev. Per Pass. Mile	$0.19	$0.32	$0.18	$0.15	$0.28	$0.16	$0.13	$0.18
Subsidy Per Pass. Mile	$0.61	$1.68	$0.46	$0.41	$2.50	$1.59	$0.56	$0.59
Percent Subsidy	76%	84%	72%	73%	90%	91%	81%	76%

m=million

Costs and revenues can vary significantly within a particular transit system, line or route. Various methods can be used to calculate the marginal cost of a particular trip (Taylor, Iseki and Garrett 2000). In general, urban-peak transit has higher costs, but also has higher load factors and so tends to have greater cost recovery (lower subsidies) per passenger-mile compared with off-peak and suburban/rural transit service. The costs of a particular transit improvement can vary widely depending on conditions, such as whether rights-of-way and equipment already exist or must be acquired. If a transit service already exists, it is sometimes possible to increase capacity at minimal marginal cost.

Measuring Transit Service Costs

Transit service costs can usually be obtained from transit agencies. Costs for specific transit programs and projects require analysis of the particular situation. For comparison it is usually helpful to calculate costs per passenger-mile or passenger-trip.

Impacts on Existing Transit Users

It is important to take into account impacts on existing users when evaluating changes in transit service and fares. This refers to trips that would be made by transit regardless of whether a new program or policy is implemented – additional transit trips made by existing users are considered in the *mobility benefits* section below.

Measuring Existing User Impacts

Financial impacts on existing users can be measured directly. For example, a new $25 per month transit subsidy provided to 100 current transit commuters represents a $30,000 annual benefit to that group. A 25¢ fare increase that applies to 1,000,000 annual fares represents an annual cost of $250,000 to existing riders.

Some service quality changes can be measured with conventional transportation evaluation techniques, such as applying standard travel time values ("Travel Time Costs," Litman 2009). Travel time is generally valued at half average wage rates, and two or three times higher for time spent driving in congestion, walking to a transit stop, waiting for a bus, or traveling in unpleasant conditions such as in a crowded vehicle, as discussed later in this report. A value of about $8 per hour is appropriate for transit passengers who are comfortable, and a higher value of $16 per hour is appropriate for time spent walking, waiting or riding in a crowded transit vehicle.

For example, a bus priority strategy that saves transit riders 10,000 hours annually in travel time can be valued at $80,000 if all passengers have a seat, or $120,000 if half of those passengers are standees for whom travel time savings values are doubled. Similarly, benefits to existing users of increased transit frequency or coverage can be calculated based on their reduced average walking and waiting time.

A service improvement that increases rider comfort, such as reducing crowding, can also be measured by reducing the cost per hour of passenger travel time. For example, if a transit service improvement reduces crowding for 5,000 passenger-hours, the benefit to these riders can be considered worth $40,000, because it eliminates the travel time cost premium associated with uncomfortable conditions, reducing travel time costs from $16 to $8 per hour.

Of course, these values should be calibrated and adjusted to reflect specific conditions, taking into account local wages and preferences, or to be consistent with other analysis models. Other service quality impacts may require more research to measure. For example, to quantify the value to existing users of improved use information or rider security it may be necessary to survey riders to determine how many are affected (the number who use a new information service or travel on vehicles with improved security) and the value they place on such improvements.

Mobility Benefits

Mobility benefits result from additional personal travel that would not otherwise occur, particularly by people who are *transportation disadvantaged*, that is, they cannot drive due to physical, economic or social constraints.

In most affluent communities public transit currently serves a relatively small portion of total trips, but the trips it serves tend to be high value to users and society. Transit provides *basic mobility* by helping people reach important activities such as medical services, education and employment. This is particularly true of Demand Response service riders, who have moderate to severe disabilities that limit their mobility, and often are unable to use other travel options, such as walking, cycling or conventional taxis. Because users have few alternatives, Nguyen-Hoanga and Yeung (2010) find that paratransit service benefits far exceed their costs. Demand for such services, and therefore the benefits of providing public transit, tends to increase as the number of seniors, people with disabilities, and low income households increases in a community (Bailey 2004).

Transit is an important travel mode for low- and middle-income non-drivers. For example, a household earning $20,000 annual income typically spends about $2,500 per year on transport. On this budget, a non-driver in a community with no transit service can only afford about five taxi trips per week (resulting in an inferior level of mobility). A non-driver who lives in a community with good transit service can purchase a monthly transit pass and still afford two or three taxi trips per week, providing a relatively high level of mobility, although still inferior to a motorist.

Several categories of mobility benefits are described below. Some of these categories may overlap. They tend to differ in their nature and distribution (who benefits), and so reflect different perspectives. For example, *user benefits* tend to interest residents and *public service support* interests public officials.

User Benefits

This refers to direct benefits to users from improved convenience and comfort (for example, from more frequent and less crowded services, or nicer stations), and increased access to services and activities, including medical services, economic benefits from schooling and employment, enjoyment from being able to attend social and recreational activities, and financial savings from being able to shop at a wider range of stores. By improving access to education and jobs transit can increase people's economic opportunities.

People living near public transit service tend to work more days each year than those who lack such access (Sanchez 1999; Yi 2006), and many transit commuters report that they would be unable to continue at their current jobs or would earn less if transit services were unavailable (Crain & Associates 1999). Similarly, a significant portion of students depend on public transit for commuting to schools and colleges, so a reduction in transit services can reduce their future productivity. A survey of adults with disabilities actively seeking work found 39% considered inadequate transport a barrier to employment (Fowkes, Oxley and Henser 1994). Increased employment by such groups provides direct benefits to users and increases overall productivity. Economic benefits to businesses are discussed in the Productivity Benefits section.

Public Service Support

Transit can support government agency activities and reduce their costs. For example, without transit services some people are unable to reach medical services, sometimes resulting in more acute and expensive medical problems. Transit services can help reduce welfare dependency and unemployment (Multisystems, et al. 2000). Transit access can affect elderly and disabled people's ability to live independently, which can reduce care facility costs. As a result, a portion of public transit subsidies may be offset by savings in other government budgets.

Equity Benefits

Transit helps achieve community equity objectives. It increases economic and social opportunities for people who are economically, physically and socially disadvantaged, and helps achieve equity objectives, such as helping physically and economically disadvantaged people access public services, education and employment opportunities (Allen 2008; CTS 2010). Transit helps reduce the relative degree that non-drivers are disadvantaged compared with motorists.

Option Value

Transit services provide *option value*, referring to the value people place on having a transport option available even if they do not currently use it (ECONorthwest and PBQD 2002). Transit can provide critical transportation services during personal and community-wide emergencies, such as when a personal vehicle has a mechanical failure, or a disaster limits automobile traffic. This is similar to ship passengers valuing lifeboats, even when they don't use them.

Measuring Mobility Benefits

Improving passenger convenience and comfort, for example, from more frequent service, reduced crowding or nicer vehicles and waiting areas, can provide travel time savings. Even if the amount of time passengers spend travelling does not decline, unit travel time costs (cents per minute or dollars per hour) can decline significantly (Litman 2008a and 2008b). For example, passenger travel time unit costs can increase as much as 2.5 times in very crowded vehicle (6 standing-passengers/m2) compared with uncrowded vehicles with available seats.

Transit mobility benefits tend to be particularly important to people who cannot or should not drive, including teenagers, seniors, and people with disabilities (Tomer, et al. 2011). The value to users of increased mobility that results from price changes (fare reductions, targeted discounts, parking cash-out) can be calculated using the "rule of half," which involves multiplying half the price change times the number of trips that increase or decrease, which represents the midpoint between the old price and the new price, and therefore the average incremental value of those trips (Small 1999). For example, if a 50¢ fare discount increases transit ridership by 10,000 trips, the value to users of these additional trips can be considered to be $2,500 (10,000 x 50¢ x ½).

In most situations the maximum value to users of mobility benefits is their savings relative to the same trips by taxi, which represents a more costly but nearly universal alternative. Cheaper alternatives are sometimes available, such as walking, cycling, ridesharing or telecommuting, so actual average savings are probably about half taxi savings, assuming a linear curve of alternative travel option costs. Transit fares average about 15¢ per passenger-mile, while local taxi service costs average about $2.25 per vehicle-mile. This implies about $1.00 net benefits per passenger-mile when a typical bundle of alternative mode trips shift to transit.

Demand response services tend to provide significantly greater mobility benefits because users face greater transportation constraints, and alternatives options tend to be more costly. Many demand response clients are unable to walk, and some cannot be accommodated by conventional taxis because they have large mechanical wheelchairs or other special needs. As a result, mobility benefits can be doubled or tripled when evaluating demand response services.

Transit passengers who shift from current routes to new routes can be assumed to benefit from increased convenience and time savings, typically from reduced walking. This can be calculated from user surveys or estimated at $1-3 value of travel time savings per trip, assuming 5-10 minute average time savings per trip. Leigh, Scott and Cleary (1999) developed a method to quantify a community's *mobility gap*, defined as the additional transit service required for zero-vehicle households to have mobility comparable to vehicle-owning households. This is a lower-bound estimate because it does not account for unmet mobility needs of non-drivers in vehicle-owning households. Only about a third of transit needs are currently being met in typical areas they evaluated, indicating a level of service (LOS) rating D (Table 13). The approach can be used to predict the LOS rating that will occur under various transit planning and investment scenarios.

Table 13 **Transit Level Of Service Ratings** (Leigh, Scott & Cleary 1999, p. VIII-3)

Portion of Demand Met	Transit Level-Of-Service
90% or more	A
85-89%	B
50-74%	C
25-49%	D
10-24%	E
Less than 10%	F

MacDonald (2013) developed a method of valuing public transit trips, and the social costs of reduced transit services that would reduce non-drivers' mobility. EcoNorthwest and PBQD (2002) describe methods of calculating *option value* based on consumers' willingness to pay to maintain a mobility option that they use infrequently. This involves assigning an additional value to each transit trip made by infrequent users, taking into account the cost to consumers of each trip, the volatility of demand and the expected frequency of such trips. In typical conditions this appears to be in the range of $1-10 annual per resident who expects to use transit a few times each year.

Stanley, et al. (2011) identify five social exclusion risk factors, including income, employment, political engagement, participation in selected activities and social support (being able to get help when needed). Applying this analysis approach in Melbourne, Australia they find that residents aged over 15 average 3.8 daily trips (all modes), but as the number of social exclusion risk factors increase, trip rates decline reduce: people with 2 or more risk factors go down to about 2.8 trips per day or lower. The difference between 2.8 and 3.8 daily trips represents a major decline in community involvement. Porter, et al. (2015) define and evaluate various benefits from improving mobility for non-drivers including improved access to education and employment, and therefore increased economic productivity, plus improved healthcare access, and resulting reductions in the costs of providing public services.

The researchers estimate the marginal rate of substitution between household income and trip making, taking into account social exclusion factors. Because of the way trip are defined, an additional trip is equivalent to undertaking an additional activity, so additional trips represent the value of engaging in additional activities. This analysis indictes that an additional trip (or an additional activity) is valued at approximately $20 at an average household income level. Even higher values are accorded to additional trip making by lower income households. This $20 value is about four times the value ascribed to such trips using traditional economic evaluation (what economists would call the generated traffic benefit, measured using the "rule-of-a-half").

The table below summarizes the four categories of transit mobility benefits and describes how they can be measured. Mobility benefits are affected by the degree to which transit service is available to those who need it and the additional mobility it provides. For example, a transit improvement that increases the number of households and worksites within a quarter-mile of bus service, or which increases the number of trips made by people with disabilities or low incomes, can be considered to increase mobility benefits. These benefits sometimes overlap; for example, some user and public service benefits can also be counted as equity benefits.

Table 14 **Categories of Basic Mobility Benefits**

Category	Description	How To Measured
User Benefits	Direct user benefits from the additional mobility provided by public transit.	Rider surveys to determine the degree that users depend on transit, the types of trips they make, and the value they place on this mobility.
Public Service Support	Supports public services and reduces government agency costs.	Consultation with public agency officials, and surveys of clients, to determine the role transit provides in supporting public service goals.
Increased productivity	Increased education and employment participation by non-drivers.	Survey transit users to determine the portion that rely on transit for education and employment.
Reduced high risk drivers	Inadequate travel options force high risk motorists to continue driving and prevent society from revoking driving privileges.	Survey experts and the public to determine whether inadequate travel options are increasing the amount of high risk driving.
Equity	Degree to which transit helps achieve equity objectives such as basic mobility for physically, economically and socially disadvantaged people.	Portion of transit users who are economically, socially or physically disadvantaged, the importance of mobility in ameliorating these inequities, and the value that society places on increased equity.
Option Value	The value of having an option for possible future use.	Transit service quality. The value society places on basic mobility. EcoNorthwest and PBQD (2002) describe ways to quantify transit option value.

Public transit provides several types of mobility benefits. These are affected by the degree that transit service is available to non-drivers, and the amount of increased mobility it provides.

Efficiency Benefits

Efficiency benefits consist of savings and other benefits that result when transit substitutes for automobile travel. These include vehicle cost savings, avoided chauffeuring, congestion reductions, parking cost savings, increased safety and health, energy conservation and pollution emission reductions.

These benefits are affected by the magnitude and type of automobile travel reduced. For example, urban-peak automobile travel reductions tend to provide greater benefits than reductions in urban off-peak or rural travel, due to greater reductions in traffic congestion, parking costs and other costs. As a city grows, these benefits become increasingly important as a cost effective way to reduce traffic congestion and parking problems, particularly to major commercial and employment centers such as downtown. These benefits increase if transit improvements and incentives are designed to attract discretionary riders (people who have the option of driving).

Except in large cities, most transit systems are designed primarily to provide basic mobility rather than efficiency benefits. Buses operate at times and locations where demand is low, and there are few incentives to attract discretionary travelers to transit. As a result, average occupancy is relatively low, averaging about 5.2 passengers per bus-mile (excluding demand response services), and so may appear inefficient when evaluated based on average operating costs, energy consumption or pollution emissions per passenger-mile. But transit demand tends to be concentrated on the corridors with the greatest traffic congestion and parking problems, so transit can provide benefits in these areas. The incremental cost of accommodating additional passengers is low, so strategies which increase average transit vehicle occupancy increase efficiency benefits. Put differently, if buses have empty seats, there is minimal cost and large potential benefits if they can be filled by travelers who would otherwise drive.

The efficiency benefits of transit improvements reflect the factors described below.

- Strategies that increase bus mileage on routes with low load factors (for example, increasing mileage on suburban and off-peak routes) may increase some costs, such as total energy consumption and pollution emissions.
- Strategies that shift travel from automobile to transit while increasing average vehicle occupancies (that is, they help fill otherwise empty buses) tend to reduce overall costs.
- Strategies that improve transit vehicle performance (for example, retrofitting older diesel buses with cleaner engines or alternative fuels, or creating busways that reduce congestion delays) tend to reduce specific costs.
- Strategies that create more accessible land use patterns and less automobile-dependent transportation systems, provide large benefits by reducing overall per capita vehicle travel.

Specific efficiency benefits and how they can be measured are discussed below.

Vehicle Cost Savings

Automobile to transit shifts provide vehicle cost savings to consumers. The magnitude of these savings depends on factors such as the type of mileage reduced and whether vehicle ownership declines ("Vehicle Costs," Litman 2009; Polzin, Chu and Raman 2008).

At a minimum, shifting from driving to transit saves fuel and oil, which typically total about 10¢ per vehicle-mile reduced. In addition, depreciation, insurance and parking costs are partly variable, since increased driving increases the frequency of vehicle repairs and replacement, reduces vehicle resale value, and increases the risks of crashes, traffic and parking citations. These additional mileage-related costs typically average 10-15¢ per mile, so cost savings total 20-25¢ per mile reduced. Savings may be greater under congested conditions, or where transit users avoid parking fees or road tolls.

Consumers save more if transit allows vehicle ownership reductions. For example, if improved transit services allow 10% of users to reduce their household vehicle ownership (e.g., from two vehicles to one), the savings average $300 annually per user (assuming a second car has $3,000 annual ownership costs), or 6¢ per transit travel passenger-mile (assuming 20 miles of transit travel a day, 250 days per year) in addition to vehicle operating cost savings. Reduced vehicle ownership can reduce residential parking costs. Cumulative savings can be large. McCann (2000) found that households in communities with good transit use save an average of about $3,000 annually on transportation costs. Litman (2004) found annual transportation cost savings of about $1,300 per household in cities with well-established rail transit systems compared with cities that lack rail.

Measuring Vehicle Cost Savings

Table 15 summarizes various categories of savings that can result from reduced automobile ownership and use. These savings typically total 30¢ per off-peak vehicle-mile and 40¢ per urban-peak vehicle-mile when automobile travel shifts to public transit. Other researchers recommend using 40-50¢ per vehicle mile reduced (ECONorthwest and PBQD 2002). Even greater savings result if transit oriented development allows households to reduce their vehicle ownership (Polzin, Chu and Raman 2008).

Table 15 **Potential Vehicle Cost Savings** ("Vehicle Costs," VTPI 2003)

Category	Description	How It Can Be Measured	Typical Values
Vehicle Operating Costs	Fuel, oil and tire wear.	Per-mile costs times mileage reduced.	10-15¢ per vehicle-mile. Higher under congested conditions.
Long-Term Mileage-Related Costs	Mileage-related depreciation, mileage lease fees, user costs from crashes and tickets.	Per-mile costs times mileage reduced.	10¢ per vehicle-mile.
Special Costs	Tolls, parking fees, Parking Cash Out, PAYD insurance.	Specific market conditions.	Varies.
Vehicle Ownership	Reductions in fixed vehicle costs.	Reduced vehicle ownership times vehicle ownership costs.	$3,000 per vehicle-year.
Residential Parking	Reductions in residential parking costs due to reduced vehicle ownership.	Reduced vehicle ownership times savings per reduced residential parking space.	$100-1,200 per vehicle-year.

Reducing automobile travel can provide a variety of consumer savings. (2001 U.S. dollars).

Avoided Chauffeuring

Chauffeuring refers to additional automobile travel specifically to carry a passenger. It can also include taxi trips. It excludes ridesharing, which means additional passengers in a vehicle that would be making a trip anyway. Some motorists spend a significant amount of time chauffeuring children to school and sports activities, family members to jobs, and elderly relatives on errands. Such trips can be particularly inefficient if they require drivers to make an empty return trip, so a five-mile passenger trip produces ten miles of total vehicle travel (Litman 2015a).

Drivers sometimes enjoy chauffeuring, for example, when it gives busy family members or friends time to visit. However, chauffeuring can be an undesirable burden, for example, when it conflict with other important activities. Transit service allows drivers to avoid undesirable chauffeuring trips while still providing enjoyable trips.

Measuring Chauffeuring Cost Savings

This benefit can be estimated based on the number of chauffeured automobile trips shifted to transit, times vehicle cost and driver travel time savings. Rider surveys and experience with service disruptions indicate that in typical conditions, 10-40% of transit trips would otherwise be made as automobile passengers (FTA 2002), and about half of these are rideshare trips (passengers in vehicles that would be making the trip anyway), meaning that 5-20% of transit trips substitute for chauffeured trips. Travel and rider surveys can help determine the portion of such trips in a particular situation.

Assuming these average 5 miles in length per trip and take 20 minutes (including waiting time and empty backhauls), travel time costs average $12.00 per driver hour (assuming a mixture of high- and low-stress driving conditions), driver travel time savings are about $4.00 per chauffeured trip avoided or 80¢ per passenger-mile shifted to transit, including 25¢ per mile vehicle costs total $5.25 per trip, or $1.05 per chauffeured vehicle-mile. Avoided taxi trips cost savings can be based on average taxi fares for those trips, which average about $2.25 per mile.

Congestion Reduction

Traffic congestion consists of the incremental delay, stress, vehicle operating costs and pollution that each additional vehicle imposes on other road users. A typical urban street lane can accommodate up to 500-1,000 vehicles per hour, and a typical highway lane up to 1,800-2,300 vehicles per hour. Congestion develops when traffic volumes approach these limits. Once roads reach capacity even small traffic reductions can significantly reduce delays. For example, reducing traffic volumes from 90% to 85% of maximum road capacity can reduce delay by 20% or more ("Congestion Costs," Litman 2009).

Congestion reduction benefits can be difficult to evaluate because urban traffic tends to maintain equilibrium: traffic volumes grow until congestion delay discourages additional peak-period trips. As a result, the road space created by roadway expansions or marginal shifts from driving to transit is often soon be filled with latent demand. However, transit service improvements can reduce the point of equilibrium, reducing total congestion delays, as discussed in the box on the following page. Transit services are most effective at reducing congestion if they:

- Offer high quality service (relatively convenient, fast, frequent and comfortable) that is attractive to discretionary travelers (who would otherwise drive).
- Serve a major share of major urban corridors and destinations.
- Be grade separated (with bus lanes or separated rail lines), so transit travel is relatively fast compared with driving under congested conditions.
- Be relatively affordable.

Care is needed to accurately evaluate transit congestion impacts (Litman 2009; Anderson 2013; Aftabuzzaman, Currie and Sarvi 2010 and 2011). Indicators such as *roadway level-of-service* or a *travel time index* measure roadway congestion *intensity*, but fail to account for factors that affect congestion exposure, the amount that people must drive during peak periods (Cortright 2010). Congestion intensity indicators are appropriate for making short-term decisions, such as how to make an urban-peak trip, but planning decisions should be evaluated based on *per capita congestion costs* (Litman 2014b). Congestion analysis is complicated by confounding factors: congestion and transit ridership both tend to increase with city size, density, transit service quality and employment rates (year-to-year, traffic congestion and transit ridership tend to increase with a business cycle). Analyses that fail to account for these factors cannot accurately indicate how transit ridership affects congestion. Studies that do account for these impacts generally indicate that public transit service improvements can reduce traffic congestion intensity and costs (Nelson\Nygaard 2006).

Most congestion cost studies ignore non-motorized travel impacts (called the *barrier effect* or *severance*, Litman 2009) although they can be significant since urban streets often have as many pedestrians and cyclists as motorists. This suggests that transit improvements that reduce vehicle traffic volumes provide additional benefits by improving pedestrian mobility and safety.

How Public Transit Reduces Traffic Congestion (Litman 2014a)
Urban traffic congestion tends to maintain equilibrium, it grows to the point that congestion delays discourage additional peak-period vehicle trips. If congestion increases, some travelers change route, destination, travel time and mode to avoid delay, and if it declines they take more peak-period trips. This is sometimes called the *Downs-Thompson Paradox*. Reducing the point of equilibrium is the only way to reduce long-term congestion.

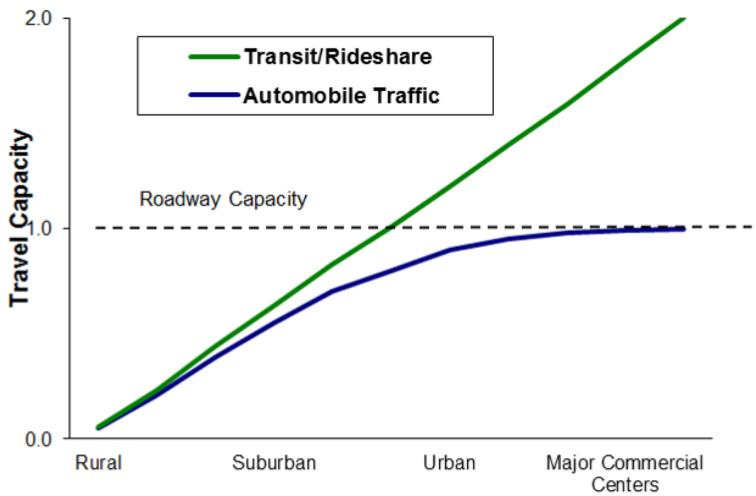
The quality of travel alternatives influences the point of congestion equilibrium: If alternatives are inferior, fewer motorists will shift mode, resulting in a higher equilibrium; if alternatives are attractive, motorists are more likely to shift modes, reducing the point of equilibrium. Improving travel options can therefore increase travel speeds for both travelers who shift modes and those who continue to drive.

To attract discretionary riders (travelers who have the option of driving), transit must be fast, comfortable, convenient and affordable. Grade-separated service (such as rail on separate right-of-way or busways) provides a speed advantage that can attract discretionary riders. When transit is faster than driving, a portion of travelers shift mode until the highway reaches a new equilibrium (that is, until congestion declines to the point that transit is no longer faster). As a result, the faster the transit service, the faster the traffic speeds on parallel highways. Several studies find that door-to-door travel times for motorists tend to converge with those of grade-separated transit (Mogridge 1990; Lewis and Williams 1999). The actual number of motorists who shift to transit may be relatively small, but is enough to reduce delays. Congestion does not disappear, but it never gets as bad as would occur if grade-separated transit service did not exist nearby.

Shifting traffic from automobile to transit on a particular highway not only reduces congestion on that facility, it also reduces vehicle traffic discharged onto surface streets, providing "downstream" congestion reduction benefits. For example, when comparing a highway widening with transit improvements, the analysis should account for the additional surface street traffic caused by the highway expansion that would be avoided if the same travelers arrive by public transit.

As cities grow, transit and ridesharing play an increasingly important role in providing mobility and reducing congestion and parking problems, as illustrated in Figure 4.

Figure 4 **Urbanization Impacts on Transit Use**



When roadways approach their maximum traffic capacity, transit and ridesharing carry an increasing portion of person-trips. In major commercial centers, a significant portion of peak-period travels use transit, vanpools or carpools.

Because transit riders tend to travel on congested urban corridors, they tend to have much larger congestion reduction impacts than their regional mode share. For example, although only 11% of Los Angeles commutes use transit, when a strike halted transit service for five weeks, average highway congestion delay increased 47%, and regional congestion costs increased 11% to 38% (Anderson 2013), with particularly large speed reductions on rail transit corridors (Lo and Hall 2006), indicating that higher quality, grade-separated service is particularly effective at reducing congestion.

Adler and van Ommeren (2016) analyzed the impacts of citywide public transit strikes in Rotterdam, in The Netherlands. They found that a strike causes only marginal weekday congestion increases on the highway ring road (0.017 minutes per kilometer) but substantially on inner city roads (0.224 minutes per kilometer) with larger impacts during rush hour and virtually no impacts on weekends. They calculate that public transit's congestion relief benefit is equivalent to about half of its subsidy.

Similarly, research by Laval, Cassidy and Herrera (2004) indicates that a disruption of the Bay Area Rapid Transit (BART) system would cause severe traffic problems on area roads. Without BART service, Bay Bridge congestion would create morning backups stretching 26 miles with 9 miles per hour speeds, and afternoon backups stretching 31 miles with 11 miles per hour speeds. "We found that the peak morning rush hour will go from two hours starting at 7 a.m. to a staggering seven hours, so half the workday would be gone by the time drivers step out of their cars," said coauthor Michael Cassidy.

Aftabuzzaman, Currie and Sarvi (2010 and 2011) also analyze the role that public transit can play in reducing roadway traffic congestion. Using factor analysis they identify and quantify three ways that high quality public transit reduces traffic congestion: (1) transit-oriented factor, (2) car-deterrence factor, and (3) urban-form factor. Regression analysis indicates that the car-deterrence factor makes the greatest contribution to reducing traffic congestion, followed by transit-oriented factor and urban-form factor. They conclude that high quality public transit provides $0.044 to $1.51 worth of congestion cost reduction (Aus$2008) per marginal transit-vehicle km of travel, with an average of 45¢, with higher values for circumstances with greater degrees of traffic congestion, and if both travel time and vehicle operating costs are considered.

