



Regulation and Design of Motorized and Non-Motorized Two-and-Three-Wheelers in Urban Traffic

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I.	INTRODUCTION	7
a.	Why a Study of Two-and-Three-Wheelers in Urban Traffic?	7
II.	SUSTAINABLE ACCESS AND MOBILITY POLICY FRAMEWORK? FOR TWO- AND-THREE- WHEELERS	9
III.	REGULATING TWO-AND-THREE-WHEELER USE	11
a.	Basic Definition	14
b.	Restrictions and Traffic Congestion.....	15
c.	Vehicle Restrictions and Safety.....	18
d.	Localized Noise and Air Pollution Issues.....	23
e.	Commercial Vehicle Regulation	24
f.	Restrictions based on Local Consensus.....	25
g.	Road Pricing.....	25
h.	Other Objections to Two-and-Three-Wheeler Operations	27
i.	Modal Targets	28
j.	Segregating Motorized Two-and-Three-Wheelers and Integrating Them Into General Traffic.....	28
k.	Segregating Non-Motorized Two- and-Three-Wheelers from and Integrating Them into General Traffic.....	35
l.	Controlling Motorcycle Access to Bicycle Lanes.....	40
m.	When Should Bikes, Rickshaws, Category I Motorcycles, Segways, or Other Light Vehicles Be Allowed to Operate on Sidewalks.....	45
n.	Integration with Bus Rapid Transit Systems.....	46
o.	Access Regulation Principles	48
p.	Parking of Two-and-Three-Wheelers in BRTs, Metro, and Bus Stations.....	49

EXECUTIVE SUMMARY

A growing number of Asian cities are experiencing a rapid rise in the numbers of motorized two-wheelers. In many of those cities, these vehicles account for the majority of traffic. This has significant ramifications, both positive and negative, for road safety, congestion, air pollution, economic development, and climate change.

Road design guidelines and traffic regulations in Asia are generally out of touch with contemporary traffic realities and hence are frequently incapable of optimizing heterogeneous traffic dominated by the motorized two- and three-wheelers. This paper examines the shortcomings in question and suggests areas for reform. The paper touches upon the non-motorized two- and three-wheelers only insofar as they are affected by the design guidelines and regulatory practices for their motorized counterparts. The former are more extensively covered in other documents such as Crow's "Design Manual for Bicycle Traffic" and ITDP's "Better Streets Better Cities: A Manual for Street Design in Urban India." For the detailed coverage of tailpipe emissions regulation, see ICCT's "Managing Motorcycles: Opportunities to Reduce Pollution and Fuel Use from Two- and Three- Wheeled Vehicles."

The inadequate regulation of both non-motorized and motorized two- and three-wheelers in Asia has a lot to do with the prejudice of public officials and the general population towards these vehicles. This paper is an attempt to reground the discussion of how to optimize two- and three-wheeler traffic in a rational, technical manner, not blinded by prejudices either "pro" or "con." It offers policy and design recommendations for further discussion by technical and political bodies. It also identifies the areas of significant uncertainty where policy and design would benefit from additional research.

The controversy around motorized two- and three-wheelers in Asia is rife because, under current regulation, they combine an extremely low operating cost with, often, an extremely high social impact, compared to the other modes. Therefore, design and regulatory guidance should aim to maximize the benefits and minimize the social costs of the motorized two- and three-wheeler operation.

Observations throughout Asia indicate that the passenger car unit equivalents (pcu) of two-wheelers tend to be in the 0.3 – 0.5 range, while the pcu for motorized three-wheelers will vary from 0.5 to as much as 2 depending on the average occupancy, vehicle mix, and other factors. This means that, except on free-flowing highways, motorized two- and three-wheelers are generally more efficient users of road space than normal passenger cars and taxis are. Due to their relatively light weight, motorized two- and three wheelers also use less fuel and generate less CO₂ emissions than their four-wheeled competitors. Regulation, road design, and public policy should thus encourage the users of private four-wheeled vehicles to switch to more efficient options such as motorized and non-motorized two- and three-wheelers, public transit, and walking.

Banning two- and three-wheelers as a congestion mitigation measure is of questionable use. The impact of two-wheeler bans on traffic congestion will depend on the redistribution of the

banned trips to other modes in each specific case. In Guangzhou, the motorcycle ban had a slightly worsening effect on the mixed traffic flow. While the majority switched to bicycle and bus, the congestion impact of those that switched to taxis and cars seems to have outweighed the benefits of the other modal shift. The impact of banning motorized three-wheelers on traffic congestion has not been studied, to our knowledge (though they have been banned on many corridors in many Asian cities); however, it stands to reason that the effects of such a ban depend on how the trips are reallocated. It is likely that this reallocation will have negative traffic impacts unless it is part of a program to create bus rapid transit, bicycle lanes, or otherwise restrict four-wheelers.

