

**EU Project Air Quality Governance in the ENPI East Countries**

**APPROACHES  
TO TRANSPORT EMISSION  
REDUCTION  
IN URBAN AREAS**

**Handbook**

**2014**

This handbook has been prepared under the European Union's (EU's) project on Air Quality Governance in the ENPI East Countries.

The Air Quality Governance project supports participating countries in improving their respective institutional and legislative frameworks in line with European standards and implementing multilateral environmental agreements and conventions. It also supports cooperation among key stakeholders in the region and helps raise public awareness regarding air quality issues.

The project, which began in January 2011 and will end in December 2014, works closely with national authorities, institutes, agencies and other organisations, providing support at the policy and strategic level to build the capacities of those working on air quality and air pollution issues. Seven countries participate, Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova, the Russian Federation and Ukraine.

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## ABBREVIATIONS

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ALS	Area Licensing Scheme
BRT	Bus rapid transit
CO <sub>2</sub>	Carbon dioxide
ERP	Electronic Road Pricing
EU	European Union
GHG	Greenhouse gas
GBP	Great Britain pound

## INTRODUCTION

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The most effective way to reduce the negative impacts of transport is to cut down on the use of motorised vehicles, especially those running on fossil fuels. Thus, the efficient movement of people and goods, not vehicles, should be the overall target for transport policymakers. Passenger transport—especially urban—is of particular concern, and ways of ensuring high vehicle load factors and high numbers of passengers per square metre of road surface are sought.

In many cities, freight transport is also an issue, especially the impacts resulting from centrally located 'production or shipment sites, such ports that have historically been in or near the centre of urban developments. Freight transport is not discussed here, however; the information presented in this handbook focuses solely on passenger transport.

The handbook consists of two parts. The first provides an overview of a variety of mechanisms (see next page for a full list of these mechanisms) that can be used to reduce greenhouse gas (GHG) emissions from transport. While some additionally reduce other emissions (e.g. noise and vibrations) as well, that is not the primary focus, although it is a useful benefit. The second part provides more detailed descriptions of several mechanisms (indicated in bold type on the list on the next page) which are known to be relatively effective and affordable.

The handbook does not address strategy development, implementation or monitoring—all of which are obviously critical to achieving any goals set with regard to emissions reduction.

The various mechanisms used by governments and the private sector to achieve reduced emissions can be divided into three broad categories. These categories are used throughout this handbook as a helpful way of categorizing mechanisms; note, however, that they are not necessarily mutually exclusive and that, depending on its actual characteristics, a given mechanism could be assigned to different categories:

- Travel demand management
- Traffic management/engineering
- Energy efficiency and fuel

In many real-world policies, a mix of mechanisms from at least two of the above categories is chosen. But the success of the mechanisms in reducing emissions ultimately relies on strong political support by government officials at the national and/or local level; this support significantly increases the chances for success.

Public awareness—particularly on the part of vehicle drivers and users—is also crucial to success, as this will ensure that policymakers do not just opt for those mechanisms emphasising potential cost savings, or which can be easily implemented at the individual or company level—and which only marginally address the environment.

# 1 OVERVIEW OF MECHANISMS

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The following pages provide an overview of potential mechanisms that could be employed in the project region and elsewhere. They comprise a wide variety of approaches in the broad categories of travel demand management, traffic management and energy efficiency and (alternative) fuels. Most of them are currently being employed somewhere in the world. While several mechanisms are more or less common practice (and primarily utilised for commercial reasons), others are still at a research or pilot stage.

This overview is intended to give a sense of the scope and substance of approaches to reducing transport emissions from which to choose. The success of each model depends on the specific circumstances and its use in combination with other mechanisms or policies. While basic characteristics of one mechanism may be replicable elsewhere, it is often difficult to reproduce comparable results. Since most mechanisms depend on behavioural change—either through an increased awareness on the part of transport users or effective enforcement by public authorities—cultural aspects play a significant role in successful application.

The following information is provided for each mechanism on the following pages:

*—Description:*—Brief description of the mechanism’s key elements.

*Examples:*—Prominent examples of the mechanism’s application.

*Strengths:*—Key advantages.

*Weaknesses:*—Essential weak points.

*Quantifiable effect:*—Any quantified emission, fuel consumption or traffic reduction effect, economic benefit, etc., indicated in the reviewed literature and material. This information is provided, as a point of reference only, as individual values can vary significantly based local conditions and analytic methods.

*Time:*—Qualitative indication (short, medium or long) of the time potentially needed implementation; this excludes consideration of issues related to complex regulatory, political or economic contexts.

*Potential:*—The mechanism’s qualitative emission reduction potential, indicated as high, medium or low. Differentiation by type of emission—e.g. carbon dioxide (CO<sub>2</sub>), nitrogen oxide (NO<sub>x</sub>), or particulate matter (PM)—is not provided, even though emission reduction potential may vary greatly by emission type.

*Comments:*—Any particularly relevant observations.

Note that the examples provided here are by no means exhaustive; for some mechanisms, like separate bicycle lanes, there are obviously hundreds of good examples available. Quantifiable effects vary significantly, and are strongly dependent on various factors specific to each case. The values presented are taken from selected examples in the literature and should not be extrapolated to other circumstances.

1. TRAVEL DEMAND MANAGEMENT	
<i><b>Congestion charging</b></i>	
Description	Fees are applied to single users based on their actual usage of road space; fees can be varied based on infrastructure, vehicle type and time of the day/week
Examples	Singapore Area Licensing Scheme (ALS) and Singapore Electronic Road Pricing (ERP)  Central London Congestion Charging Scheme
Strengths	Depending on technology: Economically optimal differentiation of charges among user and vehicle groups  Potential to change charging policies without having to change infrastructure

	Attractive to decision makers (“spirit of modernity”)
Weaknesses	<p>Deviation of traffic (geographically/timely)</p> <p>High initial investment</p> <p>High operation and maintenance (O&amp;M) costs</p> <p>Need for qualified staff for O&amp;M</p> <p>Complexity for users (registration, payment, charge levels, fines, etc.)</p> <p>Often seen as “cash cow” for public administration</p>
Quantifiable effect	<p>Singapore ALS</p> <ul style="list-style-type: none"> <li>➤ increased average speeds from 19 to 36 km/h</li> <li>➤ morning peak hours less 45% of traffic</li> <li>➤ car entries in restricted zone decreased by 70%</li> </ul> <p>Singapore ERP:</p> <ul style="list-style-type: none"> <li>➤ less 15% traffic in the restricted zone (1999).</li> </ul>
Time	++
Potential	++
Comments	<p>Costs and benefits, as well as public acceptance, strongly depend on actual technology employed, user sensitivity to charges and complementary measures (e.g. improved public transport, enhanced walking and cycling facilities, etc.). Traffic deviation has an adverse effect on emissions in zones close to the restricted area.</p> <p>There is a potential adverse effect in regions without access restrictions, e.g. export of old vehicle fleet to a foreign country (resulting in no net improvement globally).</p>
<b><i>Parking fees</i></b>	
Description	Parking fees are set at a level which influences the use of individual vehicles in certain areas
Examples	North Sydney Council, Australia
Strengths	Relatively easy to apply

	Widely accepted by the public. Known technology with many systems on the market
Weaknesses	No leverage on transit traffic Risk of traffic deviation and relocation of businesses (over the long run) No direct relation to actual vehicle usage
Quantifiable effect	No clear indication in reviewed literature
Time	+++
Potential	+
<b><i>Emission-oriented tax policies</i></b>	
Description	In many countries, fuel is subsidised and parking fees are exempted from fringe benefits; abandoning these subsidies can discourage car usage. Conversely, implementing tax exemptions on technologies with low emissions can increase their use.
Examples	United States: fuel production subsidies; tax exemptions for parking costs
Strengths	No investment required Easily applicable at a central level Does not formally restrict technology choices
Weaknesses	Fuel price elasticities are usually very small, so the effect on demand can be expected to be low Parking has no relation to actual vehicle usage An effective tax system must be existent
Quantifiable effect	No clear indication in reviewed literature
Time	++
Potential	+

