SMARTER CONGESTION RELIEF IN ASIAN CITIES

Win-Win Solutions to Urban Transport Problems

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ABSTRACT

This article describes new and better ways to solve urban traffic congestion problems. It emphasizes win-win strategies that help achieve multiple planning objectives and therefore maximize overall benefits. This reflects a new planning paradigm which expands the range of impacts and options considered in the planning process. Win-win strategies include improvements to resource efficient modes such as walking, cycling and public transport; incentives for urban-peak travelers to use the most efficient option for each trip; and smart growth development policies that reduce travel distances and therefore total congestion costs. This article discusses the importance of comprehensive and multi-modal transport planning, describes omissions and biases in current planning, identifies various win-win congestion reduction strategies, and provides examples of successful urban transportation improvement programs. The win-win approach can be applied to many types of transportation problems, and is particularly appropriate in rapidly-developing Asian cities.

INTRODUCTION

There are many possible ways to reduce traffic congestion. How they are evaluated can significantly affect urban planning decisions. If evaluated one way, congestion is considered the dominant urban transport problem and roadway expansion the preferred solution, but evaluated other ways, congestion is considered moderate compared with other transport problems and roadway expansion an ineffective and costly solution.

It is important to use comprehensive and multi-modal evaluation to identify the truly best congestion reduction strategies, since urban planning often involves trade-offs between competing objectives. For example, expanding urban roadways may reduce congestion, but creates barriers to pedestrian travel (and therefore public transport travel since most transit trips include walking links), and tends to induce additional vehicle travel which increases other transport problems such as parking costs, accident risk and pollution emissions. Other congestion reduction strategies provide additional benefits, and so are considered *win-win* solutions. For example, public transit improvements not only reduce traffic congestion, they can also help reduce parking problems, accident risk and pollution emissions, and they improve mobility for non-drivers. All these impacts should be considered when evaluating congestion reduction strategies.

This article describes ways to identify truly optimal congestion reduction strategies. It discusses new, more comprehensive ways to evaluate transport system performance, identifies win-win congestion reduction strategies, and describes examples of successful urban transportation improvement programs. This approach can be used to address various transport problems, and is particularly important in rapidly-developing cities where traffic problems are particularly intense and roadway expansion costs are high.

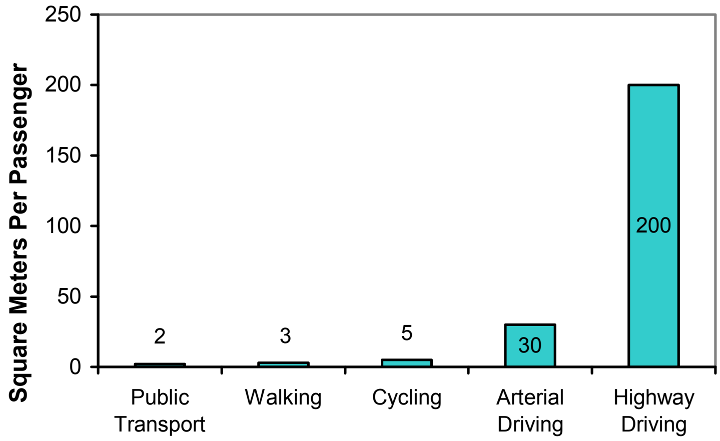
I. URBAN TRANSPORT EFFICIENCY

Cities are places where many people and activities locate close together. This provides a high level of *accessibility*, that is, by providing diverse transport options and minimizing the distances between activities they tend to reduce transportation costs. For example, urban residents often have more services and jobs within a five-minute *walk* than suburban and rural areas have within a five-minute *drive*. This maximizes urban residents' access to economic and social opportunities.

Current research is improving our understanding of factors that affect accessibility. For example, Levine, et al. (2012) found that urban density has about ten times as much influence on the number of destinations motorists can access in a given time period as a proportional increase in traffic speeds. Ewing and Cervero (2010) found that a 10% increase in roadway connectivity reduces average travel distances by 1.2%. Kuzmyak (2012) found that residents of urban neighborhoods with good travel options, connected streets and more nearby services drive a third fewer daily miles and experience less congestion delays than residents of automobile-dependent communities. These studies indicate that cities can provide high levels of accessibility, despite lower average traffic speed.

However, increased density can also increase potential conflicts, also called external costs, such as traffic and parking congestion, accident risk, and pollution emissions. Of all common activities people engage in, motor vehicle travel tends to impose the greatest external costs. Automobile travel requires far more road space, and so imposes more congestion costs than other modes, as illustrated in Figure 1.

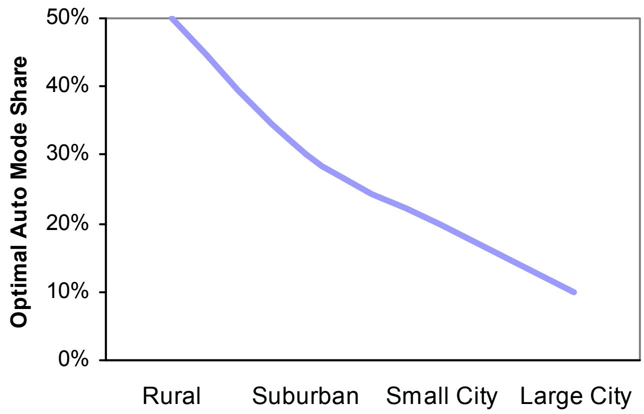
Figure 1: Road Space Required For Various Travel Modes



The space required to transport a person increases with vehicle size and speeds (faster vehicles require more "shy distance" between them and other objects), and declines as passengers per vehicle increase. As a result, automobile travel requires ten to one hundred times as much road space as walking, cycling and public transport.

As a result, transport system efficiency, economic productivity, and community livability tend to increase if automobile travel is minimized, particularly under urban-peak conditions. This does not require eliminating automobile travel entirely; even in large cities a portion of trips are efficiently made by car. However, as cities become larger and denser, automobile mode share should decline, as illustrated in Figure 2.

Figure 2: Optimal Peak-Period Automobile Mode Share (Based on Authors Calculations)



As cities become larger and denser, the optimal automobile mode share declines and the optimal share of resource efficient modes (walking, cycling and public transit) increases, particularly on major corridors during peak periods. Otherwise, traffic problems become severe, reducing economic efficiency and community livability.

However, optimal travel patterns will not occur on their own. Many city residents can afford cars. Efficient urban transport requires policies that encourage more affluent people to walk, bicycle and use public transit when appropriate, so traffic volumes stay within the roadway systems' capacity. As Bogotá Mayor Gustavo Petro explains, "A developed country is not a place where the poor have cars. It's where the rich use public transport." Achieving this goal will require reforming common transport planning practices.

