19 Multi Modal Transport in a Low Carbon Future

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Introduction

This essay investigates the role of an integrated multimodal transport system in a low carbon future. Drawing heavily on the case of Delhi, the chapter addresses the question: how far can multimodal transport help achieve a low carbon future while fostering economic progress and social equity? Two papers that have been reviewed here have both quantified carbon emissions reductions associated with a shift towards multimodal transportation. One of them refers specifically to the potential impact of a transformation in Delhi, while the other is a case of actual transformation from Bogotà, Columbia.

Despite the rhetoric, and the odd case of cities like Bogotà, the direction of travel in most cities of the world is towards a series of uncoordinated, ad-hoc interventions that help to facilitate transport disintegration, a move away from public transport, walking, cycling, and other non-motorized modes to greater dependency on private, motorized vehicles. The paper will seek to identify and establish the magnitude of these challenges and, drawing as far as possible on best-practice case studies, discuss possible ways to address them.

'Multimodal transportation' is a scientific term for something really quite simple; journeys that involve some kind of transfer from one type of travel or 'mode' to another. Even if one is travelling by car or motorcycle for example, a journey is likely to involve a short walk at the start and end points. However, trips by public transport, principally bus and Metro, typically involve a longer walk trip to access or egress them and here multimodality comes into its own. There may also be public transport journeys that involve a combination of more than two transit modes, a walk trip followed by a bus trip, then a Metro trip, and finally a cycle-rickshaw trip, for example.

To facilitate multimodality of the type needed to encourage public transit usage, a number of different kinds of integration are required:

- Integration with land-use planning
  - Building public transit links first and then developing high-density, mixed land-use around them thereby reducing the need to travel, especially by private vehicles
- Integration within and between different modes of transport
  - *Physical Integration*—facilitating direct, comfortable, convenient, and safe access to public transport (providing safe, direct road crossings, tree-shaded paths, refreshments, cycle and rickshaw parking, differently abled pavements and access points)
  - *Fare Integration*—Enabling the public transit user to pay ONCE for a journey involving different transport
  - *Route Integration*—Facilitating logical interchange points where passengers are able to transfer from one vehicle or mode to another conveniently and safely
  - *Information Integration*—Enabling a 'one-stop-shop' for public transit users, cyclists, and walkers to gain information on any journey they wish to conduct using these modes
  - *Institutional Integration*—Ensuring that different public transit providers see themselves as part of a network and provide links to other types of transit, walking, and cycling

Policy Integration with Environment, Health, Education, and Economy

Public transport starts with a disadvantage compared to the door-to-door flexibility of private transport. So there must be good reasons to set about creating a multimodal system. Climate change is conceivably one of those reasons. According to the UK's Chief Scientist, David King:

'*Climate change is the most severe threat the world is facing today, more serious even than the threat of terrorism*.'

The transport sector is responsible for approximately 25 per cent of total greenhouse gas emissions globally and is the fastest growing sector source worldwide. Between 2007 and 2030, global emissions from transport are expected to rise by 80 per cent. Three quarters of the contribution is expected to come from road transport (IPCC 2007).

Urban transport emissions are likely to be especially problematic in the Asian context due to growing city populations, rising incomes leading to higher demand for personal, motorized mobility, and the disproportionate climate change impact of short journeys due to inefficient engine use (Bannister 2008).

Compared to a 2.1 per cent increase per annum in greenhouse gas emissions from transport in the developed world, developing country emissions are expected to rise at a rate of 3.5 per cent a year to 2030 (IEA 2002). As India and China race to catch up with the 2.5 tonnes of carbon emitted per head in Europe or 5.5 tonnes per capita emitted in the US, the stabilization targets worldwide are 0.5 tonnes, similar to that of India now. The scale of the challenge looks insurmountable.

Transport and Climate Change in Delhi

The Development of Urban Form

With a population of 17 million, rising at a compound rate of 4 per cent a year, Delhi provides a very good vantage point from which to view the threat, not only because its transport system is not presently integrated but also because it is the capital city of a country that is home to more than one sixth of the world's citizens (*Economic Survey 2009–10*).

Since 70 per cent of the urban environment in Asian cities that will exist by 2050 has not yet been built, there are opportunities to develop sustainably and get ready for the transformation needed to cope with climate change challenges associated with rapid economic development (Penalosa 2008). Any successful attempt to create a multimodal transport system in India's capital city is likely to influence policy and practice in other parts of India with potentially enormous implications for developing a low carbon pathway in transport and the built environment.

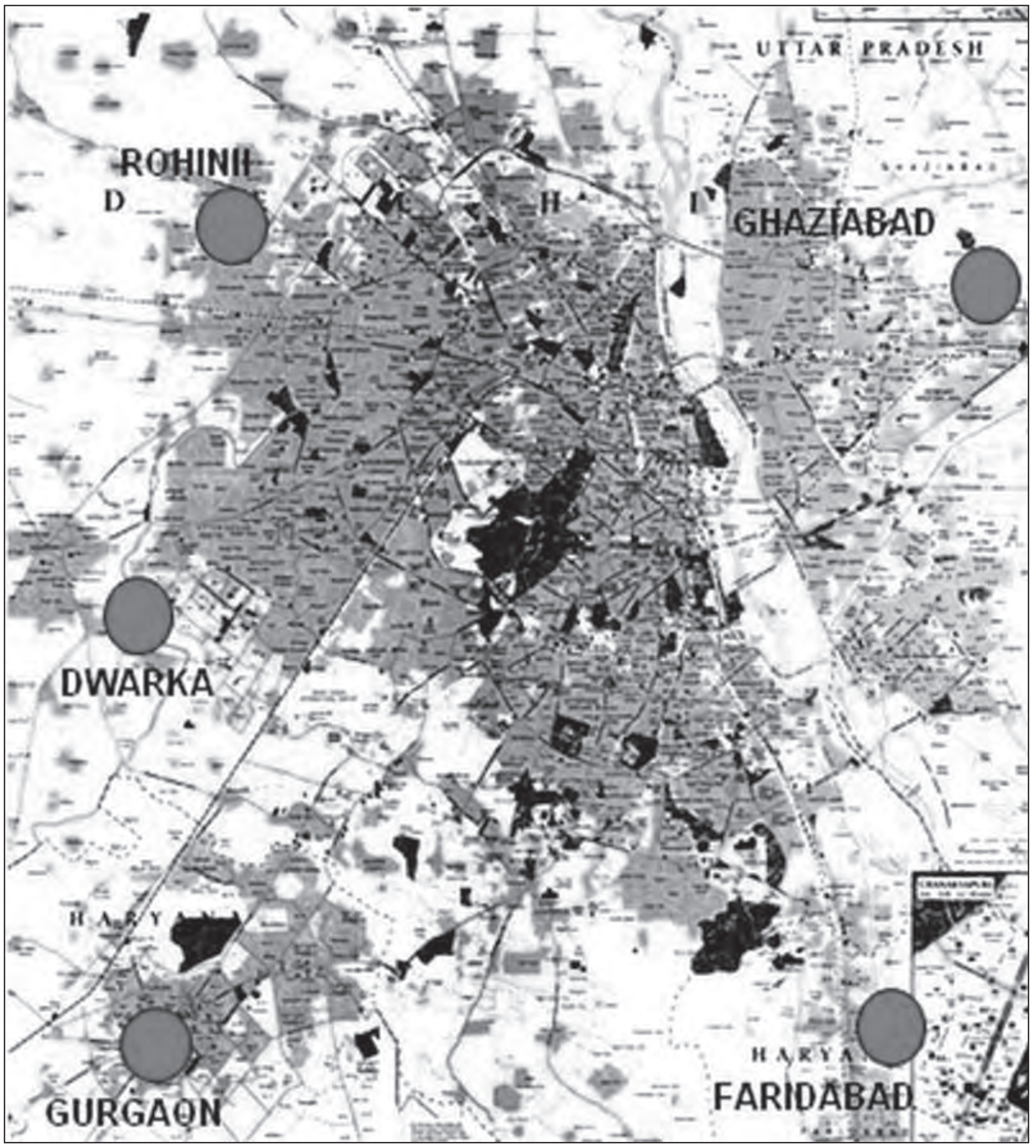
Delhi also typifies an urban structure being replicated in other Asian cities that have been booming economically for the past 20 years since economic liberalization. Unlike older cities in Europe and the US that built a central business district (CBD) in an age before mass motorization based around extensive rail networks, Delhi has no clearly identifiable CBD. As Map 19.1 shows, a number of subsidiary centres dot the landscape. These are sprawling outwards, characterized by mixed use, quite low population density and generate comparatively modest trip lengths, the majority being less than 10 km. In this context the city is becoming heavily reliant upon more flexible, low-cost transport, principally cars and motorcycles.

Road Infrastructure Development: Implications for Multimodality

As the city sprawls so does demand for mobility increase. Trip demand is expected to rise from approximately 20 million per day now to 29 million by 2021 (RITES 2005).

To cater to this demand, Delhi already owns a higher number of vehicles than the next three Indian metropolises combined—presently more than 6 million with approximately 1,100 more being added each day. In addition to the emerging urban layout described above (Map 19.1), part of the explanation rests upon GDP, rising on average between 10 and 12 per cent per year. Average incomes are now over $2,000 per annum, the level at which most countries start buying into greater personal mobility, motorcycles, and cars (Dargay and Gately 2007). Yet there remains significant room for market growth. According to the RITES study, approximately half of all Delhi households still do not own a car or motorcycle (*Economic Survey 2009–10*; RITES Ltd and TERI 2010).

