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Evaluating Public Transportation Health Benefits

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Abstract

This report investigates ways that public transportation affects human health, and ways to incorporate these impacts into transport planning decisions. This research indicates that public transit improvements and more transit oriented development can provide large but often overlooked health benefits. People who live or work in communities with high quality public transport tend to drive significantly less and rely more on alternative modes (walking, bicycling and public transit) than they otherwise would. This reduces traffic crashes and pollution emissions, increases physical fitness and mental health, and provides access to medical care and healthy food. These impacts are significant in magnitude compared with other planning objectives, but are often overlooked or undervalued in conventional transport planning. Various methods can be used to quantify and monetize (measure in monetary units) these impacts. This analysis indicates that improving public transit can be one of the most cost effective ways to achieve public health objectives, and public health improvements are among the largest benefits provided by high quality public transit and transit-oriented development.

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Summary of Findings

- High quality public transportation (convenient, comfortable, fast rail and bus transport) and transit oriented development (walkable, mixed-use communities located around transit stations) tend to affect travel activity in ways that provide large health benefits, including reduced traffic crashes and pollution emissions, increased physical fitness, improved mental health, improved basic access to medical care and healthy food and increased affordability which reduces financial stress to lower-income households.
- Traffic casualty rates tend to decline as public transit travel increases in an area. Residents of transit-oriented communities have only about a quarter the per capita traffic fatality rate as residents of sprawled, automobile-dependent communities.
- Public transit reduces pollution emissions per passenger-mile, and transit-oriented development provides additional emission reductions by reducing per capita vehicle travel.
- U.S. Center for Disease Control recommends that adults average at least 22 daily minutes of moderate physical activity, such as brisk walking, to stay fit and healthy. Although less than half of American adults achieve this target, most public transportation passengers do exercise the recommended amount while walking to and from transit stations and stops.
- Neighborhood design features that support transit, such as walkability and mixed land use, also support public health. Of people with safe places to walk within ten minutes of home, 43% achieve physical activity targets, compared with just 27% of less walkable area residents.
- The United States has relatively poor health outcomes and high healthcare costs compared with peers, due in part to high per capita traffic fatality rates and diseases resulting from sedentary living. Public transit improvements can improve health outcomes and reduce healthcare costs.
- Inadequate physical activity contributes to numerous health problems, causing an estimated 200,000 annual deaths in the U.S., and significantly increasing medical costs. Among physically able adults, average annual medical expenditures are 32% lower for those who achieve physical activity targets ($1,019 per year) than for those who are sedentary ($1,349 per year).
- Many physically and economically disadvantaged people depend on public transportation to access to medical services and obtain healthy, affordable food.
- Current demographic and economic trends (aging population, rising fuel prices, increasing health and environmental concerns, and rising medical care costs) are increasing the value of public transportation health benefits.
- A growing portion of households would prefer to drive less and rely more on walking, cycling and public transit, provided these alternatives are convenient, comfortable, safe and affordable.
- Conventional planning tends to overlook and undervalue many transportation-related health impacts. More comprehensive evaluation can better integrate transportation and public health planning objectives.
- When all impacts are considered, improving public transit can be one of the most cost effective ways to achieve public health objectives, and public health improvements are among the largest benefits provided by high quality public transit and transit-oriented development.

Introduction – "Live Long and Prosper"

Current health trends offer both good and bad news. The good news is that many simple, affordable, and often enjoyable lifestyle habits can lead to healthier and happier lives: breath fresh air, avoid dangerous driving, maintain healthy weight, be physically active, eat fresh fruits and vegetables, maintain friendships, and avoid excessive stress. Even chocolate is considered healthy if consumed in moderation!

But there is also bad news. Many people find it difficult to maintain healthy habits. As a result, the U.S. has relatively poor health outcomes compared with peer countries, and according to some projections average U.S. lifespans may actually decline in the future due to growing but avoidable health risks.

Major Avoidable Health Risks

• Unhealthy eating	• Tobacco consumption	• Social isolation
• Overweight and obesity	• Excessive alcohol consumption	• Stress and depression
• Sedentary living	• Drug abuse	• Suicide
• Pollution exposure	• Traffic crashes	• Homicide

Transportation and land use planning decisions affect many of these health risks. A growing body of research indicates that the quality of *public transportation* (also called *public transit*, *urban transport* and *rapid transit*) in a community affects public health in many ways, including some impacts that are often overlooked or undervalued. This report investigates these impacts and ways to better incorporate them into transportation planning. This analysis can help transport and health professionals better coordinate their efforts to create communities where people can live long and prosper (CDC 2010).

Travel Impacts

The quality of public transit, and the degree it is integrated into a community, significantly affects travel activity. As service quality improves and communities become more transit-oriented, residents tend to own fewer vehicles, drive less and rely more on alternative modes (walking, cycling and public transit) than they otherwise would (ICF 2008; Litman 2007).

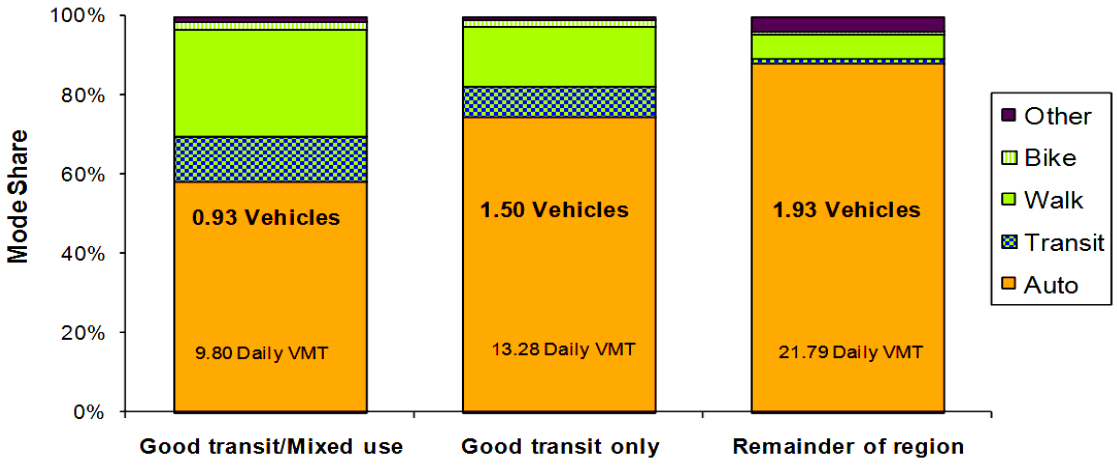
Table 1 **Impacts on Vehicle Ownership and Travel** (Ohland and Poticha 2006)

Land Use Type	Auto Ownership	Daily VMT	Mode Split				
	Per Household	Per Capita	Auto	Transit	Walk	Bike	Other
Good transit/Mixed use	0.93	9.80	58.1%	11.5%	27.0%	1.9%	1.5%
Good transit only	1.50	13.28	74.4%	7.9%	15.2%	1.4%	1.1%
Remainder of region	1.93	21.79	87.3%	1.2%	6.1%	0.8%	4.0%

Residents of transit-oriented neighborhoods tend to own significantly fewer motor vehicles, drive significantly less, and rely more on walking and public transit than residents of other neighborhoods.

Table 1 and Figure 1 illustrate this pattern in Portland, Oregon, although similar effects occur in other cities. Residents of communities with high-quality, well integrated public transit (called *transit-oriented development* or *TOD*), own half as many vehicles, drive half as many annual miles, walk and bicycle four times more, and use public transit ten times more than residents of more automobile-dependent communities. These differences partly reflect *self selection*, the tendency of people who by necessity or preference rely on alternative modes to locate in transit-oriented areas, but that is generally a minor effect (Cervero 2007). A typical household that shifts from an automobile-dependent to a transit-oriented community drives significantly less and relies much more on alternative modes. Even residents who commute by automobile tend to reduce their annual vehicle mileage by shifting mode and reducing the distances of other trips (errands, recreation, children's travel to school, etc.) due to more accessible land use.

Figure 1 **TOD Impacts On Mode Share in Portland, Oregon** (Ohland and Poticha 2006)

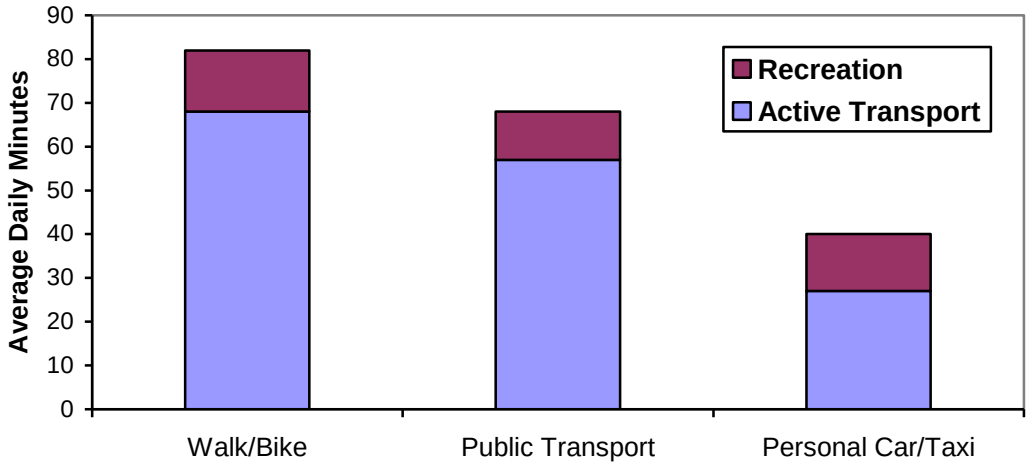


People who live in transit-oriented communities tend to own fewer vehicles, drive less and rely more on alternative modes. "Daily VMT" indicates average daily vehicle miles traveled per capita.