<b>Car sharing</b>	
Description	Several individuals use one vehicle, either on an individual basis or organised through a commercial company
Examples	<a href="http://www.carpooling.co.uk">www.carpooling.co.uk</a> (EU) <a href="http://www.erideshare.com">www.erideshare.com</a> (US)
Strengths	Relatively easy to apply Requires little or no investment Requires Internet access
Weaknesses	Requires awareness by participants Implies restrictions to individual travel behaviour (loss of flexibility) Potential security and safety issues
Quantifiable effect	carpooling.com claims its service saved 630,000 tons of CO <sub>2</sub> in the first 10 years of its existence. No data are available on unregistered car pools.
Time	+++
Potential	++
Comments	Besides daily commuter trips, long-distance trips are possible; a number of Internet platforms offer matching services.  The quantifiable effects vary significantly with the type of sharing model. Simultaneous sharing decreases the passenger car unit per person, while sequential sharing of the same car leads to standard passenger car units.
<b>Company bus services</b>	
Description	Companies pick up and return their employees along established routes according to working hours
Examples	Siemens, Mexico City

	BASF Rhine-Neckar area, Germany
Strengths	Reduces need for individual transportation No expenditure for public sector service Increases worker punctuality
Weaknesses	Only applicable for larger companies which can afford service Requires sufficient geographic concentration of employees
Quantifiable effect	Similar to public transport, possibly higher load factors
Time	++
Potential	+
Comments	Can be delivered by <i>public–private partnership</i> PPP, e.g. company contributing to public bus operator’s expenditure Low estimated potential, since only trips to and from work are affected—i.e. no leisure, shopping, etc. trips; or travel by students or pensioners
<b><i>Park and ride schemes</i></b>	
Description	Dedicated car parking spaces in suburban and peripheral areas of cities along public transport corridors to facilitate the connection of commuters to public transport
Examples	Amsterdam Berlin
Strengths	Increases public transport demand Relatively easy to apply Little investment required
Weaknesses	➤ Requires user awareness ➤ Sufficient public transport quality required to attract motorised individual transport users

	<ul style="list-style-type: none"> <li>➤ Requires basic land use planning</li> <li>➤ Uses valuable space in proximity to public transport access</li> </ul> <p>. Prioritises motorised individual transport</p>
Quantifiable effect	
Time	
Potential	
<b><i>Public bicycle rental</i></b>	
Description	Bicycles are offered at highly frequented locations to registered users for a fee; these can be returned to dedicated stations
Examples	<p>Vélib Paris, France</p> <p>Call a Bike, Germany</p> <p>Homeport Prague, Czech Republic</p>
Strengths	<p>Relatively easy to implement</p> <p>Widely accepted by the public</p> <p>Physical exercise for users</p> <p>Flexible, low-cost option for “last mile” that complements public transport</p> <p>O&amp;M not a user concern</p> <p>Known technology with many systems on the market</p> <p>No need for own space for bicycle storage</p> <p>No need to return to point of departure</p>
Weaknesses	<p>Strongly dependent on weather conditions</p> <p>Requires physical effort by user</p> <p>Not viable for longer distances</p> <p>Requires investment and O&amp;M on the part of the provider</p>

	Requires cycling infrastructure
Quantifiable effect	No clear indications in reviewed literature; one operator (JCDecaux) claims average savings of 0.67 tons of CO <sub>2</sub> per year per bicycle available
Time	+++
Potential	++
<b><i>Land use planning</i></b>	
Description	By efficiently organising residential, commercial and leisure areas, demand for individual motorised transport can be reduced and space for adequate facilities reserved; works best in areas with sufficient population density and proximity to public transport
Examples	Ottawa Nantes, France. Freiburg, Germany Manchester and Sheffield, UK
Strengths	Sustainable and radical approach No major financial investment necessary Possible to take multiple mechanisms into account at the planning stage
Weaknesses	Requires long-term vision and political support Requires reliable and stable legal framework Often difficult to apply in a built environment
Quantifiable effect	No indication in reviewed literature
Time	+
Potential	+++
Comments	Relatively easily and quickly applicable in “new city”

	developments, e.g. in China or the Middle East (time: ++)
<b><i>Distance-based vehicle taxes and insurance</i></b>	
Description	Vehicle taxes and insurances are structured in accordance with actual vehicle usage, i.e. high mileage results in higher taxes and insurance premiums
Strengths	Relatively easy to apply Usually requires no investment Applicable in a centralised manner Incentive for urban concentration
Weaknesses	Disadvantage for people living in remote areas with a need to travel long distances
Quantifiable effect	No indication in reviewed literature
Time	++
Potential	+
Comments	Where emission-oriented tax policies are in place or envisaged, these mechanisms should be considered simultaneously to avoid discrepancies
<b><i>Access restrictions</i></b>	
Description	Vehicles below certain emission thresholds are categorically not allowed to access city centres
Examples	Environmental zones ( <i>Umweltzonen</i> ) in Germany
Strengths	Simple, easily understood approach Highly effective when properly enforced
Weaknesses	May cause higher economic inefficiencies compared to a user charge No revenue generation Enforcement costs

	Political acceptance issues
Quantifiable effect	Berlin (Stage 2, 2010): Emissions reductions of 56% PM 10, 20% NO <sub>2</sub> in overall vehicle fleet. More least-polluting vehicles, i.e. 50% cars/light goods vehicle, 200% heavy goods vehicle - 25% less population affected by above-threshold pollution values
Time	++
Potential	++
Comments	Traffic deviation has an adverse effect on emissions in zones close to the restricted area. There is a potential adverse effect with regard to regions without access restrictions, e.g. export of old vehicle fleet to a foreign country (resulting in no net improvement globally).
<b><i>Rickshaw services (human-powered)</i></b>	
Description	Rickshaw services offered to pedestrians, usually for leisure purposes
Examples	Many German cities with tourist attractions
Strengths	Low-tech solution Generates employment
Weaknesses	Needs sufficient road space or separate lanes Often precarious labour conditions Acceptance issues in Western cultures (unless leisure transport) Usually small market segment, i.e. relatively little effect
Quantifiable effect	No indication in reviewed literature
Time	+++
Potential	+
<b><i>Animal transport</i></b>	
Description	Animals are used to transport passengers in carts

Examples	Istanbul
Strengths	Low-tech solution Generates employment
Weaknesses	Needs sufficient road space or separate lanes Often precarious labour conditions Acceptance issues in Western cultures (unless leisure transport) Usually small market segment, i.e. relatively little effect Waste disposal and depots needed
Quantifiable effect	No indication in reviewed literature
Time	+++
Potential	+
<b>2. TRAFFIC MANAGEMENT</b>	
<b><i>Separate bus lanes/bus rapid transit</i></b>	
Description	Separate lanes for bus traffic to reduce traffic congestion; different options exist in terms of full or partial separation and engineering solutions applied
Examples	Metrobús, Mexico City Transmilenio, Bogotá Bangkok Bus Rapid Transit (BRT) Brisbane BRT
Strengths	Increases system reliability and performance compared to conventional bus system Large savings in travel time compared to conventional bus system Relatively easy to change route structure compared to subway Potentially low-cost alternative to metro service Potential for congestion reduction

	<p>Bus rapid transit (BRT): Improved safety and accessibility for older people and people with disabilities</p> <p>Bus lane: Cheap and flexible solution</p>
Weaknesses	<p>Requires sufficient road space</p> <p>Higher emissions than electrified mass rapid transit/BRT</p> <p>Crowding out of private (mini-)bus operators (employment effects)</p> <p>Bus lane: Potential need for more enforcement since lanes are physically accessible by other forms of transport</p>
Quantifiable effect	Bogotá: potential annual average reduction of 247,000 tons of CO <sub>2</sub>
Time	+
Potential	+++
Comments	<p>The Bogotá scheme also involves an integrated fare system, centralized coordinated fleet control and improved bus management; the effects of each component are not quantified.</p> <p>Reduced traffic congestion may induce further motorised individual transport</p>
<b><i>Traffic management systems</i></b>	
Description	Coordinated traffic signalling and parking space management can enhance traffic flow and reduce congestion. Intelligent transportation systems further adapt to changing traffic situations and can give surface public transport vehicles priority over motorised individual transport.
Examples	Many cities around the world, e.g. Munich
Strengths	Integrated system capable of serving various purposes
Weaknesses	Limited scope for improvement under existing infrastructure conditions
Quantifiable effect	Green priority for heavy-duty vehicles at signalized intersections showed a reduction of up to 20% in fuel consumption, with

	estimated overall fuel savings of 16% (Vreeswijk, Mahmood and van Arem 2010).
Time	++
Potential	++
<b><i>Traffic signalling to favour public transport</i></b>	
Description	Public transport vehicles are given priority over other vehicles at traffic lights; vehicles communicate with traffic management system via radio
Examples	Many cities around the world
Strengths	Relatively easy to apply where traffic management systems exist Requires little investment
Weaknesses	Limited scope for improvement under existing infrastructure conditions Lack of acceptance by individual vehicle users
Quantifiable effect	No clear indication in reviewed literature; estimate similar to figure for traffic management
Time	++
Potential	+
<b><i>Public transport user information systems</i></b>	
Description	Detailed and timely information is provided to users to increase public transport efficiency and enable better trip planning
Examples	Most public transport systems in developed countries
Strengths	Increases efficiency of existing systems Electronic systems increase the attractiveness of public transport
Weaknesses	Requires investment and O&M Relatively high complexity of electronic systems

