URBAN TRANSPORTATION AND GREEN GROWTH

Jose A. Gomez-Ibañez
Harvard University

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Promoting economic growth and improving the quality of the environment are both important goals for developing countries, and often thought to conflict. But some development specialists argue that growth can be "green" in that rapid economic growth can be achieved without environmental losses while environmental gains need not come at the expense of growth. This paper focuses on urban transportation and argues that some transportation policies designed to promote economic growth, particularly by promoting accessibility while controlling congestion, would also help reduce local and global environmental damage. Not all policies are so compatible, however, and our record of implementing the compatible policies is poor.

To make this argument, the paper is divided into six parts. The first examines the goals of urban transportation policies, the types of policies used to achieve them, and the degree to which those policies advance both economic and environmental objectives. The next four parts consider four different policies: reducing passenger-kilometers travelled, reducing vehicle kilometers per passenger kilometer, reducing pollutant emissions per vehicle kilometer and building more highway capacity. The final section considers the challenges of implementing these policies in rapidly growing cities.

The paper draws particularly on the experiences of Jakarta and, to a lesser extent, Ho Chi Minh City and Mumbai. These three cities are not representative in that they have been growing more rapidly and are already larger than many other cities in the developing world.   But their rapid growth and size makes the pressures of economic growth more acute and obvious and the three cities vary somewhat in their local circumstances and the implementation problems they have encountered.

Conflicting or Complementary?

Economic Objectives

Cities are engines of economic growth and urban transportation services play a key role in supporting cities by making it possible for large numbers of people to work and live close to one another. Cities exist because workers are more productive and consumers enjoy more choices when located in large concentrations. These benefits, which economists call agglomeration economies, arise because cities promote sharing, matching and learning (Duranton 200X). Sharing occurs because a larger city can support more specialized suppliers for its firms and services for its consumers. Matching is improved because a bigger local labor market makes it easier for workers to find a suitable job and employers a suitable worker. And learning increases because workers are more likely to be exposed to new ideas from other workers and firms in their own or other industries.

Agglomeration economies can be large, although economists have begun to try to measure them only recently.   Most estimates are for cities in industrialized countries where the requisite data are more readily available. A meta analysis of such estimates suggests the typical elasticity of productivity to city population or workforce was .07, which means that a doubling of the size of the city would increase productivity by 7 percent. Elasticities are generally higher for service industries and lower for manufacturing (Menlo, 200X).

If agglomerations generate benefits, however, they also generate costs in the form of the increased traffic congestion, health risks, flooding, and the air, water and noise pollution that comes from concentrated activities. Urban infrastructure and land use policies of local and national governments play a potentially important role in mitigating these agglomeration costs and supporting a larger city.

There is no guarantee that the market left to its own devices will result in cities of the optimal size because migrants to the city do not capture fully either the benefits or the costs of agglomeration. The new migrant to the city does not capture the increase in productivity his decision generates for other city residents, nor does he suffer the added congestion, pollution and other costs his decision imposes on others. In economists' terms, agglomeration benefits and costs are, respectively, positive and negative externalities, and the market will tend to undersupply the former and oversupply the later.

Indeed, in some developing countries the largest cities may be too large in that the marginal or incremental costs of agglomeration exceed the marginal agglomeration benefits. In that case, economic growth would be better served by diverting migration and population growth to secondary cities.

In this context, the role of urban transportation policy is to maintain the accessibility within the agglomeration that is needed to exploit the potential for improved sharing, matching and learning while keeping congestion and transportation infrastructure costs at reasonable levels. The goal is not to eliminate congestion altogether because that would require either banning urban travel, which would eliminate the benefits of agglomeration, or making prohibitively expensive investments in transportation infrastructure. Rather, the goal is to balance the economic benefits of added travel with the costs of accommodating those trips either by tolerating the added congestion or by building additional transportation capacity to carry the trips without the added congestion. And the optimal level of congestion will be higher in larger cities and at more central locations within cities because the cost of building more capacity is typically higher in those situations.

Environmental Concerns

Urban transportation creates a variety of environmental problems but arguably the most important are emissions of air pollutants of two types: those that cause either human health problems at the ground level or those that contribute to global warming. Motor vehicles contribute to six ground-level pollutants: lead, inhalable particulate matter (PM); ozone (which is formed through a photochemical reaction in the atmosphere between volatile organic compounds, or VOCs; and oxides of nitrogen, NO_X); carbon monoxide (CO); sulfur dioxide (SO_2); and nitrogen dioxide (NO_2). The first three are the most harmful to human health, although lead has been eliminated from fuels in almost all countries. The main problem with gasoline-powered vehicles are emissions of the ozone precursors VOCs and NO_X while the main problem with diesel engines are emissions of PM and NO_X (Gwilliam, Kojima and Johnson, 2004, pp. 1-3). The severity of ground-level air pollution and degree to which motor vehicles are to blame varies considerably among cities depending upon the characteristics of their airsheds, the degree of motorization of transportation, and the location of industry and power generating stations. All else being equal, the larger and denser the city the more damaging any given emissions of ground-level pollutants since more people will be exposed to the resulting elevated ambient pollutant concentrations.

Motor vehicles emit a number of greenhouse gases that contribute to global warming, but the main concern is carbon dioxide (CO_2), which is the product of the combustion of fuel and thus proportional to fuel consumption. Worldwide, motor vehicles are thought to account for roughly 20 percent of greenhouse gases, and their share is rising (citation). A study of 12 metropolitan areas estimated that transportations' share of greenhouse gas emissions varied considerably from a low of 5 percent in Beijing to a high of 66 percent in Delhi (Sovacool and Brown, 2010).