II. THE NEW TRANSPORT PLANNING PARADIGM

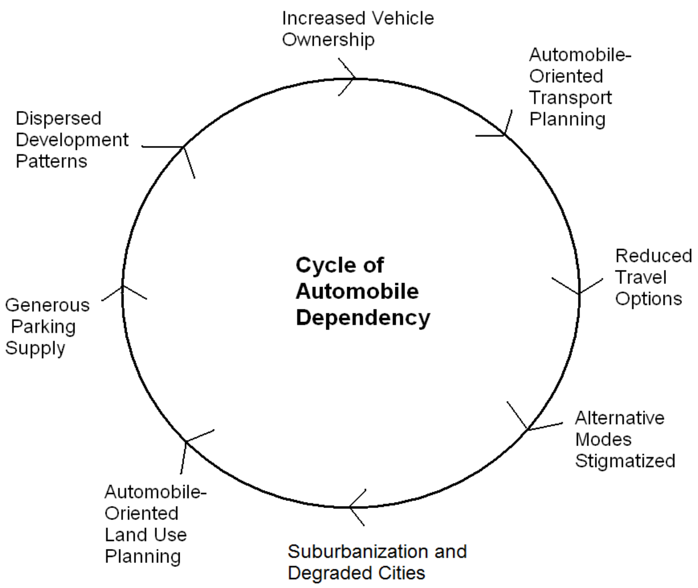
Transport planning is experiencing a *paradigm shift*, a fundamental change in the way problems are defined and potential solutions evaluated, as summarized in Table 1. Table 1. compares the old and new transport planning paradigm. As can be seen, the new paradigm applies more comprehensive and multi-modal planning.

Table 1: Transport Planning Paradigms (ADB 2009; Litman 2013b)

	Old Paradigm	New Paradigm
Definition of *Transportation*	Movement of people and goods	Ability to obtain goods, services and activities
Modes considered	Automobile, truck and transit	Multiple modes and transport services
Performance indicators	Vehicle travel speeds, roadway Level-of-Service, cost per person-mile	Quality of transport options. Proximity of destinations. Per capita transport costs.
Consideration of land use	Recognizes that land use can affect travel choice	Recognizes that land use has major impacts on transportation
Favored transport improvements	Roadway and parking facility expansions. Vehicle improvements.	Multi-modal improvements. Transportation demand management. Smart growth development policies.

The old planning paradigm evaluated transport system performance based primarily on the ease of driving, using indicators such as roadway level-of-service (LOS) and average traffic speeds. This favored automobile travel over other modes, which created a cycle of automobile dependency and sprawl, as illustrated in Figure 3. The result is inefficient and unfair since many urban trips are short enough for walking and cycling, and many residents cannot drive (Kodukula 2011). The new paradigm recognizes the important roles that walking, cycling and public transport play in an efficient and equitable transport system.

Figure 3: Cycle of Automobile Dependency and Sprawl



The old planning paradigm favored faster modes over slower modes, which contributed to a self-reinforcing cycle of automobile dependency and sprawl.

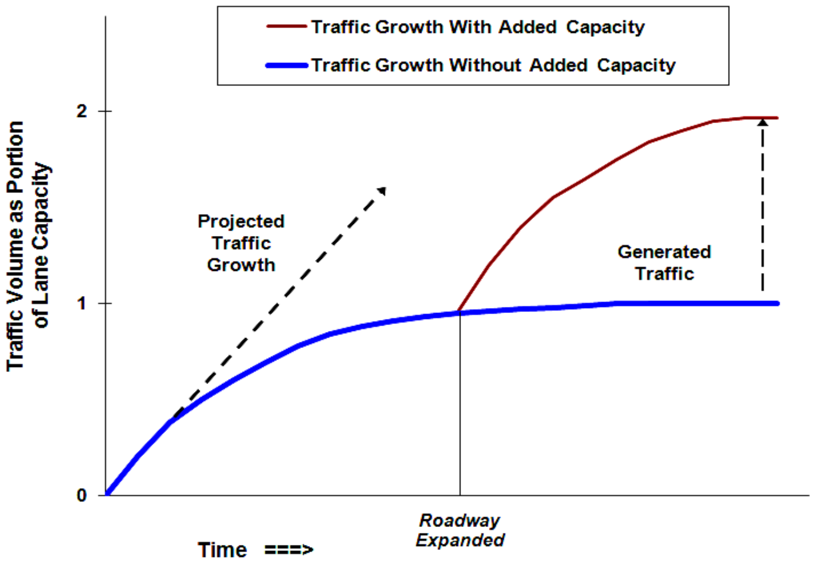
III. CONGESTION COSTING METHODS

Various methods are used to *quantify* (measure) and *monetize* (measure in monetary units) congestion costs (Grant-Muller and Laird 2007). How this is done can significantly affect results. One important factor is the *baseline* (also called *threshold*) speed below which congestion delays are calculated, which reflects the traffic speed considered appropriate under urban-peak conditions. Some studies use free-flowing traffic speeds (LOS A), although this is not economically optimal since it does not maximize traffic flow or fuel efficiency (Litman 2013a). Most experts recommend using lower baseline speeds, such as LOS C or D (TC 2006; Wallis and Lupton 2013).

Some congestion costing studies use excessive travel time values. Although some vehicles (e.g., freight trucks, buses and business travel) have high values of travel time, many urban motorists are quite price sensitive – they are only willing to pay modest fees for increased travel speeds ("Travel Time Costs," Litman 2009). Another important factor is the formula used to calculate how changes in traffic speeds affect fuel consumption and pollution emissions. Fuel consumption and emission rates are usually lowest at 60-80 kilometers per hour, so a moderate amount of congestion can actually increase efficiency and reduce emissions compared with freeflow (Barth and Boriboonsomin 2009).

Congestion cost evaluation is complicated by the tendency of congestion to maintain equilibrium: it increases until delays cause travelers to shift travel times, routes and mode, and reduce trips (Cervero 2003; Litman 2001). For example, if roads are congested you might defer trips, shift modes or choose closer destinations, but if they are expanded you would make more peak-period vehicle trips. Figure 4 illustrates this. The additional peak-period vehicle travel on that roadway is called *generated traffic*, and net increases in total vehicle travel are called *induced travel*.

Figure 4: How Road Capacity Expansion Generates Traffic (Litman 2001)



Urban traffic volumes can grow until congestion limits additional peak-period trips, at which point it maintains a self-limiting equilibrium (indicated by the curve becoming horizontal). If road capacity is expanded, traffic growth continues until it reaches a new equilibrium. The additional peak-period vehicle traffic that results from roadway capacity expansion is called "generated traffic." The portion that consists of absolute increases in vehicle travel (as opposed to shifts in time and route) is called "induced travel."

This has the following implications for congestion evaluation (Litman 2001):

- Congestion will seldom get as severe as predicted by extrapolating past trends. As traffic congestion increases it discourages further peak-period trips, achieving equilibrium.
- Roadway expansion provides less long-term congestion reduction benefit than predicted if generated traffic is ignored.
- Induced vehicle travel increases various external costs including downstream congestion, parking costs, accident risk, and pollution emissions.
- Induced vehicle travel directly benefits the people who increase their vehicle travel, but these benefits tend to be modest because it consists of marginal-value vehicle mileage that users are most willing to forego if their travel costs increase.