Quantifiable effect	No indication in reviewed literature
Time	++
Potential	+
<b><i>Integrated fares and ticketing</i></b>	
Description	Different public transport entities use a single ticketing system to allow end-to-end connections with one fare, thus increasing user convenience
Examples	German “Verkehrsverbund” system
Strengths	Increases user convenience No major investment required Electronic systems used to increase system transparency
Weaknesses	Requires operator coordination Need to identify acceptable charging system Technical complexity as compared to widely used flat fares
Quantifiable effect	No indication in reviewed literature
Time	++
Potential	+
<b><i>Dedicated bicycle lanes</i></b>	
Description	Paved bicycle lanes running parallel to main roads; these are physically separated from the roads e.g. by coloured surface or separation stripes, kerb stones, vegetated separation lane, etc.
Examples	Numerous cities, including Sydney Copenhagen and Bangkok
Strengths	Relatively low investment (depending on actual design) Contributes to road safety

	Improves traffic flow for both motorised and non-motorised vehicles Can increase user fitness CO <sub>2</sub> -neutral mobility
Weaknesses	Requires sufficient road space Requires appropriate enforcement of cyclist rights (in cases of ineffective physical separation) Cycling not an option for all terrains and weather
Quantifiable effect	No clear indication in reviewed literature; however, cycling has been shown to improve health and reduce environmental impacts and congestion significantly
Time	++
Potential	++
Comments	In many Asian cities, the negative impacts of closed bicycle lanes on air quality and road safety, with a concomitant increase in the number of motorbikes and passenger cars, can be noted
<b><i>Functional walking facilities</i></b>	
Description	Infrastructure provided in urban areas to connect people from their residence to work, shopping, , public transport, etc.
Examples	Most northern European cities
Strengths	Allows for safe and reliable “last mile” Improves cities’ image and quality of life Increases livelihood of the poor Reduces separation effect of major roads, rail lines, etc. CO <sub>2</sub> -neutral mobility
Weaknesses	Must be combined with motorised transport for longer distances
Quantifiable effect	No indication in reviewed literature; however, walking has been shown to improve health and reduce environmental impacts and congestion significantly
Time	++

Potential	+
Comments	
<b><i>Car-free city centres</i></b>	
Description	Extensive pedestrian areas in city centres where only supply vehicles for local businesses or transport for disabled people are temporarily allowed
Examples	Ghent, Copenhagen Rotterdam
Strengths	Highly beneficial for shopping areas and tourist locations Increased options for street and city design Increased road safety and leisure value
Weaknesses	Requires investment in vehicle access barriers Need for emergency or supply vehicles to access restricted areas. Can cause bottlenecks in overall city road network
Quantifiable effect	No indication in reviewed literature, but directly linked to increased walking and cycling with respective positive effects
Time	++
Potential	+
<b>3.ENERGY EFFICIENCY AND FUEL</b>	
<b><i>Fuel efficiency standards</i></b>	
Description	Vehicle combustion emission standards which serve as a basis for vehicle licensing, fees and taxes
Examples	Euro norms
Strengths	Broad effect on all consumers No need for change in user behaviour Easily controllable
Weaknesses	No relation to actual vehicle use

	Often unrealistic testing procedures Does not take account of long-term vehicle emissions
Quantifiable effect	Netherlands: Introduction of Euro VI in 2013 compared to Euro V for heavy goods vehicle led to 22% reduction of No <sub>x</sub> and 12% reduction of PM 2.5 in overall road traffic by 2020
Time	+++
Potential	Only forms basis.
<b><i>Fuel composition standards</i></b>	
Description	Fuel standards with quality criteria for nuisance substances which are controlled centrally at fuel production, import or storage facilities
Examples	Directive 98/70/EC (European Union) GOST 2084/77 (Russian Federation) GOST 305/82 (Russian Federation)
Strengths	Broad effect on all consumers No need for change in user behaviour Able to be controlled at relatively few production sites
Weaknesses	Increased production cost Risk of increased fuel contraband
Quantifiable effect	Emission reduction proportional to reduction of harmful substances
Time	+++
Potential	Only forms basis.
<b><i>Driver training</i></b>	
Description	Drivers are trained in fuel-efficient driving techniques and gain awareness of environmental issues; training is either dedicated or integrated into standard driving school lessons
Examples	DP DHL (international courier company)

	Dublin City Council
Strengths	Positive side effects on fuel and O&M expenditures Easily applicable Requires little investment
Weaknesses	Usually only short-term effects (need to re-train regularly) General awareness of participants is necessary
Quantifiable effect	2–3% less fuel consumption
Time	+++
Potential	+
<b><i>Appropriate operation and maintenance</i></b>	
Description	Vehicles are properly maintained and operated in order to achieve ideal conditions and efficiency levels; this includes optimal tire pressure, lubricants, filters, redundant loads, etc.
Examples	Deutsche Post DHL (international courier company) Dublin City Council
Strengths	Positive side effects on fuel and O&M expenditures Easily applicable No investment required
Weaknesses	Needs regular attention by qualified staff
Quantifiable effect	Reduced fuel consumption: <ul style="list-style-type: none"> <li>➤ Tire pressure 2–3%</li> <li>➤ Low rolling resistance tires: 5–8%</li> <li>➤ Smoothly flowing oil: ~2%</li> </ul> Clean filters (air, fuel, catalyts)
Time	++
Potential	+

<b><i>Vehicle licensing</i></b>	
Description	Licenses are only awarded to technically acceptable vehicles, and fee levels take into account emission quantities
Examples	Many European countries (fees charged according to Euro norms) Several African countries (age limits for vehicle imports)
Strengths	Relatively easy to apply Usually requires no investment Can be implemented centrally
Weaknesses	No relation to actual vehicle usage
Quantifiable effect	No indications in reviewed literature
Time	+++
Potential	++
Comments	Effect depends on licensing scheme; where licenses are renewed regularly and based on actual vehicle use, environmental benefits can be higher
<b><i>Scrapping schemes</i></b>	
Description	Governments offer money to owners of old vehicles when they have them scrapped, thus helping to renew a country's vehicle fleet
Examples	Germany
Strengths	Effective in reducing the use of old vehicles High visibility (political attractiveness) Incentive for car sales
Weaknesses	Short-term influence on vehicle markets

	No relation to actual vehicle usage No relation to emission levels of replacement vehicles
Quantifiable effect	No indications in reviewed literature
Time	+++
Potential	+
<b><i>Vehicle inspection and maintenance</i></b>	
Description	Vehicles are regularly inspected (including conduct of emission tests) under independent supervision; failing vehicles are banned from use
Examples	Mexico City, Mexico
Strengths	Obligates all vehicle owners to maintain roadworthiness Systematic and regular approach
Weaknesses	Requires dedicated testing sites and enforcement mechanisms Requires qualified and neutral workforce High cost of inspection system
Quantifiable effect	No clear indications in reviewed literature
Time	++
Potential	++
<b><i>Natural gas vehicles</i></b>	
Description	Vehicles fuelled with propane from fossil or renewable (“bio”) production. Biogas has the additional advantage of a more or less neutral carbon footprint. Overall PM is reduced.
Examples	Automobile market Municipal vehicle fleets
Strengths	Known and reliable technology

	Easy to use (very similar to conventional vehicles) Reduces PM emissions in urban areas
Weaknesses	Need for additional loading station network (high investment) Depending on fuel type, no carbon footprint reduction (mainly PM reduction)
Quantifiable effect	Strongly depends on technology and environment; CO <sub>2</sub> emissions may increase, while PM clearly decreases compared to diesel
Time	++
Potential	+
<b>Ethanol vehicles</b>	
Description	Vehicles fuelled by ethanol from renewable sources (e.g. sugar cane)
Examples	Brazil E10 fuel, Germany
Strengths	Depending on production method, nearly GHG-neutral Raw material readily available in certain regions of the world
Weaknesses	Needs substantial raw material production capacities Competition of food versus fuel where cereal grains are used Negative effects on habitats where additional arable land is cultivated Require specific engine
Quantifiable effect	Strongly depends on technology and environment; CO <sub>2</sub> footprint will clearly decrease compared to fossil fuels
Time	++
Potential	+++
<b>Electric vehicles</b>	