Points of Leverage

To understand the ways in which urban transportation and environmental policies conflict and complement one another it is helpful to review some simple accounting identities for congestion and emissions. Highway congestion is key since buses, taxis, cars and motorcycles account for almost all motorized trips in most cities in developing countries. And both highway congestion and motor vehicle emissions are a function of vehicle-kilometers travelled (VKT). Highway congestion is a function of the capacity of the highway system (CAP) relative to the number of VKT:

$$\text{Congestion} = f\ (\text{VKT}/\text{CAP}).$$

Motor vehicle emissions are the product of VKT and emissions per VKT (E/VKT):

$$\text{Emissions} = \text{VKT} * \text{E}/\text{VKT}.$$

VKT in turn is the product of the number of passenger kilometers travelled (PKT) and the vehicle kilometers needed to carry a passenger kilometer (VKT/PKT):

$$\text{VKT} = \text{PKT} * \text{VKT}/\text{PKT}.$$

And PKT is a product of passenger trips (PT) and trip length (TL):

$$\text{VKT} = \text{PT} * \text{TL} * \text{VTK}/\text{PKT}.$$

These equations are an oversimplification, of course, in that they ignore important feedbacks among the variables, the most important being that congestion is not just a product of PT and TL but it also influences them since high levels of congestion can discourage trips and reduce trip length. However, the equations identify several basic points of leverage on congestion and emissions:

- The first point of leverage is reducing passenger kilometers travelled, which is desirable from an environmental perspective but not from an economic perspective since accessibility is the key to generating agglomeration benefits. The conflict is less severe if passenger kilometers are reduced by cutting trip length rather than passenger trips.

- The second point of leverage is to reduce the vehicle-kilometers travelled per passenger kilometer by shifting to modes that use street space more efficiently, like the bus, or modes that do not use street space at all, like-grade separated mass transit. This policy is compatible since vehicles that use street space efficiently usually emit less pollutants per passenger kilometer as well. The problem is that the trend has so far been in the opposite direction: toward modes of transportation that require more street space per passenger kilometer rather than less.

- The option of reducing emissions per vehicle-kilometer travelled also is compatible in that it advances environmental concerns without compromising economic considerations, at least as long as the standards are not too tight. The limitation of this policy is that it may not be sufficient to offset the projected growth in vehicle-kilometers travelled.

The Challenge of Accommodating Passenger Trips

Economic Growth and Passenger Kilometers

Economic growth stimulates the demand for urban passenger travel in three ways. The first and most obvious way is by encouraging urbanization and the resulting increase in the population living in metropolitan areas. For example, Jakarta, Indonesia's political and business capital, saw its metropolitan population grow from 8.4 million in 1970 to 28.0 million in 2010 thus becoming the largest metropolitan area in Asia. Jakarta's average growth rate slowed a bit from its high of 3.5 percent per year in the 1970s and 1980s, but was still impressive with a 2.5 percent per year growth rate in the 1990s and 2000s (Indonesia, Coordinating Ministry 2011, slide 5). Mumbai, India's financial and entertainment capital, grew from a metropolitan area of 7.7 million people in 1971 to 18.8 million in 2001, with average growth rates of 3.7 percent per year in the 1970s and 2.6 percent per year in the two decades that followed (LEA International 2005, pp. 1-4). According to official statistics the population of Ho Chi Minh City, Vietnam's most important commercial metropolitan area, grew from 4.7 million in 1995 to 6 million in 2007, for an average annual growth rate of 2 percent per year. However, as many as 2 million migrants unregistered with the local governments, made up the metropolitan area, and if they had been included in the 2007 figure, the average growth rate may have been as high as 4.5 percent per year.

Economic growth also stimulates travel because the average number of trips per capita increases as incomes rise. Poor households make very few trips, mainly just to work and school, but as their disposable incomes increase they begin to travel for social, recreational or shopping purposes. Between 2002 and 2010, for example, the percentage of Jakarta metropolitan area households with incomes below 1 million rupiah (US$ 118) per month fell from 55 to 15 percent (Indonesia, Coordinating Ministry 2011, slide 8). And families with incomes between 700 thousand and 1 million rupiah (US$ 83 to US$ 118) per month make an average of only 1.87 daily trips per capita, while households earning 2 to 3 million rupiah (US$ 236 to US$ 354) per month make 2.21 daily trips per capita, an increase of 18 percent (Pacific Consultants International, 2004b).

A third source of increased travel is the increase in average trip lengths as the urbanized land area expands to accommodate more people. Using Jakarta as the example again, during the 1970s and 1980s, the metropolitan area's population growth was roughly evenly split between the capital city district, called DKI Jakarta, and the suburban cities and districts. In the two decades that followed, however, the suburbs grew more rapidly as rural land on the periphery was converted into industrial estates, new towns and subdivisions (Firman 2009). Land hungry industries expanded in the east, both in and around the suburban city of Bekasi and, to a lesser extent, to the west around the city of Tangerang. The south, in and around the city of Bogor, developed as an important residential area, in part because it was higher and cooler. As a result, the number of workers living in the suburbs and commuting to DKI Jakarta increased by 50 percent between 2002 and 2010. And during that same time period, the distance of the average commuting trip increased by 43 percent (from 6.7 kilometers to 9.6 kilometers) while the distance of the average school trip increased by 104 percent (from 2.7 to 5.5 kilometers) (Pacific Consultants International 2004b, p. 9-8). Mumbai and Ho Chi Minh City have both seen a similar expansion on the periphery and presumably an increase in average trip length as well, although historical data on trip lengths is not readily available.

The Risks of Reducing Passenger Kilometers

Reducing the growth in passenger-kilometers travelled would reduce air pollution emissions, but would almost certainly be undesirable economically and impractical politically. If cities are important engines of economic development, then their populations will continue to grow and the increased population will result in more passenger trips. As noted earlier, there is no guarantee that the market forces alone will produce the optimal size city and it is possible that some of our largest metropolitan areas have grown to the point where the marginal or incremental costs of the agglomeration exceed the marginal benefits of agglomeration. Many Indonesian and Indian urban planners believe this to be true, and as a result support public policies to promote secondary cities over Jakarta and Mumbai. But the reason that the migrants bypass secondary cities that are far less congested and expensive is that the economic opportunities are so much greater in the larger metropolitan areas. And this implies that the productivity advantages of Jakarta, Mumbai and Ho Chi Minh City are still substantial, and that it would require either politically unpalatable controls on domestic migration or extremely costly financial incentives to induce migrants to change their destinations. Either policy would risk a reduction in the rate of Indonesia's economic growth.