Table 2 summarizes various congestion indicators. Some, such as roadway *level-of-service* and the *travel time index* only measure congestion *intensity*, that is, the reduction in traffic speeds on particular roads; they do not account for the amount that people drive under urban-peak conditions and so do not reflect total congestion costs. Right columns indicate whether an indicator is multi-modal (considers delays to non-auto travelers) and comprehensive (reflects total congestion delays, accounts for travel distances).

Table 2: Congestion Indicators ("Congestion Costs" Litman 2009)

Indicator	Description	Multi-Modal	Comprehensive
Roadway Level-Of-Service (LOS)	Intensity of congestion on a road or intersection, rated from A (uncongested) to F (most congested)	No	No
Multi-modal Level-Of-Service (LOS)	Service quality of walking, cycling, public transport and automobile, rated from A to F	Yes	No
Travel Time Index	The ratio of peak to free-flow travel speeds	No	No
Avg. Traffic Speed	Average peak-period vehicle travel speeds	No	No
Avg. Commute Time	The average time spent per commute trip	Yes	Yes
Congested Duration	Duration of "rush hour"	No	No
Annual Hours Of Delay	Hours of extra travel time due to congestion	No if for vehicles, yes if for people	Yes
Congestion Costs	Monetized value of delay plus additional vehicle operating costs	Yes	Yes

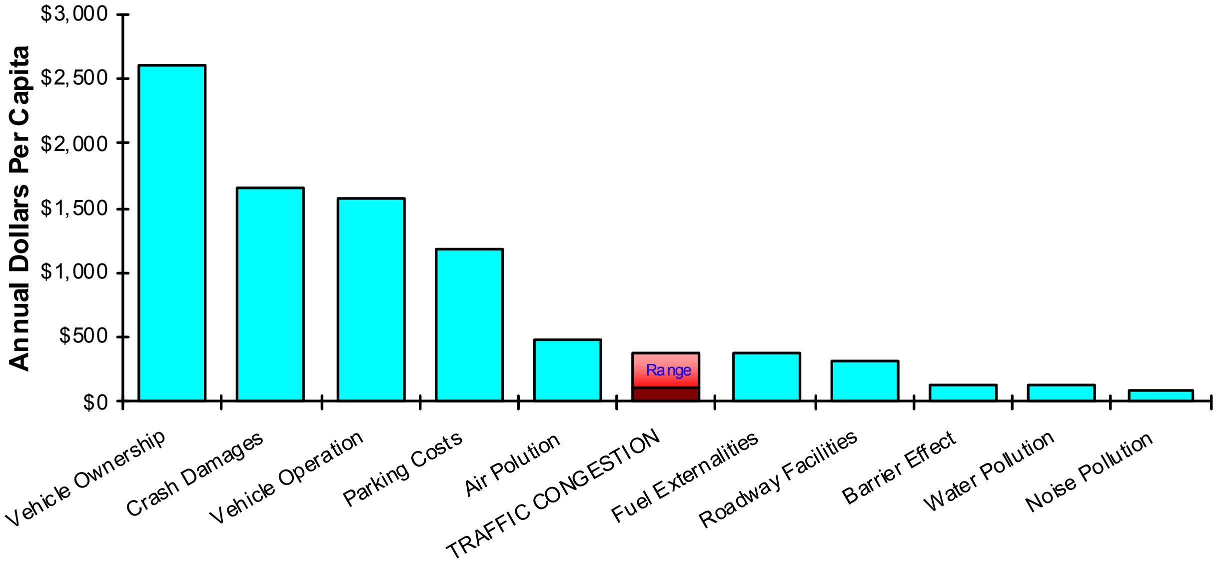
This table summarizes various congestion cost indicators. Some only consider motorists' delays and so ignore the congestion reduction benefits of mode shifts and more accessible land use.

When evaluating congestion costs and potential congestion reduction strategies it is important to apply realistic baseline speeds, value travel time and emission reductions, account for induced travel, and use comprehensive and multi-modal indicators that consider the congestion avoided when travelers reduce their urban-peak vehicle travel, for example, by shifting mode or reducing trip distances.

IV. COMPARING CONGESTION WITH OTHER URBAN TRANSPORT COSTS

It is helpful to compare congestion with other urban transportation costs. Several studies have monetized various transport costs (CE, INFRAS, ISI 2011; Litman 2009; TC 2005-08). This indicates that congestion costs are moderate overall, larger than some but smaller than others. For example, annual per capita U.S. congestion costs are estimated to total between US$110 and US$390 (Litman 2013a; TTI 2012), compared with about US$4,000 in vehicle costs, US$1,500 in crash damages, US$1,000 in parking costs, US$500 in air and noise pollution costs and US$325 in roadway costs, as illustrated in Figure 5.

Figure 5: Costs Ranked by Magnitude (Litman 2009)



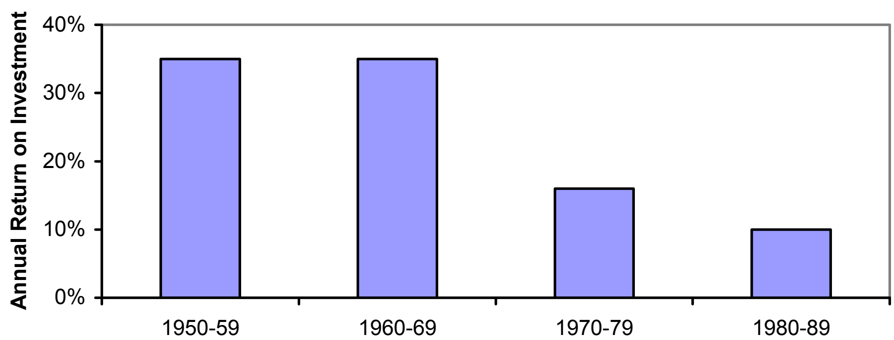
Congestion cost estimates range between US$110 and US$390 annual per capita, depending on analysis methods. Even the higher estimate is moderate compared with other transport costs.

This has important implications. It suggests that a congestion reduction strategy is economically inefficient if it causes even modest increases in other transport costs, such as vehicle expenses, crashes, parking or environmental damages, but provides far greater total benefits if it reduces these costs. For example, if roadway expansions reduce traffic congestion by 20%, but increase vehicle costs, accidents, parking and pollution emissions by 5% each because walking conditions decline and additional vehicle travel is induced, the congestion cost reductions are more than offset by other cost increases. However, if public transit improvements reduce congestion by 10% and also reduce these other costs by 5% each, the total benefits will be much larger than just congestion reductions.

V. ECONOMIC DEVELOPMENT IMPACTS

Proponents often claim that highway expansions support economic development (increased productivity, incomes and tax revenues) by reducing congestion costs. However, such claims are often exaggerated (Dumbaugh 2012). Building the first highways between cities tends to support economic development, but additional roadway capacity tends to provide declining marginal benefits (Shirley and Winston 2004). Figure 6 shows how U.S. highway investments provided high annual economic returns during the 1950s and 60s, but after the basic highway network was completed in the 1970s, the rate of return declined significantly.