Currently, motorized two- and three-wheelers are significant contributors to air pollution and noise that cause considerable damage to human health and degrade the quality of life in adjacent areas. These problems are not inherent in the technology and should be tightly controlled through regulatory means.

Motorized two- and three-wheelers are disproportionate victims and perpetrators of traffic fatalities and injuries. This poor safety record is not inherent in the technology either; rather, it is the consequence of the increased use, weight, and speed of the vehicles. The specific causes and mitigation of accidents for this mode are insufficiently studied.

Both motorized and non-motorized two- and three-wheelers disproportionately violate traffic rules, especially by ignoring lane demarcations as well as by operating and parking in spaces not intended for them. This tendency stems from (1) significant travel time reduction by skirting the regulations; (2) lax enforcement; and (3) automobile-centered road design. The prime violators are motorcyclists, particularly in Yogyakarta, Indonesia, and Delhi, where they routinely invade pedestrian and cycling spaces.

This problem has been successfully controlled in some Chinese and Indonesian cities with the use of specialized infrastructure such as bollards, steps, and high curbs. These facilities, shown in this document, are mostly localized innovations, and a systematic study of their design has yet to be undertaken.

Incursions into bicycle lanes are harder to control. Widespread evidence suggests that bicycle lanes built in countries with high levels of motorcycle use are often taken over by motorcycles. Measures such as bollards and high curbs, which are generally effective at protecting pedestrian spaces, create inconvenience for cyclists and are likely to lead them back to using mixed traffic lanes.

Therefore, in cities with high volumes of motorcycles, the bicycle lanes must be designed to ensure that they are used by cyclists and not by motorcycles.

Evidence suggests that motorcyclists will only switch to lower-speed bicycle lanes when the latter are not heavily used and the mixed traffic lanes are congested. The incursion tends to occur at saturated junctions and can, therefore, be controlled by the construction of (1) barriers; and (2) specialized lanes and boxes for motorized two- and three-wheelers at such junctions.

The motorcycle-bicycle shared lanes are already in place in some cities (for example, in Kuala Lumpur); however, while the speeds on these facilities are significantly lower than those on high speed roads, they are still too high to allow safe mixing of the two modes.

Motorized two- and three-wheelers are disproportionately used in crime activity. This is not inherent in the mode but is a consequence of inadequate law enforcement. Where criminals have adopted motorcycle as a tool of criminal activity, police will need to develop methods of countering this trend. Proponents of motorcycles need to be aware that the growing popular hatred of motorcycles, particularly in Asia and Latin America, stems from motorcyclists' routine disregard of traffic rules and from the widespread use of motorcycles in criminal activity. These were the primary motive behind the motorcycle ban in Guangzhou, China.

Asia has a history of categorical vehicle bans that have been most frequently imposed on both motorized and non-motorized two- and three-wheelers. The most common justifications for the bans on three-wheelers have been (1) that they contribute to traffic congestion; and (2) that they put their operators and passengers at risk. Both justifications are questionable because (1) is as true of non-motorized two- and three- wheelers as it is of any other mode; and (2) is generally not the operator and passenger's fault. In reality, such bans are normally motivated by the elites' misguided attempts to preserve an appearance of social well-being.

The case for outright bans of motorized two- and three-wheelers is somewhat stronger, although banning is, generally, not the optimal solution. A city with well-regulated, clean, quiet, and safe motorized two- and three-wheelers would be better off than a city that bans such vehicles. However, a city that bans noisy, polluting, and unsafe motorized two- and three-wheelers while providing safer, cleaner, and efficient alternatives (such as buses in exclusive lanes and bicycles in properly designed facilities) is better off than the status quo. Hence the growing tension around the issue. Most governments are aware of their inability to regulate traffic with subtlety and thus regard bans as the only option. From the point of view of congestion mitigation, however, there is a stronger case for banning four-wheeled, rather than three- or two- wheeled, motorized vehicles.

Regulating motorized two- and three-wheelers is made extremely difficult by their wide differences in terms of speed, weight, emissions, and noise. In general, this report recommends that governments restrict the importation, licensing, and production of motorized two- and three-wheelers into two or perhaps three categories that are clearly identifiable by average citizens and police. This division of the vehicle fleet is necessary to make the appropriate regulation possible. The report does support a ban on all motorized two- and three-wheelers not in compliance with minimum emissions and noise standards, but it leaves the detailing of such standards to the International Council on Clean Transportation (ICCT). General recommendations are made for three categories of motorized two- and three-wheelers.