If the populations of Jakarta, Mumbai and Ho Chi Minh City are destined to increase and become more prosperous, then it also seems inevitable that the metropolitan areas will expand physically. One interesting study of satellite photographs of a sample of 130 cities in developing countries estimated that the urbanized land area of a city increases twice as fast as its population (Angel 2010). Increased land coverage does not have to result in increased trip lengths if jobs follow residences to the periphery. And to a certain extent this is happening already as, for example, Mumbai has developed a secondary central business district to the north of the peninsula around Bandra Kurla; and Jakarta's central business district has moved south from Kota to the Sudirman and Kuningan areas, and new office buildings have appeared on its inner ring road. Moreover, urban planners argue that the increase in trip lengths can be moderated if land uses are carefully planned, for example, to make developments dense and contiguous and ensure jobs and housing are balanced throughout the metropolitan area. And if the density of development exceeds certain thresholds then it may make non-motorized modes or public transportation more competitive with private automobiles.

But while logic suggests that good land use planning can slow the increase in trip length and the shift to private vehicles that so often accompanies physical expansion, we simply do not know how strong the effects might be and the signs are not terribly encouraging. Research on the effects of land use patterns on travel behavior is complicated by the need to control socioeconomic characteristics, including the possibility of self-selection bias because people who dislike driving tend to locate in denser neighborhoods where they have more transportation options. The research has been confined mainly to cities in the developed world, moreover, where densities and socioeconomic characteristics are very different than those found in cities of the developing world. But a review of the evidence from North America suggests that a doubling in residential density reduces vehicle-kilometers travelled by only X percent (Transportation Research Board 2009). One of the few studies conducted in the developing city of Santiago, Chile comes to similar conclusions about residential density, but finds that a strong central business district is also helpful (Zegras 2010). And this result assumes that good land use plans can be implemented, a subject to be discussed again later.

If it is economically risky and politically difficult to resist the growth in passenger kilometers, then efforts to reduce congestion and curb emissions start at a considerable handicap. If Jakarta, Ho Chi Minh City and Mumbai are a guide, the populations of large metropolitan areas are likely to grow at an average rate of 2.5 percent per year and passenger kilometers should increase apace. If one adds another percentage point or so due to increases in the per capita trip rates and to trip lengths, then passenger-kilometers travelled might be expected to increase at a rate of around 3.5 percent per year.

The Importance of Addressing Mode Shares

Trends in Modal Shares

If passenger kilometers are growing at 3.5 percent per year, vehicle kilometers are growing much faster because, as incomes and trip lengths increase, passengers are shifting from non-motorized modes of transportation—such as walking or bicycle—to motorized modes—including buses, motorcycles and automobiles. Jakarta is in the midst of a dramatic shift among modes illustrated, in Table 1, by the results of three household travel surveys conducted in 1985, 2002 and 2010 during a series of transportation planning studies. The 2002 survey is the most comprehensive since it covers all types of trips in the metropolitan area. The earlier 1985 survey was limited to trips to, from and within DKI Jakarta, while the later 2010 survey covered the entire metropolitan area but to cut costs, asked about only work and school trips.

Between 1985 and 2002 the share of all trips made in DKI Jakarta by non-motorized modes fell by 10.6 percentage points—from 47.0 to 36.4 percent—with approximately two-thirds of those going to buses and the rest to automobiles. In the following eight years from 2002 and 2010, however, there was no appreciable further decline in non-motorized trips but the share of work trips carried by buses dropped by a shocking 25.4 percentage points (from 38.3 to 12.9 percent), while the shares carried by motorcycles and by cars and trucks increased by 27.5 and 1.5 percentage points, respectively. Jakarta's shift from walking and bicycling to motorcycles and cars is reflected in vehicle registration figures as well. Between 2000 and 2008 automobile registrations in the metropolitan area doubled while motorcycle registrations quadrupled. By 2010, surveys revealed that 23 percent of the region's households owned a car, 73 percent owned a motorcycle, and only 23 percent owned neither a car nor a motorcycle.[1]

[1] Fifty-four percent had a motorcycle only, 4 percent had a car only and 19 percent had both a motorcycle and a car (Indonesia Coordinating Ministry 2011, slides 6 and 10).

Ho Chi Minh City has also experienced a shift from non-motorized to motorized modes, although in its case, travelers bypassed the buses and shifted directly to motorcycles. Before 1986, when the Vietnamese government adopted the Renovation (Doi Moi) Policy to transform Vietnam from a centrally planned to a more market-oriented economy, most Ho Chi Minh City residents relied on non-motorized modes, particularly bicycles. During this same period the government neglected the bus system it had inherited from the defeated American-backed regime. By the 1990s, when incomes and trip lengths increased to levels where city residents wanted to shift to motorized modes of transportation, the bus service was so limited that residents adopted the motorcycle instead. In the late 1990s and early 2000s, motorcycles were carrying around 60 percent of all trips while the bus and the car carried less than 2 percent each (Table 2). By 2007, Ho Chi Minh City had 3.4 million motorcycles, or one for every two persons. And as early as 2002, 92 percent of all Ho Chi Minh City households owned one or more motorcycles, 2.6 percent owned cars, and only 5 percent were entirely dependent on non-motorized transportation.[2]

The growth in motorcycle ownership in Jakarta and Ho Chi Minh City was stimulated, in part, by the relaxation of motorcycle import duties and the easy credit offered by motorcycle dealers. In Jakarta, a buyer can put as little as 500,000 rupiah (US$ 59) down and finance the balance of a motorcycle price of 10 million rupiah (US$ 1,176) over 3 to 5 years at an interest rate of 10 to 13 percent, and similar financing terms are available in Ho Chi Minh City. Commuting by motorcycle is often less expensive than commuting by bus, especially in Jakarta where many work trips require an extra fare or two to transfer between bus routes. And in both cities, motorcycles offer the door-to-door convenience of a car and are often faster as well since they can thread their way through bottlenecks. Motorcycles allow commuters to live further away from the city center where there are often fewer bus services.

[2] HOUTRANS data as cited by Systra MVA (2008, p. 8).

Furthermore, owning and traveling by motorcycle is a status symbol among the lower middle class. The main drawbacks of motorcycle travel are the discomfort of riding in inclement weather or heat, and the increased risk of accidents.

Mumbai is very different from Jakarta and Ho Chi Minh City in that its residents rely on walking for 60 percent of their trips and on the commuter railroad for another 20 percent. (Table 3) Walking has such a high share because many Mumbai residents are very poor and the density of development is high. The importance of the commuter railroad is a product of the metropolitan area's geography, and particularly the location of the central business district at the tip of a long peninsula that serves to funnel commuters into a few corridors that are well served by a century-old train system. The high levels of traffic congestion along the peninsula will make it harder to shift to private modes as incomes increase, but will make any shift more problematic.

