Division 44
Water, Energy and Transport

Transportation Demand Management

Training Document

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gtz Transport Policy Advisory Services

On behalf of
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The document also counted with a review of earlier drafts from Mr **Michael Replogle** from Environmental Defense, who was also instrumental in developing the concept of this document.

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Preface

Cities in developing countries need innovative and effective solutions to solve their transportation problems in the short, medium and long term. Increased economic growth, coupled with a resulting increase in motorisation in recent years, has created greater congestion than has ever been seen in the world. Solutions to these problems are possible, not only through improvement of conditions of public transport and conditions for pedestrians and bicycle users, but also in the implementation of measures which promote a rational use of the automobile by means of Transportation Demand Management (TDM) instruments such as those described in this document.

The development of this training document initiated while preparing a training course on TDM in Singapore in partnership with Land Transport Academy (LTA) Singapore and Environmental Defense, under the Sustainable Urban Mobility for Asia program in March 2008. GTZ has done subsequent training courses on the topic thereafter. Various experts have given their feedback both on the concept of the document as in the initial drafts. The document has been written targeting at developing cities. For those cities which are looking forward to further assistance on the topic, GTZ may provide full course material and training courses.

Manfred Breithaupt
April 2009

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Introduction

Transportation Demand Management (TDM), also called Travel Demand Management, aims to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and promoting more effective, healthy and environment-friendly modes of transport, in general being public transport and non-motorised transport.

TDM can provide many benefits, as summarized in the table below. Conventional transportation planning tends to overlook many of these benefits. For example, transportation agencies tend to evaluate TDM measures primarily on congestion and pollution emissions, but often overlook parking cost savings and safety benefits. When all impacts (benefits and costs) are considered, TDM is often the most cost effective overall transportation improvement strategy. Moreover, many individual TDM measures may be achieved at relatively low cost, so making them especially affordable for cities with limited financial resources. Experience has shown that various TDM options and measures should be designed and implemented in a comprehensive manner to make sure that the maximum benefits can be achieved.

There are two basic types of measures that achieve the goal of improving transport system efficiency: "Push" measures that make private vehicles less attractive to use, and "Pull" measures that make other modes of transport more attractive. These are interdependent and need to be paired for maximum effectiveness.

A three-pronged approach, utilizing 1) Improve Mobility Options, 2) Economic measures, and 3) Smart Growth and Land Use Management is the most effective way to manage demand and create a resilient and efficient transport system.

This Training Manual is organized as a resource to support comprehensive TDM strategy, help identify appropriate demand management measures, and build stakeholder support (Sections 1 and 2), while providing appropriate examples (Sections 3 to 5).

Section 1 discusses the transport challenges facing developing countries and the potential role that TDM measures can play in addressing these problems.

Section 2 gives a theoretical background and defines important TDM concepts and terms.

Section 3 describes ways to improve efficient transportation options, including walking, cycling, ridesharing, public transport and telecommunications that substitutes for physical travel.

Section 4 describes various incentives that encourage the use of efficient mobility options.

Section 5 describes smart growth land use policies that create more accessible, multi-modal communities.

Table 1: Potential TDM planning benefits

Benefits	Definition
Congestion reduction	Reduced traffic congestion to motorists, bus users, pedestrians and cyclists
Road cost savings	Reduced costs to build, maintain and operate roadway systems
Parking savings	Reduced parking problems and parking facility costs
Consumer savings	Transportation cost savings to consumers
Improved mobility options	Improved mobility options, particularly for non-drivers
Road safety	Reduced per capita traffic crash risk
Energy conservation	Reduced per capita energy consumption
Emission reductions	Reduced per capita pollution emissions
Efficient land use	More accessible community design, reduced per capita land consumption
Public fitness and health	Increased physical activity and associated health benefits

Transportation demand management can help achieve a wide variety of planning objectives. Not all strategies achieve all of these benefits, but most strategies provide multiple benefits, all of which should be considered in TDM evaluation.

1. Challenging traffic growth in developing countries

TDM is particularly appropriate in developing countries where resources are limited and a major portion of residents rely on walking, cycling, ridesharing and public transport, Road improvements are important for economic development allowing a region to participate in the global economy. However, poorly planned roadway investments can create problems that harm poor people overall. For example, motorway expansion can destroy neighbourhoods and create a barrier to the mobility of people on foot and bicycle. Increased motor vehicle traffic can increase safety risks for pedestrians and bicyclists. As more road space is given over to private vehicles, bicyclists and pedestrians can get squeezed out, and the performance of public transport vehicles can suffer.

Figure 1
High travel demand causes congestion on roads used by all kinds of motorised and non-motorised travel modes, as shown in Pingyao.
Photo by Armin Wagner, Pingyao (CN), 2006

Figure 2
Heavy traffic in Delhi.
Photo by Carlosfelipe Pardo, Delhi (IN), 2005

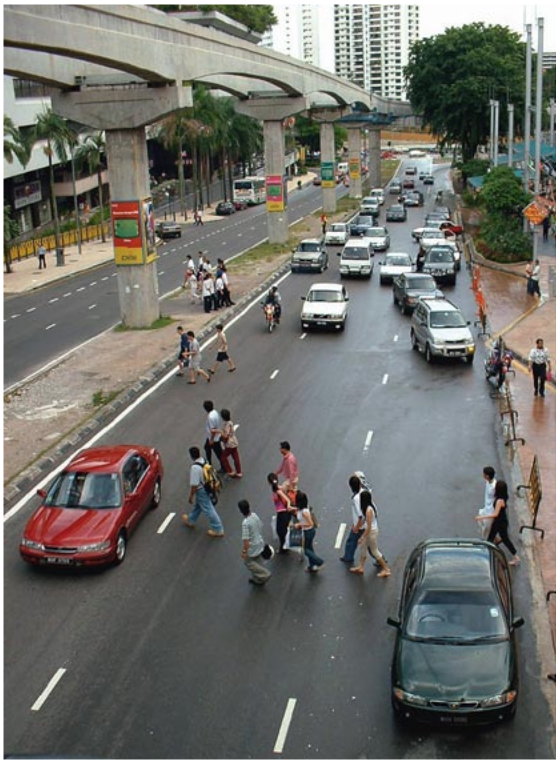


Figure 3
Dangerous streetcrossing in Kuala Lumpur due to lack of crossing options.
Photo by Karl Fjellstrom, Kuala Lumpur (MY), 2001

Many developed country cities are now working to correct such mistakes and encourage people to walk, bicycle and use buses. Developing country can avoid such problems through better policies and planning practices that use TDM to maintain a balanced and efficient transport system, as illustrated in Box 1.

TDM policies and programs can *balance* transportation investments and avoid the problems of excessive motorisation that chokes many global cities with traffic congestion and pollution. More "hard measures" tend to be utilized in developing countries, that is, measures which have a direct impact upon drivers, such as vehicle use restrictions and fees.

Box 1: Impacts of rapid motorisation in developing countries

Vehicle usage trends have largely followed ownership trends. Like vehicle ownership, vehicle usage is expected to grow for both OECD and non-OECD countries, with the highest growth rates in the developing world.

The increased usage of motorised vehicles in developing nations is a particular concern due to the types of vehicles being deployed. In the developing world, ownership has tended to arrive by way of highly polluting, used vehicles. In countries such as Peru, the lifting of used vehicle import restrictions resulted in 70% of the annual growth in vehicle fleet from older, used vehicles (Zegras, 1998). An older vehicle fleet in conjunction with poor maintenance practices and limited vehicle testing can mean that the impacts of motorisation on developing nations are many times worse than an equal level of motorisation in a developed nation. The narrower, historical streets found in many developing cities also means that even low levels of traffic can translate into heavy congestion.

In Asia and parts of Africa, the first progression from non-motorised travel is often towards two-wheel motorised vehicles such as scooters and motorcycles. "In New Delhi, for example, 45% of particulate emissions and two-thirds of unburned hydrocarbon emissions in the transport sector are estimated to come from two- and three-wheelers powered by two-stroke engines. These are estimated to emit more than 10 times the amount of fine particulate matter per vehicle-km than a modern car…" (Gwilliam, 2003, p. 205).

In much of the developing world, though, mode share is ultimately heading towards four-wheel motorised vehicles. The combination of rising incomes, poor public transport services, and lowered import restrictions all means that the developing world stands on the cusp of an explosion in private vehicle ownership.

Few regions of the world epitomise the concerns over the global consequences of mass motorisation as Asia, and particularly the nations of China and India. At present, China's vehicle ownership ratio is nine vehicles per 1,000 inhabitants, (compared to Europe with 430, and U.S. with 700). China's motorisation rate gained another boost with the country's admission into the World Trade Organization (WTO). In 2005, tariff protection for automobiles was as high as 80%, but in 2006, China's WTO commitments required that such tariffs be reduced to 25%.

The trends in car ownership are spurring a spending-spree on road-based infrastructure as well. At the end of 2004, China had 34,000 km of motorways, more than double from 2000; just 17 years ago, the nation had no motorways. Plans are to again double the length of its motorways by 2020.

"The profusion of cars has launched a new cultural revolution, transforming Chinese life and society in ways that bear surprising resemblance to what happened in America 50 years ago… In Shanghai the bridges and tunnels crossing the Huangpu River are so congested that a cab ride from one side to the other can be an hour-long ordeal" (Chandler, 2003).

Many major Chinese cities are also actively discouraging bicycle use through priority measures for automobiles and through the neglect of non-motorised infrastructure. A few Chinese cities have even banned bicycles from large sections of the urban area. In Beijing, non-motorised vehicles are increasingly being squeezed by car parking in physically segregated lanes, and the reallocation of space in wide non-motorised vehicle lanes to cars. On the Second Ring Road, the outside half of the non-motorised vehicle lane has been reassigned to cars and the nearside half is used by buses and taxis. Bicycle parking at work is increasingly being moved to distant inconvenient locations to provide more convenient space for cars.

(Figures have been updated.)

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3e: Car-free Development," by Lloyd Wright for GTZ, http://www.sutp.org

Figure 4
Despite significant investments in car-based infrastructure, Bangkok has yet to see any appreciable reductions in congestion.
Photo by Karl Fjellstrom

Figure 5
Cars are increasingly replacing two-wheelers in the modal mix in developing cities such as Dehli, generating greater congestion.
Photo by Abhay Negi, Delhi (IN), 2005

1.1 Impacts of car-oriented development

Rapid and unconstrained growth of private vehicle use in developing cities has real and significant consequences for cities and the people living in them. Environmental impacts such as degraded air and water quality soon translate into human impacts such as asthma and premature mortality. Cities are often transformed to make way for cars. New roads replace land used for living space, and new viaducts sever neighbourhoods and block non-motorised transport.

Although many of these problems are already experienced by developed country cities, many rapidly developing cities are repeating — or are poised to repeat — the same mistakes. TDM measures offer an opportunity to avoid the costly and flawed path of car domination that developed country cities now try to recover from. Figure 7 discusses some of most important impacts of unrestrained car-oriented development. The publication, "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3e: *Car-free Development*" (http://www.sutp.org), contains a more detailed discussion.

Figure 6
A parking space instead of a pedestrian path at the roadside forces pedestrians to walk on the street in Shigatse.
Photo by Gerhard Metschies, Shigatse (CN), 2002

Air quality
Vehicle emissions harm human health and the natural environment

Noise and vibration
Noise affects productivity and health

Accidents
Each year 1.2 million lives are lost due to vehicle accidents

Global climate change
Vehicles are responsible for roughly 25% of fossil-based CO_2 emissions

Natural habitats
Roadways disrupt habitats and open areas to exploitation

Waste disposal
The disposal of vehicles and vehicle parts contribute to landfill problems

Congestion
Time lost in congestion affects overall productivity

Energy security
Dependence on petrol-based mobility affects national security

Economic efficiency
Financial capital consumed by car expenditures reduces capital for other investments

Severance
Roadways sever communities and inhibit social interactions

Visual intrusion
Cars, roads, and parking areas all detract from a city's beauty

Loss of living space
Roads and parking consume large amounts of urban space

Figure 7
The impacts of increasing motorisation.
Source: Adapted from European Commission (2005) and Litman (2005a)

Many cities are in the process of recovering from a car-dominated development era: removing motorways that sever communities, reclaiming road space from cars and re-allocating it to buses, bicycles, and pedestrians, and improving public transport network extent, connectivity, and service quality. The movement toward "car-free cities" is particularly strong in Europe.

A trend of capturing the hidden costs of car use is emerging in Europe and the U.S. This means the full cost of vehicle use is made explicitly clear to drivers, and that they bear a fair share of the burden. The movement is based upon the principle that polluters should pay for the impacts of their activities, rather than the least powerful in society. For instance, European Union policy regulating tolls on lorry use will soon require that tolls are calculated to include externalized costs, including time delay from congestion, air pollution, accidents, health care costs, and noise. Since most externalities are non-monetized, considerable research was devoted to understanding how to calculate them, with the aim of using a common formula. The greatest driver of this trend is when the huge maintenance expenses for extensive road networks grow, and funding for new roads grows scarce. Developed countries are finding that they simply cannot afford to provide roads free to users forever.

1.2 Leapfrogging with TDM

Developing country cities are well positioned to skip over, or "leapfrog" an era of car-dominated development and its expensive impacts. The first step is to re-orient transportation policy, planning, and engineering around the goal of improving access for people and goods. Then a set of TDM measures which both push and pull drivers out of their vehicles should be implemented. The result will be a more sustainable development path, economically and environmentally.

Developing cities tend to have high walking, bicycling, and using public transport mode share (that is, the portion of trips made by these forms of transport.) A lower share of the population has access to cars, so expensive car-oriented developments tend to serve only a portion of the population. This tends to increase

Figure 8

Multi-modal planning – bus and bicycle lanes next to a wide sidewalk ensures safety and convenience for different users in Xian.

Photo by Armin Wagner, Xian (CN), 2006

the feasibility and importance of TDM measures, because many people already depend on alternative modes, and improvements to these modes provide large benefits to users and society overall. TDM is often much less expensive than building new roads, is better for the economy, supports equity objectives, and does more to improve the quality of life. Pricing reforms can be particularly effective at improving transport system efficiency. Besides providing a restraint on excessive car use, taxes and fees paid by drivers can be used for investments in public transport, street connectivity, and safety measures for non-motorised modes.

Box 2 discusses some other reasons TDM measures have multiple benefits in developing countries.

Box 2: TDM is particularly effective in developing countries

TDM is particularly appropriate in developing country cities, because of its low costs and multiple benefits. Developing countries have limited resources to devote to transportation infrastructure. Developing country cities often have narrow and crowded streets, limited space for parking and a diverse mix of road users, leading to conflicts over space and increased risk of crashes. Few developing countries can afford to build the motorways and parking facilities that would be needed if automobile ownership quickly reaches high levels. A major portion of the population cannot afford to own private motor vehicles, so investments and policies that favour automobiles over other travel modes are likely to be inequitable and unsatisfactory for solving most residents' travel needs.

Motorway investments sometimes appear more cost effective than alternatives such as public transport investments, but this is false economy, since roads are just a small part of the total costs. The total costs of increased automobile dependency are far higher than the total costs of providing good public transport service. Most households are better off if their community has an efficient, balanced transportation system with good quality walking, cycling and public transport service, even if they must pay more in private vehicle user fees. TDM provides opportunities to governments, businesses and individual consumers to save money and avoid indirect costs. Investments in transportation alternatives and TDM programs are often far more cost effective than continual public investments in road and parking facility expansion to accommodate increased private automobile travel.

Automobile dependency also tends to be harmful to the national economy of developing countries. Most developing countries import vehicles and parts, and many import fuel. Even countries with domestic vehicle assembly plants find that the majority of manufacturing inputs are imported (raw materials, components, technical expertise, etc.). Vehicles and fuel are the largest category of imported goods in many developing countries. Shifting expenditures from vehicles and fuel to more locally-produced goods and transport services like public transport and non-motorised transport tends to increase regional employment and business activity, supporting economic development. Even countries that produce their own petroleum are better off conserving fuel so there is more available to export.

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Countries, Module 2b: Mobility Management," by Todd Litman for GTZ, http://www.sutp.org

Table 2: Factors that justify Mobility Management in developing countries

Infrastructure supply	Infrastructure is often in poor repair. Urban roads, parking, sidewalks and paths are often congested and crowded. Streets and sidewalks serve many functions and users (walking, talking, retail businesses, sleeping, begging, etc.) Streets not well designed for heavy motor vehicle traffic.
Vehicle supply	Low automobile ownership among general population. Medium to high automobile ownership among middle-income households. High automobile ownership growth rate among wealthy households. High bicycle ownership in some regions. Medium to high supply of public transit and taxi vehicles.
Personal mobility	Large variation in mobility between different income groups: low mobility among the general population and high mobility among wealthier groups. High mobility growth rate among medium-income households.
Transportation diversity	Considerable diversity (walking, cycling, animal carts, public transit, private automobile). Conditions of alternative modes, such as walking, cycling, public transit, are often inferior (slow, uncomfortable, unsafe, unconnected, etc.).
Institutional capacity	Some developing countries have poor civil institutions to plan, implement and enforce traffic improvements. Sometimes poor cooperation between different levels of government. Most decision-makers are relatively wealthy and so tend to personally favour automobile-oriented improvements.
Government costs	Limited funding for transportation infrastructure and services.
Consumer costs	Many households spend a large portion of income on transport.
Traffic safety	High traffic casualties per motor vehicle. High risk to vulnerable road users (pedestrians, cyclists, animals, etc.).
Comfort	Low comfort levels for non-motorised travel (walking, cycling, animal carts, etc.). Low comfort levels for most public transit. Medium to high comfort for private automobile and taxi travel.
Environment	High pollution concentration in urban areas. Pavement of greenspace (farmlands and wildlife habitat) a problem in some areas.
Land Use	Medium to high accessibility in urban areas (many destinations can be reached by walking, cycling and public transit). Poor and declining accessibility in most suburbs and new communities. In some regions, limited land available for new transportation infrastructure.
Economic development	High dependence on imported transportation goods (vehicles, parts and fuel). Economic development harmed by dependency on imported goods.

2. Developing a comprehensive TDM strategy

2.1 Defining TDM

Transportation Demand Management (TDM) is a strategy which aims to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and promoting more effective, healthy and environmental-friendly modes of transport, in general being public transport and non-motorised transport.

To better understand the economic benefits resulting from TDM, it is helpful to consider transportation as a good for which there is supply and demand. Transportation agencies are responsible for designing, building, and managing road network and transport services, and for regulating vehicles. Their policies and planning practices usually based on the assumption that the goal is to maximize supply in order to increase motor vehicle traffic volumes and speeds. Supply is relatively easy to measure, indicated by the number of kilometres of paid roads, parking spaces, motor vehicles, and vehicle kilometres of travel. Transport demand is more difficult to measure, because it is based upon peoples' needs and desire for mobility, and the needs of businesses to transport goods.

It is also less clear who is responsible for managing demand, since transport decisions are based on a variety of factors, from time of day to comfort to cost. TDM measures may be implemented by transportation agencies, local, regional and national governments, and private entities like employers. Table 3 contrasts supply- and demand-side measures which may be used in a transportation system.

Table 3: Examples of transport system management measures

Increase Supply	Demand Management
Add roads and road lanes	Road/ Congestion pricing
More bus service	Fuel pricing
More light rail service	Parking policies and pricing
More commuter rail service	Vehicle use restrictions
More frequent bus service	Road space reallocation
Dedicated bus or tram corridors	Priority for bus and non-motorised modes
Bike lanes and bike parking	Clustered land uses
Sidewalks and crosswalks	Flexible work hours and telecommuting
Bridges and tunnels for bicyclists and pedestrians	Travel planning information

Motorways and bypasses generate traffic, that is, produce extra traffic, partly by inducing people to travel who would not otherwise have done so by making the new route more convenient than the old, partly by people who go out of their direct route to enjoy the greater convenience of the new road, and partly by people who use the towns bypassed, because they are more convenient for shopping and visits when through traffic has been removed.

J.J. Leeming, British road engineer,
"Road Accidents: prevent or punish?"(1969)

TDM can also be described as set of measures to influence traveller behaviour in order to reduce or redistribute travel demand. Demand for transportation follows the general economic theory of supply and demand for normal goods.

For most goods, supply and demand are balanced by pricing. For example, if demand increases for a particular type of food, the price will rise, stimulating farmers to supply more, until supply and demand achieves equilibrium. However, many components of the transportation system are inefficiently priced, creating conflicts and inefficiencies.

Although automobiles are expensive to own, most of the costs are fixed. Consumers pay about the same for vehicle purchase, financing, insurance, registration and residential parking regardless of how much they drive their vehicle. Many costs of automobile travel are external, that is, not paid directly by users, including traffic congestion, accident risk, pollution emissions and parking subsidies. Many countries subsidize motor vehicle fuel, or impose low taxes that do not even recover roadway costs. In most situations, two-thirds of motor vehicle costs are either fixed or external.

This price structure is inefficient and unfair. High fixed costs encourages motorists to maximize their vehicle travel, in order to get their money's worth, and externalized costs are inequitable, forcing people to bear uncompensated costs and damages. For instance, carpool and bus passengers are delayed by traffic congestion, although they require far less road space than private automobile passengers. TDM helps correct these distortions, resulting in a more efficient and equitable transportation system. This ultimately benefits everybody, including people who continue to drive, because they can enjoy less traffic and parking congestion, reduced accident and pollution costs, and reduced need to chauffeur non-drivers.

TDM tends to be particularly beneficial when compared with the full costs of expanding congested and unpriced roads and parking facilities. Expanding such facilities tends to stimulate *generated traffic* (additional peak-period traffic on the expanded roadway, including vehicle travel shifted from other times and routes), and *induced travel* (a total increase in motor vehicle travel, including travel shifted from other modes, more distant destinations, and total increases in per capita mileage). Generated traffic and induced vehicle travel tend to reduce predicted congestion benefits and increase external costs, including downstream traffic congestion and roadway costs, parking costs, traffic accidents, energy consumption, pollution emissions, and land use sprawl. Although the additional vehicle travel provides user benefits, these are small, because such travel represents the marginal value vehicle-miles that consumers most willingly give up if their costs increase.

Because conventional economic evaluation tends to overlook or undervalue generated traffic and induced travel impacts, it tends to exaggerate the benefits of expanding congested urban roadways, and undervalue TDM solutions. More comprehensive evaluation, which takes these factors into account, tends to recognize more benefits from TDM solutions.

TDM also affects land use patterns, due to the reciprocal relationship between land use and transportation. Land use affects transportation activity, and transportation decisions affect land use development patterns. As more land is consumed for roadways, homes and destinations tend to be farther apart, leading people to use vehicles for more and more of their trips. This feedback cycle between transportation and land use is illustrated in Figure 9. Cities tend to grow larger and more spread out, in a pattern called urban sprawl. TDM helps stop this cycle by supporting "Smart Growth" land use development patterns which create more compact, multi-modal communities and discourage sprawl.

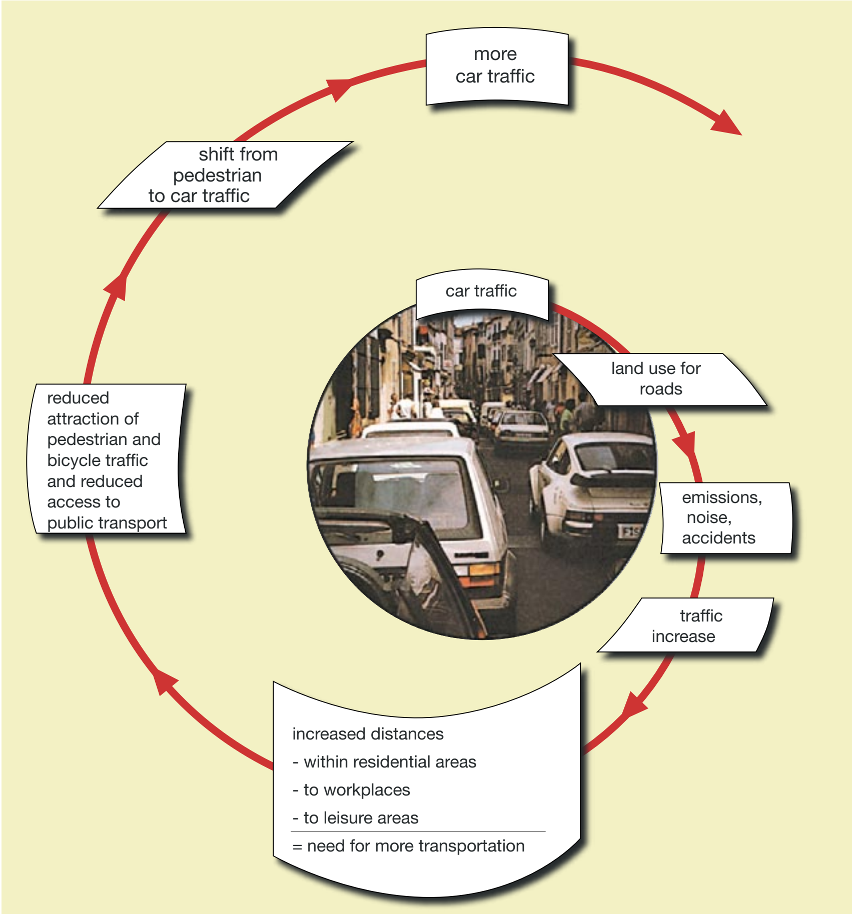


Figure 9
The vicious cycle of increasing car use.

TDM is not simply about implementing measures to improve mobility and reduce emissions, but also sending a message to all transport users that resources related to transport (road and parking space, fuel, time, public investment) are scarce and very valuable, and that social equity comes first. An adjustment in transport prices is long overdue and TDM provides a set of measures which address those concerns.

Regarding reduced travel, please see a technical paper from GTZ, which will be uploaded to http://www.sutp.org by May 2009.

Figure 10
TDM as an integral part of urban transport planning.

The challenges in urban transport and TDM

- Urban areas require proper road networks
- New roads attract more traffic and reduce the viability of public transport
- Transport benefits will be offset by future congestion

Transport Demand Management shall

- reduce the total volume of traffic
- promote shifts towards more sustainable modes of transport

with the objectives to

- reduce traffic congestion
- reduce adverse effects on the environment or public health
- generate additional revenue to improve public transport and NMT by pricing mechanisms

2.2 Principles of efficient pricing

Pricing can be an effective way to address transportation problems and increase transportation system efficiency, but to be effective, prices must reflect the following principles:

1. ***Consumer options.*** Consumers must have viable options from which to choose, so they can select the combination of quantity, quality and price that best meets their needs. For example, implementing road or parking pricing in a corridor may have little effect on traffic volumes if travellers have no viable alternatives such as high quality public transport serving that corridor.
2. ***Cost-based prices.*** To be efficient, prices (what consumers pay for a good) should reflect the incremental costs of producing that good, including direct and indirect costs of production, distribution and disposal.
3. ***Economic neutrality.*** This means that public policies treat comparable goods equally, unless there is a specific justification for special treatment. It means, for example, that policies should not favour automobile travel over other modes in terms of investments, regulations or subsidies.

Current transportation policies and planning practices are distorted in various ways that result in economically excessive motor vehicle travel, inferior travel options, and sprawled land use. Most costs of automobile travel are either fixed or external. Once the up-front investment is made to purchase a vehicle, there is an incentive to use it. When using a vehicle, drivers bear the cost of fuel and their own time, but they also impose congestion, accident, pollution, and infrastructure costs on others.

Figure 11
A bus stuck in heavy Hanoi traffic makes public transport less attractive to users.
Photo by Manfred Breithaupt, Hanoi (VN), 2006

Box 3: How sensitive is driving to price?

Economists have plenty of solid research showing that prices affect travel behaviour, but non-economists often cite anecdotal evidence that travel is insensitive to price, and so argue that price reforms are an ineffective way to affect travel behaviour. For example, they will point to a news article showing that a recent jump in fuel prices had little effect on automobile use, or data showing that people who live in countries with high fuel taxes continue to drive automobiles. "Motorists love their cars too much, they won't give them up," goes the claim. Such claims are partly true and largely false.

As it is usually measured, automobile travel is *inelastic*, meaning that a percentage price change causes a proportionally smaller change in vehicle mileage. For example, a 10% fuel price increase only reduces automobile use by about 1% in the short run and 3% over the medium run. Even a 50% fuel price increase, which seems huge to consumers, will generally only reduce vehicle mileage by about 5% in the short run, a change too small for most people to notice, although this will increase over time as consumers take the higher price into account in longer-term decisions, such as where to live or work.

But fuel prices are a poor indicator of the elasticity of driving, because over the long term consumers will purchase more fuel-efficient vehicles. Over the last few decades the real (inflation adjusted) price of vehicle fuel has declined significantly, and vehicle-operating efficiency has increased. Real fuel costs are now a third lower, and an average car is nearly twice as efficient. Residents of countries with high fuel taxes tend to purchase more fuel-efficient vehicles and drive fewer annual miles per capita. For example, fuel taxes are about 8 times higher in the U.K. than in the U.S., resulting in fuel prices that are about three times higher. U.K. vehicles are about twice as fuel efficient, on average, so per-mile fuel costs are only about 1.5 times higher, and automobiles are driven about 20% less per year, so annual fuel costs are only 1.25 higher than in the U.S. Similar patterns can be found when comparing other countries with different fuel prices. This indicates that automobile use is sensitive to price.

The relatively low elasticity of driving with respect to fuel prices hides a much higher overall elasticity of driving. Fuel is only about a quarter of the total cost of driving. The price sensitivity of driving is more evident when measured with respect to parking fees and tolls. A modest parking fee or road toll can have a major effect on travel demand. Some of this reflects changes in destination and route, but it also includes changes in mode and travel distance (Pratt, 1999). When per-mile or per-trip costs increase, motorists tend to drive less and rely more on other modes.

Table 4 below summarizes the impacts of various types of pricing changes on car ownership and car use.

Table 4: Impacts of different types of pricing

Type of impact	Vehicle fees	Fuel Prices	Fixed toll	Congestion pricing	Parking fee	Transit fares
Vehicle ownership. Consumers change the number of the vehicles they own.	✓				✓	✓
Vehicle type. Motorist chooses different vehicle (more fuel efficient, alternative fuel, etc.)	✓	✓				
Route Change. Traveller shifts travel route.			✓	✓	✓	
Time change. Motorist shifts trip to off-peak periods.				✓	✓	
Mode shift. Traveller shifts to another mode.		✓	✓	✓	✓	✓
Destination change. Motorist shifts trip to alternative destination.		✓	✓	✓	✓	✓
Trip generation. People take fewer total trips (including consolidating trips.)		✓	✓	✓	✓	
Land use changes. Changes in location decisions, such as where to live and work.			✓		✓	✓

Different price changes have different impacts on travel behaviour.
Adapted from Todd Litman, "Transportation Elasticities," 2007, http://www.vtpi.org

Box 4: The rationale for TDM

Scarce road space is currently usually allocated through queuing. The total costs of a motorised trip generally far exceed the individual costs borne by the vehicle occupants, especially in congested urban settings where the marginal costs of car use are high. This externalization of costs and inefficient allocation of road space results in worse congestion than would be the case under a pricing system where car users paid a more realistic price for their travel. Impacts of resulting urban congestion include:

- loss of time, and increased vehicle operating costs,
- more pollution than would be the case with smoothly flowing traffic,
- significant negative impacts on the viability of more efficient modes of public transport, walking, and cycling,
- dispersal of journeys to outlying city areas where current congestion is lower but to where it is likely to spread.

The basis for demand management is that unless the price directly incurred by travellers in making journeys covers the full costs of the journey, their travel will impose a net cost on the community.

Photo from Nordrhein-Westfalen/Germany

TDM promotes efficient use of street space

For example, although users may pay vehicle registration fees and fuel taxes that help finance roadway facilities these are not “efficient” prices that reflect the full marginal cost of each trip. As a result, problems such as traffic and parking congestion, excessive accident risk, and pollution emissions are virtually inevitable. This is inefficient and unfair, because space efficient vehicles, such as buses, are stuck in traffic along with space intensive vehicles such as private automobiles, so there is no incentive to use this space efficient mode. The result is an example of a “tragedy of the commons,” in which competition for resources (in this case, road space) makes everybody worse off overall.

"Underpricing increases automobile dependency and reduces travel choices, which is unfair to non-drivers and reduces the transport system's overall efficiency. Using automobiles for relatively short urban trips is a sub-optimal use of technology that exacerbates urban problems. Underpricing encourages automobile use for trips when more efficient alternatives such as walking, cycling, small low powered vehicles, and local buses are more appropriate."

British transportation planner H. Dimitriou, "Urban Transport Planning: A Developmental Approach" (1992)

A second problem is that drivers only bear a portion of the costs of vehicle use — some costs are imposed upon other drivers, but many costs are imposed upon society in general. Costs not borne directly by users are called ***external costs***, (or externalities, also called "hidden costs"). Transportation externalities include congestion, accidents, emissions and pollution, noise, and aesthetic factors which all negatively affect people and/or future generations. The external costs of transport can add up to be a significant drag on the national economy, particularly in developing countries, as shown in Box 4.

While externalized costs may account for about 3% to 5% of GDP in Europe and the U.S., they can account for as much as 10% of developing country GDP, (Breithaupt, 2000). One study at the University of California looked at transportation expenditures by people and public agencies over the ten-year period from 1990–2000. Drivers paid direct costs for road use amounting to US$600 to US$1,000 per vehicle per year, yet they imposed externalized non-monetary costs upon society ranging from US$400 to US$4,000; the social cost of motorway transportation was calculated to be US$8,800 to US$17,400 per vehicle per year. (Delucci, 1998).

Efficient pricing gives consumers incentives to choose the most efficient options for each trip. For example, congestion pricing (road tolls that are highest during congested periods) give travellers an incentive to change when and how they travel to avoid peak-period automobile trips when they can. Consumers can choose to drive during a peak period when they are willing to pay the extra financial cost, but they are rewarded with faster travel time.

2.3 Forces driving transport demand

Before any discussion on selected TDM measures, it is important to understand the driving forces behind transport sector trends. As policy challenges are identified, the appropriate policy solutions may be developed.

In order to evaluate TDM measures it is useful to consider various factors that affect travel demand and therefore influence travel behaviour. These factors include:

- Household wealth and vehicle ownership
- Road and parking facility supply and quality
- Prices (for fuel, road use, parking, transit fares)
- The relative speed, convenience and comfort of travel by private vehicle and public transport
- Walking and cycling conditions
- Land use patterns (the distribution of destinations)
- Traveller habits and expectations

As households become wealthier they are increasingly able to own and operate motor vehicles (including motorcycles and automobiles). Unless special effort is made to preserve

Figure 12
A highway interchange creates a barrier to non-motorised traffic in Beijing. Such car planning also eliminated living space in the city.
Photo by Carlosfelipe Pardo, Beijing (CN), 2007

travel options and manage travel demand, this can result in increasing traffic problems, which ultimately makes everybody worse off overall.