Ironically, on the ground is little room to accommodate future growth. Delhi already has one of the most capacious road networks in the world with 21 per cent (28,000 km) of the city's total area under tarmac and little room for further expansion. In the 25 years from 1971–2 Delhi's road network grew 3.7 times while the number of vehicles grew by more than 25 times. Offering less than 6 km per 1,000 vehicles, the road network in Delhi is rapidly becoming inadequate to the task of catering for the expanding number of vehicles (*Economic Survey 2009–10*) (see Figure 19.1).



Map 19.1 Delhi's 5 Satellite Cities

Source: Delhi Integrated Multimodal Transit Systems (DIMTS).

The graph encapsulates the first major policy response to rising transport demand: 'keeping private motorized vehicles moving' through widening and flyover construction to reduce bottlenecks as and when they arise. The City Development Plan is investing more than half its transport budget into flyovers and road capacity enhancement schemes (Arora 2010).

Less Modal Choice Implies Higher Carbon Trips

A focus on road capacity enhancement contrasts significantly with two of the key objectives of the Ministry of Urban Development (2006), firstly, to establish an 'equitable allocation of road space' and secondly, to prioritize non-motorized and public transport. Harm is also caused to another key objective; to create a multimodal transport system. In Delhi, for instance, including public transport, more than three quarters of trips in the city involve a walk or cycle trip, as shown in Figure 19.2. Over 75 per cent of access and egress trips to Metro stations are 'non-motorized' (RITES Ltd and TERI 2010).

Preserving a high non-motorized share, especially for short distance trips of 5 km or less should be a priority in any low carbon transport strategy (55 per cent of trips in Delhi are less than 5 km). The table below, taken from the US Bureau of Energy Efficiency, compares energy consumption of different means of transport (see Table 19.1). Although there are caveats associated with comparing the energy consumption of different modes,

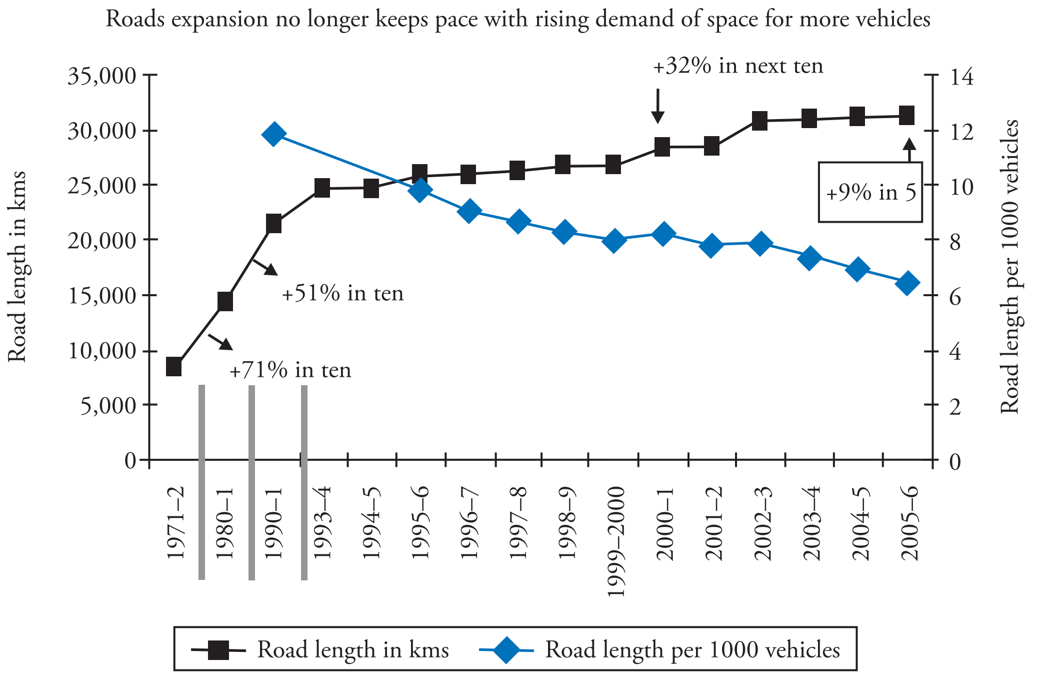


Figure 19.1 Expansion Struggling with Rising Space Demand

Source: Environment Pollution (Control and Prevention) Authority (2009).

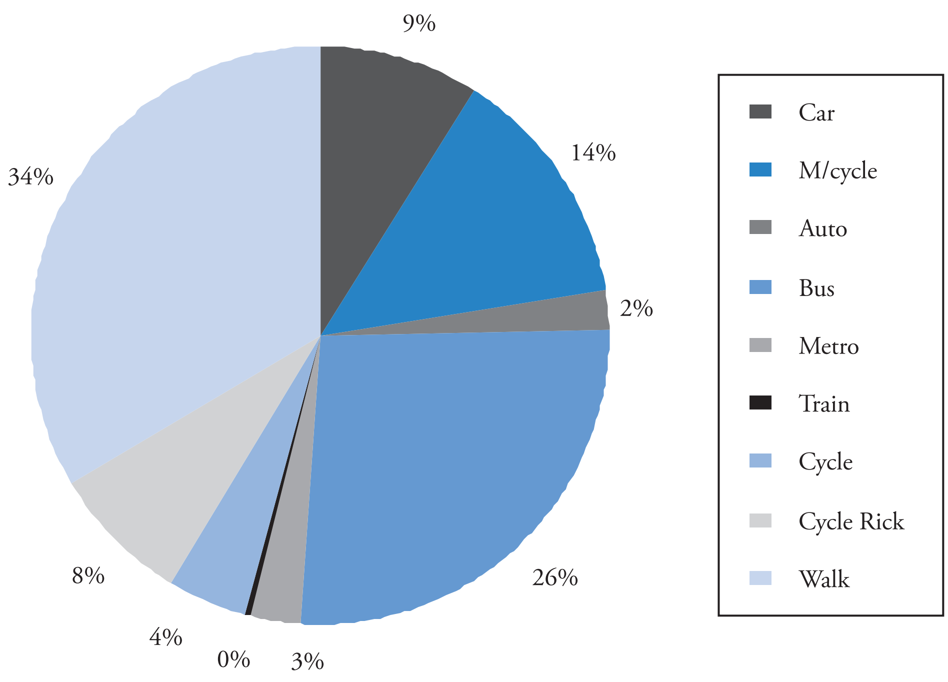


Figure 19.2 Low Carbon Transport Journeys in Delhi, 2008

Source: RITES Ltd and TERI 2010.

not least in a different country, what is interesting to note is that ridership of a bus needs to be at least 10 passengers in order to consume the energy at a rate equivalent to an average car.

In Indian cities like Delhi the picture is more favourable to lower carbon bus use, with an average of 50 passengers using one at any given time, combined with the fact that all buses in Delhi run on CNG. However, carbon dioxide

Table 19.1 Comparative Fuel Efficiency of Different Transport Modes

Transport mode	*Average passengers per vehicle*	*BTU per passenger-mile*	*MJ per passenger-kilometre*
Vanpool	6.1	1,322	0.867
Efficient Hybrid	1.57	1,659	1.088
Motorcycles	1.2	1,855	1.216
Rail (Commuter)	31.3	2,996	1.964
Rail (Transit Light and Heavy)	22.5	2,784	1.825
Rail (Intercity Amtrak)	20.5	2,650	1.737
Cars	1.57	3,512	2.302
Air	96.2	3,261	2.138
Buses (Transit)	8.8	4,235	2.776
Personal Trucks	1.72	3,944	2.586
Cycle	1	183	0.12

Source: US Department of Energy (2006).

emissions per passenger kilometre are still likely to be at least one fifth that of an equivalent averagely occupied car given the fact that average vehicle weight in Delhi is less than the US average.

Walking a kilometre, on the other hand, consumes only 0.330 MJ of food energy. Cycling uses even less energy, 0.12 MJ per km (183 BTU/mi), less than a quarter of the energy needed to carry a passenger one kilometre by bus in Delhi.

Walking (or cycling) to Public Transport is Unsafe, Consumes Unnecessary Time and Effort

Presently 40 per cent of roads in the city do not have a pavement refuge and those that do exist are often unusable, especially by the mobility impaired due to extremely high kerb heights, encroachments, and obstructions (RITES Ltd and TERI 2010). Reported road deaths are another deterrent, topping 2000 a year, with the majority of victims being pedestrians (55 per cent). Road planning is undertaken by citywide agencies and the needs of local, as opposed to regional, road planning requirements are weakly addressed.

Road crossing facilities are ripe for an upgrade; as is the need for behavioural change in drivers. Zebra crossings are routinely ignored and light controlled crossings that do secure adherence are few and far between; a penchant exists instead for hurdles to the mobility impaired like foot overbridges and subways that are now being removed in developed cities of the world in favour of accessible, street level crossings (see Figures 19.3(a) and 19.3(b)).

Figure 19.3(a) A Family Trying to Cross a Road to Change Bus

Figure 19.3(b) Buses Don't Stop at the Stop

Source: Centre for Science and Environment Photo Library, 2009.