Category I should include all vehicles that are sufficiently clean, slow, quiet, and safe to operate with bicycles, non-motorized scooters, roller blades, and Segways. Regulatory policy and road design should encourage the use of these vehicles because of their high social benefits and low social costs. Such vehicles should be operated without license and be given: (1) priority access

to desirable locations in the city; (2) exemption from road user fees; and (3) facilitated parking. The definition of Category I vehicles should be discussed with manufacturers and governments; it should also rely on convincing health and safety data.

Category II should include all vehicles that meet licensing requirements, road worthiness, tailpipe emission, noise, safety, and other standards applied to all motorized traffic. The use of such vehicles should be accorded the same level of accommodation or restriction as the other motor vehicles that, to some extent, constitute a social nuisance. Regulatory structures in much of Asia are already moving in this direction.

The only difference between a Category II and a Category III motorized two- or three-wheeler should be the latter's proven capability of operating with reasonable safety at highway speeds. Category II motorized two- and three-wheelers may or may not be allowed on highways, depending on an each country's policy.

In terms of road design, there has been some experimentation with the segregation of motorized two-wheelers, particularly in Taiwan, China, India, and Malaysia. Our preliminary assessment is that Category I motorized two- and three-wheelers should be treated in the same manner as their non-motorized equivalents in terms of road design standards.

Segregating Category II motorized two- and three-wheelers from other traffic makes the most sense in the lead-up to junctions and at the junctions themselves where vehicle saturation is the highest. There is convincing evidence that providing motorcycles and motorized three-wheelers with a segregated lane at the approach to a junction or with a "motorcycle box" in front of the stop line for mixed traffic will significantly increase mixed traffic speeds in the corridor and hence the capacity of the junction.

From the point of view of road capacity, speed, and safety, the case for segregation of motorcycles and three-wheelers mid-block is less convincing and would require further real world case studies before any conclusions could be drawn. The currently available data from Chennai, Taiwan, and Sao Paulo is either negative or inconclusive.

The case for segregation is also fairly weak when motorized two- and three-wheelers account for over 60% of the vehicle mix.

There is some evidence, though limited, that forcing motorcycles to keep to the curbside and to make turns across the opposing traffic (left turns in the US-oriented traffic systems and right turns in the British Commonwealth traffic systems) may slightly reduce motorcycle fatalities, if at the cost of some travel speed.

It should also be noted that in Asian cities where the majority of motorized traffic is composed of motorized two- and three-wheelers, the normally required lane widths (between 2.6 and 4 meters) are likely to be irrelevant. Lane demarcation may be useless and counterproductive. Striping roads with narrow lanes (2.25 meters) creates, however, some minor benefits – e.g. it makes operators of larger vehicles to be more cautious.

Traffic modeling practices in Asian cities has not yet caught up to the fact that motorized two- and three- wheelers are far more central and efficient users of road space than most traffic models would assume. This lag in perception stems from the imported Western assumption that the standard unit of traffic is a car when, in fact, in many Asian cities it is a motorcycle. This means that the amount of road space required to accommodate existing traffic may be far smaller than is presumed by the current traffic models. This also means that two- and three-wheeler-dominated city roads can be downsized without compromising vehicle capacity and speeds, thereby allowing municipal entities to give away more road space to sidewalks, bikeways, and busways than would be possible in four-wheeler-dominated cities. This document reviews the shortcomings of existing modeling methods and also some approaches for adjusting them.

I. INTRODUCTION

The following is the first attempt at a comprehensive review of the best practices in regulation and design of two-and-three-wheelers in urban traffic. While it mostly concentrates on the motorized two-and-three-wheelers in Asian cities, the review treats this mode of transportation as only one among many. It recognizes that even tightly targeted measures will affect other modes, most directly pedestrians and non-motorized two-and-three-wheelers. Therefore, in the spirit of promoting the conception of complete streets and livable cities, the review treats street and road space as a whole, discusses motorized two-and-three-wheelers in relation to other modes, and touches upon issues relevant to other modes but analogous to those of two-and-three-wheelers. As part of the Institute for Transportation and Development Policy's (ITDP) work for the Clean Air Initiative for Asian Cities (CAIAC) and Sustainable Urban Mobility for Asia (SUMA) programs, the review offers a set of recommended policy and design guidelines for discussion with all stakeholders.

a. Why a Study of Two-and-Three-Wheelers in Urban Traffic?