As the amount of land consumed for roads and parking grows, space for people to live, walk, and use bicycles for transport shrinks. With more cars crowding the roads, accidents increase and air quality deteriorates. Communities that fail to invest in comfortable and high frequency public transport become trapped in a vicious cycle where people flee rickety and unreliable buses for higher status cars. Those who can, flee cities to suburbs resulting in urban sprawl. This process can occur rapidly, shifting a community from being multi-modal (where consumers have a variety of functional travel options) to automobile dependent (where the transport system is dominated by automobile traffic) in just a few years. Communities divided by corridors of fast-moving cars become socially segregated and the mobility of those reliant on non-motorised modes becomes increasingly restricted.

"Traffic growth outpaces population and job growth, but expanding roads fails to yield long-term relief, because it induces more traffic. Transportation demand management recognizes that travel demand is not a given, but is a function of transportation policies, pricing, investments and choices."

Michael Replogle, transportation engineer and sustainability expert for Environmental Defense

These trends impose large economic, social and environmental costs, including increased traffic congestion costs, increasing road and parking facility costs, increased consumer costs, more crashes, increased energy consumption, increased pollution emissions, sprawled land use, reduced mobility options for non-drivers, and reduced public fitness and health. Described differently, policies that improve travel options and reduce urban vehicle traffic volumes and speeds provide many benefits to users, businesses, the economy, and the environment.

Many current trends point toward TDM as a solution, including increasing urban traffic and parking congestion, rising facility construction costs, aging population, rising fuel prices, increasing environmental concerns, increasing health concerns, equity objectives, and changing consumer preferences. Although each geographic region faces its own unique set of problems and development goals, many of these support increased application of TDM measures as they bring benefits to both individuals and society.

Some of the key trends are (Replogle, 2008):

- **Rising motorisation.** Increasing individual wealth results not only in higher car ownership, but also more sprawling settlements as people move to larger and higher quality residences that require more frequent and longer travel. This makes private car use more attractive and public transport less convenient.
- **Growing traffic congestion.** Increasing traffic congestion may result in dispersion and relocation of businesses to the urban edge. Declining accessibility to businesses and public institutions reduces not only quality of life but also the economic performance of cities.
- **Declining economic competitiveness**. As economic activities shift to the service sector, travel patterns become more dispersed, *i.e.* the peak demand decreases and the number of origins and destinations increases resulting in lower economic feasibility of public transport.
- **Public health and safety.** More vehicles moving at higher speeds leads to more frequent and more severe accidents, and more fatalities. High concentrations of vehicle emissions, particularly particulate matter from diesel combustion, are related to increasing cases of asthma and pulmonary disorders. Lifestyle changes resulting from more time spent in cars leads to higher rates of obesity.
- **Social segregation.** The gap between high income, high mobility citizens and others tends to grow with increasing motorisation. As lower income citizens lose access to jobs, goods, and services, mobility becomes a matter of social equity.

Figure 13: *Driving forces behind transport trends*

Driving forces	Trends in transport sector	Transport Demand Management Strategies	Trends in transport sector	Policy challenges
LOCAL				
Economic growth	Vehicle ownership ↑		Number of accidents ↑	Deteriorating health conditions
	Vehicle use ↑	Reduce/avoid need to travel, to move goods	Local air quality ↓	
Land availability	Larger vehicles ↑	Shift to environmentally friendly modes	Traffic congestion ↑	Declining accessibility
	Sprawl ↑	Promote compact growth patterns	Noise ↑	Social equity
Increasing individual wealth	Housing needs (m^2/inhabitant) ↑	Capture full cost of driving from users	Burdens on the poor ↑	Operating conditions of public transport
			Capital funds ↓	
	Expectations of comfort ↑		Operating funds ↓	
	Leisure time ↑		Non-motorised transport (NMT) marginaliszed ↑	
INTERNATIONAL				
Globalisation	Fuel consumption ↑	Promote sustainable development	Fuel prices ↑	Increasing energy demand
Urbanisation	Transport supply ↑		CO_2 emissions ↑	Climate change
Competition for foreign investment and tourism		Promote uptake of carbon dioxide (CO_2 reduction technologies		
		Improve system efficiency		

A variety of trends are increasing automobile ownership and use, which imposes economic, social and environmental costs. Transportation demand management can increase transport system efficiency, reducing costs and increasing benefits to individuals and communities.

- **Climate change.** Motorisation and sprawling growth results in more fuel consumption and vehicle emissions which contribute to global warming.

Although motorisation is increasing in many developing countries, it is possible to avoid *automobile dependency*, that is, excessive automobile use and a decline in the quality of transport options. Many developed countries are now applying TDM policies to improve travel options and encourage the use of efficient modes, resulting in the best of all worlds, a diverse transportation system in which people use the optimal mode for each trip. For example, many higher income countries such as the Netherlands, Sweden, Germany, Swizerland and Great Britain are improving walking and cycling facilities and public transport services, implementing road and parking pricing to encourage use of alternative modes, and applying smart growth land use policies to create more compact, walkable communities. Where these policies have been effectively applied, travel has shifted from automobile to alternative modes.

TDM policies have a number of justifications, including to address traffic and parking congestion problems, energy and environmental concerns, public health concerns, and a desire to create a more equitable transportation system that serves the needs of transportation disadvantaged people.

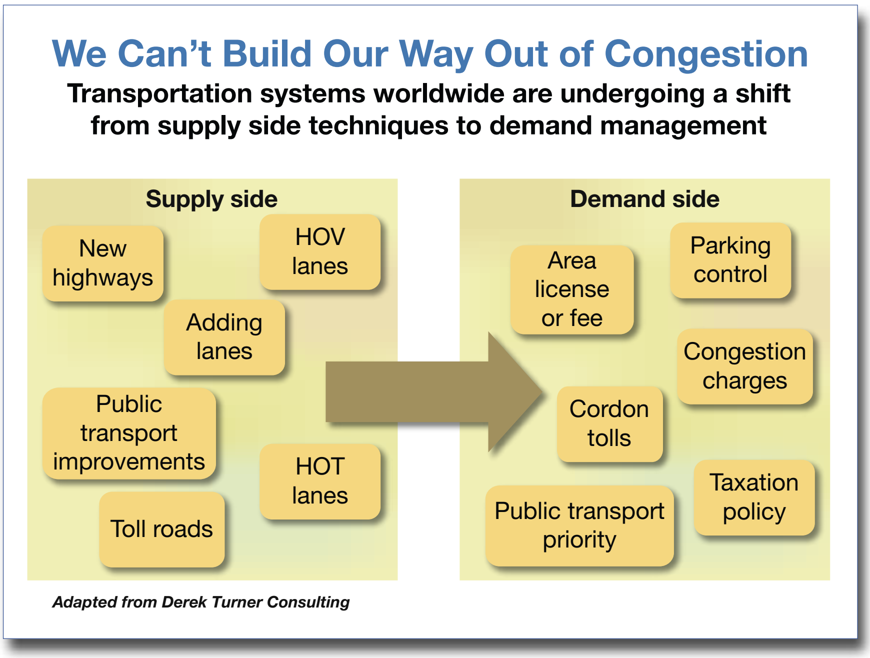


Figure 14
Paradigm shift from supply side measures to demand management.

"Supply side refers to the construction of roads and parking facilities. Although building a basic roadway system provides significant economic and social benefits, once that system becomes congested it is usually more cost effective and beneficial overall to address this problem with demand management programs that result in more efficient use of available capacity."

2.4 Travel impacts

TDM measures work in various ways with a variety of impacts. Not all TDM measures affect travel directly. Some provide a foundation for other strategies that change travel behaviour, which in turn have various economic, social and environmental impacts. These relationships are illustrated below.

Policies
(planning and investment practices, land use practices, tax policies, etc.)

↓

Programs and projects
(commute trip reduction, transportation management associations, non-motorised transport planning, parking management, school and campus trip management, etc.)

↓

Measures that directly affect travel behaviour
(parking cash out, congestion pricing, transit improvements, improved walking and cycling conditions, flextime, location efficient mortgages, higher parking fees, etc.)

↓

Travel impacts
(mode shifts, shifts in trip scheduling, shorter trip distances, reduced driving, increased load factors, etc.)

↓

Benefits
(improved mobility and access, cleaner air, road safety, road and parking facility cost savings, consumer savings, etc.)

TDM measures affect travel behaviour in various ways. An individual may change their route, mode of travel, and time of day for making their trip in response to TDM measures. A person may also travel less frequently, and choose closer destinations. When many individuals change their travel behaviour in these ways, large-scale impacts are seen, such as reduced traffic congestion, compact land use patterns and

Table 5: Examples of TDM travel impacts

TDM Measure	Mechanism	Travel changes
Traffic calming	Roadway design	Reduces traffic speeds, improves pedestrian conditions
Flexible work hours	Improved transport choice	Shifts travel time (when trips occur)
Road/congestion pricing	Pricing	Shifts travel time, reduces vehicle travel on a particular roadway
Distance-based charges	Pricing	Reduces overall vehicle travel
Transit improvements	Improved transport choice	Shifts mode, increases transit use
Ridesharing (carpool, vanpool)	Improved transport choice	Increases vehicle occupancy, reduces vehicle trips
Pedestrian and bicycle improvements	Improved transport choice, roadway design	Shifts mode, increases walking and cycling
Carsharing	Improved transport choice	Reduces vehicle ownership and trips
Compact land use (Smart Growth)	Improved transport choice	Shifts mode, reduces vehicle ownership and trip distances

Different types of TDM measures cause different types of travel changes.

viable public transport. Table 5 summarizes the travel changes that result from various TDM measures.

Models can help predict the travel impacts of various TDM measures. For example, most conventional four-step urban traffic models can predict the effects of increased transit service and road pricing, and spezialised models such as *TRIMMS* (Trip Reduction Impacts of Mobility Management Strategies) can predict the travel impacts of a commute trip reduction program, taking into account geographic location and the program features (http://www.nctr.usf.edu/abstracts/abs77704.htm). Some newer models can account factors such as land use density and mix. However, many TDM programs include strategies that are difficult to model, such as pedestrian service improvements and direct marketing programs, and so tend to overlook and undervalue comprehensive TDM programs.

Different types of travel changes can help achieve different types of planning objectives. For example, a TDM measure that shifts travel from peak to off-peak periods has different benefits and costs than a TDM measure that shifts travel modes. Table 6 shows which objectives are achieved by different types of travel behaviour changes.

Table 6: Benefits of different types of travel changes

Planning Objectives	Reduced traffic speeds	Shift trip time	Shorter trips	Shift mode	Reduced vehicle trips	Reduced vehicle ownership
Congestion reduction		✓	✓	✓	✓	✓
Road savings			✓	✓	✓	✓
Parking savings				✓	✓	✓
Consumer savings			✓	✓	✓	✓
Improved mobility options				✓	✓	✓
Road safety	✓		✓	✓	✓	✓
Energy conservation			✓	✓	✓	✓
Emission reductions				✓	✓	✓
Efficient land use			✓	✓	✓	✓
Public fitness and health	✓		✓	✓	✓	✓

Different types of travel changes help achieve different planning objectives.

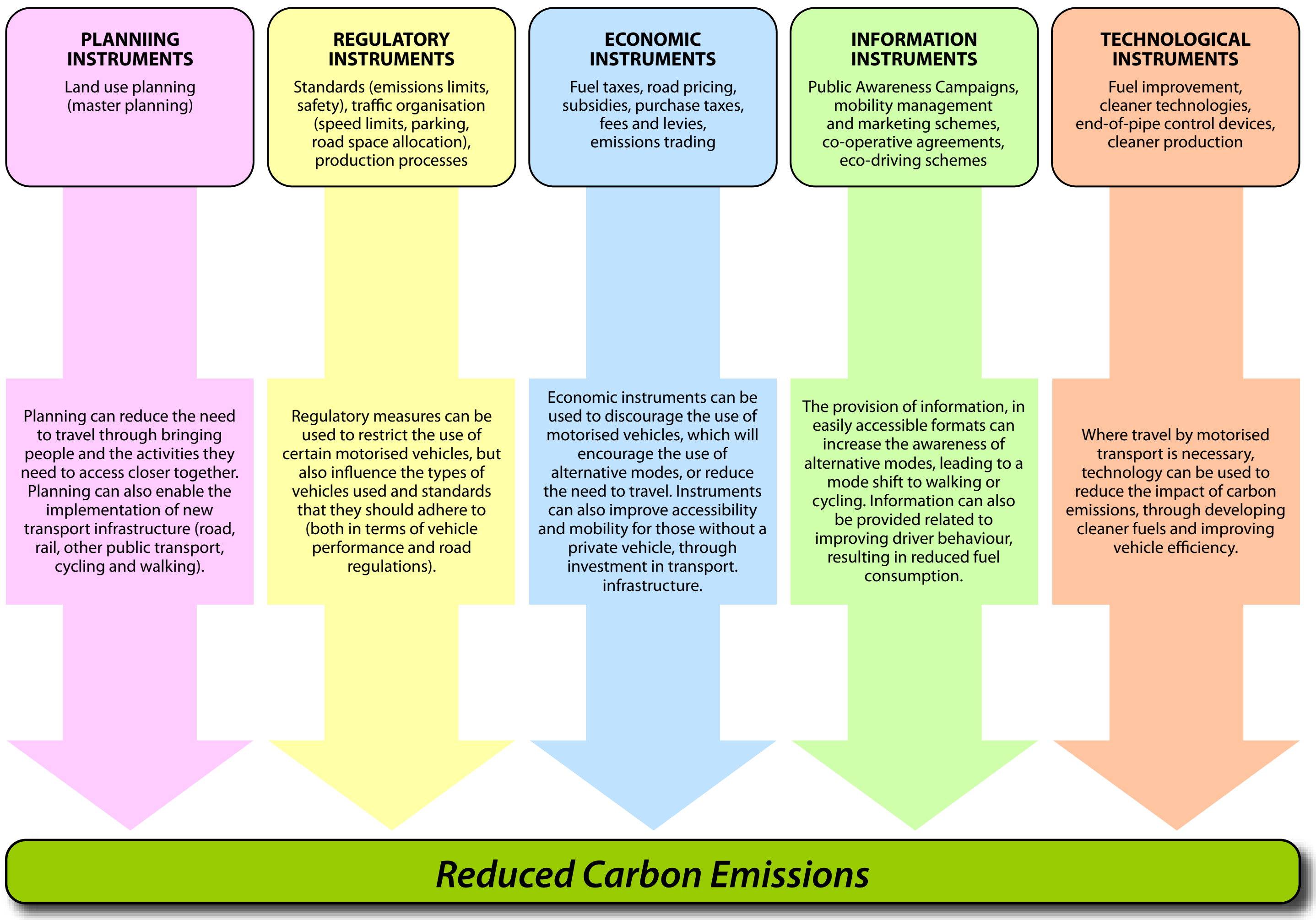
Transportation demand management allows economic development and prosperity without ever-growing motor vehicle traffic and the problems it would cause, helping to create a truly sustainable economy. For example, Singapore and Hong Kong have seen personal wealth grow while motor vehicle ownership remained steady. This is attributed to the thoughtful policy and investment changes that each city has made in providing high quality alternatives to driving, such as high frequency public transport.

Demand for travel is largely a function of the transportation options developed through the policy and investment decisions of governments. A comprehensive TDM strategy may be adopted as part of meeting broader policy goals for a nation.

Policy objectives of TDM may include, (Replogle, 2008):

- **Shaping travel mode choices to support broader policy goals.** Many TDM measures meet multiple policy goals, such as improving environmental quality and public health.
- **Promoting more efficient trip choices.** Making the cost of travel more apparent to the transport system user results in more efficient system use patterns and the elimination of unnecessary trips, which can enhance economic competitiveness.
- **Reducing unnecessary motor vehicle travel.** Providing safe and pleasant travel options, as well as ensuring that new development improves connectivity between homes and destinations, shift trips from cars to other modes.
- **Reducing trip lengths.** Promotion of compact development patterns helps conserve land for agriculture and environmental quality and enables more efficient transportation resulting in higher accessibility with less mobility.

Figure 15: *TDM as part of a sustainable transportation system*



2.5 Types of TDM measures

Figure 16
Congested street in Bangkok. Cars, motorbikes and buses are stuck in traffic most of the day.
Photo by Thirayoot Limanond, Bangkok (TH), 2006

TDM increases transport system efficiency by providing various incentives for individuals to change their travel time, route, mode, destination, frequency, and cost. People who choose more efficient options are rewarded with benefits, while people who continue with inefficient travel bear additional costs. This can provide significant savings and benefits, making everybody better off overall.

TDM focuses on access to services and activities, rather than vehicle traffic. This can greatly expand the range of solutions that can be applied to a particular transportation problem. For example, if a road or parking facility is congested at certain times, rather than expanding roads and parking facilities, TDM may encourage some people to shift from peak to off-peak periods, to travel by alternative modes (walking, cycling, ridesharing, public transport), to choose alternative destinations, or to park offsite at another parking lot.

Because TDM measures seek to influence behaviour they may involve a variety of stakeholders, not just transportation agencies. For example, a TDM program might involve regional governments (which plan roads and major transit systems), local governments (which build sidewalks and bike paths, and mange public parking), businesses (which manage employee and customer parking), and community organisations (which promote healthy and environmentally responsible behaviour).

Various policy and planning reforms are needed to help implement specific TDM measures. These can occur at various political and administrative levels. A policy refers to a goal, strategy or priority declared by a political body that guides decision making and resource allocation. A regulatory measure administratively sets standards and procedures, sometimes referred to as a “command and control” approach. Policy and regulatory measures may be implemented by many levels of government.

Enforcement and public awareness are critical supportive efforts to the successful impelementation of TDM measures. Information services should be offered to assist with behaviour change, and public opinion should be monitored to gauge acceptance. There are many ways that private sector stakeholders such as firms and individuals can make TDM measures more effective. Private-sector TDM measures which complement government efforts include encouraging businesses such as car-sharing, and cooperative agreements which engage large employers in their own awareness-raising and incentive schemes for employees.

It is helpful to categorize TDM measures in terms of their approach and the stakeholders that need to be involved in implementation, as shown in Table 7. This document divides TDM measures into three basic groupings: 1) Improve Mobility Options, 2) Economic Measures, 3) Smart Growth and Land Use Policies.

Table 7: Types of TDM measures

TDM Measure	Implemented by	Key Stakeholders
Improve Mobility Options (walking and cycling facilities; rideshare and public transport services)	City, State, National governments, transit service and shared bicycle service operators	Children and older adults, individuals with disabilities, low income individuals
Economic Measures (financial incentives to use efficient modes)	City, State, National governments, private companies (as employers), toll road and parking facility operators	Large employers, freight haulers, low income individuals,
Smart Growth and Land Use Policies (development policy to create more accessible and multi-modal communities)	City, State, National governments, developers, households (when they select a home) and businesses (when they select a building location)	Real estate developers, large employers, home buyers

This table summarizes various categories of TDM measures, organisations responsible for implementing them, and key stakeholders who are affected.

Table 8 lists various examples of measures in these three basic categories. Many of these have additional subcategories. For example, transit improvements may include a variety of specific measures that improve transit travel convenience, comfort, security and affordability.

Table 8: Examples of TDM measures

Improve Transport Options	Economic Measures	Smart Growth and Land Use Policies	Other Programs
Public transit improvements	Congestion pricing	Smart growth	School and campus transport management
Walking and cycling improvements	Distance-based fees	Transit-oriented development	Freight transport management
Mobility management marketing programs	Commuter financial incentives	Location-efficient development	Tourist transport management
Rideshare/commute trip reduction programs	Parking pricing	Parking management	
HOV priority lanes	Parking regulations	Car-free planning	
Flextime/telecommuting	Fuel tax increases	Traffic calming	
Carsharing services	Transit encouragement	Transport planning reforms	
Taxi service improvements			
Guaranteed ride home program			
Shared bicycle services			

This table lists various TDM measures, adapted from VTPI (2006). More explanation and further examples may be found at http://www.vtpi.org.

2.5.1 Improving mobility options

A variety of specific actions can improve the relative availability, convenience, speed, comfort, and security of alternative modes, including walking, bicycling, ridesharing (carpooling and vanpooling), public transport, carsharing. Implementation actions can include building new or improved transportation facilities, regulatory changes that favour alternative modes, and the provision of new services and programs.

Many of these measures involve physical design changes, such as reconfiguring streets or intersections. Some increase the capacity or comfort of the transport system, such as adding more transit services or improving transit stops and stations. Some involve new services or programs, such rideshare matching or policies that allow employees to telecommute. They may be implemented by transportation and planning agencies, private contractors, community organisations, or private businesses.

Box 5: Improving accessibility

There is an important distinction to be made regarding how the performance of the transportation system is evaluated, whether for *mobility* and *accessibility*:

Mobility Prioritizing the efficient movement of vehicles, using physical (technical) solutions to improve modal level of service;

Accessibility Prioritizing the efficient movement of people and goods, using solutions that change behaviour to encourage mode shift.

When mobility is the priority, transportation planning, policy and engineering is focused on ways to improve the transport system to increase vehicle volumes and speeds. That is, the emphasis of transport investments is on moving more *vehicles* more quickly. This is the mindset which produces the car-dominated cities. By focusing on vehicles, the most efficient solutions for moving more *people* more quickly may be overlooked. Mobility planning puts vehicles in conflict with non-motorised modes, while accessibility planning tends to create synergies.

Accessibility prioritizes the movement of people and goods. The emphasis is on the outcomes and performance of the transport system. When policy, planning and engineering are focused on improving access, a wide variety of investments are made — not just roads. Accessibility planning may begin by measuring how long it takes to travel to a city centre or a major employment destination. A "time isochrone map" may be a starting point, showing which areas have the longest travel time by public transport, and identifying major barriers to bicycle and pedestrian traffic (like wide or busy roads). Then targeted solutions may be developed, such as new transit or shuttle bus service.

For more discussion on this issue see Todd Litman, "Evaluating Accessibility" (http://www.vtpi.org/access.pdf).

Figure 17
Lane exclusively for buses during peak hours ensures efficient operation and better service in Shanghai.
Photo by Armin Wagner, Shanghai (CN), 2006

2.5.2 Economic measures

Various economic and regulatory measures can encourage travellers to use the most efficient option for each trip. These can include pricing (*e.g.* road, parking, fuel and public transport prices and taxes), and regulatory instruments which control the availability of goods, which may affect market prices (*e.g.* minimum parking requirements in zoning codes that reduce parking prices, and emission auction schemes that impose a cost on pollution).

Full cost pricing means that users directly bear all the costs resulting from the production or consumption of a good or service. When applied to transportation, this means that motorists pay directly for all costs of the roads and parking facilities they use, with fees that increase during peak periods and decline during off-peak periods. It also means that fuel prices should incorporate all direct and indirect costs of fuel production and distribution, that vehicle insurance fees should reflect the incremental crash costs for each kilometre driven, and that vehicle users should pay pollution emission fees. Full cost transportation pricing tends to be the most fair and efficient policy (unless a subsidy is specifically justified on equity grounds or to achieve strategic planning objectives). It gives consumers an incentive to use transportation resources efficiently, for example, by preventing society from devoting US$10.00 to pay for roads and parking facilities to accommodate a trip that the motorist only considers worth US$5.00.

Described differently, efficient pricing gives individual consumers the savings that result when they reduce driving. For example, if roads and parking facilities are financed indirectly, through general taxes and rents, consumers bear these costs even if they seldom or never use those facilities. This is unfair and inefficient. With full cost pricing, consumers only pay according to their use of roads and parking facilities, in order to save money by reducing their vehicle ownership and use, as illustrated in Figure 18.

Figure 18: *Efficient pricing gives consumers more opportunities to save*

Current pricing	Efficient pricing
Motorist reduces vehicle trips ⇩ Reduced costs to motorist and to society (congestion, road & parking facility costs, accidents, pollution, etc.) ⇩ Cost savings widely dispersed through economy	Motorist reduces vehicle trips ⇩ Reduced costs to motorist and to society (congestion, road & parking facility costs, accidents, pollution, etc.) ⇩ Cost savings returned to the individual motorist

With current pricing, savings from reduced driving are dispersed through the economy. Efficient pricing returns more savings to individuals who reduce their driving.

Economic measures can be powerful and effective at solving traffic problems and increasing transportation system efficiency, plus they provide additional revenues which can be used to finance new programs or reduce other taxes. However, they tend to be politically difficult to implement, because motorists frequently object to new fees and taxes. Their implementation therefore requires careful negotiation to build adequate political support, with special consideration to insure that revenues are used efficiently and in ways that provide broad community benefits.

A long-term strategy is needed to implement full cost pricing measures (or 'internalization' of transport costs). Steep price hikes in the short-term are too extreme to be politically acceptable. Adjustment of market structures, transport use, behaviour, technologies and supply/demand patterns needs time. Internalizing costs step by step in a long-term strategy, together with improvements to NMT and public transport, is necessary for full cost pricing have a chance of being accepted by market participants and gain sufficient political support.

2.5.3 Smart growth and land use management policies

Various land use factors affect travel behaviour. People who live or work in more compact, mixed, walkable, transit oriented communities tend to drive less and rely more on alternative modes. As a result, "smart growth" policies that help create more accessible, multi-modal communities can be an effective TDM strategy. This is sometimes called "integrating transportation and land use planning." For instance, by concentrating commercial development and dense housing along transit corridors and near transit stations, and improving walking and cycling conditions in such areas, overall accessibility increases, reducing total automobile travel and increasing use of alternative modes.

Smart growth and land use policies are not effective TDM measures in the short term, but rather, over a long timeframe. Many market forces can affect their effectiveness, and so they must be part of an integrated solution for mobility and growth management.

2.6 Developing a comprehensive TDM strategy

Most TDM measures have modest individual impacts, typically affecting a few per cent of total vehicle travel in an area. In order to achieve significant total impacts it is usually necessary to develop a comprehensive TDM strategy that includes an appropriate set of measures. A comprehensive TDM strategy can have synergistic effects, that is, its total impacts are greater than the sum of TDM measures implemented individually. A well planned, integrated TDM strategy allows each measure to be used most effectively, targeting the appropriate types of travel and supporting other measures.

For maximum effectiveness and benefits, a comprehensive TDM strategy needs both positive ("pull") incentives, such as improved travel options, and negative ("push") incentives, such as road and parking fees. When only "pull" incentives are implemented, such as investments to improve walking and cycling conditions and improve public transport service quality, little modal shift may be achieved. Investments in alternative modes may go unused if driving remains a cheap and time-efficient option. Likewise, when only "push" incentives are implemented, such as driving fees and road tolls, drivers are may only be frustrated and react against policy makers. It is unfair and impractical to discourage driving without providing practical alternatives. For these reasons, push and pull incentives must be paired.

Figure 19: *TDM measures with "push" and "pull" effects*

Measures with push- and pull-effects
Redistribution of carriageway space to provide cycle lanes, broader sidewalks, planting strips, bus lanes, …, redistribution of time-cycles at traffic lights in favour of public transport and non-motorised modes, public-awareness-concepts, citizens' participation and marketing, enforcement and penalizing…
Source: Müller *et al.,* (1992)

For instance, significant bus service improvements in Stockholm, Sweden initially caused little increase in ridership, but when a congestion charge was also implemented, public transport travel increased by about 5%. Planners concluded that, "Of the 22% decrease in car travel across the charge zone, only 0.1% at most could have been caused by the expanded bus services," (City of Stockholm, 2006). Section 4.2.2.2 discusses the Stockholm congestion charge in more detail.

Experience in many cities indicates similar results: increasing transportation system efficiency requires a comprehensive TDM strategy that improves mobility options and encourages users to select the most efficient mode for each trip. Such integrated programs can achieve significant mode shifts and benefits.

Just as supply-side transportation measures are implemented at a mixture of approaches and scales, so demand-side measures should be. Unless a mix of TDM measures are applied, they may not achieve the desired effects. It is important to pair "Push and Pull" TDM measures when developing a comprehensive TDM strategy.

Table 9: Pairing push and pull TDM measures

	PUSH	PULL
Policy/Regulatory/ Economic Measures	**Restrict car access** ■ road pricing ■ congestion pricing ■ sales tax/import duty ■ registration fee/road tax ■ car quota system ■ parking pricing ■ parking management ■ plate restrictions ■ low emission zones ■ 20 km per hour zones	**Improve transit services** ■ integrated system and fare structure ■ network of priority transit corridors **Incentives for commuters** ■ parking spot cashout ■ tax reduction for transit pass ■ tax reduction for biking and walking
Physical/Technical Measures	**Reduce car mobility** ■ reduce parking supply ■ traffic cells ■ traffic calming **Road space reallocation** ■ reconnect severed neighbourhoods **Restricted traffic zones** ■ pedestrianonly zones	**Improve quality of transit service** ■ bus rapid transit system ■ bus lanes ■ bus priority ■ light rail and commuter rail services **Improve bus infrastructure** ■ quality vehicles ■ comfortable bus stations ■ easy to find route and timetable information, bus information at bus stops, train arrival information at stations **Improve bicycle infrastructure** ■ bicycle lanes and parking ■ bicycle route signage and maps **Improve pedestrian infrastructure** ■ safe sidewalks and crosswalks ■ pedestrian zone **Improve mobility options** ■ car sharing services ■ shared bicycle services ■ improved taxi and pedicab/rickshaw services
Plan/Design Measures	**Integrated land use planning** ■ regional spatial planning ■ transit oriented development ■ car parking planning standards to ■ complement transport policies	**Planning for nonmotorised transport** ■ street design for bicycles/pedestrian traffic ■ connectivity of streets ■ maps and wayfinding aids
Support Measures	**Enforcement** ■ fines, tickets and towing	**Public awareness** ■ marketing transit/explaining need for TDM measures ■ events like Car Free Day

A comprehensive TDM strategy for a city requires a mix of the three types of TDM measures:

1. Improve mobility options
2. Economic measures
3. Smart growth and land use policies

A comprehensive TDM strategy is like ***a three legged stool*** — it will not stand up without all three legs, because they all reinforce each other. For instance, London implemented a package of TDM measures using a congestion charge — a "Push" measure — as the main driving force to encourage mode shift. Before it went into effect, the city's fleet of buses was nearly doubled with new, comfortable buses running on an enhanced schedule with more frequent service oriented around links to the subway system. New technology was introduced to boost the convenience and speed of the buses, such as smart farecards, priority at traffic signals, and displays at bus stops announcing the arrival of the next bus. Roads were repainted to dedicate lanes to bus and bicycle traffic. In addition, the city closed some streets to car traffic to improve safety and comfort for bicyclists and walkers, and improved pedestrian crossings and way-finding signs. This mix of "Push" measures spanning the regulatory, physical, technical, planning and design realms combined with the powerful economic incentive of the congestion charge to result in reduced car traffic, increased bus ridership, improved air quality and renewed vitality in downtown retail districts.

Another example is found in Singapore. Before Singapore introduced the Area Licensing Scheme (congestion pricing for the city area) in 1975, the bus services were completely revamped to cater for the expected change in modal shift. A park and ride service was offered from 15 car park and ride lots at the periphery of the city for those drivers who did not wish to drive into the city. The ring road skirting the city was improved so that cross-town traffic no longer needed to use the city roads. These "pull" measures helped achieve the desired modal shift.

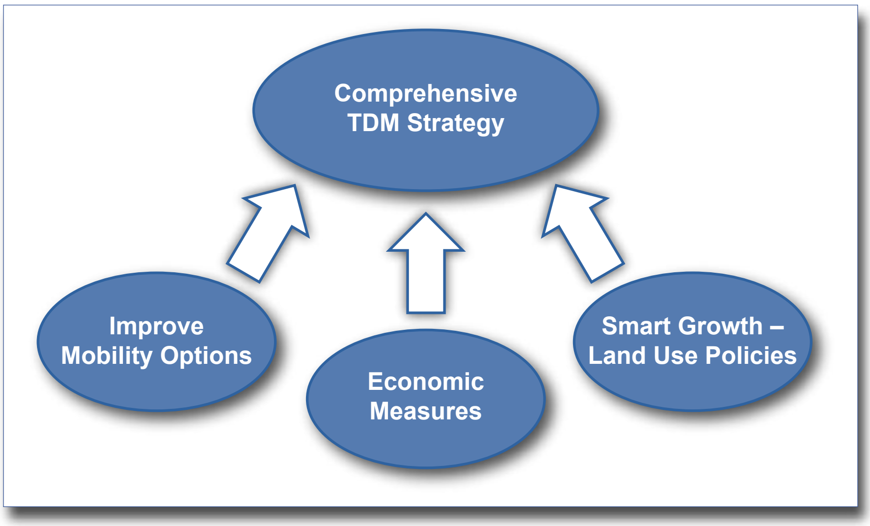


Figure 20
Three-pronged approach for successful implementation of TDM measures.

A three-pronged comprehensive TDM strategy approach requires support from the various institutions responsible for implementing TDM measures. This means that the stakeholders need to be informed, motivated, and engaged. Supportive measures implemented by law enforcement and by private-sector stakeholders also play an important legitimizing role.

Box 6: Solving transportation problems with TDM

Transport problems and solutions can be viewed in two different ways. One is as *individual problems with technical solutions*: traffic and parking congestion require building more roads and parking facilities; crash risk requires roads and vehicles that offer greater crash protection; energy problems require alternative fuels and efficiency standards. The motto is, "adjust roads and vehicles, not driver behaviour."

But this approach has a fundamental flaw. Solutions to one problem often exacerbate other problems, particularly if they increase total vehicle travel. For example, over the long run, increasing roadway capacity tends to increase crashes, energy consumption and pollution, due to induced vehicle travel; crash protection requires heavier vehicles that consume more energy; fuel efficiency standards reduce the per-mile cost of driving, stimulating more traffic congestion and crashes. As a result, this approach cannot solve all problems, because the more a solution achieves its objectives, the more it exacerbates other problems.

The other perspective is that most transportation problems share a common root: *market distortions that result in excessive automobile use.* From this perspective, solving transport problems requires planning reforms that increase transport options, and market reforms that give consumers suitable incentives to choose the best option for each individual trip. The motto is, "increase transportation system diversity and efficiency." Transportation Demand Management is the general term for this approach.

Although most individual TDM measures only affect a small portion of total travel, and so their benefits appear modest with respect any particular problem, their impacts are cumulative and synergistic. When all benefits and costs are considered, TDM programs are often the most cost effective way to improve transportation.

