Victoria Transport Policy Institute
"Efficiency · Equity · Clarity" www.vtpi.org
Telephone: 250-360-1560 | email: Info@vtpi.org

Valuing Transit Service Quality Improvements

Considering Comfort and Convenience In Transport Project Evaluation

29 June 2008

By
Todd Litman
Victoria Transport Policy Institute

Travel time values (the cost people place on time they spend traveling) are affected by comfort and convenience. Transit travel time values are particularly sensitive to waiting area conditions.

Abstract

This report investigates the value travelers place on qualitative factors such as comfort and convenience, and practical ways to incorporate these factors into travel time values for planning and project evaluation. Conventional evaluation practices generally assign the same time value regardless of travel conditions, and so undervalue comfort and convenience impacts. Yet, a quality improvement that reduces travel time unit costs by 20% provides benefits equivalent to an operational improvement that increases travel speeds by 20%. This report recommends specific travel time value adjustments to account for factors such as travel and waiting comfort, travel reliability, and real time transit vehicle arrival information. It describes how service quality improvements can increase transit ridership and reduce automobile travel.

A condensed version of this paper was published in the *Journal of Public Transportation*, Vol. 11, No. 2, Spring 2008, pp. 43-64; at www.nctr.usf.edu/jpt/pdf/JPT11-2Litman.pdf.

Contents

Preface
When making daily travel decisions, people often choose driving over more resource-efficient but less comfortable and convenient alternative modes. As a result, they feel guilty, and exacerbate problems such as congestion, infrastructure costs, consumer costs, accidents, energy consumption, and pollution emissions.

Comfort and convenience significantly influence transportation decisions. Consumers choosing a motor vehicle are as likely to decide base on seat comfort and the ease of using navigation systems as on more quantitative factors such as speed, price or fuel efficiency. Comfort and convenience also influence consumers when choosing a travel mode. Yet, planners lack guidance for evaluating such factors. This leads to underinvestment in transport comfort and convenience for modes that depend on public support, such as walking, cycling and public transit.

This report identifies ways to account for qualitative factors in transport project evaluation by adjusting travel time values to reflect comfort and convenience. This can help identify innovative solutions to problems such as traffic congestion, and increases support for alternative modes, which tends to achieve both equity objectives and increased economic efficiency.

Described differently, the methods described in this report support planning decisions that improve the comfort and convenience of alternative modes, which helps people reconcile their travel behavior with their good intentions.

Introduction

Our most valuable possession is not material wealth, it is our time – how we spend the limited hours of our lives. Much of our time is committed. During a typical day people spend about 8 hours sleeping, 8 hours working and 2-4 hours engaged in household activities such as cooking, cleaning and eating. Of the remaining 4-6 hours, about a quarter is usually spent traveling, representing a major portion of "free" time. The perceived comfort and convenience of travel conditions has significant direct and indirect impacts. It affects our health, wealth and happiness:

- For people in the prime of life (1 to 50 years of age) vehicle accidents are the greatest cause of death, and travel patterns affect our physical fitness and health. Per capita traffic fatality rates tend to decline, and physical fitness increases as use of alternative modes (walking, cycling and public transit) increase (Litman and Fitzroy, 2005)
- Transportation is a major consumer expense. Improved travel options (better walking and cycling conditions and transit service quality) saves money and increases affordability.
- The quality of daily travel conditions affects human happiness. Long and unpleasant daily commutes, in particular, tend to increase stress and reduce contentment.
- Improving the quality (comfort, convenience, reliability and safety) of alternative modes attracts discretionary travelers (people who could drive), which reduces transport problems such as congestion, accidents, energy consumption and pollution emissions.

The value people place on travel time varies depending on the type of trip, people's preferences, and travel conditions. People are often willing to pay extra in money or time for more convenience or comfort. For example, people sometimes pay extra for higher class service, choose slower modes such as walking and cycling because they enjoy the experience, or choose a longer transit route to avoid transfers.

This has important implications for planning since time costs are a dominant factor in transport project evaluation. Conventional evaluation practices tend to ignore qualitative factors, assigning the same time value regardless of travel conditions, and so undervalue service improvements that increase comfort and convenience. Yet, a quality improvement that reduces travel time unit costs by 20% provides benefits equivalent to an operational improvement that increases travel speeds by 20%.

Automobile travel comfort and convenience is continually improving with amenities such as better seats, sound systems and navigation systems. Improving the quality of alternative modes is important for attracting discretionary travelers and therefore reducing traffic problems such as congestion, accidents and pollution emissions.

This report investigates the value passengers place on transit service quality; recommends ways to measure these values for policy and planning analysis; discusses the impacts transit service quality improvements have on travel behavior; discusses implications of this analysis; and recommends additional research. This information should be useful for planners interested in finding cost effective ways to improve transit service, increase transit ridership and reduce traffic problems.

Table 1 **Transit Service Quality Objectives**

Category	Service Quality Objectives
Coverage	The walk to and from transit stops is a reasonable distance. The route network operates in very close proximity to major destinations.
Comfort	The waiting areas at bus stops are clean, attractive, well-lit and accessible. Transit shelters are placed at busy and/or exposed stops. Transit shelters are well-maintained. Modern accessible buses in good repair are used to provide service. Bus interiors and exteriors are clean and well-maintained. Buses are operated safely.
Travel Time	Buses operate at frequent intervals. Routes are direct. Buses are not delayed by traffic and parked cars. Transit priority measures are used to speed up bus service. Travel by transit is as fast as travel by car.
Reliability	All scheduled trips are operated. Vehicle breakdowns are minimized. The service operates on time. Transfer connections are made. Transit priority measures are used to eliminate schedule delays.
Convenience	A network of well-maintained sidewalks provides access to transit stops. Stop platforms and shelters are well designed and maintained in good repair. Accessible buses are used to provide service. Service schedules identify the trips operated by accessible buses. High quality snow removal on sidewalks allows wheelchair access to regular transit.
Courtesy	Passengers are treated politely and respectfully by transit staff. Staff provide reliable information to customers. Complaints are investigated promptly and corrective action is taken.

This table summarizes various service quality objectives. These are the types of factors considered in this report.

Quantifying Travel Time Values

Numerous studies have quantified and *monetized* (measured in monetary units) travel time costs by evaluating how travelers respond when faced with a tradeoff between time and money, for example, when offered the option to pay extra for a faster trip (Mackie, et al., 2003; Wardman, 2004; Litman, 2007).

There are several types of travel time, as summarized below. *Clock time* is measured objectively, while *perceived* (or *cognitive*) *time* reflects users' experience. Paid travel time costs should be calculated based on clock time but personal travel time costs should be calculated based on perceived time. *Generalized travel cost* is the sum of time and financial costs. *Effective speed* (also called *social speed*) includes time spent traveling, devoted to maintaining vehicles, and working to pay transport expenses.

Table 2 **Types of Travel Time**

Name	Description	Implications
Travel Time	Any time devoted to travel.	This is the least specific definition.
Clock Time	Travel time measured objectively.	This is how time is usually quantified.
Perceived Time	Travel time as experienced by users.	This reflects travel condition quality.
Paid (also called *on-the-clock* or *commercial*)	When workers are paid for their travel time (for deliveries, traveling to worksites etc.).	This type of travel tends to have a relatively high value per hour.
Personal Travel Time	Time devoted to personal travel (commuting, errands, etc.).	This is usually the largest category of time.
Generalized Costs	Combined travel time and financial costs.	This is how travel time is often evaluated in transport models.
Effective Speed	Total time devoted to travel and paying for transport equipment and services.	Higher costs for more expensive modes.

This table summarizes various perspectives for valuing travel time and travel time savings.

Total travel time costs are therefore the product of the amount of time (minutes or hours) multiplied by unit costs (measured as cents per minute or dollars per hour). A shorter duration trip with higher unit time costs can cost less in total than a longer duration trip with lower unit costs. For example, people sometimes choose slower but more pleasant travel options, reflecting their lower total time costs, or they might be willing to pay extra for more comfortable seats, air conditioning, traveler information, or reduced transfers.

People tend to remember an experience based on its worst rather than its average discomfort (The Economist, 2006). For example, travelers tend to rate a trip based on its most uncomfortable, insecure or stressful period; and commuters tend to choose their future mode based on the worst event they experienced during the last week. This suggests that an occasional unpleasant experience can significantly affect travel patterns, for example, by causing commuters to shift from transit to automobile travel, imposing high social costs (increased traffic congestion, accident risk, pollution, etc.).

Travel time unit costs are generally calculated relative to average wages. Personal travel time unit costs are usually estimated at 25% to 50% of prevailing wage rates, with variations due to factors discussed below (Waters, 1992; Litman, 2007).

- Commercial (paid) travel costs should include driver wages and benefits, and the time value of vehicles and cargo reflecting efficient use of assets and ability to meet delivery schedules.
- Travel time costs tend to be higher for uncomfortable, unsafe and stressful conditions (Small, et al, 1999; Wener, Evans and Lutin, 2006; Brundell-Freij, 2006).
- 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 usually have more demands on their time and so tend to be willing to pay more for travel time savings.)
- A moderate amount of daily travel often has little or no time cost, since people generally seem to enjoy a certain amount of daily travel (Mokhtarian, 2005). Recreational travel and errands that involve social activities often have minimal cost or positive value.
- Unit time costs tend to increase if trips exceed about 20 minutes in duration or total personal travel exceeds about 90 minutes per day.
- Travel time costs increase with variability and arrival uncertainly (Cohan and Southworth, 1999), and tend to be particularly high for unexpected delays (Small, et al, 1999). Late arrival imposes much higher costs than early arrival, particularly for activities with strict schedules, such as arriving at work, daycare pickup and airports (Hollander, 2006).
- Under pleasant conditions walking, cycling and waiting can have low or positive value, but under unpleasant conditions (walking along a busy highway or waiting for a bus in an area that seems dirty and dangerous) their costs are significantly higher than in-vehicle time.
- People have diverse mobility needs and preferences, so improved options allows individuals to choose the best one for each trip. For example, some people prefer driving while others prefer transit travel; having both available allows people to select the option that minimizes costs, including travel time costs, and maximizes benefits (Novaco and Collier, 1994).
- Shorter waits and nicer waiting conditions are symbols of status. Clean waiting areas and information concerning delays and expected arrival times indicate respect for passengers and can reduce perceived costs.

The following two factors are particularly important for analysis in this report:

- Transit travel conditions, and therefore transit travel time unit cost values, are extremely variable. Under pleasant conditions (comfortable, clean, quiet, and safe vehicles and waiting areas), transit travel time unit costs are lower than driving because passengers experience less stress and are able to rest or use their time productively. However, if transit conditions are unpleasant, transit travel times are significantly higher than automobile travel.
- In most communities a portion of transit travelers are captive; people who are unable to drive and so are forced to use transit regardless of service quality. However, transit will only attract discretionary travelers (those who could drive for a particular trip, also called *choice riders*) if high service quality reduces unit travel time costs relative to automobile travel.

Many of these factors have significant implications for transit project evaluation, as summarized in Table 3. More accurate analysis tends to increase the relative value of transit improvements.

Table 3 **Factors Affecting Travel Time Costs** (Pratt, 1999; Li, 2003; Litman, 2006)

Factor	Description	Transit Evaluation Implications
Waiting	Waiting time is usually valued higher than in-vehicle travel time.	Transit travel usually requires more waiting, often along busy roads, with little protection.
Walking links	Time spent walking to vehicles is usually valued higher than in-vehicle travel time.	Transit travel usually requires more walking for access.
Transfers	Transfers impose a time cost penalty.	Transit travel often requires transfers.
Trip duration	Unit costs tend to increase for trips that exceed about 40 minutes.	Transit travel tends to require more time than automobile travel for a given distance.
Unreliability (travel time variance)	Unreliability, particularly unexpected delays, increase travel time costs.	Varies. Transit is often less reliable, except where given priority in traffic.
Waiting and vehicle environments	Uncomfortable conditions (crowded, dirty, insecure, cold, etc.) increase costs.	Transit travel is often less comfortable than private vehicle travel.
Sense of control	A person's inability to control their environment tends to increase costs.	Transit travel is often perceived as providing little user control.
Cognitive effort (need to pay attention)	More cognitive effort increases travel time costs.	Varies. Driving generally requires more effort, particularly in congestion.
Variability	Transit travel conditions are extremely variable, depending on the quality of walking, waiting and vehicle conditions.	Transit benefit analysis is very sensitive to qualitative factors that currently tend to be overlooked and undervalued.
Captive versus discretionary travelers.	Some transit users are captive and so relatively insensitive to convenience and comfort, but discretionary travelers tend to be very sensitive to these factors.	Achieving automobile to transit mode shifts requires more comprehensive analysis of transit service quality factors and their impacts on transit demand.

This table summarizes various factors that affect transit time valuation and transit project evaluation.

Conventional Travel Time Evaluation

Travel time is an important factor in transportation modeling and project evaluation. Typically, 60-80% of urban transport project benefits consist of user travel time savings. How time values are calculated can significantly affect planning decisions.