A New York City Department of Health study evaluated the health benefits of active transportation. The results, summarized in Figure 2, indicate that people who commute by walking, cycling or public transit

achieve about twice the total (transportation and recreational) exercise as automobile commuters, and so are much more likely to achieve public health targets of thirty or more daily minutes of moderate physical activity. This study can be a model for use in other communities interested in tracking physical fitness and health.

Figure 2 **Recreation And Transportation Exercise By Commute Mode** (NYCDH 2011)



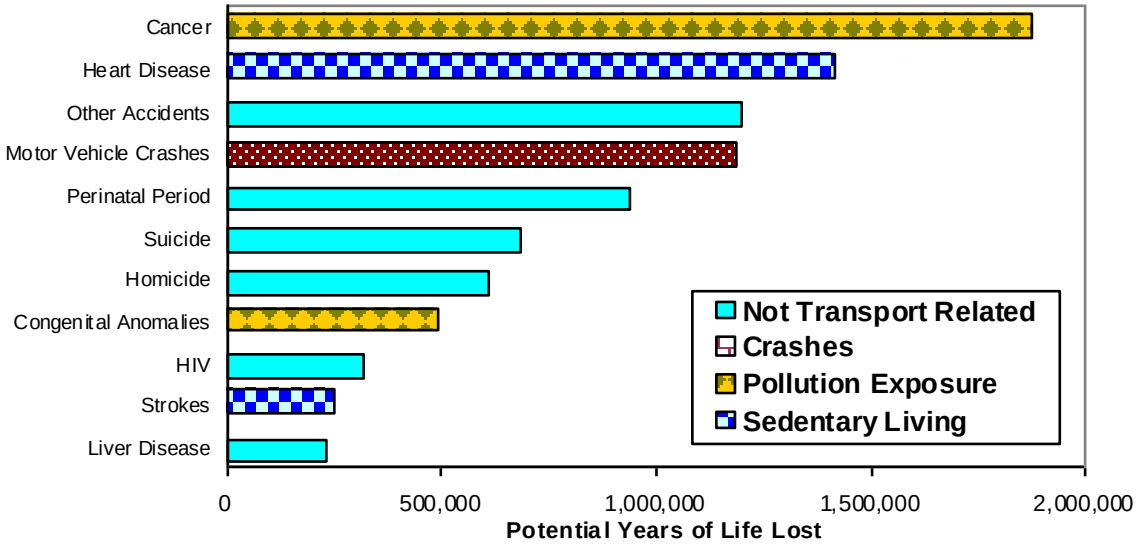
Although the amount of time people spend in recreational physical activity (sports and health club exercise) is similar for all commute groups, those who commute by walking, cycling and public transit have much more active transportation and so are much more likely to achieve the public health target of at least thirty daily minutes of physical activity. Although this study was performed in New York, the results are similar to those found in other cities.

Transportation Health Impacts

This section evaluates the degree to which transportation affects public health risks.

Travel activity affects public health in several ways. Figure 3 indicates ways that travel activity affects the ten leading causes of *Potential Years of Life Lost* (*PYLL*, which takes into account age of death and therefore reflects the greater costs to society of risks to younger people). For example, pollution contributes to cancer and congenital anomalies (birth defects), and sedentary living (inadequate physical activity) contributes to heart disease and strokes. Transport activity affects five of these health risks, including the three largest, which cause more than 60% of total potential years of life lost.

Figure 3 **Ten Leading Causes of Potential Years of Life Lost** (NCIPC 2009)



Transportation affects many major health risks. Potential Years of Life Lost (PYLL) takes into account the age at which people die and so gives greater weight to risks to younger people.

Of course, these relationships are complex. There are often several steps between a planning decision and its ultimate health impacts. Transportation activities are only a minor contributor to some of these risks. For example, motor vehicles are only one source of pollution, and pollution is only one contributor to cancer and congenital anomalies, while sedentary living increases some forms of cancer, which are not reflected in this figure.

Compared with its peers the United States has higher healthcare costs and poor health outcomes. In 2007 the U.S. had a 78.1 year life expectancy, almost one year below the OECD average of 79.0 years, and spent $7,290 per capita on healthcare, almost two-and-a-half times greater than the OECD average (OECD 2009). Transportation-related health risks are major contributors to these poor health outcomes and high healthcare costs, and public transportation health benefits can help reduce these discrepancies as described in the next section.

Public Transportation Health Benefits

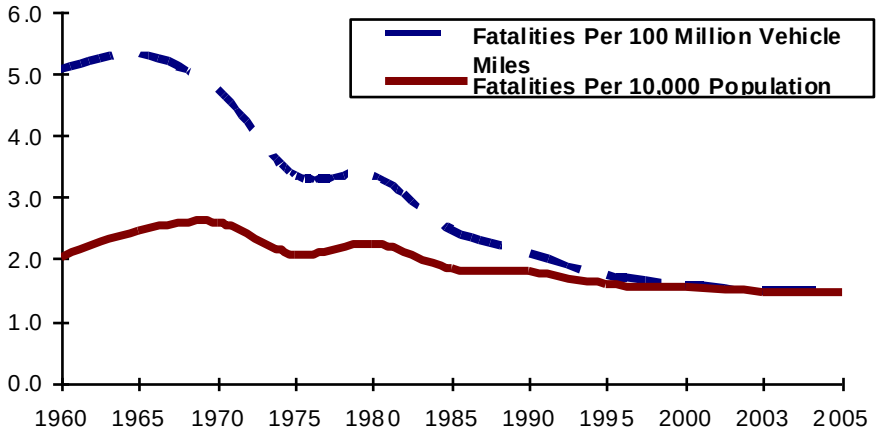
This section discusses the relationships between public transportation and specific health risks.

Traffic Crashes

Traffic crashes kill about 40,000 people annually on U.S. roads, and cause many more injuries and disabilities (BTS 2008). Crash casualties have lower average ages than victims of other major health risks, such as cancers and cardiovascular diseases, and so cause a relatively large numbers of years of life lost. According to the National Center for Injury Prevention and Control, traffic crashes caused an estimated 1,186,070 years of life lost in the U.S. in 2006, which reduces average lifespans approximately 0.4 years or about 5% (NCIPC 2009).

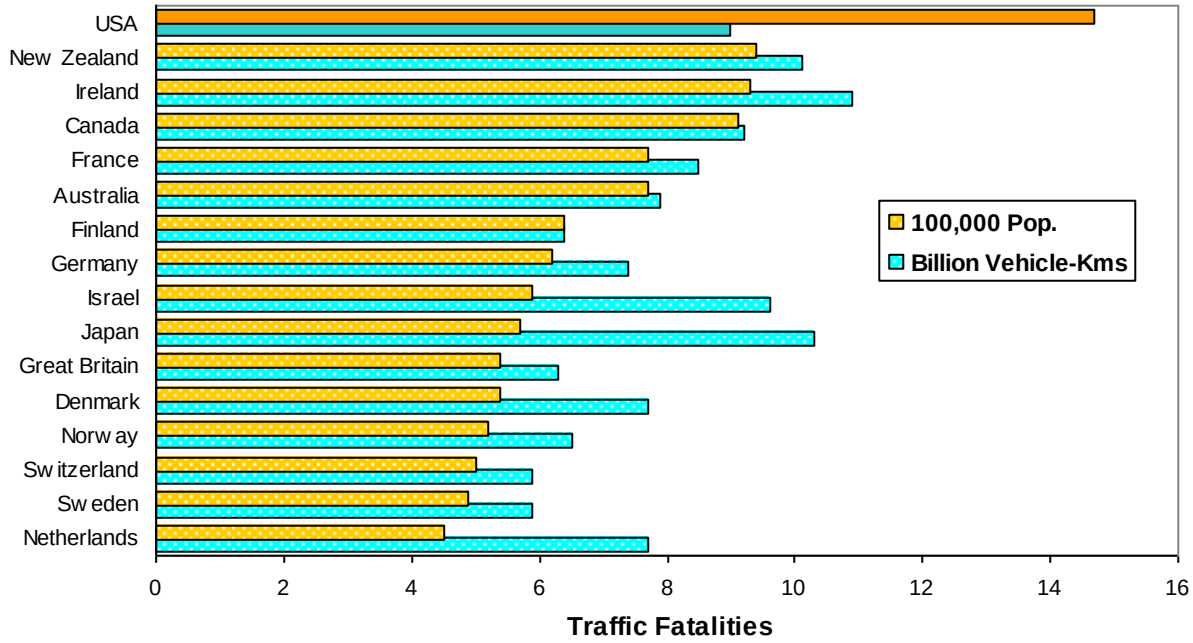
Crashes can be measured in different ways which result in different conclusions about the risk of different modes and activities (Litman and Fitzroy 2006). Distance-based units, such as fatalities per 100 million vehicle-miles, ignore the additional risk that results from increased vehicle mileage and the safety benefits of travel reductions. Figure 4 shows U.S. traffic fatality rates measured per 100 million vehicle-miles and per 10,000 residents between 1960 and 2005. The mileage-based fatality rate declined by more than two thirds during this period, which implies that existing safety programs were effective. However, this was offset by increased mileage. When measured per capita, as with other health risks, there was little improvement despite significant increases in use of safety devices (seatbelts, helmets, airbags, etc.), reductions in intoxicated driving, improved road and vehicle design, faster emergency response, and improved medical care. Taking these factors into account, much greater casualty reductions should have occurred. For example, seatbelt use grew from virtually zero in 1960 to about 75% in 2000, which alone should have reduced traffic fatalities 33% (seat belt use reduces crash fatality rates about 45%), yet, per capita traffic deaths declined just 25% during this period.