Though similar in geographical size to London, Delhi possesses approximately 750 pedestrian light controlled crossings compared to 6,500 in London. Vehicle movement is prioritized over public transport users by allowing 'free left turns' at most junctions. In this scenario, given a choice in travel mode, who is not likely to opt for a car or motorcycle?

Figure 19.4 showcases the effect of private vehicle-based development, showing the impact of installing an elevated road in Ashram Chowk on the Ring Road in Delhi. Designed to reduce congestion by allowing signal-free movement, the road elevation makes local journeys nearly impossible to conduct by non-motorized means. Everyone is forced into a motorized vehicle even for short journeys and bus stops are difficult to reach too.

Buses are an Option of Last Resort

With worsening travel conditions for pedestrians, as also most other public transport users, the use of the bus is taking a nosedive. In the last eight years the number of person trips in Delhi has increased by 22 per cent. While the city has seen a marginal shift in person trips to the new Metro service, this has been more than cancelled out by a fall in the order of 17 per cent in the total number of trips in the capital that are taken by bus. In 2008, 46 per cent of trips were taken on public transport compared to 60 per cent in 2001.

Such trends are resulting in an increasingly poor level of service for motor vehicles too. The level of service for public and privately owned motorized vehicles is falling in Delhi, which a few salient statistics clearly show. According to a recent RITES Study (RITES Ltd and TERI 2010):

- Traffic speeds are now less than 30 kmh on 70 per cent of the road network,
- Traffic capacity is exceeded on 44 per cent of network
- On another 19 per cent of network 'nearly' exceeds capacity

A Losing Battle against Climate Change

In a study of 87 cities in India, which included analysis of cities of over 5 million population as a special category (Delhi, Bangalore, Kolkata, and Mumbai), Wilbur Smith Associates used a calibrated urban transport model to establish the possible implications. The study concluded that failure to make any improvement to the existing situation in these cities will lead to a continued decline in bus patronage, falling as low as 25 per cent of modal share by 2030 (Wilbur Smith Associates 2009).

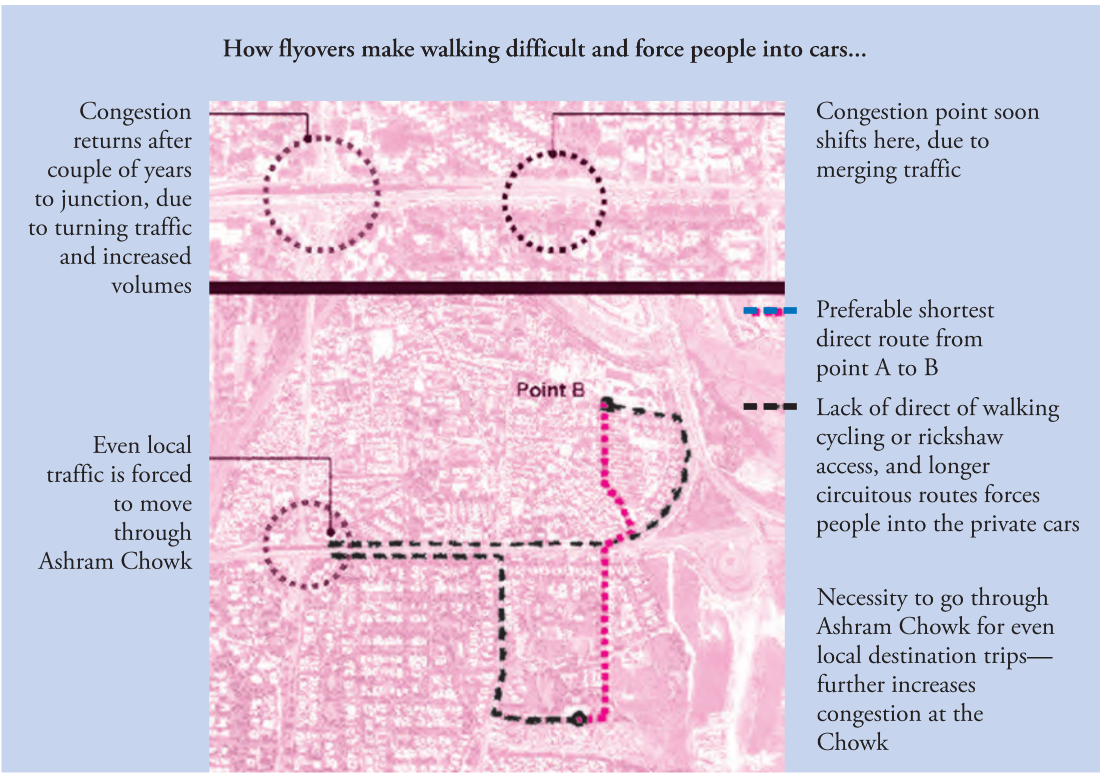


Figure 19.4 How People are Forced to Use Motorized Vehicles for Short-distance Trips—Ashram Chowk Flyover, New Delhi

Source: Solving Congestion through Transit Oriented Development, Romi Roy 2009.

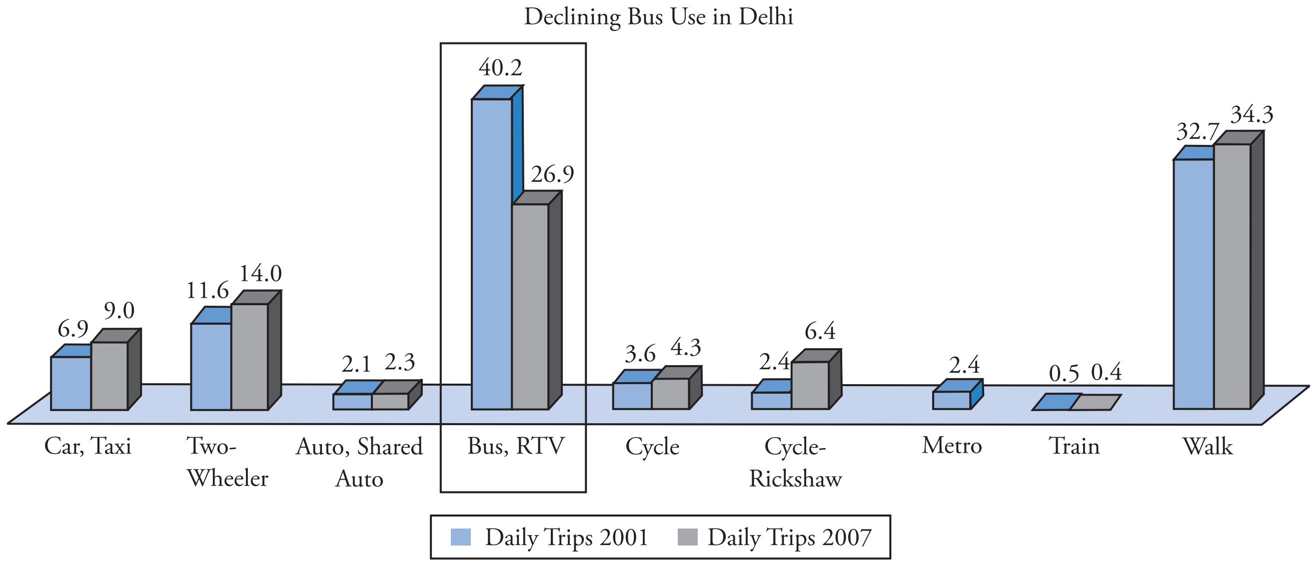


Figure 19.5 Declining Bus Use in Delhi, 2001–8

Note: Modal Split—Per cent of Person Trips in Delhi* (Figures in per cent).
Source: RITES Ltd and TERI (2010).

At the same time average trip lengths will rise from around 10 km now to 15 km by 2030. This, combined with increasing number of trips per capita, implies that:

- The total number of kilometres travelled in these four megacities will treble over the next 20 years from over 2.5 billion kilometres per day to 7.6 billion kilometres.
- Road volume to capacity ratios will increase from 1.21 to 2.9, increasing incidences of gridlock to a severely strained network.
- An extra 1,231 kilolitres of fuel will be consumed each day leading to a 65 per cent increase in emissions compared to a scenario that envisages 'an adequate public transport system' in the city.[1]