Conventional transport project evaluation models apply relatively simple travel time values, which tends to emphasize quantitative factors such as speed over qualitative factors such as comfort, convenience and reliability. For example, Table 4 shows the travel time unit cost values recommended by the US Department of Transportation. These cost values do not reflect comfort and convenience factors. Incorporating such factors often changes project evaluation results. For example, Jara-D´Iaz and Gschwender (2003) show that better accounting of transit passenger comfort justifies more frequent transit service by recognizing the high costs passengers incur when waiting for vehicles or traveling in crowded conditions.

Table 4 **Recommended Travel Time Values** (ECONorthwest and PBQD, 2002)

Time Component	Relative to Wages
In-Vehicle Personal (local)	50%
In-Vehicle Personal (intercity)	70%
In-Vehicle Business	120%
Excess (waiting, walking, or transfer time) Personal	100%
Excess (waiting, walking, or transfer time) Business	120%

This table summarizes USDOT recommended travel time values. This fails to account for qualitative factors such as travel comfort or reliability.

Researchers have developed travel time valuation methodologies that reflect many qualitative factors, such as in Table 5. These account for type of travel (commercial or personal), type of traveler (driver, adult passenger, child passenger), mode (automobile, bus, bicycle, walk), and travel condition (indicated by Level-of-Service ratings). This allows more accurate analysis of improvements that increase comfort and convenience.

Table 5 **Travel Time Values Developed For BC** (Waters, 1992)

Category	LOS A-C	LOS D	LOS E	LOS F	Waiting
Commercial vehicle driver	120%	137%	154%	170%	170%
Commercial 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 or bus passenger	35%	47%	58%	70%	70%
Child passenger under 16 years	25%	33%	42%	50%	50%
Pedestrians and cyclists	50%	67%	84%	100%	100%

This summarizes recommended travel time values, calculated relative to average wages. "Level of Service" (LOS) refers to standardized ratings, typically from A (best) to F (worst), commonly used by transportation engineers to grade service quality on particular roadways.

Transit Travel Time Values

Many of the factors that affect perceived travel time and unit travel time costs have significant implications for transit project evaluation, as summarized in the table below. More accurate analysis tends to increase the relative value of transit improvements.

Table 6 **Factors Affecting Travel Time Costs** (Pratt, 1999; Li, 2003; Litman, 2007)

Factor	Description	Transit Versus Automobile Travel
Waiting	Waiting time is usually valued higher than in-vehicle travel time.	Transit travel usually requires more waiting, often along busy roads, with little protection.
Walking links	Time spent walking to vehicles is usually valued higher than in-vehicle travel time.	Transit travel usually requires more walking for access.
Transfers	Transfers impose a time cost penalty.	Transit travel often requires transfers.
Trip duration	Unit costs tend to increase for trips that exceed about 40 minutes.	Transit travel tends to require more time than automobile travel for a given distance.
Unreliability (travel time variance)	Unreliability, particularly unexpected delays, increase travel time costs.	Varies. Transit is often less reliable, except where given priority in traffic.
Waiting and vehicle environments	Uncomfortable conditions (crowded, dirty, insecure, cold, etc.) increase costs.	Transit travel is often less comfortable than private vehicle travel.
Sense of control	A person's inability to control their environment tends to increase costs.	Transit travel is often perceived as providing little user control.
Cognitive effort (need to pay attention)	More cognitive effort increases travel time costs.	Varies. Driving generally requires more effort, particularly in congestion.

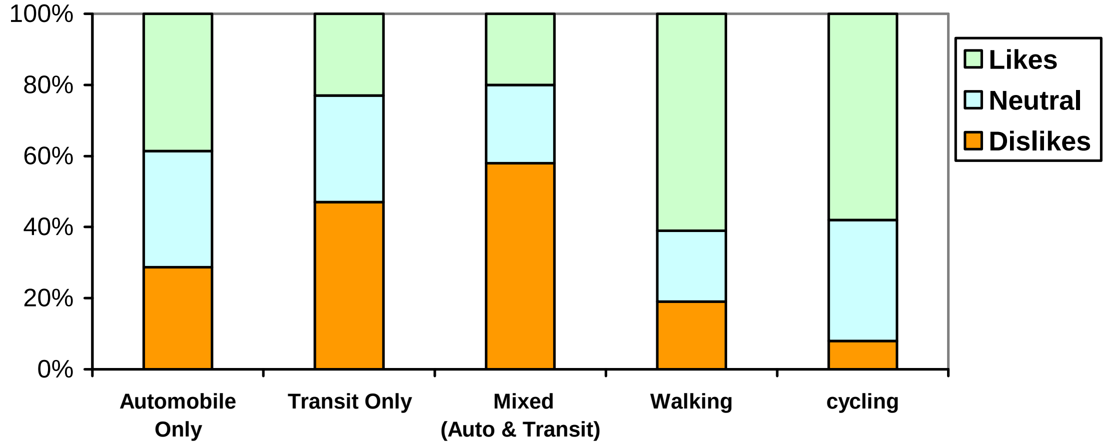
This table summarizes various factors that affect perceived travel time and therefore travel time cost values. More accurate analysis tends to recognize more value from transit service improvements.

Li (2003) describes how these factors tend to favour automobile commuting:

> "An auto commute is attractive in most courses of perceived travel time, compared to a public transportation commute. It is most likely a door-to-door service, thus minimizing the number of commute stages [transfers]. It spends time predominantly on the ride episode, usually with seats secured and even entertainment (e.g., music) of the commuter's choice. It demands the commuter's (i.e., driver's) continuous attention to road conditions and motor operation, rather than temporal cues or information, and hence exploits the cognitive resource for nontemporal information processing. Also, it avoids the temporal and monetary losses due to unreliable public transportation services. All these may result in a given journey perceived as shorter for an auto commute, and hence the commute experience to be more positively evaluated than for a commute with public transportation."

A Statistics Canada survey (Turcotte, 2006) reached similar conclusions. It found that transit users tend to dislike commuting more than automobile commuters, as illustrated in Figure 1.

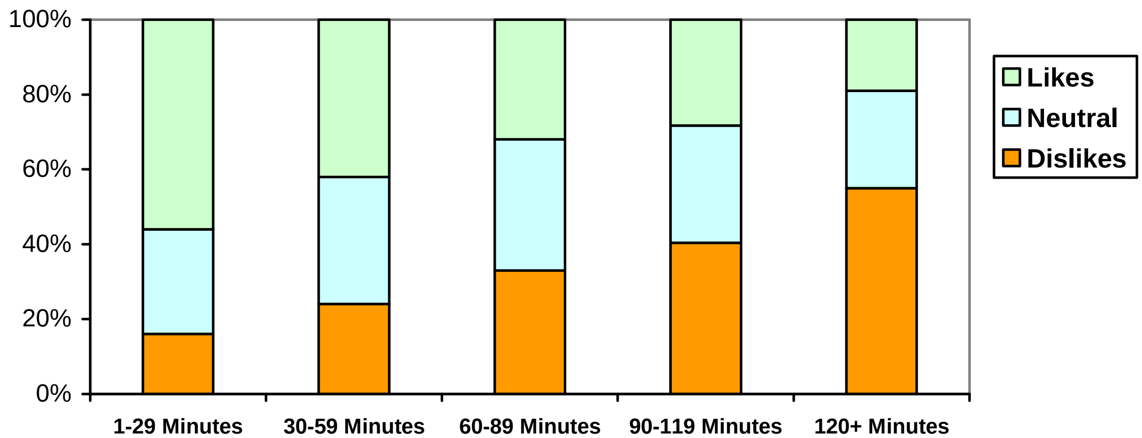
Figure 1 **Perceptions of Daily Commutes, by Mode** (Turcotte, 2006)



This figure indicates worker perceptions of commuting by mode. Public transit users tend to dislike their commutes more than commuters using other modes.

This study found that "Dislike" rates increase with commute duration, as illustrated in Figure 2, and with city size. The greater dislike of commuting by transit travellers and large city residents can be explained by their longer average commute duration and increased need to transfer. After accounting for these factors the researcher found no statistically significant difference between transit and automobile commuters. Workers who used both automobile and public transport had the highest rate of commute dislike, and the inclusion of travel time did not eliminate the correlation, indicating additional stress and delay from transfers. The study indicates that reducing perceived transit travel times can shift commutes from automobiles to transit.

Figure 2 **Perceptions of Daily Commutes** (Turcotte, 2006)



This figure indicates worker perceptions of commuting by daily commute duration. People with longer duration trips are more likely to dislike their commutes.

Transit travel can have lower unit time costs than driving, particularly if travellers can select the mode that best meets their needs and preferences. A survey of New Jersey commuters found that train users experienced less stress and fewer negative moods than drivers making similar trips, indicating the reduced effort and greater predictability of train travel (Wener, Evans and Lutin, 2006). Train commuter stress levels declined significantly after service improvements reduced their need to transfer.

Various studies provide more detailed information concerning how qualitative factors affect travel time costs. Booz Allen Hamilton (2003) used stated preference surveys to estimate own and cross-elasticities for various costs (fares, travel time, waiting time, transit service frequency, parking fees) modes (automobile, transit, taxi) and trip types (peak, off-peak, work, education, other) in Canberra, Australia. They developed generalized costs and travel time cost values, including estimates of the relative cost of walking and waiting time for transit users. The travel time cost values from a similar study in Brisbane, Australia are summarized in Table 7.

Table 7 **Brisbane Travel Time Costs** (AU$2003) (Douglas, Franzmann, and Frost, 2003)

Mode	Short (Under 30 Minutes)				Medium (30 – 45 Minutes)			
	Peak		Off-Peak		Peak		Off-Peak	
	CBD	Non CBD	CBD	Non CBD	CBD	Non CBD	CBD	Non CBD
Bus	$9.20	$7.70	$7.50	$5.90	$9.20	$8.70	$7.60	$7.50
Rail	$9.30	$6.90	$6.90	$6.00	$8.80	$7.70	$7.90	$6.70
Ferry	$10.70	-	$8.30	-	-	-	-	-
Car	$10.60	$9.00	$8.30	$7.10	$10.10	$8.00	$9.00	$6.40

This table indicates the results of a detailed travel time cost survey. Transit passengers tend to have lower unit costs than car travelers. (CBD = Central Business District)

Various studies indicate that walking and waiting time unit costs are two to five times higher than in-vehicle transit travel time (Pratt, 1999, Table 10-12). Transfers tend to impose extra costs (called a *transfer penalty*) due to the additional physical and cognitive effort they require, and the risk of missing a connection, typically equivalent to 5-15 minutes of in-vehicle travel time (Horowitz1 and Zlosel, 1981; Evans, 2004). Described differently, transfer wait time costs tend to be greatest during the first few minutes and decline as waiting duration increases. As a result, transit travelers will sometimes choose a longer or slower route to avoid transfers.

A survey of U.K. rail passengers found that many use their time for productive 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 place positive utility on such time (Lyons, Jain and Holley, 2007). When asked to rate their travel time utility, 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 portion of travel time devoted to productive activity is higher for business travel than for commuting or leisure travel, and increases with journey duration.

TransFund New Zealand uses standard travel time values summarized in Table 8. Their project evaluation manual has detailed instructions for applying these values (TransFund, 1998). For non-work (personal) travel, standing bus passengers have about twice the travel time costs as seated car or bus passengers, and a third higher than car drivers.

Table 8 **Travel Time Base Values** (1998 NZ Dollars Per Hour) (TransFund, 1998)

Mode	Work Travel	Non-Work Travel	Congestion Premium
Car, Motorcycle Driver	$21.30	$7.00	$3.50
Car, Motorcycle Passenger	$21.30	$5.25	$2.60
Light Commercial Driver	$19.25	$7.00	$3.50
Light Commercial Passenger	$19.25	$5.25	$2.60
Medium Commercial Driver	$15.80	$7.00	$3.50
Medium Commercial Passenger	$15.80	$5.25	$2.60
Heavy Commercial Driver	$15.80	$7.00	$3.50
Heavy Commercial Passenger	$15.80	$5.25	$2.60
Seated Bus Passenger	*$21.30*	*$5.25*	*$2.60*
Standing Bus Passenger	*$21.30*	*$10.55*	*$2.60*
Pedestrian and Cyclist	$21.30	$10.55	NA

"Work" travel involves travel while paid. "Non-work" travel is all personal travel, including commuting. "Congestion Premium" is an additional cost for travel in congested conditions.

Research for RailCorp (an Australian rail company) found that the average value of onboard train time was $9.46/hr during peak periods and $7.83/hr. during off-peak periods, in 2003 Australian dollars (Douglas Economics, 2004 and 2006). Full-fare ticket purchases placed about twice the value on their time ($10.36/hr) as concession ticket purchasers ($5.13/hr). Table 9 identifies how various factors affect rail travel time values.

Table 9 **Factors Affecting Rail Travel Time Values** (Douglas Economics, 2004)

Trip and Passenger Profile Effects	Travel Period & Trip Length Effects
Females more sensitive to transfer	Peak In-vehicle time sensitivity increases with trip length
Company business trips less sensitive to fare	Peak Service Interval more sensitive than off-peak
Managers/Professionals more sensitive to service interval	Service Interval sensitivity less for Very Long trips
Managers & Professionals more sensitive to transfer	Transfer Penalty greater in the Peak
Housepersons less sensitive to rail in-vehicle time	Transfer Penalty increases with trip length
Retired passengers less sensitive to service interval	Peak Transfer Penalty increases with trip length
Retired passengers less sensitive to rail in-vehicle time	Sensitivity to Fare Concession less in the peak
Sydney CBD trips more sensitive to rail in-vehicle time	Fare concession Peak Sensitivity increases with trip length

This table summarizes various factors found to affect transit travel time values.