Figure 4 **U.S. Traffic Fatalities** (BTS 2008)



When measured per vehicle-mile, traffic fatalities declined significantly, but when measured per capita they show relatively little decline due to increased per capita vehicle mileage.

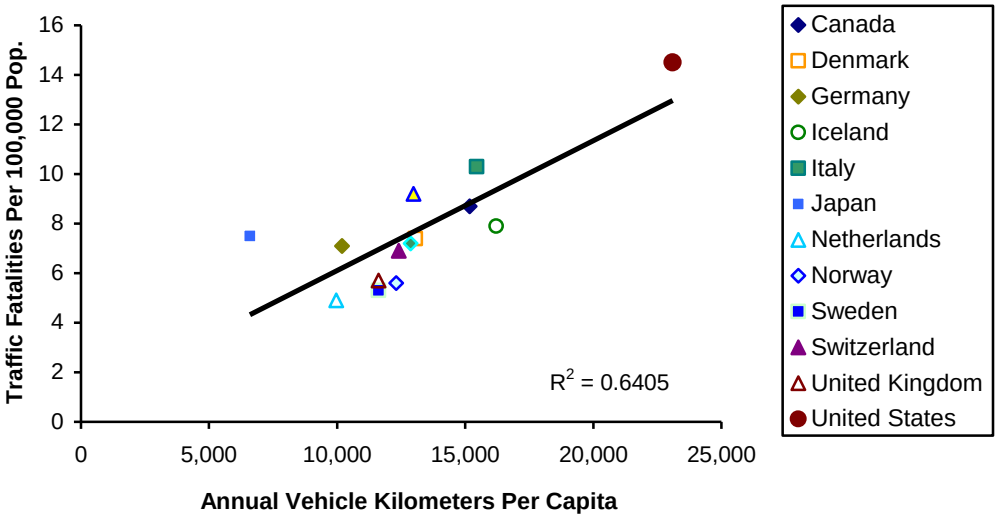
Figure 5 **International Traffic Fatalities** (Wikipedia 2009; based on WHO and OECD data)



The US has the highest per capita traffic fatality rate among peer countries.

Traffic crashes continue to be one of the largest causes of deaths and disabilities for people aged 1-44 years (CDC 2003). The U.S. has the highest *per capita* traffic fatality rates among peer countries, as illustrated in Figure 5, despite high quality highways and vehicles, and well established safety programs. This can be explained by high per capita vehicle mileage, as illustrated in Figure 6. From this perspective, traffic crashes continue to be a major health risk and new strategies may be justified to achieve safety targets.

Figure 6 **Traffic Fatalities Versus Annual Vehicle Mileage** (OECD data)

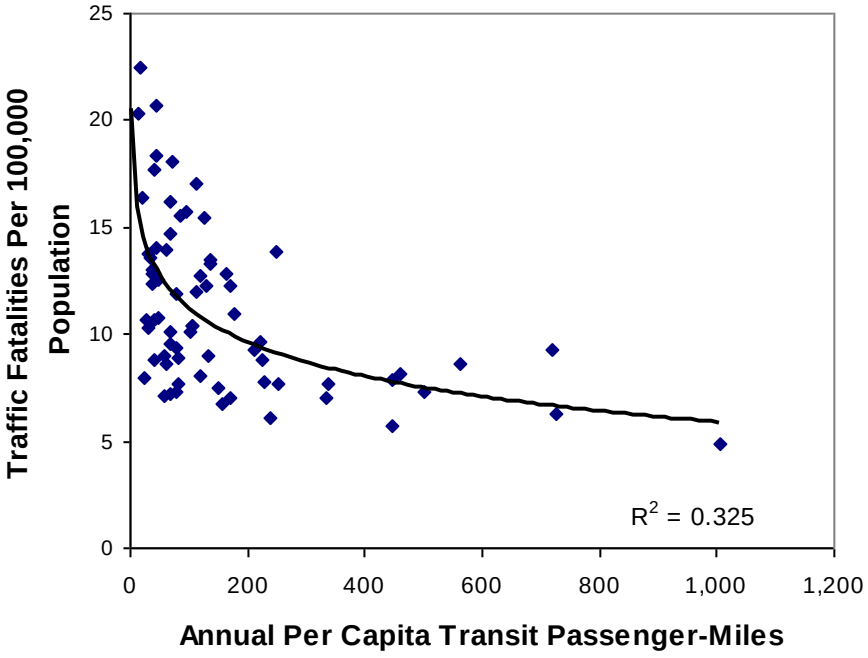


Per capita traffic fatality rates tend to increase with per capita annual vehicle mileage.

Public transit is a relatively safe mode, with only about one-twentieth the passenger fatality rate as automobile travel (Beck, Dellinger and O'Neil 2007). Even considering risks to other road users, transit travel tends to have a lower fatality rate per passenger-mile than automobile travel under the same conditions.

Transit-oriented development tends to provide particularly large safety benefits. People who live or work in transit oriented communities tend to drive fewer annual miles, drive at lower speeds, and have better travel options that allow them to avoid high risk driving, such as after drinking alcohol or when ill (Litman 2016). Although *crash rates* tend to increase with urban densities due to more frequent interactions among vehicles, crash *severity* and *casualty rates* (injuries and deaths) are higher in lower density areas due to higher speeds and slower emergency response. In other words, urban residents tend to have many minor crashes, while suburban and rural residents have fewer but more severe crashes, resulting in higher per capita disability and fatality rates. Since transit ridership tends to increase with urban density, transit is associated with higher *crash rates* (mostly minor collision that damage property but cause no injuries) but lower *casualty rates* (serious injuries and deaths). As a result, total per capita traffic fatalities (including transit and automobile occupants, and pedestrians) decline significantly as transit ridership increases in a community, as indicated in Figure 7.

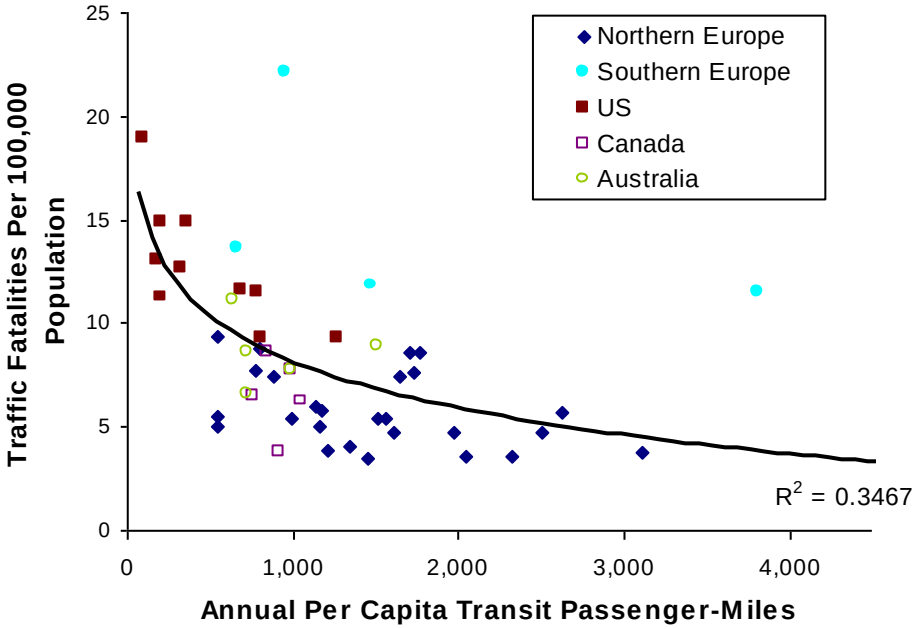
Figure 7 **Traffic Fatalities Versus Transit Travel in U.S. Urban Regions** (Litman and Fitzroy 2006)



Per capita traffic deaths tend to decline as public transportation ridership increases. Each dot represents a U.S. urban region.

International data also indicate that per capita traffic fatality rates decline as per capita transit ridership increases, as illustrated in Figure 8.