Ewing, Tian and Spain (2014) investigated the effects that Salt Lake City's University TRAX light-rail system has on vehicle traffic on parallel roadways. This rail system began operating in 2001 and expanded over the following decades with new lines and stations. It currently carries about 53,000 average daily passengers. The study found significant declines in roadway traffic after the LRT line was completed, despite significant development in the area. The study estimates that the LRT line reduced daily vehicle traffic on the study corridor about 50%, from 44,000 (if the line did not exist) to 22,300 (what currently actually occurs).

The Texas Transportation Institute (TTI) *Urban Mobility Reports* estimate the congestion reductions provided by public transit, based on the estimated increase in urban-peak traffic volumes that would occur if current transit trips shifted to automobile travel. Harford (2006) used data from the TTI reports to estimate the monetized value of transit congestion reductions, plus pollution reductions and user consumer surplus gains; he estimated that these benefits provide a benefit–cost ratio of 1.34, with lower values in smaller urban areas and higher values in larger urban areas.

Commuters Strike Out Without RTD
by Diane Carman, *Denver Post* Staff Columnist, 15 April 2006

At the risk of sounding insensitive to the striking workers' families living without paychecks or the folks who had to cancel appointments because they didn't have a ride to the doctor's office, a week without RTD was a good thing for Denver. Let's face it, there's nothing like a work stoppage to focus our attention on things we take for granted.

So what did the metro area learn from a week without RTD, I mean except for the numbing realization that gloves are a critically important accessory when bicycling to work in 40-degree weather?

> Lesson 1: Without RTD, parking in Denver is a lot like parking in New York City - scarce, cutthroat and expensive. Overnight, normally polite motorists were transformed into snotty, aggressive parking-place sneaks. And those who normally would never dream of paying $10 for a spot suddenly were bragging about finding $25 bargains outside the baseball stadium.
>
> Lesson 2: Downtown businesses are doomed without mass transit. As regular bus riders took to their cars, driving downtown became a test of patience. I sat through three light changes at East Colfax Avenue and Grant Street on Monday evening. That was enough gridlock for me. I biked to work the rest of the week and otherwise avoided downtown.
>
> Lesson 3: Denver Public Schools may be in a financial pinch now, but things would be desperate if not for RTD providing transportation for high-school students in lieu of yellow buses. The district even had to schedule makeup sessions for federally mandated tests because of high absentee rates for students who rely on RTD to get to school.
>
> Lesson 4: Sleepless in suburbia is no way to live. The heavy traffic on the major routes through town caused an average 30-minutes increase in commuting times.
>
> Lesson 5: The anti-FasTracks crowd was wrong. Light rail rocks. When the trains stopped running, traffic went nuts, especially along the popular southwest corridor light-rail line. Those 37,000 riders who board the trains each day may be doing it for the comfort, convenience, the low cost or, as the vice president has famously suggested, a sense of personal virtue. Whatever. When they were forced back into their cars, it created havoc for both the virtuous and shameless alike.
>
> Lesson 6: It could have been a lot worse. The RTD strike happened during a week of mostly warm, dry spring weather. To fully appreciate life without mass transportation, Denver commuters must visualize the same situation with 10 inches of snow, freeway traffic at a standstill and the bicycle option available only to the seriously hard-core. We got off easy.

Finally, the governor, a.k.a. Twelve-Lane Bill, was wrong back in 2004 when he said the impact of mass transit on traffic congestion is “imperceptible.” Even if the taxpayers were willing to build the highways necessary to carry all the cars, and motorists were willing to pay for more toll roads, and even if we all could abide greater dependence on $3-a-gallon gasoline and $20-a-day parking spaces, without mass transit we'd be, um, freaked. We'd spend hours mired in gridlock, especially around entertainment and sports events. Elderly citizens would be housebound. The poor would have few options for getting to work. The air would be more toxic, the community less hospitable, the economy less vital.

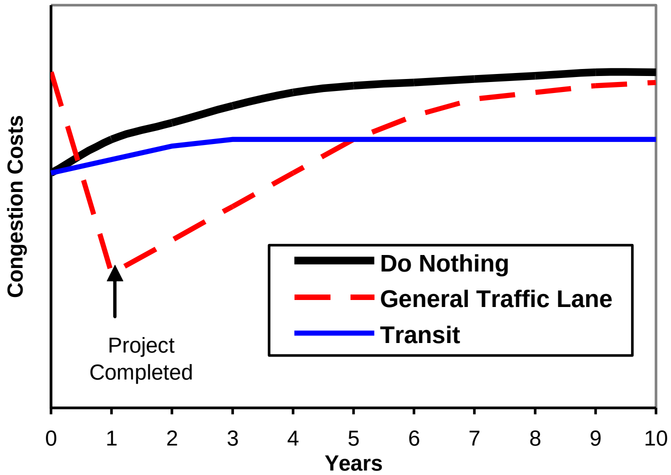
Nelson, et al (2006) used a regional transport model to estimate Washington DC transit system benefits to users, and congestion-reduction benefits to motorists. They found that rail transit generates congestion-reduction benefits that exceed rail subsidies, and the combined benefits of rail and bus transit significantly exceeds total transit subsidies. Their study overlooked other benefits such as parking cost savings, crash and emission reduction benefits, and so understates total social benefits. Similarly, Garrett (2004) found evidence that transit slowed the growth in roadway congestion in some U.S. cities after they established light rail systems. Although all experienced congestion growth between 1980 and 2000, this growth tended to decline after the light rail systems started operation. For example, in Baltimore the roadway congestion index increased on average 2.8% annually before light rail service started in 1992, but only 1.5% after; Sacramento's congestion increased 4.5% annually before and 2.2% after light rail service started in 1987; St. Louis congestion increased 0.89% before and 0.86% after light rail service started in 1993; and Dallas experienced no change after rail service started in 1996.

Congestion pricing (road tolls that are higher during congested periods) effectiveness tend to increase with transit service quality. One major study found the elasticity of Seattle-area home-to-work vehicle trips to be approximately -0.04 (a 10% price increase causes automobile commute trips to decline 0.4%), but increased four-fold to -0.16 (a 10% price increase causes automobile commute trips to decline 1.6%) for workers with the 10% best transit service (PSRC 2008). Another study found that, given financial incentives to reduce driving, households in denser transit-accessible neighborhoods reduced their peak-hour and overall travel significantly more than comparable households in automobile dependent suburbs, and that congestion pricing increase the value of more accessible and multi-modal locations (Guo, et al. 2011). These indicate that high quality public transit service significantly reduces the price (road toll or parking fee) required to achieve congestion reductions, a reflection the smaller incremental cost to travelers (less consumer surplus loss) when they shift from driving to high quality public transit, and a direct financially benefit to motorists on roadways with congestion pricing.

Winston and Langer (2004) found that both motorist and truck congestion costs in a city decline as rail transit expands, but congestion costs increase with bus transit mileage, apparently because buses are less effective at attracting motorists, contribute to congestion, and do little to increase land use accessibility. Other studies indicate that busways (as opposed to buses operating in mixed traffic) can reduce congestion on parallel roadways. Liu (2005) found that after the San Fernando Valley Orange Line busway began operation in 2005, peak-hour traffic speeds on the 101 Freeway increased about 7% (from 43 to 46 average miles-per-hour), morning traffic speeds below 35 mph declined about 14%, and daily freeway congestion began about 11 minutes later on average (shifting from 6:55 a.m. to 7:06 a.m. on average).

Highway and transit improvements provide congestion reduction benefits at different rates of time (Figure 5). If travel demand is growing and no action is taken, congestion will increase until it limits further peak-period vehicle trips. Adding a general traffic lane increases congestion during the construction period, then congestion decline significantly, but traffic grows over time so congestion eventually returns to its previous level. Grade-separated transit may initially seem to provide little congestion reduction, but roadway congestion increases much less than would otherwise occur because increased highway delays makes transit faster than driving and so attracts an increasing portion of travelers. Although roadway congestion never disappears, it never gets as bad as would otherwise occur. As a result, shorter-term analysis tends to favor roadway expansion, while longer-term analysis tends to favor transit improvements.

Figure 5 **Road Widening Versus Transit Congestion Impacts**



After a general traffic lane is completed congestion declines, but grows rapidly due to generated traffic. Grade separated transit and HOV systems initially provide less congestion reduction, but their benefits increase as roadway congestion grows, so they become relatively faster.

Critics sometimes argue that, because public transit travel tends to be slower than automobile travel, travelers who shift from driving to alternative modes are worse off. However, several factors must be considered when comparing transit and automobile speeds.

Av*erage* travel speeds are irrelevant, what matters is their travel speeds on a particular corridor. Automobile speeds tend to be lower and commute travel times longer in large cities where transit (particularly rail transit) is most common. For example, although transit service may be relatively infrequent and slow to some destinations, it tends to be more frequent, and if grade-separated, relatively fast, on the congested urban corridors where transit commuting is most common.

Even if transit travel takes more time than driving, travelers may not consider this an additional cost if it is less stressful than driving. Passengers using high-quality transit (safe, clean, comfortable and reliable vehicles), can read, work and rest, so their unit costs are relatively low (Litman 2008a and 2008b). If quality transit is available, travelers will select the mode that best meets their needs and preferences (Wener, Evans and Boately 2004). This maximizes transport system efficiency (since shifts to transit reduce congestion) and consumer benefits (since consumers can choose the option they prefer).

Measuring Vehicle Congestion Reduction Benefits

There are several ways to measure congestion reduction benefits that result from reduced vehicle traffic (TRB 1997). One approach is to model total passenger travel time with and without a transit program, and calculate the travel time and vehicle operating cost savings (ECONorthwest and PBQD 2002). The Texas Transportation Institute uses a similar method to calculate congestion reduction value of transit (TTI 2003). Another approach is to calculate the costs of increasing roadway capacity to achieve a given congestion reduction, and divide that by the number of peak-period vehicle-miles. These methods require modeling each option, and current transportation models are often not very accurate at predicting the travel impacts of a transit project.

An easier approach is to assign a dollar value to reduced vehicle travel, usually estimated at 10-30¢ per urban-peak vehicle-mile, and more under highly congested conditions ("Congestion Costs," Litman 2009; Aftabuzzaman, Currie and Sarvi 2010). Congestion benefits should reflect net impacts, that is, the reduction in automobile trips minus any additional transit impacts. Under typical conditions buses impose congestion costs equivalent to 1.5 cars on highway and 4.5 cars on surface streets, so net benefits occur when more than about three trips shift from automobile to transit. For example, if a bus carries 16 passengers under urban-peak conditions, and 8 of the passengers would otherwise travel by automobile (either driving themselves or chauffeured), the congestion reduction benefit is (8-3) x $0.25 = $1.25 per vehicle-mile.

Where transit provides significant travel time savings compared with driving on parallel highways (for example, with grade-separated rail transit or busways) it is possible to calculate the resulting reduction in congestion delays. For example, if average door-to-door travel times by automobile are 30-minutes per peak-period trip, and a proposed transit service will provide 25-minute average trip times, the transit service can be expected to reduce average travel times by approximately 5-minutes per trip for all users. Travel time cost values can be applied ("Travel Time Costs," Litman, 2003; Aftabuzzaman, Currie and Sarvi 2010).

How congestion is measured affects evaluation conclusions. Indicators that measure the *intensity of congestion* (such as roadway Level-of-Service) or the portion of *driving* that occurs under congested conditions, ignore the congestion reduction benefits of travel by alternative modes and more accessible land use. These indicators imply that congestion declines if uncongested vehicle-mileage increases. Congestion impact evaluation also depends on the scale of analysis. For example, transit oriented development may increase local congestion (within a few blocks), because it increases neighborhood density, but regional congestion can decline due to less traffic between neighborhoods. Indicators of *per-capita* congestion costs recognize the congestion reduction benefits of improved transport alternatives (STPP 2001). Measuring congestion in terms of roadway level-of-service, and failing to consider the effects of generated traffic tends to exaggerate the congestion reduction benefits of urban roadway capacity expansion, since within a few years latent demand fills much of the added capacity (Litman 2001).

A particular transit improvement may avoid the need for a specific highway project, in which case congestion reduction benefits can be calculated based on facility cost savings. For example, if roadway capacity expansion costs average $3.5 million per lane-mile, which can carry 2,000 peak-period vehicles, this averages about 37¢ per additional peak-period vehicle-mile (based on a 7% discount rate over 20 years, 255 annual commute days), plus about 3¢ per mile in operations expenses. Transit services that defer or avoid the need to expand road capacity by attracting 1,000 daily peak-period automobile trips on a 5-mile stretch provide $510,000 annual benefits (40¢ x 1,000 x 5 x 255 days).

Measuring Pedestrian Delay Reduction Benefits

Studies described in "Evaluating Nonmotorized Transport," (VTPI, 2003) and "The Barrier Effect" (Litman, 2003) indicate that barrier effect costs average about 2¢ per urban-peak car-mile, and about 1.3¢ under urban off-peak conditions. As with vehicle congestion, a bus represents about 3 passenger car equivalents.

Combined Vehicle and Pedestrian Congestion Costs

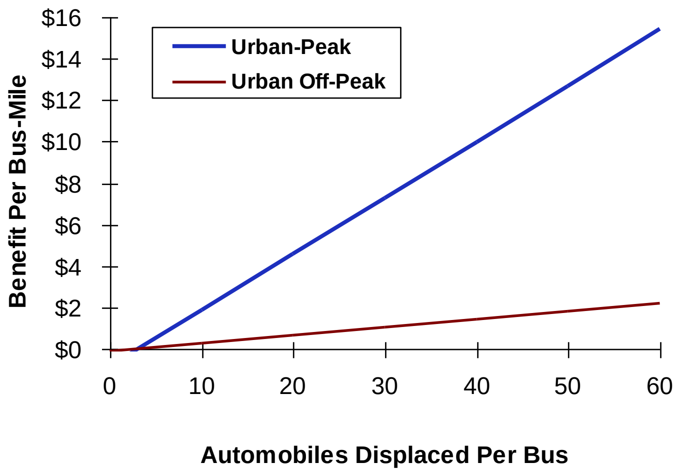
Table 17 shows the recommended congestion cost values.

Table 17 **Recommended Congestion Cost Values** (Per Vehicle-Mile)

	Urban Peak	Urban Off-Peak
Vehicle Congestion Costs	25¢	2.5
Pedestrian Congestion Costs	2¢	1.3¢
Total Congestion Costs	*27¢*	*3.8¢*

Figure 6 illustrates the net congestion cost reduction benefits provided by shifts from automobile to bus transit under urban-peak and urban off-peak conditions.

Figure 6 **Congestion Reduction Benefits**



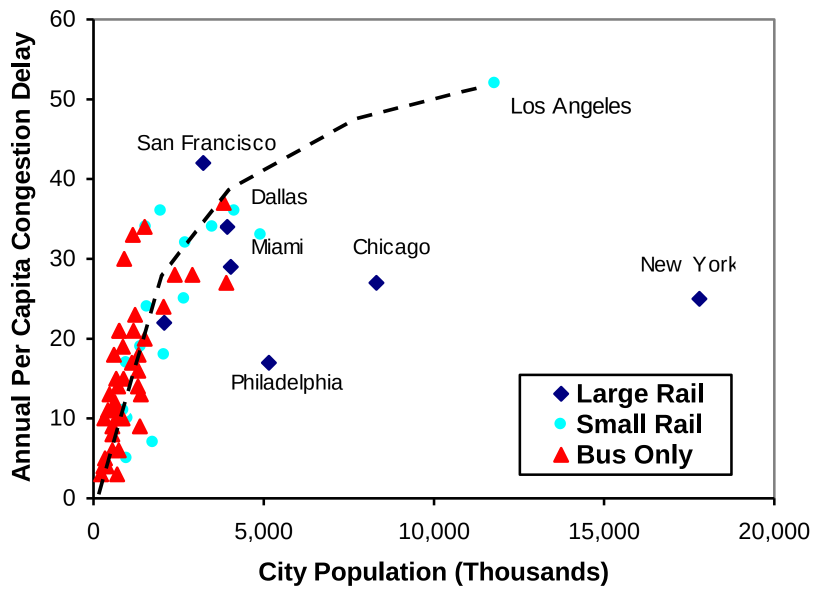
This figure indicates the net vehicle and pedestrian congestion reduction benefits caused by shifts from automobile to buses under urban-peak and urban off-peak conditions.

Buses typically carry 40-60 passengers under congested conditions (i.e., urban-peak travel in the primary travel direction), and rail transit vehicles even more (see Beamguard, 1999 for photos comparing the road space used by bus patrons, motorists and cyclists). Peak period transit service that carries 4,000 passengers an hour on highways or 1,000 passengers an hour on surface streets is approximately equal to one additional traffic lane, assuming that half of transit passengers would otherwise drive an automobile. This equals 20 to 80 buses per hour carrying an average of 50 passengers.

An indication of the congestion reduction benefit of transit is the significant increases in traffic congestion that often occur during transit strikes, even if only a small portion of transit passengers shift to driving alone (van Exel and Rietveld 2001). For example, a 1974 Los Angeles bus strike caused a 5-15 minute increase in congestion delay on one major freeway, although less than 3% of total regional trips were previously made by transit, and only about half of transit users shifted to driving (ibid).

Even a relatively small shift from driving to grade-separated transit can reduce roadway congestion delays. Comparisons between cities indicates that total traffic congestion delay tends to be lower in areas with good transit service, even though transit only carries a relatively small portion of total regional passenger travel (STPP, 2001; Litman, 2004a).

Figure 7 **Traffic Congestion** (Litman 2004a)



In cities that only have bus transit or relatively small rail systems traffic congestion delay tends to increase with city size, as indicated by the dashed curve. But cities with large, well-established rail transit systems do not follow this pattern. They have substantially lower congestion costs compared with comparable size cities. As a result, New York and Chicago have about half the per capita congestion delay as Los Angeles.

Parking Cost Savings

Shifts from automobile to transit travel reduce parking costs. Reduced vehicle ownership reduces residential parking demand (including on-street parking demand in residential areas), and reduced vehicle trips reduce non-residential parking demand, such as commercial parking requirements. This benefit can manifest itself as user cost savings where parking is priced, reduced parking congestion and increased convenience to motorists, and reductions in the need for businesses and governments to subsidize parking facilities. Reduced parking demand can also provide indirect benefits by reducing the amount of land needed for parking facilities, allowing more clustered and infill development. These land use benefits are discussed in more detail in a later chapter.

Measuring Parking Cost Savings

Parking cost savings can be calculated by multiplying reduced automobile round trips times average cost per parking space. These values will vary depending on conditions. Parking tends to be expensive and in limited supply under urban-peak conditions where shifts from driving to transit are most common, so transit tends to provide significant parking cost savings. In suburban and rural areas, parking may be inexpensive and abundant so there is less short-term benefit. Where parking is priced, parking cost savings go to users rather than businesses. Cambridge Systematics (1998) provides detailed instructions for calculating parking cost savings.

Table 18 illustrates typical parking facility costs. Park & ride trip savings consist of the difference in parking costs between a park & ride lot and worksites. Transit vehicle parking costs are incorporated into operational expenses. Transit may increase parking costs where bus stops displace on-street parking spaces.

Table 18 **Typical Parking Facility Costs** ("Parking Evaluation," VTPI, 2003)

Type of Facility	Land Costs	Land Costs	Construction Costs	O & M Costs	Total Cost	Daily Cost
	Per Acre	*Per Space*	*Per Space*	*Annual, Per Space*	*Annual, Per Space*	*Daily, Per Space*
Suburban, On-Street	$0	$200	$2,000	$200	$408	$1.36
Suburban, Surface, Free Land	$50,000	$0	$2,000	$200	$389	$1.62
Suburban, Surface	$50,000	$455	$2,000	$200	$432	$1.80
Suburban, 2-Level Structure	$50,000	$227	$10,000	$300	$1,265	$5.27
Urban, On-Street	$250,000	$1,000	$3,000	$200	$578	$1.93
Urban, Surface	$250,000	$2,083	$3,000	$300	$780	$3.25
Urban, 3-Level Structure	$250,000	$694	$12,000	$400	$1,598	$6.66
Urban, Underground	$250,000	$0	$20,000	$400	$2,288	$9.53
CBD, On-Street	$2,000,000	$8,000	$3,000	$300	$1,338	$4.46
CBD, Surface	$2,000,000	$15,385	$3,000	$300	$2,035	$6.78
CBD, 4-Level Structure	$2,000,000	$3,846	$15,000	$400	$2,179	$7.26
CBD, Underground	$2,000,000	$0	$25,000	$500	$2,645	$8.82

This table illustrates the costs of providing a parking space under various conditions. Cost recovery prices must be even higher to account for profits and load factors, if not every space is rented every day. (CBD = Central Business District.)

If an area has abundant parking supply, reduced driving may provide little short term parking cost savings, since the spaces will simply be unoccupied. But over time reduced parking demand usually provides economic benefits, by avoiding the need to increase supply or allowing facilities to be leased, sold or converted to other uses. It can also provide environmental and aesthetic benefits by reducing the amount of land paved for parking facilities. Cambridge Systematics (1998) and Litman (2009) provide guidance for calculating parking cost savings under various conditions.

Table 19 indicates recommended values for calculating parking cost savings that result when automobile travel shifts to public transit. Park & Ride trip savings consist of the difference in parking costs between Park & Ride and worksite parking facilities. These costs are measured per round-trip, rather than per vehicle-mile as with most other costs. These can be converted to per-mile units by dividing by average round trip lengths, which is currently about 7 miles, but may be higher for some transit trips, such as commuter express services.

Table 19 **Typical Parking Cost Values** (Per Round-Trip)

	Small City	Medium City	Large City
Commute Trips	$3.00	$6.00	$9.00
Other Trips	$2.00	$4.00	$6.00
Average	*$2.50*	*$5.00*	*$7.50*

This table reflects estimated average avoided parking costs for a trip shifted from driving to public transit, depending on the destination and trip type.

Dividing these values in half to reflect individual trips, and assuming that most peak-period trips are to urban destination, and off-peak trips tend to be to more suburban destination, default values are $2.18 per peak trip and $0.84 per off-peak trip. The higher cost of peak-period trips also reflects the fact that they tend to be commute trips, in which a car would be parked all day, while more off-peak trips are for errands with shorter parking requirements.

Safety, Health and Security Impacts

Transit use can affect safety, health and security in various ways (CDC 2010; Litman 2015).

Traffic Safety

Transit is a relatively safe travel mode, as indicated in Table 20. Transit passengers have about one-tenth the fatality rate as car occupants, and even considering risks to other road users transit causes less than half the total deaths per passenger-mile as automobile travel. Since risks to other road users is hardly affected by increased occupancy, average crash costs tend to decline with increased vehicle occupancy.

Table 20 **U.S. Transport Fatalities, 2001** (BTS Tables 2-1 and 2-4; APTA; TRB 2002)

	Fatalities			Veh. Travel	Occupants	Pass. Travel	Fatalities Rate	
	User	Others	Totals	Bil. Miles		Bil. Miles	Users	Others
Passenger Car	20,320	3,279	23,599	1,628	1.59	2,589	7.9	1.3
Motorcycle	3,197	19	3,216	9.6	1.1	10.6	303	1.8
Trucks – Light	11,723	3,368	15,091	943	1.52	1,433	8.2	2.3
Trucks – Heavy	708	4,189	4,897	209	1.2	251	2.8	16.7
Intercity Bus	45		45	7.1	20	142	0.3	-
Commercial Air						-	0.3	
Transit Bus	11	85	96	1.8	10.8	19	0.6	4.4
Heavy Rail	25	6	31	0.591	24	14	1.8	0.4
Commuter Rail	1	77	78	0.253	37.7	9.5	0.1	8.1
Light Rail	1	21	22	0.053	26.8	1.4	0.7	14.8
Pedestrians	4,901	0	4,901	24.7	1	25	198	-
Cyclists	732	0	732	8.9	1	8.9	82.2	-

Table 21 compares crash fatality rates for various types of transit.

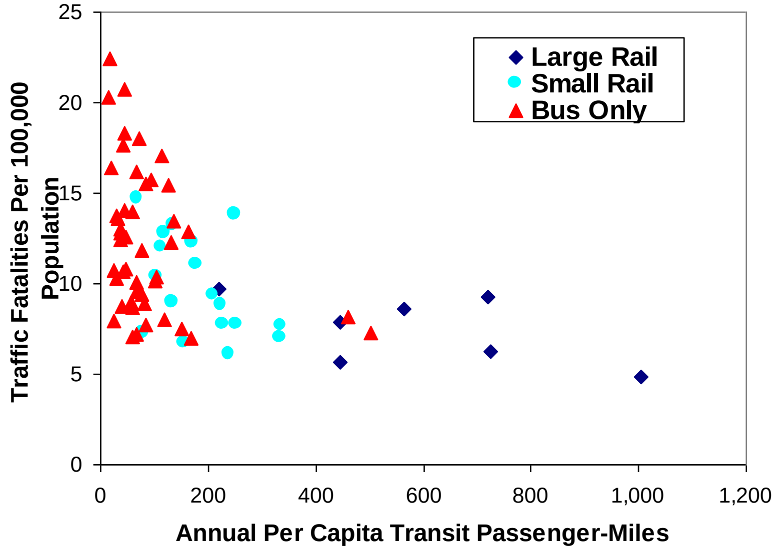
Table 21 **U.S. Transit Fatalities, 1999** (APTA 2001)

	Bus	Commuter Rail	Demand Response	Heavy Rail	Light Rail	Trolley Bus	Total
Fatalities (Excludes Suicides)							
Patrons	13	2	5	22	2	0	44
Employees	5	3	8	1	3	0	20
Other	86	68	3	3	8	1	169
Totals	*104*	*73*	*16*	*26*	*13*	*1*	*233*
Fatality Rate Per Billion Passenger Miles							
Patrons	0.61	0.23	6.15	1.71	1.66	0.00	0.98
Employees	0.24	0.34	9.84	0.08	2.49	0.00	0.44
Other	4.06	7.76	3.69	0.23	6.63	5.38	3.75
Totals	*4.90*	*8.33*	*19.68*	*2.02*	*10.78*	*5.38*	*5.17*

This table shows crash fatalities and fatality rates for various types of transit in the U.S.

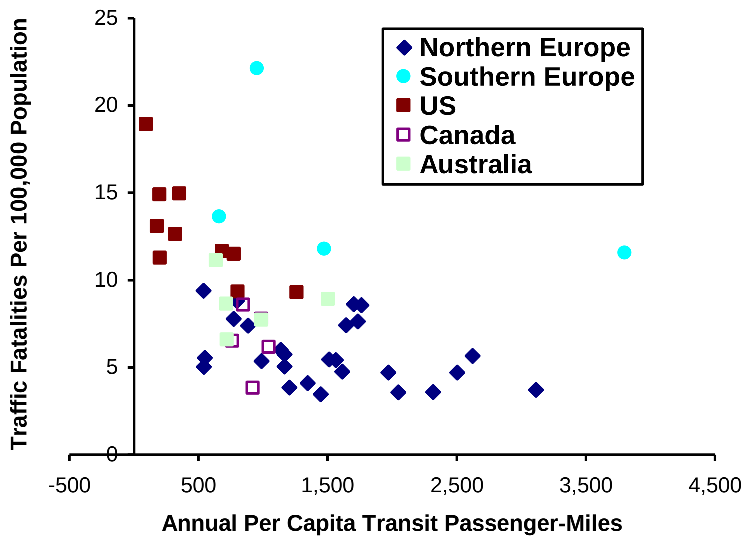
Figures 8 and 9 show U.S. and international data indicating declining per capita traffic fatalities with increased transit ridership. For additional discussion of transit safety impacts see Litman (2014 and 2016a) and Steer Davies Gleave (2005).