Transfers were found to add costs above the connection time involved, reflecting the additional effort required, and so are modeled as a fixed penalty plus wait time. The transfer penalty was estimated to equal 6.7 minutes of rail in-vehicle time, with transfer waiting time valued at 1.08 times rail in-vehicle time. Thus a transfer taking five minutes is valued at 12.1 minutes (6.7 + 1.08 x 5). This penalty is 30% higher during off-peak times and increases with trip length. For peak trips, transfer penalties varied from 9 minutes for short trips to 18 minutes for long trips, and averages 12 minutes overall. For off-peak trips the transfer penalty was estimated to equal 15 minutes of onboard time.

The study found that unexpected delays impose 3.7 times standard onboard travel time costs. The same multiplier applies to peak and off-peak trips. This can be used to calculate the total cost of unreliability. Thus, if 10% of trains are ten minutes late, the average lateness of 1 minute would be valued equal to 3.7 minutes of onboard train time. This unreliability multiplier increases to 5.0 under extremely unreliable conditions.

The study also analyzed the value of train frequency. More frequent service reduces the interval between trains and improves passengers' ability to match their schedule to the timetable. With 5 minute headways the value of a minute of service interval was estimated to be equal to a minute onboard the train. With service every 30 minutes, a minute of peak service interval was estimated to be worth 0.67 of onboard train time with off-peak service interval valued at 0.57. With hourly services, the value of a minute of service interval declined to 0.53 and 0.42 respectively.

Train riders were surveyed to assess the value they place on various service attributes. The table below summarizes vehicle service values, measured by the additional fares or time travelers would willingly bear in exchange for a 10% improvement (from 50% to 60% acceptability ratings). For example, travelers indicate that they would willingly pay 5.6¢ per minute or tolerate a 38% increase in their onboard travel times in exchange for such a 10-point improvement in train layout and design.

Table 10 **Value of Train Improvements** (Douglas Economics, 2006)

Type of Train Improvement	**Additional Fares** (2003 Aust. Cents Per Minute)	**Additional Onboard Time** (Additional Time in minutes)
Layout & Design Improvements	5.6¢ (2.2%)	0.38
Cleanliness	3.8¢ (1.5%)	0.26
Ease of Train Boarding	3.2¢ (1.2%)	0.22
Quietness	3.2¢ (1.2%)	0.22
Train Outside Appearance	2.3¢ (0.9%)	0.15
On-Train Announcements Improved	2.3¢ (0.9%)	0.16
Heating & Air Conditioning	2.2¢ (0.8%)	0.15
Improved Lighting	1.9¢ (0.7%)	0.13
Smoothness of Ride	1.5¢ (0.6%)	0.10
Graffiti Removed	1.2¢ (0.5%)	0.08
Seat Comfort	1.1¢ (0.4%)	0.07

Value of improving train attribute rating from 50% to 60%. This indicates, for example, that an average traveler would willingly pay an additional 5.6¢ in fares or an additional 0.38 minutes (23 seconds) in travel time for that incremental improvement.

Table 11 presents the additional fare or onboard time train travelers would be willing to pay for a 10% improvement of various station attributes. For example, travelers would willingly pay 2.4¢ per minute or tolerate a 0.16 minute increase in their onboard travel times in exchange for such a 10-point improvement in train layout and design.

Table 11 **Value of Station Improvements** (Douglas Economics, 2006)

Type of Station Improvement	Additional Fares (2003 Aust.Cents Per Minute)	Additional Time (Increased Onboard Time In Minutes)
Tickets	2.4¢ (0.9%)	0.16
Cleaning	1.9¢ (0.7%)	0.13
Station Building	1.4¢ (0.5%)	0.10
Staff	1.3¢ (0.5%)	0.09
Ease of Train On & Off	1.1¢ (0.4%)	0.08
Platform Surface	1.0¢ (0.4%)	0.07
Station Announcements	0.8¢ (0.3%)	0.05
Safety	0.8¢ (0.3%)	0.06
Signing	0.7¢ (0.3%)	0.05
Graffiti	0.7¢ (0.3%)	0.05
Retail	0.7¢ (0.3%)	0.05
Platform Seating	0.6¢ (0.2%)	0.04
Lifts/Escalators	0.4¢ (0.2%)	0.03
Information	0.4¢ (0.2%)	0.03
Station Lighting	0.4¢ (0.2%)	0.03
Bus	0.3¢ (0.1%)	0.02
Bike	0.3¢ (0.1%)	0.02
Toilets	0.2¢ (0.1%)	0.01
Car Park	0.2¢ (0.1%)	0.01
Car Park Drop-Off	0.2¢ (0.1%)	0.01
Platform Weather Protection	0.1¢ (0.0%)	0.01
Subway/Overbridge	0.1¢ (0.0%)	0.01
Taxi	0.1¢ (0.0%)	0.01
Telephone	0.1¢ (0.0%)	0.01

Value of improving station attribute rating from 50% to 60%. For example, this indicates that an average traveler would willingly pay an additional 2.4¢ in fares or an additional 0.16 minutes in onboard travel time for that incremental improvement.

Riders were also surveyed concerning their perceived cost of crowding. Crowded seating increases travel time costs by 17%. Thus twenty minutes of crowded seating would increase the generalised journey time by 3.4 minutes (20 x 0.17). In dollar terms, crowded seating adds 2¢ per minute if time is valued at $9.46/hr.

Table 12 **Value of On-Train Crowding** (Douglas Economics, 2006)

Level of Crowding	Crowding Cost (2003 Aust. Cents Per Minute)	Crowding Factor (Additional Time)
Crowded Seat	2.0¢	17%
Stand 10 mins or less	5.0¢	34%
Stand - 20 mins or longer	11¢	81%
Crush Stand 10 mins or less	11¢	104%
Crush Stand 20 mins or longer	17¢	152%

Crowding cost per minute in 2003 Australian cents and equivalent uncrowded minutes of travel. Based on $8.45/hr (14.08¢ per minute) value of uncrowded seating.

Crowding factors were expressed as a function of train passenger loads (passengers divided by seats), called *load factors*. Below an 80% load factor, (80 passengers per 100 seats) no crowding cost is incurred. At 80%, crowding begins to impose costs. At 100%, the additional crowding factor is 0.1, increasing onboard travel time unit costs by 10%, from 14.08¢ per minute (the uncrowded seating value of time) to 15.49¢ per minute, an increase of 1.41¢ per minute. At loads of 160%, an additional crowding factor of 0.6 minutes or 8.45¢ is added, and at 200% loading (the maximum number of passengers CityRail trains are considered to be able to carry), the additional crowding factor is 0.74 or 10.43¢ per minute. Above 200%, passengers must wait for another train.

The UK Passenger Demand Forecasting Council (PDFC) reached similar conclusions concerning passenger discomfort and delay costs (PDFC, 2002). The PDFC recommends that train load factors of 1.20 to 1.40 (120 to 140 passengers per 100 seats) result in crowding factors of 0.14 to 0.26, compared with a 0.17 crowding factor calculated for Sydney (Douglas Economics, 2006). The PDFC standing factor for Non-London flows at 0.71 is also similar to the Sydney factor of 0.81 for uncrushed standing of 20 minutes or longer. For London flows, the Sydney standing factor is less than the 1.13 factor recommended by the PDFC standing factor unless standing is in crushed conditions.

Crowding in accessways, stations and platforms makes walking and waiting time less pleasant. Table 131 indicates adjustment factors for low, medium, high and very high crowding conditions. A minute of time spent waiting under high crowding conditions is valued equal to 3.2 minutes of onboard train time whereas walking time is valued at 3.5 times higher (reflecting the additional discomfort and effort involved, but not the reduced walking speed caused by crowding). In dollar value terms, an hour of waiting under high crowding is valued at $30.33 and an hour of walking is valued at $32.65. Extreme crowding can increase costs as much as ten times.

Table 13 **Value of Platform Waiting and Access Time** (Douglas Economics, 2006)

Activity	**Crowding Level**			
	Low (<0.2 PSM)	Medium (0.2-0.5 PSM)	High (0.5-2 PSM)	Very High (>2 PSM)
Waiting vs Onboard Train Time Factor	190%	150%	320%	550%
Walking vs Onboard Train Time Factor	220%	220%	350%	620%
Waiting Value of time (2003 AU$/hr)	$18.30	$14.20	$30.30	$51.90
Walking Value of time (2003 AU$/hr)	$21.00	$21.00	$32.70	$58.90

PSM = Passengers per square metre.

Fruin developed six station environment crowding Levels-of-Service ratings, ranging from ‘A’ (no crowding) to ‘F’ (extreme crowding). Table 14 summarizes the effects of density and crowding on travel time cost values. These costs begin to increase significantly when crowding exceeds LOS D, which occurs at a density of 0.7 Passengers Per Square Meter (PSM). Crowding has an even greater impact on walking, since it both increases costs per minute and reduces walking speeds. For level of service ‘F’ characterized by the breakdown of passenger flow, the crowding cost imposes a cost 10 ten times greater than level of service A.

Table 14 **Density and Crowing Factors** (Douglas Economics, 2006)

Passengers Per Square Meter (PSM)	Level-Of-Service Ratings	Waiting	Walking
0.0	A	1.30	1.50
0.1	A	1.15	1.50
0.2	A	1.00	1.50
0.5	B	1.00	1.50
0.7	C	1.02	1.50
0.9	D	1.09	1.50
1.0	D	1.14	1.50
1.2	D	1.27	1.50
1.5	D	1.55	1.65
1.7	E	1.79	1.94
1.9	E	2.08	2.27
2.0	E	2.10	2.30
2.5	E	3.20	3.60
2.7	F	3.66	4.15
3.0	F	4.44	5.06
3.3	F	5.31	6.10
3.5	F	5.95	6.85

This table indicates the level-of-service ratings and crowding factors for various passenger densities. Crowding factors are multipliers relative to in-vehicle time cost values. This indicates, for example, that at 1.0 passengers per square meter, waiting time is 1.14 times in-vehicle travel time values, and walking time is 1.50 in-vehicle travel time.

Service quality factors can be important but difficult to quantify. For example, the perception that transit travel is unsafe or stigmatized (i.e., transit riders feel that they are treated with disrespect by operators or their peers) can significantly increase travel time unit costs and discourage transit use, although it is difficult to monetize these attributes, and results may vary depending on how questions are phrased and who is surveyed.

Stradling, et al. (2007) used travel surveys to identify transit service quality factors that affect transit ridership, and the relative value that travelers place on these factors in Edinburgh, Scotland. Respondents indicated which of 68 items were ‘Things I dislike or things that discourage me from using the bus’. Eight underlying factors are reported: feeling unsafe (e.g., ‘Drunk people put me off travelling by bus at night’); preference for walking or cycling (e.g., ‘I prefer to walk’); problems with service provision (e.g., ‘No direct route’); unwanted arousal (e.g., ‘The buses are too crowded’); preference for car use (e.g., ‘I feel more in control when I drive’); cost (e.g., ‘The fares are too expensive’); disability and discomfort (e.g., ‘There are not enough hand rails inside the bus’); and self-image (e.g., ‘Travelling by bus does not create the right impression’). The influence of age, gender, household income, car availability and frequency of bus use on factor scores was evaluated. The results can be used to help planners define the ideal urban transit journey experience, and which transit improvements can help achieve that goal.

Hensher, Stopher and Bullock (2003) used stated preference surveys to develop a transit service quality index (SQI) for use in competitive tendering of transit service (also in Hensher, 2007). This index indicates the values passengers place on various service attributes. Firms could compete on service quality as well as price in bidding for contracts, or be required to meet and improve service quality standards. For example, bidders could be required to raise the index to a higher level by improving one or more of the index attributes. The operator can determine how to achieve the target level, and take these factors into account when calculating their costs and developing bids.

To perform this survey, transit customers were asked to choose between various packages of transit service quality, for example, between a faster but crowded, or a slower but uncrowded bus; and between more comfortable but less frequent, or less comfortable but more frequent service. Statistical analysis of these results indicates the values riders place on these various factors. Table 15 lists typical transit service quality attributes for consideration. These can be modified as needed for a particular situation.