Vision 2021—Delhi Government's Multimodal Transport Strategy

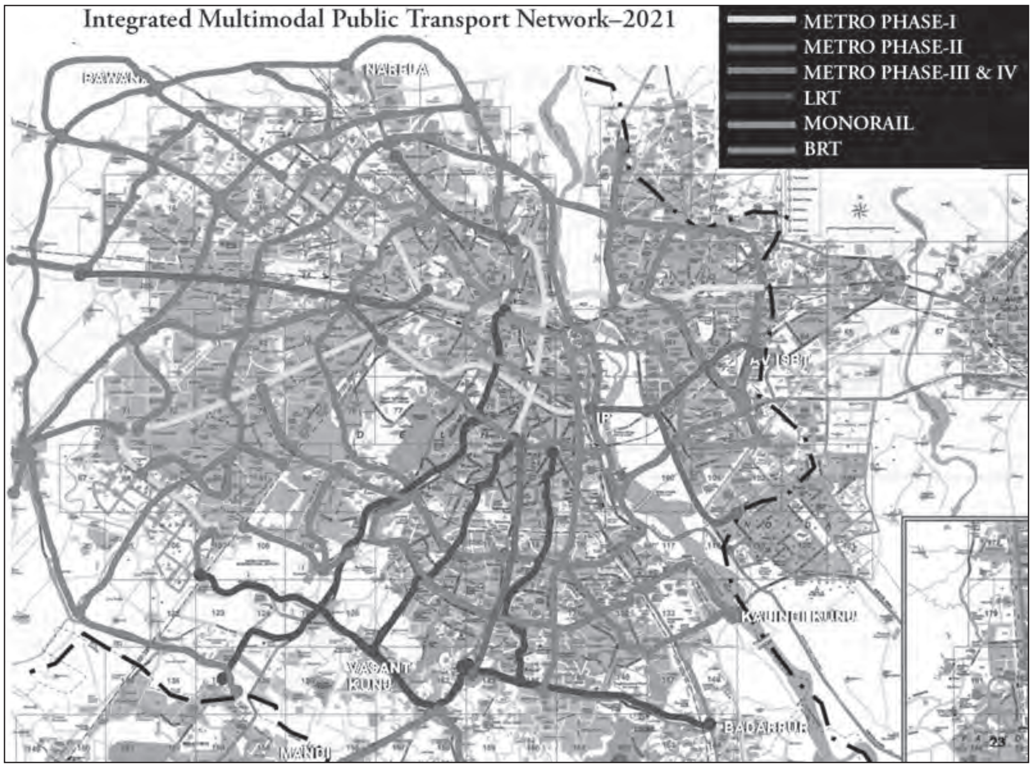
So how can a multimodal transport system help to reverse this trend, improve transport efficiency, and reduce carbon emissions in the sector? The Delhi government has developed an integrated multimodal strategy to increase the modal share of public transport to 80 per cent by 2021 translating into another 10 million journeys (RITES 2005). Known as Vision 2021, the lynchpin of the approach is to develop a citywide Metro service rivalling that of London in size, buttressed by a series of bus priority corridors covering nearly 300 km, Light Rail Transit, and Monorail (see Map 19.2). Since feasibility studies have emerged with very high unit costs for Light Rail and Monorail these are not covered in this paper.

Metro Focus

So far Metro development has had significant media support and public acceptance and has proceeded closely in line with its implementation schedule. Designed for corridors where passenger demand is typically expected to be higher than 25,000 passengers per hour, Phases I and II are nearly complete, covering 192 km of the 413 km envisaged by 2021.

The metro is expected to cater for two million trips a day by 2010, a little less than 10 per cent of the total daily trip demand recorded in the city. In effect 75 per cent of Metro users are believed to be car or motorcycle owners, the overall number of journeys catered for by Metro in the city therefore remains modest. It is not a 'silver bullet' to solve Delhi's increasing transport woes, but given its high capacity (carrying up to 25,000 passengers per hour in each route direction), eventual geographical scope, and unrivalled reliability, it can provide competitive journey times for longer distance journeys greater than 10 km (RITES 2005).

[1] Adequate public transport includes: bus modernization and augmentation including terminals and bays, improved interchange facilities, junction improvements, on-street parking management, safe crossing facilities, and cycle tracks.



Map 19.2 Vision 2021 Public Transport Network

Source: RITES (2005).

The Limits of Metro in a Multimodal Low Carbon Transport City

Yet an analysis of Metro networks in worldwide cities shows that the Metro faces considerable hurdles to ramping up its patronage to levels reaching 20 per cent of modal split. In Delhi actual Metro patronage is consistently less than figures predicated by advocates making a case for investment in this transport mode. With Phase II of the Delhi Metro nearly complete (126 km by June 2010 out of 189 km by September 2010), ridership hours around 5 per cent of all trips in the city (1.1 million), less than the number taken by cycle rickshaw. This compares with a 1995 prediction for over 3 million trips to be undertaken by the Metro on Phase I (65 km) by 2005 alone (Comptroller and Auditor General, India, 2010). The Metro is highly capital-intensive, costing INR 187 billion in the first two phases alone (DMRC 2008). Each passenger trip is subsidized to over Rs 100 (Mohan 2008). Nearly three quarters of the city's public transport budget for the City Development Plan currently finds its home in Metro expenditure but these loans are granted on the condition that ridership will eventually be high enough to pay them back. In this respect the Metro charges a rate of nearly Rs 3 per kilometre (Arora 2010). The Metro must compete with the door-to-door convenience and marginal cost of using a bus and a motorcycle which are Rs 1.25 and Rs 1 per kilometre respectively.

Climate also plays a role in limiting Metro catchments; 48 per cent of Delhi residents are beyond the 500 metre catchment area considered desirable to encourage use of public transport. Like many other cities in South Asia, for seven months of the year the soaring temperatures in Delhi are punishing. Evidence from temperate, western countries shows that people are unwilling to walk more than five minutes to a public transit stop, a factor which is increased for the Metro due to the extended time and effort in using steps and escalators to access and egress from the train. In a city like Delhi the 'willingness to walk' to public transit is, if anything likely to be much less and compounded by safety and access concerns highlighted earlier.

Car parks can be provided for vehicles, but these can only ever cater for a small number of the required number of metro passengers (2,000 or so long-stay commuter cars compares unfavourably with an *hourly* Metro capacity of 25,000 trips). Personal vehicle access to Metro stations is also likely to generate localized congestion, increase the overall carbon emissions for each journey, and can only serve one half of the access or egress trip. Only 3 per cent of trips to Metro stations are currently by car, a figure that is not likely to change significantly in the near future.

Bus Travel in a Low Carbon Transport City

Whilst the Metro can offer time savings on longer distance trips where access and egress times form a smaller portion of the overall trip duration, the 'workhorse public transit system' in Delhi needs to be low cost to cater for a large cohort on low incomes (Delhi's average per capita income is still less than $6 a day), highly flexible with stops and stations close to people's homes and workplaces, and able to cater for multiple origins and destinations with shorter trips. Traditionally, buses have been able to deliver these needs much better than fixed rail heavy transit systems.

Such a conclusion echoes a study of different cities in Latin America showing that Metro systems alone are not a sufficient means of effecting a modal shift. Despite having one of the largest networks in the world, the Mexico Metro caters for merely 14 per cent of journeys in the city. London, with a Metro network the size of Delhi's after completion handles an even lower proportion of trips. Extensive use of more flexible public and para transit options including buses, combined with land-use planning measures to create an environment-friendly network for pedestrians and cyclists would appear to be more essential components to reduce car use and carbon emissions from transport (Mohan 2008; BRT Planning Guide 2008) (see Figure 19.6).

Demand Management and Bus Prioritization

Investing in a Metro network alone brings with it no particular requirement to increase the efficiency of the road network, to cater for more trip demand using less space and energy. In the absence of any multimodal strategy to manage demand for private vehicles and to prioritize public transport, walking, and cycling, Metro facilities open up more space for private vehicles, making cars and motorcycles more convenient to use. Studies for the Asian Development Bank provide an indication of the scale of possible carbon dioxide savings from a bus-based strategy in India, Bangladesh and Sri Lanka (ADB 2006):

- Bangalore: An increase in bus share from 62 per cent to 80 per cent saves equal to 21 per cent of the fuel consumed in the base case. This leads to 23 per cent reduction in total vehicles and frees up road space equivalent to taking nearly 418,210 cars off roads. Carbon dioxide emissions can drop by 13 per cent. Particulate matter (PM) can drop by 29 per cent and nitrous oxides (NOx) by 6 per cent.
- Dhaka: An increase in bus share from 24 per cent to 60 per cent saves fuel equal to 15 per cent of the fuel consumed in the base case. This frees up road space equivalent to removing 78,718 cars from the roads. Carbon dioxide emissions drop by 9 per cent. PM can drop by 13 per cent and NOx less than 1 per cent.
- Colombo: An increase in bus share from 76 per cent to 80 per cent can save 104,720 tons of oil equivalent,

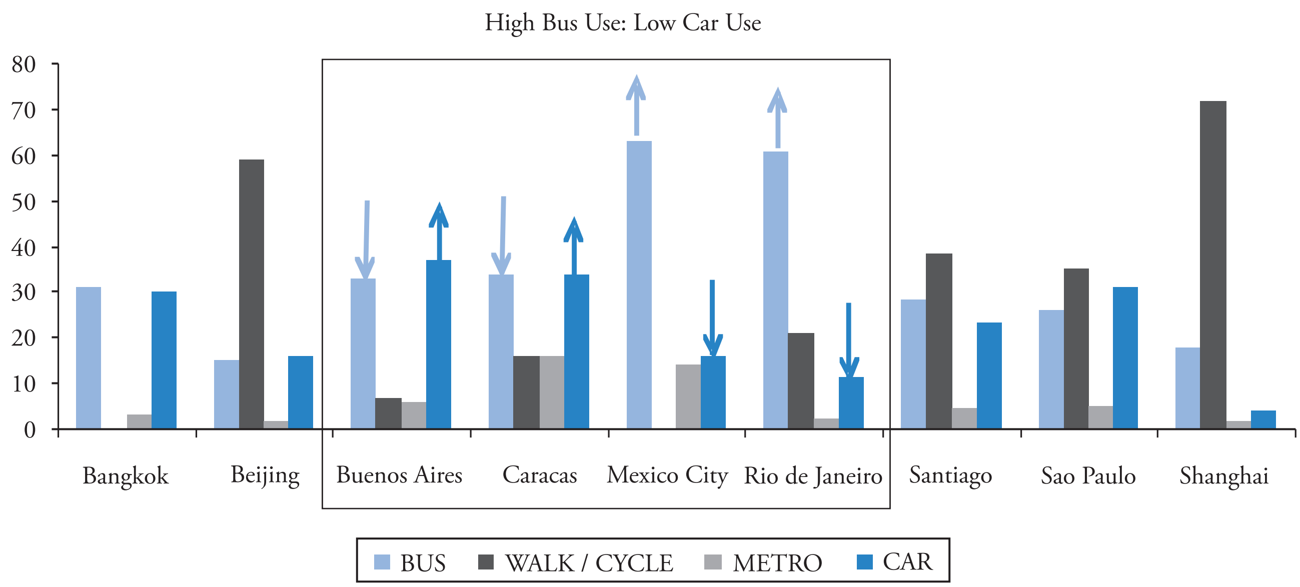


Figure 19.6 High Bus Use, Walking, and Cycling: Key Determinants of Reduced Congestion