Figure 8 **Traffic Deaths** (Litman 2004a)



Per capita traffic fatalities tend to decline with increased transit ridership. Since cities with rail have higher average transit ridership, they tend to have fewer traffic fatalities. These values include deaths to transit passengers, automobile passengers, and pedestrians.

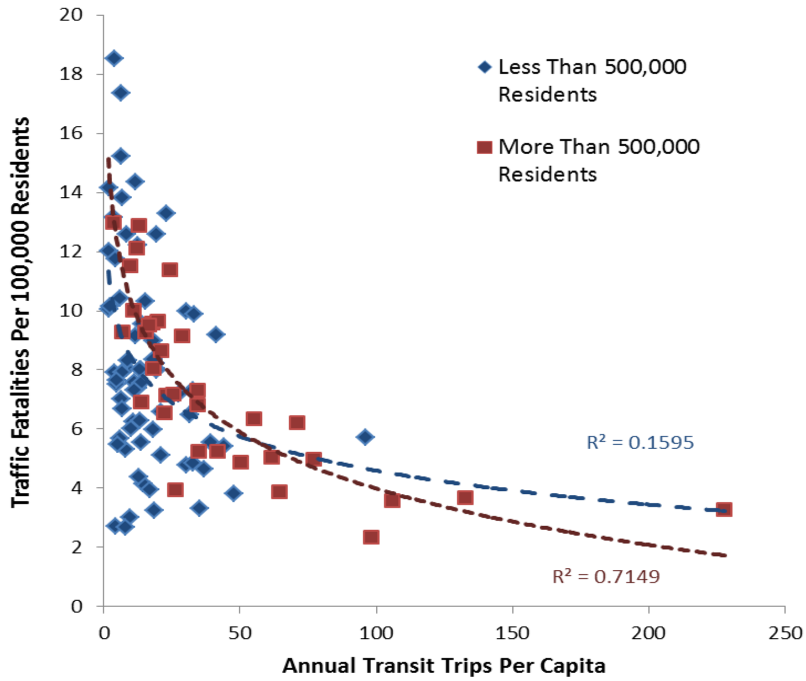
Figure 9 **International Traffic Deaths** (Kenworthy and Laube 2000)



International data indicate that crash rates decline with increased transit ridership.

To the degree that transit provides a catalyst for more accessible land use it tends to further increase road safety. Residents of transit-oriented communities have much lower per capita traffic fatality rates than residents of more automobile-dependent, sprawled communities, as indicated in the figures below (Litman 2016; Stimpson, et al. 2014).

Figure 10 **Traffic Deaths Versus Transit Ridership by City Size** (Litman 2016)



Per capita traffic death rates tend to decline as transit ridership increases.

For the 32 U.S. cities with more than 500,000 residents, the negative relationship between transit travel and traffic fatality rates is statistically very strong (R^2 is a very high 0.71). Nearly all large cities with less than 30 average annual transit trips per capita have more than 6 traffic fatalities per 100,000 residents, and nearly all with more than 50 transit trips per 100,000 have less than 6 fatalities per 100,000 residents.

Karim, Wahba and Sayed (2012) found that in the Vancouver region, crash rates decline significantly with bus stop density, percentage of transit-km traveled relative to total vehicle-kms traveled, and walking, biking, and transit commute mode share. Their modeling indicates that a strategic transport plan that encourages use of alternative modes tends to reduce total, severe, and property damage only collisions. Stimpson, et al. (2014) analyzed data from 100 U.S. cities over 29 years. Accounting for various geographic and economic factors, they found that each 10% increase in public transit's share of urban passenger travel is associated with 1.5% reduction in motor vehicle fatalities.

Evaluating intercity passenger rail, Lalive, Luechinger and Schmutzler (2012) found is that increasing rail service frequency by 10% reduced car and motorcycle use by nearly 3%, which reduced road accidents 4.6%.

Health Impacts

Inadequate physical activity contributes to cardiovascular disease, diabetes, hypertension, obesity, osteoporosis and some cancers. Many experts consider increased walking and cycling for daily transport one of the most practical ways to increase public fitness and health (AJHP 2003). Most transit trips include walking or cycling links, so transit travel tends to increase physical activity (Edwards 2008; Frank, et al. 2010; Litman 2010b). Public transit users average about three times as much walking as people who rely on automobile transport, nearly achieving the 22 daily minutes of moderate physical activity considered necessary for health (Besser and Dannenberg 2005; Weinstein and Schimek 2005; Wener and Evans 2007). Lachapelle, et al. (2011) found that transit commuters average 5 to 10 more daily minutes of moderate-intensity physical activity, and walked more to local services than people who do not use transit, regardless of neighborhood walkability. MacDonald, et al. (2010) found that a new light-rail system increased walking activity and reduced users' body weight and obesity rates. Similarly, Melbourne, Australia transit users average 41 daily minutes walking or cycling, five times more than the 8 minutes averaged by people who travel entirely by car (BusVic 2010). In addition, efforts to encourage transit and create transit oriented development often improve pedestrian and cycling conditions, which can further increase fitness and health.

Detailed studies indicate that public transportation users are more likely to walk, walk longer average distances, and are more likely to meet recommended physical activity targets by walking than non-transit users (Lachapelle and Frank 2009; Lachapelle 2010). The chance of meeting minimum walking targets (2.4 daily kilometers walked) increases by 3.87 for each transit trip taken, and is 2.23 times greater for commuters who use an employer-sponsored public transit pass. Table 22 summarizes one study's findings.

Table 22 **Walking Activity By Transit Use** (Lachapelle and Frank 2009)

	Transit User	No Transit Use
A least one walk trip	58.9%	9.3%
Average walk distance	1.72	0.16

Public transit users are more likely to take walking trips and walk farther than non-transit users.

Stokes, MacDonald and Ridgeway (2008) developed a model to quantify the public health cost savings resulting from a new light rail transit system in Charlotte, North Carolina. Using estimates of future riders, the effects of public transit on physical activity from increased walking, and area obesity rates, they simulated the potential yearly public health cost savings associated with this infrastructure investment. The results predict that the light rail system should save $12.6 million in public health costs over nine years.

Community Cohesion

Community cohesion refers to the quality of interactions among residents in a community. Many people consider cohesion a desirable community attribute, and it tends to increase neighborhood safety and security by helping neighbors cooperate and protect each other. Although many demographic and geographic factors can affect community cohesion, research indicates that, all else being equal, it tends to increase with neighborhood walkability, and therefore walkability factors such as the quality of sidewalks and street environments, and neighborhood services such as local shops, parks and schools. Public transit and transit-oriented development can provide a catalyst for this type of development.

For example, Kamruzzaman, et al. (2014) divided Brisbane, Australia neighborhoods into three categories based on their geographic factors including employment and residential density, land use diversity, intersection density, and public transport accessibility: transit-oriented development (TOD), transit adjacent development (TAD), and traditional suburbs. They found that TOD residents had a significantly higher level of trust and reciprocity and connections with neighbours compared with residents of TADs, which suggests that more compact and multi-modal development patterns foster social sustainability.

Personal Security

Personal Security refers to freedom from assault, theft and vandalism. Contrary to popular assumptions, transit users generally face lower overall crime risks than motorists, and all else being equal, per capita crime rates tend to decline as transit ridership increases in a community, probably due to a combination of improved surveillance, better policing and emergency response and improved economic opportunity for at-risk residents as summarized in Table 23.

Table 23 **How Transit improvements Can Reduce Urban Crime** (Litman 2014d)

Crime Risk Factor	Impacts of Improved Transport Options and Smart Growth
Poverty concentration	Mixed development encourages wealthy and poor residents to locate close together, which improves poor people's economic opportunities.
Natural surveillance and community cohesion	More businesses, residents and responsible (non-criminal) by-passers provide "eyes on the street" and helps build local social networks (neighbors who know and care about each other).
Vulnerable population's access to economic opportunity	Better access to education and employment for poor people (many of whom have limited access to a car).
Policing efficiency and response times	More compact, mixed density development increases policing efficiency and reduces response times.
Transit security	Increased ridership increases transit security public support and efficiency (lower costs per passenger), leading to expanded programs.
Motor vehicle ownership	Tends to reduce total vehicle ownership and associated crime risks

Improving transit services and transit-oriented development can reduce crime risk. This tends to reduce total per capita crime rates rather than simply shifting where crimes occur.

Measuring Safety, Health and Security Impacts

Karim, Wahba and Sayed (2012) provide information on methods for modeling the traffic safety impacts of specific policies and projects that affect transit use. Cole, et al. (2008) use Health Impact Assessment (HIA) methods to evaluate the health impacts of public transit fare increase and service reductions that reduce transit ridership.

Accident costs and health risks are often monetized for public policy analysis (Litman, 2003 and 2010b). Although an individual's life has essentially infinite value (most people would not give up their life for any size monetary payment), many private and public decisions involve tradeoffs between risk and financial costs. For example, when consumers decide whether to pay extra for safety options such as air bags, and when communities allocate funds for services such as law enforcement, fire protection, and medical services, they are essentially placing a price on marginal changes in human safety and health.

Traffic safety benefits are usually estimated at $2 to $5 million per fatality avoided, and smaller values for non-fatal crashes (Blincoe 1994). These values indicate that crash costs average 5-15¢ per automobile vehicle-mile (Miller 1991). This analysis uses 10¢ per vehicle mile as an average, of which 6¢ is internal (borne directly by vehicle occupants) and 4¢ is external (imposed on others). Since automobiles average 1.5 occupants, internal crash costs average 4¢ per passenger-mile.

Bus transit is estimated to impose external crash costs of 25.8¢ per vehicle-mile, based on 10¢ per mile automobile crash costs increased by the crash fatality ratio (39.6/13.4), of which 86% are to other road users. Risks to bus occupants are estimated at 0.5¢ per passenger-mile. Bus crash costs therefore average 28.9¢ per bus-mile, including risks to 5.2 average passengers and one driver, plus risks imposed on other road users. External risks do not increase with vehicle occupancy so unit costs decline as load factors increase. A bus with 10 passengers has total estimated crash costs of 31.3¢ per vehicle mile (25.8¢ + [0.5¢ x 10 passengers and a driver]), but doubling passengers only increases cost 16% to 36.3¢. A bus that replaces 10 automobile trips provides 68.7¢ per mile net safety benefits. Rail transit tends to impose even lower risks on passengers, and somewhat higher risks on non-occupants, although there is virtually no incremental risk from increased occupants in existing rail vehicles.

Transit provides greater safety benefits if it leverages additional traffic reductions, as described in the "Traffic Impacts" chapter of this guide. If each passenger-mile of transit travel reduces two to four vehicle-miles of travel, as some estimates indicate, each transit passenger-mile provides an additional 20-40¢ in crash cost savings.

Public health benefits from increased walking and cycling caused by transit use are difficult to measure and depend on the type of transit program implemented (Frank and Engelke 2000; AJHP 2003). To the degree that transit causes otherwise sedentary people to walk or bicycle an hour or more a week it provides significant health benefits. Because inadequate physical activity is such a large health risk, the public health benefits of increased transit use and more transit-oriented development may be comparable to transit's traffic safety benefits, although more research is needed to verify this.

Personal security impacts are difficult to quantify and vary depending on conditions. Litman (2014c) summarizes research on the factors that affect crime risks, relative crime risks of transit and automobile travel, and ways to improve transit security. In many situations, transit service improvements include efforts to increase security for both transit riders and non-users. For example, improved street lighting at transit stops and downtown security patrols implemented as part of transit oriented development can reduce a variety of risks.

Roadway Costs

Roadway costs include road maintenance, construction and land, and various traffic services such as planning, policing, emergency services and lighting. These costs are affected by vehicle weight, size and speed. Heavier vehicles impose more road wear, and larger and faster vehicles require more road space. These costs are not necessarily marginal. For example, a 10% reduction in vehicle traffic does not necessarily cause a 10% reduction in roadway costs. In urban areas with significant congestion problems and high land values, even a modest reduction in traffic volumes can provide large savings.

Transportation economists have performed numerous studies (called *cost allocation* or *cost responsibility* studies) that investigate the share of roadway costs imposed by various types of vehicles (FHWA, 1997; "Roadway Costs," Litman 2009). Most of these studies only consider current direct roadway construction and maintenance expenditures, and sometimes highway patrol services. Public costs not reflected in transport agency budgets are generally ignored, such as the opportunity costs of roadway land, traffic planning, local policing, emergency services, snow plowing and street lighting.

Where a transit project avoids or defers the need for major highway expansion the avoided costs can be considered a benefit of transit. Urban highway capacity expansion typically costs $4-10 million per lane-mile for land acquisition, lane pavement and intersection reconstruction (Cambridge Systematics 1992). This represents an annualized cost of $200,000-500,000 per lane-mile (assuming a 7% interest rate over 20 years). Divided by 2,000 to 6,000 additional peak-period vehicles during 250 annual commute days, and adjusting for inflation indicates typical costs $0.20 to $1.00 per additional peak-period vehicle-mile.

Measuring Roadway Costs and Benefits

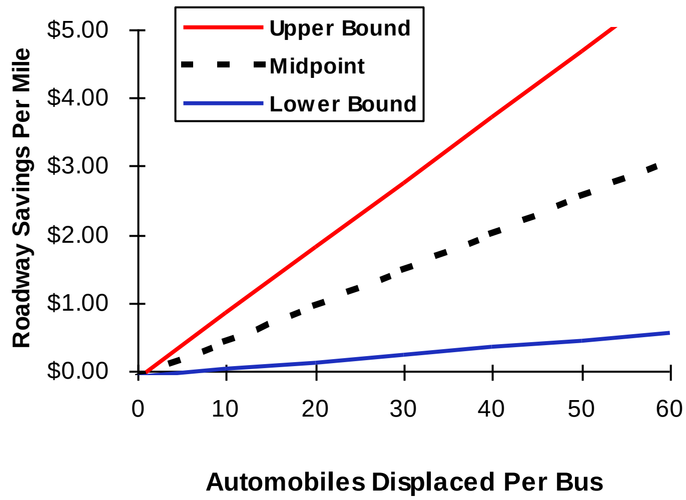
Considering only direct roadway expenditures, automobile use costs average 3.5¢ per mile and pays 2.6¢ per mile in fuel taxes, resulting in net costs averaging 0.9¢ (1.1¢ in 2003 dollars), while buses cost 11.8¢ per mile and pay 4.6¢ in taxes, resulting in 7.2¢ per mile net costs (8.9¢ in 2003 dollars) (FHWA 1997). Bus road wear costs are reduced if roadways are built for heavy vehicles, which is common on major roads to accommodate freight and service trucks. Roadway costs approximately double if the value of right-of-way land is also considered. Traffic service costs average 1-4¢ per automobile-mile.

Table 24 Roadway Cost Impacts of Automobile To Transit Shifts

Category	Description	Cost Impact
Road wear	Costs of road deterioration due to vehicle traffic, road repair costs, and increased strength during road construction to minimize deterioration.	Buses tend to increase these costs due to heavy axle weights.
Lane size	Incremental costs of wider lanes required to accommodate larger vehicles. Generally set to accommodate trucks and service vehicles.	Bus service may increase lane requirements in some locations.
Traffic services	Roadway planning, traffic controls, policing, lighting, etc.	Because these costs are based on traffic volumes, they tend to decline.
Traffic capacity	Costs of adding traffic lanes, improving intersections and other measures to accommodate increased traffic volumes and reduce traffic congestion.	Can significantly reduce these costs. This impact is reflected on congestion costs values.

Table 24 summarizes cost impacts of automobile to transit shifts. Where vans and small buses replace driving on local street, roadway cost savings typically average 1-3¢ per reduced automobile-mile. Where full-size buses operate on local streets, there is probably little or no roadway cost savings. Where buses operate on major roadways designed to accommodate heavy vehicles, roadway costs are reduced as indicated in Figure 11. Where urban automobile travel shift to rail transit, savings typically average about 5¢ per vehicle-mile reduced, or 2¢ per mile net costs taking into account fuel tax revenues). If a transit service or improvement avoids or defers the need for a specific highway project, avoided costs can be calculated. Such savings typically average 15-50¢ per reduced urban-peak automobile-mile.

Figure 11 **Roadway Savings Per Mile of Bus Travel** (2001 U.S. dollars)



This graph illustrates roadway cost savings for a shift from automobile to bus travel. Thirty car drivers shifting to transit provides savings worth between $0.24 and $2.76 per mile, depending on assumptions. Costs based on FHWA (1997) updated to 2001 dollars, plus estimates of roadway land costs and traffic services described in Litman, 2003.

Energy Conservation and Emission Reductions

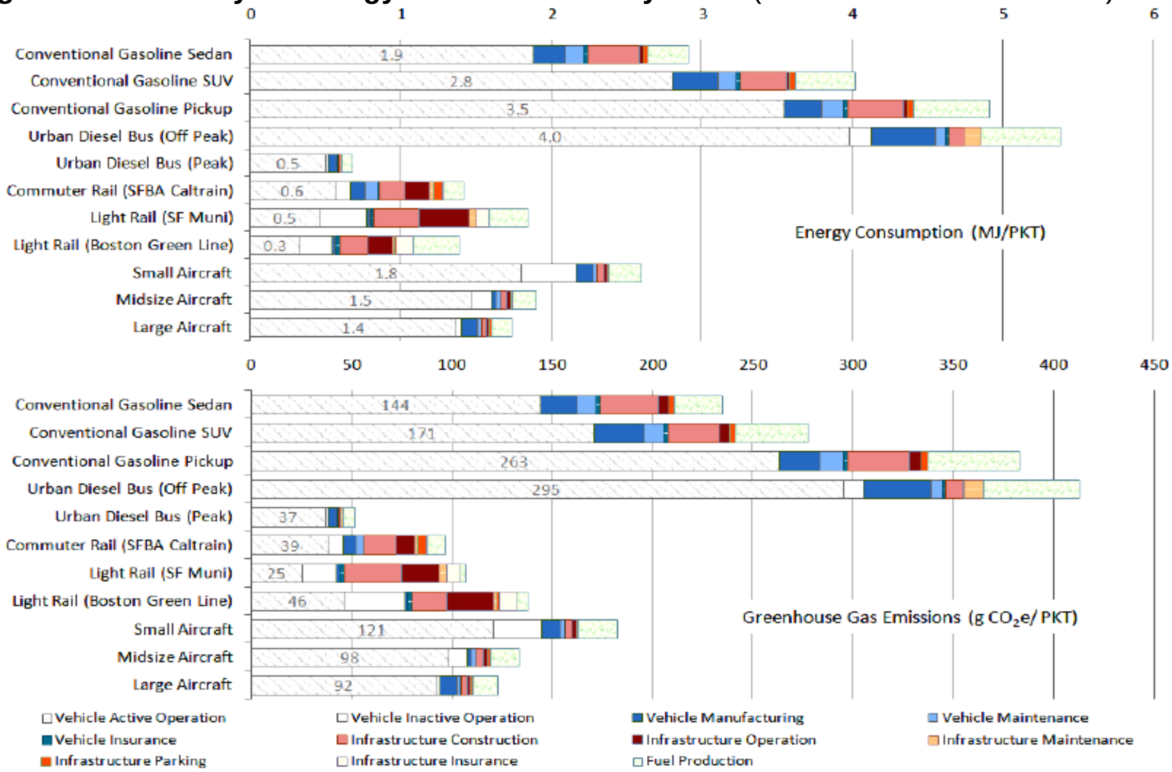
Transit can provide energy conservation and emission reduction benefits (APTA 2009; Chester and Horvath 2008; CNT 2010; Davis and Hale 2007; Gallivan, et al. 2015; ICF 2008 and 2010; NCTR 2011; Potter 2003; TCRP 2012). This analysis is complicated by the fact that many current transit systems are not very energy efficient, because they are intended to provide basic mobility to non-drivers, and so provide service in areas and at times where demand is low (such as in suburban communities and during off-peak periods). Where transit ridership is designed for efficiency, such as on major urban corridors, and strategies that increase transit load factors (such as ridership incentives) or which increase transit operating efficiency (such transit priority measures) can provide large marginal energy conservation and emission reduction benefits.

Shapiro, Hassett and Arnold (2002) estimate that urban transit travel consumes about half the energy and produces only about 5% as much CO, 8% VOCs and 50% the CO_2 and NOx emissions per passenger-mile as an average automobile. Davis and Hale (2007) estimate that at current levels of use public transit services avoid emissions of at least 6.9 million metric tonnes of CO_2 equivalent by substituting for automobile travel and reducing traffic congestion, and possibly much more by creating more accessible land use patterns. They estimate that a typical household could reduce its total greenhouse emissions by 25-30% by shifting from two to one vehicles, as can occur if they move from an automobile-dependent community to a transit-oriented development. ICF (2008 and 2010) estimates that by reducing vehicle travel, easing congestion and supporting more efficient land use patterns, public transportation reduces about 37 million metric tons of CO_2 equivalent emissions annually. 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.

Chester and Horvath (2008) and Chester, et al. (2013 and 2015), calculate total lifecycle energy consumption and pollution emissions for various transport modes, including cars, SUVs, light trucks, buses, light and heavy rail transit, and intercity passenger rail and air transport. Figure 12 compare their energy consumption rates, including fuel used in their operation, and energy embodied in vehicle and facility construction and maintenance. This indicates that public transit tends to be energy efficient, typically using less than half the energy of a sedan and a quarter of the energy as a SUV or light truck. However, transit modes are sensitive to load factors: 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. Described differently, transit policies that reduce average load factors by increase transit service to times and locations when demand is low (such as increasing fares or expanding service to suburban areas or late nights) reduces efficiency while policies that increase load factors (such as reducing fares, improving rider comfort, transit encouragement programs, and transit oriented development) tend to increase efficiency.

APTA (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 reductions in automobile travel.

Figure 12 **Lifecycle Energy and Emissions By Mode** (Chester and Horvath 2008)



Energy and emissions should generally be evaluated using lifecycle analysis which accounts for energy used in fuel production and resources embodied in vehicles and infrastructure.

Kimball, et al. (2013) performed a comprehensive 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. It concluded that marginal benefits from new rail services are likely to significantly exceed marginal costs.

Gallivan, et al. (2015) used sophistical statistical analysis to evaluate interrelationships between transit and land use patterns to understand their impacts on urban development patterns, per capita vehicle travel and pollution emissions. The study found that gross urban population densities would be 27% lower without transit systems to support compact development, and this increased density reduces urban vehicle travel, transport fuel use and GHG emissions by 8%. In addition, shifts from automobile to transit directly reduce VMT, transport fuel use and GHG emissions by 2%, indicating that indirect emission reductions leveraged by land use changes are four times larger than the direct benefits from mode shifting.

Newman and Kenworthy (1999) find that increased transit use is associated with lower per capita transport energy use, including both direct energy savings VMT reductions leveraged by transit-oriented development, as discussed previously. These impacts depend on transport impacts, travel conditions, and the type of transit vehicles used.

- Strategies that increase diesel bus mileage on routes with low load factors (such as suburban and off-peak routes) may increase total energy consumption and emissions.
- Strategies that shift travel from automobile to transit using existing transit capacity (with minimal increase in transit vehicle-miles) reduce energy consumption and emissions.
- Strategies that improve fuel consumption or reduce emission rates of transit vehicles (for example, retrofitting older diesel buses with cleaner engines or alternative fuels) can provide energy conservation and emission reduction benefits.
- Strategies that reduce the total amount of congested driving (by either reducing vehicle mileage or the amount of congestion) tend to provide particularly large energy conservation and emission reduction benefits.
- Strategies that create more accessible land use patterns, and so reduce per capita vehicle mileage, can provide large energy conservation and emission reduction benefits.

Energy Conservation

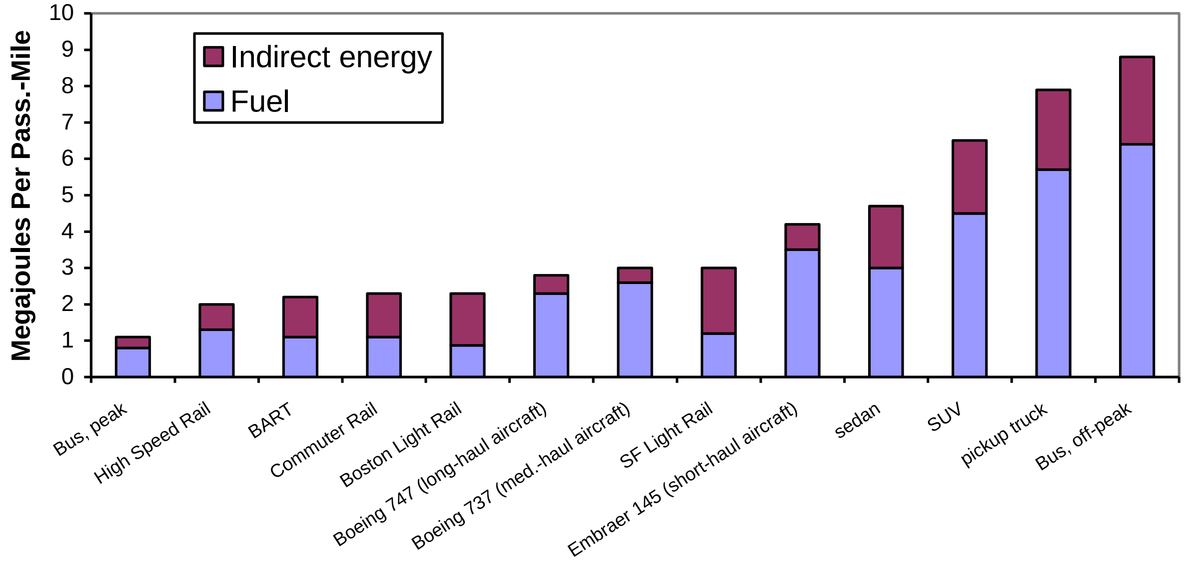
Table 25 and Figure 13 indicate average energy consumption for various travel modes. Under current conditions, U.S. transit vehicles consume about the same energy per passenger-mile as cars, although less than vans, light trucks and SUVs. This reflects low current transit load factors. Increasing ridership on existing transit vehicles consumes little additional energy. 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. 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 (General Motors Corp.)

Table 25 **Average Fuel Consumption 2001** (BTS, Tables 1-29, 4-20, 4-23, 4-24; APTA 2002)

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.

Figure 13 **Lifecycle Energy Consumption** (Chester and Horvath 2008)



Fuel and embodied energy (energy used in vehicle and facility construction) for various modes.

Air Emission Impacts

Quantifying emission impacts of a shift from automobile to transit is challenging because there are several different types of pollutants, and many possible permutations of vehicles, engines and driving conditions. As with energy consumption, current average transit emissions are relatively high in the U.S. due to low occupancy rates, but additional riders contribute minimal additional emissions so strategies that increase ridership with less than proportional increases in vehicle mileage can provide benefits.

Older diesel engines have relatively high emission rates, but these are declining due to improved emission controls. Between 1987 and 2004, allowable emission rates have been reduced about 80%. Many transit vehicles are being converted to cleaner fuels (CNG, LPG or alcohol). Hybrid electric bus drive systems are claimed to reduce particulate and hydrocarbon emissions 90% and NOx 50% compared with conventional diesels (GM, 2003). Electric vehicles produce minimal emissions.