Table 15 **Typical Transit SQI Attributes** (Based on Hensher, Stopher and Bullock, 2003)

Attribute	Typical Units	Attribute	Typical Units
Reliability	- On time - 5 minutes late - 10 minutes late	*Bus stop information*	- Timetable and map. - Timetable, no map. - No timetable or map.
Frequency	- Every 15 minutes - Every 30 minutes - Every 60 minutes	*Travel Time*	- 25% faster than current - Same as now - 25% slower than current
Walking distance to the bus stop	- Minimal distance - 5 minutes more - 10 minutes more	*Bus stop facilities*	- Bus shelter with seats - Seats only - No shelter or seats at all
Waiting safety	- Very safe. - Reasonably safe. - Reasonably unsafe.	*Fares*	- 25% more than current fares - same as now - 25% less than current fares
Access to bus	-Wide entry with no steps. -Wide entry with 2 steps. -Narrow entry with 4 steps.	*Driver attitude*	- Very friendly - Friendly enough - Very unfriendly
Onboard temperature (air conditioning and heating)	-Available with no surcharge. -Available with 20% fare surcharge. - Not available.	*Ride comfort and safety*	- Very smooth ride, no jerking. - Generally smooth ride, minimal jerking. - Jerky ride.
Cleanliness of seats	- Very clean - Clean enough - Not clean enough	*Time of day service coverage*	- Peak only. - All day. - Day and night.
Payment options (variety of tickets and passes)	- Cash fare only. - Bus tickets and passes available. - Integrated and automated fares.	*Seat availability*	- Seated all the way. - Stand part of the way. - Stand all of the way.

This table illustrates typical transit service quality index factors, which are calibrated by passenger surveys.

Below are general strategies that tend to reduce perceived transit travel time unit costs, and therefore help attract discretionary travellers:

- Increase comfort, such as adequate space, comfortable temperature, cleanliness, quiet, and smooth vehicle movement.
- Improve walking and waiting conditions.
- Reduce waiting time.

- Increase travel speeds and reliability.
- Improve user information (schedule information, transit vehicle arrival time, route guidance, easy to understand announcements, etc.)
- Information to passengers of problems, delays, and expected arrival times.
- Increase perceived safety and security.
- Improve transit travel respect and prestige.

Tired, Headachy and Cranky? Blame the Commute
Long Hours On The Road Are Taking A Toll On More Than Our Cars. Women Are Especially Hard-Hit.
By Eric M. Weiss, *Washington Post*, April 16, 2007

For seven years, Gail Ennis has been spending as many as three hours a day behind the wheel of her Subaru, commuting between her law office in Washington and her home on Gibson Island, Md. What she's gotten out of the 100-mile daily round trip is sciatica — a shooting pain down one leg — and a lack of time for exercise. "It's just too much and getting worse every year," Ennis said.

Besides taking time away from family, a long commute can be harmful to your health. Researchers have found that hours spent behind the wheel raise blood pressure and cause workers to get sick and stay home more often. Commuters have lower thresholds for frustration at work, suffer more headaches and chest pains, and more often display negative moods at home in the evenings.

In cities where gruelling commutes are a way of life, drives can be as much as an hour each way on a good day — and there aren't many good days. As a consequence, more drivers will probably suffer the health effects of a commuter lifestyle, researchers and doctors said.

"You tell someone they need to exercise or go to physical therapy, but how can they? They leave at 5 a.m. and get home at 7 or 8 p.m. at night," said Robert Squillante, an orthopaedic surgeon in Fredericksburg, Va., who has treated patients for back pain and other commuting related problems. Constant road vibrations and sitting in the same position for a long time is bad for the neck and spine, he said, and puts special pressure on the bottom disc in the lower back, the one most likely to deteriorate over the years.

Raymond Novaco, a professor at UC Irvine's Institute of Transportation Studies who has researched commuting for three decades, found a correlation between traffic congestion and negative health effects such as higher blood pressure and stress. Novaco's research team measures the blood pressure and heart rate of commuters shortly after they arrive at work and again two hours later. Commuters also fill out detailed questionnaires on their home and work lives. "The longer the commute, the more illness" and more illness-related work absences occur, he said.

"If you're driving an hour-and-a-half each way twice a day for 30 years, the consequences don't catch up with you at 32, they catch up in your 50s," said Jerry Deffenbacher, a professor of psychology at Colorado State University, who uses a computerized driving simulator to test the connection between traffic congestion and anger. "Like smoking, it wouldn't be immediately obvious."

Drivers with multiple route changes are at greater risk, Novaco found after plotting the commutes of his study subjects. "It's a physical strain as well as psychological one," he said. His research showed that long solo commutes are especially tough on women, who generally "had more responsibility for getting family up and running and were significantly more likely to report being rushed to get to work," Novaco said.

Squillante said some of his surgery patients have said the best thing about a back operation was the forced hiatus from their daily commute during recovery. Patients are desperate for solutions and swear by certain types of car-seat pillows or jury-rigged lumbar supports, Squillante said. "There are people who feel they've discovered the miracle pillow," he said, though he knows of no sure-fire solution.

Valuing Transit Passenger Information Improvements

Transit user information includes bus stop signs, printed and posted schedules, conventional and automated telephone services, transit websites (including websites designed to accommodate cellular telephones and PDAs), changeable signs or monitors at stations and stops, and announcements. Some newer systems use *real time* information on the location of individual buses and trains, so signs, monitors and websites can predict when the next vehicle will arrive at a particular stop or destination.

Figure 3 **Real Time Transit Arrival Sign**

Some transit systems provide real time information predicting how soon the next vehicle arrives.

Travelers significantly value such information. Airline pilots generally provide information to passengers on predicted arrival time and any expected delay. In a study of motorists' preferences, Harder, et al (2005) found that travelers are willing to pay up to $1.00 per trip for convenient and accurate travel-time predictions, such as when traffic is delayed and alternative routes would be faster. The value of this information is higher for commuting, special event trips, and when there is heavy congestion.

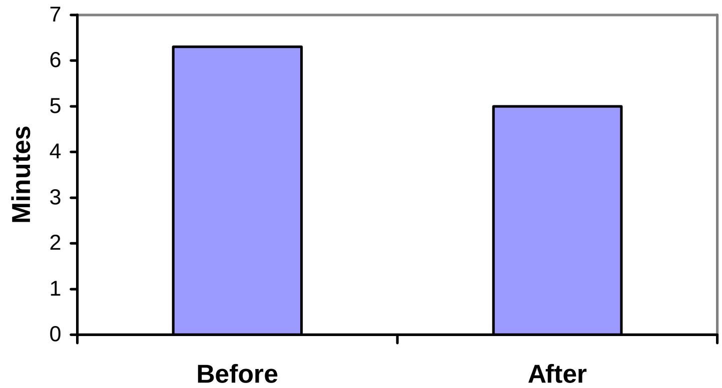
Many transit systems now offer real time information (Infopolis 2, 2000; CIVITAS, 2006). This information provides many benefits (Turnbull and Pratt, 2003). It reduces waiting stress and allows passengers to better use their time and coordinate activities. For example, if a passenger knows when the next bus will arrive they can decide whether there is sufficient time to stop at a nearby store to make a quick purchase, when they are likely to arrive at their destination, and whether they should use an alternative mode, such as calling a taxi. In situations with multi-route options, passengers use the information for enroute travel decisions. Customer response to this innovation has been positive.

- User surveys in Brussels, Belgium indicate 90% satisfaction, resulting in a 6% public transport ridership increase on the lines equipped with these displays.
- User surveys Glasgow, Scotland indicates 98% acceptance, and 46% of users say that they would be encouraged to use the bus service more often because of the system.
- Birmingham, UK residents rated real-time transit user information the single best way to encourage shifts from driving to public transit, more important than improved bus shelters or low floor vehicles. Ridership increased 30% after introduction of various service improvements on a demonstration route, including real time information displays.
- A pilot of countdown information displays at public transportation stations indicates that:
  - Waiting is more acceptable (89%).
  - Time seemed to pass more quickly when passengers knew their wait duration (83%).
  - Passengers perceive a shorter waiting time (65% felt this was so).
  - The service is perceived as more reliable.
  - Of those passengers travelling, waiting at night is perceived as safer.
  - General feelings improve towards bus travel (68%).
  - About 70% of passengers refer to the display when they arrive at a stop, about 90% look at the sign while they wait, and about 60% look at the sign at least once a minute.
  - Passengers approve of the 3 essential pieces of information provided (route number, destination and wait time).
  - There is strong overall customer support for the system.
  - Countdown has been found to generate a minimum of 1.5% new revenue.

- A study of the Timechecker real-time transit information system in Liverpool found:
  - 68% of passengers use Timechecker consistently.
  - The system claims a 90% accuracy.
  - 85% of users believe that the use of Timechecker makes waiting more acceptable.
  - 87% feel that Timechecker gives a feeling of reassurance.
  - 92% of respondents perceived real-time information to be 'accurate' or 'very accurate'.
  - 89% of respondents wanted to see electronic displays provided at all bus stops.
  - 73% of respondents found that the availability of real-time information enhanced their feeling of personal security when waiting for a bus after dark.
  - 71.5% of users considered service to improve when electronic displays were installed.
  - 57% thought that real-time displays decreased perceived wait times at bus stops.

Dziekan and Vermeulen (2006) evaluated the effects real-time information has on tram passenger perceived wait time, feelings of security and use in The Hague, the Netherlands. One month before, and 3 months and 16 months after implementation, the same sample of travelers completed a questionnaire. They found that perceived wait time decreased by 20%. No effects on perceived security and ease of use were found.

Figure 4 **Change in Perceived Wait Due To Real-Time Information System**
(Dziekan and Vermeulen, 2006)



Introduction of real time tram arrival information displays reduced perceived wait time an average of about 20% at tram stops in The Hague.

The majority (79%) of respondents in the after situation stated that they had looked at the displays at the stop. More than half of the people who looked at the displays evaluated the information shown as reliable, although 35% considered the information unreliable; they believed that the tram often arrived later or earlier than displayed. Using standard transit ridership price elasticity values the authors estimate that the provision of real time information at all area tram stations would theoretically increase total transit ridership by about 2.3%, and the project would be cost effective.

In 1984, signs providing real-time information on the status of London Underground service were tested at several platforms on the Northern Line (Turnbull and Pratt, 2003). The signs gave order of arrival information for the next three trains, route and terminal destination as needed, and the number of minutes before expected arrival. The previous signs had supplied the first two of these elements of information, but not predicted arrival time. Passenger response to the system was very favorable: 95% of respondents indicated it was useful and 65% reported it helped reduce uncertainty in waiting for a train. The information was used by 12% to select what train to take, with passengers reporting that they employed the time until arrival in selecting transfer points or choosing to wait for a close behind train that might be less crowded.

Passenger surveys indicated a small, but significant, stress reduction in response to the information system, especially for female riders. Passengers both with and without access to the information tended to overestimate actual wait times for trains, but with the information the over-estimation was reduced by 0.68 minutes on average. A cost-benefit analysis was prepared by assigning a monetary value to the wait time overestimation (to estimate social benefits) and by further applying a price elasticity to estimate ridership and revenue generation (to estimate financial benefits). Investment in the real-time information system was thus estimated to provide a simple first year social rate of return of 83%, and a first year financial rate of return of 16%.

London Transport's Countdown project involves the provision of real-time information at major bus stops. The Countdown signs list the order in which buses will reach the stop, their destinations, and the number of minutes to arrival. Information on traffic and safety conditions can also be displayed. Visual observations indicate that 90% of passengers at the equipped stops looked at the sign at least once during their wait time. Interviews showed strong support for the system, with 90% agreeing with the statement "passengers deserve Countdown." Average perceived wait time declined from 11.9 minutes before the trial to 8.6 minutes with the Countdown system, although there was no actual change in bus frequencies. 83% of respondents agreed that "if you know the bus is coming, time seems to pass more quickly" and 89% agreed that the signs made the wait time more acceptable. Respondents expressed a slight willingness to pay higher fares for the system.

A real-time bus information system was tested at the Heworth rail/bus interchange in Tyne and Wear, England, in the mid 1980s. Surveys indicate that 75% of respondents were aware of the system, 35% made use of it to plan their journeys on a more informed basis, 25% believed it led them to wait for shorter periods of time, 48% thought the information was reassuring and relieved anxiety, 56% considered the information wholly accurate, 39% indicated they would let a crowded bus go by if the display showed another would be arriving shortly, and 11% claimed to use the bus more often as a direct result of the system. A simple cost-benefit assessment indicated that a hypothetical 2% increase in passengers and fare revenues would produce a 10% annual return on the capital investment and repay operating costs.

Summertime parking and traffic problems at the resort town of Rehoboth Beach, Delaware, are addressed with seasonal Beach Bus service. Electronic signs at bus stops provide scrolling text messages and bus arrival time predictions. In the season following installation, "ridership increased over 13% from the year before. No additional service hours or miles were operated…"

The San Francisco Regional Metropolitan Transportation Commission has developed a transit connectivity plan designed to improve service quality and ridership by improving the following features (MTC, 2006):

- *Information and wayfinding.* This includes regional transit information, improved maps in and around stations, and accurate real-time bus and train arrival information (including dynamic signs at stations, websites and telephone system).
- *Schedule coordination.* Improved schedule coordination between different modes and lines, including timed-transfer and pulsed networks.
- *Fare integration.* Integrated fares, so one type of pass, rate structure and transfer policy applies to all public transportation services throughout a region.
- *Last-mile improvements.* This refers to the ease of access to transit stops and hubs, including shuttle services, bicycle and pedestrian access, and parking for automobiles and bicycles.
- *Hub (transit stop and station) amenities.* These include reduction of walking distances (between train and bus platforms and other services), enhanced comfort, weather protection, restrooms, improved security, and improved cleanliness.