Conventional evaluation practices tend to overestimate the overall benefits of technical solutions, because they ignore indirect costs (such as the problems resulting from induced vehicle travel), and they tend to underestimate the full benefits of TDM measures (such as helping to improve mobility for non-drivers, or support for strategic land use objectives). More comprehensive evaluation and planning practices are needed for TDM to receive the recognition and support that is justified.

Adapted from the Online TDM Encyclopedia by Todd Litman, http://www.vtpi.org/tdm/tdm51.htm

3. Improving mobility options ("PULL")

For maximum effectiveness and benefits, a comprehensive TDM strategy needs both positive ("pull") incentives, such as improved travel options, and negative ("push") incentives, such as road and parking fees. This section focuses on "pull" measures, which generally increase mobility options, such that drivers are "pulled" to using alternative modes of travel. Pull measures include a range of investments in high quality infrastructure and services that make alternative modes competitive with car travel for convenience and time efficiency.

Mobility options can include:

- Walking;
- Cycling;
- Ridesharing (car and vanpooling);
- Public transport (shared taxi, bus, train, ferry boat, etc.);
- Private taxi;
- Car-sharing (vehicle rental services located in neighbourhoods, designed to substitute for private vehicle ownership).

There are many different ways to improve mobility options, including increasing when and where these modes are available, making them more convenient and comfortable to use, improving user information, and increasing affordability. Improving connections between these modes also improves mobility options, for example, by providing bicycle storage at public transport stations, or arranging for stores to offer delivery services to customers who arrive by foot or public transport. Other supportive measures that improve mobility options include increasing user security, raising their social status, and by creating communities that provide better access by alternative modes. Specific types of improvements are described below.

Figure 21
Separated paths for bicycles and pedestrians reduces risk of accidents in Taipei.
Photo by Powell, Taipei (TW), 2005

Figure 22
High quality tram and bus interchange in Kassel makes public transport more time competitive.
Photo by Alex Kühn, Kassel (DE), 2005

3.1 Improving walking and cycling conditions

Frequently, new roads and infrastructure serving cars in developing cities has been built with poor regard for existing patterns of foot and bicycle travel. As a result, car infrastructure such as roads, viaducts, and parking lots can form significant barriers to non-motorised traffic, resulting in severed, or divided, communities. The issue of severance leads not only to significant shifts in travel patterns within a community, but to social divisions. It may be possible to reconnect divided communities by retrofitting busy roads with separated walk and bikeways, or building new bridge crossings over wide and busy roads.

Severance problems can be created by unsafe, high-speed roads, by restrictions to non-motorised vehicles on specific streets, by barriers to

Figure 23
Sidewalks blocked by parked vehicles reduces walkability on this Ho Chi Minh City street.
Photo by Gerhard Menckhoff, Ho-Chi-Minh-City (VN), 2004

Figure 24
Children risking their lives in Vientiane by running on the street due to lack of safe crossing options.
Photo by Thirayoot Limanond, Vientiane (LA), 2006

crossing streets, by a one-way street system, and by large canals, railroad tracks, and other impassable infrastructure. Detour factors are the distance that the average cyclist or cycle rickshaw operator needs to travel out of their way in order to reach their destination, relative to the distance as the crow flies (straight line distance).

As large infrastructure such as motorways and viaducts age, they require increasingly frequent and more expensive maintenance. Eventually the cost of maintenance can begin to outweigh the benefits of the road capacity. Several U.S. cities have experienced this cycle of infrastructure obsolescence, and have chosen to remove large and divisive structures in favour of smaller scale and more community friendly infrastructure. San Francisco is one example, where the Embarcadero viaduct along the waterfront was torn down after being damaged in an earthquake. In Seoul, an urban motorway viaduct was demolished and replaced by a river walk parkway, (see Figures 25a, b and 26).

3.1.1 Improving pedestrian infrastructure

Developing cities often have a high mode share of people walking, but could do a great deal to improve the level of service for pedestrians through changes to the infrastructure. Pedestrian infrastructure serves those walking along or across roads, ranging from sidewalks to overpasses and tunnels to signals and crosswalks.

Sidewalks and paths must accommodate many uses and types of users. People walk alone, in

Figure 25a and 25b
Demolishing an urban highway in Seoul created urban greenspace and valuable redevelopment opportunities.
Photo by Seoul Development Institute

Figure 26
Improved infrastructure in Seoul leads to increased quality of life.
Photo by Lloyd Wright, Seoul (KR), 2005

groups, walk pets, push strollers and carts, run, skate, stop to gaze and talk, play and eat on sidewalks and paths. Many paths also accommodate scooters and bicycles. Different uses and users require different amounts of space. Although a person walking alone may only need 18–24 inches (45–60 cm) of width, other users and uses require more space. A couple walking side-by-side, a person in a wheelchair or pushing a cart, a runner or bicyclist all require more space.

In addition, sidewalks and paths contain various types of "furniture" such as signposts, parking meters, mail boxes, garbage cans and sometimes café seating. When people pass each other or an object on the path, they require adequate "shy distance", or room to pass. Although a sidewalk or path may have a generous nominal width, its functional width may be much smaller due to various types of obstacles within its right-of-way. A sidewalk or path should be designed and managed to accommodate various uses and users, taking into account actual uses and conditions.

It is also useful to collect traffic accident data for accidents involving non-motorised road users from the police and map the locations as precisely as possible. At the very least, intersection and non-intersection accidents should be separated. Even though the numbers are likely to be significantly undercounted, this simple mapping exercise should make it possible to identify particularly dangerous locations. Once you have identified the locations where improving non-motorised vehicle and pedestrian facilities are a priority, specific designs can be developed.

A basic first step is to conduct an evaluation of the walking conditions, or walkability, of an area. Walkability takes into account the quality of pedestrian facilities, roadway conditions, land use patterns, community support, security and comfort for walking.

There are many physical measures that improve walkability, (from Litman, 2008):

Figure 27
A blocked pedestrian path in Pattaya due to poor design, and lack of parking enforcement.
Photo by Carlosfelipe Pardo, Pattaya (TH), 2005

Figure 28
A wide pedestrian path on the median in Bangkok has trees to separate from car traffic and also provides shade to keep users cool.
Photo by Thirayoot Limanond, Bangkok (TH), 2005

- Wide sidewalks with a clear walking area, *e.g.* utility poles, water hydrants, and other street furniture should be on the edges
- Painted, signed and lighted crosswalks
- Security lighting along sidewalks and off-street pathways
- Maintenance to repair pavements and keep pathways are free of litter and obstructions
- Pedestrian countdown signals, which indicate how many seconds are left in the walk phase
- Street furniture like benches, street lights, public toilets
- Covered waiting areas to protect transit passengers from sun and rain

Walkability improvements are usually implemented by local governments, sometimes with funding and technical support of regional or state/provincial transportation agencies. The first step is a planning process to identify problems and prioritize projects.

> ***"A walkable community is designed for people, to human scale, emphasizing people over cars, promoting safe, secure, balanced, mixed, vibrant, successful, healthful, enjoyable, and comfortable walking, bicycling and human association. It is a community that returns rights to people, looks out especially for children, seniors and people with disabilities and takes aggressive action to reduce the negative impacts of sixty-plus years of auto-centric design and uncivil driving practices. It is also a community that emphasizes economic recovery of central neighbourhoods, promotes the concepts of recovering and transforming suburban sprawl into meaningful villages, and especially takes ownership and action to protect and preserving open space."***
>
> Dan Burden of Walkable Communities (http://www.walkable.org)

Figure 29

Pedestrian and vehicle spaces are separated by bollards in Toulouse.

Photo by Andrea Broaddus, Toulouse (FR), 2007

3.1.1.1 Sidewalks and crosswalks

All urban roads should have safe areas for people walking, such that they are separated from motorised traffic. Sidewalks are commonly grade separated, that is, they are built higher than the grade of the roadway, which improves visibility and protection. However many cities have adopted a newer "shared space" approach in which textured pavements, trees, and bollards serve to slow vehicles to speeds such that pedestrians can safely walk alongside and between them.

Figure 30

A Shared Pedestrian and bicycle path in Chiba.

Photo by Lloyd Wright, Chiba (JP)

Crossing roads is a critical safety issue for those walking. Car-dominated road design results in wide roads with many lanes which are difficult for some pedestrians to cross within the time allotted by traffic signals. In such cases "pedestrian islands" are often used to give people a stopping point halfway across. Ideally people are always able to cross at a zebra crossing, a traffic signal or signed mid-block crossing. However, motorways and higher speed arterials with few traffic signals may require a separate facility for pedestrians, such as a pedestrian overpass or tunnel. These are certainly more expensive to build, but can provide invaluable safety improvements and connections within a community which has been severed by a busy road. Overpasses and tunnels require pedestrians to climb staircases; hence it is useful to provide gentle ramps or escalators (where feasible). Otherwise, people often persist in trying to cross the "barrier" road despite very unsafe conditions, resulting in injuries and fatalities.

Modern sidewalks often separate foot and bicycle traffic, which move at different speeds. This helps reduce the risk of collisions between people walking and cycling.

3.1.1.2 Pedestrian zones

In areas of the city where foot traffic is very high, it may be appropriate to close or significantly restrict vehicle traffic. Pedestrian zones are usually in city centres where streets are narrower, and in shopping or market areas. Streets in these areas may restrict normal traffic circulation, but permit resident, delivery and public transport vehicles operating at very low speeds. A large number of European cities have created pedestrian zones in historic central and shopping areas since the 1960s. These are often

Figure 31a

A zebra crossing in Bangkok forces pedestrians to climb up to the sidewalk when crossing.

Photo by Carlosfelipe Pardo, Bangkok (TH), 2005

Figure 31b

This zebra crossing in Bayonne provides a refuge for pedestrians to cross a wide street safely.

Photo by Andrea Broaddus, Bayonne (FR), 2007

Figure 31c

A multi-modal crossing for pedestrians and bicyclists in Paris guides users to avoid collisions.

Photo by Andrea Broaddus, Paris (FR), 2007

Box 7: Building safe and comfortable streets for pedestrians

The basic principles to protect pedestrians are:

Slow down traffic speeds.

- Speed restrictions paired with physical infrastructure changes
- Restructuring roads to meander around trees and medians, forcing vehicles to go slow
- Raised zebra crossings
- Changing from smooth to rough road surfaces or using rumble strips.

Reduce the distance pedestrian needs to cross.

- Traffic islands (There is a question about whether it is feasible to put traffic islands in the middle of a multi-lane one-way street. There are a few examples (including in Curitiba, Brazil), but they are rare. This is a major concern in many Indonesian cities which have very wide one-way streets with long distances between traffic lights or intersections.)
- Neck-downs at intersections, where the road is tapered, narrowing into the intersection (Most roads are wider than they need to be at intersections; neck-downs also slow turning traffic and improve pedestrian visibility to turning vehicles).

Reduce the amount of overall motor vehicle traffic on major NMT routes.

- Traffic cells (rerouting through traffic out of neighbourhoods), parking restrictions, congestion or cordon pricing, reducing lane widths, closing streets to traffic and other measures.
- Send signals to drivers that they are operating on areas intended for pedestrians, using signs, bollards, and textured/coloured pavements.
- Elevating crosswalks at intersections rather than having pedestrian descend to the roadway, which can also be done with paint, design features, and markings.

Physically protect pedestrian facilities from incursions by motor vehicles.

- Placing bollards to protect kerbs at intersections prevents lorries and motorists from jumping kerbs and hurting pedestrians. Bollards also are used to prevent motorists from parking across sidewalks.

Traffic crossing signals.

- NMT-only phase allowing pedestrians and cyclists to clear the intersection before the turning motor vehicle traffic
- No right turn allowed on red lights
- Separate signals for NMT (In the Netherlands, there are entirely separate traffic signals for bicyclists, motorists, pedestrians, and trams. While this allows tram and bicycle prioritisation, it is also visually confusing to some people.)

In developing countries, it is quite common to have very large unsignalised intersections. These large unsignalised intersections are extremely dangerous for pedestrians and NMVs.

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3d: Preserving and Expanding the Role of Non-Motorised Transport," by Walter Hook for GTZ, http://www.sutp.org

Figure 32a

Wide pedestrian crossing with markings for both directions in Singapore.

Photo by Karl Otta, Singapore, 2004

Figure 32b

Roadway overpass for pedestrians and bicyclists in Nagoya.

Photo by Lloyd Wright, Nagoya (JP), 2006

Figure 33

A roadway neckdown, sign, and speed bump ensures that cars slow down in Bayonne.

Photo by Andrea Broaddus, Bayonne (FR), 2007

accompanied by parking garages or park-and-ride lots on the edge of the pedestrian zone.

Central Copenhagen is one of the largest and oldest examples of a pedestrian zone: the auto-free zone is centred on Strøget, a pedestrian shopping street, which is in fact not a single street but a series of interconnected avenues, crossed in places by streets with vehicular traffic. Most of these zones allow delivery lorries to service the businesses located there during the early morning, and street-cleaning vehicles will usually go through these streets after most shops have closed for the night.

Argentina's big cities; Córdoba, Mendoza and Rosario have lively pedestrian zones combined with town squares and parks which are crowded with people walking at every hour of the day and night. In Buenos Aires some stretches of Calle Florida Street have been pedestrian zones since 1913. On car-free Calle Florida and other streets there is a vibrant shopping and restaurant scene where street performers and tango dancers abound.

3.1.2 Improving bicycle infrastructure

Many developing cities have a high mode share of people bicycling, but need to retain or improve the level of service for bicycles. Bicycle infrastructure ranges from space on the roadway to parking facilities to overpasses and tunnels. Table 10 describes various types of cycling facilities, including some that lack special designation or features, which should still be designed, maintained and managed to safely accommodate bicycles. Improving these facilities tends to improve cycling conditions and increase cycling activity.

Figure 34a

Car free pedestrian zone in Berlin with restricted access times for trucks and bicycles.

Photo by Manfred Breithaupt, Berlin (DE), 2003

Figure 34b

Pedestrian zones in shopping districts increase the visual interest and convenience of walking, such as this vibrant street in Naples.

Photo by Andrea Broaddus, Naples (IT), 2007

Figure 35
Pedestrian zones like this one in Chengdu may restrict cars and bicycles, but allow vendors and street performers.
Photo by Karl Fjellstrom, Chengdu (CN), 2003

Figure 36
A well designed bicycle lane with painting and textured pavement in London.
Photo by Lloyd Wright, London (UK), 2006

A significant amount of cycling occurs on roads, motorway shoulders and sidewalks that have no special designation or design features for cycling. It is therefore important to design, maintain and manage all of these facilities to accommodate cycling. For example, as much as possible roadways should have minimal potholes and cracks that can catch a bicycle tire, particularly along the kerbside lane, and shoulders should be paved and maintained in good condition.

Cycling improvements are usually implemented by local governments, sometimes with funding and technical support of regional or state/provincial transportation agencies. In the U.S., many local governments have adopted a "complete streets" policy which requires all roadways to safely accommodate pedestrian and bicycle traffic, either in new construction, or through retro-fitting during maintenance activities.

3.1.2.1 Bicycle lanes

Ensuring that conditions are safe and attractive for bicycling plays an important role in transportation demand management. Bicycle lanes are a physical measure which improves safety

Table 10: Facility types used by cyclists

Type	Description
Paths and trails	Various types of paths and trails separated from roadways. These can be built along motorways and railroad rights of way, through parks, and other locations where a linear corridor exists.
Bike lanes	Special road lanes for use by cyclists. In some cases this involves removing kerb parking, which tends to increase cyclist comfort and safety.
Bike routes	Roadways designated as being extra suitable for cycling.
Bicycle boulevards	City streets selected for and designed with features to facilitate cycling and discourage excess motor vehicle traffic speeds and volumes.
Designated shared streets	Roadways (particularly city streets) with markings to indicate that cyclists should ride in the traffic lane.
General roadways	A significant amount of cycling occurs on roadways that have no special designation or design features.
Motorway shoulders	Motorway shoulders, both paved and unpaved, are often used for cycling.
Sidewalks	Sidewalks are used by some cyclists, particularly by children and inexperienced adults, and along busy roadways that lack provisions for cycling.
End of Trip Facilities	These include bike racks, storage lockers, and shower/changing facilities.

Adapted from: Litman, Online TDM Encyclopedia, http://www.vtpi.org/tdm

Figure 37

Bicycle infrastructure in Hanoi — a roadway exclusively for bikes.

Photo by Gerhard Menckhoff, Hanoi (VN), 2005

and comfort for cyclists, as well as legitimizing their place on the road for drivers. They are usually most necessary on narrow or busy arterial roads, where conflicts with cars are more likely (*e.g.* on quieter collector streets cars can usually easily pass bicyclists). Typically about 1 meter wide, bicycle lanes are painted on the pavement and marked with a bicycle symbol. They may be on the edge of a roadway or in between a parking lane and a traffic lane.

Some cities provide bicycle lanes adjacent to roads, either at the same grade but separated by bollards or other barrier, or designated within the pedestrian area In the latter case, bike lanes adjacent to sidewalks may be designated by a painted line or different colour or texture of pavement. Such "multi-use paths" are often confusing to users, however, and may be inadequate for high volumes of bicycle traffic. Copenhagen has developed a grade-separated system of cycle tracks in response to this issue, because of the high volume of cyclists there.

Off-road bicycle paths are part of the bicycle route network of many cities, often providing cyclists with more direct routes which are off limits to vehicles, such as through parks or alongside rivers. There are advantages and disadvantages to physically separating NMT lanes, as shown in Table 11 (from Sourcebook Module 3d).

3.1.2.2 Bicycle parking

Provision of convenient and secure bicycle parking is an important part of bicycle infrastructure. In public space, plentiful bicycle racks should be located in shopping areas and outside of bus and train stations. Cities can require private parking lots and garages for cars, as well as commercial and residential buildings to provide bicycle parking. Bicycles which regularly appear locked to trees and posts are an indicator that more bicycle parking is needed at that location. Effective bicycle parking requires a properly designed rack in an appropriate location, as discussed in Box 9. An emerging practice is to integrate bicycle parking alongside car parking

Figure 38

Bicycle paths for both directions are segregated from the street in London.

Photo by Lloyd Wright, London (UK), 2006

Figure 39

Separated grade two-way bicycle path in Paris.

Photo by Manfred Breithaupt, Paris (FR), 2007

Table 11: Advantages and disadvantages to physically separating NMT lanes

Advantages	Disadvantages
Provide a greater sense of security to the NMT user	If they are too narrow, passing is difficult, and three-wheelers can obstruct the lane
They are self-enforcing	Prone to filling with debris and occupation by street vendors
Allow for two-directional NMT travel even on one-way roads	Must be located on the kerbside of parked vehicles
Ensure that NMT users will not make sudden movements into the motor-vehicle lanes or obstruct motorists	Can make lorry deliveries to store-fronts less convenient
Less frequently obstructed by double parked cars or illegal use by motor vehicles and motorcycles	Three-wheeled traffic requires more space, at least 2.4 m for two-way traffic, and 4 m where feasible

Box 8: Design of non-motorised transport (NMT) lanes

The *CROW Manual (see below)* makes recommendations regarding when to use different types of bicycle facilities. The two determinants are the volume of motor vehicles and the motor vehicle speeds. On roads where traffic speeds are less than 30 km/h, no separation is necessary. On roads with speeds between 30 km/h and 60 km/h it depends on the traffic flow. At 40 km/h, if there are more than 6,000 passenger car units (pcu)/24 hours, separate bike facilities can be justified. At over 60 km/h, with any significant volume of traffic, separated facilities are virtually always recommended.

For any facility where speed limits or actual motor vehicle speeds are 40 km/h or less, special facilities for bicycles are not really necessary. If speed limits or actual operating speeds are higher than 40 km/h, but the kerb lane or a paved shoulder is wide enough to accommodate bicycles without any specially designated lane, a special bicycle lane is also not necessary, but may be desirable for reasons stated below.

Simple measures on ordinary streets can also be very important. A major consideration is the design of storm drains. They should be designed so that bicycle wheels do not fall into them. Steep open drainage ditches also present hazards for cyclists. Steep kerb cuts are also more hazardous than rounded kerb cuts. Cyclists are also as sensitive if not more sensitive to pot holes, cracks in the roadway, overgrown plants along the roadside, sand, gravel, and oil on the roadway, and other maintenance concerns that also affect motorists.

Sometimes the simple posting of bicycle route signs on existing streets can be important for two reasons. First, sometimes non-motorised traffic can be routed off major arterials by taking secondary and tertiary arterials. The availability of these routes, however, may not be commonly known. Coded bike routes, coupled with bike maps, can help cyclists identify more bicycle or NMV friendly routes. Secondly, it can be used to indicate that, along this route, traffic signals, intersections, and roadway maintenance have been designed to prioritise bicycle and other NMV use.

On one-way streets, if the lane is not physically separated, the NMV lane should also be one-way. In countries where motorists drive on the right side of the road, it is preferable to have the NMV facility on the right side of the road. Bicyclists travelling the wrong direction on a one-way bike lane are a major cause of accidents.

Intersection design

In developed countries, most accidents occur at intersections. In developing countries there are also a significant number of accidents between intersections, mainly caused by crossings of long arterials.

There are two basic theories about how to integrate non-motorised vehicles into intersections. One is to pull them out of the intersection, and the other is to have them pulled into the intersection and clear the intersection first.

In China and Bogotá, there are actually some major motorway interchanges where bicyclists have their own fully grade separated route through the interchange, where motorists pass both above and below the bicycle paths.

The CROW Design Manual for Bicycle Traffic is a publication of the Netherlands' national Information and Technology Platform for Transport, Infrastructure and Public Space (CROW). For more information, see http://www.crow.nl/engels;

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3d: Preserving and Expanding the Role of Non-Motorised Transport," by Walter Hook for GTZ, http://www.sutp.org

Figure 40
On-street bicycle parking in Cambridge offers bicyclists enough space and helps to reduce uncontrolled parking on sidewalks.
Photo by Andrea Broaddus, Cambridge (UK), 2007

Figure 41
High bicycle parking demand can be managed with parking installations that maximize reserved space, as shown in Copenhagen.
Photo by Lloyd Wright, Copenhaguen (DK), 2006

Box 9: Factors in development of bicycle parking

Use the appropriate bicycle rack for user needs:

Short-term parking

Needed where bicycles will be left for short stops. It requires a high degree of convenience (as close to destinations as possible). At least some short-term bicycle parking should be protected from the weather (a portion can be unprotected, since demand tends to increase during dry weather).

Long-term parking

Needed where bicycles will be left for hours at a time. It requires a high degree of security and weather protection, with well-designed racks in covered areas, lockers, storage rooms, or fenced areas with restricted access.

Other factors to consider:

Visibility. Racks should be highly visible so cyclists can spot them immediately when they arrive from the street. A visible location also discourages theft and vandalism.

Security. Adequate lighting and surveillance is essential for the security of the bicycles and the users. Bicycle racks and lockers must be well anchored to the ground to avoid vandalism and theft.

Weather Protection. A portion of bicycle parking should be protected from the weather (some short-term bicycle parking can be unprotected since bicycle use tends to increase significantly during fair weather). This can use an existing overhang or covered walkway, a special covering, weatherproof outdoor bicycle lockers, or an indoor storage area.

Clearance. Adequate clearance is required around racks to give cyclists room to manoeuvre, and to prevent conflicts with pedestrians or parked cars. Racks should not block access to building entrances or fire hydrants.

Source: Todd Litman, Online TDM Encyclopedia, http://www.vtpi.org

Figure 42
Bicycle parking at a metro/tram interchange in Munich encourages the multi-modal use of transport modes.
Photo by Alex Kühn, Munich (DE), 2004

Figure 43
A shared bicycle system in Sevilla.
Photo by Manfred Breithaupt, Sevilla (ES), 2008

in the roadway, which frees up sidewalk space for pedestrians.

In most cases bicycle parking is free, although in some cities with high bicycling modal share, people will pay for higher security parking with an attendant.

3.1.2.3 Shared bicycle services

Many potential bicycle users may be discouraged by the lack of a bicycle. Some cities assist such potential bicyclists by providing free or low-cost bicycles for public use. Often the bicycles are owned by a company that rents them out, or provided by a charitable organisation. The city of Copenhagen provides specially designed bicycles with a map of tourist destinations built into the handlebars. The bicycles are free, but a €2 coin must be inserted to unlock the bike for use, which serves as a deposit.

Some European cities have encouraged firms to provide low-cost bicycle rental services. In Paris, for example, the "Velib" service consists of bike rental stations located throughout the city. Users swipe a debit card at a payment kiosk to release a bike from a storage rack, and must return the bike to another rental station when finished. In Germany, the national train operator Deutsche Bahn has a public bicycle rental division. The "Call a Bike" service allows customers to set

Figure 44
Rent-a-Cycle in Osaka.
Photo by Lloyd Wright, Osaka (JP), 2006

Figure 46 ▸▸

Cycle rickshaws like this one in Chiang Mai are an important mode of transportation throughout Asia.

Photo by Carlosfelipe Pardo, Chiang Mai (TH), 2005

up an account with a credit or debit card, and then use a cell phone to rent bikes through an automated service. The bicycles are left by users on street corners around the city, rather than at rental stations.

Pedi cabs or cycle-rickshaws are another popular form of public bicycle. They provide the same mobility services as car taxis, but without generating any pollution. Cycle-rickshaws are most plentiful in developing countries, where they are also an important livelihood for men supporting families. Pedi cabs are a growing presence U.S. and European cities, for instance London, New York and Berlin.

Figure 45

CALL-A-BIKE in Berlin — public bicycle scheme managed by the public transport operator.

Photo by Andrea Broaddus, Berlin (DE), 2007

Box 10: Examples of shared bicycle services in operation

Vélo à la Carte: A public private partnership in Rennes, France

Vélo à la Carte, which operates 200 bicycles at 25 stations, was started in 1998 as a partnership between the City of Rennes and the commercial billboard company Clear Channel Adshell. Clear Channel offers the smart bike system to local authorities that are also using other services of the company, as information kiosks or bus shelters. The company is responsible for the implementation and operation of Vélo à la Carte in Rennes. The services are paid for through advertisements which appear on outdoor furniture, funding also the smart bike programme. For Clear Channel Adshell, the service is beneficiary as it adds value to the range of street furniture as additional amenity that is provided to local authorities. The City of Rennes benefi ts from the increased mobility choices for its citizens.

OV-fi ets: Public Bicycles for rail users

OV-fi ets (OV= Public transport, fi ets=Bicycle) started in 2002 as a publicly subsidised pilot project in The Netherlands, aiming at making the bicycle a part of the public transport system. Meanwhile it is established as a permanent service and is available at 100 rail stations. OV-fi ets rental facilities provide fast and easy access to rental bikes, which can be used as extension of the rail trip. The service covers most larger stations in the Randstad (the largest agglomeration in The Netherlands) and several stations in other regions. Users have to register with OV-fi ets before they can access the service. They receive an OV-fi ets card, which enables them to check out the bicycles from a computerised system at the stations. Alternatively users can register for an existing yearly Railpass that also fi ts the system. The bicycles can be used one way, *e.g.* to the workplace, where they can be parked and locked for a certain period of time, until the user needs them for the return trip to the rail station. The user fee for OV-fi ets is €2.75 per 20 hours, with a maximum rental period of 60 hours. The user pays monthly by standing order, which requires a bank account in The Netherlands. In 2006, more than 23,000 people were registered as users of the system. In 2007, the OV-fi ets foundation will be taken over by the National Dutch rail company NS. OV-fi ets is one of the few Public Bicycle schemes that is expected to be profitable in the near future as it can reach economies of scale.

Excerpted from the EU project NICHES policy note publication, "New Seamless Mobility Services: Public Bicycles," which may be found on the project website, http://www.niches-transport.org/index.php?id=155

Figure 47
Cycle rickshaws are popular as a low cost public transport alternative in Hanoi.
Photo by Manfred Breithaupt, Hanoi (VN), 2006

Box 11: Notes on implementing of infrastructure improvements for non-motorised modes

Politically, it is often easier to implement an extremely expensive rail or motorway project than even the simple improvement of a sidewalk. This is because any large construction project has large interests which stand to make a lot of money if the project is implemented, and therefore are willing to push government officials on a regular basis to ensure it is implemented. Politicians also stand to gain by being identified with the completion of public works. Even though basic improvements like the construction of sidewalks may do more to alleviate traffic congestion and road accidents than other projects costing hundreds of times more, the low cost and everyday nature of these improvements makes it difficult to find a political constituency to ensure their implementation.

Historically, these sorts of projects have come about, because someone with political power, money, and perseverance made them happen. The most recent large-scale non-motorised transport improvement was done in the city of Bogotá. In Bogotá, improving the city's transportation system in this way was a major campaign promise of Mayor Enrique Peñalosa who was personally convinced of the importance of such measures. In the city of Bogotá, the Mayor also has enormous power, unlike in some other cities where the mayor is less powerful. Support for the NMT improvements from the NGO community existed, but it was clearly the Mayor's office which pushed it forward. Similarly, the pedestrianisation of downtown Curitiba, Brazil, was also pushed through by an enlightened Mayor (see Module 1a: *The Role of Transport in Urban Development Policy*). The prioritisation of bicycle use in China was a decision by the highest levels of the national government and party, just as today the restrictions against bike use are being pushed through national level political pressure.

In other locations, pressure from bicyclists, NGOs, and international funding agencies has proven critical. The bike facilities in most large US cities, in Western Europe, in Central Europe (Krakow, Budapest, etc), in Bangkok, and the dramatic improvement in pedestrian facilities in Seoul clearly resulted from pressure applied to governments by NGOs and cycling federations. In Accra and Tamale (Ghana), in Tanzania, in Marakina, Manila (Philippines), Lima (Peru), Gdansk (Poland), Yogyakarta (Indonesia), and Santiago de Chile, new bike and other NMT facilities were given a strong push by international organisations such as the World Bank or UNDP, and often more specifically committed individuals within these institutions.

Other factors critical to ensuring implementation are good public education efforts through the media. If the Mayor fully supports the plans, he can use his access to media to push them forward. NGOs can also make clever use of the media to win popular support for NMT improvements.

Involving all the relevant stakeholders both inside and outside the government in the planning process from the outset, and letting them take ownership of the plans, is also likely to reduce significant obstacles to implementation.

While it can cost tens of millions of dollars to properly reconstruct a single major public transport hub or intersection to ensure safe non-motorised travel integration, many measures to improve conditions for non-motorised transport can be done for the cost of basic roadway paint. Construction costs vary from country to country. Most measures can also be implemented rapidly, in less than a year. Physical construction for pilot projects will take weeks rather than months.

Developing cities should start by forming a non-motorised transport task force, which can initiate a planning process. This task force can then begin to develop and implement measures, beginning with isolated improvements, and in a relatively short period laying the foundation for a city-wide network of non-motorised transport routes.

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3d: Preserving and Expanding the Role of Non-Motorised Transport," by Walter Hook for GTZ, http://www.sutp.org

Figure 48
Modern pedi cab in Berlin.
Photo by Andrea Broaddus, Berlin (DE), 2007

3.2 Improving public transport service

3.2.1 Increased public transport services

Policy and regulatory measures which improve transit services do so generally by affecting the framework conditions for vehicle operators, and by dedicating more public resources toward capital improvements, such as new buses and stations. A thorough discussion of issues related to regulation of bus services and fares is more thoroughly addressed in Sourcebook Module 3c: *Bus Regulation and Planning*.

3.2.1.1 Integrated services

Many cities have multiple public transport operators, such as different bus companies, or different local governments. Often the route networks and schedules are not well coordinated, such that riders need to transfer between services at jurisdictional boundaries, or have long waiting

Box 12: Stages in the development of Singapore's public transport system

There are two multimodal private operators in Singapore, both running bus and commuter rail. They have set up a service company, Transit Link Pte Ltd, in an effort to integrate trains and buses to function together as one single, comprehensive public transport network. Transit Link facilitates fare integration, information integration and network integration.

Fare integration is done through a common ticketing system using a contactless smart card, called the "ez-link card," as the mode of payment. The ez-link cards can be used on trains and buses of both companies. Its main advantage is that it offers cost savings to commuters making transfers between train/bus and between bus/bus by granting cash rebates. To qualify for these rebates, the transfer has to be made within the stipulated window period of 45 minutes. Commuters enjoy transfer rebates for the first, second and third transfers on a journey. The ez-link card can be topped up with cash at train stations, bus interchanges and convenience stores; or linked to bank accounts for automatic topping up periodically. Commuters without the ez-link card are able to pay the bus fare by dropping the exact fares in a coin box, located next to the bus captain, for him to dispense a paper ticket. The fare for cash payment is however, higher than if it is paid by ez-link card.

Information integration is through the publication of a "Transit Link Guide", which lists all information on bus routes and train lines; and by putting up information panels at major bus stops on the bus services calling there. Transit Link provides an electronic guide, the e-Guide on the Internet and operates a toll-free call centre for integrated information on bus and train services.

Network integration is through centralised rationalisation of bus services whenever a new train line is introduced to reduce wasteful duplication of bus and train services. Transit Link uses a computer model (TRIPS) which is able to predict and forecast changes to commuter demand and ridership, when new train lines and new bus routes are added. However, the programs do not generate bus routes, which need experience and knowledge of conditions on the ground.

Integration of fares, information and network facilitate seamless travel for commuters. The greatest benefit is to have a common farecard for use on all forms of public transport. When cash rebates are given for commuters making transfers between modes within prescribed times, it lowers commuters' grouses towards making transfers.

Source: Lessons from Bus Operations – A P G Menon and Loh Chow Kuang, 2006

For further details please also see Sourcebook Module 3c, page 22.

times between buses and trains. Better integration of transit services is a TDM measure which does not require large capital investment, but rather improved planning and communication among operators. Seeking to integrate services into one network helps customers navigate the system, and can make it more transparent and attractive to new users.

Fare integration is another component which can improve the ease of use. Simplifying fare collection such that customers can purchase monthly passes and easily transfer between operators is more difficult to implement, because a system of revenue tracking and transfer must be developed, but it can help attract riders. Box 12 illustrates the progression of Singapore's bus system from disparate local providers to an integrated system using smart card fare collection.

Physical and technical TDM measures which improve transit services range from providing additional bus routes and service frequency, light rail and commuter rail service, and inter-city rail service. Developing cities which are served by small independent bus operators may best improve the quality of service and comfort for passengers by improving supportive infrastructure such as bus stops and rail stations. Typical urban public transport services are a mix of various vehicles:

Commuter rail – full size trains pulled by locomotives which operate at relatively high speeds on inter-city heavy rail tracks with segregated right-of-way and infrequent far-between stops, can carry several hundred passengers.