The Consequences of the Modal Shift for Congestion

The shift among transportation modes is important because the modes make different demands on street capacity and generate different levels of pollution. Traffic engineers measure the amount of street capacity different types of vehicles require relative to the capacity required by a passenger car. Thus, for example, a bus in mixed traffic typically requires between two and four "passenger car equivalents", usually abbreviated as PCEs, of capacity. A bus uses more street capacity than a car, less because it is physically larger than because it accelerates and decelerates more slowly and is less maneuverable. And the higher figure of four PCEs per bus applies to buses picking up or dropping off passengers at frequent intervals along the street, so that the buses often block traffic as they pull in and out of curbside stops. The number of PCEs required by a motorcycle has not been extensively studied but seems to depend on the proportion of motorcycles in traffic and the width of the traffic lanes. On streets where most of the traffic consists of cars and trucks and there are few motorcycles, studies suggest that a motorcycle requires one-half to one-third of a PCE. On urban streets with a high proportion of motorcycles and lanes at least three meters wide, however, a motorcycle might require as little as one-fifth or one-tenth of a PCE (Hsu *et al.* 2003). In such conditions, motorcycles can often ride several abreast in a lane or maneuver past queues of stopped cars.

Of the motorized modes, buses are clearly the most efficient users of street space as long as the vehicles are reasonably heavily loaded. Table 4 shows the street capacity and energy used by automobiles, motorcycles and the three sizes of buses that operate in Jakarta. The first pair of columns shows the typical passenger carrying capacity and peak hour loads of the different modes in Jakarta. The middle pair of columns gives the PCEs of road capacity required to carry 100 passengers under a range of plausible assumptions about the number of PCEs required per vehicle. The last two columns on each mode calculate the liters of fuel per 100 passenger kilometers under reasonable assumptions about the fuel economy of the current Jakarta fleet.

Table 4 illustrates why the shift underway in Jakarta from buses to motorcycles and automobiles is such a threat to the passenger carrying capacity of the street system. A 50-passenger diesel bus requires by far the least street capacity per 100 passengers carried, an automobile the most, while a motorcycle and the small and medium size buses are somewhere in between. A shift from large buses to automobiles is extremely problematic as it causes an eight- to fifteen-fold increase in the amount of street capacity needed per 100 passengers (from between 5.4 and 10.8 PCEs per 100 passengers to 83.3 PCEs per 100 passengers). Small and medium buses are only one-half to one-sixth as efficient users of street space as large buses, so a shift from those buses to automobiles would cause “only” a three- to eight-fold increase in street capacity per 100 passengers.

How one feels about the expanding role of the motorcycle in Jakarta and Ho Chi Minh City depends importantly on whether one regards the relevant alternative as the bus or the automobile. If motorcycle use is growing at the expense of the bus then the shift will greatly increase the demand for street capacity, but to the extent that motorcycle use is forestalling a shift to automobiles, then it is preventing an enormous increase in the demand for street capacity. The trends of the last decade strongly suggest that the motorcycle has been drawing its riders from the bus, but as incomes continue to grow the availability of the motorcycle may serve to slow the rate of growth of automobile ownership and use.

It is also important to note that a major transition to the car will be far more difficult for Jakarta and Ho Chi Minh City to accommodate than the recent transition to the motorcycle has been. A shift from the bus to the motorcycle causes far less serious street capacity problems than a shift from the motorcycle to the automobile, especially if the motorcyclists are experienced and drive in large numbers so that they require, at most, one-quarter or (more likely) one-eighth of a PCE of street space each. Under these assumptions, a shift from large bus to motorcycle requires roughly a tripling of street capacity (from between 3.9 and 7.8 PCEs per 100 passengers to between 12.5 and 25 PCEs per 100 passengers). And a shift from small and medium buses to motorcycles might cause little or no increase in street capacity as the smaller buses require roughly the same PCEs per passenger as the motorcycle. By contrast, a shift from the motorcycle to the automobile would require a three- to six-fold increase in street capacity (from between 12.5 to 25 PCEs per 100 passengers to 83.3 PCEs per hundred passengers).

The Consequences for Pollution

Using fuel consumption as a proxy for greenhouse gas emissions, Table 4 shows a similar ranking of the modes in that large buses use the fewest liters of fuel per 100 passenger-kilometers carried, while automobiles use the most, and the fuel consumption of motorcycles and small and medium buses are somewhere in between. The main difference is that the gap between the performance of the auto and the motorcycle is smaller in the case of fuel consumption than it is in the case of street capacity. Thus the conclusion that it is much more important to prevent a shift from motorcycles to autos than from buses to motorcycles holds for street capacity but not for greenhouse gases.

The bus and the motorcycle do not perform as well on ground-level air pollution emissions as they do on street capacity and greenhouse gases. Table 5 shows typical in-use emissions rates for inhalable particulates (PM) and the two precursors of ozone: oxides of nitrogen oxide (NO_X) and volatile organic compounds (VOCs). The emissions per vehicle kilometer are based on data for Mexico City and Pune drawn from the International Vehicle Emissions Model developed by Jim Lents (2011) while the vehicle types and the average daily passenger loads are intended to be representative of Jakarta.[3] For these pollutants, the bus is the highest emitter of PM and NO_X per passenger kilometer, and motorcycles are the highest emitters of VOC emissions.

The shift in modes adds to the effects of the growth in passenger kilometers discussed earlier. If every year just one percent of travelers shift to a mode that requires three times more street space or fuel (such as from large buses to motorcycles) then the demands on street capacity and greenhouse gas emissions will increase by roughly two percentage points.[4] Added to the 3.5 percent growth in passenger kilometers, the demand for vehicle kilometers—and the associated street congestion and pollution—would increase by 5.5 percent per year.

Reducing Emissions per Vehicle Kilometer

For pollution, one potential offset to the increase in vehicle kilometers is to reduce emissions for vehicles. This strategy has been used with great success by developed countries to slow the growth in vehicle emissions even while accommodating the

[3] The International Vehicle Emissions Model does not include data specific to Ho Chi Minh City, Jakarta or Mumbai.