Travel Impacts

There are many examples of specific service improvements that increase transit ridership and reduce automobile travel (Evans, 2004; Wall and McDonald, 2007). Discretionary transit users tend to be particularly sensitive to comfort and convenience improvements (Kittleson & Associates, 1999; Phillips, Karachepone and Landis, 2001, Litman, 2004; DfT, 2006).

Transport modelers use *generalized cost* (total monetary and time costs) coefficients to predict how changes in vehicle operating costs, fares and travel speeds affect travel behavior. TRL (2004) calculates generalized cost elasticities of –0.4 to –1.7 for urban bus transit, -1.85 for London underground, and -0.6 to –2.0 for rail transport. Dowling Associates (2005) estimate that in Portland, Oregon the elasticity of transit travel with respect to transit travel time is -0.129, and the cross elasticity with car travel is 0.036, meaning that each 10% reduction in transit travel time increases transit ridership by 1.29% and reduces automobile travel by 0.36%. Additional research is needed to better calibrate the impacts of transit service quality improvements on transit ridership and automobile travel in specific circumstances. Virtual Learning Arcade (IFS, 2001) is an example of an easy-to-use transportation model designed to predict the effects that transit service improvements have on transit ridership, automobile travel and traffic congestion.

A combination of factors often influence a particular travel decision, so a set of small changes (marginal increases in speed, comfort, reliability and prestige) may cause significant changes, although it can be difficult to isolate the effect of each factor. It may take several years for such changes to achieve their full ridership impacts.

Competitive Quality Transit Service
What sort of transit service would be competitive with automobile travel in terms of comfort and convenience? Luxury services are available with:

- High quality coaches with leather bucket seats and plenty of leg room.
- Worktables at each seat (so passengers can use computers or write during trips).
- Complementary snacks and drinks.
- Magazines, newspaper, television and movies.
- Reserved seating.
- Washrooms.
- Onboard personal attendants.

Because labor (drivers, cleaners and mechanics) is the main cost of transit service, upgrading rider comfort and convenience often has modest incremental costs. Such improvements can be a cost effective way to attract new riders.

Hampton Luxury Liner
(www.hamptonluxuryliner.com)

Phoenix Transit RAPID commuter bus
(www.phoenix.gov/PUBLICTRANSIT/rapid.html)

Recommended Values

This research indicates that if transit service is convenient and comfortable, unit transit travel costs are lower than for driving, since transit travelers experience less stress and can use their time to rest or work. Under such conditions, transit travel costs are estimated to average 25-35% of prevailing wages, compared with 35-50% for drivers. However, disamenities such as crowding, noise and dirt significantly increase travel time unit costs. For example, transit travel time can be valued at about 25% of wage rates when sitting, 50% of wages when standing, 100% of wages in a crowded bus or train, and 175% of wages when waiting under unpleasant conditions, such as an unsheltered bus stop adjacent to a busy roadway.

Increased transit travel speeds can be valued based on average time costs, but improvements in reliability should be valued at a higher rate, reflecting the higher unit costs of unexpected delay. Each minute of delay beyond the published schedule should be valued at 3-5 times the standard in-vehicle travel time (perhaps excepting a two or three minute grace period considered to be a "normal" delay).

The elasticity of transit use with respect to service frequency (called a *headway elasticity*) averages about 0.5, meaning that each 1% increase in transit service frequency increases ridership by 0.5%. This is consistent with case studies described earlier which indicate that installation of real-time information signs at transit stations reduced perceived wait time approximately 20% and increased transit ridership 6-13%, although these were often implemented with other service improvements, so other factors may have been involved.

Time spent walking to and waiting for transit vehicles generally has unit costs averaging two to five times higher than in-vehicle time, or 70% to 175% of prevailing wages. Improved walking and waiting conditions, such as transit area pedestrian improvements, and improved transit stop area cleanliness and security, reduces these relatively high unit costs, such as from 175% down to 70% of wage rates (from the higher to the lower end of the typical estimated cost range of these activities) or even lower, to 50% of wage rates if conditions are particularly pleasant, such as at an attractive transit station with real time information, shops and services, and other convenience features. Although the value of travel time is generally lower for children than for adults, reflecting the lower opportunity cost of their time, discomfort should be valued at the same rate as adults or even higher. For example, under poor waiting conditions children's time should probably be valued at 175% of wage rates, or even greater, the same value applied to adult travelers under the same conditions, reflecting adults concern for their children's comfort and security.

Transfers are estimated to impose penalties equivalent to 5-15 minutes of in-vehicle time. This implies, for example, that a typical passenger would choose a 40-minute transit trip over a 30-minute trip that requires a transfer. This premium reflects the physical and mental effort involved, plus the relative discomfort, insecurity and uncertainty that transit riders experience at typical transit stops and stations, and so may be reduced with better user information and more comfortable waiting conditions.

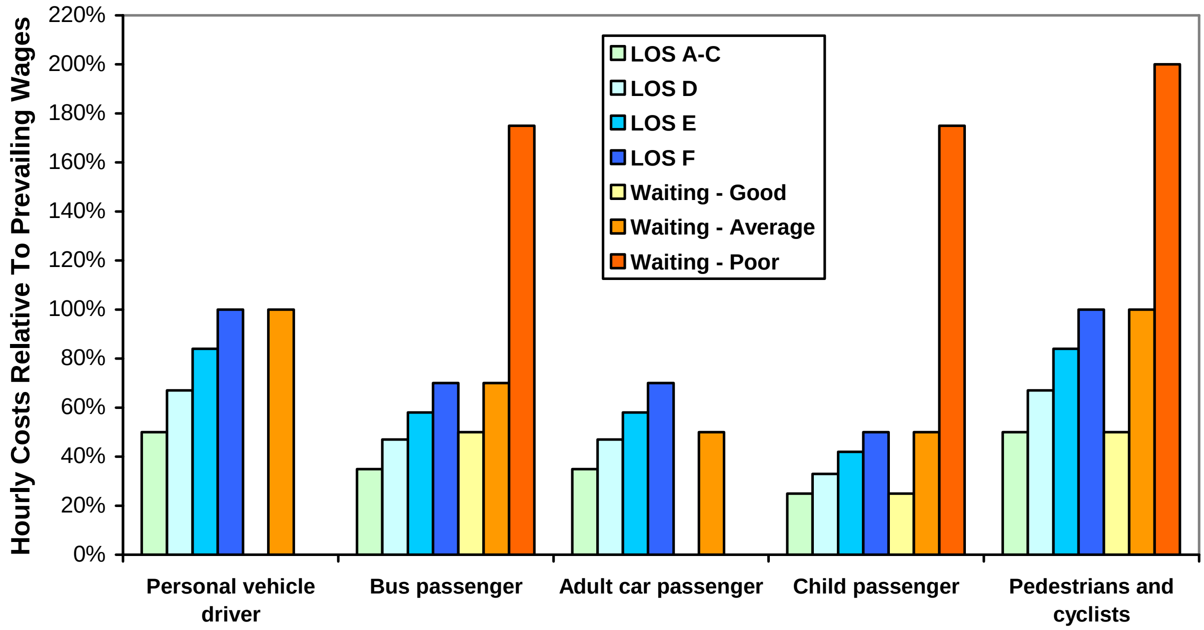
Table 16 **Recommended Travel Time Values** (Relative To Prevailing Wages)

Category	LOS A-C	LOS D	LOS E	LOS F	Waiting		
					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%		70%	
Adult transit passenger – seated	35%	47%	58%	70%	35%	50%	125%
Adult transit passenger – 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 recommended travel time values, based on Waters (1992) with additional values for transit passenger waiting, walking and transfers reflecting the quality of conditions.

Table 16 and Figure 5 illustrate travel time unit cost values, based on Waters (1992) with additional factors described in this report. These costs increase with congestion and discomfort.

Figure 5 **Summary Values**



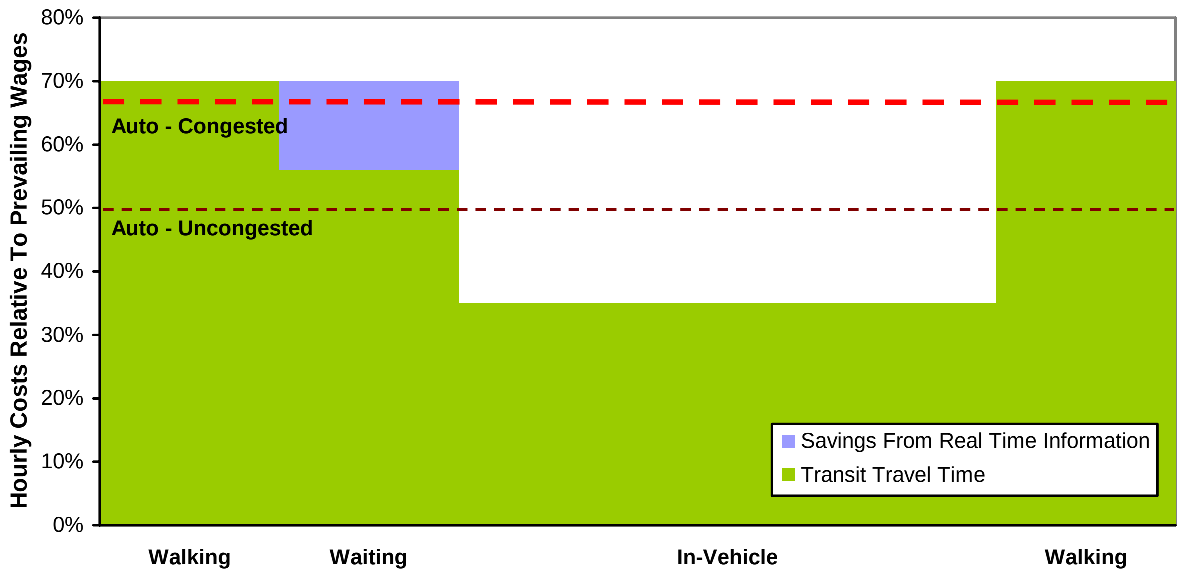
This figure compares personal travel time unit cost values under various conditions. Research in this report suggests that under favourable conditions (comfortable, safe, predictable and prestigious) transit travel unit time costs are relatively low, but under current average conditions unit costs are often comparable to automobile travel, and under very unfavourable (crowded, dirty, frightening) transit and walking unit travel time costs exceed virtually all other travel time values.

This analysis requires *Level-Of-Service* (LOS) ratings for each mode. LOS standards for automobile travel are widely used by traffic engineers, and are now available for transit and nomotorized modes, as described later in this report. Additional research is needed to verify and calibrate these values to specific situations. For example, pedestrian LOS standards may differ between university and retirement communities due to differences in fitness and therefore average walking speeds and distances.

Real-time transit vehicle arrival signs are found to reduce perceived wait times by approximately 20%, and reduce unit costs of the time spent waiting because passengers experience less stress and are able to better organize their trips. A 20% savings therefore represents the lower bound value of cost savings from such systems, provided that the information is easy to access and reliable.

Waiting represents a significant portion of total travel time for a typical transit trip, and because its unit costs are relatively high, it represents an even longer portion of total travel time costs. For example, a typical urban transit trip involves five minutes of walking to the bus stop, five minutes of waiting, fifteen minutes of in-vehicle travel, and five minutes walking to the destination. Figure 6 illustrates unit time costs for various components of this trip. In this case, waiting represents five minutes of the thirty minute trip (17%), but because time spent walking and waiting have twice the unit cost as in-vehicle time, this represents 22% of time costs. The blue box illustrates the time cost savings that result if waiting time is reduced by 20%. The dashed red lines indicate automobile travel time costs under uncongested and congested conditions.

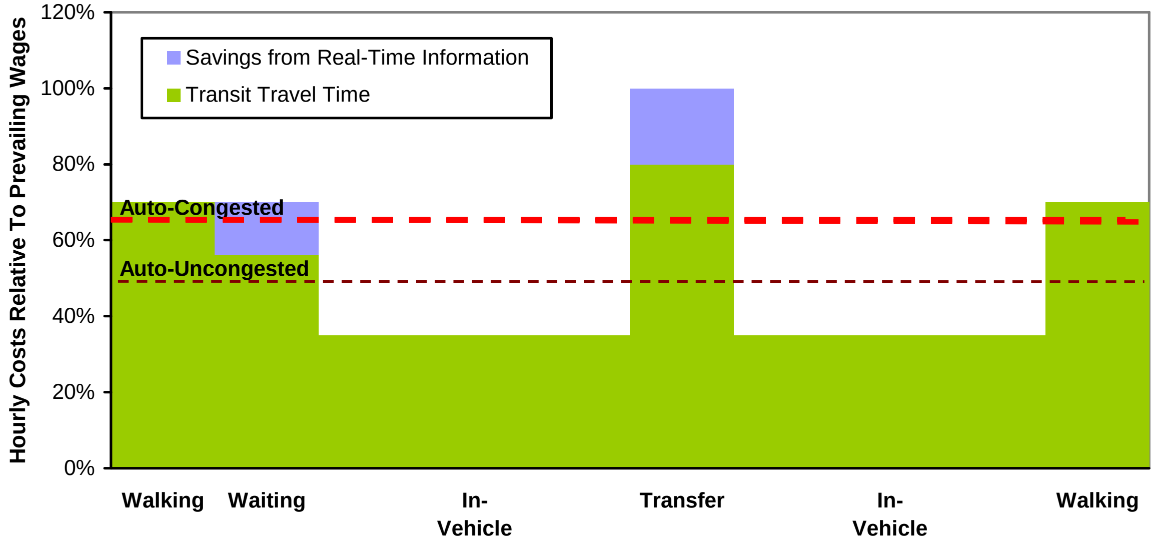
Figure 6 **Time Values During A Typical Transit Trip With Transfer**



This figure illustrates estimated travel time costs of various components of a typical transit trip. The blue area indicates cost savings from real-time information signs. The heavy dashed line indicates the costs of driving under moderate (LOS D) congested conditions (67% of prevailing wages) and the light dashed red line indicates the cost of driving under uncongested conditions (50% of prevailing wages).