Source: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and SUTP (2008).

or 3 per cent of the fuel consumed in the baseline case. This means a 5 per cent reduction in the total number of vehicles and frees up road space equivalent to removing 62,152 cars. (ADB 2006)

An Optimal Low Carbon Transport Strategy for Delhi

Using comparative risk assessment methodology researchers from Delhi and London carried out a study of five different greenhouse gas scenarios for a series of different transport investments in the two cities (The Lancet 2009). The study compared policy action to improve vehicle fuel efficiency combined with rail-based improvements to the same in enhancement of the bus network, restrictions on private vehicles, and higher standards of connectivity, safety, comfort, and access for pedestrians and cyclists.

The Delhi study used data from VIBAT and Wilbur Smith Associates to establish a baseline scenario of global emissions from the transport sector in 2004 (6.1 million tonnes carbon dioxide) and extrapolated this first to 2010 and then onwards to 2030 (Scenario 1) when the sector is expected to emit 19.6 million tonnes of carbon dioxide. This is a 526 per cent rise on 1990 carbon dioxide emissions levels in Delhi from the transport sector.

The baseline was then adapted to three different policy scenarios. Scenario 2 parallels the Delhi government's CNG initiative when all public transit vehicles were required to shift to liquid petroleum gas fuel in 2002 and subsequent requirements for vehicles to meet international EURO IV standards. The scenario assumes compliance with Euro VI standards by 2020 in line with all European countries. Efforts to up-scale the vehicle fleet are combined with significant investment to develop a citywide rail network like the Metro. The result for carbon dioxide emissions is a rise in the order of 447 per cent on 1990 levels, 73 per cent less than the baseline.

Scenario 3 of the Lancet study, meanwhile assumes a reversal in declining conditions for non-motorized transport (NMT) in Delhi, resulting in a marginal increase in walking trips and a doubling in the amount of cycle trips. Scenario 3 sees a halving in per capita carbon dioxide emissions in transport in Delhi compared to Scenario 2, achieved through restrictions on vehicle usage, ranging from road pricing and tolling to the application of tighter parking controls. Delhi is transformed from a city in which cycling and walking are a mode of necessity for those unable to afford a motor vehicle to a mode of choice. Bus trips increase marginally in Scenario 3, bucking the current downward trend. There is a significant increase in rail usage, paralleling again rising Metro patronage in Delhi. Scenario 3 sees a rise in carbon dioxide emissions in the order of 234 per cent on 1990 levels, a little more than half the amount secured through a vehicle technology and Metro focused approach.

Finally, Scenario 4 links measures implemented in Scenarios 2 and 3, seeing an increase in 199 per cent on 1990 levels of carbon dioxide emissions from the transport sector, something like a doubling on levels emitted in 2004. The results are shown in Table 19.2.

An important conclusion from the study is that *prioritization of walking and cycling and restricting vehicles through policy interventions like carbon rationing, road pricing, and traffic demand management, combined with improving conditions for those using public transport (Metro and bus), would reduce emissions more than twice as much as those from a strategy focused solely on vehicle efficiency improvements and Metro development.*

The strategy also achieves important co-benefits such as better health and improved quality of life. Health benefits include lower levels of chronic disease such as Type II diabetes and heart disease due to a combination of less airborne pollution and a fitter, more active, healthy

Table 19.2 Comparative Scenarios of Carbon Emission Mitigation Strategies in the Transport Sector, Delhi (2010–30)

	Aggregate Transport CO_2 Emissions	*Transport CO_2 Emissions Per Person (tCO_2/person)*	*CO_2 Emissions Increase on 1990 (%)*
2004 Delhi	6,146,651	0.4	97
2030 Scenario 1: BAU	19,550,693	0.8	526
2030 Scenario 2: Low Carbon Motor Vehicles (LCD)	17,069,668	0.7	447
2030 Scenario 3: Active Transport (AT)	10,458,736	0.4	235
2030 Scenario 4: Sustainable Transport (ST)*	9,327,207	0.4	199

Note: Delhi Population: 2004 = 14.8 million and 2030 = 26.0 million
* Sustainable Transport = LCD + AT
Source: Public Health Benefits & Strategies to Reduce Greenhouse Gas Emissions: Urban Land Transport (The Lancet 2009).

population. Decreasing road traffic also has a potential to reduce road accidents, although the study was not able to quantify this effect.

Bogotá, Columbia—Real-life Example of a Multimodal Transport System

It is also important to understand the costs and benefits of any strategy to mitigate carbon dioxide emissions. A study by Lloyd Wright and Lewis Fulton (Box 19.1), conducted in 2005 attempts to quantify these by drawing on empirical data from the transformation of public transport, walking and cycling facilities in Bogotá, Columbia enacted as part of 'Transmilenio' in 2000 (Wright and Fulton 2005). The authors set out to compare the costs and benefits of policies aimed at improving vehicle efficiency through fuel switching, on-board technology, lighter weight materials, and better maintenance with policies that target modal shifts secured through a multimodal transport network. Bus prioritization formed the lynchpin of the multimodal strategy supported by small, but influential investments in non-motorized transport.

Wright and Fulton started out by defining three different categories to isolate the relative impacts of fuel-based approaches and multimodal transport systems to carbon dioxide mitigation.

- The share of trips undertaken by each transport mode (car, motorcycle, bus, metro, cycle, walk, etc.) and the load factor or the number of passengers carried by a particular vehicle. Most of the subcomponents of this category have some influence on the modal choice of the consumer which is determined by considerations of convenience, safety, comfort, cost, and travel time.
- The distance travelled by each mode affected by network design and land-use planning applications.
- The application of technology to reduce emissions from improved engine design, better maintenance, vehicle weight, and driver behaviour.

As a preview to the study, the IEA (2002) found that an ordinary 120-seater diesel bus with a 50 per cent load factor carrying 8 per cent of its passengers who had switched from private vehicles could deliver reductions in carbon dioxides up to four times the emissions of a single bus. What was even more interesting was that the selection of bus engine technology had hardly any impact on the final outcome. It didn't matter if the bus was fitted with EURO I, II, or III technology, the savings in tailpipe emissions were completely overwhelmed by the effect of a modal shift.

Wright and Fulton also reviewed the impact of fuel switching policies and programmes of different governments to measure the costs and benefits of this approach to mitigate carbon dioxide emissions. The EU headed the list of big spenders on fuel switching research with an investment $3.7 billion on a 10-year programme. The expenditure on fuel switching vastly exceeded expenditure on targeting modal shifts despite a high degree of risk and uncertainty associated with investments in technology like fuel cell research.

The most tried and tested fuel switches, CNG, and hybrid fuel vehicles face problems as CNG is believed

Box 19.1
'Transmilenio'

A multimodal transport system

- Route integration is secured through a series of 'feeder routes' (309 km) linked to dedicated bus lanes (84 km).
- Physical integration with other modes has involved the construction of over 300 km of cycle routes complemented by improved pedestrian pathways and car-free pedestrian plazas linking to the BRT network directly, safely, and conveniently.
- Stations are built to minimize the distance travelled to change from a feeder to a mainline bus without needing to leave one interchange point.
- Land-use planning has been integrated requiring higher density, mixed land-use around bus stops and interchanges thereby facilitating more convenient travel by public transit.
- Demand management measures check the growth in private vehicle usage. Parking capacity has been reduced on streets served by the network and restrictions are placed on the number of cars entering the city by prohibiting vehicles with particular number plate combinations on alternate days.
- Fare integration is achieved through a system of common ticketing allowing those using feeder buses to travel on all buses without buying more permits to travel.
- Institutional reforms ensure that different public transit providers see themselves as part of a network and provide links to other types of transit, walking, and cycling.

Source: Wright and Fulton (2005).

to offer few discernible benefits in carbon dioxide reductions once methane leakages are considered. Hybrid vehicle technology has also under-performed in real life situations. Compared to manufacturers' claims of a 25 per cent baseline fuel reduction capability in Seattle, host to one of the largest hybrid diesel bus fleets in the world, actual emissions reductions were less than half those promised. Solely fuel-based approaches also ignore the additional social benefits of accident and congestion reductions.