[4] The increase would be exactly two or four percent if initially all travelers were taking the bus but it would be less if some travelers had already made the shift to the motorcycle and more if some travelers used non-motorized modes that did not require street space.

growth in vehicle kilometers. The United States and the European Union have been regulating motor vehicle emissions of ground-level air pollutants since 1968 and 1970, respectively, and have gradually tightened standards to achieve enormous reductions in emissions per vehicle kilometer through a combination of modifications to the vehicle and the use of cleaner fuels. Motivated by their pollution problems and encouraged by the international trade in assembled automobiles and parts, a number of middle-income developing countries have adopted versions of the U.S. or European Union (EU) standards for new cars including Argentina, Brazil, China, Chile, Colombia, India and Indonesia. For example, Indonesia has applied the Euro II standards for new automobiles (that went into effect in 1996 in the European Union) since 2006, and hopes to apply the Euro IV standards beginning in 2012 (Asian Clean Fuels Association 2009). India began imposing its own emissions standards in 1989, switched to EU standards in 2000 and gradually tightened them to require in 2010 Euro IV emissions levels in 12 large cities and Euro III in the rest of the country (Dieselnet 2011).

Greenhouse gas emissions have been regulated only recently, but fuel economy standards, which effectively control the most important greenhouse gas, CO_2, were established by the U.S. federal government in 1975 and have been tightened sporadically since. The State of California promulgated standards for greenhouse gas emissions measured in grams of CO_2 equivalents (gCO_2e) per vehicle kilometer beginning in model year 2009, and the federal government is in the process of issuing new standards that will reduce the inconsistencies. The European Union initially issued voluntary standards for CO_2 but in 2009 it adopted mandatory standards for CO_2e that would apply beginning in the 2012 model year. China, motivated in part by concerns about energy security, appears to be the only developing country that has followed suit so far, issuing standards in 2004 to apply to new cars beginning in model year 2005. Latin American countries have opted to require fuel economy labels on new cars instead of mandatory standards. The Chinese standards are not as stringent as those of the European Union and Japan, but stricter than those of the United States or California (Feng 2011).

The reductions in emissions of ground-level pollutants seem to have added relatively little to the initial purchase price or operating costs of automobiles, despite the warnings of some vehicle manufacturers and the petroleum refiners at the time they were imposed. Retrospective cost estimates are scarce in part because of the difficulty of allocating costs for devices like on-board computer controls that enhance acceleration and fuel economy as well as reducing emissions. One study estimated that the U.S. standards for ground-level air pollutants in the early 1980s probably added less than $1,000 to the manufacturing costs of a car at the time, and that this figure had declined since as manufacturers gained experience (Chen *et al.* 2004). The learning must have been substantial if the Nano automobile currently being built in India can meet Euro IV standards and still sell for only US$ 2,900.

Fuel economy or CO_2 standards may actually save motorists money as long as they are not too stringent. In the case of the tighter standards currently being contemplated in the United States, for example, regulatory analysts estimate that the higher initial purchase price of a car that is more fuel efficient (but otherwise equivalent in size and performance), will be more than offset by the lifetime savings from lower fuel purchases and even using a relatively high discount rate. The fact that consumers don't buy these fuel-efficient models on their own is thought to be consistent with research that suggests that consumers tend to avoid complex calculations and discount future events heavily.

Reducing emissions per vehicle kilometer may be relatively low cost so far, but the costs are likely to increase, and perhaps significantly, if standards are tightened much beyond the levels currently applied in developed countries. And there will be pressure to tighten standards to keep pace with the growth in person trips and the shift to motorized forms of transportation. Indeed, environmentalists lament that the dramatic reductions in emissions rates of motor vehicles has not been sufficient to offset the growth in travel in developed countries, let alone the more rapid growth likely in developing countries. And if vehicle kilometers are growing by 5.5 percent per year in some large metropolitan areas of developing countries, then the emission standards would have to be tightened at a comparable rate just to hold total emissions constant.

The prospect that electric vehicles or advanced bio-fuels will essentially eliminate the polluting emissions of motor vehicles seems unlikely in the next several decades. A shift to electric vehicles is likely if petroleum prices continue to rise and battery prices are low. But electric vehicles just transfer the emissions problem from the tailpipe to the electric power station. Electric cars are likely to make it easier to use renewable or nuclear sources of electricity by taking advantage of the vehicle batteries to store energy until it is needed. But for the foreseeable future much of our electricity will be generated by fossil fuels and unless or until the storage capabilities become important, a shift to electric cars will only delay the phase-out of fossil fuel plants.

Increasing Highway Capacity

One final policy option—to increase highway capacity—is usually thought to reduce congestion but increase pollution, although the extent of the conflict seems to depend on local circumstances. Increasing capacity typically stimulates more travel and thus generates more emissions, but the elimination of stop-and-go driving reduces both emissions of ground-level pollutants and fuel consumption, while higher speeds reduce emissions per vehicle mile of PM, CO and VOCs but increase emissions per vehicle mile of NO_X and fuel consumption.

Some skeptics argue that increasing capacity advances neither transportation nor environmental goals since new highways often fill up soon after they open, leaving congestion levels unchanged and emissions much higher. Even if speeds are not improved much, however, there is a transportation benefit from allowing more people to travel when and where they prefer. And the observation that speeds do not improve for long may not take into account what would have happened to speeds without the expansion.

If stop-and-go driving is eliminated or speeds improve, then the conflict between environmental and transportation goals depends upon how large the reduction in emissions per vehicle kilometer is relative to the increase in vehicle kilometers. If PM emissions in grams per vehicle kilometer decline by 30 percent when speeds increase from 10 to 20 kilometers per hour, for example, then that would be enough to offset a 30 percent increase in vehicle kilometers as a result of the scheme.

Are Transportation Plans Green?

Metropolitan Plans

One measure of the chances that green growth policies will be implemented in urban transportation is whether they are reflected realistically in metropolitan transportation and land use plans and policies. Some green growth measures—notably mandating lower emissions per vehicle kilometer for new vehicles—are usually the prerogative of the national rather than local governments, and thus are not discussed much in metropolitan plans. But other green growth measures—such as encouraging the use of modes that both use street space more efficiently and pollute less, and reducing trip lengths through more thoughtful land use—involve responsibilities of local government.