Benefits are greater for trips that include a transfer, as illustrated in Figure 7, or for routes that have larger headways which result in longer waits.

Figure 7 **Time Values During A Typical Transit Trip With Transfer**



This figure illustrates estimated travel time costs of a trip involving a transfer. The blue area indicates cost savings from real-time information signs. The heavy dashed line indicates the costs of driving under congested conditions and the light dashed red line indicates the cost of driving under uncongested conditions.

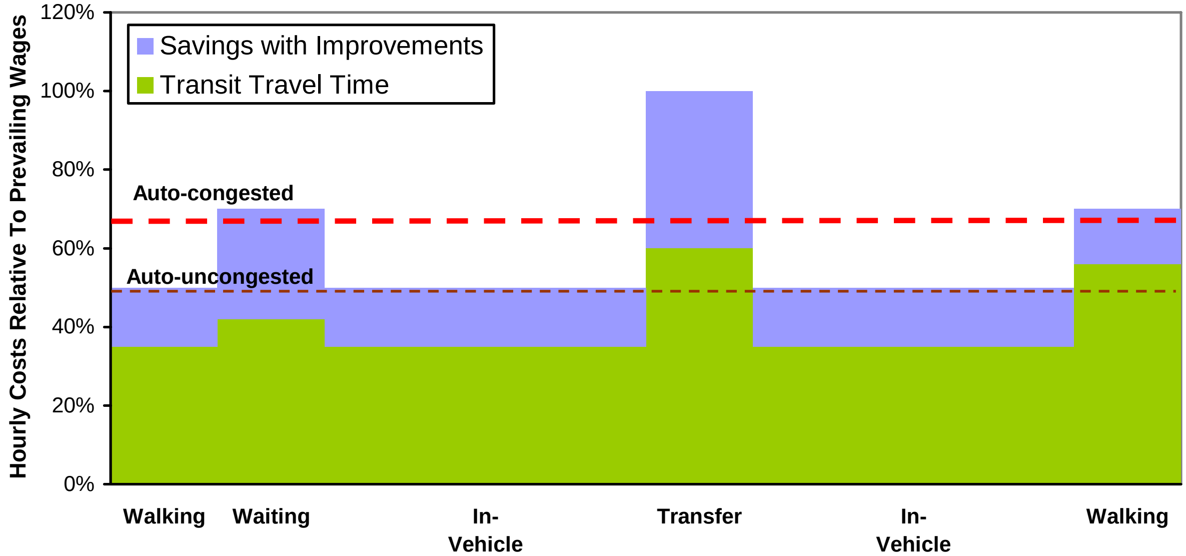
Table 17 and Figure 8 illustrate how various incremental convenience and comfort improvements to walking and waiting conditions can reduce travel time costs without increasing travel speeds. In some cases such improvements can reduce total trip travel time costs below that of driving, causing mode shifts.

Table 17 **Travel Time Costs Before And After Improvements** (Time Values measured relative to $15/hour average wages)

	Current			After Improvements			Auto Trip		
	Minutes	Wage Rates	Value	Minutes	Wage Rates	Value	Minutes	Wage Rates	Value
Walk To Stop	5	70%	$0.88	5	50%	$0.63	2	50%	$0.25
Wait At Stop	5	70%	$0.88	5	50%	$0.63	0	50%	$0.00
In-Vehicle	15	35%	$1.31	15	35%	$1.31	30	70%	$5.25
Transfer Penalty	10	35%	$0.88	5	35%	$0.44	0	70%	$0.00
Transfer Wait	5	70%	$0.88	5	50%	$0.63	0	50%	$0.00
In-Vehicle	15	35%	$1.31	15	35%	$1.31	0	35%	$0.00
Walk To Destination	5	70%	$0.88	5	50%	$0.63	3	50%	$0.38
Totals	*50*		*$7.00*	*50*		*$5.56*	*35*		*$5.88*

This table illustrates how walking and waiting condition improvements can reduce transit trip travel time costs from above to below that of driving, even if driving takes fewer minutes. Improvements that increase transit travel speed and reliability provide additional transit time cost savings.

Figure 8 Time Cost Savings Due To Various Improvements



The blue area indicates estimated travel time cost savings from a combination of incremental walking, waiting and travel improvements. The dashed lines indicate automobile travel time costs under congested and uncongested conditions.

Table 18 describes how to value the travel time savings of various types of transit service improvements. Such improvements can be particularly effective at shifting travel from automobile to transit if implemented in conjunction with other incentives such as commute trip reduction programs, parking cash-out and marketing programs (VTPI, 2006).

Table 18 Valuing Service Improvements

Improvement	Methodology
Faster travel	Travel time savings.
Reduced crowding	Reduce time unit costs from high to average.
More comfortable vehicles	Reduce in-vehicle time unit costs.
Improved waiting conditions	Reduce the high time unit costs typically assigned to waiting.
Improved walking conditions	Reduce the high time unit costs typically assigned to walking.
Improved coverage area	Reduced walking travel time.
Real time arrival information	Reduce waiting time unit costs.
Faster vehicle loading	Reduce wait and travel time costs.
More frequent service	Reduce wait time costs.
Reduced transfers	Eliminate transfer premium.
Increased travel reliability	Reduce the high time unit costs assigned unpredictable delays.
Improved user information	Surveys to determine their value and impacts on ridership.
Improved status	Surveys to determine their value and impacts on ridership.

This table summarizes methods for valuing various service quality improvements. ("Travel time" is measured in minutes and hours. "Travel time unit costs" are measured in cents per minute or dollars per hour.)

Multi-Modal Level-of-Service

The analysis methods described in this report rely on Level-of-Service (LOS) ratings to adjust travel time values to specific conditions. Roadway LOS ratings, which primarily reflect traffic congestion and delay, are widely used for evaluating automobile travel conditions. In recent years similar rating systems have been developed for walking, cycling and public transit service (Phillips, Karachepone and Landis, 2001; Kittleson & Associates, 2003a and 2003b; Litman, 2005; "Nonmotorized Evaluation," VTPI, 2006). Table 19 lists some factors that may be quantified for calculating these ratings. The Florida Department of Transportation (FDOT, 2007) developed the LOSPLAN computer program to automate these calculations.

Table 19 **Level-of-Service Factors** (Phillips, Karachepone and Landis, 2001)

Transit	Pedestrian
Availability (Daily hours of service).	Existence of sidewalks/paths.
Service frequency (how many trips per hour or day).	Separation between sidewalks/paths and vehicle traffic.
Speed (particularly compared with automobile travel).	Existence of crosswalks and crossing aids.
Reliability (how well service follows published schedules)	Shortness of crossing distance.
Comfort (whether passengers have a seat and adequate space).	Adjacent motor vehicle traffic volumes and speeds.
Security (feelings of safety).	Sidewalk/path functional width (without obstacles).
Affordability (user costs relative to their income and other travel options).	Sidewalk/path pavement condition.
Information (ease of obtaining information).	Steepness.
Cleanliness (including minimal mess, dirt, unpleasant smells, and graffiti and vandalism).	Security (feelings of safety).
Aesthetics (appearance of transit vehicles, stations, waiting areas and documents).	Shade and weather protection.
	Lighting quality.
	Seats/benches in waiting areas.
	Aesthetics (appearance of walking areas).

This table illustrates factors that can be included in transit and pedestrian Level-of-Service ratings used to adjust travel time values.

Because walking, cycling and public transit LOS standards are relatively new, they may require adjustment and calibration to better reflect specific situations. In particular, it may be appropriate to add additional comfort, convenience and reliability factors that were either not included or which reflect specific geographic conditions or demographic groups. For example, additional pedestrian LOS factors might be needed for areas that are very hilly, experience cold and frosty conditions, or to reflect the needs of young, old or disabled populations.

Illustrative Example

An urban travel corridor averages 20,000 automobile and 4,000 transit peak-period trips per day. Planners compare the benefits of highway expansion and a new transit lane. Both projects have annualized costs of $5 million, and both would save 12 minutes per affected trip. A third alternative, with $1 million annualized costs, improves transit service quality using a combination of these strategies (Wright, 2006; VTPI, 2006):

- Improve vehicle comfort and cleanliness.
- Increase service frequency to reduce wait times and vehicle crowding.
- Improve wait areas and nearby walking conditions, including development of transit stations and shelters, and transit-oriented development.
- Improve boarding ease and speed, with pre-paid fare collection, wider doors and more convenient loading areas.
- Increase fare options, discounts and passes purchased through work, school and communities, and for shoppers (similar to merchant-paid parking).
- Integrate fare systems, allowing free or discounted transfers between routes and modes.
- Improve user information, customer service, and marketing programs.
- Parking pricing, parking cash-out, commute trip reduction programs, and similar programs that promote use of alternative modes.
- Modal integration, with transit service coordinated with walking and cycling facilities, taxi services, intercity bus, and delivery services (to facilitate shopping by transit).
- Improve accommodation of people with special needs, including people with physical disabilities, poor vision and difficulty reading signs.
- Improved security for transit users and pedestrians.

Table 20 indicates a conventional evaluation of these projects, with all travel time valued at $5 per hour. In this case, the highway expansion project has a positive benefit/cost ratio, but the transit projects do not, since fewer travelers benefit, and transit service improvements provide no monetized benefit (although some traffic models recognize benefits if transit improvements cause mode shifts that reduce congestion delays).

Table 20 **Conventional Project Evaluation**

	Units	Highway Expansion	Transit Lane	Transit Service Improvement
Project Cost	Annual	$5,000,000	$5,000,000	$1,000,000
Time Value	$/hr	$5	$5	$0
Savings Per Trip	Hrs	0.20	0.20	NA
Trips	Trips/Day	20,000	4,000	4,000
Total Benefits	Annual	$6,000,000	$1,200,000	$0
Benefit/Cost		*1.2*	*0.24*	*0*

Conventional analysis applies one value to all travel time and so transit service improvement benefits.

More comprehensive analysis incorporates several additional factors, including travel time cost savings from improved transit service quality. For this analysis, comfortable in-vehicle time is valued at $4 per hour, crowded in-vehicle time at $6 per hour, and uncomfortable wait time at $10 per hour. Increasing service frequency therefore reduces in-vehicle time costs from $6 to $4 per hour, and improving waiting conditions reduces waiting time costs from $10 to $6 per hour.

The transit lane and service improvements are each projected to attract 2,000 additional daily transit riders, providing direct user benefits (valued using the "rule-of-half"; half the value of those travelers' monetized travel time savings, as described in Litman, 2001); additional fare revenue; and by reducing automobile trips, reduces roadway congestion, road and parking costs, and environmental impacts. Conversely, expanding highways tends to induce more vehicle travel, which increases downstream congestion, road and parking costs, and environmental impacts (Litman, 2001). Incorporating these factors changes project evaluation results: it reduces the value of highway expansion and raises the value of transit improvements, particularly transit service quality improvements.

Table 21 **More Comprehensive Transit Travel Time Savings Analysis**

	Units	Highway Expansion	Transit Lane	Transit Service Improvement
Project Cost	Annual	$5,000,000	$5,000,000	$1,000,000
Time Value	$/hr	$5	$5	$4/$6/$10*
Savings Per Trip	Hrs	0.20	0.20	NA
Trips	Trips/Day	22,000	6,000	6,000
Travel Time Savings	Annual	$6,600,000	$1,800,000	$1,44,000
Induced Travel Benefits	Annual	$300,000	$300,000	$300,000
Increased Fare Revenue	Annual	NA	$1,200,000	$1,200,000
Downstream Congestion	Annual	-$500,000	$500,000	$500,000
Road/Parking Cost Savings	Annual	-$1,800,000	$1,800,000	$1,800,000
Environmental Benefits	Annual	-$600,000	$600,000	$600,000
Total Benefits	Annual	$4,000,000	$6,200,000	$5,840,000
Benefit/Cost		*0.8*	*1.2*	*5.8*

This table indicates projected benefits using more comprehensive analysis.
(uncrowded in-vehicle/crowded in-vehicle/waiting)*

In this example, the comprehensive analysis indicates that both the transit lane and transit service improvement projects are cost effective (positive benefit/cost ratios), while the highway expansion is not. This illustrates how conventional analysis favors highway expansion to increase traffic speeds, while more comprehensive analysis favors alternative modes to improve comfort and convenience.