Figure 8 **Traffic Fatalities Versus Transit Travel International Cities** (Kenworthy and Laube 2000)

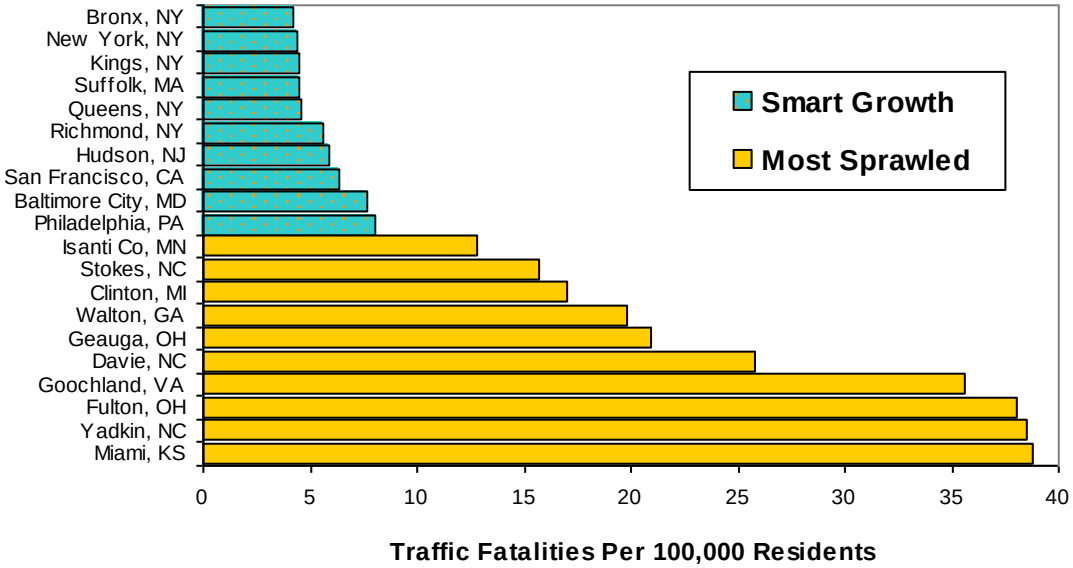


International data indicate that crash rates decline with increased transit ridership. Each dot represents a major international city.

Similarly, *smart growth* communities, where residents tend to drive less and rely more on alternative modes, have lower traffic fatality rates than more automobile-dependent communities. Ewing, Schieber and Zegeer (2003) rated 240 U.S. counties according to a *sprawl index* that considered land use density, mix and transport diversity factors. The ten smartest growth counties had about a quarter the per capita traffic fatality rate as the ten most sprawled counties, as illustrated in Figure 9. Overall, urban residents have significantly lower violent death rates, considering both accident and homicide risks (Lucy 2002).

Increased walking, cycling and public transit travel tends to increase overall security and reduce crime rates by providing more monitoring of city streets and transit waiting areas (Hillier and Sahbaz 2006). Actual and perceived security risks can be reduced by targeted efforts such as community policing and Neighborhood Watch programs, special police patrols, pedestrian escorts, monitoring of transit vehicles and waiting areas, and other strategies for crime prevention through environmental design (Zelinka and Brennan 2000).

Figure 9 **U.S. County Traffic Fatality Rates** (Ewing, Schieber and Zegeer 2003)



The ten smartest growth counties have about a quarter the traffic fatality rates as the most sprawled.

Most transit trips include walking or cycling links so the safety of these modes affects the overall safety of public transit travel. Walking and cycling have relatively high per mile casualty rates, but shifting travel from driving to nonmotorized modes generally imposes little incremental risk because (WHO 2008; Litman 2008):

1. Nonmotorized travel imposes minimal risk to other road users.
2. Road users tend to be more cautious where they expect to encounter walkers and cyclists. As a result, per-mile casualty rates tend to decline as walking and cycling activity increases in a community, called the "safety in numbers" effect.
3. Increased walking and cycling may spur communities to implement nonmotorized safety improvements, such as adding sidewalks, crosswalks and speed control programs.
4. Nonmotorized trips tend to be shorter than motorized trips. A local walking trip often substitutes for a longer automobile trip, and residents of transit-oriented development tend to travel less in total due to improved land use accessibility.
5. High walking and cycling casualty rates partly reflect special risk factors by some user groups, such as children and people with disabilities. A responsible adult who takes basic precautions such as observing traffic rules and wearing a helmet tends to have less than average risk.
6. Increased walking and cycling provides health and fitness benefits that are many times greater than incremental crash risks.

This indicates that improving public transit and creating more transit-oriented communities can increase overall safety and security, particularly if implemented with pedestrian and cycling safety programs.

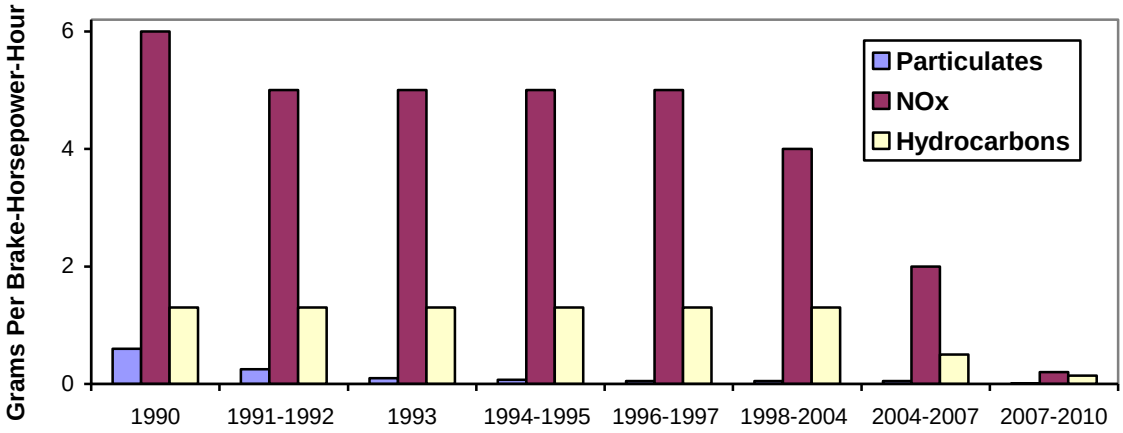
Pollution Emissions

A second category of transport-related health impacts involve vehicle pollution emissions. These include tailpipe emissions, plus "upstream emissions" (from fuel production and distribution), hot soak (evaporative emissions that occur after an engine is turned off), and particulates from road dust, brake linings and tire wear ("Air Pollution," Litman 2008).

Many factors affect vehicle pollutant human health impacts, including per capita vehicle mileage, vehicle emission rates, and exposure (the number of people located where emissions are concentrated). Motor vehicle air pollution is estimated to cause a similar number of premature deaths as traffic crashes, although air pollution victims tend to be older and so cause smaller reductions in Potential Years of Life Lost than traffic crashes (Murray, et al. 1996).

Public transit tends to produce less pollution per passenger-mile, particularly electric-powered and newer diesel vehicles, and as previously described, transit oriented development tends to reduce per capita vehicle travel and associated emissions (ICF 2008). Older diesel buses tend to have high emission rates and bus transit tends to concentrate activity close to roadways, so under some circumstances increased transit use may increase human exposure to some pollutants such as particulates and carbon monoxide. However, newer and alternative fuel buses produce far less emissions (Figure 10). Use of less polluting alternative fuels (such as natural gas) increased from just 2.0% in 1992 to 30.4% by 2009, and electric modes (electric trolley buses and electric rail transit) increased from 29% to 34% of passenger-miles during the same period.

Figure 10 **Federal Transit Bus Emissions Standards** (USDOT 2006, Table 3)



Diesel bus emission rates are declining significantly due to newer technologies and standards.

Physical Activity and Fitness

A third category of health impacts concerns the effects transport has on physical activity and fitness (WHO 2003). In recent years, public health officials have become increasingly alarmed at declining physical fitness and resulting increases in diseases associated with sedentary lifestyles (Franco, et al. 2005). Inadequate physical activity, and resulting excessive body weight, contribute to heart and vascular diseases, strokes, diabetes, hypertensive diseases, osteoporosis, joint and back problems, colon and breast cancers, and depression. Even modest reductions in these illnesses can provide large savings and benefits.

The U.S. Center for Disease Control recommends at least 150 weekly minutes (about 22 daily minutes) of moderate aerobic activity (e.g. brisk walking) for adults, as indicated in Table 2.

Table 2 **How Much Physical Activity Do Adults Need?** (CDC 2008)

Aerobic Activity	Muscle-Strengthening
2 hours and 30 minutes (150 minutes) of moderate-intensity aerobic activity (i.e., brisk walking) every week.	Muscle-strengthening activities on 2 or more days a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms).
Or	
1 hour and 15 minutes (75 minutes) of vigorous-intensity aerobic activity (i.e., jogging or running) every week.	Muscle-strengthening activities on 2 or more days a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms).
Or	
An equivalent mix of moderate- and vigorous-intensity aerobic activity.	Muscle-strengthening activities on 2 or more days a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms).
10 minutes at a time is fine - 150 weekly minutes may sound like a lot of time, but you needn't do it all at once. Not only is it best to spread your activity out during the week, but you can break it up into smaller chunks of time during the day, as long as you're doing your activity at a moderate or vigorous effort for at least 10 minutes at a time.	

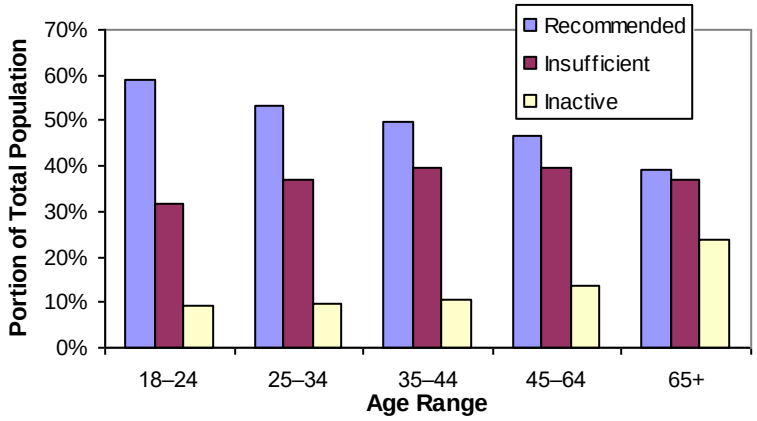
This table summarizes the U.S. Center for Disease Control's recommendations for adult physical activity.