Using data available from Transmilenio, Wright and Fulton built up a reference case based on a total of 10 million trips per day, less than half the number of a city like Delhi, but interestingly the number set to be switched to public transit by 2021. Each motorized trip was 10 km on average, if anything longer than the average trip distance in Delhi. Table 19.3 sets out the reference case, where, in comparison to Delhi, the majority of trips by bus are catered for by smaller minibuses but like Delhi are not segregated from ordinary traffic and constitute a similar modal share of the overall traffic mix.

No increase in the number of private vehicles was assumed over the 20-year period; this is clearly not realistic but it keeps the potential emissions reduction resulting from a mode switch more modest. The costs of mitigation were estimated to be $2.5 million for a km of BRT, $150,000 for a km of pedestrian improvements, and $100,000 for a km of cycle infrastructure. Low cost of infrastructure, means that Transmilenio operates without any subsidy, so none was included in the calculations.

Compared to the lowest cost fuel switching scenario in which $148 per tonne of carbon dioxide saved, the highest costs of a BRT mitigation package were less than $70 per tonne of carbon dioxide (see Table 19.4). With important lessons for Delhi, investment in cycle infrastructure alone to increase its mode share from 1 to 10 per cent of all trips, yielded carbon dioxide reductions at the lowest cost of $14 a tonne. In the case of targeted cycle track investment carbon dioxide savings from the baseline amounted to 4,160,400 tonnes alone.

Three times the amount of carbon dioxide a year was saved through the creation of a multimodal transport system grouping together walking and cycling with public transport. This is because the capture by one mode of a greater share of trips 'tends to suppress the other'. The lesson drawn is similar to that derived from the Lancet study. It is particularly important to include cycle and pedestrian improvements with bus network enhancements because a sole focus on buses will draw people from non-polluting transport onto buses, thereby reducing space for erstwhile motor vehicle users.

Reinforcing the earlier IEA study, Wright and Fulton found that very small reductions in car use in the order of one per cent could generate potentially large reductions in carbon dioxide in the order of one million tonnes over the 20-year period.

Delhi Bus Rapid Transit

As part of the Vision 2021 investment strategy, a total of six Bus Rapid Transit Corridors are slated for development in Delhi, each with the kinds of pedestrian and cycle facilities envisaged in the Wright and Fulton paper (see Map 19.3). These may help to transform the image of bus transport in the city by improving the speed, comfort, and status of this mode of transport. They may also herald something of a cycling renaissance and serve as a benchmark for future pedestrian facilities in the city, according to international experts.

Table 19.3 Transport Reference Case for Bogotá, 2001

Mode	*Mode Share (%)*	*Trips/Day (000s)*	*Passengers/ vehicle-km*	*Distance travelled/day (km 000s)*	*Fuel Consumption (litres/100 km)*	*CO_2 (kg)/ litre*	*CO_2/day (tonnes, 000s)*	*CO_2 over 20 years (tonnes, 000s)*
Automobile	20	2,000	0.15	13,333	10.8	2.42	1087.2	21,744
Motorcycle	4	400	0.105	3,809	2.2	2.42	63.2	1,266
Taxi	5	500	0.15	3,333	10.8	2.42	271.8	5,436
Minibus	50	5,000	1.3	3,846	30.3	2.87	1,043.5	20,870
BRT	0	0	5.2	0	64.1	2.87	0	0
Walking	20	2,000	1	150	0	0	0	0
Cycling	1	100	1	100	0	0	0	0
							2,465.8	49,315

Source: Wright and Fulton (2005).

Table 19.4 Carbon Mitigation Costs and Benefits of Different Transport Investment Strategies in Bogotá 2001–21

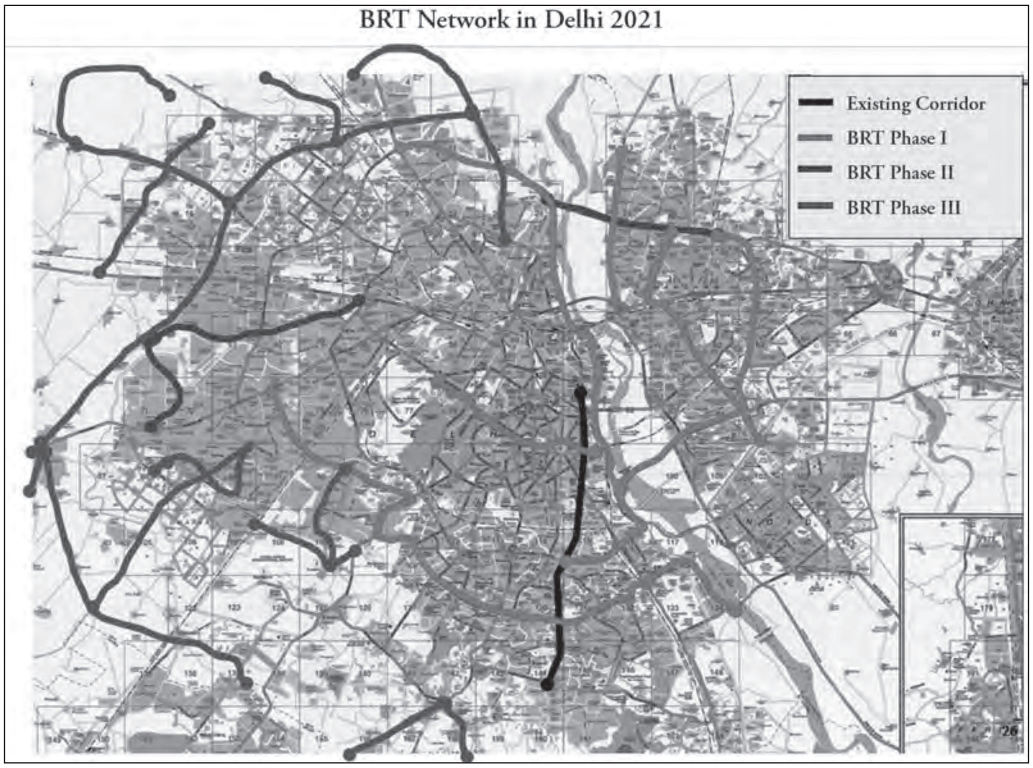
Scenario name (in per cent)	*Mode share (in per cent)*	*Carbon dioxide (CO_2) over 20 years (tonnes, 000s)*	*CO_2 reduced from the baseline (tonnes, 000s)*	*Cost of infrastructure (in US$)*	*Cost ($)/ tonne of CO_2*
BRT mode share increases from 0 to 5	Automobile 19 Motorcycle 4 Taxi 4 Minibus 48 BRT 5 Walking 19 Cycle 1	47,409.7	1,905.5	$125 million (50 km of BRT at 2.5 million/km)	66
BRT mode share increases from 0 to 10	Automobile 18 Motorcycle 4 Taxi 3 Minibus 45 BRT 10 Walking 25 Cycle 1	45,086.8	4,228.5	$250 million (100 km of BRT at 2.5 million/km)	59
Walking mode share increases from 20 to 25	Automobile 19 Motorcycle 4 Taxi 4 Minibus 48 BRT 0 Walking 25 Cycle 1				
Bicycle mode share increases from 1 to 5	Automobile 19 Motorcycle 4 Taxi 5 Minibus 48 BRT 0 Walking 18 Cycle 10	45,145.9	4,160.4	$60 million (500 km of cycleways at 100,000/km, plus $10 million promotional campaign)	14
Package: BRT, pedestrian upgrades, cycleways	Automobile 15 Motorcycle 3 Taxi 3 Minibus 34 BRT 10 Walking 25 Cycle 10	36,917.5	12,397.8	$370 million (BRT $250 million; footpaths $60 million; cycleways $60 million)	30

Source: Wright and Fulton (2005).

The Experience of Delhi's Pilot BRT Corridor—Ambedkar Nagar to Delhi Gate

One BRT is already in existence, a 14.5 km corridor running in South Delhi from Ambedkar Nagar to Delhi Gate, although only 5.8 km is currently operational. In contrast to the Metro, the Delhi BRT has been mired in controversy since it started in April 2008 despite witnessing an increase in bus patronage in the order of 10 per cent, bucking the citywide trend and a reduction in bus user travel time in the order of 33 per cent (Hidalgo and Pai 2009). In line with the Wright and Fulton study findings, another important benefit of the first corridor is the rising number of cyclists using its fully segregated lane. The number of cyclists using it has increased from 1,200 per hour to 2,800 during peak periods.

BRT, despite the controversies that surround it, remains a potentially cost-effective means of transport investment. Its true benefits will only begin to be realized once it becomes part of a more capacious public transport network. In comparison to the Metro, the total cost of



Map 19.3 Plan for Bus Rapid Transit in Delhi to 2021

Source: RITES (2005).

corridor construction was $48 million, an average of $3.3 million per kilometre. The Delhi Metro ranged from $25 million to $60 million per kilometre. Although the Delhi Metro has the capacity to cater for 25,000 passengers per hour during the peak period, the Delhi BRT already carries up to 12,000 passengers per hour at less than one tenth the capital cost. A fully fledged BRT akin to that operational in Bogotá could see this figure rise to 40,000 passengers per hour.

Challenges to Establishing a BRT Network

Issues associated with public acceptance and cultural change (the requirement that motorized vehicles stop at mid-blocks as well as at junctions to allow bus passengers to access the stops) set significant challenges to the ultimate success of BRT in Delhi from the outset.