Motorized and non-motorized two-and-three-wheelers are a major mode of transportation and are expected to remain so at least for the next three decades because (1) they provide excellent mobility solutions in the range of up to several dozen kilometers and (2) are inexpensive to manufacture, sell, operate, and repair compared to cars.

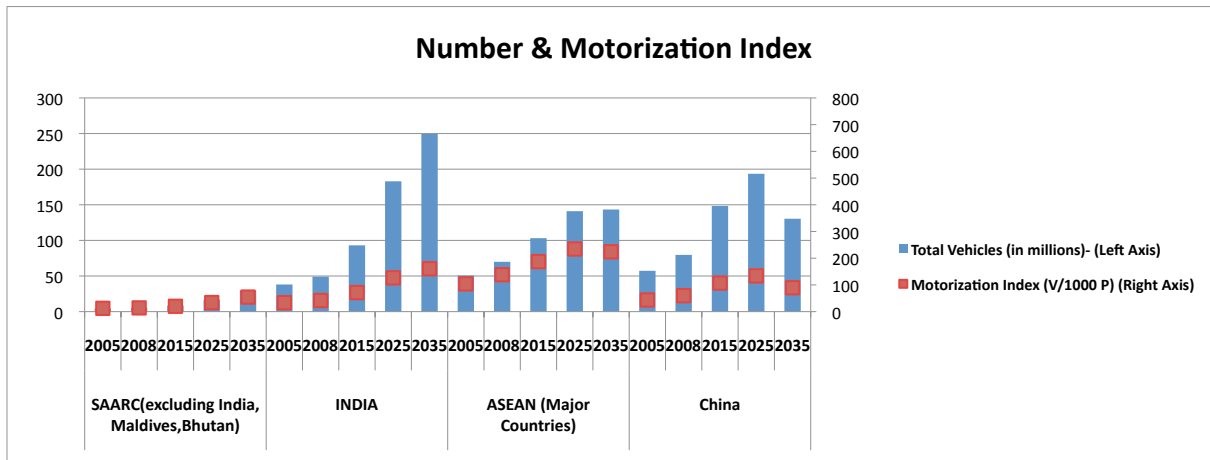
However, due to their growing numbers in cities worldwide, the intrinsic benefits of two-and-three-wheelers are increasingly offset by significant problems including, but not limited to, air and noise pollution, congestion, and safety and regulation issues. Many local governments have asked for guidance in optimizing their policies and design standards to maximize the benefits and minimize the problems of this growth.

Numbers

According to the current estimates, there are 300 million motorized two-and-three-wheelers on the roads worldwide. The precise number remains unknown due to unreliable registration statistics in many countries. It is known, however, that: 1) in 2006 over 44 million units were sold; 2) between 2003 and 2006, sales grew at the rate of approximately 14% per year; 3) Asia accounts for 85% of the total estimated number of two-and-three wheelers.

The fastest growing fleets of motorized two-and-three-wheelers are also found in Asia, though significant growth is occurring on other continents, too, including highly motorized North America and Western Europe. Several Asian countries with very large populations including China, India, and Indonesia still have a relatively small number of motorized two-wheelers on the road per capita; however, the market in these countries is expected to grow rapidly in the near future (Figure 1).

Figure 1. Two-and-Three-Wheelers in Asia



Source: CAI-Asia Center

Meanwhile, in the European Union, the fleet of motorcycles reached 28.4 million vehicles in 2005, which constitutes a 28% increase since 2000. In the United States, though starting from a low baseline and after a long, if slow, decline until the mid-1990s, motorized two-wheelers have become the fastest growing mode of transportation. Between 1997 and 2003, the number of newly registered two-wheelers rose by 262%.

Growth Factors

The increasing share of two-and-three-wheelers in urban traffic around the world is because of two main factors: urbanization and its rising costs.

In Asia, motorized two-wheelers have initiated and led the process of mass-motorization driven by urbanization, rapid population growth, and low per-capita income that have for decades characterized many of the developing countries in the region. Recent trends, such as rising household incomes and dwindling vehicle costs, have stimulated large numbers of people to upgrade to more powerful motorized two-wheelers (e.g. from those with 50-90 cc engines to those with 125-150 cc ones) as well as motorized four-wheel vehicles.