The World Health Organization (WHO 2000) states that regular physical activity can provide:

- 50% reduction in the risk of developing coronary heart disease (similar to not smoking).
- 50% reduction in the risk of developing adult diabetes.
- 50% reduction in the risk of becoming obese.
- 30% reduction in the risk of developing hypertension.
- 10/8-mmHg decline in blood pressure in people with hypertension (a similar effect to drugs).
- Reduced osteoporosis and falls in the elderly.
- Relief of symptoms of depression and anxiety.

Currently, less than half of American adults achieve recommended physical activity targets, and participation declines with age, as illustrated in Figure 11. This indicates the importance of finding practical ways to increase physical activity, particularly for currently sedentary, overweight and older people. Although there are many ways to exercise, some, such as organized sports and gym exercise, require special time, skill and expense, which discourages participation. Many experts believe that increasing walking and cycling (together called *active transportation*) is the most practical way to improve public fitness, particularly for vulnerable populations such as children, seniors and low income people who often have difficulty participating in structured exercise programs due to financial and time constraints (WHO 2003; Gilbert and O'Brien 2005).

Figure 11 **U.S. Physical Activity Statistics** (CDC 2007)



Recommended: 150+ weekly minutes of moderate intensity physical activity.

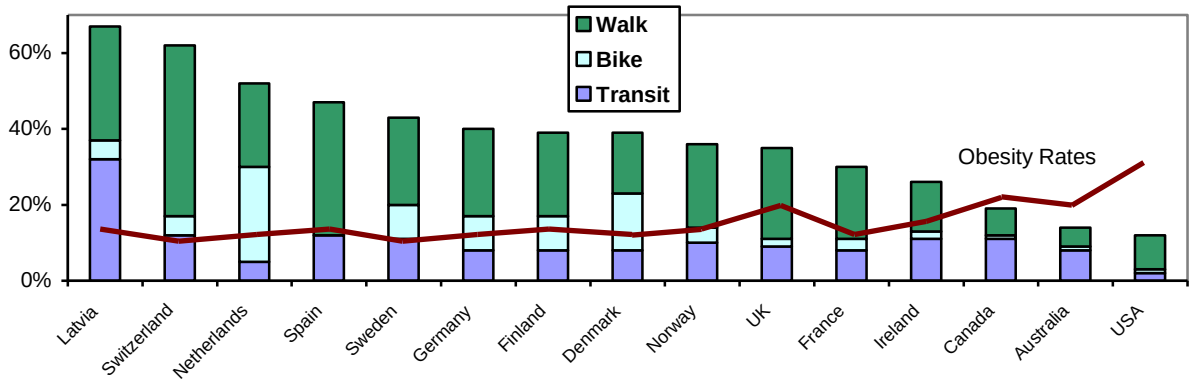
Insufficient: 10+ weekly minutes of moderate intensity physical activity.

Inactive: less than 10 weekly minutes of moderate intensity activity.

Less than half of U.S. adults achieve recommended physical activity targets, and rates decline with age.

Public transport and transit-oriented development tend to increase physical activity, since most public transit trips involve walking links, transit-oriented development includes walking and cycling improvements, and transit systems often provide amenities such as bikeracks on buses and lockers at stations. Several targeted studies indicate that public transit travel significantly increases physical activity. Research also suggests that obesity rates tend to be inversely related to use of alternative modes (walking, cycling and public transit), as indicated in Figure 12.

Figure 12 **Mode Split Versus National Obesity Rates** (Bassett, et al 2008)

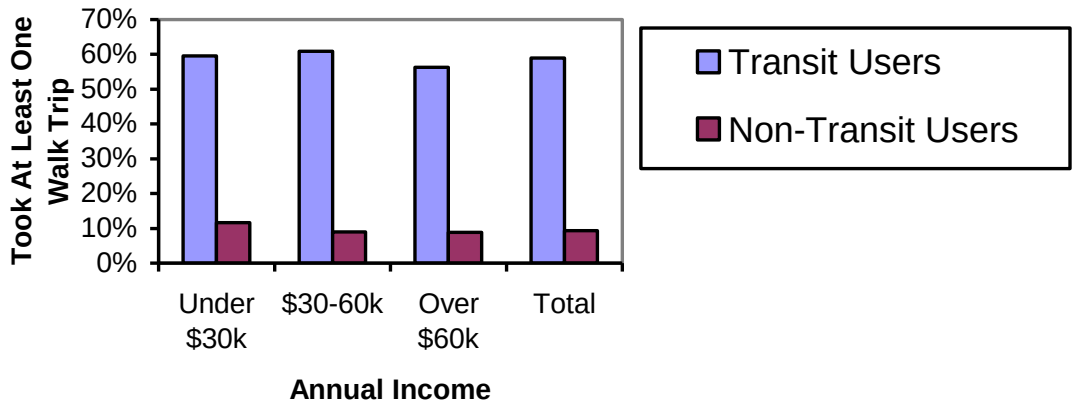


This and other data indicate that obesity rates are inversely related to use of alternative modes.

Although overall North Americans only walk about 6 daily minutes on average, public transit users spend a median of 19 daily minutes walking, which nearly achieves the target of 22 daily minutes of moderate physical activity (Besser and Dannenberg 2005; Weinstein and Schimek 2005). Using pedometers and surveys to track walking activity, Wener and Evans (2007) found that train commuters averaged 30% more walking, more frequently reported walking for 10 minutes or more, and were 4 times more likely to achieve the 10,000 daily steps recommended for fitness and health, than car commuters. Rundle, et al. (2007) found that New York City residents' Body Mass Index (BMI) ratings tend to decline significantly with greater subway and bus stop density, higher population density, and more mixed land use in their neighborhood. Analysis of walking activity by Lachapelle, et al. (2011) found that public transit commuters average 5 to 10 more minutes of moderate-intensity physical activity, and walked more to services and destinations near home and near the workplace, than transit nonusers, regardless of neighborhood walkability.

An Atlanta, Georgia travel survey found 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). They found that transit users average 1.7 daily kilometers of walking a day, which represents approximately two-thirds the recommended physical activity target, and is ten times greater than the 0.16 kilometers of walking averaged by non-transit users. Public transit travel increased walking activity for all income classes, as illustrated in Figure 13, indicating that encouraging transit travel can support public health for various demographic groups.

Figure 13 **Daily Walking Trips And Transit Travel** (Lachapelle and Frank 2008)



Public transit users walk more than non-transit users, regardless of income.

Lachapelle (2010) analyzed relationships between household location preferences, housing location decisions, neighborhood design, transit use, and active transport (walking and cycling) using data from the *Neighborhood Quality of Life Study* of residents in 32 neighborhoods in Metro Seattle, WA and Baltimore, MD. He found higher frequencies of utilitarian walking to destinations near the home and workplace, independent of neighborhood walkability, car availability, and enjoyment of moderate physical activity. MacDonald, et al. (2010), found that, controlling for various demographic factors, light rail transit commuting by Charlotte, North Carolina residents is associated with an average 1.18 reduction in BMI and an 81% reduced odds of becoming obese. Similarly, residents of Melbourne,

Australia who used public transit spent an average of 41 minutes walking or cycling for transport, five times more than the 8 minutes averaged by residents who travel only by automobile (BusVic 2010).

Smart growth community design provides health benefits, particularly for children by encouraging physical activity (The American Academy of Paediatrics 2009). Residents of smart growth, multi-modal communities tend to walk more and have lower rates of obesity and hypertension than in sprawled areas (Ewing, et al. 2003). Frank, et al. (2010) found that residents of more neighborhoods with more and better transit service tend to walk significantly more and drive significantly less than residents of more automobile dependent neighborhoods. Research by Sturm (2005) found that, accounting for demographic factors such as age, race/ethnicity, education and income, the frequency of self-reported chronic medical conditions such as asthma, diabetes, hypertension and cancer increased with sprawl (Sturm 2005). Overall, 1,260 chronic medical conditions are reported per 1,000 residents; each 50-point change toward less sprawled location is associated with 96 fewer conditions. For example, shifting from automobile-oriented San Bernardino, California to transit-oriented Boston, Massachusetts would reduce 200 chronic medical conditions per 1,000 residents, a 16% reduction.

People sometimes fear that these health benefits may be offset by other risks, such as increased pedestrian and cycling accidents, or transit passenger assaults, but empirical evidence indicates that shifts alternative modes tends to increase longevity overall (SQW 2007; WHO 2008). Although people should practice reasonable caution when walking, cycling and riding public transport, in general, shifts from driving to these modes increases overall health and safety.