Journey times for car users have increased by 14 per cent since the corridor began (EMBARQ 2009). In purely textbook terms the first corridor might have fitted the bill for conversion to BRT; a large number of buses, cycles, pedestrians, and a high number of personal vehicles that were ripe for segregation. Politically, however, the corridor was challenging.

Much of BRT's promised success rested on people being willing to switch to public transport to reduce dwell times in the mixed traffic lanes. That might have been possible if the whole network was able to capitalize on such an expectation. Despite the recent introduction of a new fleet of low-floor vehicles, outside the single BRT corridor buses remain stuck in traffic, unreliable, overcrowded and, overall a poor competitor to private vehicles that face subsidized parking costs and lower taxes than buses (see Corporatization of Private Stage Carriages in Delhi section below) (Narain 2009). Neither are there deterrent policy measures against using a car or motorcycle apart from congestion, something which experts acknowledge has a greater impact in effecting modal shift than supply side improvements alone (Dasgupta et al. 1994).

The government appears to remain a long way from asking the public to leave their vehicles at home and switch to the bus. Only 0.2 per cent of the City Development Plan is spent on raising public awareness on transport (Arora 2010).

A decision to now shift the second part of the BRT corridor for the final 7 km stretch from central lane to left lane operating could compromise operational efficiencies gained in bus speed and passenger throughput in the first corridor. There will be no physical segregation of the bus lane and it will almost certainly be shared with other vehicles. Despite the initial plan to develop six corridors of BRT by 2010, it is unlikely that even the first corridor will be fully operational by this time.

With the bus operating in an unsegregated left lane, experts suggest that fleet size requirements will as much as double as bus speeds fall due to greater friction with pedestrians, hawkers, slow-moving vehicles, parked, and left-turning vehicles at the kerbside leads to higher levels of unreliability. Audits conducted by engineers, cyclists, and the Traffic Police, of the constructed cycle lane on the new section of corridor from Moolchand to Delhi Gate also show service disruption as the need to put bus stops on the left side causes breaks in footpath and cycle track continuity.

Complementing BRT—The Corporatization of Private Stage Carriages in Delhi

Delhi is working to improve integration within and between different modes of public transit, integrate fares and routes, and improve the availability of information for public transport users. The 'vehicle' to achieve this restructuring is known as 'The Corporatization of Private Stage Carriage Services Scheme'.

Status of Bus Services in Delhi

Presently around half the bus services in Delhi are provided for by private contractors who typically own a very small number of buses. Each contractor operates his or her bus on individual routes, competing against 60 per cent of buses served by the state operator, Delhi Transport Corporation, and other private operators. As a consequence, the system is highly inefficient, encourages unsafe driving practices, and delivers few 'network' benefits. Only individually remunerative routes are operated by private operators. Less remunerative routes are sometimes served by the state-run DTC. However, like many other state-run transport companies there are weak incentives to provide efficient services. Recently a Comptroller Auditor General (CAG) report found that less than three quarters of DTC kilometres are actually run, a figure that has been falling for a number of years.

Bus Network and Management Reform Measures

The corporatization scheme aims to group cohesive bus networks into 17 area-wide clusters, each of which will be run by one operator for a contractual period of 10 years. The number of routes operated will increase from an estimated 500 actually run now to 657, thereby bringing the network within 500 metres of every home in Delhi. With the aim of reducing unsafe driving practices the operator will be paid according to the number of kilometres he runs.

Performance-based Management System

Compared to the state-run DTC buses, however, final operator payments will depend on how each bus performs in accordance with a pre-determined timetable. Operators with 'No shows' and late buses will either forfeit their payment or be renumerated less than those arriving on time, serving passengers in line with a number of predetermined standards. Performance will be measured through an on-board GPS bus tracking system linked to a Central Control Room that records individual data.

Intermodal Integration

A smartcard system will enable passengers to 'touch in' and 'touch out' of each bus, ending the requirement for time-consuming cash transactions every time passengers interchange.

Information Integration

A journey planner is under development, presently piloted on over 200 buses using the Bus Rapid Transit corridor in Delhi, which will use mobile phone and internet technology to feed real-time travel information to bus users. The first bus cluster of 17 has already been awarded and a further four more are currently out for tendering.

Walking and Cycling in a Low Carbon Transport System

Greater attention to improving NMT facilities could have a serious impact on the Delhi transport sector's contribution to climate change as the Lancet study clearly showed. Even a shift from a bus to a bicycle or foot can reduce carbon dioxide emissions more cost-effectively than the introduction of fuel-efficient vehicle technology. Early morning and evening commuting trips could be made feasible during summer months with the availability of better street infrastructure including high levels of tree shading, work showers, changing rooms, cycle parking, and a supportive management.

A number of different NMT initiatives are currently coming together under a combination of a pro-active stance taken by the Delhi Metro and the manager of Delhi's BRT corridor, DIMTS, and a desire to 'beautify' and 'streetscape' for the Commonwealth Games. The latter involves the application of new Pedestrian Design Guidelines which have adopted the highest possible standards for pedestrian facilities and are mandatory to follow (UT and TC 2009). Both cycle sharing and these new 'showcase' pedestrian and cycle infrastructure projects have the potential to demonstrate the role that an NMT could play in reducing carbon dioxide emissions in the city.

Cycle Sharing Schemes in Delhi

The first initiative is a cycle sharing scheme that involves installing hire bicycles near to BRT stops and Metro stations. The idea is that people could use this means of zero carbon transport to undertake a motorized public transport connecting trip or as an alternative to short-distance journeys often undertaken by car or motorcycle (see Figure 19.7).

The most successful international cycle sharing scheme is run by the advertising company, JC Decaux, in Paris for the municipal government, with other, smaller schemes in Lyon, Berlin, Vienna, and Barcelona.

In Paris a total of 20,600 bicycles are used every day by over 81,126 people. Even assuming that a modest 20 per cent of customers would have otherwise used a car to travel an average of 7.5 km (half now using a bus for 10 km and half using the cycle alone for 5 km) this is a reduction in vehicle kilometres in the order of 121,680, all that would have been driven in the central urban area and most at peak travel times when carbon dioxide emissions per passenger km would have been at their highest due to high levels of congestion (Schlebusch 2010).

Ignoring the scale differences between the two schemes for a moment, an examination of the utilization rate and the fare structure shows that Delhi's scheme is not currently securing maximum usage of its cycles, many remain parked in outlying areas to be returned only when the user makes a return trip to the station (see Table 19.5).

The Paris scheme, on the other hand, has cycle stations installed at destination and origin points away from the public transit stop or station and provides a financial incentive for cycle sharers to utilize the bicycle for a short trip before it deposited at the drop off point. This enables the user to drop off the cycle thereby making it available for another user. The results are shown in the comparative

Figure 19.7 Cycles for Hire Outside Delhi Metro Station and BRT Stop

Source: Schlebusch (2010).

Table 19.5 Comparative Assessment of Cycle Hire Schemes in Delhi and Paris, 2008

System/City	*Paris*	*Delhi*
Number of Bicycles	20,600	130
Number of Stations	1,451	13
Number of Daily Customers (Average)	80,126	150
Duration of Trip (Average)	18 mins	174 mins
Bicycle Occupancy Per Day (Average)	3.89	1.16
Fare Structure	Free—first 30 mins	Rs 10 first 4 hours
	1 Euro—31–60 mins	Rs 5 each extra hour
	2 Euro—61–90 mins	
	4 Euro—Each extra 30 mins	

Source: Schlebush (2010).

utilization rates of both schemes. Other advantages of the Parisian system that Delhi would do well to replicate include: easy booking option for cycles over the internet or by mobile, and a strong brand identity through the choice of a modern bicycle that is distinctive comfortable and attractive to ride.

Despite this, a survey of the Delhi Cycle Sharing Scheme conducted by the German Development Agency, GTZ shows that the scheme has great potential to substitute for short-distance trips by car and motorcycle. The user survey found that two thirds had an above average education level, an average income of up to Rs 5,000 per month, and half-owned a car or a motorcycle but were not using it because 'a bicycle is (more) convenient' (Schlebusch 2010).

Streetscaping and Beautification for the Commonwealth Games

As part of the preparations for the Commonwealth Games a number of streets have been earmarked for high-quality pedestrian and cycle infrastructure development. Although the work is not yet complete at many of the locations it is already possible to see that a high degree of professionalism has been applied at the design stage to ensure that facilities are *direct, safe, attractive,* and *comfortable* to use. Adherence to Delhi's Pedestrian Design Guidelines is part of the way towards achieving these goals.

In the context of cycle infrastructure one of the key challenges remains in incorporating these new facilities into a clearly legible network, which fits with existing (and future) travel patterns. The GIS maps 19.4, 19.5, and 19.6 compare the existing routes provided by municipal agencies, including new facilities being developed for the Commonwealth Games with those that might be considered in any way 'usable' and finally with existing cycle flows. The first map (Map 19.4) shows that, according to the municipalities' definition of a cycle track, there already exists a fairly large number of tracks in the city. At the same time there are significant gaps between them, making them difficult to use.

The second map (Map 19.5) shows cycle routes that were audited by experts in a recent evaluation exercise. Compared to the first map, the number of cycle tracks that were deemed relatively free of encroachments, direct, comfortable, safe, and attractive was quite limited. Most

Map 19.4 Existing Cycle Tracks in Delhi

Source: New Delhi Municipal Corporation, Public Works Department, Municipal Corporation of Delhi, March 2010.