Figure 6: Highway Economic Returns (Nadri and Mamuneas 1996 and 2006)



Highway investment economic returns declined after the basic Interstate network was completed.

As previously described, congestion is just one of many factors that affect overall accessibility, and roadway expansion tends to be an ineffective and costly congestion reduction strategy by inducing additional vehicle travel. Theoretical and empirical research indicates that improving alternative modes and efficient transport pricing tend to support economic development much more than urban roadway expansions (Cambridge Systematics 2012; Jiwattanakulpaisarn, Noland and Graham 2012). Table 3 compares the economic impacts of selected congestion reduction strategies, as identified by the author.

Table 3: Economic Impacts of Congestion Reduction Strategies

Economic Impacts	Roadway Expansion	Improve Alt. Modes	Efficient Pricing
Traffic congestion	Reduces congestion in the short-run, but less over the long-run	Reduces congestion	Reduces congestion
Employment pools	Expands car commuters' work options	Expands all commuters' work options	Expands most commuters' work options
Parking costs	Increases parking costs	Reduces parking costs	Reduces parking costs
Vehicle and fuel imports	Increases	Reduces	Reduces
Land use accessibility	Causes sprawl, which reduces accessibility	Encourages compact development which improves accessibility	Encourages compact development which improves accessibility

Roadway expansions can reduce congestion in the short-run, but do little to improve non-drivers' work options, and can have undesirable economic impacts including increased parking costs, vehicle and fuel imports, and sprawl. Other congestion reduction strategies often provide more economic benefits.

VI. COMPREHENSIVE IMPACT EVALUATION

A comprehensive evaluation framework can help identify the most beneficial congestion reduction strategies. *Multi-criteria analysis* considers various impacts (benefits and costs). This analysis may be *qualitative* (described), *quantitative* (measured), or *monetized* (valued in monetary units). For example, Table 4 uses qualitative analysis to evaluate how four congestion reduction strategies affect ten planning objectives. Roadway expansions reduce congestion and vehicle operating costs, but by degrading walking conditions and inducing additional vehicle travel, they tend to contradict other objectives. Improving alternative modes, efficient transport pricing reforms, and "smart growth" development policies (i.e. policies which result in more accessible, multi-modal communities) tend to achieve a wider range of objectives.

Table 4: Comparing Congestion Reduction Strategies

Planning Objectives	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth
Congestion reduction	✓	✓	✓	×/✓
Roadway cost savings	×	✓	✓	✓
Parking savings	×	✓	✓	✓
Consumer cost savings	✓/×	✓	✓/×	✓
Improved mobility for non-drivers	×	✓	✓	✓
Improved traffic safety	×	✓	✓	✓

Planning Objectives	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth
Reduced pollution	×	✓	✓	✓
Energy conservation	×	✓	✓	✓
Efficient land use	×	✓	✓	✓
Improved fitness and health	×	✓	✓	✓

(✓ = helps achieve that objective. × = Contradicts that objective.) Roadway expansion helps reduce congestion but by inducing additional vehicle travel it tends to contradict other objectives. Improving alternative modes, pricing reforms and smart growth policies help achieve many objectives.

Quantitative analysis can apply weights to each objective (for example, giving twice as much weight to a 1% reduction in consumer costs as, say, a 1% reduction in air pollution). Monetized analysis assigns dollar values to each impact (for example, a 1% reduction in per capita accident costs is valued at $15). This type of evaluation can indicate when a solution to one problem contradicts other planning objectives, and helps identify win-win strategies.

Multi-modal evaluation considers how planning decisions affect various accessibility factors, besides automobile traffic speeds, including walking and cycling conditions, public transport service quality, roadway connectivity and geographic proximity. This is important because planning decisions often involve trade-offs between different types of accessibility. For example, roadway expansions can increase automobile and bus accessibility, but often degrade walking conditions, and therefore transit access since most transit trips involve walking links, and induce sprawl which reduces geographic proximity. Improving alternative modes (pedestrian and cycling improvements, transit service improvements, rideshare matching, etc.), transport pricing reforms (road tolls, parking fees, distance-based vehicle insurance, fuel price increases, etc.), and smart growth development policies may reduce vehicle traffic speeds but improve other forms of accessibility. Table 5 indicates these trade-offs.

Table 5: Congestion Reduction Impacts on Accessibility Factors

Accessibility Factors	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth
Automobile access	✓	×	✓/×	✓/×
Active transport	×	✓	✓	✓
Public transport	✓ (bus)	✓	✓	✓
Roadway connectivity	×	-	-	✓
Geographic proximity	×	✓	✓	✓

(✓ = helps achieve that objective. × = Contradicts that objective.) Roadway expansions increase automobile and bus access, but by degrading active transport (walking and cycling) conditions and inducing sprawl tend to reduce other forms of access. Alternative mode improvements, transport pricing reforms and smart growth development may in some ways reduce automobile access, by reducing traffic speeds, but tend to improve other forms of access.

VII. SMART CONGESTION REDUCTION STRATEGIES

This section describes various win-win congestion reduction strategies.

7.1 Improving Alternative Modes

Alternative modes include walking and cycling, public transport (buses and trains), and sometimes, high-occupancy vehicles, carsharing, telecommuting, taxi services, and delivery services. If alternative modes are inferior (inconvenient, uncomfortable, dangerous, etc.), people who own a motor vehicle will drive even if congestion is severe, but if alternatives are improved some travelers will shift from driving, reducing congestion. Even small shifts can provide significant benefits. For example, a 5% reduction from 2,000 to 1,900 vehicles per lane-hour typically increases roadway traffic speeds by 10 to 20 kilometers per hour.

Table 6: Typical Alternative Mode Improvements

Walking	Bicycling	Public Transport
• More sidewalks and paths • More crosswalks • Traffic speed reductions • Improved wayfinding • More compact and mixed development so more services are within walking distance • Improved safety and security • *Universal design*, so pedestrian facilities accommodate pedestrians with disabilities • Improved connectivity	• More paths • More bike lanes • Traffic speed reductions • Improved wayfinding • Bike parking • More compact and mixed development so more services are within cycling distance • Improved safety and security • Loans and subsidies to purchase bicycles and safety equipment (lights and helmets) • Bicycle training and encouragement programs • Bicycle racks for buses	• More routes • More frequent service • Faster service • Grade separation (bus lanes) • Nicer vehicles • Nicer stations • Improved user information • Improved safety and security • Reduced fares and more convenient payment systems • Improved stop/station access • Better marketing • *Universal design*, so transit services accommodate pedestrians with disabilities