Description	Electric engines installed in dedicated vehicles
Examples	Automobile market Autolib Paris, France Deutsche Bahn Carsharing, Germany
Strengths	No direct emissions (only at power plant) Accepted by people not ready for bicycle
Weaknesses	Not viable for longer distances Requires investment and O&M Weight of batteries Potential safety issues with batteries Need for loading stations
Quantifiable effect	Strongly depends on technology (power generation) and environment; local PM emissions will clearly be reduced
Time	++
Potential	+++
<b>Hybrid vehicles</b>	
Description	Vehicles which use electric and conventional engines for different speeds and driving types, e.g. electric engine in slow or stop-and-go traffic
Examples	Automobile market
Strengths	Easy to use (very similar to conventional vehicles) No direct emissions in stop-and-go-traffic or at low speed Depending on technology, no need for a charging station
Weaknesses	Consumer mistrust of the technology Increased maintenance costs
Quantifiable effect	Depending on type, up to 40% fuel (and hence emission) savings

Time	+++
Potential	++
<b><i>Hydrogen-powered vehicles</i></b>	
Description	Vehicles fuelled by hydrogen.
Examples	Pilot vehicles by certain manufacturers
Strengths	Easy to use (very similar to conventional vehicles) No direct harmful emissions
Weaknesses	Technology still being researched Not readily available at affordable prices
Quantifiable effect	No emission by vehicles (only during hydrogen production)
Time	+
Potential	++

## 2 HIGH-POTENTIAL MECHANISMS

---

This section presents details on a set of mechanisms capable of reducing urban contamination by air emissions; these were selected from among those profiled in the previous section. The mechanisms are included here based on their applicability—i.e. the potential for being introducing them within a relatively short period of time (a few years) combined with their emission reduction potential.

### 2.1.1 Congestion charging

Congestion charging has been promoted by cities such as London and Gothenburg, Sweden, in recent years and has been a topic of interest for academics and researchers for several decades. Under favourable conditions (as in Singapore, discussed below), this mechanism can greatly affect a city's emission footprint.

There are several constraints regarding congestion charging that involve policy (e.g. general targets, social considerations), methodology (e.g. calculation of congestion costs, establishment of demand elasticities) and practical implementation (e.g. type of collection system, enforcement). On the other hand it is one of the mechanisms than can bring about the most fundamental changes.

#### 2.1.1.1 Concept

Singapore and London are among the most prominent examples of congestion charging in urban transport. While Singapore relies on a sophisticated distance- and time-related electronic charging system, London has set up a so-called “cordon-pricing” scheme that sets access boundaries around one of the city's central districts.

**Singapore: distance-/time-related charges.** As an island of about 700 km<sup>2</sup> (roughly the size of Hamburg or half that of St. Petersburg), Singapore comprises a relatively small, easily controllable area. Moreover, because its dominant political party has been in power for decades, the chances of

divergent political interests are relatively low, which facilitates the implementation of politically sensitive policies.

Singapore started its area licensing scheme in 1975 and introduced electronic road pricing in 1998. The ALS operated in a restricted zone around the central business district and was manually operated, with all users being charged a flat rate for access to the central district and violators fined. There were no exemptions for residents; ultimately, however, emergency vehicles were exempted from the scheme. The ALS increased average speeds from 19 to 36 km per hour, while traffic volumes during morning peak hours fell by 45 per cent, and car entries into the restricted zone decreased by 70 per cent (see Santos and Frasier 2006 and the literature cited therein for details).

### **Figure 1: Singapore ERP gantry with radio frequency identification sensors**

*Source: Singapore Ministry of Transport*

The ERP scheme introduced in 1998 charges by location point rather than for entry into a specific area. Charging times vary, but in general these are from 7:30 a.m. to 7:00 p.m. on very central roads, and from 7:30 a.m. to 9:30 a.m. on expressways and outer roads. Vehicles, equipped with radio frequency identification –based In-vehicle units into which the driver’s smart card is inserted, are charged automatically each time they cross a gantry without the need to slow down. If motorists pass through an operational ERP gantry without a properly inserted smart card or with a smart card with insufficient balance to pay the charge, enforcement cameras take a digital picture of the rear licence plate, and the registered owner of the vehicle is fined. Only emergency vehicles are exempt. ERP rates, published on the Land Transport Authority website, vary with vehicle type, time of day and gantry location. In 2003, a graduated ERP rate was introduced in the first five minutes of the time slot to discourage motorists from speeding up or slowing down to avoid higher charges.

According to the Singapore Ministry of Transportation website, the Land Transport Authority is now considering development of ERP II. As

congestion becomes increasingly pervasive, it would not be practical to continue erecting physical gantries to address the congestion problem. In addition, the ERP charges imposed at discrete gantry points lead to undesirable consequences—e.g. congestion spillover to nearby minor roads in residential areas, thus leading to localised congestion.

The ministry envisages that ERP II can help overcome such problems by making distance-based congestion charging possible along congested stretches of roads and expressways. This would be a more equitable and economically efficient system than the current system, in which motorists are charged based on the number of gantries they drive through rather than the distance travelled on a congested road. Furthermore, motorists who join a congested road after the gantry points are not charged even though they contribute to that road's congestion.

**London: cordon pricing.** In 2002, the Central London Congestion Charging Scheme was introduced, charging vehicles entering the London central business district a lump sum of GBP 5 per day. In 2005, this charge was increased to GBP 8, which led to a further reduction in the number of vehicles operating in the covered district.

The London scheme is based on cameras installed both at entry roads and within the district that detect vehicle number plates. Number plates are automatically matched via a central database to which users have to register in advance. Users can pay before entering the restricted zone or—for a small supplement—on the same day. No or delayed registration results in significant fines. Compared to the time- and distance-related approach applied in Singapore, cordon pricing has fewer options for differentiation.

Transport for London introduced a green vehicle discount that exempts all cars from the congestion charge that emit 100 g/km or less of CO<sub>2</sub> and that meet the Euro 5 standard for air quality. Registration is still required (GBP 10 per year). Since it is anticipated that new electric and hybrid electric plug-in vehicles will be brought to market with significantly lower emission levels, the discount criteria will be kept under review, with the intention of reducing discount levels to 80 g/km or lower when the time is

right. Transport for London thus combines different mechanisms in the context of one overarching charging system.

### 2.1.1.2 Assessment

Depending on the actual technology employed, congestion charging allows a high degree of price differentiation according to time, distance, vehicle type, etc. At the same time, it requires significant investment in access control and vehicle registration equipment, related data processing and storage tools, and administration. While congestion charging has proved to be an effective and visible mechanism for charging vehicle users and increasing awareness of the external costs of driving, its actual emission reduction potential remains to be seen.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Depending on technology: Economically “optimal” differentiation of charges among user and vehicle groups.</li> <li>➤ Possibility to change charging policies without need to change infrastructure.</li> <li>➤ Attractiveness to decision makers (“spirit of modernity”).</li> </ul>	<ul style="list-style-type: none"> <li>➤ Deviation of traffic (geographically/timely).</li> <li>➤ High initial investment.</li> <li>➤ High O&amp;M costs.</li> <li>➤ Need for qualified staff for O&amp;M.</li> <li>➤ Complexity for users (registration, payment, charge levels, fines, etc.).</li> <li>➤ Often seen as “cash cow” for public administration.</li> </ul>

As discussed above, congestion charging in Singapore benefits from a number of factors, notably an easily controllable area, which greatly aids in keeping the expenditure for access control infrastructure within acceptable limits. Other complementary measures include the development of mass rapid transit, a stable (local) government dedicated to implementation of the scheme and a highly restrictive vehicle licensing policy.

Other examples of congestion charging schemes include Stockholm and Gothenburg in Sweden and Ho Chih Minh City.

### 2.1.2 Emission-oriented tax policies

This mechanism encompasses two basic approaches: (1) the reduction of subsidies (i.e. tax exemptions) or increase of taxes on high-emitting technologies, and (2) the reduction of taxes or introduction of tax exemptions for more environmentally friendly technologies.

#### 2.1.2.1 Concept

Two basic areas can be differentiated in the context of tax regulation: fuel production and parking. While taxes on fossil fuels have an effect on all conventional vehicles, parking principally applies to all users of parking spaces.