Map 19.5 Fully Segregated Cycle Tracks in Delhi Identified Through Audit

Source: Schlebusch (2010).

tracks given by the agencies were service lanes only, many filled with parked vehicles and all without any signage indicating their status.

The final map (Map 19.6) is useful, illustrating as it does roads with substantial cycle flows. Comparing cycle flows to existing and usable cycle lanes, however, indicates that current facilities need to be linked to a series of new cycle tracks in areas where cycling has a higher modal share and aligned further with cycling origin and destination patterns. Linkages also need to be made with public transit interchanges with facilities for cycle parking. This is not to undermine the usefulness of currently existing tracks as they are situated in central areas with a comparatively well-off population who must form part of a new target group to start cycling as a healthy activity.

However, more effort and investment clearly needs to be made in other parts of the city to improve conditions for cyclists if modal share is to be maintained in this transport mode. According to a recent study of the City Development Plan, 0.8 per cent of Delhi's transport budget is dedicated to NMT infrastructure and 0.5 per cent to pedestrian facilities (Arora 2010). If the National Urban Transport Policy headlines on securing an 'equitable allocation of roadspace' with priority given to non-motorized modes is to be realized on ground, significantly greater effort will be needed to create a multimodal transport system to encourage people to walk, cycle, and use public transport.

Conclusions

The potential role of small-scale, local transport schemes which provide travel options for those walking and cycling for short trips and as a means of accessing motorized public transport has not yet been realized in India as a very good means of reducing carbon dioxide emissions. Local planning is weak.

A transport network based on buses, para transit, and with greater attention placed on making streets pedestrian and cyclist-friendly will reduce carbon emissions more than a strategy focused on the Metro and improving fuel efficiency of vehicles alone. In the end the growing size of population in megacities in India is likely to mean that both strategies will be needed but presently investment is heavily skewed to heavy infrastructure whilst pavements, road crossings, cycle facilities, pedestrian, and public transport interchanges are neglected.

The argument that 'a good public transport system is needed before demand management measures can be

Map 19.6 Roads with 'Significant' Cycle Flow (over 10 per cent of mode share)

Source: RITES Ltd and TERI (2010).

introduced' does not hold. Measures are urgently needed to reduce the need to travel, increasing not only the supply of public transit but also the quality of public transport, while simultaneously introducing incentives to use it: higher parking charges, road pricing, equitable taxation between modes, etc.

Although many politicians and bureaucrats have been attracted to Bogotá as a successful model of how to achieve transport improvements while reducing carbon dioxide emissions, Bogotá worked because the Mayor, Enrique Penalosa, had a clear vision of what he wanted to achieve and stuck doggedly to the task despite powerful opposition from vested interests. A strong political leadership is an essential prerequisite for a multimodal transport system.

Greater capacity and skills needs to be developed amongst public agencies on how to design multimodal streets and roads. Whilst Delhi has witnessed some very innovative cycle and walking schemes emerging in preparation for the Commonwealth Games, they are not integrated with pedestrian and cycle networks at a local and then a city-wide level. There is no programme to promote cycling and walking as 'responsible', 'high status' means of transport. Likewise rickshaws are banned on most roads. Quality standards for rickshaws are absent and these vehicles are rapidly becoming antiquated and perceived as part of the problem rather than as part of the solution to transport woes.

Recommendations

- Creation of a Unified Metropolitan Transport Authority with responsibilities for land-use planning and transport investment with the mission of securing Transit Oriented Development through a new 'Road Users Act', a Transport Strategy and Plan that is fully funded, time-bound, and 'owned' by the Mayor.
- Re-balancing of investment in line with recommendations of the National Urban Transport Policy towards public transit, walking, and cycling and away from road capacity enhancement schemes in urban areas.
- In medium- to large-scale cities, higher levels of investment in Bus Rapid Transit and a faster approach to implementation involving the creation of a body, supported in law, solely responsible for BRT in the city.
- Modernization of bus vehicles focused on medium- to large-scale cities to be combined with structural reform

to management of bus operations. Private corporations invited to run area-based franchises as part of a bus network better integrated with other walking, cycling, other buses, and Metro services. Private corporations to be a 'public sector comparator'. If public bus operations do not improve, privatize them.

- Creation of an NMT Centre of Excellence, part of the Urban Metropolitan Transport Authority (UMTA) mooted for Delhi and tooled with adequate funding to invest in cycle and walking infrastructure. Infrastructure planning only approved with cycle and pedestrian plans (at local and network planning levels).
- Standards of design to accord with those of the Pedestrian Design Guidelines set by the United Traffic and Transportation Centre (UTTIPEC) in Delhi and forthcoming Indian Cycle Design Guidelines based on Dutch CROW Cycle Design Manuals.
- A significant thrust towards greater road safety, including the development of targets for the NMT Centre of Excellence and targets for the Traffic Police to reduce road casualties while increasing cycling and walking mode share. Traffic Police to be re-named 'Transport Police'.
- Local bodies to be consulted on measures to improve road safety in their area and to be involved in small-scale, adequately resourced local transport (walking/cycling/public transport access) audits, improvement, and road safety schemes.
- Introduction of a suitable methodology and plan to alter streets in line with the Pedestrian Design Guidelines: better quality street furniture, including tree shading, spaces for hawkers to provide road users with refreshments, spots to congregate, and take a breather away from traffic.
- Introduction of demand management schemes to encourage use of public transport, walking and cycling such as road pricing, stricter parking control, and removing subsidies on fuel and parking.
- As investment in public transport, walking and cycling facilities grow, with greater efforts to explain policy changes to the public through a series of carefully targeted campaigns.

References

Arora, Anvita (2010). 'The Demand Perspective of Low Carbon Transport: The Need for Socio-Economic Impact Assessment of Urban Transport Projects', UNEP Workshop Promoting Low Carbon Transport in India, February.

Asian Development Bank (2006). *Energy Efficiency and Climate Change: Considerations for On Road Transportation in Asia.*

Bannister, David (2008). 'Cut the Commute and Fly Less Too', *Civil Society*, 5(11), September–October.

Comptroller and Auditor General of India (2010). *Report into Phase I of the Delhi Metro*.

Dargay, Joyce and Dermot Gately (2007). 'Vehicle Ownership and Income Growth Worldwide—1960–2030' *The Energy Journal*, 28(4), pp. 143–70.

Dasgupta, M., R. Oldfield, K. Sharman, and V. Webster (1994). *Impact of Transport Policies in Five (UK) Cities*, Project Report 107, Transport Research Laboratory, Crowthorne, Berks.

Delhi Metro Rail Corporation (2008). *Annual Report 2008*, National Capital Region Planning Board, Ministry of Urban Development, Government of India, New Delhi.

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and SUTP (2008). *Bus Rapid Transit Planning Guide*, The Institute for Transportation and Development Policy (ITDP), United Nations Environment Programme, the Hewlett Foundation, and Viva, New York, June 2007.

Environment Pollution (Control and Prevention) Authority (2009). Briefing Paper 5, Delhi, 5 February 2009.

Economic Survey (2009–10) (2010). Ministry of Finance, Government of India, New Delhi.

Hidalgo, D. and M. Pai (2009*). Review of Delhi BRT Corridor*, EMBARQ.

International Energy Agency (2002). *World Energy Outlook.* Paris.

IPCC (2007). *The Fourth Assessment Report on Climate Change*, Intergovernmental Panel on Climate Change.

Ministry of Urban Development (2006). *National Urban Transport Policy*, Union Government of India, New Delhi.

Mohan, D. (2008). 'Metros, Mythologies and Future Urban Transport', *TRIPP Report*, 08–01, Transportation Research and Injury Prevention Programme, Indian Institute of Technology, Delhi, New Delhi.

Narain, Sunita (2009). 'In Poverty and in Wealth', *Business Standard*, 26 February 2009.

Penalosa, Enrique (2008). 'Create Public Spaces to Bring Equality and Joy', *Civil Society*, 5(11), September–October.

RITES Ltd (2005). *Integrated Multi-Modal Public Transport Network for the National Capital Territory of Delhi*.

RITES Ltd and TERI (2010). *Traffic and Transport Demand Study for the National Capital Territory of Delhi.*

Roychowdhury Anumita (2009). *Seeking Solutions to Air Pollution, Congestion and Climate: The Role of Transportation & Mobility*, Centre for Science and Environment.

Schlebusch, Sebastian (2010). Bicycle Sharing in Delhi, Presentation by Sebastian Schlebusch, GTZ Research Student) (forthcoming).

The Lancet (2009). *'Public Health Benefits & Strategies to Reduce Greenhouse Gas Emissions: Urban Land Transport'*, 374(9705), December.

US Department of Energy (2006). *US Transportation Energy Data Book.*

United Traffic and Transportation (Planning and Engineering) Centre (UT and TC) (2009). *Pedestrian Design Guidelines*, Delhi, November 2009.

Wilbur Smith Associates (2008). *Study on Traffic and Transportation Policies and Strategies in Urban Areas in India* for Ministry of Urban Development, Government of India.

Wright, L. and L. Fulton (2005). 'Climate Change Mitigation & Transport in Developing Countries', *Transport Reviews*, 25(6), pp. 691–717, November.