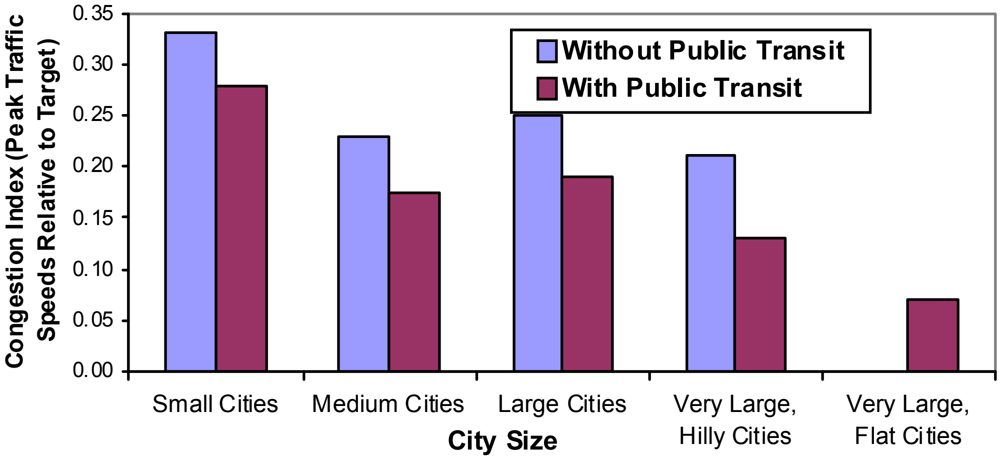
There are many possible ways to improve alternative modes.

Walking and cycling improvements can reduce traffic congestion in several ways. Poor walking and cycling conditions force people to drive for even short trips. In urban areas a significant portion of motor vehicle travel (typically 10-30%) consists of short trips that could shift to non-motorized modes. Poor walking and cycling conditions also force motorists to chauffeur non-drivers for local trips, for example, driving children to school and friends. Such trips often include empty backhauls, so a kilometre of passenger travel generates two kilometers of vehicle travel. Since most public transport trips include walking and cycling links, improving these modes tends to increase public transit travel.

Studies indicate that the quality of public transit service affects travel speeds and congestion delays on parallel highways (Vuchic 1999). A key factor is the relative speed of transit compared with driving, so grade-separated transit services, such as bus lanes and trains on their own rights-of-way, tend to be particularly effective at reducing congestion.

Even if transit only carries a minor portion of total regional travel, it usually carries a significant portion of travel on major urban corridors where traffic congestion is most intense. For example, although Los Angeles has only 11% transit commute mode share, transit reduces regional congestion costs by 11% to 38%; when a strike halted transit service in that city for five weeks, average highway congestion delay increased 47% (Anderson 2013). Aftabuzzaman, Currie and Sarvi (2010) concluded that in Australian cities, high quality public transit provides \$0.044 to \$1.51 worth of congestion cost reduction per marginal transit-vehicle km of travel, with higher values on the most congested corridors. Similar patterns are found in developing countries. Figure 7 shows that Indian cities with rail transit have less intense roadway congestion.

Figure 7: Traffic Congestion in India (Wilbur Smith 2008)



Traffic congestion is lower in Indian cities with higher quality public transit.

Under typical urban traffic conditions, 20 buses carry more passengers than a general traffic lane, and 45 buses carry more passengers than a freeway lane, so an urban arterial with more than 20 buses per peak hour, and an urban highway with more than 45 buses per peak hour, should have dedicated bus lanes and other bus priority features to maximize travel efficiency and attract more discretionary travelers to transit.

Improving alternative modes can provide other efficiency benefits. Travelers who shift from driving to alternative modes in response to service improvements must benefit overall or they would not change. Even if the alternative modes are slower their total costs may decline, for example, if they can walk or bicycle for enjoyment and exercise, and so avoid the need to spend time and money at a gym, or if transit passengers can relax or work, so their unit time costs (dollars per hour) are reduced (Litman 2008).

Walking, cycling and public transit improvements tend to help create more compact communities where residents own fewer automobiles, drive less and rely more on alternative modes. This can leverage additional vehicle travel reductions, so increases in walking and public transit cause proportionately larger reductions in automobile travel (ICF 2010). High quality transit also complements congestion pricing: it reduces the toll required to achieve a given reduction in traffic volumes (PSRC 2008).

7.2 Transport Pricing Reforms

Various transport pricing reforms can help reduce traffic congestion and provide other benefits. Congestion pricing, with higher fees for driving on congested roads and lower fees at other times and locations, is particularly effective at reducing traffic congestion because it can cause peak-period travel to shift to other times, routes, modes and destinations. However, congestion pricing tends to have high implementation costs and raises privacy concerns, and only applies to a minor portion of total vehicle travel. Other pricing strategies (flat road user fees, efficient parking pricing, higher fuel prices and distance-based pricing) tend to affect a larger portion of total travel and therefore tend to be more effective at achieving other planning objectives such as reducing parking costs, accident risk, and pollution emissions. Table 7 summarizes various pricing reforms and their impacts on travel and congestion.

Table 7: Transport Pricing Reforms (Spears, Boarnet and Handy 2010; VTPI 2009)

Type	Description	Travel Impacts	Congestion Impacts
Congestion pricing	Road tolls that are higher under congested conditions.	Shifts urban-peak driving to other times, routes, modes and destinations.	Tends to provide large congestion reductions.
Flat tolls and vehicle travel fees	Tolls and mileage-based vehicle fees intended to generate revenue.	Shifts automobile travel to other modes and destinations. Reduces total vehicle travel.	Effects are dispersed. Provides modest congestion reductions.
Efficient parking pricing	Fees for using parking facilities with higher rates during peak periods, and parking “cash out” (offering non-drivers the cash equivalent of parking subsidies)	Shifts driving to other modes and destinations. Reduces total vehicle travel.	Because this is implemented most in dense urban areas, it tends to provide large congestion reductions.
Fuel tax increases	Increase fuel prices to generate revenue and internalize external costs.	Shifts driving to other modes and destinations. Reduces total vehicle travel. Increases vehicle fuel efficiency.	Effects are dispersed. Provides modest congestion reductions.
Distance-based pricing	Prorate vehicle insurance premiums and registration fees by mileage.	Shifts automobile travel to other modes and destinations. Reduces total vehicle travel.	Effects are potentially large but dispersed, so tend to provide modest congestion reductions.

This table summarizes major pricing reforms and their travel and congestion reduction impacts.

7.3 Smart Growth Development Policies

Smart growth is a general term for various policies that create more compact, multi-modal communities where residents tend to own fewer vehicles, drive less and rely more on alternative modes. There is debate concerning how smart growth affects congestion. Experts often assume that increasing density increases congestion (Melia, Parkhurst and Barton 2011), but smart growth also includes features that reduce vehicle travel and congestion. Table 8 summarizes how various smart growth features affect traffic congestion.

Table 8: Smart Growth Congestion Impacts

Smart Growth Feature	Congestion Impacts
Increased development density	Increases vehicle trips within an area, but reduces trip distances and supports use of alternative modes
Increased development mix	Reduces trip distances and supports use of alternative modes
More connected road network	Reduces the amount of traffic concentrated on arterials. Reduces trip distances. Supports use of alternative modes.
Improved transport options	Reduces total vehicle trips.
Transportation demand management	Reduces total vehicle trips, particularly under congested conditions.
Parking management	Can reduce vehicle trips and support more compact development

Smart growth includes many features that can reduce traffic congestion.