Light rail transit (LRT) – smaller trains operating at moderate speeds within urban areas with

Box 13: Measures to improve public transport services

General categories of transit improvements:

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

Specific measures that grow transit ridership:

- Additional routes, expanded coverage, increased service frequency, and longer hours of operation.
- HOV Priority (HOV lanes, bus ways, queue-jumper lanes, bus-priority traffic signals, and other measures that reduce delay to transit vehicles). Grade separate transit lines, so they are not delayed by cross-streets and traffic congestion.
- Reallocate Road Space to transit and walking.
- Comfort improvements, including bus shelters and better seats.
- Lower and more convenient fares (such as discounts for frequent users).
- More convenient fare payment using electronic "smart cards".
- Improved rider information and Marketing programs, including real-time information on transit vehicle arrival (Dziekan and Vermeulen, 2006).
- Transit Oriented Development and Smart Growth, which result in land use patterns more suitable for transit transportation.
- Pedestrian and Cycling Improvements that improve access around transit stops.
- Bike and Transit Integration (bike racks on buses, bike routes and Bicycle Parking near transit stops).
- Universal Design of vehicles, stations and pedestrian facilities to accommodate people with disabilities and other special needs.
- Park & Ride facilities.
- Improved Security for transit users and pedestrians.
- Create a Multi-Modal Access Guide, which includes maps, schedules, contact numbers and other information on how to reach a particular destination by public transport.
- Improved coordination of transit modes and networks to increase rider convenience and access to information.
- Services targeting particular travel needs, such as express commuter buses, Special Event service, and various types of Shuttle Services

Source: Online TDM Encyclopedia, http://www.vtpi.org more frequent stops linking neighbourhoods and commercial areas, with separate right-of-way that can be within road corridors. Vehicles usually consist of two cars capable of carrying up to 120 passengers; they may be diesel or electric powered.

Streetcars – also called trams or trolleys, small trains operating at lower speeds on urban streets and often mingling with vehicle traffic with very frequent stops, usually one car or two cars with 40–80 passenger capacity, typically electric engines.

Bus – large vehicles carrying approximately 40 passengers, usually diesel powered but cities with air quality problems may use LPG, CNG or electricity. Modern designs have low floors and wide doors to ease entry for senior passengers or those with baby carriages; articulated buses which are double the usual length with a flexible central section.

Bus Rapid Transit (BRT) – high quality bus service with greater frequency and higher travel speeds operating primarily in dedicated corridors. Vehicles may be conventional buses or resemble rubber-tired trains. BRT is discussed in greater detail in Section 3.2.1.2 below, and are the topic of Sustainable Transport Sourcebook Module 3b.

Ferry – boats operating in urban harbours linking different parts of a city separated by water; capable of carrying dozens to hundreds of passengers. Often ferry services are the only part of a publicly operated system which is contracted out to private concessionaires.

3.2.1.2 Bus rapid transit (BRT)

Bus rapid transit (BRT) is a broad term for bus systems designed to provide service quality similar to rail transit, but with lower cost and greater flexibility. This includes having fixed guide ways or bus ways to maximize speed and comfort, high frequency service, attractive stations, and quick boarding systems and other features to minimize delay. Both developed and developing cities are now building BRT systems.

BRT right-of-ways may be created at-grade within an existing roadway, or at an elevated grade. Tram-like vehicles may be used which allow rapid boarding and a smooth ride. Some systems have platforms resembling those used by train services, with high quality shelters and passenger information. Ideally, a fare collection is located on the platform, avoiding a source of conventional bus service delay.

3.2.1.3 Bus lanes

Reliable travel times make bus travel more attractive. Dedicated bus lanes are a physical measure which improves bus reliability by allowing buses to move separately from congested traffic, and without merging in and out

Figure 49

Bogotá's TransMilenio BRT stations provide fast, convenient boarding.

Photo by Carlosfelipe Pardo, Bogotá (CO), 2006

Figure 50

BRT stations are located on the median. Exclusive lanes ensure short travel times.

Photo by Carlosfelipe Pardo, Bogotá (CO), 2006

Box 14: Bus rapid transit (BRT)

Bus rapid transit takes part of its name from rapid transit which describes a high-capacity rail transport system with its own right of way, its alignment often being elevated or running in tunnels, and typically running long trains at short headways of a few minutes. Because of the name similarity one tends to associate the merits of rapid transit also with the newer BRT expression. BRT encompasses a broad variety of modes, including those known or formerly known as express buses, limited bus ways and rapid bus ways and even BHNS in France (Bus à Haut Niveau de Service).

Ironically, the term bus rapid transit does not refer to the speed of BRT buses. Typical transit speeds of BRT systems range from 12–30 miles per hour (19–48 km/h), which compares well with surface running light rail transit. BRT design features provide high quality and cost-effective transit service. These include:

- Grade-separated right-of-way including bus ways (for bus use only) HOV lanes (for buses, vanpools and carpools), and other transit priority measures. Some systems use guide ways which automatically steer the bus on portions of the route.
- Frequent, high-capacity service with passenger waits of less than 10-minutes during peak times
- High-quality tram-like vehicles, those are easy to board, quiet, clean and comfortable to ride.
- Pre-paid fare collection to minimize boarding delays.
- Integrated fare systems, allowing free or discounted transfers between routes and modes.
- Convenient user information and marketing programs.
- High quality bus stations with transit oriented development in nearby areas.
- Modal integration, with BRT service coordinated with walking and cycling facilities, taxi services, intercity bus, rail transit, and other transportation services.
- Excellent customer service.
- Improved security for transit users and pedestrians.

How it is Implemented

Bus rapid transit systems are usually implemented through a cooperative effort involving local planning agencies and transit service providers. To be effective it requires coordination of roadway design and management, bus purchasing, transit operations, local land use planning decisions, transit marketing and TDM programs.

Bus Rapid Transit requires that bus transit be given increased respect and priority in transportation planning decisions, including investments, roadway management and land use development. Where transit service quality is currently poor, BRT implementation may require policy and institutional reforms, such as changes in transportation planning and roadway management practices (to give buses priority in traffic); vehicle purchasing; transit regulations and contacting (to maintain a high quality of service); and urban design (to increase development near BRT routes).

Major barriers to BRT implementation include a lack of leadership, limited funds, automobile oriented land use planning, and stigma that is sometimes associated with buses.

Source: Todd Litman, Online TDM Encyclopedia, http://www.vtoi.org

of traffic. "With-flow bus lanes" are bus lanes in the same direction as the normal traffic flow and only require separation by painted road lines. They are easily implemented but require good enforcement to be effective. Often other vehicles that form an alternative to cars are allowed in bus lanes, such as taxis, motorcycles, and bicycles. Singapore introduced its bus lanes in 1974 along the kerbside lane of most major roads operating during peak hours resulting in bus improvements of up to 15%. Another advantage is that since buses keep to the kerbside lane, bus drivers never skip bus stops, and are less hampered by cars merging from lane to lane.

Figure 51
Reliability attracts more passengers. An exclusive bus lane like this one in Seoul improves travel time.
Photo by Lloyd Wright, Seoul (KR), 2005

Table 12: BRT myths and reality

Myth	Reality
BRT cannot compete with rail system capacity.	Bogotá's TransMilenio system moves 36,000 passengers per hour per direction while BRT corridors in Sao Paulo can also provide capacities over 30,000 passengers per hour per direction. This is more than all LRT systems and many metro systems.
BRT is only appropriate for small cities with low population densities.	BRT is implemented in many large cities, including Bogotá which has 7 million inhabitants, Manila, Bangkok, Jakarta, and Beijing.
BRT requires a great deal of road space and cannot be built in narrow roadways	Design solutions exist for virtually every road space circumstance. Quito runs a BRT system through three metre wide streets in its historical centre. Even rail takes space, for example, support pillars for SkyTrain require a traffic lane.
BRT cannot compete with rail options in terms of speed and travel time	A US GAO study found that a comparison of BRT and LRT systems actually showed that BRT systems produced faster average speeds (US GAO, 2001).
BRT uses vehicles with rubber tyres which is an inferior technology; customers will never accept BRT	It is doubtful that anyone in Bogotá, Curitiba, or Quito feels that they have an "inferior technology". The appearance of BRT stations, terminals and vehicles can all be made to appear as sophisticated and inviting as any rail option.
BRT cannot deliver the transit-oriented development and land use advantages of rail	Experience in cities such as Bogotá and Curitiba indicate that BRT can stimulate urban development around stations similar to rail transit, if given appropriate support.
BRT is fine as a feeder service, but it cannot serve main corridors	BRT can provide both feeder service and on high-density mainline urban corridors.

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 3b: Bus Rapid Transit," by Lloyd Wright for GTZ, http://www.sutp.org

Figure 52
Bus priority lane in London.
Photo by Lloyd Wright, London (UK), 2006

Some bus lanes may be used only to bypass a congestion point and may not be very long, in some cases with flow bus lanes may only be in effect during peak hours. Some may be a single contra-flow bus lane that allows buses to travel in the opposite direction on a one-way road. In some cases bus lanes may only be in effect during peak hours. For contra-flow bus lanes, it is preferable to separate the lane from others by a physical divider. However, Tianjin in China uses contra-flow bus lanes without the use of dividers quite effectively. Contra-flow bus lanes usually operate throughout the day.

In some cases entire roadways are dedicated to buses, making them "bus ways" or "bus malls". Examples are Oxford St in London and Fulton St in New York, which are only open to buses, taxis and delivery vehicles. Use of bus lanes is sometimes permitted for High Occupancy Vehicles (HOV), or vehicles carrying a relatively large number of passengers, such as vanpools and carpools. These are typically on high capacity arterials or motorways. Bus ways may be developed as part of a transit priority network which improves bus operations throughout the

Figure 53
The environmental axis in Bogotá is restricted to use by TransMilenio buses and pedestrians.
Photo by Carlosfelipe Pardo, Bogotá (CO), 2006

Box 15: Use of telematics for bus priority in Aalborg, Denmark

Public transit has to develop its services, convenience, and comfort in order to keep pace with private cars. The introduction of advanced ITS in the public transport system made Aalborg the leading city in Denmark in this field. These measures improved the quality and image of public transport services. Real-time bus arrival information is known to reduce perceived waiting times and increase customer satisfaction.

Some of the objectives and targets of the telematics initiatives were to:

- Integrate public transit services in one unified system;
- Promote public transit as a "modern" means of transportation;
- Ensure reliable public transport services throughout the day;
- Provide easy access to travel information;
- Pave the way for future ITS services in public transit
- Improve the working climate for the drivers;
- Reduce perceived waiting times;
- Increase perceived security.

By 2008, 209 buses — approximately 80% of the fleet — were fitted with bus computers. The new local train stations in the built-up area and the new nodal points in the restructured bus network were fitted with real-time passenger information. Passengers also benefit from reduced walking distances and a clearer structure via the flexible utilisation of platforms, which minimized the size of the facility.

Several technological measures were taken:

- The ITS telematics allows public transport vehicles to gain priority at intersections.
- It provides real-time passenger information at primary transfer points.
- Existing services on the Internet are expanded (http://www.aalborg-trafikinfo.dk).
- The system is designed to open up possibilities for future services via SMS etc. A Travel Information Centre with an online Info-kiosk is provided at the coach-terminal.

Source: http://www.civitas-initiative.org

entire system. In a transit priority network, roadways or sections of roadway in congested areas are classified according to which type of traffic gets the priority for space and travel speed: bus, car, or non-motorised traffic.

3.2.1.4 Bus priority at intersections

A technical measure that helps buses travel faster and improves reliability is signal prioritization. This involves equipping buses with transponders which communicate with traffic signals. With this telematics technology, the traffic signal knows that a bus is approaching and reacts in order to allow the bus to pass, either by turning green or remaining green for an extended period. Intersection priority can be particularly helpful when implemented in conjunction with bus lanes or streets, because general-purpose traffic does not intervene between buses and traffic signals.

3.2.1.5 Improving public transport infrastructure

In addition to public transport service, the quality of infrastructure serving passengers can be improved for comfort and safety, which helps retain and attract riders. Such infrastructure includes bus stops, shelters, bus transfer stations, and rail stations. Low cost infrastructure which can increase the speed and reliability of bus service include bus turnouts, boarding islands, and kerb realignments.

At bus stops, adequate lighting and visibility are basic necessities for public security. Provision

Figure 54▲
Bus station in Curitiba.
Photo by Manfred Breithaupt, Curitiba (BR), 2006

Figure 55▲
A high level platform like this one in Curitiba reduces boarding time, and so bus travel time.
Photo by Manfred Breithaupt, Curitiba (BR), 2006

Figure 56
BRT station in Changzhou.
Photo by Josef Traenkler, Changzhou (CN), 2007

Figure 58
Real-time bus arrival information at a bus stop in Munich.
Photo by Andrea Broaddus, Munich (DE), 2007

Figure 57
Bus shelter in Nagoya.
Photo by Lloyd Wright, Nagoya (JP), 2006

Box 16: Public private partnership to improve commuter facilities in Singapore

In a household interview perception survey conducted in 1989 after new train service started, respondents rated the bus below the car and the train in terms of speed, riding comfort, safety and noise. The bus scored above the car and the train only in terms of cost of travel. A number of measures were taken by the bus agency to improve the quality of the travel experience and make the bus more attractive to passengers.

One of the hassles of taking public transport is making transfers between modes. There are walking and waiting times to contend with. Much effort has gone into physical integration of commuter facilities near train stations. Bus stops, taxi stops, car pick-up/drop off points and controlled pedestrian crossings are provided near to train stations, for commuters to transfer easily from one mode to another conveniently.

The bus journey is most tiresome when commuters need to transfer between modes or travel during rainy days, which is typical of Singapore's weather. Therefore, facilities are provided for commuters to walk to bus stops under cover and wait at bus shelters comfortably. In another effort to make walking to bus stops and train stations fully sheltered from the sun and the rain, there is a network of covered walkways over roadside footpaths and across open areas leading to these terminals, from areas of high pedestrian concentration. This makes the public transport experience more acceptable.

Of the 4,400 bus stops, more than 90% have bus shelters with seats. Bus shelters are often compared unfavourably with train stations, which are much more comfortable with better amenities. Commuters at bus shelters experience noise, dust and fumes, and buses do not come as regularly as trains. It is thus necessary to provide commuters with a place where they can wait comfortably for the buses.

Initially, the bus shelters were small and spartan in appearance. There were requests for bigger bus shelters that protect the commuters from sun and rain. This is difficult to achieve in a tropical city with humid weather and occasional thunderstorms. If the commuters are to be protected from the rain, the shelter has to be enclosed, but an enclosed bus shelter will be unbearable on a hot humid day. Over the years, bus shelters have become larger and some even have high roofs to protect commuters from the rain when they board double decker buses

Since 1995, private firms have been given advertisement rights for a fixed number of years in return for building/maintaining new bus shelters and cleaning them periodically. Tastefully designed lighted advertisement panels that change displays as frequently as a fortnightly, are commonplace at most bus shelters. In the remote areas where firms have no interest in advertising, the government builds and maintains the bus shelters.

Source: Lessons from Bus Operations – A P G Menon and Loh Chow Kuang, 2006

Box 17: Bus lanes and infrastructure improvements in London

The main objective of this measure was to build an optimised and user-friendly infrastructure for public transport activities, which will encourage people to use public transport. The goal was to create a seamless, accessible passenger environment with consistent quality and branding. This included:

- Improved infrastructure, signage, information, and access at interchanges (transfer points)
- Improved quality and quantity of information available on the street
- Enhanced cleaning/maintenance through a dedicated telephone number to report faults
- All facilities were audited for security
- Cycle parking is provided at all stations, interchanges and key shelters
- Bus priority on roadways across the network, improving passenger journey times and efficiency
- Revised traffic calming scheme to provide more predictable running times
- Real-time telematics display at bus stops
- Bus Shelter Working Group established to identify best practices and implement damage report system

By 2007, £1.1 million capital funding had been spent on the overall scheme. 125 bus stops were upgraded to Quality Bus standards including raised kerbs, the majority with shelters (88), clearways and timetable information.

Source: Dianne Taylor, http://www.civitas-initiative.org

Box 18: Improving bus and rail transit in Beijing

To achieve the prioritization of public transport, Beijing has adopted many measures for road construction, optimization of the motorway network, vehicle update, personalized services, ticketing, and policy and institutional reform in recent years.

Since economic reform and opening up, public transport has developed quickly in Beijing. However, with socioeconomic development, the urbanising population, and the continuous expansion of the city, urban traffic problems become increasingly serious. Traffic congestion and inconvenient travel are huge barriers to people's normal life and socioeconomic development. The modal share of motor vehicles increased from 38% in 1986 to 61% in 2003, while the modal share of public transport decreased from 35% to 26%.

Mr. Wang Qishan, Mayor of Beijing Municipality, described the blueprint for the future five years of Beijing in his comments to the Fourth Session of the Twelfth People's Congress of Beijing in 2006. "We will prioritize the development of public transport. The mileage of rail transit will reach 270 km, and the modal share of public transport in downtown areas will reach 40%. Buses will travel through each administrative village. We will strengthen the construction and maintenance of motorways, and make sure all villages and towns are accessible to the motorway network. The land use for public transport facilities should be guaranteed first, and buses should enjoy the priority use of road resources. Public investment in transit should be given priority. Laws should be formulated and regulations and rules for public transport should be strengthened by the supervision of the government on public transport, so as to promote the healthy, coordinated and sustainable development of the public transport industry in Beijing."

Rail transit. By 2015, 19 routes will be finished, thus forming a rail transit network with a length of 561 km characterized as "three loops, four horizontals, five verticals, and seven radiations."

Improving the "microcirculation" system. Strengthen the construction of sub-trunks and branch routes, achieving 50% of the set planning, namely 270 km from 2006–2008.

Public transport station construction. Conduct repair or reconstruction on the 23 bus stations located inside the fourth ring road with serous traffic congestion. The existing bus stations will be lengthened from 40 meters to 50 meters, and the large-scale bus stations lengthened from 80 meters to 100 meters. Moreover, the parking lanes for buses are also marked, which prohibits the intrusion of other vehicles.

Optimizing public transport routes. Rationalize the allocation of public transport routes. Withdraw 32 bus routes and adjust 147 bus stations around the areas of Qianmen, Beijing Railway Station and Dongdan.

Reform ticketing system of public transport. In May of 2006, the public transport "IC card" system has been carried out completely; passengers can use the card to take 8,000 buses, subways and 30,000 taxis.

Source: Leilei Liu, http://www.cititas-initiative.org

Figure 59a, b
Bus infrastructure in Beijing allows rapid boarding for convenience and accessibility.
Photo by Armin Wagner, Beijing (CN), 2006

of benches, route and schedule information at bus stops are also basics. Modern bus shelters include high tech amenities like ticket automats and internet kiosks. Cities with buses equipped with telematics systems give passengers real-time information about for bus arrival times. Using the same technology as that used for bus prioritization, transponders on the bus communicate with digital displays at bus stops which show its expected arrival time. This technology can also allow passengers to check bus arrival times on their cell phone. It is also important to consider the pedestrian environment around bus stops, that is, the quality of the sidewalks and road crossings which people use to access the bus stop. Similar considerations apply to stations where passengers wait for buses. It should be easy for passengers to find route and schedule information, and to figure out where to catch the bus they need.

3.3 Car sharing

Some firms are directly involved in the business of transportation demand management, such as car sharing firms. Organisations that rent cars to customers on an hourly basis — a practice known as car sharing — have sprung up in cities around the world. Car sharing firms make cars available to their members in specific locations all around a city. Much like a library or video rental system, car sharing firms serve a customer base of members. This allows them to screen the driving records of their customers, for a group insurance policy. The hourly rental rate includes fuel and insurance costs. Most car sharing systems require members to reserve a particular car by using a website or phone reservation system. Members use a special key or chip card to open the car they have reserved.

The main function of car sharing is to reduce the need to own a car. In developing countries, car sharing could help families with occasional car needs to retain a car-free lifestyle. It could become an intermediary status offering customers the glamour of car use, without the financial burden of car ownership. In Bremen, the city's new car sharing firm StadtAuto partnered with the local transit authority to build a customer base by linking transit use with shared cars (Box 19).

Box 19: Bremen's "Transit plus Car" card

Launched in 1998, customers of Bremen's public transport system were offered the "Transit plus Car" card (Bremer Karte plus AutoCard) as a combination transit monthly or annual pass and membership with the car sharing firm, StadtAuto. Customers receive a discount on their transit pass, but are charged a deposit and a one-time fee to join the car sharing service. They must also set up an account for car charges. Car use is charged per hour and per kilometre travelled. StadtAuto has shared cars located at 25 stations of the Bremen public transport system, where customers may transfer seamlessly from a bus or streetcar to a shared car. A smart card is used to access the cars.

The Transit plus Car card was marketed extensively through the media and on transit vehicles with advertisements and brochures. Two months after the start of the project, StadtAuto gained 150 new members to add to its base of 1,100, an increase of 14%.

Source: Rainer Counen, http://www.eltis.org/studies

Figure 60

Car sharing vehicle in Frankfurt. A variety of different vehicle sizes are typically offered by car sharing organisations.

Photo by Armin Wagner, Frankfurt (DE), 2005

4. Economic measures ("PUSH")

Various economic measures are used to encourage efficient transportation, including pricing reforms and roadway facility management. Many pricing measures are designed to capture the externalized costs of travel, and so tend to increase economic efficiency. Pricing measures can generate revenue that can be used to improve mobility options or substitute for other taxes. Economic measures are often the most effective components of a comprehensive TDM strategy, although they often face resistance from drivers and so can be politically difficult to implement. For these reasons it is important to implement pricing reforms with clear goals for the revenue stream they create, sometimes accomplished through earmarking, (see Box 20). For further details please see Sourcebook Module 1: *Economic Instruments* http://www.sutp.org.

Table 13 ranks common vehicle fees in terms of how well they represent the marginal costs of vehicle use. The most economically efficient fees vary by time and location, for example, charging more for driving under congested conditions or for parking in an urban centre where land costs are high. Mileage-based fees and fuel taxes reflect the amount that a vehicle is driven but do not reflect time or location. Fixed vehicle fees, such as insurance and registration fees internalize costs to vehicle owners as a group, but do not reflect the amount that a vehicle is used. This is economically inefficient and results in cross-subsidies between those who drive less than average, and therefore impose relatively low costs, and those in the group who drive more than average and impose higher costs.

Table 13: How well different fees represent marginal vehicle costs

Rank	General Category	Examples
Best	Time- and location-specific road and parking pricing	Variable road pricing, location-specific parking management, location-specific emission charges
Second best	Mileage-pricing	Weight-distance charges, mileage-based vehicle insurance, prorated motor vehicle excise tax (MVET), mileage-based emission charges
Third best	Fuel charges	Increased fuel tax, general sales tax applied to fuel, pay-at-the-pump insurance, carbon tax, and hazardous substance tax
Bad	Fixed vehicle charges	Current MVET, vehicle purchase and ownership fees
Worst	External costs (not charged to motorists)	General taxes paying for roads and traffic services, parking subsidies, uncompensated external costs

Box 20: Use of revenues from economic measures

Sources of revenue from economic measures include:

- Surcharge on parking fee
- Fuel tax surcharge
- Licensing fees/bounties
- Business location licenses
- Surcharge on terminal fees

How revenues are to be spent is a highly political debate which is most often settled before the economic measure is implemented. Common mechanisms include earmarking the revenues for specific projects or purposes, and creating a trust fund, or "pot of money" which may be spent for a variety of projects that meet a set of defined criteria.

Earmarking: The allocation of revenues a specific project or purpose.

Trust Fund: Revenues can only be used for purposes defined by a set of criteria.

Examples of projects and purposes funded by economic TDM measures include:

- Financing better technology (scrapping of old cars, CNG buses);
- Financing non-motorised transport infrastructure improvements;
- Financing public awareness campaigns;
- Environmental trust fund (as exists in Mexico City, where revenues can only be used for sustainable transportation measures).

Source: Manfred Breithaupt, 2008

Table 14: Economic instruments used as TDM measures

Type of incentive or disincentive	Possible Economic Instrument(s)	Selected Economic Measure(s)
- Discourage motorized vehicle ownership	- tax/charge on vehicle purchase/ownership/ scrappage	- annual vehicle tax - registration tax/charge - (re)sales tax/charge - scrappage tax/charge
	- restricting the number of vehicles and/or new registrations	- auction schemes competitive bidding for new licenses - licensing car ownership
- Discourage motorized vehicle use - Encourage switch to public or non-motorized transport	- tax/charge on vehicle use	- fuel tax - pay-at-the-pump (sur)charges
	- tax/charge on road and/or infrastructure use, - restricting access to urban centres or special areas	- parking fees - city tolls - road pricing - bridge tolls - cordon pricing - congestion pricing
	- subsidies for public transport and/or multimodal transport (modal subsidies)	- subsidised public transport fees - subsidies for public transport networks and operation - tax-deductable public transport expenses - P&R schemes
- Encourage lower emission technology use and innovation	- taxes/charges on vehicle purchase/ownership/ scrappage, - taxes/charges on vehicle use, - taxes/charges on road and/or infrastructure use	- tax differentiations based on emissions - carbon/energy taxes - emission fees - emission-based surcharges - subsidies, tax rebates for low emission vehicles/technologies

Table 15: Economic Instruments in the OECD

Implementation on...	Federal level	Local level
Differentiated fuel taxes (promote cleaner fuels)	✓	✗
Vehicle taxes (purchase, use, waste)	✓	✓
Property taxes, development levies	✗	✓
Road pricing (differentiated according to emissions, time, day, area, etc.)	✓	✓
Parking charges, taxes for parking	✗	✓
Subsidies for clean cars or for conversion	✓	✓
Fiscal incentives to remove older cars	✓	✓
Promoting/subsidizing public transport	✓	✓

Source: Manfred Breithaupt, 2008

To be efficient, pricing policies should:

- Remove distortions by eliminating hidden and overt subsidies for private car users;
- Support sustainable transport modes;
- Create new local revenue sources which are integrated into strategic planning;
- Provide efficient, equitable, and sustainable access for people to urban destinations;

Successful implementation of pricing strategies depends upon: (from Breithaupt, 2008);

- Institutional/regulatory strength (enforcement, monitoring, control abilities);
- Price and income elasticities of demand
- Removal of counter-productive subsidies (*e.g.* for diesel fuel);
- Strategic considerations (*e.g.* competitiveness concerns);
- Lobbying activities (*e.g.* preference for voluntary agreements, information dissemination, and widespread public support).

Different types of pricing reforms are implemented by different levels of government (see Table 15). Some pricing strategies, such as off-street parking pricing and employee financial incentives, may be implemented by private businesses. They may be implemented as part of larger market reforms, such as regulating bus companies. The steps of implementation are discussed in great detail in Sustainable Transport Sourcebook Module 1d: *Economic Instruments*.

Many studies have examined how changes in prices affect travel behaviour, including:

- Todd Litman (2005), *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*, Victoria Transport Policy Institute, http://www.vtpi.org/elasticities.pdf.
- Richard H. Pratt (1999–2007), *Traveler Response to Transportation System Changes*, TCRP Report 95, TRB, http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1034.

Studies generally indicate that transportation is "inelastic" meaning that a price change causes a proportionately *smaller* change in travel activity. For example, a 10% fuel price increase typically reduces vehicle travel by 1% in the short term and about 2% in the long term, if all other factors (such as driver population and parking pricing) are held constant. However, this reflects, in part, the fact that fuel represents only about a quarter of total vehicle costs borne directly by consumers, so a 10% increase in fuel price only represents about a 2% increasing in total vehicle costs. Considering all costs, automobile transportation is relatively price sensitive and can be considered "elastic" over the long run.

The elasticity of vehicle travel depends on many factors, including the type of price change and the alternatives available. In general, the better the transport options available, the more sensitive travel will be to prices. For example, if walking conditions and public transport services are of poor quality or unsafe, an increase in road tolls, fuel prices or parking fees will cause relatively little reduction in vehicle travel, but if walking conditions and public transport service are safe, convenient, and pleasant, travellers will be more responsive to price changes.

4.1 Controlling car ownership growth

Despite the expense of cars as luxury items, car ownership is growing rapidly in many developing countries. Vehicle sales taxes, import duties, registration fees and taxes can affect the number and type of vehicles that residents purchase. Quotas can also be used to limit vehicle ownership, as discussed in Section 4.1.3.

4.1.1 Sales tax/Import duty

Many countries impose a tariff, or import duty, on foreign vehicles in order to favour those which are domestically produced. A sales tax applies more broadly to all vehicles purchased. In some cases, lower sales taxes for fuel efficient vehicles are designed to encourage fleet turnover, or replacement of older polluting vehicles, to meet environmental quality objectives. Although these are not usually designed to suppress vehicle purchase, they can be an effective TDM measure if set high enough. In developing countries, taxation measures are commonly used, as illustrated by China's multi-phased vehicle tax policy in Table 16.

4.1.2 Annual registration/road fee

In developed countries, car owners are commonly charged an annual or bi-annual fee which contributes to a road maintenance fund. The level of the fee may be based on engine size, in order to encourage more fuel efficient vehicles. In the US, it is called a registration fee and ranges from around US$30 to US$150 per year, and is enforced by a sticker displayed on vehicle plates. In addition to a "road fee" for residents, many European countries require purchase of a "vignette" or time-based sticker which is sold by the year, month, week, or day for the use of national roadways by residents of other countries.

Singapore's road tax is differentiated according to engine size, fuel type, and type of vehicle (car, motorcycle, etc), in order to encourage the use of low emission vehicles. Under this system, a small car with a 1,000 cc engine may pay US$600 per year, while one with a large 4,000 cc engine may pay over US$6,000. Diesel vehicles pay 6 times the amount by a similar gasoline car.

Table 16: China's multi-phase vehicle taxation

Type	Tax or Fee	Rate
Vehicle Purchase	Tariff Excise Tax Value Added Tax Vehicle Acquisition Tax	 3–5% 17% 10%
Vehicle Ownership	New Car Checkout Fee Vehicle License Plate Fees Vehicle Usage Tax	 60–320 RMB/year (US$8.70–46.80)
Vehicle Use	Insurance Fee Road Maintenance Fee Consumption Tax	 110–320 RMB/month (US$16–46.80) 3–20% (by engine size)

Box 21: Tax incentive scheme to improve air quality in Hong Kong

A tax incentive scheme was introduced in April of 2007 in Hong Kong, with the aim of improving air quality by encouraging the use of environmental-friendly petrol private cars with low emissions and high fuel efficiency. The program offers a 30% reduction of the First Registration Tax (FRT) to buyers of newly registered environmental-friendly petrol private cars, subject to a cap of HK$50,000 per car (US$6,452).

Cars must meet the following criteria to qualify as environmental-friendly:

- Emitting about 50% less hydrocarbons (HCs) and nitrogen oxides (NO_X);
- Consume 40% less fuel (measured by mileage travelled with one litre);
- Than conventional petrol Euro 4 cars.

The Environmental Protection Department (EDP) will review the qualifying standards annually in the light of technological advancement (current standards are published on EDP website: http://www.epd.gov.hk/epd).

Adapted from: Manfred Breithaupt (2008), "Environmental Vehicle Taxation: International Experiences", presented at the International Workshop on Integrated Transport for Sustainable Urban Development in China (15–17 December 2008)

Table 17: German vehicle tax for passenger cars

Emission Group	Tax per 100 ccm in € for GASOLINE cars	Tax per 100 ccm in € for DIESEL cars
Euro 3, Euro 4 and "3 litre car"	6.75	15.44
Euro 2	7.36	16.5
Euro 1	15.13	27.35
Euro 0 (formerly without ozone ban on driving)	21.07	33.29
Other Passenger Cars	25.36	37.58

Adapted from: Manfred Breithaupt (2008), "Environmental Vehicle Taxation: International Experiences", presented on the International Workshop on Integrated Transport for Sustainable Urban Development in China (15–17 December 2008)

4.1.3 Car quota

The nation of Singapore implemented a quota system to limit the number of cars which may be sold and registered in a given year. The system auctions a limited number of Certificates of Entitlement (COE), which allow a resident to purchase and register a vehicle. This TDM measure has been extremely effective at limiting the growth of private vehicle traffic as the nation's prosperity has grown.

The Vehicle Quota System in Singapore

Singapore's Vehicle Quota System (VQS), which came into effect in May 1990, is part of a series of measures to optimize traffic flow by managing the growth of vehicle ownership to acceptable levels. Under the VQS, motor vehicles are classified into several categories, with a separate licence quota for each category. For categories A, B, and D, the licence is non-transferable.

The Land Transport Authority (LTA) determines the quota for each category every year. In order to register a new vehicle, the would-be-buyer must bid for and obtain a licence, referred to officially as a Certificate of Entitlement (COE). The COEs can be obtained through an auction, the COE electronic Open Bidding System, which is held twice a month (fortnightly). The Quota Premium (QP) represents the price for a COE. The QP is the price of the highest unsuccessful bid plus $1 for that category e.g, if there are 250 in the quota for a particular category for that fortnight, the QP is the bid price of the 251st ranked bid plus $1, which everyone whose bids rank from 1 to 250 pays. Bidders who successfully obtain a COE have to register the vehicle within 3 (for categories C and E) and 6 months (for categories A, B and D) respectively. The COE is valid for 10 years. After this period, the vehicle needs to be deregistered or the COE has to be renewed by paying a Prevailing Quota Premium (PQP), which is the 3 months' moving average of the QP.

The Quota Year (QY) starts in May and ends in April of the following year. In the QY 2008, the total quota was originally set at 115,946 COEs, but reduced during the September 2008 mid-quota year review to 110,354. For the QY 2009, the total quota is fixed at 83,789 COEs. This figure takes into account a 1.5% vehicle growth based on the vehicle population as at 31 December 2008, replacements of vehicles expecting to be deregistered in 2009, and adjustment for any over/under-estimation of vehicle deregistration in the previous year.

The COE Open Bidding System is conducted annually online where users may monitor prices in real-time and place or revise bids by phone or computer. A bid represents the maximum amount that a person is willing to pay for a COE of a specific category. The top bids up to the amount of COEs available under the quota are accepted and automatically paid from the bidder's account. The license is valid for 10 years. After this period the vehicle needs to be deregistered or the license has to be renewed by paying a Prevailing Quota

Premium (PQP), which is the 3 months moving average of the license premium (QP). In 1999, the average premium for the smallest cars (less than 1,000 cc) was US$27,367, and US$30,566 for the largest cars.

The results of the second COE Annual Open Bidding process for February 2009, are shown in Table 18. The total quota available for this tender was set at 4,415 vehicles. Cars and taxis with engines less than 1600 cc were the most popular category with 2,722 received bids for 1,846 COEs and a price of $4,460. Category E, an open category for registration of all types of vehicles, shows the highest price with $5,889. The PQP for category A vehicles is $4,516.