Table 26 **Average Emissions 1999, Grams Per Mile** (APTA 2002)

Vehicle Type	Carbon Dioxide	CO	Nitrogen Oxides	VOCs
Bus (10 passengers)	2,387 (239)	11.6 (1.2)	11.9 (1.2)	2.3 (0.23)
Diesel Rail (20 passengers)	9,771 (489)	47.6 (2.4)	48.8 (2.4)	9.2 (0.5)
Automobile (1.5 passengers)	416 (277)	19.4 (12.9)	1.4 (1.0)	1.9 (1.3)
SUVs & Light Trucks (1.5 pass.)	522 (348)	25.3 (16.9)	1.8 (1.2)	2.5 (1.7)
Hybrid Electric Bus (10 pass.)	1,194 (119)	NA	6.0 (0.6)	0.23 (0.02)

This table summarizes average emissions of various vehicles. Numbers in parenthesis indicate emissions per passenger-mile based on indicated occupancy rates.

Table 27 **Lifecycle GHG Emissions, Grams CO_2e** (Chester and Horvath 2008)

Vehicle Type	Sedan		SUV		Pickup		Bus-Average		Bus-Peak	
Avg. Occupancy	1.58		1.74		1.46		10.5		40	
	VMT	PMT	VMT	PMT	VMT	PMT	VMT	PMT	VMT	PMT
Operations	370	230	480	280	480	330	2,400	230	2,400	59
Manufacture	45	29	71	41	48	33	320	31	320	8.1
Idling	0	0	0	0	0	0	80	7.6	80	2
Tire production	7.2	4.5	7.2	4.1	7.2	4.9	2.5	0.24	2.5	0.064
Maintenance	17	11	19	11	19	13	45	4.2	45	1.1
Fixed Costs	5.6	3.6	5.7	3.3	5.8	4.0	14	1.4	14	0.35
Roadway const.	52	33	52	30	52	36	52	4.9	52	1.3
Roadway maint.	0	0	0	0	0	0	210	20	11	0.27
Herbicides/Salting	0.37	0.24	0.41	0.23	0.41	0.28	0.37	0.036	0.37	0.0094
Roadway lighting	13	8.5	14	7.8	14	9.4	4.9	0.47	4.9	0.012
Parking	8.5	54	8.5	49	8.5	58	0	0	0	0
Fuel production	59	38	98	56	100	71	260	24	260	6.4
Totals	*578*	*412*	*756*	*482*	*735*	*560*	*3,389*	*324*	*3,190*	*79*
Operations/Total	*0.64*	*0.63*	*0.63*	*0.65*	*0.65*	*0.65*	*0.75*	*0.76*	*0.75*	*0.75*

***VMT** = Vehicle Miles Traveled;* ***PMT** = Passenger Miles Traveled;* ***Operations** = tailpipe emissions*

Noise Impacts
Traffic noise is a moderate to large cost in urban areas ("Noise Costs," Litman, 2003). Conventional buses are noisy due to their relatively large engines and low power to weight ratio. A typical diesel bus produces the noise equivalent of 5 to 15 average automobiles, depending on conditions (Delucchi and Hsu, 1998). Staiano (2001) concluded that light rail is somewhat quieter than a diesel bus, and electric trolley buses are significantly quieter. Hybrid buses are much quieter than direct drive diesel.

If a bus displaces just one unusually noisy vehicle (for example, a bus rider would have ridden a noisy motorcycle or driven a car with a faulty muffler or high volume stereo), it can reduce noise overall. If residents walk rather than drive to transit stops, local street noise is reduced. This suggests that diesel bus noise costs per trip are probably about the same as for automobile travel, and hybrid and electric transit reduces overall noise costs.

Water Pollution
Motor vehicles contribute to water pollution due to leaks from engines and brake systems, during fuel distribution, and waste fluids (such as used crankcase oil) that are disposed of inappropriately. Transit travel tends to produce less water pollution because it requires fewer vehicles, and they tend to be maintained better than private vehicles.

Measuring Energy Conservation and Emission Reduction Benefits

Computer models can predict the impacts of transport energy conservation and emission reduction strategies (Transportation Air Quality Center, www.epa.gov/oms; *TravelMatters* www.travelmatters.org; Hendricks, et al. 2010). Various studies monetize emission costs, and therefore the value of transport emission reductions (Litman 2009). These indicate that under typical urban conditions emission costs average 2-5¢ per vehicle-mile for a gasoline automobile, twice that for an SUV, van or light truck, and 10-30¢ per vehicle-mile for older diesel buses, with lower costs for buses with newer engines or alternative fuels. Table 28 summarizes estimated cost for various vehicles.

Table 28 **Recommended Pollution Costs (Cents Per Vehicle-Mile)**

	Urban	Suburban	*Average*
Current Diesel Bus	30¢	15¢	*22.5¢*
New Diesel Bus (meets 2004 standards)	15¢	5¢	*10¢*
Hybrid Electric Bus	5¢	3¢	*4¢*
Average Car	5¢	3¢	*4¢*
SUV, Light Truck, Van	10¢	6¢	*8¢*
Average Automobile	7.5¢	4.5¢	*6¢*

This table indicates estimated average energy, air, noise and water pollution costs of various vehicles. "Average automobile" reflects a weighted average of cars, SUVs, light trucks and vans.

Since most new transit service will be provided by newer, cleaner buses, pollution reduction benefits can generally be calculated based on a shift from average automobile to new diesel or hybrid electric buses. Benefits are larger for CNG, hybrid or electric power transit vehicles. As with other impacts, greater benefits result if transit improvements leverage an overall reduction in per-capita automobile mileage.

Travel Time Impacts

Special consideration is needed when evaluating transit travel time costs, including the relative speeds, unit costs (cents per minute or dollars per hour), and factors such as whether transit travel reduces the need for motorists to chauffeur non-drivers or spend special time exercising (Litman 2008). For more discussion see "Is Transit Travel Slow and Inefficient?" later in this report.

Various studies indicate that consumers place a higher cost on time spent driving, particularly in congestion, than the same amount of time spent as a passenger in pleasant conditions (i.e., uncrowded, a comfortable seat, clean and safe vehicles, not too noisy), because passengers experience less stress and can rest, read or even work. According to current travel time cost values, passengers' travel time is charged at 35% average wage rates, while drivers' time is charged at 50% of wage rates, with a premium of 33% for Level of Service (LOS) D, 67% for LOS E, and 100% for LOS F (ECONorthwest and PBQD 2002; "Travel Time," Litman 2009). Although different agencies assign different values to driver and passenger time, there is little disagreement among experts over the basic concept that, for an average consumer, time spent driving in congestion incurs a higher cost than the same amount of time spent as a comfortable passenger.

Of course, every trip is unique. For some trips transit is not an option because it does not serve a destination, or travelers carry large loads, or require a vehicle at work. Some travelers do not want to take transit because they smoke or have difficulty with transit trip walking links. Some people dislike riding transit or enjoy driving even in congested conditions. But if quality transit is available, travelers can select it when it meets their needs and preferences. This maximizes consumer surplus by letting consumers choose the best option for each trip.

Driving in congestion and uncomfortable transit travel causes psychological stress. Wener, Evans and Boately (2005) surveyed transit commuters before and after a major public transit service improvement that provided a "one-seat ride" from New Jersey into New York City who previously had to transfer trains. Respondents indicated reduced stress in the post-change period, including reduced stress at their jobs, while those staying with the previous service did not. Women who had children at home appear to experience the greatest stress reduction.

A survey of U.K. rail passengers found that many use their travel time productively for activities such as working or studying (30% some of the time and 13% most of the time), reading (54% some of the time and 34% most of the time), resting (16% some of the time and 4% most of the time) and talking to other passengers (15% some of the time and 5% most of the time), and so tend to place a positive utility on such time (Lyons, Jain and Holley, 2007). When asked to rate their travel time, 23% indicated that "I made very worthwhile use of my time on this train today", 55% indicated that "I made some use of my time on this train today," and 18% indicated that "My time spent on this train today is wasted time." The potion of travel time devoted to productive activity is higher for business travel, and tends to increase with journey duration.

These factors have important implications for evaluating public transit improvements. Strategies that increase transit speeds and reliability provide direct benefits to users, particularly if they provide an alternative to driving in congested conditions. Strategies that increase transit user comfort, security and prestige can reduce travel time costs even if they don't reduce the amount of time actually spent in travel, because they reduce per-minute costs. Strategies that improve access to transit, for example by making it easier to walk or cycle to transit stops, also reduce travel time costs. Travelers who shift from driving to transit in response to transit improvements or other positive incentives (such as financial benefits to transit users) can benefit overall, even if transit trips take more time.

Measuring Travel Time Costs and Benefits

Transport models can be used to calculate transit travel speeds (Krizek, et al. 2007). The value of travel time changes can be calculated using a comprehensive travel time cost framework that accounts for the following factors:

- Travel time should be measured door-to-door, taking into account each trip link, including time spent walking and waiting.
- Personal travel is usually estimated at one-quarter to one-half of prevailing wage rates.
- Travel time costs for drivers tend to increase with congestion, and for passengers if vehicles are crowded or uncomfortable. Unexpected delays impose high costs.
- Costs tend to be lower for shorter trips and small travel time savings, and tend to increase for longer commutes (more than about 20 minutes).
- Under pleasant conditions, walking and cycling can have positive value, but under unpleasant or unsafe conditions, time spent walking, cycling and waiting for transit has costs two or three times higher than time spent traveling.
- Travel time costs tend to increase with income, and tend to be lower for children and people who are retired or unemployed (put differently, people with full-time jobs are generally willing to pay more for travel time savings).
- Personal preferences vary. Some people prefer driving while others prefer transit or walking, as reflected in their travel time cost values.
- Public transit can provide specific travel time savings, for example, by reducing the need for motorists to chauffeur non-drivers. For example, in automobile-dependent locations parents must drive children to school and sport events, and non-driving relatives and friends to shopping and medical appointments, trips that are avoided if high quality public transit service is available.

Table 29 **Recommended Value of Travel Time** (ECONorthwest & PBQD 2002)

Time Component	Reference	Value
In-Vehicle Personal (local)	Of wages	50%
In-Vehicle Personal (Intercity)	Of wages	70%
In-Vehicle Business	Of total compensation	100%
Excess (waiting, walking, or transfer time) Personal	Of wages	100%
Excess (waiting, walking, or transfer time) Business	Of total compensation	100%

This table illustrates USDOT recommended travel time values. Personal travel is calculated relative to wages, and business travel relative to total compensation, averaging 120% of wages.

Box 1 **Recommended Travel Time Values** ("Travel Time Costs," Litman 2009)

	Travel Time Values
Commercial vehicle driver	Wage rate plus fringe benefits
Personal vehicle driver	50% of current average wage
Adult car or bus passenger	35% of current average wage
Child passenger under 16 years	25% of current average wage

Congestion increases driver's travel time costs by the following amounts according to roadway Level of Service (LOS) ratings:

LOS D: multiply by 1.33 LOS E: multiply by 1.67 LOS F: multiply by 2.0

Under unpleasant or insecure conditions (waiting for transit in a dirty and insecure area, or walking on busy roads that lack sidewalks), time spent walking, cycling and using transit has two or three times the cost of time spent traveling, depending on the degree of discomfort.

This box summarizes travel time values developed by leading transportation economists.

For this analysis we recommend a default value of $8.00 per hour for travelers in comfortable conditions and $16 per hour for travelers in uncomfortable conditions, or use of the adjustment factors in Table 30. Conventional transportation models are generally not very sensitive to qualitative factors, and therefore tend to undervalue transit service improvements that improve rider comfort, convenience and access speed.

Table 30 **Travel Time Values Relative To Prevailing Wages** (Litman 2008)

Category	LOS A-C	LOS D	LOS E	LOS F	Waiting Conditions		
					Good*	Average	Poor
Commercial vehicle driver	120%	137%	154%	170%		170%	
Comm. vehicle passenger	120%	132%	144%	155%		155%	
City bus driver	156%	156%	156%	156%		156%	
Personal vehicle driver	50%	67%	84%	100%		100%	
Adult car passenger	35%	47%	58%	70%		100%	
Adult transit passenger – seated	35%	47%	58%	70%	35%	50%	125%
Adult transit pass. – standing	50%	67%	83%	100%	50%	70%	175%
Child (<16 years) – seated	25%	33%	42%	50%	25%	50%	125%
Child (<16 years) – standing	35%	46%	60%	66%	50%	70%	175%
Pedestrians and cyclists	50%	67%	84%	100%	50%	100%	200%
Transit Transfer Premium					5-min.	10-min.	15-min.

This summarizes travel time values that incorporate traveler convenience and comfort factors. (Wait time unit costs are reduced another 20-30% where real-time vehicle arrival information is provided.)*

Land Use Impacts

Transit can help achieve various land use planning objectives by reducing the amount of land required for roads and parking facilities, and providing a catalyst for more compact urban redevelopment (Banister and Thurstain-Goodwin 2011; CTOD 2009; Litman 1995; Portland 2009; TCRP 2012). Transit is an important component of *smart growth*, which refers to policies designed to create more resource efficient and accessible land use patterns. Table 31 lists potential smart growth benefits.

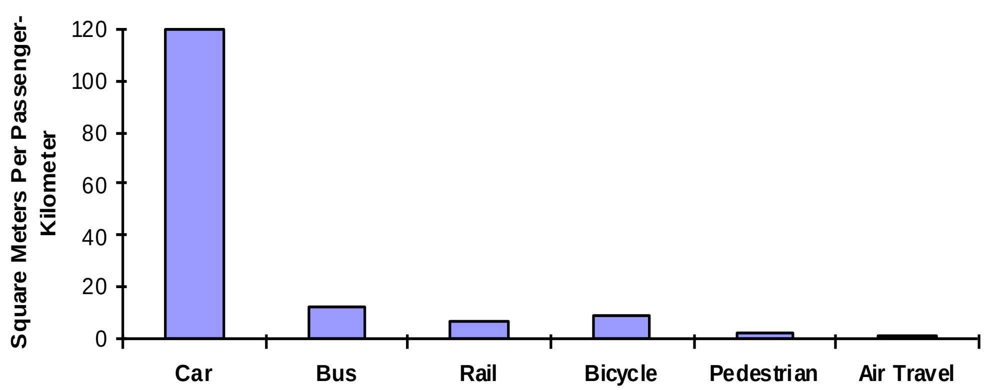
Table 31 **Smart Growth Benefits** (Burchell, et al 1998; Litman 1995)

Economic	Social	Environmental
• Reduced development and public service costs. • Consumer transportation cost savings. • Economies of agglomeration. • More efficient transportation.	• Improved transport options, particularly for nondrivers. • Improved housing options. • Community cohesion.	• Greenspace and wildlife habitat preservation. • Reduced air pollution. • Reduced resource consumption. • Reduced water pollution. • Reduced "heat island" effect.

This table summarizes various benefits to society of smart growth development patterns.

Transit can reduce the amount of land required for roads and parking facilities compared with urban-peak automobile trips, as illustrated in Figure 14. Transit is particularly helpful in creating certain land use patterns including major commercial centers (more than 5,000 employees in one area), multi-modal (walkable) neighborhoods, urban redevelopment, and some types of tourist attractions.

Figure 14 **Road Space By Mode** (Banister and Button 1993)



Transit requires far less space than automobile travel.

Transit-oriented development can provide economic benefits by improving accessibility, reducing transport costs, and providing economies of agglomeration, as described in the next section of this guide. In some cases, increased property values near transit stations can offset most or all transit subsidy costs (RICS 2002; Smith and Gihring 2003; CTOD 2010). Even people who do not use transit can benefit from these land use patterns.

Not every transit project has these effects. Appropriate land use policies, transit ridership incentives and consumer acceptance are necessary to be effective. The following types of transit improvements tend to have the greatest positive land use impacts:

- Transit programs that are part of an overall smart growth land use program.
- Transit oriented development, which intentionally integrates transit improvements with compatible land use development.
- Transit improvements that encourage infill and redevelopment of older urban neighborhoods.
- Transit stations located at major commercial centers with large numbers of commuters.
- Transit improvements as an alternative to roadway capacity expansion.
- New urbanism, parking management and other TDM policies implemented in conjunction with transit improvements.

Transit can also have some negative land use impacts. Rail facilities require land, can divide neighborhoods, and can be unattractive. In some situations transit improvements can increase urban sprawl by facilitating longer-distance commutes.

Measuring Land Use Impacts

The first step in valuing these impacts is to determine how a particular transit program or policy will affect land use patterns, including changes in the amount of land used for transport facilities (roads, parking, rail lines and terminals), changes to development patterns (density, clustering, urban expansion, per capita pavement, etc.), changes in accessibility (the ease of travel between destinations), emergency service response times, and changes in per capita vehicle ownership and VMT (CTOD 2010). Some communities have comprehensive transport/land use models that can predict these impacts, but in most cases predictions rely on professional judgment by planners and real estate professionals.

The final step is to place of monetary value on impacts as much as possible. Some impacts are monetary, such as reduced costs of providing public services to more clustered development, and parking cost savings that result from reduced vehicle ownership. Others require placing a value on non-market goods. For example, monetized values may be assigned to greenspace preservation. Impacts that cannot be monetized should be described qualitatively. For example, equity impacts can be quantified using indicators of the change in accessibility by disadvantaged groups (e.g., the ability of people with disabilities or low incomes to access common destinations).

Generally, impacts should be measured per capita. Increased density can increase the intensity of some impacts within a particular area, but reduces costs per capita. For example, higher development densities may reduce greenspace (parks, lawns and farms) within a neighborhood, but preserve regional greenspace by reducing per capita pavement and urban expansion. Similarly, increased development density tends to increase per-acre vehicle trips and pollution emissions, but reduce per capita impacts, since residents of more clustered communities tend to drive fewer annual vehicle-miles.

A more qualitative approach is to identify a community's land use development goals and objectives (based on community plans and other official documents), and rate each transportation option in terms of effects on them. For example, many communities have goals to encourage infill development, create more multi-modal communities, protect and redevelop existing neighborhoods, improve walking conditions, and preserve greenspace. Transit improvements can help achieve these objectives, particularly if implemented as part of an integrated community development program.

A matrix such as the one below can be used to evaluate and compare the land use impacts of various transport options based on a particular community's planning objectives. The simplest approach is to check a box if an option supports an objective. A better approach is to rate each objective, for example from 5 (very supportive) to –5 (very harmful). Objectives can be weighted to reflect their relative importance. For more information see discussion of *Multi-Criteria Analysis* in Litman, 2001b.

Land Use Impact Matrix

Planning Objective	Option 1	Option 2	Option 3
1. Reduces roadway and parking facility land requirements.			
2. Reduces total impervious surface coverage (amount of land covered by roads, parking and buildings).			
3. Encourages urban infill and redevelopment of existing neighborhoods.			
4. Increases development densities (residents and jobs per acre).			
5. Increases accessibility (the ease of travel between common destinations), particularly for non-drivers.			
6. Improves community walkability (quality of walking conditions).			
7. Reduces per-capita vehicle travel.			
8. Improves quality or reduces costs of public service (emergency response, garbage collection, utility networks and services, schools, recreation facilities, etc.)			
9. Improves housing options (types of housing available) and affordability (by reducing parking costs and land requirements).			
10. Enhances neighborhood livability (environmental quality experienced by people who live, work and visit an area).			
11. Preserves greenspace (parks, farms, forests, etc.).			
12. Preserves cultural resources (historic sites and traditional communities).			
13. Enhances community cohesion (quantity and quality of interactions between people who live and work in a community)			
14. Supports local economic development plans (e.g., downtown redevelopment, tourist industry expansion, etc.).			
15. Others…			
Totals			

A matrix such as this can be used to evaluate and compare land use impacts. It should reflect a community's planning objectives. Each option is rated to indicate how much it supports or contradicts each objective.

Economic Development Impacts

Economic development refers to increased productivity, business activity, employment, income, property values and tax revenue. Transit can support economic development in several ways (Banister and Thurstain-Goodwin 2011; Cambridge Systematics 1998; CTOD 2011; EDRG 2013 and 2014; ECONorthwest and PBQD 2002; FHWA 2014; Laube, Rainville and Lyons 2014; Litman 2004a; Mackie, Laird and Johnson 2012; Nelson, et al., 2013; Sadler and Wampler 2013).

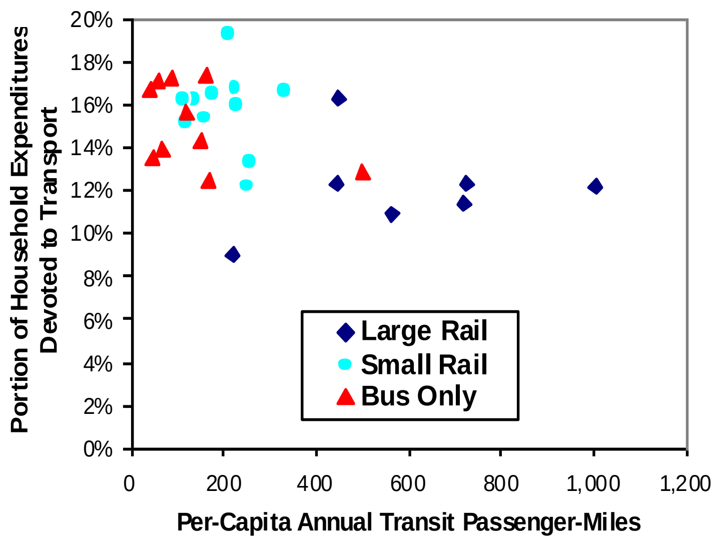
Direct Expenditures

Because transit is labor intensive, transit expenditures tend to provide more jobs and local business activity than most other transportation investments. A million dollars spent on public transit typically generates 30-60 jobs (ECONorthwest and PBQD, 2002; APTA 2003). A typical set of transit investments creates 19% more jobs than the same amount spent on a typical set of road and bridge projects (STPP 2004).

Consumer Expenditures

Transit supports economic development by shifting consumer expenditures. Residents of cities with quality transit systems tend to spend less on transportation overall, as illustrated below (also see Newman and Kenworthy, 1999). For example, residents of cities with large, well-established rail transit systems spend an average of $2,808 on personal vehicles and transit (12.0% of their total household expenditures), compared with $3,332 in cities that lack rail systems (14.9% of total household expenditures), despite higher incomes and longer average commute distances in rail cities.

Figure 15 **Percent Transport Expenditures** (Litman, 2004a)



The portion of total household expenditures devoted to transportation (automobiles and transit) tends to decline with increased per-capita transit ridership.

Money spent on vehicles and fuel provides relatively little regional employment or business activity because they are capital intensive and much of their value is imported. Analysis summarized in Table 32 indicates that a million dollars spent on public transit services generates 31.3 jobs, compared with 17.3 jobs from the same amount spent on a typical bundle of goods, 13.7 jobs if spent on vehicles, and 12.8 jobs if spent on fuel. As a result, in 2006, a million dollars shifted from fuel to general consumer expenditures generated 4.5 domestic jobs, and if shifted to public transit generated 18.5 jobs. These impacts are likely to increase as oil import costs rise.

Table 32 **Impacts per $1 Million Expenditures** (Litman 2004, based on Chmelynski 2008)

Expense category	Value Added	Employment	Compensation
	2006 Dollars	FTEs*	2006 Dollars
Auto fuel	$1,139,110	12.8	$516,438
Other vehicle expenses	$1,088,845	13.7	$600,082
Household bundles including auto expenses	$1,278,440	17.0	$625,533
Household bundles with auto expenses redistributed	$1,292,362	17.3	$627,465
Public transit	$1,815,823	31.3	$1,591,993

In 2006, a million dollars shifted from fuel to general consumer expenditures generated 4.5 domestic jobs, and if shifted to public transit expenditures generated 18.5 jobs. These impacts are likely to increase as oil import costs rise. (FTE = Full-Time Equivalent employees)*

Productivity Gains

Transit services can increase economic productivity by improving access to education and employment (Porter, et al. 2015), as discussed in the *Mobility Benefits* section; reducing traffic congestion, roads and parking facility costs, accidents and pollution (as discussed in the *Efficiency Benefits* section); by stimulating more compact and efficient land use development, and by supporting certain industries, such as tourism (CTOD 2011). For example, transit services may benefit a restaurant by increasing the pool of available employees and reducing absenteeism from vehicle failures, reducing employee parking costs, and by providing mobility for some tourists. Similarly, a delivery company may be more productive if transit reduces traffic congestion.

Aschauer and Campbell (1991) found that transit investments provide more than twice the increase in worker productivity as highway spending. A study by Leigh, Scott and Cleary (1999, Appendix K) concludes that transit increases economic growth in Colorado by about 4% over what would otherwise occur. EDRG (2007) used quantitative analysis to estimate that the current Chicago region transit plan provides an estimated 21% annual return on investments, an enhanced plan provides a 34% return, and adopting Transit-Oriented Development, as proposed in the region's official comprehensive plan, would increase the return to 61%. Failure to maintain the transit system will harm the region's commuters and the economy, estimated at over $2 billion annually. Faulk and Hicks (2015) found that in U.S. counties, increased fixed-route bus service is negatively related to employee turnover rates, which provides cost savings to businesses by reducing the costs of training new workers.

Land Use Efficiencies

As described earlier, high quality transit tends to create more compact and accessible land use patterns, creating agglomeration efficiencies that increase regional productivity (Chatman, et al. 2012; Currie 2011; Hazledine, Donovan and Bolland 2013). One published study found that doubling a county-level density index is associated with a 6% increase in state-level productivity (Haughwout 2000). Using data on US metropolitan areas, Chatman and Noland (2013) found that, by increasing central city employment density, a 10% increase in transit service raises regional wages $1.5 million to $1.8 billion. Meijers and Burger (2009) found that regional labor productivity generally declines with population dispersion (more residents living outside urban centres), and increases with polycentric development (multiple business districts, cities and towns in a metropolitan region, rather than a single large central business district and central city). This suggests that high quality transit systems with transit oriented development tend to support regional economic development by encouraging more efficient development patterns. Although these impacts are difficult to measure, they are potentially large.

Supports Strategic Economic Development Objectives

Transit services can support specific strategic economic development objectives such as local commercial development and increased tourism. For example, bus or trolley systems can be designed to serve visitors and provide access to major sport and cultural attractions, and historic train stations can be a catalyst for downtown redevelopment (Portland 2009).

Property Values

Property values generally increase in areas served by quality transit (Nelson, et al., 2013; RISC 2002; Smith and Gihring 2003). The table below summarizes various studies on rail station proximity impacts on property values. Rodriguez and Targa (2004) found that, after controlling for other factors, a reduction of 5 minutes walking time to BRT stations increases property prices 6.8% to 9.3% in Bogotá, Colombia. Munoz-Raskin (2007) found that middle-income households, who tend to use BRT most, pay 2.3% to 14.4% more for housing located close to Bogotá BRT stations.

Table 33 **Rail Proximity Property Value Impacts** (Hass-Klau, Cramption & Benjari 2004)

City	Factor	Difference
Newcastle upon Tyne	House prices	+20%
Greater Manchester	Not stated	+10%
Portland	House prices	+10%
Portland Gresham	Residential rent	>5%
Strasbourg	Residential rent	+7%
Strasbourg	Office rent	+10-15%
Rouen	Rent and houses	+10%
Hannover	Residential rent	+5%
Freiburg	Residential rent	+3%
Freiburg	Office rent	+15-20%
Montpellier	Property values	Positive, no figure given
Orléans	Apartment rents	None-initially negative due to noise
Nantes	Not stated	Small increase
Nantes	Commercial property	Higher values
Saarbrűcken	Not stated	None-initially negative due to noise

Bremen	Office rents	+50% in most cases

This table summarizes how proximity to rail stations affects property values in various cities.