**United States: fuel production subsidies.** The subsidisation of fossil fuel-based transport often starts with the subsidisation of oil production, particularly exploration, or import. For example, in the United States, independent producers can deduct costs for the exploration and drilling of oil wells. Integrated oil companies may deduct 70 per cent of such costs and recover the remaining 30 per cent over five years with cost-depletion deductions. Because these expenses occur prior to production and are properly attributable to future output, normal abandoning tax rules would treat them as capital costs and allow deductions for depletion only as the resources from the well are extracted (Toder 2007). Without these subsidies, the actual cost of fuel production would be passed on to consumers and the choice of other fuels would potentially become more attractive.

**United States: tax exemptions for parking costs.** Parking is another area where significant tax benefits are provided in a number of countries. The example provided here is from the United States, where companies can deduct from their taxes the cost of providing employees with parking space. In 2007, there were tax-free limits of USD 110 per month on public transport and car-sharing benefits and USD 215 per month on parking

(Toder 2007). This benefits car users compared to public transport users. Beyond this discrimination, avoiding tax exemptions on parking lots would set incentives for the use of public transport and impose the full cost of land use on users.

In this context, it is useful to note that parking costs amount to approximately 17 per cent of total vehicle ownership costs (source), so a reduction in parking subsidies would make vehicle owners bear that share of the costs to society.

### 2.1.2.2 Assessment

While these mechanisms may be politically sensitive, they have the advantage of increasing government revenues. The additional funds may be used to increase expenditure for environmentally friendly technologies. (In London, for example, workplace parking charges at the city’s airport are used to subsidise public transport.) From an administrative and implementation cost point of view, tax regimes are rather attractive since they can be applied from a central level and do not require any physical investments.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ No investment required.</li> <li>➤ Easily applicable at a central level.</li> <li>➤ Does not formally restrict technology choices.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Price elasticities of fuel are usually very small, so the effect on demand can be expected to be low.</li> <li>➤ Parking stands in no relation with actual vehicle usage.</li> <li>➤ An effective tax system has to be existent.</li> </ul>

With regard to this mechanism, it must be noted that political consultation and decision processes may change taxing conditions in a manner that is more politically acceptable, but methodologically less sensible.

Overall, this approach will benefit from an efficient public transport system and transparency in the use of funds received from abandoned tax exemptions (user pays for service).

Another area for tax exemption is the cost for trips between home and work. In Germany, for example, commuters can deduct from their taxable income costs incurred for work-related travel. While this applies to any means of transport, it still facilitates urban sprawl and the use of motorised individual transport.

### 2.1.3 Car sharing

Car sharing can either be organised on an individual basis, usually between colleagues commuting to work; or through platforms matching supply with demand, usually via the Internet.

#### 2.1.3.1 Concept

For people who regularly use the same route with their own vehicles, sharing one vehicle can be beneficial in terms of cost and possibly social factors. This benefit can be achieved by driving intermittently—each participant making the trip in his or her own vehicle in turn and taking the others along—or if one person does the driving and the others pay for the service.

The system can be facilitated by companies which match people living close to each other according to their addresses, but most of the time, the car-share groups develop on their own since many personal as well as organisational factors are involved. Companies can also offer preferential parking lots (e.g. closer-in spaces) for car shares.

The offer of dedicated marketplaces is an alternative approach. Today, these platforms—such as [www.carpooling.co.uk](http://www.carpooling.co.uk) (United Kingdom) or [www.erideshare.com](http://www.erideshare.com) (United States)—are Internet-based, but phone-based services existed in the past for an administrative fee. People offering trips can publish them, indicating start and end locations, start time, price, number of free places on the vehicle, etc., and users contact

suppliers if they find a matching offer. The service allows regular trips to be organised, but is particularly helpful for longer distance and irregular trips, since drivers and passengers can arrange the trips several days in advance via email or phone.

**Figure 2: Examples of carpooling sites in the United Kingdom and the United States**

Sources: *carpooling.com, erideshare.com*

**2.1.3.2 Assessment**

A car-sharing system requires user awareness, and there must be a basic culture of respect, honesty and punctuality to make the system work. In the case of commuters, corresponding working hours are an essential success factor.

In the case of Internet-based platforms, safety (vehicle condition, driving style, insurance) and security (robbery by drivers or passengers) are concerns for system viability. Due to the dynamic character of car sharing, Internet platforms and fragmented user groups, it is difficult to control access to the system or its performance; more recent developments such as user evaluations are answering to these issues.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Relatively easy to apply.</li> <li>➤ Little/no investment necessary.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Requires awareness by participants.</li> <li>➤ Restrictions to individual travel behaviour (loss of flexibility).</li> <li>➤ Potential security and safety issues.</li> <li>➤ Internet access required.</li> </ul>

Car-sharing systems benefit from park and ride schemes and unreliable or expensive public transport.

## 2.1.4 Park and ride schemes

Park and ride refers to the provision of dedicated car parking spaces in suburban and peripheral areas of cities along public transport corridors to facilitate commuter connection to public transport.

### 2.1.4.1 Concept

Public authorities provide parking spaces according to estimated usage of the scheme in close proximity of BRT, tram or commuter train stations in suburbs or completely outside the city. This extends the catchment area of the public transport system to commuters who would otherwise have used a private vehicle for the full trip or whose vehicles would potentially have contributed to congestion if parked elsewhere around the particular public transport station. From the users' perspective, the mechanism facilitates intermodal trips by public transport and private vehicle and takes advantage of both modes—i.e. the flexibility of the private vehicle (“last mile”) and the ease of reaching central locations in the city without the inconvenience of high parking charges or the need to search for a parking place.

Parking spaces can be provided free of charge to users—as in most German cities—or for a moderate fee. In Amsterdam, the parking fee can be combined with a public transport ticket that allows users to travel to the city centre in other cities.

### Figure 3: Map of P+R locations in Amsterdam, photo of P+R location in Berlin

Sources: *City of Amsterdam, Stadtentwicklung Berlin*

### 2.1.4.2 Assessment

Where sufficient space is available or basic land use planning is in place, park and ride schemes are relatively easy to apply and do not require large investments. However, the public transport system must be of sufficient quality to attract private vehicle users—usually drivers of cars,

who tend to be better off economically than typical public transport users. The mechanism contributes to public transport ridership and can increase its performance. In many countries, park and ride schemes are politically attractive due to their visibility, but actual usage sometimes lags expectations.

Two major points of criticism regarding the mechanism are the occupation of valuable land close to public transport access points in urban areas and the contribution to a focus on motorised individual transport. However, in more rural areas (e.g. a city with a large catchment area) park and ride schemes can make a valuable contribution to the use of public transport in terms of intermodal commuter trips.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Increases public transport demand.</li> <li>➤ Relatively easy to apply.</li> <li>➤ Little investment required.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Requires users' awareness.</li> <li>➤ Sufficient public transport quality required to attract motorised individual transport users.</li> <li>➤ Requires basic land use planning.</li> <li>➤ Uses valuable space in proximity to public transport access.</li> <li>➤ Contributes to a fixation on motorised individual transport</li> </ul>

Park and ride schemes benefit from a well-functioning public transport system and a reasonably safe environment in which users can leave their cars in suburban parking spaces without the risk of vandalism or burglary. Basic land use planning is required to allow sufficient space.

### 2.1.5 Public bicycle rental

The availability of rental bicycles at docking stations at locations highly frequented by pedestrians is an increasingly familiar phenomenon in many cities around the world. Given the shortness of average trips (around 11.5

km in Europe, according to Eurostat 2007), the bicycle is an excellent alternative to other transit modes in many cases.

### **2.1.5.1 Concept**

There are two basic approaches to public bicycle rentals: systems with docking stations and systems without docking stations. The first concept is far more frequently seen in practice and has—from a provider point of view—the advantage of a fixed number and structure of locations at which bicycles can be rented and returned. It is a less technologically complex system.

The “free” system (i.e., no docking stations) has bicycles equipped with global positioning system (GPS) receivers and a small user registration device. As in the “fixed” system, users must register online in advance and can use any bicycle they find in the city. Bicycles must be returned at defined arterial locations—usually, public transport stations, major intersections, entries to pedestrian precincts, etc.—and fastened with locks installed on all vehicles. Users pay a penalty fee if they leave the bike at a non-authorized location.

There are several advantages to the free system:

- Users do not need to search for an alternative docking station in case the target station at the end of their trip is fully occupied.
- The operator can potentially collect valuable data on travel behaviour through the GPS.
- There is no need to install and maintain docking stations.
- Stationing areas can be changed according to user, provider or authority needs.

### **Figure 4: Vélib station in Paris and Call-a-Bike bicycle registration device (photos)**

*Sources: rtl.fr*

Notwithstanding these advantages, the more widespread use of fixed systems indicates that these are easier to implement and/or are more economical.