Empirical studies indicate that comprehensive smart growth policies tend to reduce congestion costs. For example, a major study in Phoenix, Arizona, found less intense congestion, reduced per capita vehicle travel, and less total congestion delay in older, compact, multi-modal neighborhoods than in newer, lower-density suburban areas (Kuzmyak 2012). In the urban neighborhoods, commute trips averaged about 7 miles and shopping trips 3 miles, compared with almost 11 and 4 miles in suburban areas. Overall, urban residents drive about a third fewer daily miles than suburban residents. This occurs because urban neighborhoods have more mixed development, more connected streets, better walking conditions and better public transit services.

7.4 Support Programs

Various programs can support congestion reduction strategies. These include employee trip reduction programs at worksites, campus transport management programs, mobility management marketing programs that promote use of resource-efficient modes in a community, and various other Transportation Demand Management (TDM) programs (VTPI 2009). Such programs provide an institutional framework for implementing strategies such as rideshare matching and efficient parking pricing, and information and encouragement for travelers to use efficient modes. As a result, they tend to increase the effectiveness of other congestion reduction strategies.

7.5 Summary

Table 9 evaluates the impacts of four congestion reduction strategies and the degree that these are considered in transport modeling and planning. Urban roadway expansions often provide only short-term congestion reductions, tend to increase other costs, and have few co-benefits. Conventional traffic models often exaggerate roadway expansion benefits and conventional planning tends to favor this solution. Other strategies tend to provide more long-term congestion reductions and more co-benefits, but are often undervalued in conventional transport modeling and planning.

Table 9: Congestion Reduction Strategies

	Roadway Expansion	Improve Alternative Modes	Pricing Reforms	Smart Growth
Congestion impacts	Reduces congestion in the short-run, but this declines over time due to generated traffic.	Reduces but does not eliminate congestion.	Can significantly reduce congestion.	May increase local congestion intensity but reduces per capita congestion costs.
Indirect costs and benefits	By inducing additional vehicle travel and sprawl it tends to increase indirect costs. Minimal co-benefits. Small energy savings and emission reductions.	Numerous co-benefits. Parking savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Revenues, parking savings, traffic safety, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Infrastructure savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.
Consideration in traffic modeling	Models often exaggerate congestion reduction benefits by underestimating generated traffic and induced travel	Models often underestimate the congestion reduction benefits of high quality alternative modes	Varies. Can generally evaluate congestion pricing but are less accurate for other reforms such as parking pricing	Many models underestimate the ability of smart growth strategies to reduce vehicle travel and therefore congestion

	Roadway Expansion	Improve Alternative Modes	Pricing Reforms	Smart Growth
Consideration in current planning	Commonly considered and funded	Sometimes considered and funded, particularly in large cities	Sometimes considered but seldom implemented	Not generally considered a congestion reduction strategy

Different congestion reduction strategies have different types of impacts and benefits. Current traffic models and planning practices tend to undervalue many of these impacts.

Many of these strategies have synergistic effects – they are more effective if implemented together. For example, if implemented alone, public transit improvements, more efficient parking pricing and more compact development policies might only reduce vehicle travel 5% each, but if implemented together provide 30% reductions because travelers have both the opportunities and incentives to reduce their peak-period vehicle travel. For this reason, impacts and benefits tend to be greatest if congestion reduction strategies are implemented as an integrated program.

VIII. OPTIMAL CONGESTION SOLUTIONS

This analysis indicates that optimal congestion reduction involves the following steps:

1. Improve alternative modes, including walking, cycling and public transit, and where appropriate, programs that support ridesharing, carsharing and telecommuting. Provide targeted improvements on congested urban corridors, such as more frequent transit services on congested roads, and commute trip reduction programs at major employment centers.
2. Manage roadways to favor space-efficient modes, such as bus lanes on urban arterials with more than 20 buses per hour during peak periods, transit-priority traffic control systems, and High Occupant Vehicle (HOV) lanes on urban highways.
3. If possible, apply congestion pricing (variable tolls or fees that are higher during congested periods), with prices set to reduce traffic volumes to optimal levels (typically level-of-service C or D).
4. Regardless of whether or not congestion pricing is applied, implement efficient transport pricing reforms to the degree that is politically feasible, including road tolls, parking pricing, fuel price increases, and distance-based insurance and registration fees. These reforms may be justified on various economic efficiency and social equity grounds.
5. Implement support programs such as commute trip reduction and mobility management marketing programs wherever appropriate.
6. Only consider urban roadway expansions if, after all of the previous strategies are fully implemented, congestion problems are significant and congestion pricing would provide sufficient revenues to finance all associated costs, which tests users' willingness-to-pay for the additional capacity. For example, if a roadway expansion would have US$5 million annualized costs, it should be implemented only if peak-period tolls on that road will generate that much revenue. Off-peak tolls can be used to finance general roadway costs, such as maintenance and safety improvements, but not capacity expansion.

These policies and investments are not necessarily justified by their congestion reductions alone, but are often justified when all their benefits are considered, including increased social equity, since improving alternative modes and more efficient pricing ensure that non-drivers receive a fair share of transportation improvement benefits, and are not forced to subsidize road and parking facilities they do not use.

Any additional reform revenues from increased parking fees, road tolls, fuel taxes and vehicle fees can be used to help finance roadway costs, improve alternative modes, reduce transit fares, or reduce local taxes (they can be considered compensation for the impacts that urban roadways impose on adjacent communities). It is particularly appropriate to use some revenues to improve public transport and rideshare services, and provide support programs, in the areas where they are collected to help travelers shift from driving to alternative modes, and therefore reduce congestion.

IX. EXAMPLES

Many cities around the world are implementing various transportation demand management strategies to reduce traffic congestion and achieve other planning objectives (CAI-Asia 2007; Strompen, Litman and Bongardt 2012).

More than 150 cities have implemented Bus Rapid Transit (BRT) systems which provide convenient, fast, comfortable and affordable urban bus services that attract discretionary travelers (*BRT Global Database*). For example, Bogotá, Columbia's TransMilenio system has 1,500 buses on dedicated bus lanes, plus 410 feeder buses. Seventy-five percent of Bogota residents rate the system as good or very good. The city has also developed an extensive pedestrian and bicycle path network, and many TransMilenio stations have large bicycle parking facilities.

In 2002, Seoul, Republic of Korea, implemented various transport innovations including removal of a major downtown highway, development of a BRT system with more than 5,000 high-quality buses operating on 107 km of busways and pedestrian and cycling improvements, plus a traffic control center which monitors traffic and parking problems on major arterials. This has greatly reduced congestion delay and accident risk.

In 1993, Kunming, China established its *Public Transport Masterplan* which gives priority to walking, cycling and public transport over private automobiles. The first bus lane opened in 1999, followed by a second in 2002. The plan also includes pedestrian and cycling improvements, and smart growth policies that focus new development around railway stations. Public survey found that 79% of residents were satisfied with the project in 1999, and this grew to over 96% satisfaction in 2001.