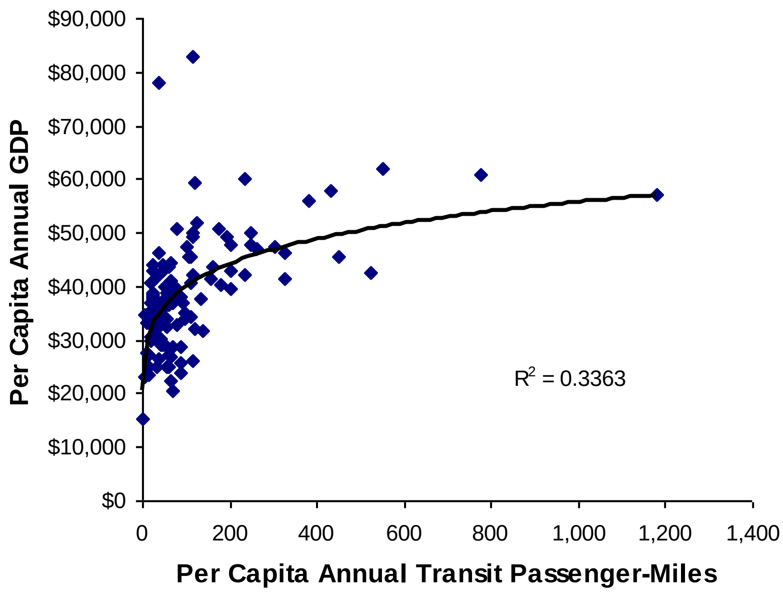
Transit System Efficiency Improvements

Many transit improvements increase system efficiency. Transit priority and improved payment systems increase operating speed and reduce delays, reducing operating costs. Many transit costs are fixed, so increased ridership reduces unit costs, particularly if ridership increases when there is excess capacity. Transit services experiences efficiencies and network effects. As per-capita ridership increases the system can expand, increasing service frequency, coverage, and operating hours, and transit can be more integrated with other transportation system features (for example, more businesses will choose to locate near transit). For these reasons, strategies that increase transit ridership can increase service efficiency and quality. Transit systems in cities with higher-quality transit systems and higher levels of per capita transit ridership tend to have lower transit operating costs, higher cost recovery, and lower per capita transportation expenditures than more automobile-dependent cities (Newman and Kenworthy 1999; Litman 2004a).

Cumulative Effects

Per capita Gross Domestic Product (GDP) tends to increase with public transit ridership (Figure 16) and fuel prices, and declines with per capita vehicle travel and roadway supply (Litman 2011b). This probably reflects the cumulative effects of various economic development impacts described above, including improved accessibility and consumer savings, shifts in consumer expenditures that increase regional economic activity, agglomeration benefits, and more efficient land use development.

Figure 16 **Per Capita GDP and Transit Ridership** (Litman 2011b)



GDP tends to increase with per capita transit travel. (Each dot is a U.S. urban region.)

Measuring Economic Development Impacts

A variety of techniques can be used to measure different types of economic development impacts, including transportation-land use models, benefit-cost analysis, input-output models, economic forecasting models, econometric models, case studies, surveys, real estate market analysis and fiscal impact analysis (Chatman, et al. 2012; Currie 2011; Hass-Klau, Crampton and Benjari 2004; Hazledine, Donovan and Bolland 2013; HLB 2002; Litman 2009; Lewis and Williams 1999; Smith and Gihring 2003; Weisbrod 2000). The table below summarizes categories of benefits and how they can be measured.

Table 34 **Economic Development Impacts**

Category	Description	How It Can Be Measured
Employment and Business Activity	Increased employment and business activity resulting from expenditures on transit services.	Local expenditures on transit services times multipliers from a regional Input-Output table. "New" money brought into a region.
Consumer Expenditures	Consumer expenditures shifted from vehicles and fuel to more locally-produced goods.	Consumer expenditure shifts, evaluated using an Input-Output table to determine net change in regional employment and business activity.
Land Use Efficiencies	Increased accessibility and clustering, providing agglomeration efficiencies.	Changes in property values around transit stations.
Productivity Gains	Improved access to education and jobs, and reduced costs to businesses.	Methods described in *mobility*, *efficiency* and *land use* benefits sections, with emphasis on employment gains and businesses savings.
Strategic Economic Development	Transit facilities and services support strategic development objectives.	Role of transit in community's identity supporting strategic industrial development.
Transit System Efficiency	Reduced unit costs and improved services.	Estimates of per capita transportation cost savings provided by public transit services.

Transit improvements may provide various types of economic benefits and evaluation techniques.

It is important to avoid double-counting these benefits, or counting economic transfers as net economic gains. For example, the productivity gains of more accessible land use should be counted as land use benefits or economic benefits, but not both. On the other hand, it is appropriate to highlight ways transit supports particular economic development objective. For example, if area businesses have difficulty finding lower-wage employees, improving transit or providing special welfare-to-work services may help address this problem. Similarly, where downtown growth is constrained by traffic and parking congestion, transit improvements can be identified as part of the redevelopment program.

Impact Summary

Table 35 summarizes the categories of benefits and costs to consider in a comprehensive transit evaluation framework.

Table 35 **Transit Impacts**

Impact Category	Description
Transit Service Costs	*Financial costs of providing transit services*
Fares	Direct payments by transit users.
Subsidies	Government expenses to provide transit services.
Existing User Impacts	*Incremental benefits and costs to existing transit users*
Various	Changes in fares, travel speed, comfort, safety, etc. to existing transit users.
Mobility Benefits	*Benefits from increased travel that would not otherwise occur.*
Direct User Benefits	Direct benefits to users from increased mobility.
Public Services	Support for public services and cost savings for government agencies.
Productivity	Increased productivity from improved access to education and jobs.
Equity	Improved mobility that makes people who are also economically, socially or physically disadvantaged relatively better off.
Option Value/ Emergency Response	Value of having mobility options available in case they are ever needed, including the ability to evacuate and deliver resources during emergencies.
Efficiency Benefits	*Benefits from reduced motor vehicle traffic.*
Vehicle Costs	Changes in vehicle ownership, operating and residential parking costs.
Chauffeuring	Reduced chauffeuring responsibilities by drivers for non-drivers.
Vehicle Delays	Reduced motor vehicle traffic congestion.
Pedestrian Delays	Reduced traffic delay to pedestrians.
Parking Costs	Reduced parking problems and non-residential parking facility costs.
Safety, Security and Health	Changes in crash costs, personal security and improved health and fitness due to increased walking and cycling.
Roadway Costs	Changes in roadway construction, maintenance and traffic service costs.
Energy and Emissions	Changes in energy consumption, air, noise and water pollution.
Travel Time Impacts	Changes in transit users' travel time costs.
Land Use	*Benefits from changes in land use patterns.*
Transportation Land	Changes in the amount of land needed for roads and parking facilities.
Land Use Objectives	Supports land use objectives such as infill, efficient public services, clustering, accessibility, land use mix, and preservation of ecological and social resources.
Economic Development	*Benefits from increased economic productivity and employment.*
Direct	Jobs and business activity created by transit expenditures.
Shifted expenditures	Increased regional economic activity due to shifts in consumer expenditures to goods with greater regional employment multipliers.
Agglomeration Economies	Productivity gains due to more clustered, accessible land use patterns.
Transportation Efficiencies	More efficient transport system due to economies of scale in transit service, more accessible land use patterns, and reduced automobile dependency.
Land Value Impacts	Higher property values in areas served by public transit.

This table summarizes potential transit benefits and costs identified in this section. These are impacts to consider when evaluating a particular transit policy or project.

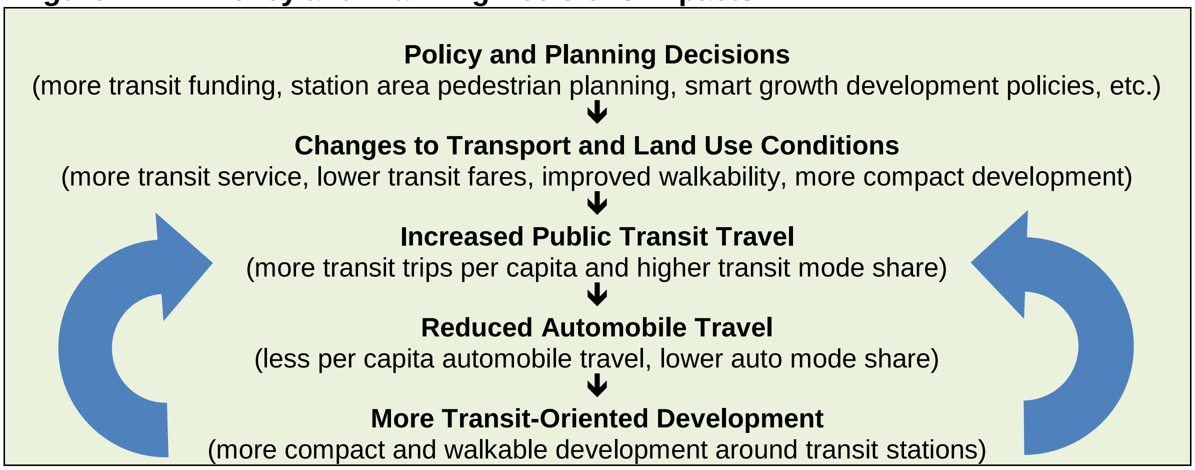
Table 36 **Public Transport Benefits and Costs**

Category	Improved Transit Service	Increased Transit Travel	Reduced Automobile Travel	Transit-Oriented Development
Indicators	Service Quality (speed, reliability, comfort, safety, etc.)	Transit Ridership (passenger-miles or mode share)	Mode Shifts or Automobile Travel Reductions	Portion of Development With TOD Design Features
Benefits	• Improved convenience and comfort for existing users. • Equity benefits (since existing users tend to be disadvantaged). • Option value (the value of having an option for possible future use). • Improved operating efficiency (if service speed increases). • Improved security (reduced crime risk)	• Mobility benefits to new users. • Increased fare revenue. • Increased public fitness and health (if transit travel stimulates more walking or cycling trips). • Increased security as more non-criminals ride transit and wait at stops and stations.	• Reduced traffic congestion. • Road and parking facility cost savings. • Consumer savings. • Reduced chauffeuring burdens. • Increased traffic safety. • Energy conservation. • Air and noise pollution reductions.	• Additional vehicle travel reductions ("leverage effects"). • Improved accessibility, particularly for non-drivers. • Reduced crime risk. • More efficient development (reduced infrastructure costs). • Farmland and habitat preservation.
Costs	• Increased capital and operating costs, and therefore subsidies. • Land and road space. • Traffic congestion and accident risk imposed by transit vehicles.	• Transit vehicle crowding.	• Reduced automobile business activity.	• Various problems associated with more compact development.

Public transport can have various types benefits and costs. Many benefits tend to be overlooked or undervalued in conventional transportation economic evaluation.

Table 37 indicates various public transit benefit categories. Some reflect benefits to existing transit users, others result from increased transit travel or reduced automobile travel, and some result from more transit-oriented development which leverages additional vehicle travel reductions and other benefits. Each category is evaluated using different indicators. Figure 17 shows the steps that may exist between a particular planning decision and its ultimate impacts.

Figure 17 **Policy and Planning Decisions Impacts**



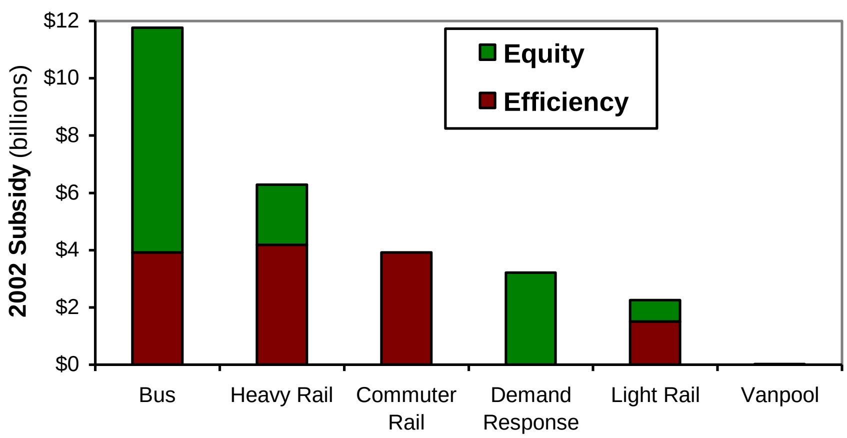
There are often several steps between a policy or planning decisions and its ultimate transport and land use impacts, and resulting benefits. Transit-oriented development tends to leverage additional increases in transit ridership and reductions in automobile travel. It is important to consider these relationships when evaluating benefits.

Evaluating and Quantifying Transit Benefits

Transit benefits can be divided into two major categories: *equity-oriented*, which result from the availability and use of transit by disadvantaged people, and *efficiency-oriented*, which result when transit substitutes for automobile travel. Some transit services are primarily *equity-justified*, others are primarily *efficiency-justified*, and many are intended to provide both. For example, demand response services, and bus transit in areas and times with low load factors, are primarily equity-justified, since they provide basic mobility and do little to reduce traffic congestion, facility costs or pollution emissions. Vanpooling, express bus and commuter rail services are primarily efficiency-justified, since they tend to serve middle- and higher-income patrons, and are intended to reduce congestion and other negative traffic impacts, although they incur some additional equity-justified costs to accommodate people with disabilities (such as special equipment and features for people in wheelchairs), which slightly increase their costs.

In general, transit in rural areas and smaller cities is primarily equity-justified, while conventional bus and rail service services in large cities provide both benefits. Within a particular system, efficiency-justified routes tend to have the highest cost recovery and lowest subsidy per passenger-mile. The figure shows the size of subsidies devoted to different modes, and categorizes them according to whether they are primarily equity- or efficiency-justified, assuming that 2/3 of bus service and 1/3 of light- and heavy-rail are primarily equity-justified. This suggests that about half of transit subsidies are equity-justified and half are efficiency-justified, although it is difficult to give a precise accounting since many benefits overlap.

Figure 18 **Transit Subsidies** (APTA 2002)



About half of transit subsidies are equity-justified and about half are efficiency-justified.

The distinction between equity- and efficiency-justified subsidies is often important for transit evaluation (Walker 2008). For example, it would be wrong to criticize equity-justified transit for failing to reduce traffic congestion or pollution emissions, and it would be wrong to criticize efficiency-justified transit for failing to serve lower-income travelers, since that is not their primary justification.

Many transit benefits are partly or completely ignored in conventional transport economic analysis, as summarized in the table below. In most cased, conventional evaluation only measures the direct benefits resulting from travel shifted from automobile to transit, but ignores indirect benefits that result when quality transit services leverage additional reductions in vehicle ownership and use. Most conventional evaluation only quantifies user travel time savings (for example, if grade-separated transit service increases transit travel speeds), but not the value of improved comfort (such as reduced crowding, more comfortable seats and better waiting areas), although by reducing unit (per-hour) travel time costs these measures are equivalent to increasing travel speeds.

Table 38 **Transit Benefits** (Litman 2004)

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, but not quantified.
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.

The quantification of transit benefits is complicated by the fact that some impacts overlap. For example, direct user savings and benefits are partly capitalized into land values around transit stations, so it would not be appropriate to simply add all of those benefits together. But many transit benefits are indirect or external and so are not perceived by users or capitalized in property values, as illustrated in the Table 39.

Table 39 **Transit Benefits**

Benefits	Capitalized In Property Values
User benefits	Yes
Congestion Reduction	Direct yes, indirect no
Facility cost savings	Direct yes, indirect no
Consumer savings	Direct yes, indirect no
Transport diversity	Direct yes, indirect no
Road safety	Mostly not
Environmental quality	Mostly not
Efficient land use	Some
Economic development	Some
Community cohesion	Some
Public health	Possibly

Only a portion of transit benefits are directly perceived by users and so reflected in land values.

In addition, transit systems experience economies of scale: as more people use the service becomes more efficient overall and benefits increase exponentially. As a result, marginal benefits are greater than average benefits. There is also land use economies of agglomeration leveraged by transit, particularly high quality rail transit that provides a catalyst for more compact, mixed, multi-modal community development. Large central business districts, which provide significant, unique economic benefits, simply could not exist without high quality transit services. These additional economic benefits are not capitalized in land values or measured through conventional indicators.

For these reasons it would be wrong to assume that all, or even most transit benefits are capitalized in property values. Although more research is needed to better quantify the distribution of costs and benefits, it is likely that most are not directly perceived by users, so total benefits are far greater than what is measured through property value impacts.

Comparing Transit and Automobile Costs

It is often useful to compare the costs of transit with other modes, to evaluate the cost efficiency and fairness. This section discusses factors to consider in such analysis.

For *efficiency-justified* service (intended to reduce congestion, accidents and pollution problems) transit and automobile transport can be compared using cost effectiveness indicators such as costs per passenger-mile or benefit/cost ratio. For *equity-justified* service (intended to provide basic mobility to disadvantaged people) there are reasons to subsidize transit more than automobile travel, since transit bears additional costs to accommodate people with disabilities (such as wheelchair lifts), and many non-drivers have low incomes so low fares achieve equity objectives. Since many transit users cannot drive, transit service costs should be compared with taxi costs, or a combination of taxi and automobile travel costs (including driver's time costs) for chauffeured car trips.

Various cost comparison issues are described below.

Government Subsidy Per Passenger-Mile

When measured per *passenger-mile*, transit subsidies often appear large. Transit subsidies average about 60¢ per passenger-mile, about 40 times larger than the approximately 1.5¢ per automobile passenger-mile roadway subsidies (Litman 2009). However, about half of transit subsidy costs are equity-justified, including costs for wheelchair lifts, paratransit and service in suburban and rural areas. Considering just efficiency-justified subsidies (bus and rail transit on major urban corridors), transit subsidies are about 30¢ per passenger-mile, 20 times greater than automobile roadway subsidies. Automobile use requires other public expenditures besides roads, include traffic services (policing, emergency services, street lighting, etc.) and publicly subsidized parking. These are estimated to total at least 6¢ per passenger-mile. This implies that transit subsidies are 10 times greater than automobile subsidies, or 5 times efficiency-justified subsidy.

Table 40 **Automobile and Transit External Costs Per Passenger-Mile** (Litman, 2003)

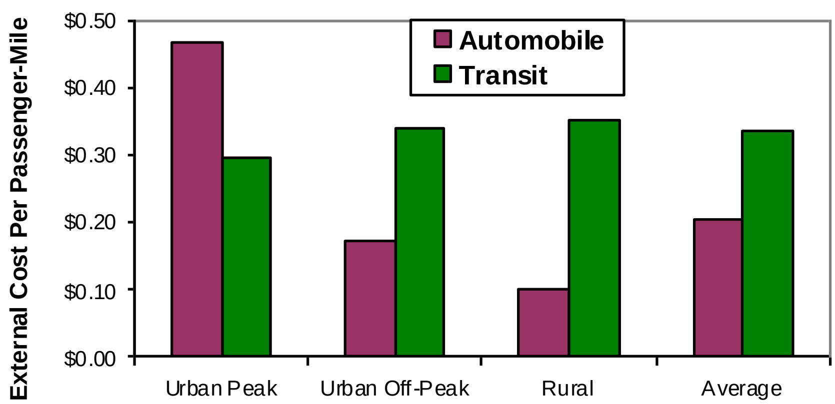
	Urban Peak		Urban Off-Peak		Rural		Average	
	Average Car	Diesel Bus	Average Car	Diesel Bus	Average Car	Diesel Bus	Average Car	Diesel Bus
Average Occupancy	*1.1*	*25.0*	*1.5*	*8.0*	*1.5*	*5.0*	*1.42*	*10.20*
Operating Subsidy	0.000	0.250	0.000	0.250	0.000	0.250	0.000	0.250
Crash costs	0.032	0.008	0.023	0.025	0.023	0.040	0.025	0.028
External parking	0.109	0.000	0.027	0.000	0.013	0.000	0.038	0.000
Congestion	0.155	0.014	0.013	0.005	0.000	0.000	0.036	0.005
Road facilities	0.015	0.003	0.011	0.009	0.007	0.008	0.010	0.007
Roadway land value	0.022	0.001	0.016	0.003	0.016	0.005	0.017	0.003
Traffic services	0.014	0.001	0.007	0.001	0.003	0.001	0.007	0.001
Air pollution	0.056	0.007	0.035	0.020	0.011	0.014	0.029	0.015
Noise	0.009	0.002	0.007	0.006	0.003	0.005	0.006	0.005
Resource externalities	0.026	0.006	0.017	0.016	0.014	0.022	0.018	0.017
Barrier effect	0.014	0.002	0.007	0.003	0.003	0.003	0.007	0.003
Water pollution	0.012	0.001	0.009	0.002	0.009	0.003	0.009	0.002
Totals	*$0.464*	*$0.295*	*$0.172*	*$0.340*	*$0.102*	*$0.351*	*$0.202*	*$0.336*

This table summarizes external costs of automobile and transit in mills (thousandths of a dollar).

Vehicle travel imposes other external costs, including parking and fuel production subsidies, congestion delays and crash risk imposed on other road users, and pollution emissions. A typical urban parking space has a $500 to $1,500 annualized value and there are 3-4 off-street parking spaces per vehicle, indicating $1,500 to $6,000 annual parking costs per automobile ("Parking Costs," Litman 2009). Most non-residential parking is government mandated and subsidized, financed through taxes, rents, lower wages, and higher costs for retail goods. These costs are borne by people regardless of their vehicle ownership and use, resulting in many hundreds of dollars in annual cross subsidies from low-vehicle-ownership to high-vehicle-ownership households. For example, a typical middle-income zero-vehicle urban resident is required to pay for at least one residential parking space, plus an estimated $2,000 annually for parking at work and businesses that they seldom or never use, so their neighbors who do rely heavily on automobile transport will have abundant and free parking at most destinations. These non-residential parking subsidies average about 17¢ per mile ($2,000/12,000 annual VMT per automobile), or about 25¢ per mile for a typical urban automobile commute ($1,000/4,000 annual VMT per automobile-commuter) who uses a "free" parking space.

Table 40 indicates automobile and transit external costs under various travel conditions. Figure 19 illustrates the totals. These external costs are particularly high under urban-peak conditions, which is where transit tends to be most cost-effective. As a result, transit is often more cost effective than automobile travel under urban-peak conditions on efficiency grounds (Condon and Dow 2009). In addition, a certain amount of transit service is justified under all conditions to provide basic mobility.

Figure 19 **Transit and Automobile External Costs** (Litman 2009)



This figure compares estimated average external costs for automobile and transit under various travel conditions, including operating subsidies, congestion, road, parking subsidies, accident externalities and pollution emissions. Transit has lower costs under urban peak conditions.

Taxi operating costs (for vehicles, drivers and business expenses) average about $2.25 per mile, plus external costs of 20-50¢ per mile (the same as automobile travel). Transit subsidies are therefore about a quarter of taxi costs, indicating that transit is often more cost effective than other options available to non-drivers.

Per Capita
Equity analysis requires per capita cost analysis. Transit dependent people tend to travel less than motorists, so higher costs per mile are more than offset by fewer annual miles. For example, a non-driver who rides transit 3,000 annual miles with 60¢ per passenger-mile external costs receives $1,800 total annual subsidy, while a motorist who drives 12,000 annual miles with 25¢ per mile external costs receives a $3,000 annual subsidy. Transit subsidies can therefore be justified on horizontal equity grounds, to insure that non-drivers receive a fair share of transport funding.

Economies of Scale and Second-Best Pricing
Public transit services experience scale economies (unit costs decline as use increases), which justifies subsidies (Vickrey 1994, pp. 197-215; Parry and Small 2007). As described previously, automobile travel imposes significant external costs. Until such costs are internalized through more efficient road, parking and fuel pricing, subsidies can be justified to improve transit service and attract travelers who would otherwise drive on *second-best* grounds, to help reduce traffic congestion, parking and accident problems.

Project-Specific Comparisons
The analysis above compares transit and automobile travel using generic, average values, but when evaluating transit projects and comparing them with other options in a particular planning situation it is best to use specific marginal costs and benefits. This can identify whether transit is most cost-efficient, and can help design transit projects to maximize net benefits. Marginal costs are often lower than average costs for transit services. For example, once a decision is made to provide transit to provide basic mobility to non-drivers there is often little incremental cost to carrying more riders.

Cost Comparison Summary
Table 41 summarizes different ways of comparing costs. Considering just direct financial subsidies transit appears more costly than automobile travel, but when other costs are considered, transit costs and subsidies turn out to be lower overall, particularly under urban-peak conditions.

Table 41 **Comparing Transit And Automobile Costs Per Passenger-Mile**

Perspective	Transit Versus Automobile Cost Ratio	
	Total	Efficiency-Justified
Transit subsidy versus roadway subsidy	40:1	20:1
Total external costs of transit and automobile	1.5:1	0.75:1
Urban-peak external costs of transit and automobile	0.5:1	0.5:1
Per capita annual external costs of transit and automobile users	0.6:1	0.3:1
Marginal cost of addressing various transport problems	Transit Often Cheapest	Transit Often Cheapest
Project-specific analysis	Varies	Varies

This table summarizes different ways to compare transit and automobile costs. Transit receives more government financial subsidy per passenger-mile, but automobile travel imposes other external costs, particularly under urban-peak conditions. As a result, transit improvements are often cheaper than the total costs of accommodating more urban driving, and transit users impose much lower external costs per capita than motorists. These are generic estimates to indicate the general magnitude of costs, more detailed analysis is needed to determine costs in a particular situation.

Perspectives

Transit and automobile costs can be compared from various perspectives, such as these three.

Consumers

Although most North American adults reply primarily on automobile transportation, many still experience periods in life they can benefit from having transit available, including when they are too young to drive, if they have limited incomes, if they have a disability that limits driving (which is particularly common during old age), when their vehicle fails or for any reason they are not allowed to drive, if a family member of friend would need to be chauffeured, during special events that attract large crowds, and if they commute to a destination with significant congestion or parking costs.

From consumers perspective transit can be a cost effective investment. Residents of communities with high quality public transit services save hundreds of dollars on avoided transportation costs (CTOD and CNT 2006; Litman 2004a). High quality transit typically costs residents an extra $100-300 in annual subsidies but provides about $500 to $1,000 in transportation cost savings, plus other benefits such as reduced accidents and improved mobility options (Litman 2010).

Transit Can Make You A Millionaire

Here is a strategy that can provide a million dollars to a person with an average income, and it is enjoyable, healthy and ethical. Simply minimize your driving expenses and invest the savings. After a few decades you'll be rich. It's as simple as that.

Most households can reduce their vehicle expenditures. For example, owning and operating a typical new luxury car, SUV or van costs about $8,000 a year, and most households own multiple vehicles. If you buy a reliable used car, share it with other family members, and minimize your driving by using transit, cycling and walking when possible, you can reasonably cut your vehicle expenses in half. Although you'll lead a less mobile lifestyle, you'll enjoy greater financial freedom.

What happens if you invest the $4,000 annual savings at 7% annual return? In ten years you have $55,266, in twenty years you have $163,982, and in less than forty-four years you have a million dollars. In other words, excessive car expenses consume a million dollars of accumulated wealth over a typical working lifetime.