### 2.1.5.2 Assessment

In the context of the countries covered by the Air Quality Governance project (Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova, Russian Federation and Ukraine), climatic conditions will probably be a decisive factor in determining whether to introduce a public bicycle system. Cities with long winters where roads tend to be covered with snow and ice are not likely to have suitable conditions for bicycle rentals, given convenience and safety concerns.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Relatively easy to apply.</li> <li>➤ Widely accepted by the public.</li> <li>➤ Physical exercise for users.</li> <li>➤ Flexible, low-cost option for “last mile” that complements public transport.</li> <li>➤ No need for user to care about O&amp;M.</li> <li>➤ Known technology with many systems on the market.</li> <li>➤ No need for own space for bicycle storage.</li> <li>➤ No need to return to point of departure (compared to conventional rental).</li> <li>➤ Depending on system type: No need to find free docking space.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Strongly dependent on weather conditions.</li> <li>➤ Requires users’ physical effort.               <ul style="list-style-type: none"> <li>▪ Not viable for longer distances and difficult terrain types.</li> </ul> </li> <li>➤ Requires investment and O&amp;M (provider).</li> <li>➤ Cycling infrastructure required.</li> </ul>

Nonetheless, this mechanism has numerous advantages compared to other technologies, including its flexibility and low cost in enabling public transport users to cover their “last mile” between public transport stations and their point of origin or final destination. The physical effort required by users can be considered either an advantage or a disadvantage, depending on their preferences.

To meet its potential, the public bicycle rental mechanism requires dedicated cycling infrastructure, an awareness on the part of the general public (potential users) and sufficient provisions for cycling safety.

The financing of public bicycle rentals can be enhanced with bicycle frames being used as advertising surfaces. Especially for public transport operators, the combination of cycling with their services can improve overall system performance.

## **2.1.6 Land use planning**

From a macrocosmic perspective, land use planning is the most radical and permanent solution for reducing the negative impacts of transport. By keeping distances of frequent travel short and by diversifying commercial and other uses, many external costs can be saved.

### **2.1.6.1 Concept**

The form and structure of cities and urban agglomerations have a direct effect on the population’s demand for mobility. Land use forms that (1) increase the proximity between residence, work and transit facilities; (2) reduce travel distances; (3) increase or maintain population density; and (4) make walking, cycling and transit modes more attractive are sought in this context. In recent years, patterns of land use that strictly segregate certain activities (e.g. industrial/leisure and housing) have been overcome in most industrialised countries in favour of more diversity and density .

Long-term land use planning based on a solid legal and administrative basis is vital. Such planning requires sufficient data on past and actual land uses, demography, economy, and forecasts of future scenarios and their likely impact on land use. In accordance with these scenarios, as well as with the population's needs and policy targets, unused land should be reserved for certain purposes and strategies developed for the future use of built land. These functions will usually be the responsibility of municipal authorities. Only through systematic and reliable land management can a sustainable city layout be ensured, comprising the most efficient forms of transport.

As indicated above, increasing urban density is an important factor in determining the viability of public transport and non-motorised transport. This increase can be achieved by (re-)developing brownfield sites, conserving so-called green belts around cities for recreational purposes, introducing transit-oriented development, allowing for a diversity of uses (e.g. commercial surfaces at the ground floor level and housing in upper floors) and exploiting urban design (HiTrans). To enhance development of cities in this spirit, the following points should be taken into account:

- Re-plan and improve public spaces.
- Balance the use of cars, public transport, walking and cycling.
- Restore and improve pedestrian routes.
- Renovate properties adjacent to the urban multi-modal transport network.

From a practical point of view, public transport technologies can be important for a city's image. A smart design of public transport vehicles, the application of new technologies such as electronic ticketing, user information and ticketing via smart phones, etc., are factors that are usually positively perceived by users, visitors and decision makers.

It is possible to recoup part of the increased property values from owners in the context of public transport developments along dedicated corridors

through special taxes. This money can then be used to co-fund public transport and make it more sustainable.

### 2.1.6.2 Assessment

As mentioned above, land use planning is perhaps the most radical approach to reducing the negative impacts of transport, such as GHG emissions. However, it is very much a behind-the-scenes approach, in that it needs a long-term vision, perseverance in its preparation and application, sufficient administrative capacities and clear responsibilities, as well as a stable and unambiguous legal basis. Given these factors, land use planning is not necessarily very attractive politically (e.g. as compared to opening a new BRT line) and can be difficult to implement in complex political/institutional/regulatory contexts.

Pros	Cons
<ul style="list-style-type: none"><li>➤ Sustainable and radical approach.</li><li>➤ No large financial investments necessary.</li><li>➤ Possibility to take into account multiple mechanisms at the planning stage.</li></ul>	<ul style="list-style-type: none"><li>➤ Requires long-term vision and political support.</li><li>➤ Necessity for reliable and stable legal framework.</li><li>➤ Often difficult to apply in a built environment.</li></ul>

The interactions between land use and transport recall the classic chicken-and-the-egg dilemma: Do intensive public transport links result in dense population and concentrated land use patterns, or are the latter a precondition for the viability of public transport? Regardless, it can be argued that land use planning and management with respect to the structure of cities can benefit from mass rapid transit development. And the development of mass rapid transit lines usually results in a viable alternative to motorised individual transport in terms of travel times along corridors and the formation of high-density quarters around stations.

## 2.1.7 Separate bus lanes/bus rapid transit

To enhance the transit speed of public buses, physically separated lanes for their exclusive use can be developed. Different approaches to and levels of separation are possible. Note that lane separation is but one feature in a BRT system, and that the use of separate lanes in an otherwise standard bus route system will have a far lower capacity potential than a BRT.

### 2.1.7.1 Concept

Separating bus lanes from other traffic—mostly in the form of a BRT system—has proven to be an effective approach in increasing the performance of public transport systems. Creating a separate route network enables operators to schedule and design their services more precisely along defined corridors without having to take into account a lot of intersecting traffic.

Many options exist with regard to route and vehicle configuration and actual separation levels. While systems such as the oft-cited Transmilenio in Bogotá, Colombia or the Metrobús in Mexico City are fully separated, street marking solutions such as those implemented in New York City and Hamburg are less costly. System design must be carefully matched to the needs and potential of the respective city and its inhabitants.

#### **BRT: Transmilenio, Bogotá (source: World Bank 2004).**

The TransMilenio system is an integrated BRT system incorporating bus ways, stations and terminals adapted for large-capacity buses as well as fare-integrated operations with smaller buses on the outskirts of the city. Before its introduction, Bogotá had an extremely high level of bus congestion due in part to a proliferation of informal small and minibuses—up to 1,000 vehicles per hour per direction on arterial roads—with associated environmental and safety impacts.

The first phase of the TransMilenio system was implemented between 1999 and 2002, with operations beginning in December 2000. Measures

were taken during BRT implementation to accommodate small and minibus operators, including by incorporating them into the feeder network or transferring them to other functions. Two subsequent phases of the TransMilenio system have been implemented, and a fourth phase is planned.

### Figure 5: TransMilenio road space separation (photo)

Source: World Bank

Trunk line services are operated by articulated diesel vehicles (Euro 2 and 3 standards) with a capacity of 160 passengers per bus. On some high-capacity corridors, bi-articulated buses for up to 240 passengers are operated; feeder buses are standard vehicles.

Some vehicles stop at every station, some are operated as express services stopping only at certain locations. Passengers pay a unique flat fare at entry to the stations or at terminals when transferring from feeder buses; alternatively, e-tickets with integrated chip cards are available that allow cash-free payments according to actual use. Since all stations and terminals are fully closed, interchanges between routes and feeder and trunk buses are possible at all stations.

**Separated bus lanes** . Bus lanes can be separated from regular traffic lanes using a coloured line, striping and/or pavement in order to enhance the service of conventional buses. The lane separation mechanism can be used for the whole length of a bus route, along sections experiencing particularly high densities of other traffic, or only at intersections. The actual design of the separated lane will depend on the bottlenecks buses face under normal conditions, overall traffic volumes, policy targets and available funding.

### Figure 6: Separated bus lanes at intersections in New York

Source: New York City Department of Transport

Where queuing at traffic lights is a particular problem, an additional lane for buses can improve their operation by enabling them to overtake other

vehicles waiting for a green light. Where left turns are a particular difficulty, a short section of colour-marked lane can improve bus service, as well as general traffic flow.

Compared to a physically separated BRT-style solution, street markings are a low-cost alternative providing more flexibility, due to less permanent changes in road design. The street markings can also serve as a first step in a staged approach to a BRT system—e.g. to sensitise the population for intended future development or to try out route alignments and their impact on overall traffic.