Mental Health Impacts

Public transportation service quality can affect mental health in various ways. High quality public transit can reduce emotional stress by improving people's access to education and employment activities (and therefore their long-term economic opportunities), improving community cohesion (positive interactions among neighbors), improving access to social and recreational activities (and therefore their positive social interactions and physical activity), and by reducing insecurity and crowding at transit waiting areas and in transit vehicles (Allen 2008; Appleyard 1981; Bell and Cohen 2009). Increased neighborhood walkability is associated with reduced symptoms of depression (Berke, et al. 2007). Many commuters find high quality public transit travel less stressful than driving (Wener and Evens 2007). These mental health benefits are difficult to quantify but potentially large.

Affordability

Affordability refers to reduced financial burdens, particularly for lower-income household. It generally means that transportation expenditures are less than 20% of household budgets, and transportation and housing expenditures total less than 45% of household budgets (CNT 2010). Public transportation and transit oriented development can increase affordability by reducing the need to own and operate personal vehicles, by providing affordable mobility for non-drivers, and by reducing residential parking costs (Bell and Cohen 2009; Sengupta, et al. 2013). This supports public health in several ways: it leaves households with more money to purchase goods required for health, such as adequate shelter, healthy food and medical care, and it reduces emotional stresses associated with poverty.

Basic Mobility

Basic mobility refers to peoples' ability to access services and activities considered essential, such as healthcare services, basic shopping, banking, education and employment opportunities, and a certain amount of social and recreational activities ("Basic Mobility and Accessibility," VTPI 2008). Public transportation and transit-oriented development provide basic mobility and accessibility, particularly for physically and economically disadvantaged people, such as people with disabilities and lower-income seniors. This is important for public health and helps reduce healthcare costs (AARP 2015). Inadequate mobility can cause patients to miss appointments, which exacerbates medical problems and wastes medical resources, or forces patients or health care agencies to pay for more costly transport, such as taxis (APTA 2003). According to one survey, approximately 4% of U.S. children (3.2 million) were unable to access necessary medical services at least once during 2004 because of inadequate transportation (Redlener, et al. 2006). A survey of Americans aged 65 or older found that non-drivers make 15% fewer trips to the doctor; 59% fewer shopping trips and restaurant visits; and 65% fewer trips for social, family and religious activities compared with those who drive (Bailey 2004).

Summary

Table 3 summarizes various ways that public transportation helps improve public health and indicates how these benefits are considered in transport planning. Conventional planning generally considers only a small portion of these health impacts, primarily crash and emission rates per vehicle-mile. Physical fitness, mental health, affordability and basic mobility benefits are often overlooked or treated as special issues of limited importance, and are seldom quantified in economic analysis. Measuring crash and emission rates per vehicle-mile, rather than per capita, ignores the health costs of planning decisions that stimulate vehicle travel, and many benefits of strategies that reduce per capita vehicle mileage. These omissions tend to undervalue public transportation improvements and transit-oriented development.

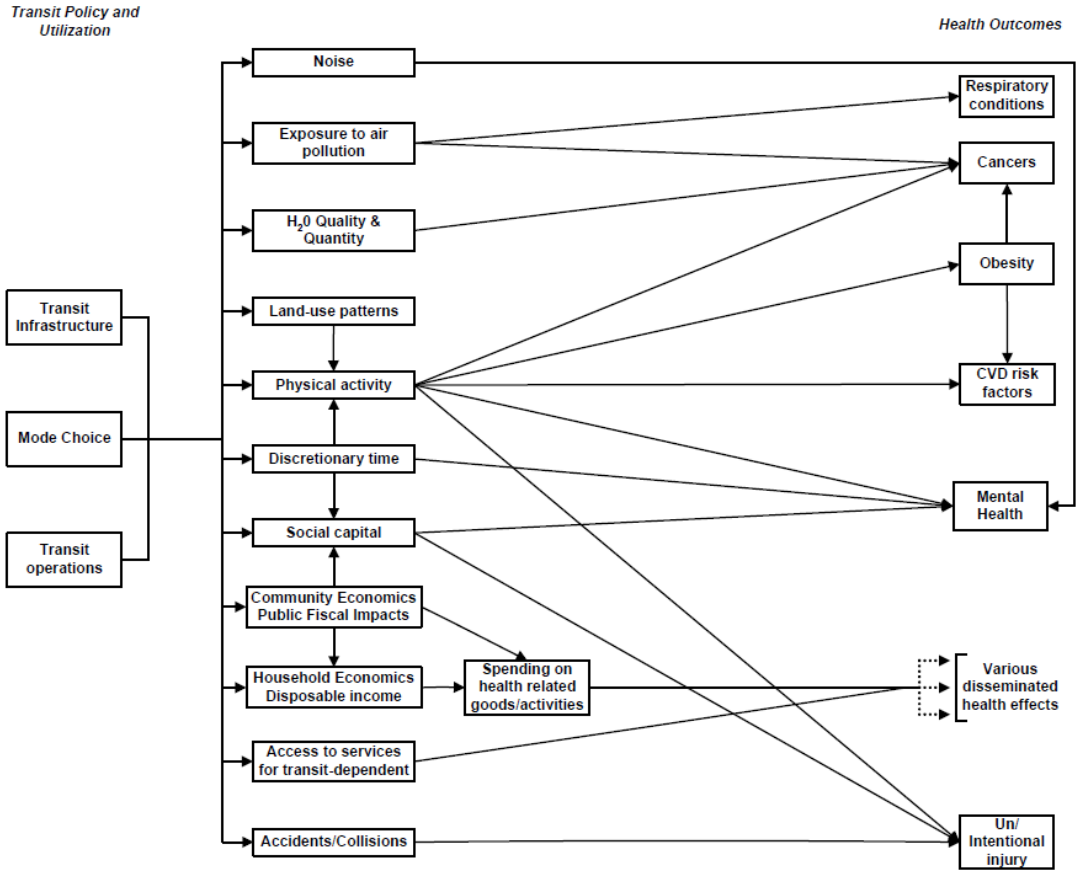
Table 3 **Public Transportation Health Impacts**

Health Benefit	Public Transit Impacts	Consideration In Conventional Planning
Traffic safety. Reduced traffic crash injuries, disabilities and deaths.	Significant reductions in per capita injuries and deaths, particularly if total vehicle travel is reduced.	Considers per-mile crash and injury rates, but often ignores mileage reduction safety benefits.
Pollution reduction. Reduced exposure to harmful air, water and noise pollution.	Generally reduces emissions per passenger-mile and per capita, particularly if transit uses alternative fuels or state-of-the-art emission controls.	Considers differences in emission rates per vehicle-mile, but often ignores mileage reduction impacts.
Physical fitness. Increased physical activity by walking and cycling.	Since most transit trips involve walking or cycling links, and TOD improves nonmotorized conditions, transit improvements tend to increase fitness.	Not generally considered a transportation planning issue and generally overlooked in quantitative analysis.
Mental health. Reduced emotional stress.	High quality transit and transit oriented development can reduce emotional stresses and improve access to economic, social and recreational opportunities.	Not generally considered a transportation planning issue and generally overlooked in quantitative analysis.
Affordability. Reduced financial burdens, particularly for lower-income households.	Public transit and transit-oriented development can reduce transportation costs, which leaves money to purchase housing, healthy food and medical care.	Sometimes considered but not generally quantified.
Basic mobility. Ability for people to access essential goods and services.	Public transit and transit-oriented development provide basic mobility and accessibility.	Sometimes considered when evaluating specific policies and projects, but not generally quantified.

This table summarizes public transit health benefits and how they are considered in conventional planning.

Some researchers have applied *Health Impact Assessment* (HIA) methods to public transit. Cole, et al. (2008) and James, et al. (2007) use HIA methods to evaluate the health impacts of public transit fare increase and service reductions that reduce transit ridership. Figure 14 illustrates the

Figure 14 **Transit Funding Health Impact Assessment Framework** (Cole, et al. 2008)



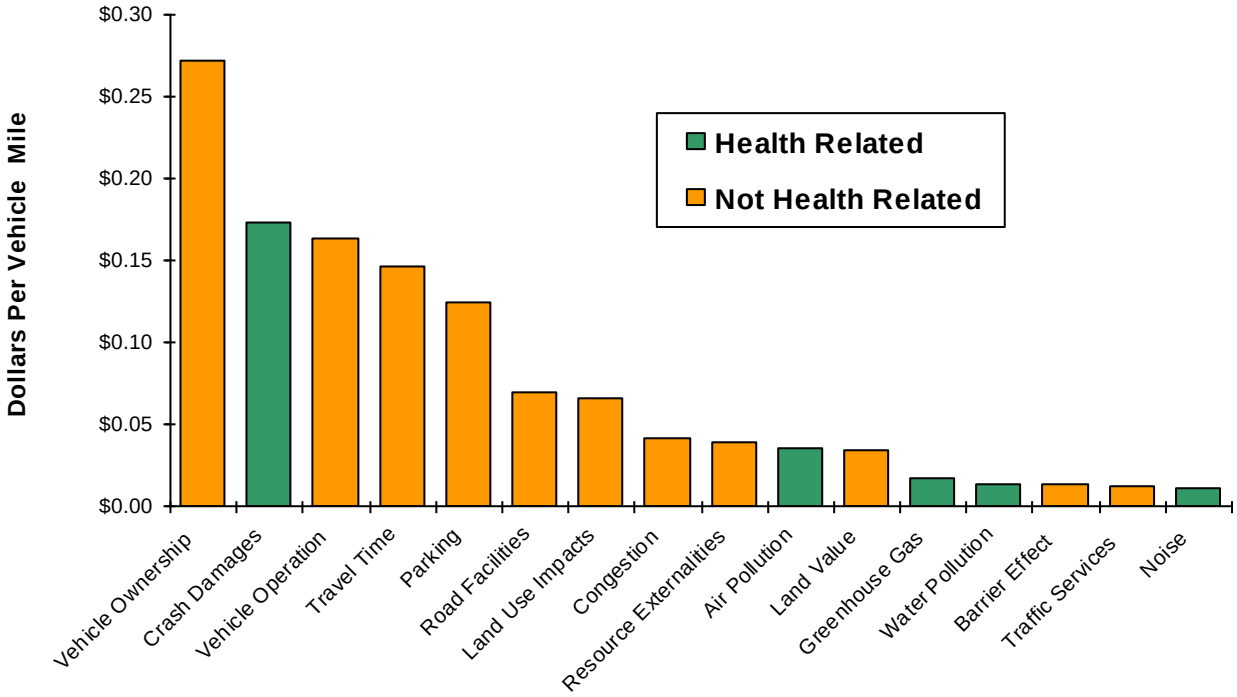
This figure illustrates how changes in public transport funding can affect travel activity (mode choice), which can have various physical impacts and health effects.