Perhaps you have other priorities besides retiring rich. You can use the savings to buy a nicer home, put children through college, travel, or work fewer hours. This alternative is not transportation deprivation. You can still have a household car available when you need it, you simply can't own a particularly flashy vehicle or lead an extremely automobile-dependent lifestyle.

Business
Public transit can benefit businesses by improving employee access, reducing costs and supporting community land use and economic development. Below are examples of benefits to various types of businesses:

- *Service-Oriented Business.* Public transit can expand the pool of available workers and provide a fall-back option for commuters who normally drive when their vehicles are for any reason unavailable. This is particularly important for industries that hire numerous lower-wage workers, such as hospitality and retail businesses.
- *Downtown Developer.* Transit is important for downtown economic development. It reduces parking costs and allows higher densities and more design flexibility than would occur if visitors all arrived by car.
- *Tourist Attraction.* Transit can support tourism by providing mobility for visitors who arrive without a car, by reducing the economic and aesthetic costs of providing visitor parking, and by providing commute transportation to lower-wage employees.
- *Small Retail Business*. Downtowns offer a unique retail environment. Transit service reinforces the economics and ambiance of downtown by reducing automobile traffic and parking problems, and bringing a critical mass of customers into a walkable commercial area.
- *Manufactures, Shippers and Service Companies.* Public transit benefits businesses that use roadways by reducing traffic and parking congestion.

Public Officials and Taxpayers
Transit services and support strategies such as commute trip reduction programs and transit oriented development can provide government savings and achieve public objectives.

- *Transportation Agency.* Transit improvements are often the least-cost way to improve mobility, reduce urban traffic and parking congestion, and address particular problems, such as congestion during roadway construction projects or special events.
- *Social Services.* Transit services support public services by providing access to medical services, education and employment by disadvantaged populations.
- *Schools and Colleges*. Public transit can make education more affordable and available to disadvantaged students, and helps reduce traffic and parking problems around schools and campuses.
- *Economic Development*. Transit services support economic development, by reducing government and business costs, improving access to jobs, and supporting various economic development efforts such as urban redevelopment and tourism.
- *Land Use Planning*. Transit can help support strategic land use objectives, such as redevelopment of existing urban communities and reduced sprawl.
- *Special Events.* Transit can help address traffic and parking problems that occur during major sport and cultural events.
- *Environmental Quality*. Public transit can help achieve energy conservation, pollution emission reduction and greenspace preservation objectives.

Motorists

Critics sometimes assume that there is a conflict between the interests of motorists and transit users. They often claim that public transit receives an excessive portion of transportation funding, and challenge the use of vehicle user fees to fund public transit services. But motorists have many reasons to support public transit, as listed below.

Congestion Reduction. Quality transit service that is attractive to discretionary travelers can be an effective way to reduce traffic and parking congestion.

Roadway and Parking Facility Cost Savings. When all costs are considered, transit improvements are often cheaper than increasing road and parking facility capacity. This reduces costs to governments and businesses.

Improve Choice. Even people who don't currently use transit may value having it as a mobility option for emergencies and future use, similar to the value that ship passengers place on having a lifeboat, even if they don't use it.

Consumer Cost Savings. High-quality transit service, and transit-oriented land use, can provide thousands of dollars in annual savings per household (McCann 2000).

Reduced Chauffeuring. Quality transit service can reduce motorists' need to give rides to non-driving friends and family members.

Safety Benefits. Transit travel tends to have lower crash risk than automobile travel, reducing crash risks to transit riders and other road users.

Efficient Land Use. Some land use patterns, including large commercial centers, multimodal neighborhoods and some types of resorts, are only feasible with high quality transit service.

Equity. Transit provides basic mobility for people who are economically, physically and socially disadvantaged.

Economic Development. Expenditures on transit tend to provide much more employment and regional business activity than consumer expenditures on automobiles and fuel.

Environmental Benefits. Transit consumes fewer resources and causes less pollution than automobile travel.

Critics sometimes imply that it is hypocritical or unfair for people to support transit if they don't currently use it (e.g., "Supporters simply want transit for other people to use, so they can continue driving"). But there is no reason that support for transit should be limited to currently users. It is both rational and moral for motorists to support transit to improve mobility for others, reduce traffic and parking congestion, and provide a transport option that they may use in the future. Put another way, over a typical lifecycle most people have periods when they rely on public transit. Non-users can support transit as a way to insure it will be available when they will need it in the future.

Common Errors Made When Comparing Transit and Automobile Transport

Below are common errors made when comparing transit and automobile costs and benefits. For more discussion see "Comprehensive Planning," VTPI (2004) and Ehrenhalt (2009).

- *Confusing efficiency and equity objectives.* Because transit services are justified for both efficiency and equity objectives, it is important to consider these objectives separately in economic analysis. Some efficiency-justified services may seem inequitable (for example, premium services to attract commuters out of their cars), and some equity-justified services may seem inefficient (such as special services and features to accommodate people with disabilities, and off-peak service to provide basic mobility).
- *Comparing average rather than marginal costs.* When comparing automobile and transit investments, some analysts use generic average costs, ignoring the greater efficiency of transit and higher costs of automobile travel under urban-peak conditions.
- *Ignoring parking costs.* Economic analysis often ignores the parking cost savings that result from reduced automobile ownership and use.
- *Underestimating vehicle cost savings.* Economic analysis often considers only fuel, oil, tire wear and tolls when calculating the savings from reduced driving, ignoring additional savings from reduced vehicle ownership and mileage-based depreciation savings.
- *Undervaluing safety and health benefits.* Safety benefits from reduced accidents, and health benefits from increased walking are often overlooked.
- *Ignoring transportation diversity benefits.* There are benefits to having a diverse transport system that are often overlooked, including improved mobility for non-drivers, consumer savings and choice, increased efficiency, increased system flexibility and resilience.
- *Ignoring non-drivers interests.* Transportation planning sometimes assumes that everybody has access to an automobile, giving little consideration to the needs of non-drivers, or the negative impacts that increased vehicle traffic and automobile-oriented land use have on pedestrians, cyclists and transit users.
- *Ignoring generated traffic impacts*. Failure to consider the effects of generated traffic tends to overstate the benefits of highway capacity expansion and understate the benefits of alternative solutions, particularly grade separated transit (Litman 2001).
- *Ignoring strategic land use objectives.* Transit tends to support land use objectives such as reduced sprawl and urban redevelopment.
- *Ignoring construction impacts.* Transport projects, particularly highway construction, often cause delays and accident risk, and displace residents and businesses. These can offset a significant portion of the project benefits (McCann, et al 1999).
- *Undervaluing congestion reductions.* Transit can provide significant long-term congestion reductions when it is faster than driving, but this impact is often overlooked.
- *Ignoring consumer preferences and latent demand.* Travelers sometimes prefer alternative modes and will choose them over driving even if they are slower. Where high quality public transit is provided, ridership tends to significantly increase.
- *Ignoring strategies for increasing transit benefits.* A transit option that does not appear justified under current conditions may become cost effective if implemented as part of a coordinated program that includes ridership incentives and transit oriented development.

Transit Versus Automobile Comparison Summary

Public transit and automobile transport have very different benefit and cost profiles that should be considered when comparing their cost efficiencies and evaluating their roles in an efficient transport system. Transit requires relatively large subsidy per passenger-mile. As previously discussed (see Figure 18), about half of these subsidies are for features to provide basic mobility (wheelchair lifts, paratransit, and service in lower-density areas), which increase transit costs but are often cheaper than alternatives: inadequate mobility for non-drivers, taxi rides, or chauffeuring by motorists. Automobile transport has other subsidies and external costs, including parking and fuel production subsidies, congestion and accident risk imposed on other road users, and pollution emissions.

Public transit and automobile transport have opposite cost curves: transit costs decline while automobile costs increase with density. Transit cost efficiency varies widely depending on conditions and can be significantly increased with support strategies such as grade separation, transit-oriented development, and efficient road and parking pricing. Transit service experiences scale economies. As a result, transit improvements are often more cost effective than accommodating additional automobile travel on urban roads.

By helping create more compact, multi-modal communities high quality transit can leverage additional vehicle travel reductions, so a transit passenger-mile reduces several automobile vehicle-miles (ICF 2008 and 2010). People who rely on transit tend to travel fewer annual miles and so receive less per capita subsidy than motorists. A typical transit commuter receives a third of the transport infrastructure subsidy as a typical urban automobile commuter. Public transit subsidies are therefore justified on fairness grounds, to ensure that non-drivers and urban areas receive a fair share of transport funding.

High quality public transit provides numerous benefits including congestion reductions, road and parking facility cost savings, consumer savings, reduced accident risk, improved mobility for non-drivers and reduced chauffeuring burdens for motorists, energy conservation, pollution emission reductions, support for more efficient land use development, and improved public fitness and health. Even people who currently do not use public transit enjoy many of these benefits and so have reason to support service improvements that increase its attractiveness (Litman 2010a). Considering all benefits, public transit investments often provide high economic returns. Conventional planning tends to overlook or undervalue many of these benefits leading to underinvestment in transit service improvements and support strategies.

Current trends are increasing the benefits and cost efficiency of high quality public transit. These include aging population, rising fuel prices, increasing traffic and parking congestion, increasing urbanization, increasing costs to expand roads and parking facilities, changing consumer preferences, and increasing health and environmental concerns. Consumer demand for alternative modes and transit-oriented development is increasing (Litman 2006). As a result, policies and investments that support high quality public transit are increasingly justified to create a more diverse and efficient transport system that responds to future consumer demands and economic conditions.

Evaluating Transit Criticism

There is sometimes debate over the merits of transit. Critics argue that it is ineffective at improving transportation system performance and is wasteful, but their analysis reflects various omissions, errors and misrepresentations. *Evaluating Rail Transit Criticism* (Litman 2005a) and various related documents (Litman 2011 and 2014b) examine these criticisms in detail. Below are some key points.

- Critics tend to ignore or understate many transit benefits and underestimate the full costs of accommodating more automobile traffic under urban-peak conditions. For example, they compare the costs of rail transit projects and average highway expansion costs, although automobile travel requires vehicles, roads and parking, and road and parking facility cost are generally higher than average in dense urban area. An accurate analysis compares rail system costs with the full costs of owning and operating automobiles, expanding roadways and providing parking on the same congested urban corridors.
- Critics argue that North Americans will not ride transit, and that North American cities are unsuited to efficient transit systems. But experience in several North American cities show that with high quality service and supportive policies transit ridership will grow, and transit can be cost effective compared with other transportation improvement options.
- Critics are wrong when they claim that rail transit fails to reduce traffic congestion. There is plenty of evidence that high quality transit services reduces roadway traffic congestion.
- Critics claim that transit is not a cost effective solution to individual problems such as traffic congestion, air pollution, inadequate mobility for non-drivers, etc. They may be correct if transit is evaluated based on just one objective, but because it provides multiple benefits, when all impacts are considered, rail transit is often very cost effective overall.
- Critics claim that transit carries too few travelers to solve regional transport problems. But transit operates on the most congested routes where even a small reduction in traffic volumes can provide significant road, parking and vehicle cost savings.
- Critics argue that transit is too slow to be useful or attractive. But on congested urban, automobile travel is also slow due to congestion, so transit trips are often competitive. In addition, travel time unit costs (cents per minute or dollars per hour) are generally lower for high quality public transit (passengers have a seat, vehicles are comfortable, safe and quiet, and so can use their time productively) than for driving in congested conditions.
- Critics claim that transit is excessively subsidized, but transit subsidies are often lower than the total external costs of automobile transport under urban travel conditions, including road and parking subsidies, and congestion, accident and pollution costs imposed on others. Transit subsidies are partly justified for equity sake, to reduce problems such as traffic and parking congestion, and to help achieve a strategic planning objective such as urban redevelopment, factors that critics generally ignore.
- Critics argue that automobile travel offers more freedom than public transit. This is only partly true. In a typical community, 10-30% of the population cannot drive and so does not enjoy the freedom of driving. Although motorists are not restricted by schedules, they must work longer hours to pay for their vehicles, and are burdened by the stress of driving. For many people, public transit improvements, and more transit-oriented development, provide more freedom than additional roadway expansion.
- Critics claim it is cheaper to subsidize automobiles than to provide transit services, but they overlook many important factors, as discussed in the following section.

Debates about the value of transit often reflect differences in the scope and definition of impacts (benefits and costs). Transit services and improvements should generally be evaluated based on their *total* benefits and costs, rather than a few performance indicators such as dollars per reduction in congestion delay or ton of emissions. This can be done formally, by monetizing (measuring in monetary units) all impacts to calculate *net present value*, or less formally using some sort of matrix of performance indicators (Litman 2001a).

At a minimum, these impacts should include congestion reduction, road and parking cost savings, consumer cost savings, reduced crash costs, energy conservation and emission reduction benefits, improved mobility for non-drivers, and support for strategic planning objectives such as reduced impervious surface, urban redevelopment and economic development, as discussed in this report. Quantification can be difficult because so many of the benefits and a few of the costs of transit, particularly rail transit, do not lend themselves to be easily measured and monetized. For example, transit improvements and transit-oriented development tend to improve accessibility for disadvantaged populations, an equity objective. It is difficult to place a dollar value on this benefit, although most people would probably agree that it is important to consider when evaluating options. Similarly, it can be difficult to quantify the full benefits of energy conservation (what value to put on reduced dependency on imported oil) although most people will probably agree that it is significant.

It is wrong to evaluate public transit based on just one or two performance indicators, such as congestion or air pollution reduction, just as you wouldn't evaluate a possible house to purchase based only on the size of its bedroom or the quality of its appliances. A house provides a complex set of services. So does a transportation system. Evaluation must be multi-faceted, recognizing the full range of direct and indirect impacts. One of the greatest challenges of good decision-making is the temptation to focus on easy-to-measure impacts at the expense of more-difficult-to-measure impacts.

Rail transit and transit-oriented development are often criticized because their full benefits take many years to be achieved, since rail is built one link at a time, and transit-oriented development requires changing land use patterns. But they can provide diverse benefits and these benefits are extremely durable once implemented. Rail transit and TOD therefore provides a long-term legacy of increased accessibility and community livability for the future. A short-term perspective will therefore undervalue these strategies.

Is Transit Travel Slow and Inefficient?

Critics sometimes argue that transit is inefficient because transit travel tends to be slower than driving, citing particular trips that take much longer by transit than automobile. Such comments are understandable, since public transit often does take longer to reach a particular destination, but such analysis overlooks several important factors that can result in public transit being overall efficient and cost effective.

Although for an individual traveler driving is often faster, total travel times can often be reduced if travelers shift from driving to public transit on congested corridors. For example, consider a particular length of roadway can carry 4,000 maximum vehicles per hour, vehicle travel takes 30 minutes under uncongested conditions and 40 minutes under congested conditions, and bus travel takes an additional 10 minutes for access and waiting time. If all 5,000 travelers drive they all experience congestion, resulting in 200,000 total minutes travel time (5,000 times 40 minutes). However, if 1,000 of those travelers shift to public transit, reducing vehicle traffic volumes to the road's capacity, the total travel time is reduced to 160,000 minutes (4,000 motorists at 30 minutes plus 1,000 transit passengers at 40 minutes per trip), saving 40,000 total minutes.

In addition, travel time unit costs (cents per minute or dollars per hour, as reflected by opportunity costs and consumers willingness to pay for travel time savings) are generally lower for high quality public transit than for driving, since transit travelers can work or relax. As a result, even if transit travel takes more minutes per trip, travel time costs may be lower. For example, if transit travel is comfortable its travel costs are estimated to average 25% of wage rates, compared with 50% or more of wage rates for driving under congested conditions. Of course, these values will vary depending on conditions and personal preferences; some travelers will place a higher or lower value on transit travel or driving. However, if high quality transit service exists, travelers can self-select so those who prefer driving continue to drive and those who prefer transit can choose that option, minimizing travel time costs.

Transit travel often has faster *effective speeds* (considering total time devoted to travel, including both time spent traveling and devoted to maintaining vehicles and working to pay transport expenses) than automobile travel, as illustrated in the table below.

Table 42 **Effective Speed** (Tranter 2004)

	Luxury Car	Sport Utility Vehicle	Average Car	Economy Car	Public Transit	Bicycle
Annual vehicle costs (Aus$)	$14,161	$17,367	$9,753	$5,857	$966	$500
Annual hours worked ($20/hrs)	644	790	444	266	44	23
Average travel speed (km/hr)	45	45	45	45	2	20
Travel time (hours)	333	333	333	333	600	750
Support time (maintenance, etc.)	51	51	50	51	60	55
Total time	1,028	1,174	827	650	704	828
Effective speed (km/hr)	*14.6*	*12.8*	*18.1*	*23.1*	*21.3*	*18.1*

This table compares estimated effective speeds of various vehicles.

When people shift from driving to public transit they often change their destinations to increase efficiency. For example, automobile travelers tend to shop at automobile-dependent suburban locations. People who rely on transit tend to shop more at neighborhood stores and downtown business districts. Described differently, transit travel tends to take longer to access automobile-oriented locations, but transit-oriented development, which increases local services and concentrates destinations near high quality transit stations, improves accessibility. In automobile-dependent areas transit travel often requires long walks to bus stops, long waits due to infrequent service, slow vehicle speeds, and multiple transfers due to limited routes. With high quality transit and transit-oriented development most destinations are within a five-minute walk of frequent transit stops and stations, multiple routes provide more direct links, and service is fast due to quick loading systems and grade separation. As a result, the total amount of time people devote to travel is no greater in transit-oriented locations than in otherwise similar automobile-oriented communities.

Transit can also provide special time savings by reducing the need for special chauffeuring trips and for exercise. In automobile-dependent locations parents often drive children to school and sport events, and non-driving relatives and friends to shopping and medical appointments, trips that are avoided where high quality public transit is available. Since most transit trips involve walking or cycling links, most transit travelers achieve daily physical activity targets, saving time in traveling to a gym and exercising.

For all of these reasons it is wrong to assume that public transit travel is necessarily less efficient or more time consuming than driving. This is not to suggest that transit is always more efficient and cost effective or that every trip should be made by public transit. An optional transport system provides effective travel options so people can choose the most efficient and preferable mode for each trip. For example, they can choose to walk and bicycle for local errands and trips during good weather, and enjoy exercise. They can choose high quality public transit when traveling on major urban corridors, and be able to work or relax instead of bearing the stress of driving in congestion. And they can choose to drive, their own car or a rented vehicle, when traveling to dispersed destinations, or in a group, when carrying large loads, or when other circumstances require.

Is It Cheaper To Subsidize Cars Instead Of Transit?

Critics sometimes argue it would be cheaper to subsidize car ownership for low-income people than transit service. For example, Castelazo and Garrett (2004) calculate it would be cheaper to provide free cars to the 14% of St. Louis rail transit riders that lack automobiles, than to subsidize that service. Cox (2004) claims that carsharing subsidies for non-drivers would be cheaper than U.S. transit subsidies. However, such claims tend to overlook important factors (Cervero and Guerra 2011; Litman 2005a).

- Transit is subsidized for several reasons besides providing mobility to lower-income travelers, including congestion reduction, road and parking facility cost savings, consumer cost savings, increased safety, pollution reduction and support for strategic development objectives. Only a small portion of transit subsidies could efficiently or equitably be shifted to any one of these objectives.
- Many transit riders cannot or should not drive. They are too young, disabled, or prohibited from driving. Subsidizing cars instead of transit service would not solve their mobility problems, and would tend to increase higher-risk driving. It is easier to reduce driving by high-risk motorists in communities with good transit systems, for example, by delaying teenage vehicle ownership, revoking driving privileges for dangerous drivers, and reducing vehicle use by elderly residents, which helps explain the much lower per capita traffic fatality rates in areas with good transit service.
- Substituting car ownership for transit service is more expensive than proponents claim. Increased vehicle traffic on busy urban corridors would significantly increase traffic congestion, road and parking costs, accidents, pollution and other external costs.
- Eliminating scheduled transit service would force riders who cannot drive to use demand-response or taxi services, which have far higher costs. Cox assumes this could be accommodated by doubling demand-response funding, but since demand response services only provide 1.4% of total transit passenger-miles, doubling its funding could not compensate for reducing the other 98.6% of services. People tend to significantly increase their travel when they shift from transit to having an automobile, so even if per-mile costs decline, per-user costs would likely increase.
- There are substantial practical problems with offering free cars or carshare subsidies to low-income people who currently rely on public transit. Low-income transit riders are not a distinct, identifiable group, they consist of a much larger group, many of whom use transit part-time, or who sometimes do not own an automobile. Rather than giving 7,700 households a car, it would be necessary to offer a much larger number of households a part-time car, with provisions that account for constant changes in vehicle ownership and travel status, and for the increased travel that occurs when non-drivers gain access to an automobile. Like any subsidy program, it would face substantial administrative costs and require complex rules to determine who receives a subsidy and how much each user is allocated in a way that seems fair and effective at achieving its objectives. It would create perverse incentives, rewarding poverty and automobile dependency.
- Transit in general and rail transit in particular can provide a catalyst for mixed-use, walkable urban villages and residential neighborhoods where it is possible to live and participate in normal activities without needing an automobile. This is particularly beneficial to non-drivers. Subsidizing cars rather than transit services would cause an additional harm to transportation disadvantaged people, by stimulating urban sprawl and automobile dependency.

Rail Versus Bus Transit

There is considerable debate over the relative merits of bus and rail transit (Pascall 2001; GAO 2001; Warren and Ryan 2001; Demery and Higgins 2002; Ben-Akiva and Morikawa 2002; Thompson and Matoff 2003; Hass-Klau, et al. 2003; Litman 2004a; Steer Davies Gleave 2005; Currie and Delbosc 2013; Vuchic 2005; NJARP 2006; LRN 2006; Vincent and Callaghan 2007; Hensher 2007). Table 43 compares performance of various transit types. Of course, actual performance depends on specific designs and conditions.

Table 43 **Transit Performance Factors** (Steer Davies Gleave, 2005, Table 3.1)

Standard	Conventional Bus	Double-deck Bus	Articulated Bus	LRT	Two-Car Trams
Length	10m	12m	18m	24.5m	2 x 30m
Width	2.5m	2.5m	2.5m	2.55m	2.65m
Passenger Capacity	75	105	125	160	350
Seating	35	95	50	60	150
Standing	40	10	75	100	200
Maximum Hourly Capacity	4,500	6,300	7,500	9,600	21,000

Advantages of Rail

Proponents argue that rail transit provides superior service quality that attracts more discretionary users (people who have the option of driving). Rail can carry more passengers per vehicle and requires less land per peak passenger-trip, and so tends to be more cost effective than bus on high-density corridors. Bruun (2005) calculates that on a typical trunk line, above 2,000 passenger-spaces-per-hour LRT tends to become more efficient and cost effective than BRT. Voters seem more willing to support funding for rail than bus service. Rail causes less noise and air pollution than diesel buses. As described earlier, rail tends to have higher demand within its service area (Pushkarev and Zupan 1977; Henry and Litman 2006; CTS 2009a), although this may partly reflect performance factors such as service frequency, speed and station quality that BRT systems may provide (Currie 2005). Rail tends to have greater land use impacts – rail transit stations often serve as a catalyst for transit oriented development – which provides additional economic, social and environmental benefits (Currie 2006).

Accessibility and Mobility

When comparing bus and rail it is important to appreciate the difference between mobility and accessibility (Litman 2009a). *Mobility* refers to physical movement. *Accessibility* refers to peoples' ability to obtain desired goods, services and activities, which is affected by mobility and land use patterns. Automobiles offer users a high level of mobility, but heavy automobile traffic degrades other forms of mobility (particularly walking) and encourages dispersed land use patterns. Bus transit can provide a high level of mobility, with direct service to many destinations, but has minimal land use impacts. Rail transit provides moderate mobility and is often a catalyst for more accessible land use patterns, call *transit-oriented development*. Rail transit is therefore most attractive in terms of accessibility rather than mobility.

Advantages of Bus

High quality bus systems, called Bus Rapid Transit (BRT) can attract high ridership and stimulate transit-oriented development (Hidalgo and Carrigan 2010). Bus advocates argue that bus service is cheaper and more flexible, that buses can be designed to be nearly as fast and comfortable as rail, and that much of the preference for rail reflects prejudices rather than real advantages (Hensher 2007; Cain, Flynn and McCourt 2009). Bus transit can serve a greater area, and so can attract greater total ridership than rail with comparable resources, particularly in areas with dispersed destinations. Some argue that rail investments (which tend to benefit higher-income people) drain funding from bus service (which tends to benefit lower-income, transit-dependent people), and so are inequitable, although this is not true if rail projects receive special funding that increases total transit budgets, and some rail lines carry large numbers of lower-income riders.

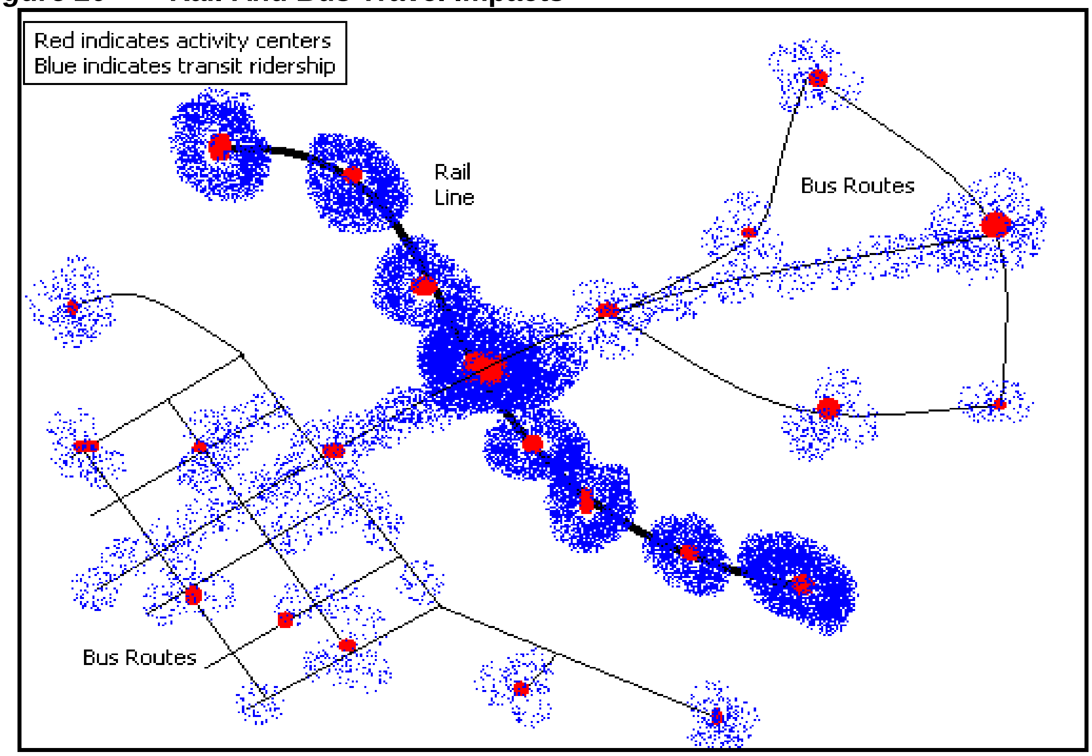
Summary of Rail Versus Bus

Key differences between bus and rail transit are summarized below. Rather than a debate which is overall superior, it is generally better to consider which is most appropriate in a particular situation. Bus is best serving areas with dispersed destinations and lower demand. Rail is best serving corridors with concentrated destinations and ridership, such as large commercial centers and urban villages (Kuby, Barranda and Upchurch 2004). Rail tends to attract more riders within an area but buses can cover more area, so overall ridership impacts depend on conditions. Both become more efficient and effective at achieving planning objectives if implemented with supportive policies that improve service quality, create more supportive land use patterns and encourage ridership.