Our three metropolitan areas have been the subject of many plans in part because their rapid growth makes any plan obsolete soon after it is issued. The first comprehensive transportation and land use plan for DKI Jakarta was prepared in 1965, for example, but, recognizing that growth was spreading beyond the capital district's boundaries, a plan for the metropolitan area was completed in 1975 (Silver 2008). Comprehensive plans have been prepared every ten to fifteen years since, while more specialized metro or highway plans have been issued and updated far more frequently.[5] Similarly in Mumbai, regional development planning was initiated in 1967 and the first regional plan was completed in 1970 to cover the years 1970-1991 and a second issued to cover 1996-2011. Comprehensive transportation studies have been completed at similar intervals, the last two in 1994 and 2008 (LEA International 2008, Ch. 1). Ho Chi Minh City's rapid growth prompted the World Bank to fund a comprehensive transportation and land use plan for 2020 that was formally adopted in 1998, but just 10 years later it was superseded by a new comprehensive plan. Most of these plans are not strategic in that they do not compare in detail alternative land use and transportation policies and select the best performing. Rather, they explain the rationale for their specific recommendations in fairly general terms and forecast the likely effects on travel and land use patterns.

Land Use Policies

At the risk of much simplification, the land use plans typically have two major components: restrictions on development on environmentally sensitive lands and the encouragement or accommodation of decentralized development but concentrated in subcenters—a policy one plan labels as "concentrated deconcentration". In most cases, the environmentally sensitive areas are wetlands where preservation is needed to control flooding. In Ho Chi Minh City over 50 percent of the land is less than 2 meters above sea level and protected by wetlands along the Saigon River, while in Mumbai the mangrove marshes perform a similar function. Jakarta has important wetlands to the northeast while the southern part of the metropolitan area serves as a recharge area for the region's watertable, which has been declining due to excessive pumping.

Concentrated deconcentration recognizes that the spreading out of metropolitan areas is inevitable, or perhaps even desirable, given high levels of congestion in the center of the metropoli. Concentrating that development in subcenters helps to

[5] For a list of 39 plans prepared between 1965 and 2000 see Pacific Consultants International (2004b, pp. 1-5).

preserve green space and environmentally sensitive lands. And, as noted earlier, logic suggests that sub-centers can reduce trip lengths and encourage public transportation if they are sufficiently dense and contain concentrations of employment as well as residences.

As laudable as these land use policies seem, they are not always implemented well in practice. The reasons vary somewhat among the three metropolitan areas. One problem found to some degree everywhere, is that politically influential developers often seem to get variances from the plans or ignore them altogether. In Jakarta this difficulty is compounded because the nine local governments that make up the metropolitan area often lack the technical capacity and incentives to enforce the metropolitan plan. During the Suharto dictatorship, the plans for the metropolitan area were prepared by the central government with a strong top-down approach, but important land use and transportation permitting decisions remained in the hands of municipal and district governments. In 1976, the central government established a special agency, the BKSP, to coordinate the land use and transportation plans and projects of the local and provincial governments that made up the metropolitan area. The BKSP had no powers to resolve differences among those governments, however, and, as result, was left in a largely secretarial role. [6]

The prospects for coordination in Jakarta were further complicated in 1999 when, in the wake of the democratic revolution, a process of political decentralization was initiated. By 2002, the Indonesian Parliament had shifted the responsibility for delivering and paying for public services to the local (district and municipal) governments, which numbered over 450 in the country. To a lesser extent, local governments gained autonomy over public revenues. In 2004, Parliament went further by providing for the direct election of the governors of provinces and the

[6] On the performance of BSKP see Dail Umamil Asri, "Participatory Planning Toward an Integrated Transportation Master Plan for Jabodetabek", Proceedings of the Eastern Asia Society for Transportation Studies 5 (2005): 2308-2319 and Pacific Consultants International, "Master Plan Development Policies and Strategies'" pp. 1-25 to 1-27 .

heads of districts and municipalities.[7] The local governments have few powers to levy taxes of their own, however, and rely heavily on multiple types of annual block grants and funding transfers from the central government, many of which were based on a formula that measures the difference between their spending needs and their local revenue sources. The results of decentralization have been mixed so far, with some local governments using their new resources and autonomy to improve services while others becoming mired in corruption. But since local governments receive some financial benefit from land development, they are often tempted to use their land permitting powers to pursue their own rather than metropolitan agendas.

Ho Chi Minh City's land use plan incorporates some contradictions in that it calls for building a new downtown on a large wetland on the opposite bank of the Saigon River from the historic downtown and port. But implementation is allegedly discouraged by ambiguity both in the plan and in property rights. As is often the case, Ho Chi Minh City's plans provide only general guidance on where growth should be encouraged and lack the specifics on permissible land uses and densities. This defect of vagueness is compounded by weak and confused implementation. The City's Office of the Chief Architect and the Department of Land and Housing, that are nominally responsible for implementing the plan, have few qualified staff. And the land permitting process is very cumbersome, and involves controls at the district as well as city level. Lacking better guidance and control, development is often opportunistic, where real estate promoters and city officials believe profits would be highest and resistance lowest.[8]

An added problem is that much of the land in the historic downtown and the neighboring port is occupied by government agencies that have the right to occupy the land only as long as they continue to use it for their official purposes. The inner-city port area, for example, contains nine terminals and shipyards operated by

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[7] This account of the reforms draws heavily from Firman (2003 and 2009, pp. 335-337).

[8] For criticisms of the 2020 plan see Urban Planning Institute of HCMC and Nikken Sekkki Consultants (2008, pp. 2-23 to 2-34) and Ha and Wong (1999).

various national and local agencies and the military. As it became apparent in the 1990s that the inner-city port was not big enough to accommodate the expected traffic growth, the government developed plans for a new port at a site 80 kilometers down the Saigon River where there was plenty of land for modern terminal operations. And in 2005 the Prime Minister issued a directive that the operators should build new terminals in the new port and abandon their inner-city sites by 2010. This deadline was ignored by the agencies, despite the fact that they had built terminals with more than enough capacity at the new port, largely because if they gave up maritime operations at the inner-city sites the land would revert to the state without compensation. The port operators were pressing instead for permission to develop their inner-city sites for commercial and residential uses, perhaps with some nominal maritime use to justify their continued control. But the upshot was that the transportation and economic benefits from redeveloping these valuable inner-city sites were being delayed (Thanh and Pincus 2011).