Even this analysis fails to value all transit service improvement benefits. For example, it does not account for land use benefits if transit service improvements (including improved walking conditions) lead to more compact and accessible development patterns, economies of scale from increased transit ridership, and health benefits from increased walking associated with transit travel.

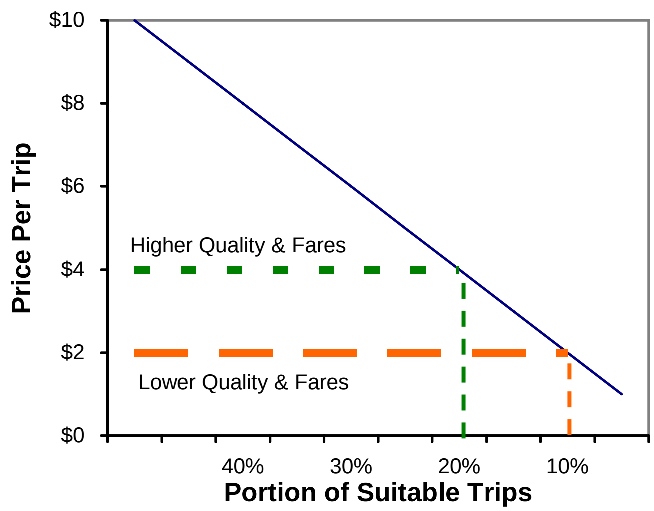
Consumer Impacts

Current policies supply public transport with low service quality and fares in order to provide basic mobility for physically, economically or socially disadvantaged people. Because most public transit service relies on direct public financial subsidies (unlike automobile travel, which relies on more indirect subsidies, such as the value of public lands devoted to road rights-of-way, free parking provided by governments and businesses, and external accident risk and pollution costs), public officials are reluctant to fund transit service improvements that may be considered excessive and wasteful.

For these reasons, most current public transit services only satisfy the lower end of the demand curve, that is, consumers who prefer cheaper service with minimal amenities. This reduces consumer surplus for travelers willing to pay more for higher quality transit service, and by stimulating more automobile travel it increases external costs. For example, market studies indicate that a portion of current automobile commuters will shift to transit if the service is comfortable and convenient (Project for Public Spaces and Multisystems, 1999; TranSystems Corporation, 2005), and are willing to pay higher fares, but these travelers' needs are generally unmet, so they continue to drive, increasing traffic congestion, parking costs, accident risk and pollution emissions.

On corridors with lower fares and service quality, transit is used almost entirely by people who, for various reasons, cannot use an automobile, typically representing 5-10% of potential travelers (people who could use transit if they wanted). However, on corridors with higher service quality (comfortable vehicles, frequent service, comfortable stations, more prestige, etc.), 20-40% of travelers will typically choose transit, even if their fares are higher (for example, for coach bus or commuter rail service).

Figure 9 **Transit Service Quality Demand Curve**



With lower fares and service quality, typically 5-10% of potential users choose transit. With higher quality service, 20-40% of travelers will ride transit.

Additional Research

This study identifies several types of research needed to improve our ability to quantify and monetize transit service quality factors and incorporate them into transit evaluation.

1. Survey transit operators who have implemented various service quality improvements, such as reduced crowding and real-time information signs, to better understand their experience. In particular this research should attempt to identify:
    - The impacts of these improvements on patron satisfaction and transit ridership.
    - How individual improvements are coordinated to maximize their effectiveness.
    - How to avoid potential pitfalls.

2. Use the unit cost values in this report to estimate the travel time costs of various types of trips and the cost savings from various types of transit service improvements. For example, calculate the travel time costs of a typical suburb to downtown commute, and the reduction in travel time costs from increased transit speeds and improved waiting conditions. Consult planners, transit users and non-users to determine whether the results make sense, based on their perspectives and experience.

3. Perform detailed studies to evaluate the value that travelers place on various service quality attributes, similar to the studies performed by Douglas Economics (2004 and 2006). Such surveys should include both current transit riders and people who currently drive but may be amenable to using transit.

4. Perform detailed before-and-after studies of any transit service improvements. For example, before implementing service improvements collect appropriate baseline data through surveys and traffic counts as a basis for evaluating how they affect patron satisfaction, travel and operations.

5. Develop Level of Service standards for walking, waiting conditions and transit travel that can be used to adjust unit travel time values in order to evaluate specific improvements and changes. These can be based on existing multi-modal LOS rating systems, with testing and calibration to quantify and monetize travel time costs.

6. Develop demand models which can predict how changes in transit service quality and price affect transit ridership and motor vehicle travel. Make these models available to planners and the general public (for example, posted on website).

Conclusions

There are many possible ways to improve transit service quality, including reduced crowding, increased service frequency, nicer waiting areas and better user information. Because discretionary passengers (people who have the option of driving) tend to be particularly sensitive to service quality, these strategies often increase transit ridership and reduce automobile traffic. Although few motorists want to give up driving altogether, many are willing to drive less and rely more on alternative modes, provided that those alternatives are comfortable, convenient and reliable. Improving transit service quality can therefore provide many benefits, as described in the box below.

Transit Service Quality Improvement Benefits (Litman, 2005)

1. Benefits existing transit passengers (who would use transit even without the improvements).
2. Benefits new transit passengers (who would only use transit if service is improved).
3. Benefits society by reducing traffic problems (congestion,[1] roadway and parking costs, consumer costs, accidents, energy consumption and pollution emissions).
4. Benefits from economies of scale (increased ridership can create a positive feedback cycle of improved service, increased public support, more transit-oriented land use, and further ridership increases).
5. Benefits transit agencies by increasing fare revenue.

Current transport evaluation methods tend to focus on quantitative factors such as speed and price, and undervalue qualitative factors such as comfort, convenience and reliability. This skews planning and investment decisions in the following ways:

- Cost-effective transit improvement strategies are overlooked and undervalued, resulting in underinvestment in transit service quality improvements, making transit less attractive relative to automobile travel.
- Automobile improvements are favored over transit improvements, contributing to a cycle of increased automobile dependency, reduced transit ridership and revenue, land use sprawl, stigmatization of transit, and reduced public support for transit improvements.
- Opportunities for modal integration are overlooked, since many transit quality improvements involve improving walking and cycling conditions, or improving connections with other modes.

[1] Urban traffic congestion tends to maintain equilibrium. If congestion increases, people change route, destination, travel time and mode to avoid delay, and if it declines they take additional peak-period trips. Reducing the point of equilibrium is the only way to reduce long-term congestion. The quality of travel alternatives affects the level of congestion equilibrium: If alternatives are inferior, few motorists will shift mode and the point of equilibrium will be high (slow traffic). If alternatives are attractive, motorists are more likely to shift modes, reducing the equilibrium (speeding traffic). Improving travel options can therefore increase travel speeds for both those who shift modes and those who continue to drive. For more discussion see Litman, 2006.

Techniques described in this report allow service quality to be incorporated into transport planning by adjusting travel time values to reflect factors such as comfort, convenience and reliability. This means, for example, that a quality improvement that reduces travel time unit costs (cents per minute or dollars per hour) by 20% provides benefits equivalent to an operational improvement that reduces travel time (minutes or hours) by 20%. The values recommended in this report are based on extensive research from various sources. They can be used as defaults, although they should be calibrated for specific conditions.

This analysis indicates that high quality transit service unit time costs are lower than driving. In other words, if service is comfortable and convenient, many people will choose transit rather than driving for some trips, even if it takes somewhat more time, since transit travel is less stressful and passengers can rest or work while traveling. However, transit is often uncomfortable, inconvenient and unreliable, resulting in unit travel time costs higher than driving, which dissuades people from using transit.

In a modern, affluent society consumers are accustomed to high quality goods and services. Most travelers place a high value on comfort, convenience and reliability. Motorists are able to express these values by paying extra for more luxurious vehicles, more convenient parking, and sometimes higher quality toll roads. In contrast, individual transit passengers are generally unable to purchase higher quality service. In theory it is possible to offer various classes of public transit service, ranging from inexpensive, basic service to premium priced, luxury service, as is common for some other modes such as air and rail, but in practice there is seldom sufficient demand or political willingness. Since transit service is subsidized and funds limited, and public officials may be criticized if their expenditures appear wasteful, transit agencies tend to provide basic service with minimal amenities. As a result, transit does not satisfy travelers who willing to pay extra for higher service quality – they must shift to driving. Failing to satisfy such demand is a market distortion which reduces economic efficiency and consumer welfare. Ultimately everybody loses, since consumer demand is unmet, transit ridership declines, transit becomes stigmatized, and traffic problems increase.

This is actually good news because it indicates that there are many cost-effective ways to improve transit service quality and increase ridership that tended to be overlooked. Many transit comfort and convenience improvements are relatively inexpensive and provide additional benefits such as improved walking conditions, improving mobility for non-drivers, and support for more compact, smart growth development.

With better evaluation techniques planners can identify policies and programs that more effectively respond to consumer needs and preferences, including transit service improvements.

Acknowledgements

This research was supported by TransLink, the Vancouver, BC regional transport agency.

References

Booz Allen Hamilton (2003), *ACT Transport Demand Elasticities Study*, Canberra Department of Urban Services (www.actpla.act.gov.au/plandev/transport/ACTElasticityStudy_FinalReport.pdf).

David Brownstone and Kenneth Small (2005), "Valuing Time And Reliability: Assessing The Evidence From Road Pricing Demonstrations," *Transport. Research A*, Vol. 39 (www.elsevier.com), May, pp. 279-293.

Karin Brundell-Freij (2006), *User Benefits and Time in Road Investment and Maintenance: The Role of Speed Choice and Driving Comfort*, TRB Annual Meeting, TRB (www.trb.org); at www.mdt.mt.gov/research/docs/trb_cd/Files/06-0158.pdf.

Cambridge Systematics (2005), *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation*, FHWA Office of Operations (www.ops.fhwa.dot.gov); at www.ops.fhwa.dot.gov/congestion_report/index.htm.

CIVITAS (2006), *Provision of Real Time Passenger Information*, CIty-VITAlity-Sustainability (www.civitas-initiative.org/measure_sheet.phtml?lan=en&id=271).

Harry Cohan and Frank Southworth (1999), "On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways," *Journal of Transportation and Statistics* (www.gcu.pdx.edu/download/2cohen.pdf), Dec. 1999, pp. 123-131.

L.F. Cunningham, C. Young and M. Lee (1997), "Developing Customer-based Measures of Overall Transportation Service Quality in Colorado: Quantitative and Qualitative Approaches," *Journal of Public Transportation* (www.nctr.usf.edu/journal.htm), Vol. 1 No. 4, pp. 1-22.

DFT (2006), *Transport Analysis Guidance*, Integrated Transport Economics and Appraisal, Department for Transport (www.webtag.org.uk/index.htm).

Douglas Economics (2004), *Value Of Rail Travel Time*, RailCorp (www.railcorp.info); contact George.Karpouzis@railcorp.nsw.gov.au to request document.

Douglas Economics (2006), *Value and Demand Effect of Rail Service Attributes*, RailCorp (www.railcorp.info); contact George.Karpouzis@railcorp.nsw.gov.au to request document.

N.J. Douglas, L.J. Franzmann, and T. W. Frost (2003), *Estimation of Demand Parameters for Primary Public Transport Service*, Douglas Economics (www.Douglaseconomics.co.nz).

Neil Douglas and G. Karpouzis (2005), *Estimating the Cost to Passengers of Station Crowding*, 28th Australasian Transport Research Forum (www.patrec.org/atrf), Sydney September 2006.

Neil Douglas and G. Karpouzis (2006), *Estimating the Passenger Cost of Train Overcrowding*, 29th Australasian Transport Research Forum (www.patrec.org/atrf), Gold Coast September 2007.

Neil Douglas and G. Karpouzis (2006), *Valuing Rail Service Quality Attributes through Rating Surveys*, 29th Australasian Transport Research Forum (www.patrec.org/atrf), Gold Coast.

Dowling Associates (2005), *Predicting Air Quality Effects of Traffic Flow Improvements: Final Report and User Guide*, NCHRP Report 535, Transportation Research Board (www.trb.org).

Katrin Dziekan and Arjan Vermeulen (2006), "Psychological Effects of and Design Preferences for Real-Time Information Displays," *Journal of Public Transportation*, Volume 9, No. 1 (www.nctr.usf.edu/jpt/jptv9n1.htm), pp. 71-89.

Katrin Dziekan and Karl Kotterhoff (2007), "Dynamic At-stop Real-Time Information Displays For Public Transit: Effects on Customers," *Transportation Research A*, Vol. 41, Issue 6 (www.elsevier.com/locate/tra), pp. 489-501. Also see *Customer Perceptions And Behavioural Responses To IT-Based Public Transport Information*, Banverket www3.banverket.se/raildokuffe/pdf/MN2158.pdf.

ECONorthwest and PBQD (2002), *Estimating the Benefits and Costs of Public Transit Projects*, TCRP Report 78, (http://gulliver.trb.org/publications/tcrp/tcrp78/index.htm), TRB (www.trb.org).