### 2.1.7.2 Assessment

Extensive research and literature exists on the various types of BRT systems. In terms of capacity and comfort, they are an intermediate solution between conventional buses and subways, and consequently are in direct competition with light rail transit systems.

BRT is often promoted as an economic alternative to rail-based systems. While this certainly is true compared to subway systems, the difference with light rail transit is less distinct.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Increases system reliability and performance compared to conventional bus system.</li> <li>➤ Large travel time savings compared to conventional bus.</li> <li>➤ Relatively easily changeable route structure compared to subway.</li> <li>➤ Potentially low-cost alternative to metro service.</li> <li>➤ Congestion reduction potential BRT: Improved safety and accessibility to disabled and elderly</li> </ul>	<ul style="list-style-type: none"> <li>➤ Requires sufficient road space.</li> <li>➤ Higher emissions than electrified mass rapid transit.</li> <li>➤ BRT: Crowding out of private (mini-) bus operators (employment effects).</li> <li>➤ Bus lane: Potential need for more enforcement since lanes physically accessible by other traffic.</li> </ul>

people.

- Bus lane: Cheap and flexible solution.

The advantages of BRT compared to conventional buses are obvious, with travel time savings and increased comfort, reliability and safety being the most important ones. Insufficient road space can be an issue, and temporary employment effects due to the crowding out of private small-scale bus operators must be taken into account.

BRT systems benefit from integrated ticketing that allows users living farther away from corridors to take a connecting public transport line without having to buy an additional ticket. As in any public transport system, it is important to allow for a safe and reliable “last mile” to users’ final destinations; thus, good feeder services and non-motorised transport infrastructure enhance system performance. It is helpful to consider the interactions between BRT and land use planning (e.g. transit-oriented planning) before and while developing the system.

### **2.1.8 Integrated fares and ticketing**

The necessity to buy a ticket for each transport link puts a burden on users. This situation pertains particularly where small-scale private operators are the norm in bus transport, or when modal transfers (e.g. bus to subway) have to be made and no integrated ticketing exists.

#### **2.1.8.1 Concept**

Users can buy a single ticket that is valid for several cross-modal legs of one continued trip. This trip can be single, return or repeated; additionally, a time-bound multi-use ticket (e.g. weekly, monthly) can be acquired. This integrated approach requires a single system provider covering all legs of the trip, or multiple transport operators joining together to offer a single ticketing and billing system.

Where multiple operators use an integrated system, strong coordination and a clear set of rules are needed to guarantee the benefits and

obligations of each contributing partner. In particular, the distribution of revenues and costs—as well as of potential subsidies—must be managed transparently by a competent entity, usually a representative of the association or a specialised service provider under contract to the association.

The essential feature is that the public transport user is offered a simple and transparent fare structure and that ticket sales are decentralised to allow system access at any station. E-ticketing combined with chargeable smart cards or mobile phones are the newest developments in this regard, offering a number of additional benefits to users and system providers alike.

### 2.1.8.2 Assessment

The key advantage of integrated ticketing systems is improved convenience (and hence acceptance) of public transport by users. To arrive at this point takes significant preparation and time in order to change public transport operators’ behaviour and to promote the long-term advantages of the system.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Increases users’ comfort.</li> <li>➤ Does not require major investments.</li> <li>➤ Electronic systems used increase system transparency.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Requires operator coordination.</li> <li>➤ Need to identify acceptable charging system.</li> <li>➤ Technical complexity compared to widely used flat fares.</li> </ul>

Integrated ticketing can only improve user benefits from public transport if the system is already functioning at an acceptable level and inter-modal trips are a common choice.

### 2.1.9 Dedicated bicycle lanes

The provision of dedicated bicycle lanes physically separated from motorised transport and pedestrians increases the safety of both cyclists

and pedestrians, and generally increases the acceptance of cycling among the broader population.

### **2.1.9.1 Concept**

Paved bicycle lanes are either built alongside roads or are physically separated from the road surface with coloured markings, kerb stones, or separation walls or fences. At intersections, cycling lanes are marked in a similar way as pedestrian crossings.

By separating bicycles from other traffic, overall safety can be increased—which in turn contributes to user acceptance. Since average trip lengths are relatively short (around 11.5 km in Europe, according to Eurostat, 2007), there is a high potential for motorised individual transport or public transport trips to be transferred to cycling.

As cycling is (except for the production of bicycles and spare parts) emission free, its emission reduction potential is very high. According to estimates of the Stern Review on the Economics of Climate Change, 4.9 pence and 31.6 pence of costs to society could be saved per car kilometre for petrol engines and diesel engines, respectively, removed in urban agglomerations (far lower values in rural areas).

### **Figure 7: Bicycle lanes at intersections (photos)**

*Sources: Lautenschlage & Kopp, City of Salzburg*

Beyond environmental benefits, cycling has strong impacts on both health and traffic congestion. According to Stear Davis Gleave (2008), :

- “Physical activity reduces the risk of developing major chronic diseases (e.g. coronary heart disease, stroke and type 2 diabetes) by up to 50%, and the risk of premature death by about 20–30%;
- Based on the risk factors for chronic diseases and levels of inactivity, it is estimated that the value of reducing these risk factors is £11.16 a year for those under 45 and £99.53 a year for those between 45 and

64. Other similar models have used values of £123 a year (Sustrans and DfT model).

While there are studies that estimate even greater benefits for cycling (or disadvantages for not doing so), it is obvious that integrating cycling and walking (instead of driving) in day-to-day activities can make a huge difference for each individual and for society as a whole.

As to traffic congestion, Stear Davies Gleave (2008) estimates that if a cyclist makes 160 trips a year of 3.9km, rather than by car, this would equate to savings for other road users of £137.28 a year as a result of reduced congestion in urban areas” (£68.64 in rural environments).

### 2.1.9.2 Assessment

Cycling is strongly dependent on economic and cultural factors. In many East Asian cities, cycling used to be a central pillar of urban mobility as long as motorbikes and cars were relatively expensive. This modal shift has changed significantly over the last few decades.

Over the same period cycling has maintained—or even increased—its share of overall trips in a few cities in Western Europe, while it has decreased in most others. This indicates that income and bicycle use are not necessarily negatively correlated, but that environmental, traffic congestion and health factors are all involved. Bicycles are also fashionable among some groups of society.

The development of cycling networks has a number of benefits primarily related to increased health, road safety, road congestion and emission neutrality. On the other hand, sufficient road space and protection of cyclists’ interests is required, and cycling is not necessarily viable in all weather and terrains. While separate lanes with high-quality pavement are the preferred choice, considerable costs in terms of construction and maintenance may be incurred (even though these could be lower than the cost of providing alternative road space for cars).

Pros	Cons
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- Relatively low investment (depending on actual design).
- Contribution to road safety.
- Improves traffic flow for both motorised and non-motorised vehicles.
- Can increase users' fitness
- CO<sub>2</sub>-neutral mobility

- Requires sufficient road space.
- Appropriate enforcement of cyclist rights necessary (unless effective physical separation).
- Cycling not an option for all terrain and weather types.

Bicycle parking spaces (closed or open) can improve public acceptance of cycling as a means of non-motorised transport and reduce the problems users face. Also, spaces for bicycles on public transport vehicles facilitate inter-modality. Bicycle route maps further aid users, by allowing them to find the most convenient ways to their destination.

## 2.1.10 Fuel efficiency standards

Governments can set targets or limits for conventional motor vehicle fuel efficiency, thus incentivising or obligating manufactures to improve the per km emissions of their vehicles. This approach has been adopted by the European Union and its member states as well as by other countries.

### 2.1.10.1 Concept

Like other technical standards, air emission standards for motorised vehicles are set to achieve common thresholds—in this case, for GHG and PM thresholds to measure vehicles' pollution potential. In practice, these thresholds are applied to types of vehicles before their central licensing; i.e. they are not applied to every single vehicle, but for whole vehicle production types. Emission potential is assessed and classified according to defined testing procedures.

The Euro norms are among the most widely used on a global basis. Since 1992, the European Commission has introduced norms consisting of a series of staged reductions in key air emissions such as CO<sub>2</sub>, NO<sub>x</sub>, hydrocarbons and PM. The norms are designated Euro 1–6 for light

vehicles (differentiating between petrol- and diesel-fuelled) and Euro I–VI for heavy vehicles above 3.5 tons. The most recent and restrictive norms have the highest number.

The norms have been adopted in a number of countries outside Europe, including India and China, and often serve as a basis for technical specifications for public transport vehicles. They are an essential element in implementing emission-related taxes, environmental zones restricting access by high-polluting vehicles, and other emission-related restrictions and incentives.