In total, the Land Transport Authority (LTA) received 6,957 bids. 4,383 were successful while 2,574 were rejected.

Table 18: COE open bidding results of Singapore's 2nd quota auction in February 2009

Final results for February 2009 2nd open bidding exercise

Category		Quota	QP (US$)	PQP (US$)
A	Car (<= 1600 cc) & Taxi	1 846	4 460	4 516
B	Car (> 1600 cc)	1 101	4 889	3 004
C	Goods Vehicle & Bus	272	4 190	3 733
D	Motorcycle	434	801	928
E	Open	762	5 889	NA

QP: Quota Premium
PQP: Prevailing Quota Premium (a moving average of the QP over the last 3 months)

Category		Received	Successful	Unsuccessful	Unused
A	Car (<= 1600 cc) & Taxi	2 722	1 842	880	4
B	Car (> 1600 cc)	1 675	1 090	585	11
C	Goods Vehicle & Bus	403	271	132	1
D	Motorcycle	650	434	216	0
E	Open	1 507	746	761	16

Received: Total Bids Received
Unused: Unused Quota carried forward

Source: Land Transport Authority (http://www.onemotoring.com.sg); Gopinath Menon (2009).

4.2 Reducing car use

A variety of economic measures can affect driver behaviour and reduce single-occupant vehicle trips. Economic measures that reduce vehicle use provide price signals to drivers based on the marginal cost of vehicle use, that is, the more a person drives, the more they pay out of pocket. Such measures include fuel taxes, road tolls and parking fees.

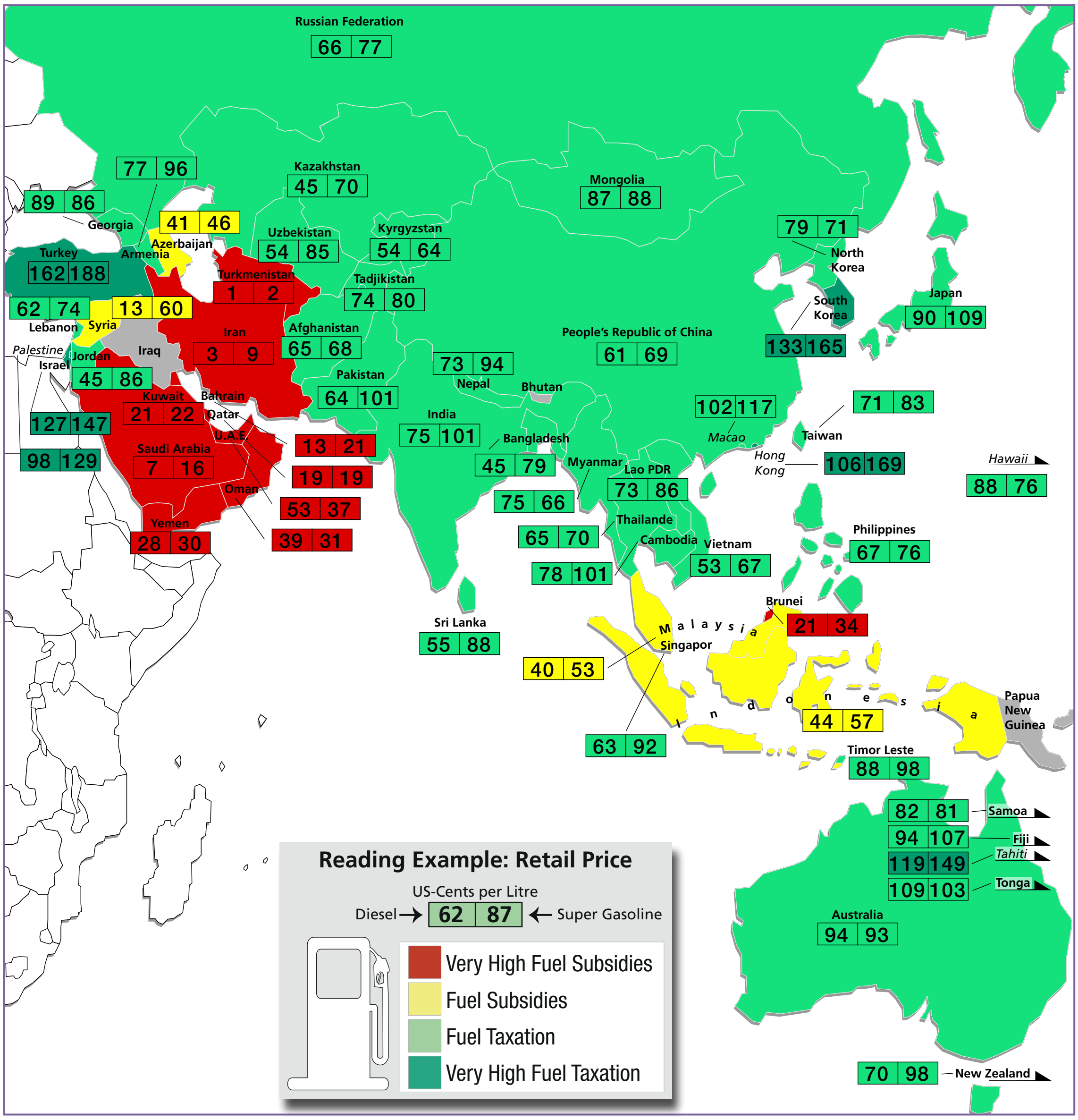
4.2.1 Fuel tax

Most countries charge fuel taxes, as shown in Figure 61. Such taxes can be considered a general tax or a road user fee. Fuel tax revenues are generally used for transportation purposes, and in some cases are strictly limited to the road network. Fuel taxes may be charged by national, state/provincial or local governments. For example in the U.S., the federal fuel tax for gasoline and diesel of US$0.048 and US$0.064 per litre, respectively, is dedicated to all surface transportation modes, from motorways to public transport to bicycle and pedestrian trails. The additional state tax (average state fuel tax of $0.07 per litre) is limited to roadway purposes in 36 states. However, this level of fuel taxation is too low to function as a TDM measure, nor is that an aim of U.S. fuel taxation.

In Europe, where policy makers do aim to reduce car use through fuel taxation, the tax levels are much higher. In Germany, for instance, drivers pay a federal fuel tax equivalent to US$0.81 per litre gasoline and US$0.58 per litre diesel. Empirical results from OECD

Figure 61

Comparison of regional fuel prices.



Source: Armin Wagner (2008), "Fuel taxation as an economic instrument to tackle climate change", presentation Bangkok 14.11.2008, http://www.gtz.de/de/dokumente/gtz2008-en-fuel-taxation.pdf

experience indicate that gasoline price changes have a very long reaction horizon (short run elasticity of -0.05 to -0.1). Yet in the long run, say ten years, price elasticity is roughly double. Thus fuel prices must rise faster than inflation and income rates of growth in order to have an effective demand management effect.

For more information on international fuel prices see http://www.gtz.de/en/themen/umwelt-infrastruktur/transport/10285.htm. GTZ produces biannual worldwide fuel price surveys, with the next comprehensive report expected in April 2009. (There is also a regular monthly newsletter, which you can sign up for on the website).

4.2.2 Road pricing

The practice of charging drivers a direct fee for road space is known as road pricing. Fees may be charged to drive within a certain area or per kilometre on certain roads. The aims of road pricing schemes are to: reduce traffic volumes and pollution, increase efficient use of road capacity, to generate revenues for public transport, and to mitigate the environmental impacts of traffic congestion. As a public policy, it has been implemented with targeted purposes such as reducing traffic congestion at certain times or in certain areas, or with the general purposes of recovering costs of road construction and repairs, or to finance public transport improvements. Fees may be charged by time of day, by vehicle type, or by distance travelled, depending on the goals of the road pricing scheme.

The key factor that has made road pricing a feasible solution to road congestion in recent years is the availability of new technologies that make it feasible to realize pricing road use based on time, distance, and place. Common objectives of road pricing schemes are:

- To deliver a more efficient transport pricing;
- To be fair, respect privacy, and promote social inclusion and accessibility;
- To deliver higher economic growth and productivity;
- To deliver environmental benefits.

New technologies have made it possible to collect fees from drivers without requiring vehicles to stop at a toll plaza. Fees may be paid electronically with on-board units (OBUs) or chip cards while vehicles are in traffic, or by more traditional means at pay stations. Older toll roads that collect fares using coin machines or attendants have a capacity limited to 300 vehicles per hour per lane, which reduces the efficient performance of the roadway. New automated toll collection uses electronic transponders mounted on overhead gantries using Direct Short Range Communication (DSRC). Illustrated in Figure 62, this system keeps traffic free flowing, increasing roadway capacity to 1600 vehicles per hour per lane or higher. The most modern satellite-based GPS toll collection systems are capable of collecting tolls for road use or parking anywhere, anytime, eliminating the need for near-roadside infrastructure altogether.

4.2.2.1 Toll roads

The traditional method for financing new roads, bridges, and public transport is using fuel tax revenues. The fuel tax is paid by road users, and therefore also a form of road pricing. Fuel taxes have also historically been used to pay for road and bridge maintenance. However, in many developed countries, aging and outdated motorways and bridges have increased transport system costs to a stage where needs are so great that new sources of financing are needed. Especially where political factors have kept fuel taxes low, the fuel tax alone is insufficient to pay for the extent of road and public transport improvements needed.

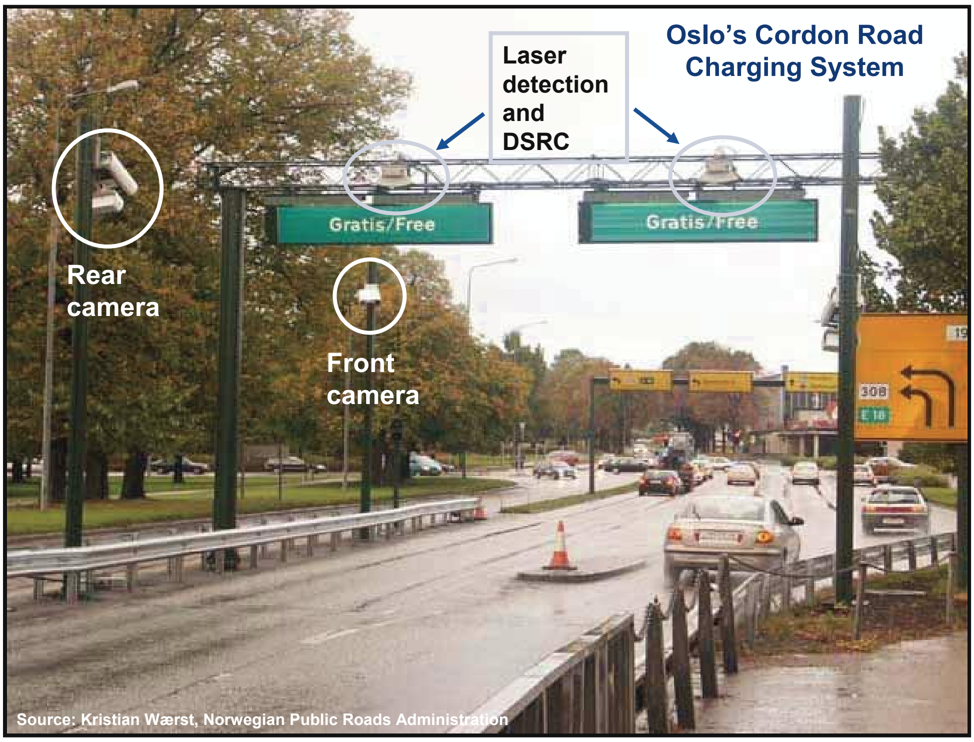
Toll roads create a revenue stream from users that can pay the debt associated with major infrastructure projects, allowing them to pay for themselves over time. This gets around the chicken and egg issue of transport investment — we cannot invest if we do not have revenue, but we will not have revenue if we do not invest. The level of the toll is calculated based on projected traffic volumes and the terms of debt repayment. Vehicles are typically charged based on distance travelled on a toll road, or per bridge crossing on a toll bridge.

A recent practice is for a government to sell the rights to revenue collection to a third-party operator, known as a “concessionaire”, who is also responsible for maintenance and operations. This form of public private partnership is in widespread use throughout France, Spain, Malaysia, and other countries where the national roadway system is owned and operated by several regional concessionaires.

Some toll systems are designed to cross-subsidize investment in public transport. For example, in Norway, several cities have toll rings, or cordons, which charge vehicles as they enter a central area. Voters in Oslo approved a toll cordon whose revenues are dedicated to a set of specific projects, including road improvements, extending a central rail line, and re-aligning trams to connect with the central rail station. About half of the toll revenues are used for road projects, and 20% for public transport improvements. About 250,000 vehicles pay the toll each day, mainly by the 50% of Oslo’s population which lives outside the cordon. Motorists know what they are paying for when they pay the toll, which has greatly helped public acceptability. The level of the toll is based on what is needed to repay project debt and operating costs over a 15 year period.

Many European countries charge vehicles for use of national roadways using automated toll collection systems. For example, Germany charges a toll for heavy goods vehicles (*e.g.* lorries over 12 tons) using its 12,000 km autobahn network. A new technology was deployed for this purpose, using satellite technology. Introduced in 2003, the toll collection system uses Global Positioning System (GPS) and on-board units to charge lorries an average toll

Figure 62
Automated toll collection system.



of €0.12 per kilometre with 50% toll premium for older more polluting lorries. The operator Toll Collect is a public private partnership with a consortium of German companies handling various aspects of operation, such as Deutsche Telekom and Siemens. With over 500,000 on-board units in operation, the system processes over 1 million transactions per day. In 2006, over €2.6 billion of toll revenue was collected, which was used to pay for road maintenance. The scheme charges cleaner vehicles lower fees, leading to a 10% increase in registrations of low-emission lorries. Road pricing has also caused hauliers to increase their efficiency and productivity. An indicator of such optimization is the share of "empty trips", that is, where lorries make return trips without a load, which has fallen by 20% since introduction of the toll.

Similar road pricing schemes targeting lorries on national roadways are in operation in Switzerland and Austria. The Netherlands is poised to become the first country to implement a national road pricing scheme which will apply to all vehicles and all roads. The first phase is planned for launch in 2009, accompanied by reductions in vehicle taxes.

Road pricing has been criticized for disproportionately affecting those people who are the least able to pay, or who may have no choice but to drive. For instance, low-paid service workers may work at locations or start their shift at times when public transport service is not available. Road pricing schemes which charge a flat fee can function as a regressive tax, that is, falling more heavily on poor drivers than on the rich. Economists call this an issue of distributional equity — the most efficient tax is not necessarily the most equitable. It should be considered when designing the pricing of a new scheme, but the initial impacts will decline over time as people adjust to the new price regime, and make changes to minimise their expenses. This process is assisted by phasing in new schemes over a gradual and predictable timeframe.

Ultimately, whether road pricing is regressive depends on how much the charged roads are used by lower-income drivers, the quality of travel alternatives, and how revenues are used. Schemes may be more progressive by providing discounts or a limited quantity of free passes for low-income households to preserve affordability. Local governments should consider the issue of disproportionate impacts in designing any road pricing scheme. Public acceptability depends on the relative size of the groups who benefit or suffer, as summarized in Table 19.

Table 19: Winners and losers of road pricing

Direct winners	Direct losers
■ Bus and rideshare travellers who enjoy improved service due to reduced congestion and economies of scale; ■ Wealthier motorists who value their travel time savings more than their toll costs; ■ Recipients of toll revenues.	■ Lower income motorists who pay the toll, because they have no travel alternative, but do not value their time savings as much; ■ Road users on un-tolled roads who experience increased congestion; ■ Motorists who forego trips due to tolls; ■ Motorists who shift to other routes to avoid tolls; ■ Motorists who shift to transit or other modes due to tolls (although improved service from economies of scale may make some net winners).

Excerpted from Gomez-Ibanez, 1992.

4.2.2.2 Congestion pricing

Both toll roads and congestion pricing charge drivers for road usage. However, the fundamental difference is that congestion charging is a traffic management measure targeted for the purpose of reducing traffic congestion. A toll road operator would like to see an increase in the use of his road, because it brings in larger revenues and will adjust his toll rate accordingly. The primary objective is to generate revenues for road maintenance. A congestion pricing operator is indifferent to road use and prefers to see his charges reduce road usage, thus road pricing rates are adjusted for reducing usage.

Congestion charging is a type of road pricing with higher fees under congested conditions as a way to reduce traffic volumes to optimal levels. Ideally, the charging system should vary over time and location, with the highest fees under for the most congested times, for example, adjusting every fifteen minutes, giving travellers an incentive to shift from the maximum peak to slightly off-peak (called "shoulder") periods.

A concern about congestion charging is that making a city centre more expensive to access by car will drive shoppers away and hurt retailers. There is some evidence that the opposite is true in the short term: the improved quality the shopping environment has drawn people and sales have grown. However, long term effects are difficult to predict. The Singapore experience shows that if the congestion pricing scheme operates for the whole day, there may be some negative business impacts. But negative retail effects were partly overcome by improvement in public transport services to the city.

Economists expect that increasing the cost of city access should result in two types of effects. The 'income effect' is a result of motorists paying the congestion charge having less disposable income for retail purchases. The 'substitution effect' is a result of motorists choosing to make purchases outside the charging zone, redistributing economic activity. The viability of a city centre shopping district over time depends in large part on whether new shopping areas are allowed to proliferate on the edges of urban areas. This in turn depends on the quality of regional planning and the political will to stick

Figure 63
Congestion charging in Stockholm, with prices varying during the day based on peak demand.
Photo by Manfred Breithaupt, Stockholm (SE), 2006

to growth management plans. It also depends on whether local congestion charge schemes are incorporated into a national system of road pricing.

There are several specific ways to implement congestion charging:

- Cordon ring: A fee is paid when a vehicle crosses a cordon to enter a central area, usually only during peak hours.
- Area license: Vehicles purchase a day license to enter a central area.
- Corridor: Vehicles using a specific road, lane, tunnel or bridge are charged a fee.
- Network: Vehicles are charged a per-kilometre fee for use of entire road network, or portion of the network (*e.g.* national motorways)

Table 20 summarizes common congestion pricing schemes implemented in Europe. The design of a congestion pricing scheme must ensure that vehicles are unable to evade the charge. The most common design is a cordon ring, where a circle is drawn around the area targeted for congestion relief, and the charge is applied to vehicles crossing this perimeter. Physical features which help to limit access to the charged zone are often incorporated. For instance, the boundaries of the Stockholm scheme are the rivers surrounding the city centre, with the charge applied to vehicles crossing bridges to access it. Drivers may pay the charge by a variety of methods, and the scheme is enforced by cameras monitoring the registration plates of vehicles passing the congestion charge boundary points. Unlike other types of road pricing schemes, congestion charges are only in effect during peak times of congestion.

Figure 64
An overhead gantry controls the congestion charge in Stockholm.
Photo by Manfred Breithaupt, Stockholm (SE), 2006

The design and technology of congestion pricing schemes ranges from low-tech to state-of-the-art. The most basic payment system is a toll collector in a booth, where vehicles must stop to pay. Modern schemes offer frequent users the option of using an on-board unit (OBU), installed in the vehicle, which communicates electronically with units mounted on overhead gates over the roadway, called gantries. This type of scheme is called a tag and beacon system. Vehicles must slow down, but not stop, to pay, which saves motorists time, and they are less expensive to operate due to fewer staff. Tag and beacon systems are in operation in many European countries, such as France, Spain, Portugal, Italy, and Germany.

Singapore was the first city to introduce congestion pricing in 1975. It was a cordon scheme known as the Area Licensing Scheme. A central area within a cordon was termed the Restricted Zone, and tolls were enforced using a simple low-tech paper license. It quickly proved successful in reducing traffic congestion and causing a modal shift to public transport. In 1998, the system was modernized to be fully automatic, with a state-of-the-art Electronic Road Pricing System using DSRC technology and all vehicles fitted with In-vehicle Units (IUs). Congestion pricing charges are deducted automatically from smart cards as the vehicle goes under an overhead control gantry.

The most modern version of road pricing are network charging schemes, which are comprehensive systems capable of charging motorists for travel on an entire road network. Network charging schemes treat road use like the consumption of other public utility service, such as water or electricity. Network charging comes closest to the ideal road pricing system described above, where the price of road use varies according to construction and maintenance costs, pollution and noise costs, and the costs of delays to other drivers when road space is in high demand. Thus road users get a direct price signal about how much their trip imposes costs upon society, and may adjust travel accordingly.

Figure 65
Singapore's Electronic Road Pricing (ERP) gantry automatically deducts payment from CashCards inside In-vehicle Units (IUs).
Photo by Manfred Breithaupt, Singapore, 2003

Figure 66
Short-range radio communication system is used to deduct ERP charges automatically.
Photo by Karl Otta, Singapore, 2004

Table 20: Types of congestion pricing systems

	Cordon ring	Area license	Corridor	Network
Description:	All vehicles entering a certain central city zone defined by a cordon are charged a flat fee when they cross the boundary at peak use times.	All vehicles operating within a central city area during certain times are charged a daily fee.	All vehicles using tolled road, bridge, or tunnel pay a flat fee. In some cases, the fee changes dynamically based on peak use times.	Vehicles pay for each kilometre travelled on a road network. Fees may be differentiated by type of vehicle, emissions class, roads used, and/or peak use times.
Aims:	Reduce traffic congestion in central area	Reduce traffic congestion in central area	Reduce congestion on the corridor (also finance a specific road or bridge)	Reduce congestion, increase efficiency (also finance transport infrastructure)
Technology:	DSRC, Toll plazas and/or plate-recognition cameras	Plate-recognition cameras	Toll plazas and/or tag and beacon system with on-board units	On-board units and GPS satellites
Financing:	Public	Public	Public and Private	Public and Private
Operator:	Public	Public	Public or Concessionaire	Concessionaire
Revenues used for:	Road and public transport improvements/other public projects	Public transport improvements	Road improvements	Road, railway and public transport improvements
In use:	Bergen, Durham, Florence, Kristiansand, Namsos, Oslo, Rome, Singapore, Stavanger, Stockholm, Tonsbjerg, Tromso, Trondheim, Valletta	London	Czech Republic, England, France, Greece, Italy, Portugal, Spain	Austria, Germany (lorries on autobahn) Switzerland (lorries on all roads) Planned: Netherlands

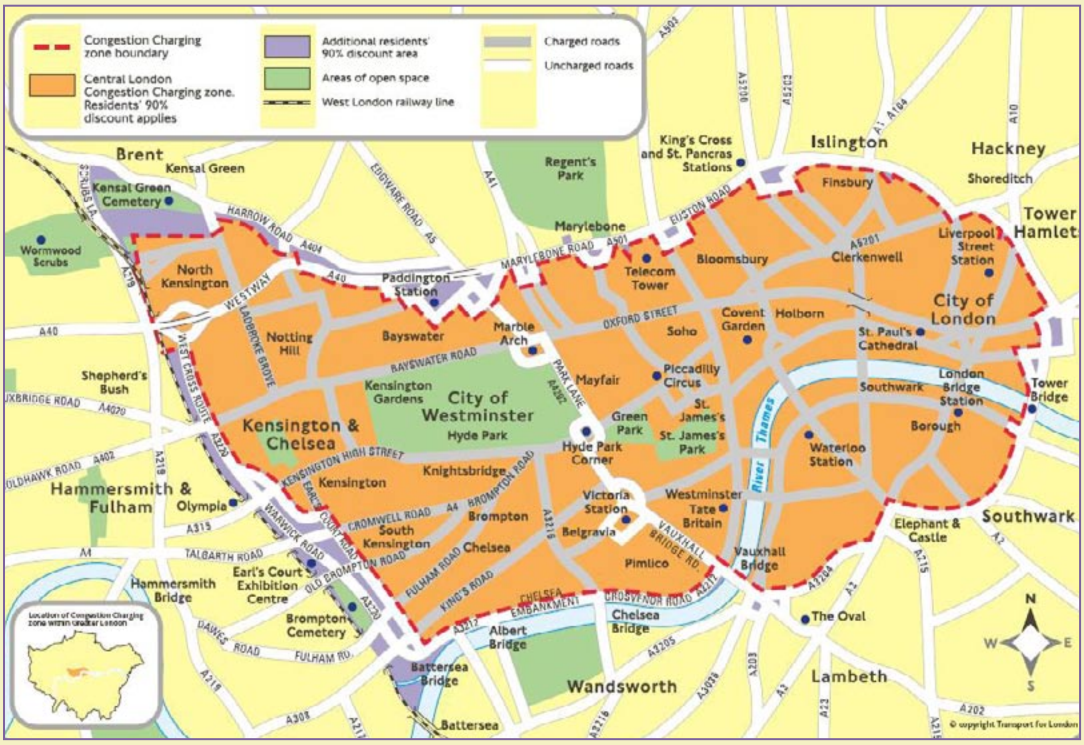
Excerpted from Transport & Environment, 2007.

Box 22: London's congestion charge

In February of 2003, Mayor Ken Livingston introduced London's Congestion Charge as a measure to address traffic congestion in the central city — the worst in the UK in terms of driver delay. Drivers in central London spent an estimated 50% of their time in queues, adding up to a time loss of £2–4 million every week (TfL, 2007). The aims of the congestion charging scheme were to discourage the use of private cars, reduce congestion, and support investment in public transport. It is considered a success for having achieved these aims.

The effects of the congestion charge were immediate and dramatic. In the first two days, traffic levels fell by 25%, and drivers reported that journey times were reduced by as much as half (TfL, 2007). An extra 300 buses were introduced on the same day. Although London already had a relatively high share of commuters using public transport, it further increased significantly.

As of 2007, London remains the largest city in the world to have adopted a congestion charge model. The organisation responsible for the charge is Transport for London (TfL), in conjunction with a private operator. The congestion charge is a flat fee charged to motorists within a central London area, defined by a cordon. It is an area charging scheme, meaning that motorists crossing the cordon are charged, as well as vehicles operating entirely within the zone. The cordon was initially limited to the eastern business districts of London, but was extended to include western residential boroughs in February of 2007. The charged zone is an area of approximately 8 square miles.



When launched, the congestion charge was £5; since 2005, the charge is £8. Vehicles are charged upon entry to the congestion charge zone between 7:00 and 18:00. The scheme is enforced by ANPR plate-recognition cameras monitoring vehicles within the zone. Non-compliant vehicles are automatically mailed a penalty.

The traffic-reduction effect of the congestion charge has remained consistent over time. In 2003, TfL assessed the first six months of the charge and found that the number of cars entering the central zone was 60,000 less than the previous year. Around 50–60% of this reduction was attributed to trips shifted to public transport, 20–30% to journeys avoiding the zone, and the remainder to car-sharing, reduced number of trips, more travelling outside the hours of operation, and increased use of motorbikes and cycles. Journey times were reduced by 15%. In 2006, TfL found that congestion reductions and journey time saving effects remained in place. Congestion was still reduced by about 26% in comparison with the pre-charge period.

Source: Commission for Integrated Transport, 2008

Box 23: Stockholm's congestion charge

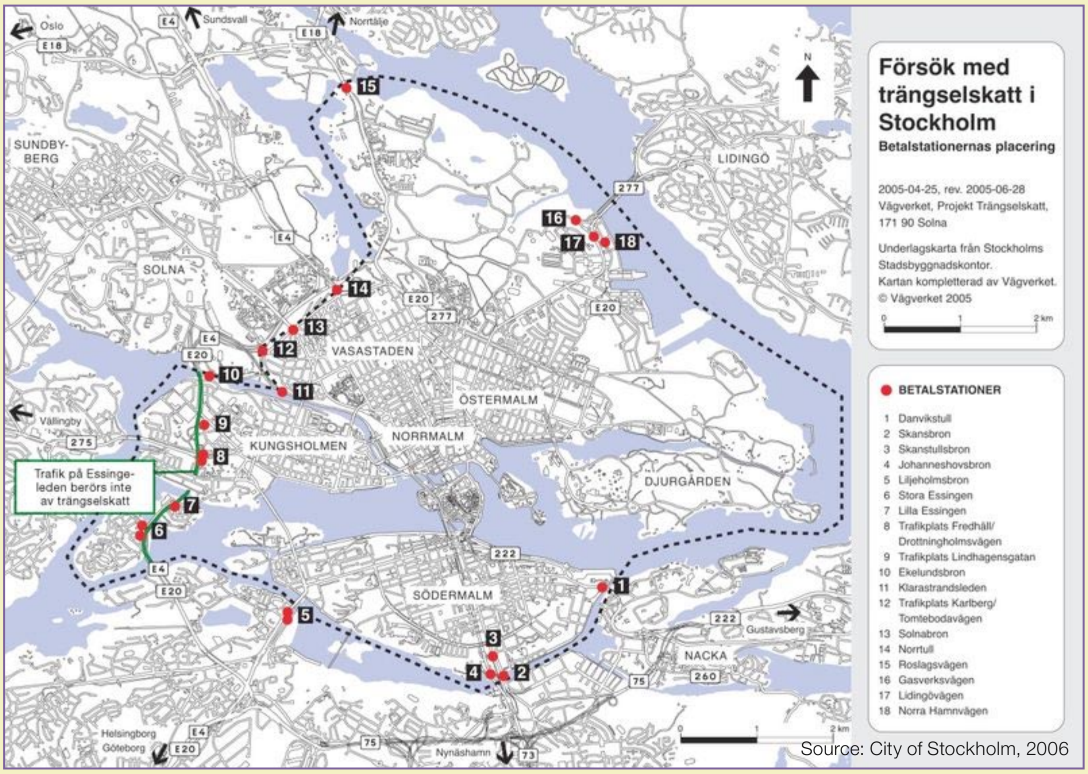
The City of Stockholm, Sweden adopted a congestion charge in August of 2007 after a trial process to test the effects of the scheme. Facing a congestion problem degrading the economy and quality of life, Stockholm leaders also realised that their road expansion options were limited. They determined that supply-side measures, such as ring roads or expanded public transport service, came with high costs and limited benefit to relieve pressure on the road network, saying "Traffic congestion is a big-city phenomenon that cannot be removed through investments in roads or public transport." (City of Stockholm, 2006)

A trial congestion charging scheme was developed with four aims: to reduce vehicles entering the centre city at peak hours by 10–15%, to improve access on Stockholm's busiest roads, to reduce CO_2 and other vehicle emissions, and to gain a perceived improvement in the street-level quality of life for city residents.

The Stockholm Trial began in July of 2005, with expanded public transport services. New bus routes, more rail frequent service, and new park-and-rides were introduced in advance of the congestion charge. The first day that vehicles were charged was 3 January 2006. The fee remained in effect until 31 July 2006, at which point the City conducted an evaluation in preparation to put the matter to a public vote. The evaluation showed that traffic during peak hours fell by 22%, exceeding the city's goal. Displacement traffic on the bypass road was lower than feared, only 4–5%, and also minor on ring roads. Of the approximately 80,000 fewer daily car passages across the charging cordon, more than half were found to be work or school trips. These trips were made by public transport instead, with passenger counts showing a 6% increase from spring of 2005 to 2006.

The trial scheme was considered a success for improving access to the city centre. Travel times fell dramatically, particularly on approach roads to the centre city, where queue times fell by a third in the morning peak, and were halved in the afternoon. Increased productivity due to shorter travel times was calculated as a benefit of 600 million SEK per year, or US$23 million. Commercial vehicles, buses, and drivers of company cars especially benefited from better travel-time reliability.

Fewer vehicles in the city centre meant lowered CO_2, NO_2, and particulate emissions. Carbon dioxide emissions fell by 14%. Harder to measure were related positive effects on public health, road safety, and the perception of city environment quality. Polls showed that public attitudes changed in favour of the congestion charge over the period of



Source: City of Stockholm, 2006

the trial as people experienced its effects. A poll in the fall of 2005 showed a baseline negative attitude, with 51% of county residents saying a congestion charge was a "fairly/very bad decision". By May of 2006, only 42% still held that opinion, with 54% responding that the charge was a "fairly/very good" decision, (City of Stockholm, 2006).

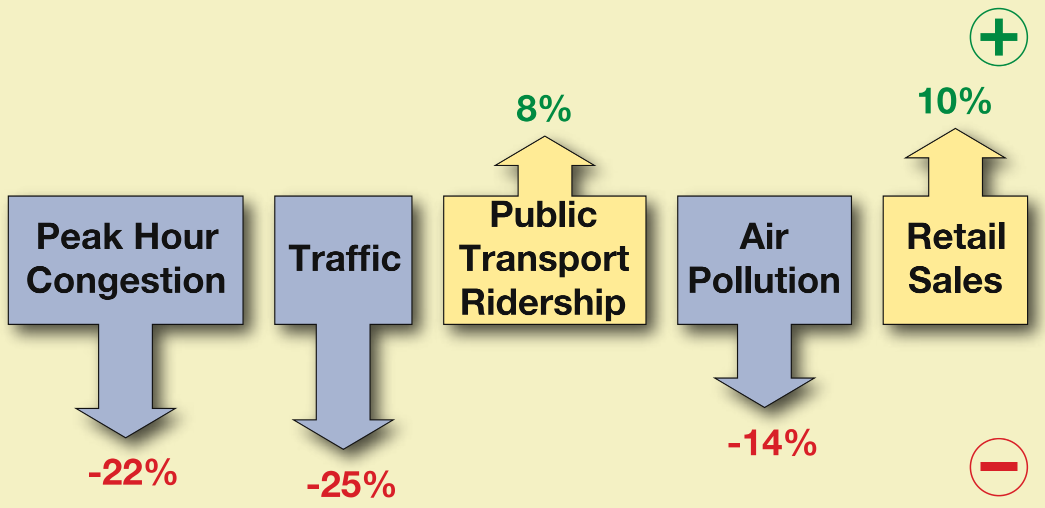
An important finding during the trial period was that improved public transport service by itself had very little impact on traffic congestion. Expanded transit services were introduced six months in advance of the congestion charge, allowing Stockholm's transport managers to measure the effects on traffic congestion. They concluded that, "Of the 22% decrease in car travel across the charge zone, only 0.1% at most could have been caused by the expanded bus services," (City of Stockholm, 2006). They named the fee as the reason that drivers made the switch, "The congestion tax seems to have caused an increase in travel by public transport by approximately 4.5%."

A referendum on whether to adopt the congestion charge was held in the County of Stockholm in conjunction with the general elections on 17 September 2006. The issue was on the ballot in the City of Stockholm and 14 surrounding municipalities. With a high percentage of voters participating (76%), a majority of city residents (53%) voted in favour of keeping the congestion charge, while it failed in the surrounding areas. It fell to the National Parliament to make the final decision, and they voted in June 2007 to implement the congestion charge permanently. It has been in effect since 1 August 2007.