In 1975, Singapore first implemented an Area Licensing Scheme (ALS) which required motorists to purchase a paper license before entering the central area. In 1998 this was replaced by an automated Electronic Road Pricing (ERP) system which uses congestion pricing to maintain optimal traffic speeds of 45 to 65 km/h on expressways and 20 to 30 km/h on arterial roads.

In 2009, the City of Delhi, India published its *Pedestrian Design Guidelines*, a detailed guidebook that describes the role of non-motorized modes in an efficient and equitable transport system; defines minimum design and maintenance requirements for sidewalks, crosswalks and other pedestrian facilities; and describes international best practices for enhancing the pedestrian environment.

In 2007 Paris, France launched the Velib bicycle sharing system with 1,450 stations, 20,000 bicycles, and about 120,000 daily users. Since then, many other cities around the world have established bicycle sharing systems.

Many Asian cities have relatively few parking spaces, so motorists must often pay for using a parking space, and in some cities motorists must show that they have an off-street parking space before they are allowed to register a vehicle (Barter 2010). This tends to reduce vehicle ownership and traffic, and encourages use of alternative modes.

X. CONCLUSIONS

Traffic congestion is a significant problem in most cities. There are many possible congestion reduction strategies, some of which have significant indirect costs or benefits. It is important to use comprehensive and multi-modal analysis when evaluating these strategies.

The old planning paradigm assumes that traffic congestion is the most important urban transport problem and roadway expansion is the preferred solution. But congestion is actually a moderate cost overall, smaller than other transport costs such as vehicle costs, accident risks, parking costs and environmental damages, and roadway expansions can add significant indirect costs. It would therefore be harmful overall to reduce traffic congestion in ways that increase these other costs. A congestion reduction strategy is worth far more if it reduces other costs.

Chronic traffic congestion can be considered a symptom of more fundamental transport system problems, including inadequate transport options, underpricing, and sprawled development. Under such conditions, roadway expansions usually provide only short-term congestion relief and generally exacerbate transport problems. Roadway expansions also tend to be unfair to people who rely on walking, cycling and public transport, and therefore do not directly benefit and are harmed by increased vehicle traffic.

A more effective approach is a congestion reduction program which include a combination of improvements to alternative modes, efficient transport pricing and pricing reforms, smart growth development and land use policies, and various support activities. Though they may provide only modest short-term congestion reductions, their impacts tent to be synergistic (total impacts are greater than the sum of their individual impacts) and increase over time. As a result, these *win-win* strategies are usually the most efficient and equitable overall.

Win-win congestion reduction strategies are particularly appropriate in developing countries where most residents rely primarily on walking, cycling and public transport. It is important that decision makers and the general public understand these issues when choosing solutions to congestion problems.

REFERENCES

ADB (2009), *Changing Course: A New Paradigm for Sustainable Urban Transport*, Asian Development Bank. Available from www.adb.org/Documents/Books/Paradigm-Sustainable-Urban-Transport/new-paradigm-transport.pdf.

BRT Global Database. Available from www.brtdata.org.

CAI-Asia (2007), *Compendium of Air Quality Management and Sustainable Urban Transport Projects in Asia*, Clean Air Initiative for Asian Cities. Available from www.cleanairnet.org/caiasia/1412/article-58567.html.

Cambridge Systematics (2012), *Assessing The Economic Benefit Of Transportation Infrastructure Investment In A Mature Surface Transportation System*, National Cooperative Highway Research Program. Available from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24(80)_FR.pdf.

CE, INFRAS, ISI (2011), *External Costs of Transport in Europe – Update Study for 2008*, Studie im Auftrag des Internationalen Eisenbahnverbandes (UIC), CE Delft, INFRAS AG, Zürich, Fraunhofer-ISI, Karlsruhe, External Transport Cost Study. Available from http://ecocalc-test.ecotransit.org/CE_Delft_4215_External_Costs_of_Transport_in_Europe_def.pdf.

Chad Shirley and Clifford Winston (2004), "Firm Inventory Behavior and The Returns From Highway Infrastructure Investments," Journal of Urban Economics, Volume 55, Issue 2, March 2004, pp. 398-415.

Eric Dumbaugh (2012), "Rethinking the Economics of Traffic Congestion," Atlantic Cities, 1 June 2012. Available from www.theatlanticcities.com/commute/2012/06/defense-congestion/2118.

Frederik Strompen, Todd Litman and Daniel Bongardt (2012), Reducing Carbon Emissions Through TDM Strategies - A Review of International Examples, Transportation Demand Management in Beijing (www.tdm-beijing.org), GIZ and the Beijing Transportation Research Centre.

G.B. Arrington and Kimi Iboshi Sloop (2010), "New Transit Cooperative Research Program Research Confirms Transit-Oriented Developments Produce Fewer Auto Trips," *ITE Journal*, Vol. 79, No. 6, June, pp. 26-29. Available from www.dot.ca.gov/hq/tpp/ offices/ocp/sp_files/Transit-Oriented_Developments_Produce_Fewer_Auto_Trips_-_ITE_Journal_June_2009.pdf.

Ian Wallis and David Lupton (2013), *The Costs Of Congestion Reappraised*, Report 489, New Zealand Transport Agency. Available from www.nzta.govt.nz/resources/ research/reports/489/docs/489.pdf.

ICF (2010), *Current Practices in Greenhouse Gas Emissions Savings from Transit: A Synthesis of Transit Practice*, TCRP 84, TRB. Available from http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_84.pdf.

J. Richard Kuzmyak (2012), *Land Use and Traffic Congestion*, Report 618, Arizona DOT. Available from www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/ AZ618.pdf.

Jonathan Levine, Joe Grengs, Qingyun Shen and Qing Shen (2012), "Does Accessibility Require Density or Speed?" *Journal of the American Planning Association*, Vol. 78, No. 2, pp. 157-172. Available from www.connectnorwalk.com/wp-content/uploads/JAPA-article-mobility-vs-proximity.pdf.

M.I. Nadri and T.P. Mamuneas (1996), *Contribution of Highway Capital to Industry and National Productivity Growth*, FHWA, USDOT; citied in USDOT (1997), *Transportation in the United States: A Review*, USDOT (http://ntl.bts.gov/ data/titustxt.pdf). Also see, (2006), "Production, Consumption and Rates of Return to Highway Infrastructure Capital". Available from https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=IIPF62&paper_id=11.

Matthew Barth and Kanok Boriboonsomin (2009), "Traffic Congestion And Greenhouse Gases," *Access 35*, University of California Transportation Center, pp. 2-9. Available from www.uctc.net/access/35/access35_Traffic_Congestion_and_Grenhouse_Gases.pdf.