Bus	Rail
• **Flexibility.** Bus routes can change and expand when needed. For example, routes can change if a roadway is closed, or if destinations or demand changes. • **Requires no special facilities.** Buses can use existing roadways, and general traffic lanes can be converted into a busway. • **More suitable for dispersed land use**, and so can serve a greater rider catchment area. • **Several routes can converge onto one busway**, reducing transfers. For example, buses that start at several suburban communities can all use a busway to a city center. • **Lower capital costs.** • **Used more by transit dependent people**, so bus service improvements provide greater equity benefits.	• **Greater demand.** Rail tends to attract more discretionary riders than buses. • **Greater comfort** due to larger seats, more legroom, and smother and quieter ride. • **More voter support for rail than for bus** improvements. • **Greater maximum capacity.** Requires less space and is more cost effective on high volume routes. • **Greater travel speed and reliability**, where rail transit is grade separated. • **More positive land use impacts**. Rail tends to be a catalyst for more accessible development patterns. • **Increased property values** near transit stations. • **Less air and noise pollution**, particularly when electric powered. • **Rail stations tend to be more pleasant than bus stations**, so rail is preferred where many transit vehicles congregate.

Rail transit can only serve a limited number of stations. Those stations tend to stimulate more intense development, with increased density (residents, employees and business activity per acre), higher per capita transit ridership and walking trips, and lower per capita vehicle ownership and trips. Bus transit can serve more destinations, including some dispersed, suburban activity centers, but attracts fewer riders per capita, and by itself has little or no effect on land use patterns. Which will attract the most riders and be most cost effective depends on the circumstances: rail tends to attract more riders in the area it serves, but buses can directly serve more destinations over a larger area.

Figure 20 **Rail And Bus Travel Impacts**



This illustrates differences between rail and bus transit travel impacts. Rail tends to stimulate transit-oriented development where households tend to own fewer automobiles and people drive less and rely more on alternative modes. Bus transit can serve more destinations, including dispersed, suburban activity centers, but attracts fewer riders per capita and tends to have less effect on land use patterns. Both types of transit can attract more riders and become more effective if implemented with supportive transport and land use policies.

Chatman (2013), found substantially lower vehicle ownership, and lower auto commute and shopping trip mode shares for households located in transit-oriented development, but that residential density, housing type, local bus service and limited parking supply had more impact than rail accessibility. He concludes that smart growth development policies, which help create more accessible, compact and multi-modal neighborhoods, can help increase transport system efficiency with or without rail transit development.

Bruun (2005) found that both Light Rail Transit (LRT) and Bus Rapid Transit (BRT) are typically cheaper to operate per passenger-space-kilometer than regular buses. For lines carrying less than about 1,600 spaces-per-hour, adding capacity tends to be cheapest for BRT, while above 2,000 spaces-per-hour BRT headways become so short that traffic signal priority becomes ineffective, reducing service efficiency and increasing unit costs, making LRT cheaper. The marginal cost of adding off-peak service is lowest for LRT, higher for BRT, and highest for regular buses.

Tirachini, Hensher and Jara-Díaz (2009) modeled the infrastructure, operating costs and user time costs of three public transport options (light rail, heavy rail and bus rapid transit) in relatively sprawled Australian cities. They conclude that in most scenarios BRT is most cost effective because it has the lowest total costs (infrastructure, rolling stock and operating cost), shortest access time and waiting time cost. Rail is more cost effective only if it operates fast enough that the speed difference outweigh the BRT's advantage on operator cost and access and waiting times. The analysis held trip generation factors constant and so did not account for rail and BRT's ability to increase transit ridership and create transit-oriented development.

Scherer and Dziekan (2012) surveyed Germany and Switzerland transit users concerning differences in attitudes between rail- and bus-based public transport. The research found a preference for using rail assuming equal service conditions of 63% for regional train and 75% for trams compared to bus services. They conclude that this reflect emotional and social attributions. Vincent and Callaghan (2007) evaluated a Los Angeles area BRT system compared it with other transit services in the region. The BRT exceeded ridership projections, reducing travel times, easing congestion, and attracting people out of their cars. They conclude that full BRT is more cost effective than rail and attracts more motorists than basic bus services. Hidalgo and Carrigan (2010), use research and interviews with planners and public officials to evaluate BRT demand and common obstacles to BRT development, and provides recommendations on avoiding or mitigating such problems when introducing bus reforms.

Rail and bus transit systems are generally integrated, with buses providing local service and servicing more dispersed destinations, and rail providing service along the highest density corridors. Both types of transit can become more effective if implemented with supportive transport and land use policies. Rail transit can be compared to a luxury vehicle: it costs more initially but provides higher quality service and greater long-run value. As consumers become wealthier and accustomed to higher quality goods it is reasonable that they should demand features such as more leg-room, comfortable seats, smoother and quieter ride (and therefore better ability to read, converse, and rest), and greater travel speed associated with grade-separated transit. The preference of rail over bus can be considered an expression of consumer sovereignty, that is, people's willingness to pay extra for more amenities. Analysis of qualitative factors such as rider comfort is needed to evaluate the full value of rail transit.

Strategies To Increase Transit Benefits

Various strategies can increase transit investment benefits. Benefits tend to increase if transit is implemented with support strategies that increase efficiency and ridership. Examples of these support strategies are described below. More information is available in the *Online TDM Encyclopedia* (www.vtpi.org/tdm), Cervero and Guerra (2011), Stanley and Hyman (2005), TranSystems (2007), CODATU (2009), and Hidalgo and Carrigan (2010).

Transit Priority

There are various ways to help transit vehicles avoid congestion delays and travel faster, including managed lanes, traffic signal preemption, special intersection design, and preferred loading and parking locations. 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 is likely to occur. Pratt (1999) provides detailed discussion of the travel effects of busway and HOV facilities.

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 of reducing automobile trips. Cost-based parking pricing (parking fees set to recover parking facility costs) typically increases transit ridership by 10-30%, depending on the previous level of transit ridership and the range of travel options available.

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%.

Marketing and User Information
Transit marketing and user information includes market surveys, improved route schedules and maps, wayfinding information, and other types of information.
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:

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

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 (Cervero, et al 2004; Cervero and Guerra 2011; Litman 2016b).
Travel Impacts: Residents of TODs typically reduce single-occupant vehicle commuting by 15-30%, about half of which shifts to transit. Impacts depend on specific design features, and other geographic and demographic factors.

Least Cost Planning
Current transportation planning practices are biased in various ways that favor highways and parking investments over transit (Beimborn, and Puentes, 2003; "Comprehensive Transport Planning," VTPI, 2004). More neutral planning provides various benefits, including increased efficiency and equity.

Travel Impacts: Difficult to predict, but probably significant.

Evaluation Examples

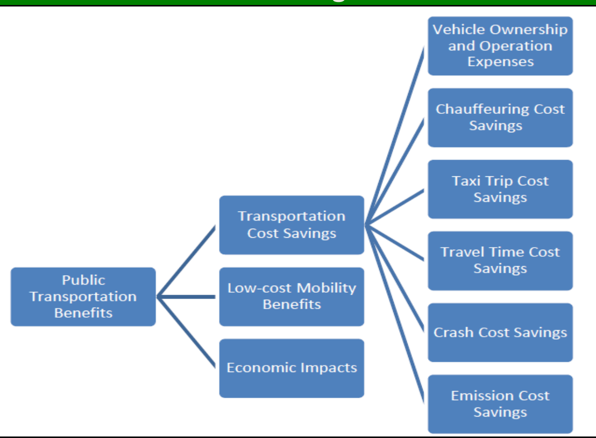
This section provides various examples of transit economic evaluations. A spreadsheet computer model available at www.vtpi.org/tranben.xls is used for some of these examples, based on a "typical" middle-size city, with a half-million residents who make an average of 24 transit trips annually. This analysis can be adjusted to reflect other conditions and assumptions.

Transit Benefit/Cost Analysis

Several recent studies have estimated benefit-cost ratios for various types of transit services (Ferrell 2015). They indicate that public transit investments generally provide positive economic returns, that is, each dollar spent on transit services provides more than a dollar in economic benefits. Although the highest benefit-cost ratios tend to be found in larger urban areas, most rural transit economic studies indicate that they provide net monetary benefit. In their report, *Cost-Benefit Analysis of Rural and Small Urban Transit*, Godavarthy, Mattson and Ndembe (2014) estimated the benefit/cost ratio for rural public transit services in each U.S. state, considering various categories of benefits, as illustrated in Figure 21. Because that study only considered a portion of transit benefits (for example, it ignores parking cost savings, and the value that non-drivers place on having independent mobility rather than being forced to depend entirely on rides by family members and friends), total benefits are probably greater.

Figure 21 **Rural Transit Benefit Analysis** (Godavarthy, Mattson and Ndembe 2014)

Benefit Categories



Benefit Estimates

Table 8.4 Benefit-Cost Ratios for US States/Regions in Rural Areas

Benefit-Cost Ratio of Public Transit in Rural Areas			
State	B/C Ratio	State	B/C Ratio
Alabama (AL)	1.46	Montana (MT)	1.93
Alaska (AK)	1.48	Nebraska (NE)	1.67
Arizona (AZ)	1.34	Nevada (NV)	1.26
Arkansas (AR)	0.82	New Hampshire (NH)	2.28
California (CA)	1.14	New Jersey (NJ)	0.72
Colorado (CO)	2.01	New Mexico (NM)	1.53
Connecticut (CT)	1.27	New York (NY)	1.17
Florida (FL)	0.37	North Carolina (NC)	0.46
Georgia (GA)	0.55	North Dakota (ND)	1.30
Hawaii (HI)	1.79	Ohio (OH)	0.84
Idaho (ID)	1.01	Oklahoma (OK)	1.05
Illinois (IL)	0.86	Oregon (OR)	1.50
Indiana (IN)	1.26	Pennsylvania (PA)	1.11
Iowa (IA)	1.87	South Carolina (SC)	1.48
Kansas (KS)	2.01	South Dakota (SD)	1.45
Kentucky (KY)	0.41	Tennessee (TN)	0.66
Louisiana (LA)	0.32	Texas (TX)	0.66
Maine (ME)	0.32	Utah (UT)	4.19
Maryland (MD)	2.57	Vermont (VT)	0.70
Massachusetts (MA)	1.79	Virginia (VA)	1.39
Michigan (MI)	0.61	Washington (WA)	1.48
Minnesota (MN)	1.77	West Virginia (WV)	1.16
Mississippi (MS)	1.60	Wisconsin (WI)	0.63
Missouri (MO)	1.29	Wyoming (WY)	3.00
		Total	1.12

This figure illustrates the categories of benefits, and benefit estimate results for each U.S. state.

Conventional transportation planning tends to overlook or undervalue many of these benefits. As a result, few rural areas invest in public transit to the degree justified by comprehensive economic evaluation.

TPICS (Transportation Project Impact Case Studies) System (http://transit.tpics.us)

TPICS is a searchable database of past projects and their observed impacts on economic development, and a predictive tool that estimates the range of likely impacts of proposed new projects, based on results from already-built projects.

Transit Improvement Economic Evaluation Model (ICF International 2009)
Most transport project economic evaluation models (such as MicroBenCost and HDM-4) are designed primarily to evaluate highway improvements and so fail to account for many of the impacts that result from mode shifts and changes in total travel activity. The study, *Benefit/Cost Analysis Of Converting A Lane For Bus Rapid Transit* describes various benefits and costs that should be considered when evaluating public transit service improvements such as converting a traffic lane into a bus lane. These include:

Benefits
Direct Benefits
- Travel time savings for transit users.
- Vehicle operation and parking cost savings to travelers who shift from auto to transit.
- Improved access to jobs and amenities to transit dependent travelers.
- Accident reductions.
- Reduced emissions and other environmental damages.
- Reduced transit operating costs due to increased efficiencies and higher ridership.

Indirect Benefits
- Benefits from increased economic activity and/or agglomeration of businesses.
- Benefits from property development owing to transit investment.
- Growth in employment in transit service area.
- Benefits to government from increased taxes generated by new development.

Costs
Direct Costs
- Capital costs of materials, equipment and vehicles
- Delay for travelers in mixed-flow travel lanes.
- Infrastructure construction costs (including roadway improvements, bus shelters, IT).
- Operations and maintenance costs.
- Additional delays to commercial and government fleets using mixed-flow travel lanes.
- Enforcement costs to prohibit use of dedicated lanes by other traffic.

Social Costs
- Traffic delays during construction.
- Noise pollution costs
- Costs of emissions if congestion on remaining lanes of highway increases.
- Costs of travel delay to others if congestion on remaining lanes of highway increases.

Access to Jobs and Workers via Transit (Ramsey and Bell 2014)
Access to Jobs and Workers via Transit is a free geospatial data resource and web mapping tool for evaluating neighborhood employment access by public transit. Using U.S. census data it calculates transit travel times between blocks groups, and the number of residents and jobs accessible by transit within 45-minute total (including access, waiting and in-vehicle) travel times. This information can be used to measure the transit accessibility individual block groups and metropolitan regions.

Optimal Transit Subsidy and Fares (Allison, Lupton and Wallis 2013)

This investment model is designed to help transportation agencies maximise allocative efficiency (ensure that society gains the greatest overall net benefit) when making public transit investment decisions. It takes into account operating costs and externalities of both public and automobile transport, including safety and congestion effects, and benefits to existing public transit users from service frequency changes. It incorporates the interactions between prices, service levels and patronage for public transport (bus initially) and private car, and associated performance indicators. The model was developed as a spreadsheet that is capable of expansion to include rail and other cities.

Optimal Transit Fares and Subsidies (Parry and Small 2007)

Parry and Small determine socially optimal fare subsidies for peak and off-peak urban rail and bus systems, based on transit system benefits and costs in metropolitan Washington (D.C.), Los Angeles, and London. Their analysis accounts for congestion, pollution, and accident externalities from automobiles and transit vehicles; scale economies in transit supply; costs of accessing and waiting for transit service as well as service crowding costs; and agency adjustment of transit frequency, vehicle size, and route network to induced changes in demand for passenger miles. The results support the efficiency case for large fare subsidies (in almost all cases, subsidies of 50% or more provide net benefits to society), and are robust to alternative assumptions and parameters.

Rural Transit Evaluation (Godavarthy, Mattson and Ndembe 2014),

This study identifies ways to evaluate the qualitative and quantitative benefits of small urban and rural public transit systems. It provides an evaluation framework which focuses on three main areas of transit benefits most relevant to rural and small urban areas: transportation cost savings, low-cost mobility benefits, and economic development impacts based on data from U.S. rural and small urban community transit systems. The benefits, costs, and benefit-cost analysis results are presented nationally, regionally, and locally. Sensitivity analysis was also conducted to illustrate how transit benefits and benefit-cost ratios vary with changes in key variables. With estimated benefit-cost ratios greater than 1, the results show that the benefits provided by transit services in rural and small urban areas are greater than the costs of providing those services.

International Urban Transportation Planning (JICA 2011)

The report, *Research on Practical Approach for Urban Transport Planning* by the Japan International Cooperation Agency (JICA) summarize research on factors that affect public transit demand and system efficiency, and therefore the type of transit system most suited to various types of cities. It includes detailed analysis of the relationships between factors including city size and growth rates, density, income or GDP, vehicle ownership, mode share, transit service type (metro rail, Bus Rapid Transit, and conventional bus), and types of urban transportation problem (traffic congestion, high accident rates, pollution, lack of public transit service, crowded transit and social inequity), based on comprehensive data from 398 major cities around the world, including 65 cities where JICA has helped develop urban transport master plans. The results can help determine where and when various types of urban transportation improvements are justified.

BRT Evaluation (EMBARQ 2013)

The report, *Social, Environmental And Economic Impacts Of BRT Systems* summarizes research regarding BRT performance, costs and impacts, including evidence from four case studies. The analysis compared construction costs with transit efficiency gains, travel time savings, environment and health benefits. It indicates that BRT projects can provide net positive benefits to society and can be socially profitable investments. Table 43 summarizes some results.

Table 44 **BRT Benefits** (EMBARQ 2013)

Impact	How does BRT achieve the benefit?	Empirical Evidence
Travel time savings	• Segregated busways separate BRT buses from mixed traffic; • Pre-paid level boarding and high-capacity buses speed passenger boarding; • Traffic signal management and high-frequency bus service minimize delays.	• Johannesburg BRT users save on average 13 minutes each way • The typical Metrobüs passenger in Istanbul saves 52 minutes per day
GHG and local air pollutant emissions reductions	• Reduce VKT by shifting passengers to highcapacity BRT buses • Replace/scrap older, more polluting traditional vehicles • Introduce newer technology BRT buses • Better driver training leads to improved driving cycles which have lower fuel consumption and emissions	• In Bogota, the implementation of TransMilenio combined with new regulations on fuel quality is estimated to save nearly 1 million tCO2 per year. • Mexico City's Metrobús Line 1 achieved significant reductions in carbon monoxide, benzene and particulate matter (PM2.5) inside BRT buses, traditional buses and mini-buses.
Road safety improvements – reductions in fatalities and crashes	• Improve pedestrian crossings • Reduce VKT by shifting passengers to highcapacity BRT buses • Reduces interaction with other vehicles by segregating buses from mixed traffic • BRT can change drivers' behaviors by reducing on-the-road competition and improving training	• Bogota's TransMilenio has contributed to reductions in crashes and injuries on two of the system's main corridors. • On average, BRTs in the Latin American context have contributed to a reduction in fatalities and injuries of over 40% on the streets where they were implemented.
Reduced exposure to air pollutants	• Cleaner vehicle technologies and fuels lower concentration of ambient air pollution citywide or inside the BRT vehicles; • Reduce time passengers are exposed to air pollution at stations or inside the bus by reducing travel times.	• After the implementation of TransMilenio, Bogota reported a 43% decline in SO2 emissions, 18% decline in NOx, and a 12% decline in particulate matter. • By reducing emissions of local air pollutants, especially of particulate matter, Metrobús Line 1 in Mexico City would eliminate more than 6,000 days of lost work, 12 new cases of chronic bronchitis, and three deaths per year saving an estimated USD $3 million per year.
Increased physical activity	• Spacing of BRT stations tend to require longer walking distances than all other motorized modes with the exception of Metro • Higher operation speeds increases passengers' willingness to walk to stations	• Mexico City's Metrobús passengers walk on average an additional 2.75 minutes per day than previously • Users of the Beijing BRT have added 8.5 minutes of daily walking as a result of the BRT system

Experience indicates that Bus Rapid Transit (BRT) can provide many significant benefits.

Urban Rail External Benefits

In 2008, the Independent Pricing and Regulatory Tribunal of New South Wales, Australia commissioned a study to determine optimal fares for the CityRail urban rail system in Sydney (Smart 2008). The study estimated the external benefits provided by the CityRail system, including reductions in roadway traffic congestion, accidents and pollution emissions, plus improved mobility and social inclusion, particularly for disadvantaged groups. It estimated that the total marginal external benefit of the rail system AU$5.71 per passenger trip, consisting primarily of congestion reduction benefits. Based on these findings, the Tribunal decided that that, to optimize benefits, approximately 71.5% of the transit system's revenue requirement should be funded by government subsidies.

Transit Versus Highway Improvements

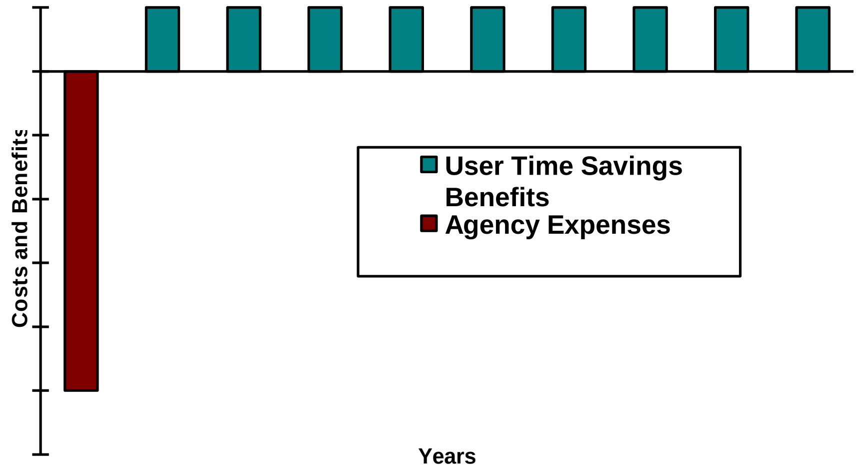
This example illustrates the effects of applying more comprehensive analysis when evaluating possible transportation improvements on a congested corridor. The "Conventional" analysis reflects standard highway evaluation practices which give no consideration to impacts such as parking cost savings and reduced surface street traffic congestion that result when people travel by transit rather than automobile. It also ignores construction traffic delays from the highway project, and the effects of generated traffic. It assumes that travelers saved only about 10¢ per mile when they reduce their vehicle use. It gives no weight to equity benefits from increased transport options for non-drivers, or strategic land use objectives in region land use plans. The conventional analysis concludes that highway capacity expansion is more cost effective than transit improvements. But a more comprehensive analysis shows the transit option actually provides greater net benefits, as illustrated in Table 45.

Table 45 **Conventional and Comprehensive Planning**

Conventional – Only Considers Direct Project Costs	
Light Rail	$300
Highway Expansion	$250
Highway Net Benefits	***$50***
Comprehensive – Considers Additional Costs	
Parking cost savings (3,000 urban parking spaces at $10,000 each)	$30
Surface street traffic congestion (3,000 additional vehicles traveling 6 miles per day, 300 days annually, at 20¢ per mile)	$20
Additional vehicle costs ($500 annual savings per transit user)	$29
Highway construction delays	$2
Generated traffic (reduces highway net benefits)	Probably Substantial
Environmental & social benefits	Probably Substantial
Transit Net Benefits	***$30+***

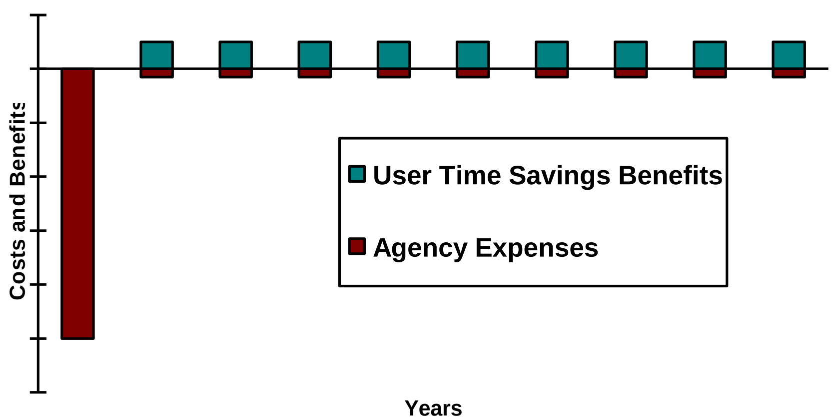
Figures 22 and 23 illustrate lifecycle cost analysis of roadway and transit investments using a conventional analysis. The graphs indicate benefits (bars above the baseline) and costs (bars below the baseline) projected ten years into the future for a highway and rail transit investment.

Figure 22 **Conventional Highway Investment Analysis**



This figure illustrates conventional analysis of highway project costs and benefits. (For simplicity this figure ignores discounting, which would reduce the value of future impacts.)

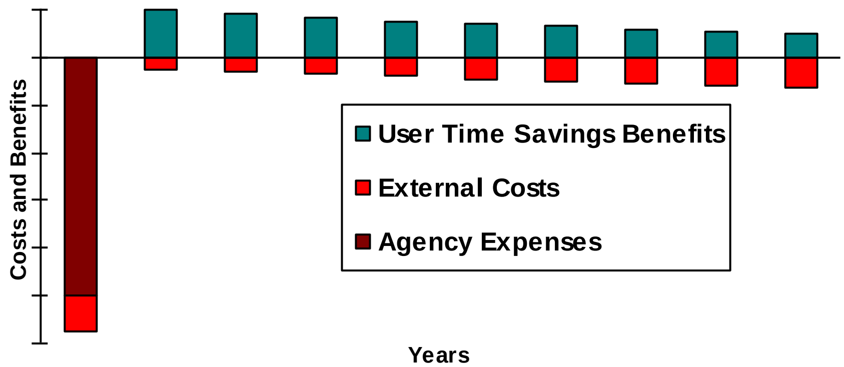
Figure 23 **Conventional Transit Investment Analysis**



Conventional analysis only considers direct financial public agency expenditures as costs, and congestion reduction (primarily user travel time savings) as benefits. This tends to make highway investments appear most cost effective.

More comprehensive investment analysis incorporates several other factors. It takes into account the increased congestion and declining traffic speeds that occur over time due to generated traffic. It incorporates external costs from increased automobile use, such as parking demand, surface street congestion, accidents and pollution. It accounts for transit benefits such as increased travel options for non-drivers and more efficient land use. The conventional analysis ignores many of these impacts, and so tends to skew planning decisions toward automobile-oriented improvements and away from more alternatives that involve alternative modes or management strategies.

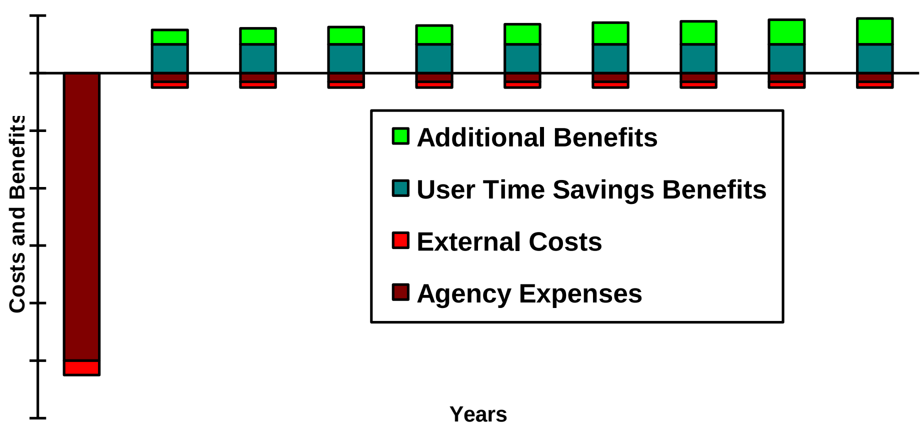
Figure 24 **Comprehensive Highway Investment Analysis**



This figure shows the effects of generated traffic and the external costs of the induced vehicle travel, which reduces the long-term net benefits of highway capacity expansion.

Figures 24 and 25 illustrate more comprehensive analysis of projected benefits and costs, taking into account these additional impacts. This is not to suggest that transit is always more cost effective than highway improvements. However, it shows how more comprehensive analysis can affect planning decisions.

Figure 25 **Comprehensive Transit Investment Analysis**



Comprehensive analysis incorporates the impacts of generated traffic, external costs, and mobility benefits provided by transit. This indicates greater costs for highway investments and greater benefits for transit investments.

More comprehensive analysis can also take into account the potential of increasing transit benefits by applying various support strategies, such as commute trip reduction programs, transit priority, parking and road pricing, transit-oriented land use development polities, and improved marketing. By increasing ridership and operating efficiency, such strategies can make transit more cost effective and competitive.