Valuing Health Benefits

It is interesting to compare health impacts with other transportation planning objectives. Several studies have quantified and monetized (measured in monetary units) various transport costs, including costs to consumers of owning and operating vehicles, costs to governments for transportation facilities and services, costs to businesses of parking facilities, accident costs and pollution damages (Blincoe, et al. 2002; Delucchi 2005; Maibach, et al. 2007; Litman 2008). Although these impacts are measured as *costs* they also reflect *benefits*. For example, benefits such as financial savings, increased safety and improved health benefits are measured as reductions in vehicle, infrastructure, crash and pollution costs.

Figure 15 illustrates a summary of a typical automobile's costs. Crash damages, estimated to average 17¢ per vehicle mile, are one of the largest cost categories. As mentioned earlier, vehicle pollution probably causes a similar number of premature deaths, but fewer potential years of life lost and less property damages, and so has a lower monetized cost value.

Figure 15 **Overall Average U.S. Motor Vehicle Costs** (Litman 2008)



This figure shows estimated costs of an average automobile per vehicle-mile, ranked by magnitude. For more information on these cost estimates see Delucchi (2005) and Maibach, et al. (2007).

Improved public fitness and health also provides large health benefits and savings. One major literature review found that (ECU 2004b):

- Physical inactivity contributes to numerous physical and mental health problems, and is responsible for an estimated 200,000 deaths per year.
- Annual medical expenditures of physically able adults averaged $1,019 if they report being regularly physically active, but increased 32% to $1,349 if they are sedentary.
- Average annual per capita health care costs increase an average of $125 for people who are overweight and $395 for people who are obese. The annual incremental costs associated with U.S. obesity total $117 billion.
- Nearly 80% of obese adults have diabetes, high blood cholesterol levels, high blood pressure, coronary artery disease or other major ailments.
- The incidence of excess weight or obesity among U.S. adults increased from 47% in 1976 to 56% in 1994, and 64% in 2000.
- In 2000, 15.3% of U.S. children aged 6 to 11 years and 15.5% of adolescents aged 12 to 19 years were overweight, tripling the numbers from two decades ago.
- Of people with safe places to walk within ten minutes of home, 43% achieve recommended activity levels, compared with just 27% of those who lack safe places to walk

Several new analysis tools can help quantify the benefits of increased physical activity for planning applications. The *Active Transport Quantification Tool* (ICLEI 2007) calculates vehicle cost savings, plus the value of reductions in heart disease, diabetes, congestion, pollution and crash risk of shifts from driving to nonmotorized modes. Similarly, the *Physical Inactivity Cost Calculator* (www.ecu.edu/picostcalc) calculates medical cost savings from increased physical activity (ECU 2004a). Stokes, MacDonald and Ridgeway (2008) developed a model to quantify public health benefits of a new light rail transit system in Charlotte, NC. Using estimates of future riders, the effects of public transit on physical activity (daily walking to and from the transit stations), and area obesity rates they estimate future public health cost savings. They estimate that the light rail system would provide cumulative public health cost savings of $12.6 million over nine years.

The Transportation Research Board report *Guidelines for Analysis of Investments in Bicycle Facilities* (TRB 2006) uses a median value of $128 annual per additional pedestrian or cyclist, based on an average of estimates from various previous studies, although these were not standardized or adjusted for inflation. Assuming these users average one additional daily mile this represents 35¢ per mile. The World Health Organization developed the *Health Economic Assessment Tool for Cycling* which estimates economic benefits from increased cycling (WHO 2008). Lindsay, Woodward and Macmillan (2008) used this model to calculate the economic benefits of shifting short urban trips from automobile to cycling in New Zealand.

Land Transport New Zealand's *Economic Evaluation Manual* (LTNZ 2006) provides monetary values for the health benefits of active transportation resulting from planning decisions that increase walking or cycling activity. It estimates that each additional kilometer of walking has a health value of 40¢ New Zealand (48¢ U.S.) and each additional kilometer of cycling has a health value of 16¢ New Zealand (19¢ U.S.), as summarized in Table 4. Half the estimated benefits are internal to the people who increase their activity, and half are external benefits to society due to medical cost savings.

Table 4 **Active Transportation Health Benefits** (LTNZ 2006)

	2005 $ NZ/km	2007 US$/km	2007 US$/mile
Cycling	0.16	0.12	0.19
Walking	0.40	0.30	0.48

These values reflect the health benefits of increased walking and cycling for economic analysis.

Boarnet, Greenwald and McMillan (2008) developed a framework for quantifying the health benefits from improved neighborhood walkability that can be applied to transit-oriented development. The table below summarizes their estimated benefits of an increase in walkability from a median to the seventy-fifth (lower value) and ninety-fifth (higher value) percentile rating, for example, if the number of intersections within a half mile increased by 0.3816 (lower value) or 1.1844 (higher value), for a hypothetical 5,000 resident neighborhood. Guo and Gandavarapu (2010) developed a similar model that monetized the physical fitness and pollution reduction benefits of public policies that reduce driving and increase active transport, such as increased neighborhood sidewalks.

Table 5 **Neighborhood Walkability Benefits** (Boarnet, Greenwald and McMillan 2008)

Neighborhood Walkability Changes	Per Capita Benefits	
	Lower	Higher
Increase number of intersections within 1/2 mile	$451	$4,641
Increase retail employment density	$93	$3,666
Increase employment density	$31	$3,898
Increase population density	$311	$1,671
Distance from central business district	$902	$12,345

This table summarizes estimated health benefits from neighborhood design changes that increase walking activity. "Lower" and "Higher" values indicate results using higher- and lower-bound assumptions.

This research suggests that health impacts are significant compared with other transportation economic impacts, and that methods are available to quantify and monetize these impacts for economic evaluation.

Conventional planning tends to overlook or undervalue many of these health impacts. Transport project evaluation generally considers direct crash and emission impacts but overlooks other safety and health impacts. For example, when comparing highway expansion with a public transportation improvement, the analysis generally considers changes in crash and emission rates by automobiles traveling on that corridor, but ignores factors such as increases in per capita crash and emission rates resulting from induced vehicle travel, and degraded walking and cycling conditions that result from wider roads and higher traffic speeds; impacts that can be avoided or reduced if public transportation improvements are implemented instead of highway expansions. Of course, exact impacts vary depending on circumstances; some highway projects include streetscaping that improves walking and cycling conditions, and some public transportation projects can create barriers to walking and cycling, but in general, public transport improvements and transit-oriented development provide additional health and safety benefits which tend to be overlooked or undervalued in conventional economic evaluation.

This research suggests that health impacts are large compared with other transportation economic impacts, but tend to be overlooked in conventional transport economic evaluation. A transportation policy or project is worth far more if it reduces vehicle traffic and increases walking and cycling activity,

due to resulting health benefits. Conversely, a policy or project that stimulates vehicle traffic and reduces walking and cycling activity is probably worth far less than conventional analysis indicates due to negative health impacts. Public transport improvements and transit oriented development tend to provide significant but often ignored health benefits by reducing traffic crashes and pollution emissions, and increasing walking and cycling activity.

For example, when transportation agencies evaluate whether to invest in highway expansion or public transit improvements, or when municipal governments are deciding whether to implement land use policy reforms that support transit-oriented development, they should consider all benefits that result from transit oriented solutions, including safety and health benefits. This is not generally done. For example, the Federal Transit Administration *New Starts* and *Small Starts* project evaluation framework considers congestion reductions, emission reductions and economic development impacts, and reductions in per-mile crash risks from safer public transit, but generally ignores community-wide safety benefits provided by reductions in total vehicle travel and public health benefits from increased walking and cycling activity (FTA 2007).

These health benefits are just one of several factors that can justify policies to improve public transit service quality and support transit oriented development. Such policies also tend to reduce traffic congestion, road and parking infrastructure costs, consumer costs and environmental impacts (ECONorthwest and PBQD 2002; Litman 2007). Aging population, increasing traffic congestion, rising fuel prices, increased urbanization, increasing environmental concerns, and changing consumer preferences are increasing demand for alternative modes and transit-oriented development (Reconnecting America 2004; Litman 2006).

Modern consumers have sophisticated tastes: they choose fresh organic food, purchase designer clothes, and are often willing to pay a premium for first-class travel. Similarly, they demand higher quality public transit service than what is currently available in most communities.