Designed as a cordon scheme, Stockholm's system charges vehicles a fee of as they enter and exit the charging ring. The fee is charged during morning and afternoon peak hours, but varies from 10–20 Swedish Kronors (US$0.25–0.75) depending on the exact time. It is enforced using automated number plate recognition cameras (ANPR).

Box 24: Travel impacts of Stockholm's congestion charge

Next to a significant reduction of traffic (25% peak hour congestion was successfully reduced by 22%. Public transport and retail sales rose by 8% and 10% respectively. The congestion charge did not harm the business, in contrary; business has increased the number of Mass Transit users by 40,000/day. (Michele Dix, 2006)



Adapted from: Manfred Breithaupt (2008), "Environmental Vehicle Taxation: International Experiences", presented on the International Workshop on Integrated Transport for Sustainable Urban Development in China (15–17 December 2008)

Box 25: Singapore's congestion charge

The oldest and perhaps most well-known congestion charging scheme is Singapore's Congestion Pricing Scheme. The objective was to charge vehicles at places and at times where and when they caused congestion. The revenues were not earmarked for transport purposes but went into a general consolidated fund. Transport projects on road and urban rail had to be justified economically to obtain funds to carry out.

The first congestion pricing scheme, introduced in June 1975, was called the Area Licensing Scheme (ALS). An imaginary cordon was placed around the most congested parts of the city, termed the Restricted Zone (RZ), an area of 720 hectares. Each of the 33 entry points to the RZ had an overhead gantry sign with the word "Restricted Zone". To enter this area during the period of 7:30–10:15 on weekdays and Saturdays, cars and taxis needed to purchase and display an area license. These paper licenses which came in daily (US$2.20 daily) and monthly (US$43 monthly) forms had to be displayed clearly on the vehicle windscreens. The licenses were distinguishable from each other by shape and colour. Licenses were available at post offices, convenience stores, petrol stations and at special license sales booths set up along the approach roads to the RZ. They could not be purchased at the entry points.

Cars and taxis carrying four persons (car pools) including the driver were given free entry. Police personnel were stationed in sentry huts at the entry points. They observed whether the vehicles were displaying the correct area licenses as they passed the entry points. Offending vehicles were not stopped, but their particulars were taken down and they received a summons for entering the RZ without a valid license. The penalty was US$50. Escape routes were provided at the main entry points to ensure that vehicles were not forced unwittingly to enter the RZ. There was no policing within the RZ. Vehicles were free to move around and leave the RZ.

The three main milestones until 1998 (when ALS was replaced by the Electronic Road Pricing ERP) were:

- June 1975 when the morning ALS was introduced for cars and taxis only, with exemption given to other vehicles and carpools.
- June 1989 when the ALS scheme was also extended to the evening (16:30–19:00); and all exemptions (for other than public scheduled buses and emergency vehicles) were withdrawn.
- January 1994 when the whole day ALS (7:30–17:00) was introduced with separate peak hour and lower off-peak hour fees.

Throughout the years, there were also enlargements in the area of the RZ and in the price of licences. From 1975–98, the city area has grown by about 30% in terms of area with increases in employment and commercial activity. The vehicle population has increased by 245% from 276,866 at beginning of 1974 to 677,818 in mid-1997 over the same period. Yet traffic conditions in the city roads were better than what it was in 1975. The average traffic speeds in the city during the working day varied from 26–35 km/h, as compared with about 15–20 km/h prior to implementation of ALS.

In 1975, the public transport share of the work trips to the city was 46%. In 1998, it was 67%. With the gradually increasing patronage, public transport operators had been able to improve their services. There has also been a fundamental shift in the attitude to the car. True that the car is still a much-sought after commodity by many, but public transport has become a respectable and acceptable alternative.

ALS started off in 1975 in a simple manner by having restrictions for cars and taxis only, during the morning peak hours. As it was subsequently extended to cover the whole day with different rates for different vehicle classes and lower rates during the off-peak hours, the number of licenses mushroomed. While the regular motorists who bought licences often had no problems, the occasional user faced confusion. The motorist had a choice of 14 licences to choose from, which was considered too many. With the ALS it was difficult to change the area and the times of restriction

With the paper license, motorists could make an unlimited number of entries into the controlled area. This was not keeping in the spirit of the concept of congestion pricing, which was meant to make the driver pay for the use of the road at times and places when and where they cause congestion. The fairest way would be to make the motorist pay each time he uses the controlled area.

Therefore, a search for an automatic alternative started in 1989 when technologies for electronic toll collection started appearing. This is how the Electronic Road Pricing (ERP) started.

The ERP system introduced in 1998 is a dedicated short-range radio communication system (DSRC) using a 2.54 GHz band. There are three components, namely:

- The In-vehicle Unit (IU) with the smart card called CashCard
- ERP gantries (or control points) located at the same points as the control points for ALS
- A control centre where the system is monitored by enforcement personnel

The IU is a pocket dictionary sized device powered by the vehicle battery and which is fitted permanently to the windscreen of vehicles, and on the lower right hand corner or handlebars of motorcycles and scooters. In the database of IUs, each unique IU number is tied to the registration number of the vehicle to which it is affixed. The IU has a slot for receiving a prepaid stored value contact smart card. The smart card, called the CashCard, is issued and managed by a consortium of local banks. The CashCard is reusable (for about 2–3 years) and can be topped up in cash value to a maximum value of US$500 at petrol stations or automatic teller machines.

The IU has a backlit liquid crystal display. It displays the CashCard balance when the card is inserted into the IU and the remaining balance after the deduction of a charge when the vehicle goes under an ERP gantry. These displays only last for 10 seconds and then the screen goes blank. As the vehicle approaches within 10 metres of the first antenna of the ERP gantry, the antennae interrogates the IU, determines its validity, classifies the vehicle according to the IU and instructs it to deduct the appropriate ERP charge, which it looks up and determines from a charge table resident in the local controller. Between the two gantries, the IU deducts the appropriate charge from the stored value of the CashCard and confirms that it has done so to the second antenna. On the IU of the vehicle, the new balance in the CashCard after the deduction of the ERP charge is displayed for 10 seconds. At the same time, the optical sensor detects the passage of the vehicle. If there has been a valid ERP transaction *i.e.* the correct ERP charge has been deducted, this information is stored in the local controller.

If there has not been a valid transaction for some reason, the enforcement camera takes a digital image of the rear license plate of the vehicle, recording the reason, *i.e.* no CashCard etc, and also stores this information at the local controller. The local controller sends back all the ERP transaction data and digital images to the control centre at regular intervals.

The records of valid ERP transactions are stored for a day and at the end of which, they are used to claim the total ERP charges from the CashCard operator. The violation/error images are kept for a period of 6 months, as they may need to be used if drivers challenge the summons issued for violations.

As in the case of ALS, ERP has proven to be reliable and has been successful in keeping traffic congestion in the controlled area to manageable levels.

The demand price elasticity figures for cars vary between -0.12 and -0.35. The elasticity figures for motorcyclists vary between -0.7 and -2.8. Motorcyclists appear to be sensitive to price changes, while car drivers tend to be less affected by price changes. This sensitivity may be partly explained by the fact that car owners tend to be generally in a higher income bracket that the motorcyclists.

Source: Various reports on ALS and ERP by A P G Menon and Chin Kian Keong, (1992–2004)

4.2.3 Low emission zones

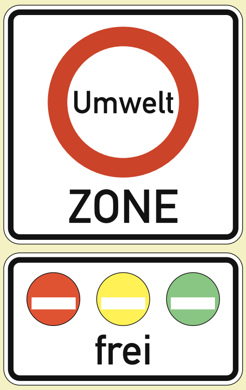
TDM policy measures which restrict car access are often closely related to other policy goals, such as reducing vehicle emissions and increasing road space for other users. For example, some European cities have elected to create Low Emission Zones which limit access to cars of a certain low pollution class, or restrict all cars from heavily trafficked central areas during peak use hours. Besides encouraging use of public transport and non-motorised modes to access Low Emission Zones, improved air quality and noise levels make them all the more attractive for visitors and residents. Business owners, at first wary of such traffic restrictions, have found that an increase of foot traffic is good for business.

Low Emission Zones are most often created around the historic city core. An example is Bologna, where city leaders decided to pedestrianise the city's historic central Piazza Maggiore (although buses are allowed) and limit traffic in the surrounding area to permitted vehicles. Delivery vehicle access is only permitted during certain morning and afternoon hours, when retractable bollards allow passage. On Sundays, vehicle circulation is prohibited from 9:30–12:00 and from 15:30–18:30 in a "Zona a

Box 26: Low emission zones in Germany

An emission zone cannot be considered as a tax. It is a restriction scheme for polluting vehicles. In Germany, low emission zones were implemented as areas from which highly polluting motor vehicles are banned. Vehicles are banned from the city centre in three stages, and must display a permit sticker ('Vignette').

The low emission zones in Berlin, Hannover, and Cologne became effective on 1 January 2008. Since then, all major German cities have followed. Vehicles are classified in four different classes based on the Euro emissions class of the vehicle. The following table gives an overview of the national scheme.



Emission class	1	2	3	4
Sticker	No Sticker			
Requirement for diesel vehicle	Euro 1 or worse	Euro 2 or Euro 1 + particulate filter	Euro 3 or Euro 2 + particulate filter	Euro 4 or Euro 3 + particulate filter
Requirement for petrol vehicles	Without a catalytic converter			Euro 1 with catalytic converter or better

Source: http://www.lowemissionzones.eu/content/view/45/61

In Berlin the implementation is divided in two stages:

Stage 1, effective 1 January 2008:
Vehicles (lorries and passenger cars) must at least meet the requirements of Pollutant Class 2 of the recently adopted national vehicle marking scheme. Therefore, only vehicles with red, yellow and green stickers are allowed.

Stage 2, effective 1 January 2010:
Only vehicles in Pollutant Class 4 – thus, only vehicles with green stickers– can drive in the Low Emission Zone.

Exemptions are provided for:
Police and fire service vehicles, transport of severely disabled persons, ambulances, cleaning vehicles, mopeds, motorbikes and some other vehicles.

Penalties:
For driving into a Low Emission Zone without a permit, there is a €40 fine and a penalty point on your driving license registry.

70 towns and cities in eight European countries introduced or are planning to introduce Low Emission Zones in order to improve air quality in their city centres.

The central aim is to improve the air quality and to protect the health of the residents. Road traffic is the main source of noxious substances, like fine dust (PM_{10}) and nitrogen dioxide (NO_2). Emissions of particulate matter increases the danger of asthmatic and pulmonary diseases, as well as cardiovascular disturbances and lung cancer. In many city centres the given upper limits are exceeded regularly.

Adapted from: Manfred Breithaupt (2008): "Environmental Vehicle Taxation: International Experiences". Presented on the International Workshop on Integrated Transport for Sustainable Urban Development in China (15–17 December 2008)

Trafico Limitato" comprising nearly the whole city centre, an area of approximately 80 hectares. (Lehmbrock).

Some cities have implemented larger scale Low Emission Zones. For instance, starting in 2008, London has imposed a daily fee of £200 (US$350) for more highly polluting lorries and buses which do not meet the Euro 3 emission standard for driving in the Greater London Area, (approximately 8 square miles). A network of cameras is used for enforcement. The system raises approximately US$100 million a year, which is four times the initial cost of establishing the camera-based enforcement and charging system.

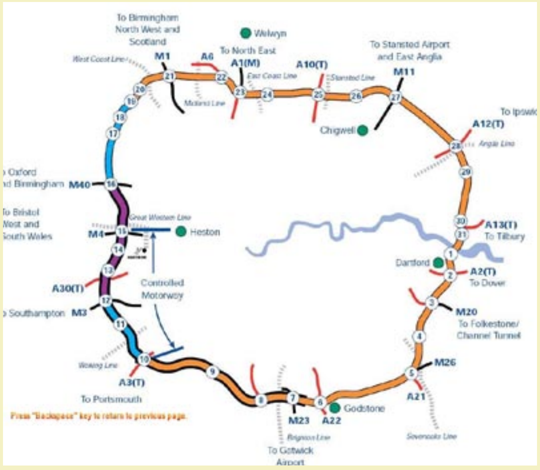
Box 27: Low emission zone charging in Milan, Italy: EcoPass

On 2 January 2008, a one-year trial of EcoPass started. It is a scheme of emissions-based charges for the entry into Milan's Limited Traffic Zone (ZTL), which is controlled by 43 gates. Cameras record vehicle license plate numbers and pollution class, and debit the card holder's account. The fee is charged from 7:30–19:30, Monday to Friday.

Charges are based on the Euro emissions class of the vehicle, the fuel type, the availability of particulate filters, and the type of transport (personal or goods). Vehicles using alternative fuel (*e.g.* LPG, CNG, electric), gasoline cars and lorries (Euro 3 and later), and diesel cars and lorries (Euro 4 and later) are not charged. The maximum toll is €10 (US$12.52) per day. A multiple access card (50 days of access, not consecutive, with a reduced price) and a subscription card are offered to frequent visitors and for residents of the ZTL.

Penalties are enacted if the charge is not paid by midnight, and/or if a lower pollution class is paid contrary to the vehicle's class, and/or if the vehicle is not authorized to enter the zone.

The penalty charge is ranging from €70 (US$89) to €275 (US$349).

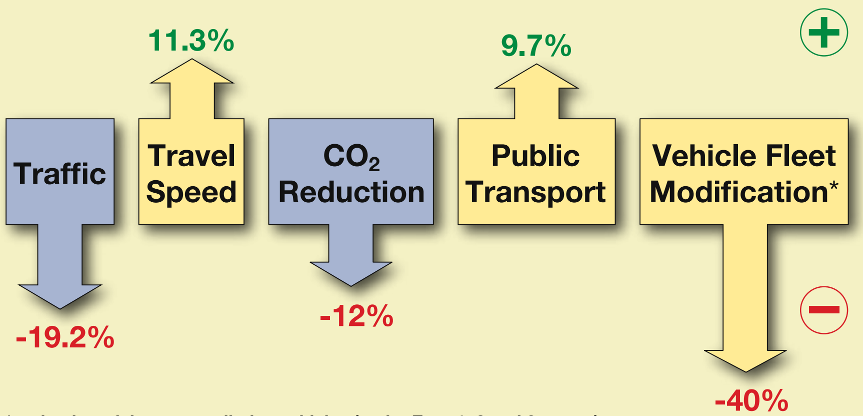


Exemptions are provided for:

- mopeds, scooters, motorbikes,
- vehicles carrying disabled persons and/or bearing a disabled passenger badge.

Travel impacts:

Since introduction, the results show a significant reduction of traffic (19.2%) within Milan's central core, and an increase in travel speed (11.3%). Furthermore, it can be noticed that the use of public transport has risen by 9.7%.



* reduction of the most pollution vehicles (under Euro 1, 2 and 3 norms)

Adapted from: Manfred Breithaupt (2008), "Environmental Vehicle Taxation: International Experiences", presented on the International Workshop on Integrated Transport for Sustainable Urban Development in China (15–17 December 2008)

For further information: http://www.comune.milano.it/dseserver/ecopass/index.html

Box 28: Shanghai bans heavy polluting vehicles

Effective 1 October 2006 Shanghai banned heavy polluting vehicles (below Euro 1 Standard) from entering the downtown area. Cars, lorries and buses entering downtown between 7:00 and 20:00 must comply with the Euro 1 standard under the new rule. At the time of introduction, 350,000 vehicles were not meeting the emissions criteria.

- The restricted zone is a 110-square-kilometre area within the Inner Ring road;
- Motorists must apply for stickers (free of charge) certifying their vehicles are environmental-friendly;
- Violators are fined up to 200 Yuan (US$25) and two points will be added to their driving safety records (motorists with 12 points face licence suspension).

Source: China Daily, 30 December 2005

4.2.4 Parking pricing

While parking management strategies will be discussed more thoroughly in Section 5.2.3, some parking demand management measures are specifically aimed at changing the price of parking. Of the factors affecting demand for parking, perhaps the most overlooked is the price. Most parking is provided to users for free, although it is not free to build or operate. For further details on parking pricing, please see the module on Parking Management from GTZ which will be published by May 2009 (http://www.sutp.org).

> *"The basic cause of confusion is that our society has not made up its mind whether a parking space should be provided at a market (commercial) price, or as a 'social service'."*
>
> G. J. Roth, "Paying for Parking," 1965

Many developed countries have followed the *social service* approach to parking, with a practice of providing ample and free parking in cities. Parking is routinely provided for free by shop owners, employers, and home developers, meaning that drivers do not take it into account when making travel choices. An oversupply of parking encourages excessive car use and resulting increases in air pollution and traffic congestion.

A paradigm shift in parking policy is currently underway. Planners and city leaders are starting to see free parking as a hindrance to improving urban quality of life and housing affordability. Out-dated parking policies are coming under scrutiny as many cities move to improve parking management as a strategy promoting compact, transit-oriented smart growth. Cities are moving from supply-oriented to demand-management oriented policies. The new approach to parking policy is as follows:

Table 22: Paradigm shift in parking policy

	Old paradigm	New paradigm
Parking considered as	Public good	Commodity
Demand assumed	Fixed/Inelastic	Flexible/Elastic
Supply should	Always grow	Be managed in response to demand
Government regulations	Set minimums and no standards	None/set maximums
Pricing maximizes	Utilisation	Availability
Turnover encouraged via	Time limits	Pricing
Costs should be	Bundled with goods	Transparent to users

Figure 67

Solar-powered electronic parking meter for on-street parking.

Photo by Karin Rossmark, Brasov (RO), 2004

Figure 68

Sign informing about parking charges in Singapore. Cars and motorcycles are charged for parking.

Photo by Karl Fjellstrom, Singapore, 2002

The supply of on-street parking spots is relatively fixed once streets have been built. Yet even as demand increases for this fixed supply of spots, kerb parking is free or cheap in most cities. This leads to inefficient utilization of on-street spaces, where some vehicles may remain in place all day while others circulate in traffic, searching for a spot. This "search traffic" can form a significant portion of traffic on city streets, in some cities as much as 74% (Shoup, 2005).

Performance pricing is a policy solution that ensures on-street parking spots will be available to those who value them the most. With performance pricing, the per-hour price for on-street spots is based on demand, such that 15% are always available, (Shoup, 2005).

4.2.5 Vehicle restrictions

Policies and regulations which restrict car access do so by limiting parking, closing some streets to cars, and prohibiting cars from circulating in certain areas or at peak hours. Also car-free zones are getting increased popularity, as well as car-free days (once a year or regularily such

Box 29: Parking levies

City and regional governments can encourage efficient parking management and generate revenue by charging a special tax or levy on parking spaces. Such taxes and fees encourage businesses to reduce their parking supply, and if passed on to users, encourage commuters to use alternative modes of transport.

Parking space fee: A fee on every non residential parking space.

Benefits:

- Easy to implement and administer;
- Encourages a reduction in parking spaces;
- Revenues can be dedicated to public transport.

Examples:

- Sydney: US$615 per space per year. City earns US$31 million per year in revenue;
- Perth: City earns US$8.2 million per year. Resulted in a reduction of 6,000 parking spaces.

as every Sunday, like this is the case in Bogota, Rio de Janeiro (Avenida Copacabana) and Jakarta, for just naming a few examples). The shared space concept also contributes towards less dependency on motorised travel and puts all modes on equal footing (for details see the GTZ Module 3e: *Car-free Development*). These measures are generally not costly, but can be controversial to implement.

4.2.6 Vehicle number plate restrictions

Another example of a TDM policy that can be used in certain situations is vehicle license number restrictions. This is a policy where vehicles are restricted from driving in an area on certain days of the week, based on registration plates, with the aim of reducing the overall number of cars in use. International experience includes many cities which have implemented such measures with varying degrees of effectiveness, (see Box 31). In most cases, the plate restriction applies to certain types of vehicles, certain zones, or certain times of day; although in some cities it may apply for the full day. It is a general agreement that vehicle plate restrictions alone is not an effective measure in the long term, due to the fact that it does not respond to an increase in the amount of vehicles on the road. So-called "even/odd" schemes have pros and cons, as shown in Table 23.

Figure 69
Car-free zone in Xian.
Photo by Armin Wagner, Xian (CN), 2006

Table 23: Advantages and disadvantages resulting from number plate restrictions

Advantages	Disadvantages
Accepted by the public as a demonstration of commitment by government to take action on congestion and air pollution.	Cannot provide a long term solution as it will be undermined by growth in vehicle ownership over time.
Provide instant, measurable traffic reduction effects.	Can be vulnerable to fraudulent practices such as fake number plates.
Can provide temporary relief while long-term solution is developed, such as public transport improvements or central area congestion pricing.	Increased taxi trips result if taxis are excluded from the scheme.
Less difficult to enforce than feared.	Can be undermined by exemptions.
Improve performance of road based public transport, at least in the short term.	Households increase the number of vehicles owned as a way to avoid restrictions, but this effect can be reduced by limiting restrictions to peak period travel.

Excerpted from Pardo, 2008

Box 30: Restricting car use with plate restrictions

In order to be effective, mechanisms to avoid purchases of second cars should accompany a plate restriction policy, otherwise number plate restrictions can encourage used car purchases:

1. Apply restrictions to peak periods only;
2. Ban four numbers each day (instead of two);
3. Change number combinations quarterly or biannually;
4. Require new number plates for used car purchase.

Source: Pardo, 2008

Figure 70

Vehicles may be restricted by plate number.

Photo by Carlosfelipe Pardo, Bangkok (TH), 2006

Box 31: Examples of plate restrictions schemes in developing cities

Mexico City uses a scheme which prohibits car use throughout the federal district with number plates ending in "1" and "5"on Mondays, "2" and "6" on Tuesday etc. for the working week ("Hoy No Circula");

Bogotá uses a scheme in which 40% of private vehicles cannot operate in the city from 7:00–9:00 and from 17.30–19.30 in accordance with designated number plates ("Pico y Placa");

Santiago de Chile uses a scheme which is in effect only on days where atmospheric pollution reaches emergency levels. All vehicles except buses, taxis and emergency vehicles are prohibited from circulation in morning and evening peaks on the six principal roads connecting the outer areas and city centre;

Sao Paulo uses a scheme over a wide central area (within the Inner Ring, 15 km diameter) in which 20% of vehicles ("1" and "2" on Mondays etc.) are prohibited from 7:00–8:00 and 17:00–20:00 for weekdays;

Manila uses a scheme which prohibits certain vehicles, identified by number plates, from operating on the main traffic arteries during peak periods.

From Cracknell, 2000.

Singapore has an off-peak car plate restriction scheme which complements its transportation policies. These are normal cars with red number plates which are allowed to be on the road only during the night-time hours and weekends, *i.e.* 18:00–7:00 on weekdays, after 15:00 on Saturdays and whole day on Sundays and public holidays. The scheme offers drivers the option to save on car registration and road taxes in return for reduced usage of the car. In 2005, off-peak cars accounted for about 2% of the total car population.

4.2.6 Employee travel management

There are many steps that businesses can take to encourage more efficient employee travel, particularly to reduce peak-period automobile commuting, often called Commute Trip Reduction (CTR). Such programs typically include some of the following TDM measures:

- Commuter financial incentives (parking cash out and transit allowances, so employees who commute by alternative modes receive a benefit comparable to subsidized parking).
- Rideshare matching (helping employees organize carpools and vanpools).
- Parking management and parking pricing.
- Alternative scheduling (flextime and compressed work weeks), which reduces peak-period trips and allows employees to accommodate carpool and transit schedules.
- Telework (allowing employees to work at home, and using telecommunications to substitute for physical travel in other ways).
- TDM marketing which promotes use of alternative modes.

- Guaranteed ride home (providing transportation services for employees who commute without a car when they occasionally need to travel home).
- Walking and cycling encouragement.
- Walking and cycling improvements.
- Bicycle parking and changing facilities.
- Transit encouragement programs.
- Produce a transportation access guide, which concisely describes how to reach a worksite by walking, cycling and transit.
- Worksite amenities such as on-site childcare, restaurants and shops, to reduce the need to drive for errands.
- Company travel reimbursement policies that reimburse bicycle or transit mileage for business trips when these modes are comparable in speed to driving, rather than only reimbursing automobile mileage.
- Company vehicles, to eliminate the need for employees to drive to work in order to have their cars for business travel.
- Proximate commuting, which allows employees to shift to worksites that are closest to their home (for employers who have multiple work locations, such as banks and other large organisations).
- Special event transport management, for example, to provide special employee travel services during special events, peak shopping periods, roadway construction projects or emergencies.
- Worksite locations accessible by alternative modes.

CTR programs must be able to meet employees' diverse and changeable needs. Many employees can use transportation alternatives part-time, if given suitable support and incentives. For example, many employees can carpool, telecommute or flextime two or three days a week. Some employees can bicycle commute part of the year.

Box 32: Rotterdam hospital allows employees to "cash out" their parking spot

The Erasmus Medical Centre in Rotterdam employs about 10,000 people. A major renovation of the hospital in 2004 caused a shortage of parking spaces for members of staff, visitors and patients. The reduced the number of parking spots motivated the hospital board to implement a number of measures in reducing car commuting by the personnel.

Before introducing TDM measures, the Medical Centre conducted a mobility survey amongst personnel, visitors and patients. Results showed 80% of the visitors and patients travelled by car to the hospital, and that 45% of the employees commuted by car, while 60% worked during office hours. Of the 700 employees living within 5 to 6 km from the hospital, a significant share commuted by car.

The hospital chose to take measures regarding transport supply and demand for its employees. As for supply, a new car park was constructed. For transport demand, employees were offered two possibilities:

1. 'Car arrangement' where employees were allowed to travel to work by car, but were required to pay for it. Employees were charged:
   - €1.50 a day when arriving during peak hours (from Monday to Friday between 6:30 and 13:00)
   - €4.00 a day when arriving during peak hours (from Monday to Friday between 6:30 and 13:00) and living within 5 to 6 km from the hospital,
   - €0.50 a day when arriving during off-peak hours,
   - No travelling cost expenses paid to employees travelling alone by car.
2. Individual Travelling Budget where employees were credited €0.10 for every km not travelled by car, and the permission to travel 12 times a year by car to work during peak hours, at a value of €1.50 a day.

All measures were communicated to the employees using articles in the internal newsletter, intranet, a leaflet explaining the 'car arrangement' and the 'individual travelling budget', and a service point where employees could ask questions.

An evaluation in 2006 showed the hospital's aim to reduce car travelling has been reached. The number of commuters travelling by car has dropped from 45% in 2003 to 20–25% in 2006. This decrease meant 700 parking spots could be used by visitors and patients. This means sufficient parking space was created without the construction of new parking spots.

Source: Elke Bossaert, http://www.eltis.org/studies

4.3 Supportive measures

For a successful implementation of a comprehensive TDM strategy, enforcement and public awareness are critical supportive efforts. TDM measures are legitimized and gain public acceptance by enforcement activities and social marketing campaigns.

4.3.1 Enforcement

New traffic laws regulating bicycles and pedestrians may require education and training efforts with police officers. Cars which violate regulations beyond the roadway where police efforts tend to be focused are easily overlooked. For instance, a typical violation when new bicycle lanes are built is cars using them for parking, blocking bicycle traffic. Stricter enforcement of rules requiring cars to stop for pedestrians can help to break the "car is king" culture and create a new culture legitimizing NMT.

Planning regulations also require enforcement. It is very easy, and often more profitable, for local governments who are in competition for new development within a region to disregard the overall long-term land use strategy in order to gain short-term development revenues. Regional plans are most effectively enforced by oversight from a higher government body. For instance, the planning system in Norway requires the state Ministry of Environment to review all local development plans before permits may be issued.

Figure 71▲
Strict enforcement is a critical complementary effort for the success of TDM measures.
Photo by Manfred Breithaupt, London (UK), 2007

Figure 72▲
A wheel clamp zone in London protects pedestrian access.
Photo by Karin Roßmark/Torsten Derstroff, 2003

Figure 73
Car free day in Zurich. Children take over the streets to paint and play.
Photo by Lloyd Wright, Zurich (CH), 2005

4.3.2 Public awareness

TDM measures that incentivize behaviour change — especially Pull measures — benefit greatly from efforts to inform the public. A public awareness campaign should be part of every comprehensive TDM strategy. This is especially critical when economic measures such as road pricing are to be implemented, as people are much more receptive when they understand the benefits of the new charge. Push measures such as investments in public transport services need to present as part of a TDM strategy package to aid public acceptability. For further information on this topic, please see also Sourcebook Module 1e: *Raising Public Awareness about Sustainable Urban Transport* (http://www.sutp.org).

Public transit service faces the same challenge as any other product on the marketplace, in that the more people that know about it, the more people will buy it. Marketing new transit service is a key aspect of growing ridership. Information about routes and fares should be made easily available to new users through multiple channels, such as websites, maps, signs, kiosks, telephone hotlines, and billboards.

Public events and marketing campaigns can help raise public awareness about TDM efforts, but also help to win hearts and minds. Such events can help a local government to distribute maps and other information, provide advice on bicycling and transit use, and receive feedback on proposed plans. An example of a public event which has spread to cities around the world is Car Free Day, where city streets are closed to cars and freed for people walking, bicycling, jogging, roller-blading, skateboarding, using Segways, and so forth. It tends to be a social and recreational event, where people interact and experience the city in a different way, enjoying the quiet and clean air. On 24 February 2000, the city of Bogotá organized the largest scale Car Free Day event, where the entire city was closed to private cars from 6:30 to 19:30 on a regular working day (Box 33).

Figure 74
Car free day in Zurich. Children take over the streets to paint and play.
Photo by Lloyd Wright, Zurich (CH), 2005

Box 33: The world's largest Car Free Day event in Bogotá

The city of Bogotá, Columbia first established an official Car Free Day on 24 February 2000, organized by Mayor Enrique Peñalosa and The Commons, an international environmental organisation. This was one of the first Car Free days organized in a developing country. The event was successful and highly popular, and as a result the organizers won the prestigious Stockholm Challenge Award (http://www.challenge.stockholm.se). Below is the mayor's summary:

"It was a formidable achievement of Bogotá's citizens. A city of seven million inhabitants functioned well without cars. This exercise allowed us to catch a glimpse of what must be the transportation system of the city in ten or fifteen years: an excellent public transport system and rush hours without cars.

Most important of all, was the sense of community that was present that day. We fortified our confidence in our capacity of making great collective efforts to build a more sustainable and happier city. Surveys revealed that 87% of the citizens were in agreement with the Car Free Day; 89% did not have any difficulty with the transportation system used; 92% said there was no absenteeism at their office, school or university; and 88% said they would like to have another Car Free Day.

Now we want to bring a referendum to our voters, proposing a goal for the year 2015: Between 6:00 and 9:00, and between 14:30 and 19:30, all cars must be off the streets. Therefore the city should move exclusively in public transport and bicycles."

Adapted from Todd Litman, Online TDM Encyclopedia, http://www.vtpi.org

Box 34: "Bike to Work" day in Bavaria

Each year the German state of Bavaria sponsors the "Bike to Work" campaign encouraging people to commute by bicycle. It has grown from 900 participating companies in 2002 to 4,400 companies in 2005. The number of employees bicycling to work in Bavaria has grown from 10,000 to 50,000 in that time.

The campaign has multiple goals: to shift people out of cars and onto bicycles, to assess bicycle facilities, and to improve public health. Lack of exercise is a major risk factor for ailments associated with modern lifestyles such as respiratory illnesses and overweight. Only 30 minutes of exercise a day will increase general fitness while lowering the risk of illness. It is therefore important to integrate exercise in daily life such as by commuting, which is a form of day-to-day exercise that does not require any extra time.

Another goal lies in influencing decision-makers towards an attitudinal sea change. The surrounding conditions are just as important as individual behavioural changes. The willingness of a person to integrate more exercise in day-to-day life will only increase if the necessary infrastructure is established. The campaign therefore also provides building blocks for a change in external conditions.

The initiative is advertised directly in Bavarian companies. The client service determines contact persons — intercompany coordinators — who advertise the campaign and can be contacted by interested parties. Employees who choose to participate cycle to work in teams (four individuals, independently of their respective ways to work). Participants cycle to work on a previously determined number of days over a specified period of time. Individuals are eligible to win attractive prizes. It is a prerequisite that all team members fulfil this target.

The state is able to assess the user friendliness of bicycle facilities through a participant survey. Participants are asked answer five questions concerning the cycling-friendliness of their residential communities. The result helps determine the most cycling-friendly communities which are then awarded certificates. Bavarian municipalities are provided with information on the competition in the run-up to give them an opportunity to effect changes in the short term, if required. The competition thus sensitizes municipalities to the subject matter and encourages them to take action.

Source: Renate Wiedner, http://www.eltis.org/studies

5. Smart growth and land use policies ("PUSH and PULL")

"How street space is allocated and managed tells people how to travel. Infrastructure speaks and people follow."

Michael Replogle, Transportation Director for Environmental Defense (U.S.A.)

TDM measures in the form of urban planning and design controls are intended to affect future development patterns and ensure that new growth patterns will not make people dependent on cars for transportation. Smart growth land use policies improve land use accessibility by increasing development density and mix of uses, which reduces the distance required to reach common destinations. Smart growth policies promote transit-oriented development and roadway designs that make walking safe and pleasant. In many communities this involves retrofitting existing automobile-oriented land use patterns, such as reconfiguring streets or intersections to provide more comfort and safety for walkers and bikers, and developing buildings on land currently devoted to parking facilities.

Box 35: Smart growth and transit-oriented land use policy resources

CCAP (2005), Transportation Emissions Guidebook: Land Use, Transit & Transportation Demand Management, Center of Clean Air Policy (http://www.ccap.org/guidebook). This Guidebook provides information on various smart growth and mobility management strategies, including rules-of-thumb estimates of VMT and emission reductions.

Todd Litman (2006), Smart Growth Policy Reforms, Victoria Transport Policy Institute (http://www.vtpi.org); at http://www.vtpi.org/smart_growth_reforms.pdf, and "Smart Growth," http://www.vtpi.org/tdm/tdm38.htm.

Anne Vernez Moudon, *et al.*, (2003), Strategies and Tools to Implement Transportation-Efficient Development: A Reference Manual, Washington State Department of Transportation (http://www.wsdot.wa.gov), WA-RD 574.1; at http://www.wsdot.wa.gov/Research/Reports/500/574.1.htm.

PennDOT (2007), The Transportation and Land Use Toolkit: A Planning Guide for Linking Transportation to Land Use and Economic Development, Pennsylvania Dept. of Transportation, PUB 616 (3-07); at (ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%20616.pdf).