Rail Transit Service Travel Impacts (Boarnet and Houston 2013)

The Exposition (Expo) light rail line in Los Angeles began operation in 2012. This study enrolled experimental households, within ½ mile of a new Expo Line station, and control households, living beyond ½ mile from the station. In fall of 2011, those households were asked to track their travel for seven days, recording daily odometer readings for all household vehicles and logging trips by travel mode and day for each household member 12 years or older. In approximately half of the households, an adult also carried a geographic positioning device (GPS) and an accelerometer, to measure travel and physical activity. In total, 204 households (103 in the experimental neighborhoods, 101 in control neighborhoods) completed before and after travel tracking. The study found:

- In "before opening" travel data collection, experimental and control households had the same travel patterns. Before the Expo Line opened there were no statistically significant differences across experimental and control households in their daily travel activity
- After opening, the differences-in-differences approach shows that the experimental group reduced their daily household VMT by 10 to 12 miles relative to the control group. That result persists after outlier observations are removed and when alternative statistical methods are used.
- Using the GPS data to validate vehicle odometer logs, we find no evidence of any systematic reporting biases that would reduce our faith in the result that experimental households reduced their VMT by 10 to 12 miles, relative to control group households, after the Expo Line opened.
- In some statistical tests, there is evidence that the Expo Line increased rail transit ridership among experimental households. Control group households also increased their rail ridership, but not by as much as experimental households. On net, the differences-in-differences evidence suggests that the Expo Line resulted in about 0.1 more daily train trips per household in the experimental group, but we caution that this result is not nearly as robust as the finding for VMT reduction among experimental group households.
- The experimental and control group households had no statistically significant differences in vehicle CO_2 emissions before the Expo Line opened, but after opening experimental group households had approximately 30% less vehicle CO_2 emissions than control group households. That "after opening" difference is statistically significant.
- The accelerometer data allow us to measure physical activity in minutes of moderate or vigorous activity per day. After the Expo Line opened, those individuals living in the experimental neighborhoods who were the least physically active had the largest increases in physical activity relative to control group subjects. The Expo Line opening was associated with increases in physical activity among approximately the 40% of experimental subjects who had the lowest physical activity levels before the line opened. The impact was as high as 8 to 10 minutes of increased daily moderate or vigorous physical activity among those experimental group subjects who were the least active before the Expo Line opened. Note though that for more than half of the experimental group subjects (those more physically active before the Expo Line opened) our statistical test suggests that the Expo Line is associated with decreases in physical activity.

- The impact of the Expo Line on VMT and rail ridership was larger near stations with more bus lines and near stations with streets with fewer traffic lanes, suggesting that bus service increases the impact of rail transit and that wide streets (which can be barriers to pedestrian access) reduce the impact of rail transit, at least in the Expo Line corridor.

Intercity Bus Service Benefits

A study for the American Bus Association (Damuth 2008) describes, and when possible quantifies, various benefits provided by the motor coach industry, which consists of private companies that provide scheduled, charter, tour, sightseeing, airport shuttle, commuter, and special operation services. These benefits include:

- Basic mobility, particularly in rural areas not served by other public transport modes.
- Employment, tourism, and economic development.
- Affordability
- Energy conservation
- Safety

According to the study, motorcoach service covers 89% of rural residents, compared with 70% covered by air services and 42% covered by intercity rail. For 14.4 million U.S. rural residents, motorcoaches are the only available mode of intercity commercial transportation service. The motorcoach industry helps non-drivers access medical services, employees commute to work, airline passengers shuttle to and from airports, ocean cruise-line passengers shuttle to and from ports, students travel for field trips and outings, senior citizens travel to places of cultural and historical significance, and during local and national emergencies, people rely on motorcoaches to transport them to safety.

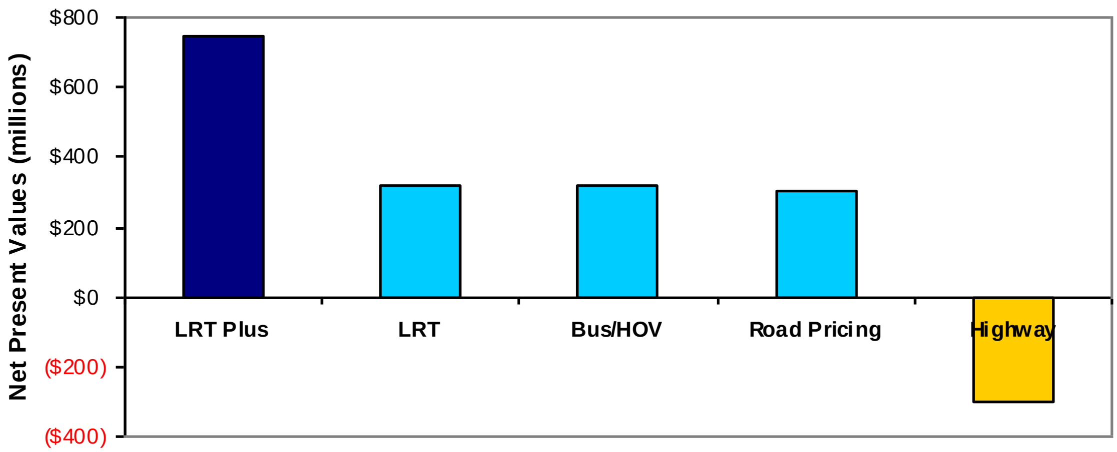
Comparing Mobility Improvements

A study evaluated various options for improving transportation between the city of Victoria and various suburbs called the Western Shore (Litman 2002). Five transportation options were considered:

- *Highway expansion* - build an additional general purpose travel lane on the main roadways between downtown Victoria and Langford Center.
- *Road pricing (tolls)* - implement variable electronic road tolls to reduce peak-period traffic volumes to optimal levels.
- *High occupancy vehicle lane (HOV)* - build an additional highway lane for buses, carpools and vanpools, plus traffic signal preemption for buses.
- *LRT Basic* - build an 18 kilometer rail system from James Bay to Langford Center, with traffic preemption, as proposed in the ND Lea report (1996).
- *LRT Plus* - build a rail system and implement the Regional Growth Strategy’s smart growth policies that further support use of alternative transportation options.

These five options were evaluated using a comprehensive analysis framework that included monetized values of various consumer, economic, social and environmental impacts. The graph below shows the results. Although all five options reduce traffic congestion, their net benefits (total benefits minus total costs) vary due to other impacts. *LRT Plus*, which includes additional features that improve accessibility, increase transit ridership and support regional development objectives, ranks highest because it provides the greatest range of overall benefits. The *Bus/HOV*, *Road Pricing* and basic *LRT* options also provide net benefits. The highway option has negative net value because it increases total vehicle traffic, which increases parking costs, downstream congestion and crashes that more than offset congestion reduction and vehicle costs savings benefits.

Figure 25 **Quantitative Analysis** (20-year Net Present Value)



LRT Plus ranks highest, followed by LRT Basic, HOV, road pricing and highway expansion.

Current Service

This analysis examines the value of current bus and demand response services. Table 46 summarizes the results. Because this is a medium-size city, about half of transit trips are assumed to be made by transit dependent riders, and half are assumed to be discretionary trips that substitute for automobile travel. This analysis indicates that the current transit system imposes net annual costs (costs minus fares) of about $28 million, and benefits of about $58 million, or about $30 million in net annualized benefits. It also provides 773 additional region jobs compared with the same money spent on motor vehicles expenses.

Table 46 **Current Transit Service Benefits**

	Bus	Demand Response	Totals
Total Costs (Sum of all program costs)	$28,627,500	$4,957,088	$33,584,588
Net Costs (Costs minus fare revenues)	-$20,627,500	-$3,957,088	-$24,584,588
Benefits (Sum of benefits)	$50,449,743	$7,404,562	$57,854,305
Net Benefits (Benefits minus project costs.)	$29,822,243	$3,447,474	$33,269,717
Benefit/Cost Ratio	1.8	1.5	1.7
Regional Jobs Created	620	153	773

This only includes impacts suitable for quantification. Additional benefits include equity value from improved mobility for physically, economically or socially disadvantaged people, and economic development benefits due to support for activities such as higher education and tourism. Economic benefits are particularly large from a regional perspective because much of the funding is from external sources.

Rider Incentives

Many transit systems have relatively low load factors. Buses seldom operate full. This unused capacity is an opportunity to increase benefits. Various targeted incentive and promotional programs have proven effective at increasing transit ridership, including UPass programs (bulk purchase of transit passes for college or university students), commute trip reduction programs, parking pricing and parking cash out, fare discounts, park & ride facilities, improved information services, and marketing.

This analysis evaluates the benefits of a new ridership incentive program that increases costs by 10% ($2,000,000), requires 4% additional peak-period bus service (a 1% increase in total bus-miles), and increases ridership by 20% (2.4 million additional annual trips). For this analysis we assume that these programs include a combination of positive and negative incentives (e.g., improved service and increased parking fees), and so user benefits (mobility benefits, option value, reduced chauffeuring costs, and vehicle costs) are calculated at half their total value.

Table 47 **Incremental Benefits From 20% Ridership Increase**

	Current	With Incentives	Difference
Total Costs (Sum of all program costs)	$28,627,500	$30,695,650	$2,068,150
Net Costs (Costs minus fare revenues)	-$20,627,500	-$21,895,650	-$1,268,150
Benefits (Sum of benefits)	$50,449,743	$56,879,052	$6,429,309
Net Benefits (Benefits minus project costs.)	$29,822,243	$34,983,402	$5,161,159
Benefit/Cost Ratio	1.8	1.9	0
Regional Jobs Created	620	682	62

Table 47 summarizes the result, indicating that, in this case, a $2 million incentive program increases benefits by $6.4 million dollars. This analysis illustrates the large potential benefits that can result from incentives that encourage automobile commuters to shift to transit where there is available capacity. Programs such as this are cost effective even if some additional peak-period service must be added due to the large savings that result when urban-peak travel is reduced, reducing congestion, road and parking costs, accident risk and pollution emissions.

Transit Service Economic Evaluation (Corporate Economics 2014)

The report, *Importance of Public Transit in Canada and Calgary, and Who Should Pay*, commissioned by Calgary Transit used conventional transportation economic evaluation methods to estimate the return on public transit investments in the city of Calgary, Canada. The analysis took into account congestion reductions, direct user benefits (based on consumer surplus analysis), and emission reductions, which were estimated to total $529 million annually, compared with $320 million in annual operating costs, providing a 1.8 benefit/cost ratio.

New Bus Route

A new bus route is proposed which is projected to cost $500,000 in additional annualized costs, and would to attract about 1,000 daily riders, or 200,000 additional annual trips of which half would substitute for automobile travel. Table 48 shows the estimated benefits by category, totaled over a 15-year period. Mobility benefits (increased mobility by people who are transportation disadvantaged) is the largest single benefit, but efficiency benefits are also significant, including vehicle cost savings, congestion reduction and parking cost savings.

Table 48 **New Bus Transit Route Benefits**

Direct Benefits	Net Present Values
Mobility Benefits	$3,912,864
Option Value Benefits	$167,694
Route Shift Benefits	$1,956,432
Transit Service Quality Improvements	$0
Chauffeur Driver Time Savings	$805,803
Vehicle Operating Costs - Peak	$752,083
Vehicle Operating Costs - Off-peak	$443,192
Congestion - Peak	$470,052
Congestion - Off-Peak	$36,933
Roadway Costs	$167,876
Parking Costs - Peak	$1,107,798
Parking Costs - Off-Peak	$335,388
Crash Costs - Internal	$167,876
Crash Costs - External	$134,301
Pollution	$201,451
Totals	*$10,659,742*

Table 49 summarizes the results over the 15 year period. This indicates that when all monetized impacts are considered, the project costs provide $9.7 million dollars in direct benefits, or $6.1 million in net benefits (benefits minus costs), a 2.7 benefit/cost ratio. It would generate about 209 additional annual jobs, including direct employment of drivers and mechanics, and multiplier effects.

Table 49 **New Bus Transit Route Summary** (15-year Net Present Value)

	Impacts
Total Project Costs	-$5,869,976
Net Costs (Public Subsidy)	-$3,634,053
Project Benefits	$10,659,742
Net Benefits	$7,025,689
Benefit/Cost Ratio	2.9
Regional Jobs	205

New Rail Route

A new rail line is being evaluated which would cost $250,000,000 in construction expenses and $5,000,000 in additional annual operating costs, and would to attract a projected 10,000 daily riders, or 2,200,000 additional annual trips of which almost half would substitute for automobile travel. Table 50 shows the estimated benefits by category, totaled over a 15-year period.

Table 50 **New Rail Transit Route Benefits** (15-year Net Present Value)

Direct Benefits	Net Present Values
Mobility Benefits	$58,692,964
Option Value Benefits	$139,745
Route Shift Benefits	$11,738,593
Transit Service Quality Improvements	$22,359,224
Chauffeur Driver Time Savings	$8,058,032
Vehicle Operating Costs - Peak	$7,520,830
Vehicle Operating Costs - Off-peak	$4,431,918
Congestion - Peak	$4,700,519
Congestion - Off-Peak	$369,326
Roadway Costs	$1,678,757
Parking Costs - Peak	$11,077,979
Parking Costs - Off-Peak	$3,353,884
Crash Costs - Internal	$1,678,757
Crash Costs - External	$1,343,005
Pollution	$2,014,508
Totals	*$139,158,042*

Table 51 summarizes net value analysis. Considering just direct travel impacts the project has a negative net value of -$139 million, and a 0.5 benefit/cost ratio, but when indirect travel impacts are considered, resulting from reductions in per capita vehicle ownership and vehicle mileage, it provides $89 million in net benefits and has a 1.3 benefit/cost ratio. Such projects tend to provide additional economic and social benefits, including improved accessibility and reduced sprawl. It would generate about 2,050 additional annual jobs from direct employment of drivers and mechanics, and multiplier effects.

Table 51 **New Rail Transit Route Summary** (15-year Net Present Value)

	Impacts
Total Project Costs	-$299,802,725
Net Costs (Public Subsidy)	-$277,443,500
Direct Project Benefits	$139,158,042
Direct Net Benefits	-$138,285,458
Direct Benefit/Cost Ratio	0.5
Indirect Project Benefits	$226,949,758
Direct and Indirect Project Benefits	$366,107,800
Direct and Indirect Net Benefits	$88,664,300
Direct and Indirect Benefit/Cost Ratio	1.3
Regional Jobs	2,050

Transit Oriented Development

A transit oriented development is proposed which will house 1,000 residents. It will incur incremental construction costs of $5 million (above standard developing costs), and $500,000 annual additional operating costs for improved walking and cycling facilities and transit shelters, plus small increases in transit operating costs. Comparisons with other similar developments indicates that this can reduce average annual automobile travel from 12,500 to 10,000 vehicle-miles per resident, a total reduction of 2,500,000 annual vehicle-miles, and increase average transit ridership by 20 trips annually per resident, or 20,000 total trips. By reducing automobile ownership and use it provides efficiency benefits, including user savings, and reductions in the congestion costs, parking costs, accident risk and pollution emissions they impose on others. Table 52 summarizes the results. It also improves mobility options for non-drivers (including both walking and transit) and increases walking which improves public health, benefits not quantified in this analysis.

Table 52 **Transit Oriented Development** (15-year Net Present Value)

	Impacts
Capital Investments	$5,000,000
Annual Costs	$500,000
Annual Ridership Increase	20,000
Project Costs (NPV)	-$9,922,392
Net Costs (Net Additional Fares)	-$9,698,799
Direct Project Benefits	$121,983,774
Direct Net Benefits	$112,284,974
Direct Benefit/Cost Ratio	12.6
Indirect Project Benefits	$440,868,927
Direct and Indirect Project Benefits	$562,852,701
Direct and Indirect Net Benefits	$553,153,901
Direct and Indirect Benefit/Cost Ratio	58.0
Regional Jobs Created	720

Quantifying Public Transit Benefits (SECOR Consulting 2004)

A study by the Board of Trade of Metropolitan Montreal titled *Public Transit: A Powerful Engine For The Economic Development Of The Metropolitan Montreal Area*, evaluated the benefits of public transit. It found a positive link between public transit, economic development, and quality of life. It concluded that Montreal's public transit services produce $937 million in economic benefits, providing a 45% return on investment for the provincial and federal governments. "The economic benefits generated by public transit are not limited to the expenditures of transit authorities in the region. In 2003, for example, public transit enabled Montreal households to save almost $600 million in travel expenses. These savings gave additional purchasing power to the households, which could then spend more on shopping, cultural outings, and recreation. This, in turn, generated double the economic benefits for the Montreal area as spending the same amount on car operating expenses – to the benefit of a host of local merchants and manufacturers," explained Board of Trade CEO Benoit Labonté.

Strategic Urban Transport Assessment

In the article, "New Approaches to Strategic Urban Transport Assessment," Hale (2011) argues that conventional transport project assessment primarily reflects the incremental impacts of individual projects, and so fails to account for broader, strategic planning objectives and long-term impacts. He argues that more comprehensive impact analysis is particularly important for evaluating walking, cycling and public transit project benefits. He emphasizes the need for a broader indictor set for more comprehensive evaluation of metropolitan region transport outcomes related to society, environment and economy, as summarized in Table 53.

Table 53 **Comprehensive Evaluation Metrics for Consideration** (Hale 2011)

Category	Performance Indicators	
1. Metropolitan multimodal travel and transport characteristics	Mode share Sustainable mode use (walking, cycling and public transport) Vehicle km per capita Household transport expenditures Daily commute time Mode share splits for journey types	Trip generation rates Transport capital investment Per capita vehicle ownership Fuel and annual car ownership taxes Average travel speeds by mode (transit/car) Length dedicated protected bike paths
2. Mass transit system indicators and metrics	Operating ratio (expenses to revenues) System capacity System patronage Rail system length System networking Peak/off-peak ratio Cost per passenger served Average peak period passenger loadings Rail station access mode splits	Annual capital investment Cost per passenger km Standard service frequencies Operating hours/span Annual maintenance expenditure Provision of real time information Fleet maturity Provision of regional smart card
3. Land use	Urban density Regional population Portion of population within 800m of transit Suburbanisation	Location efficiency Housing stress (proportion of households with housing costs that exceed 30% of household budgets). Transit real estate strategy
4. Transit accessibility to key amenities	CBD access Higher education access	Public health access
5. Qualitatively-oriented review categories	Multi-destination network? Transit investment linked to local land use planning changes? Fully-developed TOD policy framework?	Number of proposed TOD locations Travel Demand Management (TDM) Bike and pedestrian network quality
6. Analyses particular to the corridor, sub-regional and precinct scales	Transit service-levels Transit usage Pedestrian and cycling infrastructure Walking and cycling performance Station access mode splits	Jobs/housing balance Residents/jobs within station catchment Project and precinct-level densities Car ownership Multi-modality
7. Transit project and investment economics	BCR (benefit cost ratio) Net Present Value (NPV)	Full identification and monetisation of sustainable transport benefits

Hale (2011) proposed these regional transport performance indicators.

Quantitative Analysis

Not all benefits are suitable for monetization. These programs can also be evaluated qualitatively, in terms of their ability to support various objectives, as illustrated in Table 54. To apply this methodology in a particular situation, a committee of stakeholders assigns ratings for each option based on their judgment to reflect community values. This approach can help identify strategies that are particularly effective at supporting community values and objectives.

Table 54 **New Transit Qualitative Analysis**

Category	Existing Service	Incentives	New Bus Route	New Rail Route	TOD
Existing Users					
Price Changes	0	4	0	0	0
Service Quality	0	4	3	5	0
Mobility Benefits					
User Benefits	3	4	3	4	3
Public Services	3	1	3	3	3
Equity	3	4	3	3	3
Option Value	3	0	3	4	3
Efficiency Benefits					
Vehicle Costs	3	0	3	3	3
Chauffeuring	3	1	3	3	3
Vehicle Congestion	3	5	3	3	2
Pedestrian Congestion	3	4	3	3	5
Parking Costs	3	5	3	3	3
Safety, Health and Security	3	3	3	3	4
Roadway Costs	0	0	0	3	0
Energy and Emissions	3	3	3	3	3
Travel Time	0	0	0	3	0
Land Use					
Transportation Land	1	3	1	4	4
Land Use Objectives	1	3	1	5	5
Economic Development					
Direct Expenditures	2	0	3	4	1
Consumer Expenditures	2	3	3	4	3
Land Use Efficiencies	1	3	1	5	5
Productivity Gains	2	4	2	4	3
Strategic Development	1	3	1	5	3
Transit Efficiencies	2	3	2	3	3
Totals	*45*	*60*	*50*	*80*	*62*

Conclusions

Public transit includes a variety of transport services available to the general public, ranging from shared taxi and vanpools, to buses, trains, ferries and their variations. These services can play various roles in a modern transportation system and have various benefits and costs, including some that are indirect and external. Table 55 summarizes public transit benefit and cost categories. Not every transit improvement has all of these impacts, but most have several.

Table 55 **Public Transport Benefits and Costs**

Category	Improved Transit Service	Increased Transit Travel	Reduced Automobile Travel	Transit-Oriented Development
Indicators	Service Quality (speed, reliability, comfort, safety, etc.)	Transit Ridership (passenger-miles or mode share)	Mode Shifts or Automobile Travel Reductions	Portion of Development With TOD Design Features
Benefits	• Improved convenience and comfort for existing users. • Equity benefits (since existing users tend to be disadvantaged). • Option value (the value of having an option for possible future use). • Improved operating efficiency (if service speed increases). • Improved security (reduced crime risk)	• Increased user security, as more users ride transit and wait at stops and stations. • Mobility benefits to new users. • Increased fare revenue. • Increased public fitness and health (if transit travel stimulates more walking or cycling).	• Reduced traffic congestion. • Road and parking facility cost savings. • Consumer savings. • Reduced chauffeuring burdens. • Increased traffic safety. • Energy conservation. • Air and noise pollution reductions.	• Additional vehicle travel reductions ("leverage effects"). • Improved accessibility, particularly for non-drivers. • Reduced crime risk. • More efficient development (reduced infrastructure costs). • Farmland and habitat preservation.
Costs	• Increased capital and operating costs, and therefore subsidies. • Land and road space. • Traffic congestion and accident risk imposed by transit vehicles.	• Transit vehicle crowding.	• Reduced automobile business activity.	• Various problems associated with more compact development.

Public transport can have various types of benefits and costs, including some that are often overlooked or undervalued in conventional transport planning.

Incremental costs tend to be relatively easy to measure – incremental financial costs are reported in transit agency budgets and users experience increased crowding, but many benefits tend to be overlooked or undervalued in conventional transport planning. For example, by tradition conventional transport project evaluation tends to ignore the parking cost savings that result when travelers shift from driving to public transit, and the vehicle ownership cost savings that result when transit-oriented development allows households to reduce their vehicle ownership. The benefits of high quality public transit (transit services that are relatively convenient, comfortable, integrated and affordable) and transit-oriented development tend to be particularly large because they leverage additional vehicle travel reductions, so each transit passenger-mile results in 2-9 reduced automobile vehicle-miles.

Public transit services also have significant costs, including capital costs for facilities such as rails, bus lanes, stations and vehicles; operating costs for drivers, fuel and maintenance; and various external costs such as accident risk, air and noise pollution. Many of these costs are fixed and public transit services tend to experience scale economies (costs per passenger-mile tend to decline as total passenger-miles increase) so marginal costs (the incremental costs of additional passenger-miles) is often low.

How transit is evaluated can affect the perceived value of public transit. Different evaluation methods give very different conclusions concerning the value of a particular service or improvement. The selection of evaluation method is not simply a matter of opinion or preference. Comprehensive evaluation is essential for producing accurate results. Some important factors are described below.

- Evaluation that ignores parking and vehicle cost savings that result when consumers shift from driving to transit tends to undervalue transit and favor automobile investments.
- Some methods of measuring traffic congestion (such as roadway level-of-service, travel time index and average traffic speeds) only consider impacts on motorists, ignoring congestion cost reductions to people who shift from automobile to grade-separated transit modes.
- Increased highway capacity tends to increase traffic volumes on surface streets, increasing "downstream" traffic congestion. Shifting travel to transit tends to reduce such impacts.
- Many people find riding quality transit (convenient, comfortable and safe) less stressful than driving in congestion. Evaluation that ignores this factor tends to undervalue transit.
- Some transit improvements increase transit travel speed, convenience and comfort, providing benefits to both existing transit users and those who shift mode in response to these improvements. Evaluation that ignores any of these benefits tends to undervalue transit.
- There are many possible ways to evaluate the value of transit in a community. Analysis that considers the portion of total mobility by transit tends to favor automobile solutions. Marginal impact analysis that considers transit's ability to address specific problems (traffic and parking congestion, mobility for non-drivers) tends to favor transit-oriented solutions.
- There are many possible ways of measuring the transit-dependent population in a community. A narrow perspective only considers residents who live in zero-vehicle household. A more comprehensive perspective considers anybody who uses transit occasionally (such as during the last two months), or who has a frequent transit user in their household.
- Rail transit tends to encourage urban infill and is often a catalyst for more walkable neighborhoods, while urban roadway expansion tends to stimulate sprawl. Evaluation that considers land use planning objectives tends to place a greater value on rail transit. Evaluation that ignores these factors tends to favor highway investments.
- Highway capacity expansion tends to reduce congestion during the short term, but this benefit declines over time, and the resulting generated traffic can increase other costs such as downstream congestion, accidents and pollution emissions. Transit benefits tend to be smaller in the short term, but increase over time. As a result, evaluation that focuses on short-term impacts tends to favor highway expansion, while those that take a longer-term perspective tend to favor transit improvements.

- Transit improvements tend to improve mobility for non-drivers, particularly where transit provides a catalyst for more walkable neighborhoods. As a result, evaluation that considers equity objectives tends to favor transit over highway improvements, particularly comprehensive programs that include transit-oriented development.
- Transit service and ridership tend to increase if transit is implemented with various support strategies. Evaluation that ignores these strategies will tend to undervalue the full potential benefits of a comprehensive transit improvement program.

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Organizations

American Public Transit Association (www.apta.com) provides extensive information on public transit issues.

Association for Commuter Transportation (http://tmi.cob.fsu.edu/act/act.htm) is a non-profit organization supporting TDM programs.

Bus Rapid Transit Website (www.fta.dot.gov/brt) provides information on various strategies to improve bus transit service performance.

Bus Partnership Forum (www.dft.gov.uk/stellent/groups/dft_localtrans/documents/divisionhomepage/032414.hcsp), by the UK Department for Transport, includes extensive information on ways of improving local bus service quality.

Canadian Urban Transit Association (www.cutaactu.on.ca) the voice of the Canadian transit industry, and provides a variety of information and resources.

Center for Urban Transportation Research (http://cutr.eng.usf.edu) provides TDM materials and classes and publishes *TMA Clearinghouse Quarterly.*

Center for Transportation Excellence (www.cfte.org) provide research materials, strategies and other forms of support on the benefits of public transportation.

Commuter Choice Program (www.epa.gov/oms/traq) provides information, materials and incentives for developing employee commute trip reduction programs.

Commuter Check (www.commutercheck.com) works with transit agencies to provide transit vouchers as tax exempt employee benefit.

Economic Development Research Group (www.edrgroup.com) provides information on economic evaluation methods, including studies of the economic impacts of transit projects.

Federal Transit Administration (www.fta.dot.gov) provides a variety of resources for transit planning.

International Union of Public Transport (www.uitp.com) is an international organization that supports public transit.

Volvo Research and Education Foundation (www.vref.se).