The Economist (2006), "Happiness (And How To Measure It)" and "Economics Discovers Its Feeling," *The Economist* (www.economist.com), 23 December 2006, p. 13, pp. 33-35.

John E. Evans (2004), *Transit Scheduling And Frequency*, TCRP Report 95, Transportation Research Board (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c9.pdf.

FDOT (2007), *LOSPLAN Software*, Florida Department of Transportation (www.dot.state.fl.us/Planning/systems/sm/los/los_sw2.htm).

G. J. Fielding, T. J. Babitsky and M.E. Brenner (1985), "Performance Evaluation for Bus Transit," *Transportation Research*, Vol. 19, No. 1, pp. 73-82.

John J. Fruin (1971), *Pedestrian Planning & Design*, Metropolitan Association of Urban Designers and Environmental Planners (New York).

Kenneth Gwilliam (1997), *The Value of Time in Economic Evaluation of Transport Projects; Lessons from Recent Research*, World Bank (www.worldbank.org).

Kathleen A. Harder, John R. Bloomfield, David M. Levinson, and Lei Zhang (2005), *Route Preferences and the Value of Travel-Time Information for Motorists Driving Real-World Routes*, University of Minnesota Department of Civil Engineering (www.lrrb.org/pdf/200520.pdf).

David A. Hensher (1992), "Total Factor Productivity Growth and Endogenous Demand: Establishing a Benchmark Index for the Selection of Operational Performance Measures in Public Bus Firms," *Transportation Research B - Special Issue on Performance Measurement*, Guest Edited by D.A. Hensher, 26B (5), 435-48.

David Hensher, Peter Stopher and Philip Bullock (2003), "Service Quality - Developing a Service Quality Index in the Provision of Commercial Bus Contracts," *Transportation Research A* (www.elsevier.com/locate/tra), Vol. 37, No. 6, July 2003, pp. 499-517.

David A. Hensher (2007), *Bus Transport: Economics, Policy and Planning*, Research in Transportation Economics Vol. 18, Elsevier (www.elsevier.com).

Yaron Hollander (2006), "Direct Versus Indirect Models For The Effects Of Unreliability," *Transportation Research A*, Vol. 40, Is. 9 (www.elsevier.com/locate/tra), Nov. 2006, pp. 699-711.

Alan J. Horowitz1 and Dennis J. Zlosel (1981), "Transfer Penalties: Another Look At Transit Riders' Reluctance To Transfer," *Transportation*, Vol. 10, No. 3, September 1981, 279-282.

IFS (2001), *Virtual Learning Arcade – London Transport*, Institute for Fiscal Studies (www.ifs.org.uk); *Tackling Traffic Congestion: More about the METS Model*, (www.bized.ac.uk/virtual/vla/transport/index.htm).

Infopolis 2 Consortium (2000), "Inventory: At-stop Display," *Passenger Information on Public Transport* (www.ul.ie/~infopolis) and (www.ul.ie/~infopolis/existing/stopdisp.html),

Hiroyuki Iseki and Brian D. Taylor (2007), *Not All Transfers Are Created Equal: Toward a Framework Relating Transfer Connectivity to Travel Behavior*, Transportation Research Board Annual Meeting (www.trb.org).

I. T. Transport (2005), *Valuation Of Travel Time Savings: Empirical Studies In Bangladesh, Ghana And Tanzania And A Practical Model For Developing Countries*, UKDID (www.ittransport.co.uk).

Sergio R. Jara-D´Iaz and Antonio Gschwender (2003), "Towards A General Microeconomic Model For The Operation Of Public Transport," *Transport Reviews* (www.tandf.co.uk/journals), Vol. 23, No. 4, pp. 453–469.

Kittleson & Associates (2003a), *Transit Capacity and Quality of Service Manual*, Web Document 100, TCRP, TRB (www.trb.org); at www.trb.org/news/blurb_detail.asp?id=2326.

Kittleson & Associates (2003b), *Guidebook for Developing a Transit Performance-Measurement System*, Web Document 88, TCRP, TRB (www.trb.org); at www.trb.org/news/blurb_detail.asp?id=1120.

Kittleson & Associates (2007), *Bus Rapid Transit Practitioner's Guide*, Report 118, Transit Cooperative Research Program, TRB (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_118.pdf.

Yuen-wah Li (2003), "Evaluating the Urban Commute Experience: A Time Perception Approach," *Journal of Public Transportation*, Vol. 6, No. 4, pp. 41-67; at www.nctr.usf.edu/jpt/pdf/JPT%206-4%20Li.pdf.

Rongfang Liu, R.M. Pendyala and S. Polzin (1998), "Simulation Of The Effects Of Intermodal Transfer Penalties On Transit Use," *Transportation Research Record 1623*, TRB (www.trb.org), pp. 88-95; summary at http://pubsindex.trb.org/document/view/default.asp?lbid=540166.

Henry Liu, Will Recker and Anthony Chen (2004), "Uncovering the Contribution of Travel Time Reliability to Dynamic Route Choice," *Transportation Research A*, Vol. 38, No. 6 (www.elsevier.com), July 2004, pp. 435-453.

Todd Litman (2001), *What's It Worth? Life Cycle and Benefit/Cost Analysis for Evaluating Economic Value*, Presented at Internet Symposium on Benefit-Cost Analysis, Transportation Association of Canada (www.tac-atc.ca); at www.vtpi.org/worth.pdf.

Todd Litman (2004), "Transit Price Elasticities and Cross-Elasticities," *Journal of Public Transportation*, Vol. 7, No. 2, (www.nctr.usf.edu/jpt/pdf/JPT 7-2 Litman.pdf), pp. 37-58; updated version at www.vtpi.org/tranelas.pdf.

Todd Litman (2005), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

Todd Litman (2006), *Smart Congestion Reductions II: Reevaluating The Role Of Public Transit For Improving Urban Transportation*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/cong_reliefII.pdf.

Todd Litman (2007), "Travel Time," *Transportation Cost and Benefit Analysis*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tca/tca0502.pdf.

Todd Litman (2007), *Build for Comfort, Not Just Speed: Valuing Service Quality Impacts In Transport Planning*, VTPI (www.vtpi.org); at www.vtpi.org/quality.pdf.

Todd Litman and Tom Rickert (2005), *Evaluating Public Transit Accessibility: 'Inclusive Design' Performance Indicators For Public Transportation In Developing Countries*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranacc.pdf.

Todd Litman and Steven Fitzroy (2006), *Safe Travels: Evaluating Mobility Management Traffic Safety Benefits,"* VTPI (www.vtpi.org); at www.vtpi.org/safetrav.pdf.

Glenn Lyons, Juliet Jain and David Holley (2007), "The Use Of Travel Time By Rail Passengers In Great Britain," *Transportation Research A*, Vol. 41, No. 1, Jan. 2007, pp. 107-120.

P. Mackie, et al. (2003), *Values of Travel Time Savings in the UK*, Institute for Transport Studies, University of Leeds (www.its.leeds.ac.uk), U.K. Department for Transport (www.dft.gov.uk/stellent/groups/dft_econappr/documents/page/dft_econappr_610340.hcsp).

Brian E. McCollom and Richard Pratt (2004), *Transit Pricing and Fares*, Chapter 12, Report 95, TCRP, TRB (www.trb.org); at www.trb.org/publications/tcrp/tcrp_rpt_95c12.pdf.

MTC (2006), *MTC Transit Connectivity Plan*, Metropolitan Transportation Commission (www.mtc.ca.gov/planning/connectivity/Final_Connectivity_Study/finalsummary.pdf).

Patricia L. Mokhtarian (Editor) (2005), *Transportation Research – Special Issue: The Positive Utility of Travel*, Vol. 39A, Issues 2-3, February/March.

NextBus (www.nextbus.com) is a private company that uses Global Positioning Systems (GPS) to provide real-time transit vehicle arrival information to passengers and managers in various North American cities.

Raymond Novaco and Cheryl Collier (1994), *Commuting Stress, Ridesharing, and Gender: Analysis from the 1993 State of the Commute Study in Southern California*, UCTC 208 (www.its.berkeley.edu).

PDFC (2002), *Passenger Demand Forecasting Handbook*, Passenger Demand Forecasting Council (www.atoc.org/RPDFS/index.asp).

Rhonda Phillips, John Karachepone and Bruce Landis (2001), *Multi-Modal Quality of Service Project*, Florida DOT, (www.dot.state.fl.us/Planning/systems/sm/los/default.htm).

Richard H. Pratt (1999), *Traveler Response to Transportation System Changes, Interim Handbook*, TCRP Web Document 12, TRB (www.trb.org); at www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1034.

Richard Pratt and John Evans (2004), *Bus Routing and Coverage: Traveler Response to Transport System Changes*, Chapter 10; Report 95, TCRP, TRB (www.trb.org); at http://gulliver.trb.org/publications/tcrp/tcrp_rpt_95c11.pdf.

Project for Public Spaces (1999), *The Role of Transit Amenities and Vehicle Characteristics in Building Transit Ridership: Amenities for Transit Handbook and the Transit Design Game Workbook*, Transit Cooperative Research Program Report 46, TRB (www.trb.org); at www.nas.edu/trb/publications/tcrp/tcrp_rpt_46-a.pdf.

W. T. Pullen (1993), "Definition and Measurement of Quality of Service for Local Public Transport Management, *Transport Reviews* (www.transportreviews.com), Vol. 13, No. 3, pp. 247-64.

T. B. Reed (1995), *Reduction In The Burden Of Waiting For Public Transit Due To Real-Time Schedule Information*, Vehicle Navigation and Information Systems Conference, pp. 83-89.

Thomas B. Reed and Jonathan C. Levine (1997), "Changes in Traveler Stated Preference for Bus and Car Modes Due to Real-Time Schedule Information: A Conjoint Analysis," *Journal of Public Transportation*, Vol. 1, No. 2, (www.nctr.usf.edu/jpt/journalfulltext.htm).

Kenneth Small, et al (1999), *Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation*, NCHRP 431, TRB (www.trb.org).

Stephen G. Stradling, Michael Carreno, Tom Rye and Allyson Noble (2007), "Passenger Perceptions And The Ideal Urban Bus Journey Experience," *Transport Policy* (www.elsevier.com/locate/transpol), Vol. 14, No. 4, July 2007, pp. 283-292.

J. Swanson, L. Ampt and P. Jones (1997) Measuring Bus Passenger Preferences, *Traffic Engineering and Control* (www.tecmagazine.com), Vol. 38, No. 6, June, pp. 330-36.

Paul J. Tranter (2004), *Effective Speeds: Car Costs are Slowing Us Down*, University of New South Wales, for the Australian Greenhouse Office (www.greenhouse.gov.au/publications).

TransFund (1998), *Project Evaluation Manual*, TransFund New Zealand (www.transfund.govt.nz).

TranSystems Corporation (2005), *Elements Needed to Create High Ridership Transit Systems*, Transportation Research Board (www.trb.org), TCRP Web Document 32 (http://trb.org/publications/tcrp/tcrp_webdoc_32.pdf).

TRL (2004), *The Demand for Public Transit: A Practical Guide*, Transportation Research Laboratory, Report TRL 593 (www.trl.co.uk); at www.demandforpublictransport.co.uk.

Martin Turcotte (2006), *Like Commuting? Workers' Perceptions Of Their Daily Commute*, Statistics Canada (www.statcan.ca); at www.statcan.ca/english/freepub/11-008-XIE/2006004/pdf/11-008-XIE20060049516.pdf.

Katherine F. Turnbull and Richard H. Pratt (2003), *Transit Information and Promotion: Traveler Response to Transport System Changes*, Chapter 11, TCRP 95; TRB (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c11.pdf.

USDOT (1997), *Departmental Guidance on the Evaluation of Travel Time in Economic Analysis*, memo, USDOT (www.fhwa.dot.gov); used in STEAM software (www.ota.fhwa.dot.gov/steam).

VTPI (2006), *Online TDM Encyclopedia*, Victoria Transport Policy Institute (www.vtpi.org).

Mark Wardman (2004), "Public Transport Values of Time," *Transport Policy*, Vol. 11, No. 4 (www.elsevier.com/locate/transpol), Oct. 2004, pp. 363-377.

William Waters (1992), *Value of Time Savings for The Economic Evaluation of Highway Investments in British Columbia*, BC Ministry of Transportation (www.th.gov.bc.ca/publications/repopubs.htm).

Richard Wener, Gary W. Evans and Jerome Lutin (2006), *Leave The Driving To Them: Comparing Stress Of Car And Train Commuters*, American Public Transportation Association (www.apta.com/passenger_transport/thisweek/documents/driving_stress.pdf).

Graham Wall and Mike McDonald (2007), "Improving Bus Service Quality and Information in Winchester," *Transport Policy*, Vol. 14, No. 2 (www.elsevier.com), March 2007, pp. 165-179.

Lloyd Wright (2006), "Bus Rapid Transit" (www.itdp.org/brt_guide.html) and "Mass Transit Options," (www.gobrt.org/SourcebookMassTransitOptions.pdf), *Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*, Sustainable Urban Transport Project – Asia (www.sutp-asia.org), Deutsche Gesellschaft fur Technische Zusammenarbeit (www.gtz.de), and the Institute of Transportation and Development Policy (www.itdp.org).