The following reforms can help incorporate health objectives into transport planning:

- *Consider all health impacts* in transport policy and planning analysis, including crash risk, pollution emissions, physical fitness, mental health, affordability and basic mobility.
- *Measure impacts per capita*, rather than per vehicle-mile, to account for the increased crash risk and pollution emissions that result from planning decisions that stimulate vehicle travel, and the health and safety benefits that result if travel shifts to alternative modes.
- *Create transit-oriented development.* Integrate transit into communities with more compact and mixed development, walking and cycling improvements, streetscaping and traffic calming, better parking management, and more affordable housing in transit rich areas.
- *Improve public transit service quality*, including increased service frequency and speed, reduced crowding, improved comfort and security, nicer waiting conditions, improved pedestrian and cycling access, and amenities such as washrooms.
- *Provide incentives* for travelers to shift from driving to public transit, including commute trip reduction programs, employee transit subsidies, parking pricing and cash out, road pricing, increased fuel taxes and improved marketing.

Estimating Benefits

This section discusses how to calculate the potential health benefits of public transport improvements.

Quantifying and monetizing the health impacts (benefits or costs) of a particular transportation policy or project involves the following steps:

1. *Travel impacts.* Determine changes in how and how much people travel.
2. *Health impacts.* Determine how these travel changes affect traffic casualties, pollution exposure, physical activity, and other health impacts.
3. *Monetization.* Assign monetized values to health impacts.

Table 6 summarizes an example of estimated health benefits from public transportation improvements in a typical North American town or city. This analysis uses the Portland region travel survey data summarized in Table 1 to estimate how high quality public transit service and transit-oriented development affect travel activity. Compared with the regional average, residents of areas with high quality public transit service drive 3,106 fewer annual miles, and residents of transit-oriented development drive 4,376 fewer annual miles, and significantly increase their walking, cycling and public transport travel. According to Cervero (2007), approximately 20% of these shifts result from self-selection, so high quality public transit is estimated to cause residents to reduce 2,485 annual vehicle-miles, and transit-oriented development is estimated to cause residents to reduce 3,501 annual vehicle-miles, in addition to causing significant increases in public transit, walking and cycling travel.

These travel changes are multiplied by the appropriate unit benefit and cost values (cents per mile) for crash risk, pollution emissions and physical fitness (Litman 2008; LTNZ 2006). This assumes that each mile of reduced urban automobile travel provides 12.2¢ worth of accident reductions and 5.6¢ worth of reduced air, noise and water pollution reductions, and each additional mile of walking provides 48¢ of health benefits, and each additional mile of cycling provides 19¢ in health benefits. This model also incorporates values for additional accident and pollution costs of increased public transit travel. The *Transit Health Benefits Calculator Spreadsheet* (www.vtpi.org/thbc.xls) used for this analysis is available for review and can be modified to reflect specific conditions.

Table 6 **Estimated Public Transit Health Benefits** (www.vtpi.org/thbc.xls)

	Base Case	Good Transit	Transit-Oriented Development
	Typical North American public transit service quality	High quality urban rail or bus rapid transit service	High quality transit service with walkable, mixed-use development around stations
Per Capita Annual Mileage	*Annual Miles Per Capita*		
Automobile travel	7,953	4,847	3,577
Transit travel	100	658	958
Walking	100	249	443
Cycling	35	61	83
Change From Base Case	*Annual Miles Per Capita**		
Automobile travel	base case	-2,485	-3,501
Transit travel	base case	447	687
Walking	base case	119	274
Cycling	base case	21	39
Annual Monetized Benefits	*Annual Dollars Per Capita*		
Crash reduction	base case	$276.89	$378.30
Emission reduction	base case	$16.70	$23.49
Walking health benefit	base case	$57.29	$131.57
Cycling health benefit	base case	$3.99	$7.32
Total health benefits		*$354.86*	*$540.68*

This table summarizes the reductions in automobile travel, and increases in walking, cycling and public transit that result from high quality public transportation and transit oriented development. These are multiplied by health benefit values described in this report to determine per capita annual health benefits.

Total benefits depend on the number of people affected. Table 7 summarizes estimated health benefits of region-wide policies that increase the portion of households located in transit-oriented developments from a base of 10% up to 20% or 40%, in a city with a million residents.

Table 7 **Annual Benefits of More Residents Living in TOD** (www.vtpi.org/thbc.xls)

	Portion Residents in Transit Oriented Development (TOD)	
	Increase from 10% to 20%	*Increase from 10% to 40%*
Crash reduction	$55,377,185	$151,321,950
Emission reduction	$3,340,009	$9,396,593
Walking health benefit	$11,457,049	$52,626,885
Cycling health benefit	$798,000	$2,926,000
Total health and safety benefits	**$70,972,244**	**$216,271,428**

This table estimates the total health benefits that result as a greater portion of residents in a one-million population city are able to locate in transit-oriented communities.

This analysis can be adjusted to reflect specific circumstances, for example, if a project is expected to cause larger or smaller travel changes, or occurs in an area with unusually high or low crash or pollution costs. Similarly, walking and cycling benefit values could be increased if a project targets people more sedentary than average, for example, if it occurs in a community with high obesity rates. This analysis can also be expanded to account for other impacts by assigning values to factors such as improved basic mobility.

Comprehensive Evaluation

This section discusses how to account for additional economic, social and environmental impacts.

This report investigates transportation health impacts. Of course, other impacts should also be considered in transport policy analysis, as illustrated in Table 8. For example, expanding roadways can reduce traffic congestion, but if it induces additional vehicle travel it tends to exacerbate other problems such as parking congestion, accidents, energy consumption and pollution emissions, and can degrade walking and cycling conditions which reduces physical activity and fitness. Similarly, increasing vehicle fuel efficiency reduces energy consumption and pollution emissions, but by reducing the per-mile cost of driving tends to increase total vehicle travel and so tends to increase traffic congestion, accidents and sprawl. Public transportation improvements tend to reduce total vehicle travel and encourage use of alternative modes, and therefore help achieve the greatest range of benefits. Comprehensive planning considers all these impacts.

Table 8 **Comprehensive Evaluation Framework**

Planning Objective	Roadway Expansion	Fuel Efficient Vehicles	Public Transportation
Vehicle Travel Impacts	*Increased*	*Increased*	*Reduced*
Congestion Reduction	✓	×	✓
Roadway Cost Savings		×	✓
Parking Costs Savings	×	×	✓
Consumer Costs Savings			✓
Reduced Traffic Accidents	×	×	✓
Improved Mobility Options			✓
Energy Conservation	×	✓	✓
Pollution Reduction		✓	✓
Land Use Objectives (sprawl)	×	×	✓
Physical Activity and Fitness	×		✓

Some transport improvement strategies achieve one or two objectives (✓), but by increasing total vehicle travel contradict others (×). Public transportation improvements support many planning objectives and so are often most cost effective overall, considering all impacts.

Critics sometimes argue that automobile travel is faster than other modes, so shifting to walking, cycling and public transit wastes time and reduces overall efficiency. This is not necessarily true (Litman 2007). For example, motorist save time if high quality public transit reduces traffic congestion or reduces the need to chauffeur non-drivers. Similarly, people benefit if walking and cycling improvements allow them to integrate exercise into their daily travel, reducing their need to drive to a gym to work out. Improving transportation options allows consumers to use the best mode for each trip, which maximizes overall efficiency and consumer benefits.

Conclusions

Public transportation can provide significant health benefits. People who live or work in communities with high quality public transportation tend to own fewer vehicles, drive less, and use alternative modes more than they would in more automobile-oriented locations. This can provide large reductions in traffic crashes and pollution emissions, increases in physical fitness and mental health, and improved access to healthy food, housing and medical care. These health benefits are significant in magnitude compared with other planning objectives, but are often overlooked or undervalued in conventional transport planning.

The U.S. has traffic fatality and obesity rates two or three times those of peers countries, which contribute to poor health outcomes (nearly a year shorter average life expectancy compared with the OECD average) and high per capita healthcare costs (two-and-a-half the OECD average). Traffic fatalities alone reduce average U.S. lifespans approximately 0.4 years or about 5%, and the combined effects of vehicle air pollution and sedentary living probably cause even greater longevity reductions. Reducing U.S. traffic accidents, sedentary living, and obesity rates to that of its peers could significantly reduce the discrepancy between U.S. and OECD lifespans, providing tens of billions of dollars worth of benefits and savings.

This is not to suggest that people should be forced to shift from driving to walking, cycling and public transit travel just to achieve health objectives, but it does suggest that decision makers and the general public should be informed about the substantial safety and health benefits that can result from improved public transit and more transit-oriented development. Recent research can be used to quantify and monetize (measure in monetary units) transportation health impacts, to allow more accurate and comprehensive policy and project analysis.

This is a timely issue. Current demographic, economic and market trends are increasing demand for alternative modes and increasing the benefits provided by high quality public transit and transit-oriented development. Market surveys indicate that a growing portion of households want to rely more on alternative modes and live in more accessible, multi-modal communities, provided that they are convenient, comfortable, affordable and attractive. Accommodating this demand would provide benefits to users and society, including significant health benefits.

When all impacts are considered, improving public transit can be one of the most cost effective ways to achieve public health objectives, and public health improvements are among the largest benefits provided by high quality public transit and transit-oriented development.

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