### 2.1.10.2 Assessment

Fuel efficiency standards are globally widespread. They increase awareness of emissions on the part of vehicle purchasers, and are combined with economic incentives aimed at reducing congestion—e.g. lower licensing fees and taxes for low-emission vehicles. They have a broad effect on all users and can be tested and controlled in a centralised manner, which makes their implementation relatively inexpensive. However, there is no correlation between efficiency standards and vehicle usage. Moreover, the test procedures used to establish a vehicle’s fuel efficiency (in grams of CO<sub>2</sub> equivalent per km) do not match up with real-world results. Also, a vehicle’s per km emission levels vary over its lifetime, increasing with the vehicle’s age.

Pros	Cons
<ul style="list-style-type: none"> <li>➤ Broad effect on all consumers.</li> <li>➤ No need for behavioural change of users.</li> <li>➤ Easily controllable.</li> </ul>	<ul style="list-style-type: none"> <li>➤ No relation to actual vehicle use.</li> <li>➤ Often unrealistic testing procedures.</li> <li>➤ No account of long-term emissions of vehicles.</li> </ul>

The effect of fuel efficiency standards can be improved through awareness-raising initiatives and tax incentives.

## 2.1.11 Driver training

The way drivers use their vehicles has a significant impact on fuel consumption and vehicle emissions. Awareness of environmental concerns and defensive driving are key in this context.

### 2.1.11.1 Concept

In many countries, economically and ecologically sound driving are taught in driving schools prior to driver tests, and environmental aspects are covered in driver testing. By embedding these issues in basic driver education and licensing, all newly trained drivers are—to a certain degree—aware of the harm motorised vehicles can do to the environment.

However, this awareness and knowledge usually fades over time, and drivers need to be re-trained. Ordinary drivers rarely seek out such re-training—unless they are particularly environmentally conscious or wish to economise on vehicle O&M costs—but many commercial or public sector drivers are trained in this way. DP DHL, the world’s largest courier service, for example, has a huge training programme for its drivers, who operate more than 120,000 vehicles—the size of this fleet necessitates and enables economies of scale. Experience shows that re-training must be done every three to six months to maintain ecologic/economic driving behaviour.

As used here, ecologic driving encompasses:

- Controlling speed according to circumstance and remaining proactive
- Using the brakes as little as possible
- Upshifting gears early in order to maintain engine rotation at a low level
- Using appropriate tires, tire pressure, and low-resistance oils and lubricants
- Avoiding luggage racks or any unnecessary loads, etc.

### 2.1.11.2 Assessment

This mechanism is relatively easy to implement by introducing appropriate requirements and training materials in basic driver education and licensing. For organisations that rely on drivers to fulfil their business aims, the benefits are evident; but awareness of the win-win potential of economic/ecologic driving should not be assumed. Consequently, initiatives by public authorities may be needed. Note too that the need for regular re-training may be an obstacle to acceptance of this mechanism, since it requires long-term dedication and a strategy for implementation.

Pros	Cons
<ul style="list-style-type: none"><li>➤ Positive side effects on fuel and O&amp;M expenditure.</li><li>➤ Easily applicable.</li><li>➤ Little investment required.</li></ul>	<ul style="list-style-type: none"><li>➤ Usually only short-term effect (need to re-train regularly).</li><li>➤ General awareness of participants necessary.</li></ul>

The effect of driver training can be improved through awareness-raising initiatives and tax incentives.

### 2.1.12 Vehicle licensing

By differentiating vehicle license fees according to technical and emission standards, an incentive for less-polluting vehicles can be created.

#### 2.1.12.1 Concept

When procuring a vehicle, owners usually have to register it and pay a license fee to operate it. This can be a one-off or repeated fee payable every year, at inspection intervals or some other frequency. Generally, licensing and its related fees are linked to engine and vehicle dimensions and attributes (e.g. number of axles) or type of use. To better take environmental considerations into account, the type of fuel and emission

quantities and qualities can be factored in in setting the license fee: the higher the emissions, the higher the fee.

In the European Union, data on CO<sub>2</sub> emissions has to be provided by manufacturers for each vehicle type in accordance with specified testing procedures . Manufacturers frequently use this information to attract environmentally conscious consumers. Public authorities should decide on and publish a classification of emission quantities and relevant fees.

### 2.1.12.2 Assessment

Where a functioning licensing system exists, this mechanism is—aside from political resistance—relatively easily to implement at an administrative level. However, it is a relatively poor tool since it does not reflect actual vehicle usage. This means that a high-polluting SUV (sport utility vehicle) which is driven only 5,000 km per year actually contributes less pollution than a technically more fuel-efficient car that is driven 40,000 km per year.

Pros	Cons
<ul style="list-style-type: none"><li>➤ Relatively easily applicable.</li><li>➤ Usually no investment necessary.</li><li>➤ Applicable in a centralised manner.</li></ul>	<ul style="list-style-type: none"><li>➤ No relation to actual vehicle usage.</li></ul>

In general, higher license fees will not likely discourage a large number of buyers from choosing a high-emission vehicle. But the fee may contribute to raising public awareness, and the additional fees collected can be used to fund other emission-reduction mechanisms.

This mechanism benefits from public awareness activities, driver training, and effective enforcement of vehicle and traffic regulations by police.

### 2.1.13 Vehicle inspection and maintenance

Regular inspection and maintenance in accordance with established technical standards is an essential approach to economically and ecologically sound vehicle usage.

#### 2.1.13.1 Concept

This mechanism addresses the most basic aspects of economically and ecologically sound vehicle operation. Inspection should be done according to established—ideally, internationally accepted—technical standards and procedures by independent service providers under state control. To incentivise appropriate O&M, vehicle licensing and fees should be linked to satisfactory inspection results.

Vehicle inspection and maintenance helps improve air quality by identifying high-emitting vehicles in need of repair—through visual inspection, emissions testing and/or the downloading of fault codes from a vehicle’s on-board computer—and requiring vehicle owners to fix the identified problems as a prerequisite to vehicle licensing or license renewal.

#### 2.1.13.2 Assessment

Inspection and maintenance are—aside from environmental considerations—an important means of controlling the condition of a vehicle fleet and setting incentives for its maintenance; safety is a primary concern here. In addition, checking vehicles for the fitness of their engines and overall road-worthiness generally improves their environmental performance. The considerable cost of this mechanism ought to be at least partly borne by users.

Pros	Cons
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- |  |   |
|--|---|
| <ul style="list-style-type: none"><li>➤ Obligates all vehicle owners to maintain road-worthiness.</li><li>➤ Systematic and regular approach.</li></ul> | <ul style="list-style-type: none"><li>➤ Dedicated testing sites and enforcement mechanisms required.</li><li>➤ Qualified and neutral workforce necessary.</li><li>➤ High cost of inspection system.</li></ul> |
|--|---|

This mechanism benefits from driver training and should be directly linked to vehicle licensing. It benefits from effective enforcement of vehicle and traffic regulations by police.

## CONCLUSION

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The choice of mechanisms aimed at reducing GHG emissions from urban transport should always be determined in line with overall urban transport policy targets, and must take into consideration current and planned/expected future infrastructure and service needs and availability. Choosing a good mechanism in the wrong circumstances is a bad choice.

The policy on emissions reduction will have to be set within the context of competing targets such as availability of technologies, costs, societal acceptance, benefits/effectiveness of mechanisms under given conditions, interrelationships between mechanism bundles, etc.

When reducing emissions in the context of urban passenger traffic, the underlying objective should always be to get individual motorised (fossil fuel) traffic off the road—where no alternative to motorised transportation exists—and to make use of economies of scale by introducing larger transportation units under acceptable load factor conditions. Doing so will normally result in a win-win situation, with reduced overall cost of service provision, reduced cost to other traffic participants due to less pollution and congestion, and reduced infrastructure capacity needs compared to motorised individual transport in conventional cars.

Reducing emissions always has to do with behavioural changes. Consequently, strong political support and the development of clear strategies at the national or city level are key success factors. On the other hand, changes can be introduced at lower levels of organisation or at the individual level. Both spheres are important and have to be motivated or—as is the case with many behavioural changes—enforced.

Functional technical inspection and legal enforcement based on sound standards and a clear and stable legal framework support the implementation of emission reduction mechanisms. Additionally, much can be achieved through awareness raising, education, and training—especially since inspection and enforcement cannot completely control human behaviour.

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# **APPROACHES TO TRANSPORT EMISSION REDUCTION IN URBAN AREAS**

## **Handbook**

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