Mumbai's problem is not so much that sensible land use plans are not implemented than that some of the features of the plan are not sensible. In particular, since 1964 Mumbai has not only encouraged the formation of subcenters in the suburban areas but has sought to restrict the growth of Mumbai's central city, Greater Mumbai, by strict controls on the density of development as measured by the Floor Space Index (FSI). The FSI, which is called the Floor Area Ratio (FAR) in the United States, is the ratio of the floor area of a building to the area of the lot on which it sits. An FSI of 4, for example, means that a building has 4 times the area as its lot, which would imply 4-storey building if the building were built to the edges of the lot lines. Usually buildings are set back from at least some of the lot lines—to allow access, ventilation and light; to discourage the spread of fire; or for other reasons—so that a building with an FSI of 4 has more than 4 stories.

Many cities around the world use FSI limits to prevent areas from becoming more built up than the infrastructure can support or to ensure that new buildings fit in with their surroundings, but Mumbai's limits are unusually strict for a metropolitan area of its size. Mumbai initially set FSI limits of 4.5 in the central business district, 1.3 elsewhere in the peninsula and 0.5 in the suburbs. Mumbai's limits were typical of those adopted in the 1960s by other major Indian cities—such as Delhi and Kolkata—reflecting the concern of Indian planners that their cities were too congested already and that future rural-urban migration should be discouraged. But they are more stringent than those found in many other major cities: in Manhattan, for example, FSI limits of 12 are common in residential districts while limits of 15 are typical in office and commercial districts. Critics argue that the FSI limits raise housing prices unnecessarily in the center, forcing people of modest means to either live in slums or move to the periphery and commute long distances (Bertaud 2004). As a result, Mumbai has one of the highest population densities of any major city in the world despite having among the lowest FSI limits found outside of India

By the 1996 regional plan, however, officials had come to view the city not as over-grown but as a generator of economic development and the announced strategy changed from one of limiting growth in the center to facilitating that growth by building infrastructure (Mumbai Metropolitan Region Development Authority 1996, p. i). The FSI limits seem to have been largely retained, however, in part because officials had come to rely on using waivers from the strict controls to induce real estate developers to advance public purposes, such as building housing for slum dwellers. The waivers have value only as long as the FSI limits are low enough to keep housing prices high.

Building New Capacity Versus Managing Old

Another common feature of the plans in these metropolitan areas is a bias toward building new highway or mass transit capacity to cope with the growth in vehicle-kilometers travelled rather than seeking to manage the existing capacity better. The major focus of Ho Chi Minh City's plan for 2025, for example, is a proposal to build a 161-kilometer rail system—including six mass rapid transit (MRT) lines, a tram line and a monorail—for an "order of magnitude" cost of US$ 9.7 billion. The plan also calls for a number of highway improvements the most is a system of four elevated toll expressways within the city's second inner ring road. Similarly, Jakarta's plans call for building a 15-kilometer starter MRT line at a cost of $1.5 billion, for several billion dollars in improvements to the existing commuter railroad system, and for a 72-kilometer elevated ring road within the current inner ring road. Jakarta's most recent plans are notable in that they consider in some detail the possibility of discouraging auto use through an electronic road pricing system similar to those of Singapore or London and expanding the use of reserved bus lanes by extending the metropolitan area's bus rapid transit (BRT) system. And all three metropolitan areas plans call for reforms to the existing bus industry to improve the quality of service. But the main focus is on the rail and highway expansion capital improvement programs while the auto restraint and bus reform get little attention and are seldom implementing.

The bias toward new facilities is partly due to donor preferences. A new highway or MRT line is a visible and durable contribution to the city's development. In the case of bilateral aid, a portion of the funds are often recycled in the form of construction or equipment contracts to companies from the donor country. And multi-lateral aid agencies, like the World Bank and the regional development banks are primarily in the business of making loans for capital projects, although they also give loans and grants for technical assistance.

In addition, building new facilities often seems much easier than managing existing capacity. The main drawback to new facilities is if the right-of-way does not exist already but must be assembled by displacing homes and businesses. But if the right-of-way is not too much of a problem, a new facility seems to avoid the problem of dealing with incumbent interests. Tolling on an existing highway that motorists currently use for free or taking way an existing traffic lane for the exclusive use of buses is likely to generate many more objections from motorists than building a new highway. And reorganizing a bus system that is used by millions of commuters daily and provides a livelihood for tens of thousands of drivers, conductors, mechanics and others is likely to be much more controversial or complicated than opening a new MRT line.

But adding transportation capacity is often extremely costly per trip served. Jakarta, for example, has already invested quite heavily in the capacity of its transportation system. Over the last several decades Jakarta has built an extensive urban expressway network, financed in part by tolls, that includes a half dozen important radial expressways, an inner ring expressway just inside the border of DKI Jakarta and an outer ring expressway in the suburbs that is missing only a few segments to be complete. Jakarta has made fewer investments in its public transportation system, the most notable being the 174-kilometer TransJakarta BRT system opened over the last decade.

Further expansions of capacity are becoming progressively more costly and controversial. The difficulties are most obvious in the case of public transportation. For example, the first 10 lines of TransJakarta were built at a cost of only around US$ 230 million, but some of the key corridors had roadways with as many as five or six lanes in each direction, which meant that taking one of those lanes for the exclusive use of buses caused much less congestion and fewer complaints from motorists than it would have on narrower streets. The next five lines are being built in narrower streets where the taking of an existing lane for buses is more difficult. On those lines, planners are being forced either to pay the added cost of building bus lanes or flyovers on elevated structures or underground, or to accept degraded performance because the buses will have to operate for longer distances in mixed traffic. And as extensive as the TransJakarta system is it carries only abut 350,000 passengers a day, less than one percent of all passenger trips and less than one tenth of all bus trips in the metropolitan area (Gomez-Ibanez , Brandon and Hornig 2011).

The high cost of adding transportation capacity is even clearer in the case of Jakarta's MRT line that is currently scheduled to begin construction in 2012 and open in 2016. Proposals for an MRT system were advanced as early as 1975 but were delayed largely because of concerns that only a fraction of the cost could be recovered from passenger fares. The Japanese government has recently agreed, however, to provide 120 billion yen (13 trillion rupiah or US$ 1.53 billion) in financing, of which 42 percent will be a grant and 58 percent a loan to the central government on very generous terms. The sum is expected to cover 85 percent of the cost of constructing a 15-kilometer starter line, with DKI Jakarta responsible for the balance of the construction cost and any operating deficit. Even though the line runs down Jakarta's most congested north-south arterial (Sudirman), it is expected to carry only 173,000 passengers per day when it first opens and perhaps as many as 400,000 per day after five years. The net increase in public transportation trips is likely to be much smaller, moreover, because the MRT alignment parallels the most heavily used line on the existing BRT system, and presumably will capture most or all of its riders. And, even if all the MRT riders are drawn from cars or motorcycles rather than BRT, the projected ridership amounts to only one-half of one percent of the 37 million trips made in the metropolitan area during a weekday in 2002, or to only roughly one-fifth of the growth in passenger trips that might be expected in a single year alone.