Md Aftabuzzaman, Graham Currie and Majid Sarvi (2010), "Evaluating the Congestion Relief Impacts of Public Transport in Monetary Terms," *Journal of Public Transportation*, Vol. 13, No. 1, pp. 1-24. Available from www.nctr.usf.edu/jpt/pdf/JPT13-1.pdf. Also see, "Exploring The Underlying Dimensions of Elements Affecting Traffic Congestion Relief Impact of Transit," *Cities*, Vol. 28, Is. 1, February 2011, Pages 36-44. Available from www.sciencedirect.com/science/journal/02642751.

Michael L. Anderson (2013), *Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion*, Working Paper No. 18757, National Bureau of Economic Research. Available from www.nber.org/papers/w18757.

Paul Barter (2010) *Parking Policy in Asian Cities*, Asian Development Bank. Available from http://beta.adb.org/publications/parking-policy-asian-cities.

Piyapong Jiwattanakulpaisarn, Robert B. Noland and Daniel J. Graham (2012), "Marginal Productivity Of Expanding Highway Capacity," Journal of Transport Economics and Policy (JTEP), Vol. 46, No. 3, September, pp. 333-347; summary. Available from http://ideas.repec.org/a/tpe/jtecpo/ v46y2012i3p333-347.html.

PSRC (2008), *Traffic Choices Study: Summary Report*, Puget Sound Regional Council. Available from http://psrc.org/assets/37/summaryreport.pdf.

Reid Ewing and Robert Cervero (2010), "Travel and the Built Environment: A Meta-Analysis," Journal of the American Planning Association, Vol. 76, No. 3, Summer, pp. 265-294. Available from http://pdfserve.informaworld.com/287357__922131982.pdf.

Robert Cervero (2003), "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis," Journal of the American Planning Association, Vol. 69/2, Spring, pp. 145-163.

Santhosh Kodukula (2011), *Raising Automobile Dependency: How to Break the Trend?,* GIZ Sustainable Urban Transport Project. Available from www.sutp.org/dn.php?file =TD-RAD-EN.pdf.

Shih-Che Lo and Randolph W. Hall (2006), "Effects of the Los Angeles Transit Strike On Highway Congestion," Transportation Research A, Vol. 40, No. 10, December 2006, pp. 903-917. Available from www.elsevier.com/locate/tra.

Steve Melia, Graham Parkhurst and Hugh Barton (2011), "The Paradox of Intensification," *Transport Policy*, Vol. 18, No. 1, pp. 46-52. Available from http://eprints.uwe.ac.uk/10555/2/melia-barton-parkhurst_The_Paradox_of_Intensification.pdf.

Steven Spears, Marlon G. Boarnet and Susan Handy (2010), Draft Policy Brief on the Impacts of Road User Pricing Based on a Review of the Empirical Literature, for Research on Impacts of Transportation and Land Use-Related Policies, California Air Resources Board. Available from http://arb.ca.gov/cc/sb375/policies/policies.htm.

Susan Grant-Muller and James Laird (2007), *International Literature Review of the Costs of Road Traffic Congestion*, Scottish Executive. Available from www.scotland.gov.uk/ Publications/ 2006/11/01103351/0.

Susan Handy, Gil Tal and Marlon G. Boarnet (2010), Draft Policy Brief on the Impacts of Network Connectivity Based on a Review of the Empirical Literature, California Air Resources Board (http://arb.ca.gov/cc/sb375/policies/policies.htm).

TC (2005-08), The Full Cost Investigation of Transportation in Canada, Transport Canada (www.tc.gc.ca/pol/en/aca/fci/menu.htm).

TC (2006), *The Cost Of Urban Congestion In Canada*, Transport Canada. Available from www.adec-inc.ca/pdf/02-rapport/cong-canada-ang.pdf.

Todd Litman (2001), "Generated Traffic; Implications for Transport Planning," *ITE Journal*, Vol. 71, No. 4, April, pp. 38-47, ITE. Available from www.vtpi.org/gentraf.pdf.

Todd Litman (2002), "Evaluating Transportation Equity," World Transport Policy & Practice (http://ecoplan.org/wtpp/wt_index.htm), Vol. 8/2, Summer, pp. 50-65. Available from www.vtpi.org/equity.pdf.

Todd Litman (2007), *Evaluating Public Transit Benefits and Costs*, VTPI. Available from www.vtpi.org/tranben.pdf.

Todd Litman (2008), Valuing Transit Service Quality Improvements, *Journal of Public Transportation*, Vol. 11, No. 2, Spring 2008, pp. 43-64; . Available from www.nctr.usf.edu/jpt/pdf/JPT11-2Litman.pdf; a more complete version is available from www.vtpi.org/traveltime.pdf.

Todd Litman (2009), Transportation Cost and Benefit Analysis, Victoria Transport Policy Institute. Available from www.vtpi.org/tca.

Todd Litman (2011), "Smart Traffic Congestion Reductions: Comprehensive Analysis of Congestion Costs and Congestion Reduction Benefits," *Traffic Infra Tech*, Oct-Nov, Vol. 2, No. 2, pp. 42-46. Available from www.trafficinfratech.com/smart-traffic-congestion-reductions.

Todd Litman (2012), *Toward More Comprehensive and Multi-modal Transport Evaluation,* VTPI. Available from www.vtpi.org/comp_evaluation.pdf.

Todd Litman (2013a), *Smart Congestion Relief: Comprehensive Analysis Of Traffic Congestion Costs and Congestion Reduction Benefits,* Victoria Transport Policy Institute (www.vtpi.org); . Available from www.vtpi.org/cong_relief.pdf.

Todd Litman (2013b), "The New Transportation Planning Paradigm," *ITE Journal* (www.ite.org), Vol. 83, June, pp. 20-28. Available from www.vtpi.org/paradigm.pdf

TTI (annual reports), *Urban Mobility Report*, Texas Transportation Institute (http://mobility.tamu.edu/ums).

VTPI (2012), Online TDM Encyclopedia, Victoria Transport Policy Institute. Available from www.vtpi.org.

Vukan R. Vuchic (1999), Transportation For Livable Cities, Center for Urban Policy Research, CRPR Press. Available from www.policy.rutgers.edu/cupr.

Wilbur Smith (2008), *Traffic & Transportation Policies and Strategies in Urban Areas in India*, Ministry of Urban Development. Available from http://urbanindia.nic.in/moud/programme/ut/Traffic_ transportation.pdf.

TTI (annual reports), *Urban Mobility Report*, Texas Transportation Institute (http:// mobility.tamu.edu/ums).

VTPI (2012), *Online TDM Encyclopedia*, Victoria Transport Policy Institute. Available from www.vtpi.org.

Vukan R. Vuchic (1999), *Transportation For Livable Cities*, Center for Urban Policy Research, CRPR Press. Available from www.policy.rutgers.edu/cupr.

Ian Wallis and David Lupton (2013), *The Costs Of Congestion Reappraised*, Report 489, New Zealand Transport Agency. Available from www.nzta.govt.nz/resources/research/reports/489/ docs/489.pdf.

Wilbur Smith (2008), *Traffic & Transportation Policies and Strategies in Urban Areas in India*, Ministry of Urban Development. Available from http://urbanindia.nic.in/moud/programme/ut/Traffic _transportation.pd