SGN (2002 and 2004), Getting To Smart Growth: 100 Policies for Implementation, and Getting to Smart Growth II: 100 More Policies for Implementation, Smart Growth Network (http://www.smartgrowth.org) and International City/County Management Association (http://www.icma.org).

USEPA (various years), Smart Growth Policy Database, US Environmental Protection Agency (http://cfpub.epa.gov/sgpdb/browse.cfm) provides information on dozens of policies that encourage more efficient transportation and land use patterns, with hundreds of case studies.

M. Ward, *et al.*, (2007), Integrating Land Use and Transport Planning, Report 333, Land Transport New Zealand (http://www.landtransport.govt.nz); at http://www.landtransport.govt.nz/research/reports/333.pdf.

5.1 Integrated land use planning

The models that transportation engineers use to project traffic growth are problematic in part, because they fail to account for different patterns of land use. Traditional transportation and spatial planning methods tend to give rise to car-oriented new growth, resulting in rising demand for driving. Therefore, TDM measures that affect new growth are a critical way to halt the trend of rapidly increasing traffic growth.

Most land use development controls are in the hands of local governments. They range from zoning codes regulating land use, density, and parking supply, to design standards for new construction, such as street width, sidewalks and connectivity.

5.1.1 Regional spatial plans

Effective growth management in large urbanized areas begins from a regional perspective. Modern metropolitan regions may encompass

Figure 75

High quality NMT infrastructure was integrated into new urban development in Bilbao.

Photo by Andrea Broaddus, Bilbao (ES), 2007

several formerly independent cities which have grown together. They may have rapidly growing or sprawling edge areas which generate a lot of incoming traffic. Traffic patterns may be highly complex, with growing numbers of trips between suburban centres. For all of these reasons, it is important to look at a metropolitan region as a whole and plan where future growth should be focused, and where new public transport supply can relieve congestion on major roads.

Planning policies that manage growth can be national, regional/provincial, and local. They usually set priorities for compact growth, meaning focusing new buildings in existing urbanized areas rather than on green sites. They also identify areas of a region which should be protected from growth, for public recreation and

Box 36: Decades of regional spatial and transport planning in Freiburg

The Vauban case study highlights the wider growth of Freiburg based on sustainable development principles following a compact model, which avoids low-density sprawl and car-orientated patterns, seen elsewhere in many parts of Europe. Since the 1960's Freiburg has experienced strong growth in both population (23%) and employment (30%) and consequently increased private car use. In attempt to alleviate this growth, the city has been planned to exploit the availability of the tram network and new lines have been constructed to serve areas of new settlement in attempt manipulate modal split.

One example of these policies in practice is the residential development of Vauban. Vauban is located on the site of a former French military base on the southern edge of the city, with a total area of 42 hectares, accommodating about 5,000 residents. In 1997, the implementation began (due to be completed later 2006), of a compact urban residential area with the following strategic aims:

- The creation of a district with greatly reduced car ownership;
- Provision of affordable housing;
- Housing schemes based on innovative low-energy solutions.

The public transport connection to Vauban was significantly improved in 2003 with the installation of a new tramline. The first line connects Vauban with the Merzhauser area, running through the city centre and was completed in 2006. The second line began construction in 2005 with the aim of connecting Vauban to the wider regional transport system.

A particular feature of the new development has been the very proactive approach to community involvement. A number of working groups have been set up and regular open meetings are convened with residents. New residents are deliberately targeted through marketing campaigns to help expand the positive public transport culture. An important element of this approach is an ongoing effort to educate local people in the benefits of the 'high quality' public transport network to correspond with wider policies discouraging car use and promoting sustainable transport modes. Households can choose to nominate themselves as car-free households, which requires them to pay a one-of fee of €3,500 (and annual administrative fee) to the 'Car-free Living Association' to purchase land (which would otherwise be used as parking spaces) for the creation of community spaces, such as playgrounds, sports facilities or parks.

In contrast, residents who own cars are required to purchase a car parking space from the municipality property owner, costing around €17,000 (about 10% of the actual housing unit costs).

As a result of the Car-Free Living scheme, around half of the households in Vauban have chosen alternative modes for commuting and leisure journeys. Local planners hope that towards the end of the decade this scheme will achieve the goal of 75% car free households within the Vauban district.

Source: Michael Carreno, http://www.eltis.org/studies environmental purposes, which is air and water quality protection. These can take the form of parks, ridge protections, green belts, and floodplain and waterfront protection. The most effective policies not only require planning, but have review processes which enforce those plans.

5.1.2 Transit oriented development (TOD)

One of the most effective land use planning TDM measures is to increase the density of commercial and residential development along public transport corridors and stations. The set of policies which support this practice are called Transit Oriented Development or TOD. The concepts of density and clustering which support TOD are discussed in Box 37.

The main characteristic of TOD is to support the transit station as a centre of local commercial activity, with high-density residential development within a 20 minute walking distance. For instance, a TOD may be anchored by a train, light rail, or BRT station with a few multi-story commercial buildings with retail shops on the ground floor, and be surrounded by several blocks of apartment buildings and town homes. Single-family homes on their own lots would be further away, say 1 or 2 kilometres. Higher densities are needed to support high frequency transit service and foot traffic for shops.

Some key characteristics of TOD are (from TCRP Report 95):

- Higher density commercial and residential development along transit corridors and around stations
- A mix of land uses, particularly ground-floor retail shops in office and residential buildings
- Comfortable and attractive pedestrian environment, especially pathways to access transit
- A mix of housing unit sizes and affordability within walking distance of a transit corridor
- A range of employment and services like child care and health care near transit stations
- Studies have shown that TOD can increase property values in an area. Some public transport authorities have been able to harness the value of the land they own by selling or leasing development rights, especially air rights, (the development rights above rail tracks). When the public transport authority is involved in new development in this way, it is known as Joint Development. The rents from development rights provide an income stream for public transport authorities which can be used to help finance new transit system expansion. Such projects are known as Value Capture strategies, where the costs of transit improvements are paid through additional income or sales tax revenue from TOD. Sometimes TOD strategies are used in urban redevelopment efforts, to retrofit car-dominated areas and grow transit ridership.

Box 37: Illustration of density and clustering to support Transit Oriented Development (TOD)

Density and clustering are somewhat different concepts. Density refers to the number of people or jobs in an area, while clustering refers to the location and mix of activities in an area. For example, simply increasing population densities in a residential-only area may do less to improve accessibility than clustering destinations such as schools and shops in the centre of the development. Rural and suburban areas have low densities, but common destinations such as schools, shops and other public services can be clustered in villages and towns. This increases accessibility by making it easier to run several errands at the same time, increases opportunities to interact with neighbours, and creates transportation nodes (rideshare stops, bus stops, etc.).

Density refers to the number of people or jobs in a given area. A rural area might have less than 1 resident per acre, for example, while compact urban areas have 20 or more. More densely populated areas can support better public transport service. Clustering (also called Compact Development) refers to land use patterns in which related activities are located close together, usually within convenient walking distance.

Compact land use development policy (clustering) is more effective at reducing automobile use if it is complemented by other TDM measures. For example, automobile commuting tends to decline if employment centres are clustered with shops, restaurants and day-care centres (destinations that employees want to visit during their breaks).

Clustering can be implemented in urban, suburban or rural conditions, either incrementally or as part of a master-planned development. Clusters can range from just a few small buildings (for example, a restaurant, a medical office and a single retail store) to a large commercial centre with hundreds of businesses.

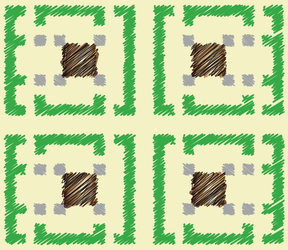
Density and Clustering can occur at various scales and in many different ways. Office buildings, campuses, shopping malls, commercial districts, towns and cities are examples of clustering. Density and Clustering at a neighbourhood level (areas of less than a mile in diameter) with good pedestrian conditions creates multi-modal centres (also called urban villages, transit villages or walkable centres), which are suitable for walking and transit. Clustering is illustrated as follows:

A shows a conventional suburban development with buildings surrounded by parking and isolated from each other. There are often no paths connecting the buildings or sidewalks along the streets. Only automobile transportation can effectively serve such destinations.

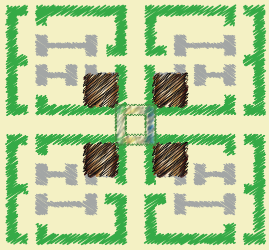
B shows the same buildings sited so they are clustered together and oriented toward the street, with main entranceways that connect directly to the sidewalk rather than being located behind parking. This type of clustering also facilitates Shared Parking, particularly if the buildings have different types of land uses with different peak demands. For example, if two of the buildings are offices with peak parking demand during weekdays, another is a restaurant with peak demand during the evenings, and the fourth is a church with peak demands weekend mornings, they can share parking and reduce total parking requirements, which allows even greater clustering.

C shows eight buildings clustered around a park. As the cluster increases in size the efficiency of pedestrian improvements, rideshare and public transport service and other TDM measures also increase, due to economies of scale.

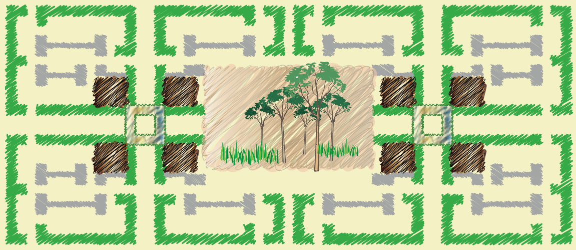
D shows the eight-office building integrated into a park or campus, creating more convenient and attractive pedestrian connections between the buildings, further improving access and supporting transportation alternatives.



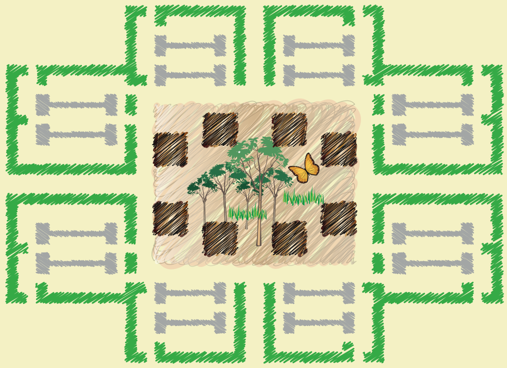
A. Every Office an Island



B. Clustered Offices



C. Two Offices Clustered Around Recreational Open Space



D. Eight Office Cluster

Adapted from Todd Litman, Online TDM Encyclopedia, http://www.vtpi.org

Figure 76
Dense urban development in Shanghai.
Photo by Armin Wagner, Shanghai (CN), 2006

Figure 77▲
Every public transport passenger is also a pedestrian, leading to huge sidewalk volumes in Tokyo.
Photo by Lloyd Wright, Tokyo (JP), 2005

Figure 78 shows the difference between various cities worldwide concerning urban density and transport-related energy consumption.

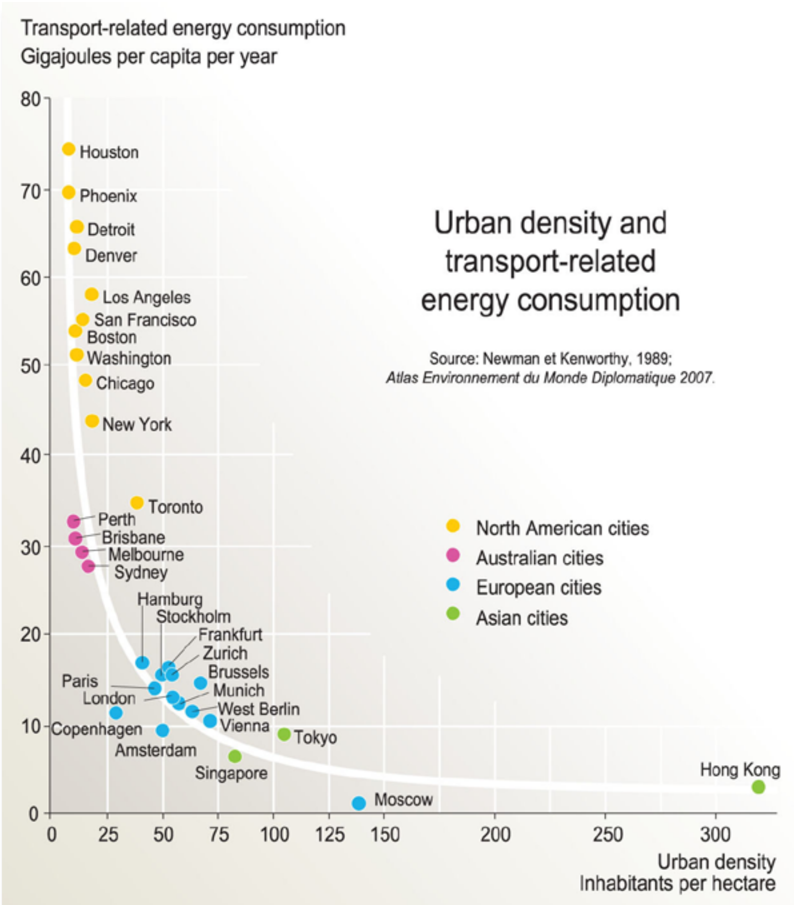


Figure 78▶
Urban density and energy efficiency

Box 38: Public private partnership TOD in Graz, Austria

In 2007, a new shopping centre, Murpark, was opened in Graz as a best-practice-example of the cooperation of spatial planning, city development and mobility management. Within the 36,000 square meters of the shopping centre there are not only shops but also offices and coffee shops, etc. A private company invested in this Public Private Partnership (PPP) project together with the city of Graz, for a total of approximately €75 million. This shopping centre is not only directly linked to a passing-by motorway, but is also a direct stop of the city tram 4 which goes from the inner city of Graz to the shopping centre, and other stops of national bus system. A park-and-ride lot at the shopping centre guarantees that people coming to Graz for work can directly go from their car to the public transport system. Thus the economic side of the city of Graz is also being supported.

A private company was the driver behind the creation of this shopping centre. They already had a shopping complex which they wanted to expand, which required a change in the existing zoning plan of the city of Graz. However, the city of Graz — in exchange for the zoning change — set the condition that the shopping centre must develop a sustainable mobility solution.

One of the most important parts of this project was the mobility management which ensured that this location is easily accessible by the public transport system, including the bus. The city of Graz built a park-and-ride-car-deck with approximately 500 parking places as part of the project. This is the first time that a shopping centre in Graz is directly linked with a public transport system.

For the successful implementation of this PPP-model, the project was linked from the very beginning with the sustainable mobility programme, within which the aspect of the public transport system was the most important part. The cooperation between the public and the private side is rather innovative. Customers of the shopping centre can park their car for €5 in the parking garage for a whole day and can — included with the €5 fee — use the entire Graz public transit system. It is also possible to purchase a monthly ticket for €39.

Murpark is the first shopping centre to realise economic and mobility goals. This is a very positive counter-example to the “normal” shopping centres which are planned and realised “on the green field” somewhere outside the city and which normally lack any connection to the public transport system.

Source: Daniel Kampus, http://www.eltis.org/studies

Box 39: Thirty years of transit oriented development in Arlington County, Virginia

Arlington County, adjacent to Washington DC, is one of the most successful examples of transit-oriented development in the U.S.A. Nearly 18,000 residential units and more than 46 million square feet of office and retail space have been built in Arlington during the last two decades. This type of development would not be possible without the Metrorail transit system. Prior to the development of Metrorail, the Rosslyn-Ballston corridor in Arlington County was an aging, low-density commercial corridor with declining commercial activity. To help support the area's economic development, County leaders insisted that the Metrorail commuter rail line be built underground rather than at the surface in motorway medians, where adjacent commercial uses would be limited by the presence of the motorway.

In order to promote economic development above the underground rail stations, the County channelled nearly all new development along the Metrorail lines. It promoted high-density development adjacent and above rail stations, with relatively high density housing within convenient walking distance. Development therefore follows a Bulls Eye pattern, with the greatest land use densities around the rail stations. There are high-rise commercial and residential buildings (up to 20 stories) above each subway station. The building density declines with distance away from the stations, into medium-density residential (apartments, duplexes and townhouses), and then into two-story single-family neighbourhoods. The area's General Land Use Plan was adjusted as needed to allow additional development in the Metrorail corridor while preserving older, established residential neighbourhoods and historic buildings further away from it.

Despite population and employment growth in Arlington County, traffic volumes on local roads has increased little, and the area has far less commuter parking than would normally be required, due to high levels of transit ridership (most transit riders get to the rail station by foot, bicycle or bus), frequent local bus service, excellent walking and cycling conditions, and mixed land use that locates so many activities close together, minimizing the need to drive. As a result, the County has grown rapidly without major expansion of the motorway network or parking facilities, while maintaining low tax rates for residents. The Metrorail corridors provide 50% of the County's tax base on only 7% of the land. The area enjoys low vacancy rates and higher lease and sale prices than otherwise comparable locations. Transit ridership has grown steadily. Mixed land use has resulted in relatively balanced ridership over the day, rather than two sharp peaks experienced on some systems.

Source: "Arlington's TOD Strategy," Hank Dittmar and Gloria Ohland, 2004 http://www.co.arlington.va.us

5.2 Roadway prioritization and design

Roadway right-of-way is one of the most valuable assets owned by most city governments, and roadway design can have a significant effect on a community's character and its transportation patterns. Conventional transport planning practices tend to devote most road space to general traffic lanes and automobile parking. Since automobiles are relatively space intensive and impose crash risk, noise and air pollution impacts on non-motorised travel, motor vehicle traffic tends to "squeeze out" other modes of transport. Reallocation of road space involves shifting more road space to specific transportation activities, and prioritizing within the roadway to favour higher value trips and lower cost modes.

Roadway prioritization explicitly allocates resources to favour higher value trips and lower-cost modes priority over lower value, higher cost

Figure 79
Multi-modal road design in Amsterdam. Roadway space is divided into separate right-of-way for tram, car, bicycle, and pedestrian.
Photo by Andrea Broaddus, Amsterdam (NL), 2007

trips in order to improve overall transportation system efficiency and support strategic planning objectives. For example:

- *Vehicle restraint measures* that slow or diverts vehicle traffic on a particular road, or even restrictions on car access at certain locations and times.
- *Road space reallocation* converts general traffic and parking lanes (which favour automobile travel) to HOV priority lanes (which favour bus and rideshare vehicles), bicycle lanes and sidewalk space (which favour non-motorised travel).
- *Parking management* can use regulations and fees to favour higher priority trips, such as delivery vehicles, customers, taxis and ride-share vehicles.
- *Roadway design and management* that increases motor vehicle traffic volumes and speeds tends to create environments that are less suitable for pedestrian travel. Traffic calming and traffic speed reduction programs tend to favour non-motorised accessibility over motor vehicle mobility.
- *Transit improvements* that include bus lanes, traffic signal prioritization, and other measures to increase bus service speed, comfort and operating efficiency.
- *Efficient road and parking pricing* often reduces automobile travel and encourages use of alternative modes.

Figure 80

Bicycles dominate this street in Beijing, providing greater comfort and safety to bicycle users.

Photo by Carlosfelipe Pardo, Beijing (CN), 2006

Transportation resources are already prioritized in many circumstances. For example, it is common for emergency vehicles to have priority over general traffic, and for delivery vehicles to have the most convenient parking spaces. Tremendous resources have been invested in motorways, which favour longer-distance automobile travel, leading to automobile dependency and sprawl. Roadway prioritization can be used to support mobility management objectives, such as improving the attractiveness of efficient modes, and applying road and parking pricing to reduce congestion.

Prioritization is often used to support a *road use hierarchy* that favours non-motorised modes, high-occupant vehicles, public transport and service vehicles over single occupant private vehicles in policy and planning decisions, called a *Green Transportation Hierarchy* (TA, 2001).

An example of the latter is the city of Bologna, where residents voted to designate its historic centre a "car-restricted zone" (*zona a traffico limitato*). From 7:00 to 20:00, only residents, business owners, taxis, delivery vehicles, and other vehicles with special access needs are permitted to enter the area. The system is enforced by an automated vehicle license plate identification system. As a result, the number of vehicles

Figure 81

Pedestrian-only shopping street in Shanghai helps to define the character of the city.

Photo by Karl Fjellstrom, Shanghai (CN), 2002 entering the core during the restricted period declined 62%, although traffic is a major problem during the late evening when automobiles are no longer restricted.

5.2.1 Road space reallocation

Road space is a limited and valuable resource which should be managed by cities to support strategic goals. In many situations, road space currently devoted to automobile traffic and parking can be reallocated to more efficient modes, including rail transit lines, bus lanes, High Occupant Vehicle (HOV) lanes (which include buses, vanpools and carpools, and sometimes freight vehicles and motorcycles), bicycle lanes, sidewalks and green space. This can be implemented as part of *access management* (roadway redesign to reduce traffic conflicts and integrate transport and land use planning), *traffic calming* (roadway redesign to reduce traffic speeds and volumes) and *streetscaping* (roadway redesign to improve overall design and aesthetics). *Road diets* refer to the conversion of higher-speed automobile-oriented arterials to more multi-modal and attractive streets that emphasize local circulation and walkability.

It is also the key to review design specifications for new roads and ensure that all modes are provided for in new construction. Sidewalks should always be included, as well as provision for buses and bike parking on busy arterial roads.

5.2.2 Connectivity

The way that streets are connected together can have a great effect on transportation demand management. When traffic is funnelled onto wide, multi-lane roads designed to move cars at high speeds, non-motorised traffic is frustrated. Since the 1960s, the standard for roadway system design has been a "hierarchical system" which divides streets into categories with different design standards. The hierarchical system is designed to keep vehicle traffic volumes on residential streets low, for instance by use of cul-de-sacs, and to concentrate vehicle traffic on a few major arterial roads. However, this concentration of vehicle traffic with few alternate routes contributes greatly to traffic congestion.

A newer design strategy focused on improving street connectivity helps make a road network more resilient to congestion by providing more possible routes for vehicles. It also supports a mix of land uses by making a greater portion of destinations accessible than the cul-de-sac design, which tends to block possible routes

Box 40: Design standards that improve connectivity

Providing convenient connections is key to bicycle and pedestrian access. Connectivity can be increased during roadway and pathway planning, when subdivisions are designed, by adopting street connectivity standards or goals, by requiring alleyways and mid-block pedestrian shortcuts, by constructing new roads and paths connecting destinations, by using shorter streets and smaller blocks, and by applying Traffic Calming rather than traffic restrictions.

Typical street connectivity standards or goals include the features listed below. Of course, such standards must be flexible to accommodate specific conditions, such as geographic barriers.

- Encourage average intersection spacing for local street to be 300–400 feet.
- Limit maximum intersection spacing for local streets to about 600 feet.
- Limit maximum intersection spacing for arterial streets to about 1,000 feet.
- Limit maximum spacing between pedestrian/bicycle connections to about 350 feet (that is, it creates mid-block paths and pedestrian shortcuts).
- Reduce street pavement widths to 24–36 feet.
- Limit maximum block size to 5–12 acres.
- Limit or discourages cul-de-sacs (for example, to 20% of streets).
- Limit the maximum length of cul-de-sacs to 200 or 400 feet.
- Limit or discourages gated communities and other restricted access roads.
- Require multiple access connections between a development and arterial streets.
- Require or create incentive for a minimum connectivity index.
- Specifically favour pedestrian and cycling connections.

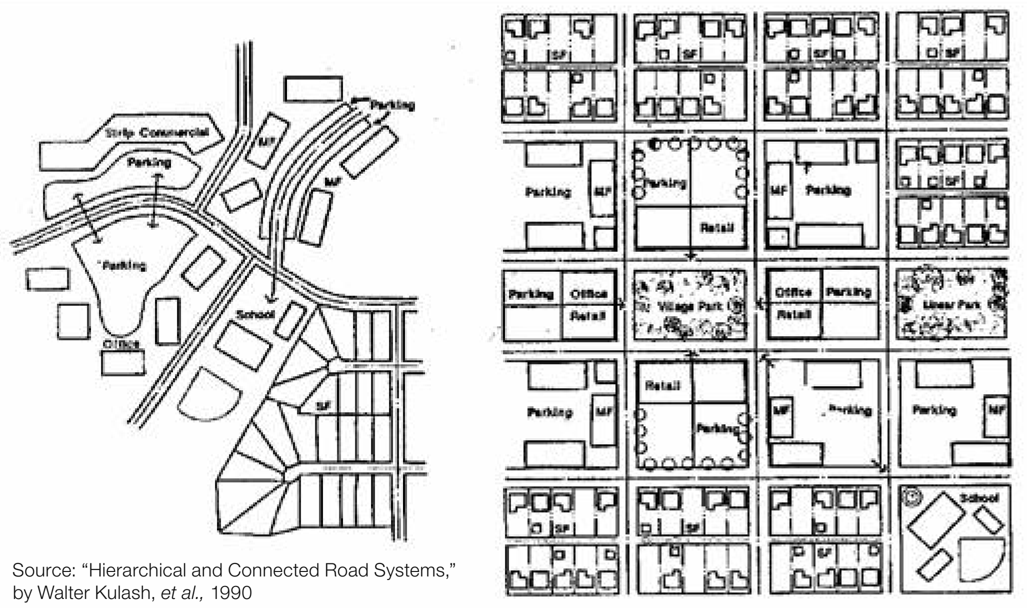
Source: Todd Litman, Online TDM Encyclopedia, http://www.vtpi.org

for bicycling and walking. An illustration is provided in Box 40. “Complete Street” design standards consider how roadways function for pedestrians, bicycles and public transport, in addition to private vehicles. Complete streets measure roadway performance by people through-put, not just vehicle through-put.

Box 41: Illustration of increasing route options for non-motorised transit

Connectivity refers to the directness of links and the density of connections in path or road network. A well-connected road or path network has many short links, numerous intersections, and minimal dead-ends (cul-de-sacs). As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations, making the system more resilient to congestion.

The hierarchical road system, illustrated on the left, has many dead-end streets and requires travel on arterials for most trips. A connected road system, illustrated on the right, allows more direct travel between destinations, offers more route options, and makes non-motorised travel more feasible.



Source: “Hierarchical and Connected Road Systems,” by Walter Kulash, *et al.,* 1990

5.2.3 Parking management

Parking management includes a variety of specific strategies that result in more efficient use of parking resources. Many of strategies help achieve TDM objectives by encouraging use of alternative modes or supporting more compact land use development.

Table 24 summarizes the parking management strategies described in this report. It indicates the typical reduction in the amount of parking required at a destination, and whether a strategy helps reduce vehicle traffic, and so also provides congestion, accident and pollution reduction benefits. For further details, please, see the module on Parking Management from GTZ, to be published in May 2009.

Parking management measures are often among the most effective and beneficial TDM measures. Inefficient parking management increases development costs, stimulates sprawl, increases motor vehicle traffic, and imposes external costs. Parking facilities consume large amounts of land. In developing cities, space for parking can be very limited, leading to vehicles taking

Table 24: Parking management strategies

Strategy	Description	Parking Supply Reduced	Vehicle Traffic Reduced
Shared Parking	Parking spaces serve multiple users and destinations.	10–30%	
Parking Regulations	Regulations favour higher-value uses such as service vehicles, deliveries, customers, quick errands, and people with special needs.	10–30%	
More Accurate and Flexible Standards	Adjust parking standards to more accurately reflect demand in a particular situation.	10–30%	
Parking Maximums	Establish maximum parking standards.	10–30%	
Remote Parking	Provide off-site or urban fringe parking facilities.	10–30%	
Smart Growth	Encourage more compact, mixed, multi-modal development to allow more parking sharing and use of alternative modes.	10–30%	✓
Increase Capacity of Existing Facilities	Increase parking supply by using otherwise wasted space, smaller stalls, car stackers and valet parking.	5–15%	
Parking Pricing	Charge motorists directly and efficiently for using parking facilities.	10–30%	✓
Improve Pricing Methods	Use better charging techniques to make pricing more convenient and cost effective.	Varies	✓
Financial Incentives	Provide financial incentives to shift mode such as parking cash out.	10–30%	✓
Unbundle Parking	Rent or sell parking facilities separately from building space.	10–30%	✓
Parking Tax Reform	Change tax policies to support parking management objectives.	5–15%	✓
Improve User Information and Marketing	Provide convenient and accurate information on parking availability and price, using maps, signs, brochures and electronic communication.	5–15%	✓
Improve Enforcement	Insure that parking regulation enforcement is efficient, considerate and fair.	Varies	
Transportation Management Associations	Establish member-controlled organisations that provide transport and parking management services in a particular area.	Varies	✓
Overflow Parking Plans	Establish plans to manage occasional peak parking demands.	Varies	
Address Spillover Problems	Use management, enforcement and pricing to address spillover problems.	Varies	
Parking Facility Design and Operation	Improve parking facility design and operations to help solve problems and support parking management.	Varies	

Source: Todd Litman, 2006, Parking Management: Strategies, Evaluation and Planning, Victoria Transport Policy Institute (http://www.vtpi.org); at http://www.vtpi.org/park_man.pdf

Figure 82

Growth of demand for space to park cars in New Delhi

(ECS = Equivalent Car Space, or 23 m²)

Source: "Chock-a-Block: Parking Measures to Leverage Change," draft report from the Centre for Science and Environment, 2007.

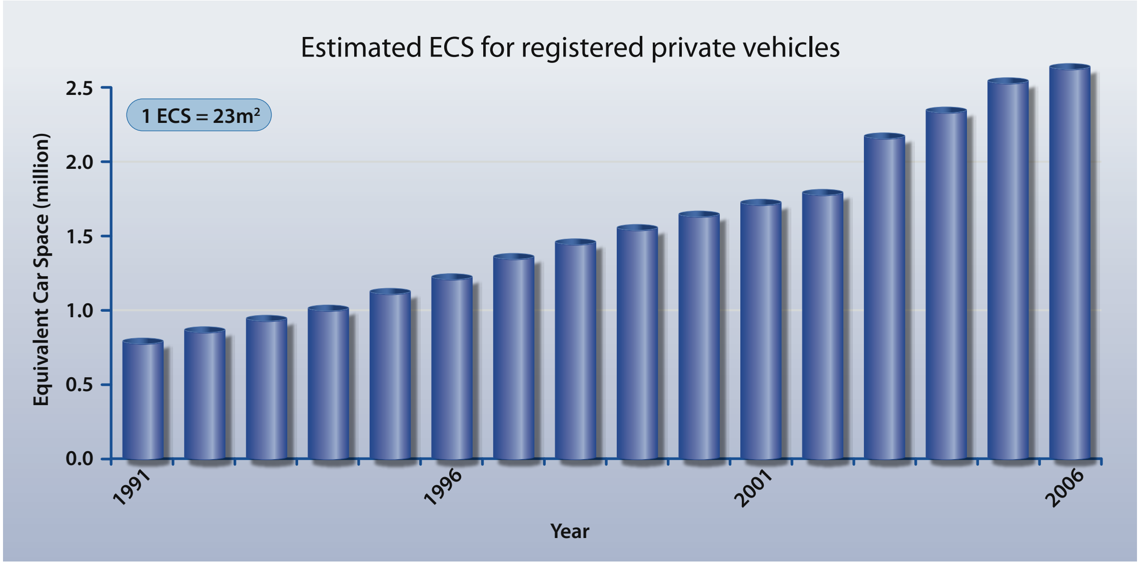


Figure 83

Huge parking demand in the CBD of Delhi, in part due to improper parking management schemes.

Photo by Abhay Negi, Delhi (IN), 2005

Figures 84a, b, c, d

Bogota before and after parking reform.

Enrique Penalosa 2001, presentation to the Surabaya City Council

over public space and crowding out pedestrians, obstructing bicycle lanes, and destroying green space. Figure 82 shows how rapid growth in car ownership has led to a growing demand for space to park cars in New Delhi.

> ***"Parking spaces attract cars; so they generate car traffic. Parking needs space, which is not available for other street uses. Nothing else has changed the traditional streetscape as dramatically as parked cars have done during the last few decades."***
>
> Hartmutt H. Topp, Professor at the University of Kaiserslautern, Germany

Besides urban form and the quality of public space, parking policy has an influence on many other city interests, from traffic flow to economic development.

A recent study conducted for the city of Dar es Salaam in Tanzania identified many urban functions of parking other than car storage, as described in Box 42. The study found that the city had an abundance of under-utilized parking, and that revenues from on-street parking could be easily tripled by closer attention to the number of parking spots and rates charged by a contractor.

Table 25 describes a variety of parking management strategies that are effective TDM measures in practice worldwide.

Box 42: Managing parking supply in Dar es Salaam

The city of Dar es Salaam in Tanzania is in the process of building a new bus rapid transit system. Development of the Salaam Rapid Transit (DART) will remove about 1,000 of 13,800 on-street and garage parking spots in the city centre. A study was conducted in 2007 to assess the impacts of the loss of this parking capacity, and to assess whether the spots should be replaced.

The study included a survey of parking occupancy which found that there is no shortage of parking in central Dar es Salaam. Only 77% of legal parking spaces were currently in use on a typical weekday, well within the level considered optimal for efficiency (85–90%). Thus it concluded that ample parking would be available following DART construction, however, there were several localized "hot spots" where parking is routinely fully occupied and it can be difficult to find a spot, particularly in the central business district (CBD). Specific strategies were recommended for these areas.

It was found that off-street parking was underutilized in general, and even in parts of the CBD where on-street parking is at a premium, there were numerous empty spaces in garages. One garage serving a local mall was using its upper levels for storage.

The study revealed that Dar es Salaam is not realizing the full revenue potential from parking. The contract with an operator responsible for revenue collection identified 3,676 spaces in the CBD, yet the survey identified 5,986 spaces in the same area — 63% more. Partly this gap could be accounted for by the presence of government and United Nations vehicles, but a significant discrepancy remained. An analysis of revenue per space showed that the City was receiving revenues equating to an occupancy rate of 17%-28%, significantly lower than what the City could reasonably expect to achieve. With occupancy rates measured at about 85%, the study estimated that Dar es Salaam could expect to at least triple its parking revenues, which are currently about 50 million shillings per month.