Moreover, the perception that adding capacity is relatively easy is not always right. Some observers believe that TransJakarta's ridership is disappointing given the size of its busway network. And they tend to blame a variety of implementation problems including the lack of a dedicated or coordinated network of feeder routes and poor enforcement by traffic police against cars and motorcycles using the bus lanes. Solving some of these problems will be difficult, particularly the introduction of feeder services that are likely to fight for ridership with existing routes.

This is not to argue against expanding the capacity of the transportation systems of cities like Jakarta, Ho Chi Minh City or Mumbai. There may be many improvements to the highway and public transportation systems that are cost-effective. But one cannot rely on expanding capacity as the primary means of coping with the inevitable increase in passenger trips. Adding to capacity is increasingly costly and controversial, so that the increments to capacity that are likely to be built will be dwarfed by the growth in trips in the metropolitan area.

Adding significantly to capacity is difficult in part because the existing capacity of Jakarta's transportation system is so enormous, which implies that improving the efficiency of the existing system is potentially far more important than building new capacity. Much of the existing capacity of the system is in streets and highways, and one of the most important ways of squeezing more capacity out of the road system is to promote the use of modes of travel, like the bus, that have the potential to use roads more efficiently.

Table 1: Percentage of Trips in Jakarta by Mode Used, 1985 to 2010

	All trips in DKI Jakarta only (percent)			Work trips only in Jabodetabek (percent)		
	1985	2002	Difference	2002	2010	Difference
Non motorized	47.0	36.4	-10.6	23.7	22.6	-1.1
Motorcycle	10.7	14.0	+3.3	21.2	48.7	+27.5
Car, truck	12.2	11.3				
Taxi, bajaj	3.1	1.8				
Subtotal car, truck, taxi, bajaj	15.3	13.1	-2.2	11.6	13.5	+1.9
Bus	26.9	33.2	+6.3	38.3	12.9	-25.4
Other motorized	3.0	3.2	+0.2	5.3	2.3	-3.0
Total all modes	100.0	100.0	0.0	100.0	100.0	0.0

Sources: Figures for Jakarta DKI in 1985 and 2002 from Pacific Consultants International, "Trip Characteristics Based on Person Trip Survey in Jabodetabek", Technical Report Vol. 1 of The Study on Integrated Master Plan for Jabodetabek (phase 2), March 2004, p. 2-5. Figures for work trip in Jabodetabek in 2002 and 2010 from Coordinating Ministry for Economic Affairs, "Progress of Jabodetabek Urban Transportation Policy Integration Project," January 5, 2011, PowerPoint presentation, slide 12.

Table 2: Percentage of Trips in Ho Chi Minh City by Mode Used, 1996 and 2002

	1996, without walking		2002, without walking	2002, with walking
Walking	---	Walking	---	17.1%
Bicycle	20.4%	Bicycle	17.4%	14.4%
Bus	0.2%	Bus	1.7%	1.4%
Motorcycle	76.5%	Motorcycle	74.5%	61.8%
Car	2.2%	Car	1.4%	1.2%
Truck	0.7%	Conventional taxi and other	4.1%	3.4%
All modes	100%	Motorcycle taxi (Xe Om)	0.8%	0.7%
		All modes	100%	100%
Trips per weekday (millions)	8.2			11.9

Sources: 1996 figures from DFID 1998 Ho Chi Minh City Transportation Study as cited by Japan Bank for International Cooperation (1999, pp. iii and 12). 2002 figures estimates from Almec Corporation (2004, vol. 1, p. 2-17).

Table 3: Percentage of Person-trips and Person–kilometers in Mumbai Metropolitan Area by Mode Used, 2006

	Not including walk trips		Person trips
	Person trips	Person kilometers	including walk trips
Walk	--	--	60%
Bicycle	3%	1%	1%
Train	50%	79%	20%
Bus	23%	10%	9%
Taxi/rickshaw	9%	3%	4%
Motorcycle	7%	3%	3%
Car	7%	5%	3%
All modes	100%	100%	100%

Source: LEA International Ltd. (2008, p. 4-12). Shares with walk trips calculated by author based on 60 percent walk share from LEA International Ltd (2008, p. 4-11).

Table 4: Road Capacity and Fuel Used by Mode in Jakarta

	Pass. capacity	Typical peak pass	PCEs/ vehicle	PCEs/ 100 peak pass	Liters/ 100 km	Liters/ 100 pass-km
Automobile	5	1.2	1	83.3	11.7	9.7
Motorcycle	1	1	0.125-0.25	12.5-25	3.6	3.6
Large bus	50	51.4	2-4	3.9-7.8	28.6	0.6
Medium bus (microlet)	24	22.3	2-4	8.9-17.9	25.0	1.1
Small bus (angkot)	9-14	7.7	2	25.9	13.3	1.7

Source: Estimates of occupants per vehicle are drawn from the Japan International Cooperation Agency Study Team (2011, slide 18).

Table 5: Ground Level Air Pollution Emissions by Mode in Typical Developing Country Cities

	Pass. Capacity	Typical average pass	PM grams/ Km	PM grams/ pass km	NOX grams/ km	NOX grams/ pass. km	VOCs grams/ km	VOCs grams/ km
Automobile	5	1.2			0.1	0.08	0.6	0.5
Motorcycle	1	1			0.2	0.2	2.0	2.0
Large bus	50	37			28	0.8	3.6	0.1
Medium bus (microlet)	24	18			18	1.0	2.4	0.13
Small bus (angkot)	9-14	7			12	1.7	1.6	0.16

Rough averages of in-use emissions rates per vehicle kilometer in Pune and Mexico City from simulations using the International Vehicle Emissions model developed by Professor Jim Lents (2011) of University of California Riverside.

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