Adapted from "Bus Rapid Transit for Dar Es Salaam, Parking Management Final Draft Report," Nelson\Nygaard Associates and the Institute for Transportation & Development Policy (ITDP), 2006

Table 25: Parking management measures for TDM

Parking restraint measure	Scheme features	Locations Implemented
Parking pricing	Charged on-street parking	Many cities world-wide
Residential parking zones	Residents-only parking by permit	London, other UK cities, US cities
Controlled-parking zones	Management of parking in area to balance demand and supply	UK cities, German cities
No long-stay parking in city centre	Time restrictions preventing all-day parking	UK cities
Bus lanes/clearways	Removal of on-street parking during peak periods	London, many UK cities
Pedestrian-only zones	No traffic at all in street	European, Japanese cities
Maximum parking standards	Maximum number of parking spots for new development	London, other UK cities, US cities
Commuted (in-lieu) payment schemes	Developers pay amount-in-lieu of providing parking spots	London, other UK cities, US cities
Parking ceiling	Maximum number of total spaces in city centre set	Portland, Boston
Ban parking spaces in new buildings	Parking spaces banned in new buildings in certain parts of city	Zurich
Ability to reduce minimum standards	Minimum parking standards can be reduced if carpool spaces or free public transport passes provided	Seattle
Maximum parking standards tied to public transport provision	Maximum number of parking spots — lower maximum where higher pubic transit level of service	Zurich, Bern
Parking levy on off-street parking spots	Levy of fixed amount per year on all business district car parking spots	Sydney CBD & North Sydney business district
HOV parking priority	Spaces reserved for carpools	US cities
Long-stay vs. short-stay charges	In public parking lots, long-stay spaces charged at higher rate than short-stay spaces	US cities
Parking levy at public parking lots	Parking tax on all public parking (generally % added to parking charge)	US cities
Park & Ride lots	Located on periphery of city centre in conjunction with dedicated bus service	Oxford, Aachen, Muenster
Tax on commercial parking	Tax on employer funding of carparks	Australia, New Zealand
Pakring cash out	Requires employers to provide employees with the option of receiving the cash equivalent of parking subsidy.	Cambridge, California, Minneapolis, Maryland

Source: Anon 2006, International Approaches to Tackling Transport Congestion: Paper 2 (Final): Parking Restraint Measures, Victorian Competition and Efficiency Commission, April, p. 10.

Box 43: Parking policy and regulations for TDM

Cities should minimise the amount of public space devoted to car parking. For example, avoid converting public squares, streets, sidewalks and unused public land into car parking areas. Instead, create municipal and private off-street paid parking. On-street parking should only be provided where roads have sufficient space, it should not block traffic lanes, it should not displace sidewalks, and it should be regulated and priced to give priority to higher-value users.

The most convenient parking spaces should generally be managed to favour priority uses, by regulating the type of users (*e.g.* loading, deliveries, visitors), regulating time limits (5-minute loading zones, 30-minutes adjacent to shop entrances, one or two hour limits for on-street parking in commercial areas), or pricing (higher prices and shorter payment periods at the most convenient spaces). Priority, short-term parkers can be favoured with parking methods that include small increments (a few minutes) and allow users to pay for just the amount of time they are parked. Longer minimum time periods (such as parking tickets that are only sold in units of two hours or more) tend to overcharge short-term users. Cities including Washington, D.C. and Belgrade, Yugoslavia, for example, apply a scale of parking charges so that the hourly rate becomes progressively more expensive for each additional hour.

Parking can be regulated to encourage efficient use of existing capacity:

- Limit on-street parking duration (amount of time that a vehicle can be left in a spot).
- Limit use of on-street parking to area residents.
- Limit on-street parking of large vehicles.
- Prohibit on-street parking on certain routes at certain times (such as arterials during rush hour).

As much as possible, motorists should pay directly for using parking spaces, with prices set to make the most convenient parking spaces available for short-term uses and to provide revenues for transportation programs. For example, on-street parking spaces, which tend to be the most convenient and so are most suitable for short-term uses such as deliveries and shopping, should have shorter time limits than off-street parking, which is more suitable for long-term use by commuters and residents.

For example, a strategy used successfully in Bogotá, Columbia as part of the city's program to reduce private car use was to increase public parking fees and to remove limits on the fees that private parking companies could charge. The additional revenue from the higher city parking fees is dedicated to road maintenance and public transport service improvements.

Parking pricing typically reduces parking demand 10–30% compared with unpriced parking. Pricing of commuter parking is particularly effective at reducing peak motor vehicle travel. Charging motorists directly for the parking is more economically efficient and fair.

Parking policies available to local governments include:

Parking requirements. Parking standards tend to be excessive in developing countries with lower vehicle ownership rates, in urban areas with more diverse transportation systems, where parking is priced. Parking requirements can typically be reduced 10–30% at appropriate sites if standards more accurately reflect parking demand. Dense developing cities should consider setting maximum rather than minimum parking standards in city centres. Parking requirements may be lower in locations with good multi-modal access (good walking, cycling and transit), to encourage higher density and infill development.

Unbundle parking. Unpriced parking is often "bundled" with building costs, which means that a certain number of spaces are automatically included with building purchases or leases. It is more efficient and fair to sell or rent parking separately, so building occupants pay for just the number of spaces that they require.

Parking maximums. Some urban areas limit the maximum amount of parking capacity allowed for various types of buildings or within a particular area. For example, the City of Seattle allows a maximum of one parking space per 1,000 sq. ft. of downtown office space, and the City of San Francisco limits parking to 7% of a downtown building's floor area.

Allow "in lieu" fees as an alternative to on-site parking. In lieu fees means that developers are allowed to pay into a fund for off-site municipal parking facilities instead of providing their own on-site parking. For example, rather than building 20 parking spaces at their site, a developer may contribute toward the construction of a 50-space parking facility that is shared among several sites.

Require vehicle owners to have off-street parking. Some cities with limited parking supply require residents to show that they have an off-street parking space before they are allowed to register an automobile, for instance Tokyo, Japan.

Bicycle parking. Require bicycle parking in new development, and allow bicycle parking to substitute for minimum automobile parking in zoning codes.

Establish parking information systems. Real time parking information systems can help drivers avoid cruising for parking. These can be integrated with advance reservation systems, pay-by-the-minute parking systems, and other telematics supported initiatives that foster higher productivity of transportation resources.

Implementation

Parking management is usually implemented by local governments or individual businesses in response to specific parking and traffic problems. Transportation engineers and planners, within public agencies or consultants, are usually responsible for developing parking management plans.

The steps for developing a parking management plan are:

1. Define general problems to be addressed (parking congestion, traffic congestion, excessive parking facility costs, poor pedestrian environments, etc.) and the geographic areas to be considered.
2. Perform parking study that includes:
   - A parking supply inventory (public/private, on/off-street, short/long-term, free/paid, etc.)
   - A parking utilisation study (what portion of each type of parking is used, *i.e.* peak-periods)
   - Projections of how parking supply and demand are likely to change in the future
   - Use this information to identify when and where parking supply is inadequate or excessive.
3. Identify potential solutions.
4. Work with all related stakeholders to prioritise options.
5. Develop an integrated parking plan that identifies changes in policies and practices, tasks, responsibilities, budgets, schedules, etc.

Adapted from "Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, Module 2b: *Mobility Management*," by Todd Litman for GTZ, http://www.sutp.org

Figure 85
Realtime parking availability in Aachen. Vehicles searching for parking are removed from traffic, reducing congestion.
Photo by Andrea Broaddus, Copenhagen (DK), 2007

5.2.3.1 Managing parking requirements for new development

Often planning regulations are responsible for generating excessive parking supply and dedicating land that would otherwise be available for housing or commercial uses to cars. Most cities regulate parking supply in new development by requiring developers to build a minimum number of off-street spots based on the estimated traffic generation of their project. For example, a typical U.S. parking requirement might require construction of 4 spaces per 1,000 ft^2 (93 m^2), although peak demand only averages 2 to 3 spots per 1,000 ft^2 (93 m^2). Such Minimum Parking Requirements are intended to minimize the impact of new development on surrounding areas, for instance, so that neighbouring streets are not filled with the parked cars of new residents or workers. However, it has been found that such policies tend to stimulate automobile ownership and use, and urban sprawl.

Increasingly, cities around the world are abolishing such minimum parking requirements and replacing them with maximums which cap new parking supply. Thus a movement toward Maximum Parking Requirements has been underway since the 1990's. Large cities such as London which under great traffic congestion pressure are revising their parking policy to limit the parking supply created with new development. Often this includes a restriction on new parking

Table 26: Revised standards of minimum parking requirements

Land Use	Typical minimum	Revised standard
Single family housing	2 per dwelling unit	1 per dwelling unit
Multi-family housing	1.5 per dwelling unit	0.5–1 per dwelling unit
Hotel	1 per guest room	0.5 per guest room
Retail shopping	5 per 100 m^2 floor space	2–3 per 100 m^2 floor space
Office building	3 per 100 m^2 floor space	1 per 100 m^2 floor space
Light industrial	2 per 100 m^2 floor space	0.5–1 per 100 m^2 floor space

around transit stations. In some cases, cities leave parking decisions to developers, which can result in more market-sensitive decisions.

Many cities around the world are revising their minimum parking requirements to create fewer new parking spots with new development or rehabilitation of older urban properties (Table 26).

Singapore's parking management policy specifies the minimum parking requirements for various land uses. This is to ensure that all buildings look after their own parking requirement by building off-street car parks in their developments and not pass the parking problem to the transport authority. In the city area for example, 1 car parking lot is specified for 500 square meters of office space and 1 lot for 400 square meters of commercial space and so on. If the building development is within 200m radius of a commuter rail station, the minimum number could be reduced by 20% as an incentive for use of public transport. If the building development is not able to comply, a deficiency charge is levied for each lot not provided. The transport authority may use the deficiency charges collected in an area to build a central

Box 44: Reform of parking standards in London

With the rapid growth in car ownership in the UK during the 1950s, on-street parking became a major impedance to traffic flow. To free up this congestion, new office and other commercial buildings were required to build private off-street parking spaces. The new standards required developers to provide a minimum of 1 space for every 165 sq meters of office space in inner London. With the rapid construction of new commercial space in central London, tens of thousands of new private non-residential (PNR) parking spaces were created without any regard to the capacity of the surrounding road system.

As a result, by the mid 1970s the PNR parking stock had grown to 57,000 spaces in the Central Business District and 450,000 outside. These parking spaces attracted about 40% of arrivals during the two hours between 8:00 and 10:00 and had a daily turnover of only 1 trip per space. In the 1980s, the Greater London Council (GLC) proposed higher minimum standards to limit the further growth of PNR parking capacity.

In 1996, the London Planning Advisory Committee (LPAC) advised further restraint with maximum provisions:

- Central London: 1 space/300–600 square meters Gross Floor Area
- Inner London: 1 space/600–1,000 square meters Gross Floor Area
- Outer London: 1 space/1,000–1,500 square meters Gross Floor Area

There is still a need to eliminate existing stock if traffic congestion is to be moderated. Of the peak 57,000 spaces in the late 1970s, there are perhaps 50,000 today. It appears unlikely that most private owners of PNR space will convert it to other uses without a fairly powerful incentive.

However, it can be concluded that parking controls have helped reduce the growth of car use in congested conditions. The number of cars has grown by 24% in London over the last twenty years compared with 64% nationally. Whilst public transport passenger kilometres have fallen by 10% since the mid 1970s nationally, there has been an increase of 18% in the use of public transport in London.

Clearly, there are many factors which have contributed to these lower motorisation trends in London, including the improved performance of the public transport system during this period. However, it appears that parking policy control measures have contributed to this.

Source: David Bayliss, http://www.civitas-initiative.org car park in the vicinity to meet the shortfall in car parking lots. Other than that, the authority does not build car parks other than providing pay roadside lots along minor roads (on-street parking) when there is a demand. As for residential parking, this is provided by the Housing Authority for public housing and the private developers for private housing.

Figure 86
Red kerb zone in London — no parking allowed at any time.
Photo by Andrea Broaddus, London (UK), 2007

5.2.3.2 Unbundle parking

As a result of generous minimum parking requirements, unpriced on-street parking, and weak enforcement of parking restrictions, parking is often free or highly subsidized. Unpriced parking tends to increase vehicle ownership and use. In general, unpriced parking increases vehicle ownership by 5–10%, and vehicle trips by 10–30% compared with what would occur if users pay directly of parking.

Parking is often "bundled" (automatically included) with residential units, such that building occupants are forced to pay for a certain number of parking spaces regardless of how many they actually want or need. This practice increases the costs of housing and business activity, and therefore the costs of customers for goods and services. A study of housing sales in San Francisco showed that parking added 9–13% to the selling price of condominiums, regardless of whether the home buyer owned a car (Klipp, 2004).

Innovative policies can correct these distortions. Parking can be "unbundled" from residential units, so renters only pay for the number of parking spaces they actually need. For example, rather than paying US$1,000 per month for an apartment or office that includes two free parking spaces, the apartment or office rents for US$800, plus US$100 per month for each parking space. This lets the building occupant decide how many parking spaces they actually need, and offers a financial incentive to reduce parking demand and vehicle use.

Since many businesses own large parking facilities, they have little incentive to encourage use of alternative modes, since this would result in costly parking spaces being unoccupied. The result is that businesses subsidize parking but offer no comparable benefit to employees or customers who arrive by other transport modes. This is inefficient and unfair, because it stimulates automobile travel and parking demand beyond what consumers would choose if they had more options to choose from, and it subsidizes motorists more than people who use alternative modes.

An important parking management strategy is to *cash out* free parking, so commuters offered a subsidized parking space can instead choose to receive its cash equivalent. A typical employee would receive US$50 to US$150 in additional cash or other benefits if they give up their parking space and use an alternative commute mode. These benefits can be prorated, so employees who use alternative modes part-time receive a proportional benefit, such as 40% if they use alternative commute modes two days a week, and 80% if they use alternative modes five days a week.

Box 45: The Dutch ABC parking policy, as applied in The Hague

The Dutch ABC Location Policy is based on two key concepts:

1. ***The proximity principle*** tries to get the origins and destination of trips together as close as possible.
2. ***Accessibility profiles*** try to get the right businesses (also new urban developments) in the right places in terms of transport needs.

The main objectives of the traffic and transport policies of The Hague are:

- Minimising the increase of private car use;
- Improving accessibility to the city centre; and
- Improving environmental quality of the city.

Although the idea is to limit the need to use the private car, the role of the private car is not denied. Therefore the plan also aims to regulate the scarce space for car parking. The ABC location policy with regard to parking measures has as a general objective to improve city centre access and limit car traffic. A key characteristic of the parking policy is the recognition that parking demand of an office building is related to the number of employees. If demand is unknown, it is estimated that each employee will on average occupy about 25 square meters. The parking demand for visitors is also related to this.

The parking measure is part of the ABC location policy. The key features of the parking policy are:

- The places most accessible by public transport receive the strictest norms for parking spaces. These are the 'A' locations;
- The 'C' locations are far more difficult to reach with public transport and therefore the parking norms are far less stringent;
- The 'B' locations are situated in between and have both public transport and automobile access.

The three 3 parking policy standards are:

A location – Inner city/surroundings of 2 main stations: 1 place/10 employees;

B location – The zone around the inner city: 1 place/5 employees;

C location – Others: 1 place/ 2 employees.

ABC location parking policy can be introduced in larger towns that have an accessibility problem and have introduced paid parking. The latter is crucial, because the measure implements norms for maximum allowed parking spaces for firms. If parking in the area is free, location policy can be neglected by the firms as parking spaces of the area can be used. As The Hague is a city with a relatively high demand for office space resulted in an increasing zone for paid parking and an accessibility problem. The ABC location policy has been successfully introduced here. The parking norms applied to firms/offices that are related to the PT provision have the advantage that they will receive easier support from firms (because they have the alternative transport means) and they push firms to think about mobility management.

Source: Tom Rye, http://www.eltis.org/studies

Boxes 46 and 47 present parking management measures proposed for Dar es Salaam and New Delhi.

Box 46: Measures for managing parking supply in Dar es Salaam

The quantity of parking provided and the way in which parking is managed are fundamental determinants of the character of any city. Parking supply affects urban form, such as the intensity of development and pedestrian friendliness; transportation characteristics; and municipal finances. For these reasons, there is a close relationship between parking policies and the success of the planned Dar es Salaam Rapid Transit (DART) system.

In Dar es Salaam, there are also more direct considerations, as the proposed DART routing along Morogoro Road and Kivukoni Front will necessitate removal of many on-street parking spaces, plus at least part of the off-street lot adjacent to City Hall. Parking policy in Dar es Salaam influences many aspects of city function:

Economic Development. While private cars account for a small share of trips — less than 13% — it is critical to retain good private car access to the CBD, given its economic role and its political importance to decision makers. This is particularly true in advance of full implementation of DART on all major corridors. The impacts of CBD access constraints (*i.e.* congestion) can already be seen, in that many new retail and office development are choosing to locate on the Bagamoyo Road corridor, undermining the pre-eminence of the CBD.

Vehicle Speeds. On many streets in the CBD, on-street parking is the only effective form of traffic calming. By narrowing the effective right-of-way to about 2 meters, parking reduces vehicle speeds substantially. Parking has been well-placed on many streets to achieve this goal (see image).

Public Revenue. On-street parking provides about 50 million shillings in net monthly revenue to the City Commission — or about US$6 million annually. More efficient management could boost this considerably.

Traffic Congestion. Dar es Salaam's street network has finite capacity, and parking planning needs to be coordinated with decisions on roadway capacity. If no new roadway capacity is planned to the CBD, as seems likely, then it is ultimately futile to construct more parking for all-day commuter use in the CBD; this parking would only add to existing congestion and undermine the ridership base for DART. Parking on Indira Gandhi Street narrows the effective right of way and calms traffic.

DART Ridership. One of the most exciting aspects of DART is that it will appeal to a wide cross-section of the City's population, including more affluent residents who do not ride the daladalas. However, if parking is free and unlimited, there will be little incentive for people to use DART instead of their cars.

Pedestrian Safety and Comfort. On some streets, parking in the CBD provides a useful buffer between moving vehicles and the walkway, improving pedestrian comfort and safety. On other streets, however, the reverse is true; parking on the walkway and in pedestrian crossings forces pedestrians into the roadway and affects visibility.

Urban Design. Central Dar es Salaam benefits from a lively, interesting street fabric, with continuous active frontages on most streets in the CBD and Kariakoo. However, there are some examples of recent off-street parking facilities that interrupt these frontages, most notably the large (temporary) surface lot across from City Hall. On the other hand, parking garages such as the underground PPF House facility show how parking can blend into the streetscape. The JM Mall entrance, meanwhile, is from the side street (Mission), maintaining the continuous retail frontage on the key pedestrian corridor (Samora).

Demands for Right-of-Way. Streets in Dar es Salaam have many functions: movement (cars, buses, pedestrians and bicycles); exchange (social interaction and street vending); and storage (parking). On many streets in the CBD, there is insufficient right-of-way to accommodate all of these functions, and space dedicated to parking is unavailable for movement or exchange functions.

Adapted from "Bus Rapid Transit for Dar Es Salaam, Parking Management Final Draft Report," Nelson\Nygaard Associates and the Institute for Transportation & Development Policy (ITDP), 2006

Box 47: Parking management strategies proposed for New Delhi

A study was conducted in 2007 to assess New Delhi's parking policy and develop strategies to deal with rapidly growing car use at the city's markets. New Delhi is a densely populated city of 15 million people, with 4 million registered personal vehicles. In 2006, the city added 360,000 new vehicles, or approximately 1,000 per day. This is nearly double the rate from the year 2000, with continued exponential growth expected. With space for parking already scarce, and parking facilities at the city's nine main markets already saturated, Delhi is seeking new parking strategies.

Following are the parking recommendations of the study:

Promote efficient utilisation of existing spaces

- Use currently wasted areas (corners, edges, undeveloped land etc), particularly appropriate for small cars, two-wheelers and bicycles.
- Where there is adequate street width, change from parallel to angled on street parking
- Maximise the number of on-street parking spaces by using a kerb lane during off-peak.
- Use valet parking, particularly during peak time. This can increase parking capacity by 20 to 40 per cent compared to users parking their vehicles.
- Identify sites where on-street parking should be restricted during peak hours or for all day parking.

Review the setting of all proposed multi-level parking structures

- Develop these as remote parking with park and ride systems and integrate with public transport. They should be located near the interchange points of public transport nodes, or at the periphery of the commercial centres, with free shuttle buses and free transit service.
- These facilities can also be developed as overflow parking plan and special event management.
- Taxis and three-wheelers can play an important role in the feeder system for park and ride system.

Improve user information for proper management of existing spaces

- Develop public information system to inform people about parking availability, regulations and prices.
- All civic agencies must develop parking inventory for their respective jurisdictions.
- GIS mapping of parking lots.
- All civic agencies should review the current contracts and guidelines for development of parking lots, for lower retrieval times, electronic metering for variable parking rates, and other physical planning.

Promote shared parking for maximum utilisation of existing spaces

- As far as possible parking spaces should be managed as common areas.
- Discourage dedicated individual spaces to maximise the usage of the available facilities.

Assess parking standards

- Delhi Development Authority has done upward revision of the parking norms for the Master Plan 2021. It is important to ensure enforcement and contain spill over.
- Consider flexible need based parking standards in the future.
- Develop parking inventory, and assess parking utilisation pattern to identify areas of deficit, and then identify specific measures, tasks, responsibilities, budgets and schedule.
- Plan for capping the maximum parking supply that can be allowed.

Need management coordination

- Create institutional interface to address parking pricing, management and parking regulations and enforcement across jurisdictions in a composite manner.

Strengthen enforcement

- Ultimately, the traffic management authority should be able to effectively enforce a restrictive parking policy, to collect parking fee, and to fine offenders.

Source: "Chock-a-Block: Parking Measures to Leverage Change," draft report from the Centre for Science and Environment, 2007

Yet despite the growing body of effective TDM parking policy measures, parking issues faced by developing cities can present unique local challenges. For instance, the city of Yogyakarta in Indonesia has found it necessary to develop a negotiating strategy to deal with the network of informal parking operators that are entrenched in the city's central business district, as described in Box 48.

Box 48: Negotiating with parking operators in Yogyakarta

The city of Yogyakarta in Indonesia has a crowded and chaotic central business district (CBD). Transportation services are largely unregulated. There are about 1600 buses and 800 taxis operating independently, with little regard for passenger comfort or safety. Conditions for those walking, bicycling, and riding in becaks (cycle rickshaws) is increasingly crowded and slow-going. Those who can prefer to acquire their own vehicles, leading to rapid motorisation. Of Yogyakarta's 260,000 private vehicles, 80% are motorcycles, yet the heavily utilized road network is still carrying 15,000 passenger car units per day, with 40,000 smp per day in the CBD. Respiratory problems are dramatically on the rise, and traffic casualties are the second highest after Central Java. Becak operators are seeing fewer passengers as people fear being mixed in traffic with motorised vehicles.

As fewer pedestrians brave the streets, vendors are seeing fewer buyers. As a result, the central area of Malioboro has lost billions of rupiahs worth of business. Streets that used to carry 70,000 pedestrians per hour are now down to 25,000 per hour, even during holiday peak season. Traffic conditions that force pedestrians into motorised traffic, along with chaotic parking conditions, especially in rapidly developing areas, are blamed.

A study of the situation revealed that a profitable system of informal parking services operating in the street were largely responsible for blocking pedestrians from the sidewalks. About 270 men working as parking attendants in the city's two central business areas are running parking illegally on the street. They earn an estimated 15,000 rupiahs per day, which is a good wage, and support families. The city sought to legalize the activities of these men and the parking services by relocating them to underutilized off-street garages and lots. Estimating that the parking attendants could increase their parking income from 450,000 to 2.5 million rupiahs (US$37.50 to US$208.50) per month, city officials thought they had a good offer. However, the parking attendants held a demonstration in 2005 refusing the deal.

Investigating why the parking attendants refused to move their operations revealed an entrenched system of dependencies and payoffs. The main parties were identified in the parking network as parking attendants and their bosses, land owners, and area leaders. It turned out the city had vastly underestimated the profits realised by the illegal parking mob. Parking attendants were able to re-use valid parking tickets and increase their profits to 500,000 rupiahs (US$41.70) per month. Bosses overseeing 8 parking attendants could realize a monthly profit of around 1 million rupiahs (US$83.40). The bosses in turn had to pay land owners with political power, who could receive up to 1 million rupiahs (US$83.40) monthly. And finally, area leaders hidden within the ranks of the police and military service received payoff from land owners, around 500,000 rupiahs (US$41.70) per property. Collectively, the political and informal power of this profit structure proved well sufficient to frustrate the aims and efforts of the government to reform parking services.

Thus the study concluded that the government must first broadly address the issue of organized crime. The parking attendants are seen as the weakest party which should be protected and aided in providing parking services legally.

Source: "Problems in Reforming Transportation and Parking: A Case Study in Yogyakarta," Cholis Aunorrohman, 2005

5.2.4 Traffic cells and diverters

Traffic cells are a technique of traffic management which reduces speed and convenience for cars. A traffic cell is created within a neighbourhood or city district such that it is difficult or impossible for cars to cut through between arterial roads, and must circle around on one-way streets. The overall effect of a traffic cell is to make car use less attractive and convenient within a certain area by making it necessary to travel further and by a less direct route. Traffic diverter structures may be built to block streets or intersections to divert traffic from direct routes. Traffic circles can be built which force cars to slow down while travelling through intersections.

In the early 1960s, the city of Bremen was divided into four sectors, or "traffic cells". Cars are allowed to travel within each cell, but to travel between these cells they must use a circumferential ring road. Pedestrian, bicycle and transit vehicles can travel directly between these cells. As a result, vehicle traffic volumes are significantly reduced and travel by other modes is significantly improved.

The city of Gothenburg is Sweden's second largest city, with almost half a million residents. In the late 1960s, the city's historic centre was divided into five traffic cells. As in Bremen, cars can travel within each cell but not directly between cells, they must use a ring road. Pedestrian, bicycle and transit vehicles can travel directly between cells. The result has been a 48% reduction in vehicle traffic despite increased vehicle ownership by residents, improved pedestrian and cycling conditions (and a 45% reduction in pedestrian accidents), and improved transit service.

Bollards are widely used both to separate cars from NMT traffic, and to restrict car access to certain streets. Often pedestrian zones are bounded by retractable bollards which are lowered at certain times of day to allow delivery vehicle access.

5.2.5 Traffic calming

Traffic calming refers to various design features and strategies intended to reduce vehicle traffic speeds and volumes, and improve the comfort and safety of non-motorised traffic on a particular roadway. Some of these strategies are

Figure 87

Contra-flow bicycle lane in Gothenburg. Cars may only drive in one direction, while bicyclists can use both directions.

Photo by Andrea Broaddus, Gothenburg (DK), 2007

▲**Figure 88**

Pedestrian zone in Amsterdam. Entry is restricted by a retractable bollard, but bicycles are allowed.

Photo by Andrea Broaddus, Amsterdam (NL), 2007

Figure 89

Pedestrian area in Shanghai is defined by bollards.

Photo by Armin Wagner, Shanghai (CN), 2006 described in Table 27. Traffic calming projects can range from minor modifications of an individual street to comprehensive redesign of a road network. Mainly traffic calming measures are implemented on urban streets, especially in residential areas. Often they are requested by neighbourhood residents who are concerned about safety.

Traffic calming involves road planners and engineers using flexible standards for road design, sometimes a practice called Context Sensitive Design. The most common traffic calming measures are speed bumps, which are simply humps of asphalt across the roadway that cars must drive over slowly. Wider ones made of concrete are known as speed tables. Another common technique is narrowing the roadway by building features which protrude into it, for instance tree boxes. Some research indicates that improved roadway landscaping and tree

Table 27: Traffic calming strategies and devices

Type	Description
Kerb extensions “pinch points”	Kerb extensions, planters, or centreline traffic islands that narrow traffic lanes to control traffic and reduce pedestrian crossing distances. Also called “chokers”.
Speed tables, raised crosswalks	Ramped surface above roadway, 7–10 cm high, 3–6 m long.
Mini-circles	Small traffic circles at intersections.
Median island	Raised island in the road centre (median) narrows lanes and provides pedestrian with a safe place to stop.
Channelization islands	A raised island that forces traffic in a particular direction, such as right-turn-only.
Tighter corner radii	The radius of street corners affects traffic turning speeds. A tighter radius forces drivers to reduce speed. It is particularly helpful for intersections with numerous pedestrians.
Speed humps	Curved 7–10 cm high, 3–4 m long hump.
Rumble Strips	Low bumps across road make noise when driven over.
Chicanes	Kerb bulges or planters (usually 3) on alternating sides, forcing motorists to slow down.
Roundabouts	Medium to large circles at intersections (Kittelson, 2000).
Pavement treatments	Special pavement textures (cobbles, bricks, etc.) and markings to designate special areas.
Bike lanes	Marking bike lanes narrows traffic lanes.
“Road diets”	Reducing the number and width of traffic lanes, particularly on arterials.
Horizontal shifts	Lane centreline that curves or shifts.
2-lanes narrow to 1-lane	Kerb bulge or centre island narrows 2-lane road down to 1-lane, forcing traffic for each direction to take turns.
Semi-diverters, partial closures	Restrict entry/exit to/from neighbourhood. Limit traffic flow at intersections.
Street closures	Closing off streets to through vehicle traffic at intersections or midblock.
“Neo-traditional” Street design	Streets with narrower lanes, shorter blocks, T-intersections, and other design features to control traffic speed and volumes.
Perceptual Design Features	Patterns painted into road surfaces and other perceptual design features that encourage drivers to reduce their speeds.
Street Trees	Planting trees along a street to create a sense of enclosure and improve the pedestrian environment.
Woonerf	“Living street”, residential streets with mixed vehicle and pedestrian traffic, where motorists are required to drive at very low speeds.
Speed Reductions	Traffic speed reduction programs. Increased enforcement of speeding violations.

Adapted from: Litman, Online TDM Encyclopedia, http://www.vtpi.org/tdm

Figure 90

Traffic calming in Brussels. A neckdown, speed bump, bollards and zebra crossing combine to reduce car speed and increase pedestrian safety.

Photo by Andrea Broaddus, Brussels (BE), 2007

planting encourages walking and reduces accident rates. Trees can be particularly beneficial in hot areas where they provide shade. Frequently the sidewalk is extended into intersections, forming a "bulb out". In some cases, the narrowing features change the road from being straight to curvy, which forces cars to slow down. There are dozens of traffic calming strategies and devices, as shown in Table 27.

Box 49: Traffic calming with roundabouts

A roundabout is an intersection built with a circular island around which traffic rotates in one direction. Many older roundabouts (which were also called traffic circles or rotaries) were built primarily as a location for a fountain or statue, with little regard to traffic principles. As a result, there has been considerable variation in design features and traffic regulation, causing confusion and accidents. For many years roundabouts were unpopular with the public and traffic professionals.

During the late Twentieth Century, traffic engineering organisations developed roundabout design standards and management practices to maximize traffic efficiency and safety.

These are called "Modern Roundabouts". They have the following features:

- ***Yield at Entry***. Traffic entering the roundabout yields the right-of-way to the circulating traffic. This prevents traffic from locking-up and allows free flow movement.
- ***Deflection***. The entry lane is designed with a small deflector island to reinforce the yielding process and slow traffic.
- ***Limited size***. Modern roundabouts usually have just one, and never more than two, rotating lanes.

In addition, there are mini-roundabouts, which are small traffic circles located within local intersections. They still require yield-at-entry but do not have a deflector island.

Research has shown that roundabouts can improve reduce vehicle stops and delays, reduce traffic speeds, and increase safety compared with other intersection designs. They are also used to provide a gateway or aesthetic feature. As a result, roundabouts are once again being promoted by traffic engineers and planners, and are an important Traffic Calming tool. They are increasingly common throughout the world. To maximize safety and establish consistency it is very important that all roundabouts be designed (and existing ones redesigned) to reflect Modern Roundabout principles.

Source: Todd Litman, Online TDM Encyclopedia, http://www.vtpi.org

Figure 91
A painted roundabout in Cambridge achieves the desired effect of forcing vehicles to slow down for minimal cost.
Photo by Andrea Broaddus, Cambridge (UK), 2007

5.2.6 Planning for NMT

Planning TDM measures are also aimed at growing the mode shares for walking, bicycling, and public transport by ensuring that new growth patterns are friendly and encouraging to these modes. These measures range from local street design regulations controlling how new streets are built, to the provision of information and street furniture which improve the comfort and ease of bicycling and walking.

Design standards for streets should be bicycle and walking friendly. In the U.S., a movement for "complete streets" got started due to fact that many residential areas were built without sidewalks, and many commercial areas lack bicycle lanes and parking. Rather than expensive retrofitting, developing cities should take care to build complete streets — designed to be safe and comfortable for foot and bicycle traffic — to begin with.

The most important characteristic of NMT planning is the process, that is, how it is done. Best practices usually include the involvement of community members who are bicycling and walking frequently and can help identify problem areas. The basic process is as follows, (adapted from and with further discussion in Sustainable Transport Module 3d):

1. Establishment of a project team and a non-motorised transport task force or committee.
2. Selection of area to be improved.
3. Inventory of existing regulations and conditions.
4. Development and prioritization of planned improvements.
5. Selection and design of facilities.
6. Testing after implementation.

Box 50: Re-designing public space for pedestrians and bicycles in Toulouse

Toulouse has carried out an integrated package of accompanying actions and mobility changes in the city centre in anticipation of the opening of its second subway line in 2007. The goals are to create an access control system for both private car and freight transport, re-allocate public space to pedestrians, and give priority to bicycles and public transport on the roads.

Measures to redesign public space in the city centre:

- Facilitate mobility and convenient use of public transport;
- Favour the way and the accessibility of pedestrians to the subway stations;
- Re-allocate place on the streets in favour of pedestrians and cycles;Among other by installing bicycle parking equipment around all new metro stations;
- Create specific lanes for freight delivering.

Source: Gerard Chabaud, http://www.civitas-initiative.org

Box 51: Maps and wayfinding

A Push TDM measure which is inexpensive but frequently overlooked is the provision of information resources about bicycle and walking routes. Most cities publish maps which are oriented toward helping drivers find their way, for instance, they may fail to show the locations of transit stations. Increasingly cities are publishing separate Bicycle Maps which show bicycle facilities and signed routes. These maps are sometimes designed to be water-resistant, to accommodate for bicyclists' exposure to the weather.

Figure 92a ▲

A wayfinding sign in Bonn. Maps and signs along the bike path make users feel safe.

Photo by Andrea Broaddus, Bonn (DE), 2000

Figure 92b ▲

Wayfinding kiosk in Brussels.

Photo by Andrea Broaddus, Brussels (BE), 200

◀ **Figure 92c**

Maps and wayfinding signs in cities are often used by tourists, such as this one in Amsterdam.

Photo by Andrea Broaddus, Amsterdam (NL), 2007

Signs which help those walking and driving find their way — wayfinding guides — can make the pedestrian environment much friendlier. These are usually located at intersections and along sidewalks and multi-use trails. These signs give commuters a sense of legitimacy and are especially helpful and welcoming to tourists.

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