Nevertheless, it is noteworthy that rising incomes and increased car ownership do not necessarily lead to a declining role of two-wheelers, either motorized or non-motorized. In Taipei, China, where the total number of registered motorcycles was over 13 million in 2006, the majority of households own a car; however, there is also one motorcycle for every two persons, which translates into the highest motorcycle density in the world, or more than 356 per square km. In comparison, the Netherlands has seen the number of motorcycles double since 1998, reaching 634,000 motorcycles and about 500,000 mopeds and scooters for about 16.4 million people and 18,000,000 bicycles. Bicycle ownership also tends to rise with increasing income in parallel with car ownership, although the use of bicycles does not.

The resurgence of motorized two-wheelers in countries that have been highly motorized and dominated by four-wheeled vehicles for half a century or more is largely occurs in cities. The

rising cost of driving (fuel, tax, insurance) as well as road and parking congestion have combined to make motorcycles a more attractive option. Increasingly assertive public policies that discourage the use of single-occupancy vehicles are emerging in the cities worldwide. Measures such as reduction in road space (also known as “road diet”), removal of flyover and elevated motorways, on-street parking restrictions, and full pricing of road and parking externalities are becoming increasingly common. Light vehicles such as two-and-three-wheelers are less vulnerable to these policies than cars. For example, motorcycles have not been subjected to the congestion pricing recently established in central London and their use has risen by 40% since the institution of the toll zone. Moreover, the newly elected Mayor Boris Johnson ordered the bus lanes under the authority of the city-wide Transport for London to be opened to motorcycles in addition to previously allowed bicycles, taxis, and, indeed, buses.

Problems

Most road design and regulatory standards originated in Western developed countries where the use of two-and-three-wheelers has been quite low. In Asia and a growing number of cities in other regions, however, two-and-three-wheelers represent the majority of traffic, which renders the existing design standards and regulations increasingly inadequate.

The phenomenon of urbanization and motorization, driven to a significant extent by two-and-three-wheelers, has put a serious stress on the already overcrowded transportation systems and led to the acceleration of urban sprawl. Many cities are also facing increasing external costs of two-and-three-wheeler operation. For example, research from Hanoi indicates that vehicular emissions represent as much as 40% of the known local emission sources in terms of particulate matter. More specifically, motorcycles, which are the primary contributors to local traffic emissions, account for 43% of the total particulate emissions, 54.5% of carbon monoxide, and 54.1% of hydrocarbon. The impact of this transportation mode is further driven home by the complete ban on certain categories of two-and-three-wheelers in many cities across Asia.

In London, the Mayor’s initiative of allowing motorcyclists to share the Transport for London bus lanes with bicycles, taxis, and buses has been met with mixed reactions. Though it has satisfied motorcycle advocates, it has also disappointed bicycle and pedestrian advocates, who argue that sharing space with heavy and powerful motorized two-wheeler is a threat to their safety.

Whatever the effect of such ad-hoc traffic mitigation measures, it is clear that the growing use of two-and-three-wheelers must be adequately managed through enlightened urban transportation policies to reduce the environmental, social, and economic consequences. These consequences include, but are not limited to, worsening congestion, increasing air and noise pollution, declining safety of travel, and displacement of people by road widening.

II. SUSTAINABLE ACCESS AND MOBILITY POLICY FRAMEWORK? FOR TWO- AND-THREE-WHEELERS

The main recommendation for policy makers is that regulations and policies governing two- and-three-wheelers on urban roads be consistent with a sustainable access and mobility policy framework. Such a policy framework should strive to take advantage of all transportation modes, encourage their use for the most appropriate circumstances, while prioritizing access

and mobility provision that is the least costly in terms of emissions and nuisances, safety and security, energy and space consumption.

Personal motor vehicle operators (e.g., automobiles, motorized two-and-three wheelers, etc.) should be charged the full social cost of their use. Revenues raised from any taxes, licensing fees, parking fees, or road user charges imposed on such vehicles should be prioritized for rehabilitation of the degraded walking and cycling environments as well as public transport infrastructure. Any such charging mechanism should be proportional to the social costs of the use of that type of vehicle.

The social costs of operating non-motorized two-and-three-wheelers are far lower than those associated with their motorized counterparts. Therefore, in accordance with the best practices in both the developing and developed countries, urban transportation policy should, as a minimum, enable safe and convenient non-motorized travel, while urban real estate should be developed in a manner that encourages walking and cycling.

Much remains to be done, however, to understand and measure the full social cost and benefits of every transportation mode. From the point of view of traffic congestion, single occupant four-wheeled motor vehicles, for example, are the least optimal, but newer four-wheeled cars may be cleaner than motorcycles with two-stroke engines

So far, motorcycles and motorized three-wheelers have firmly occupied a significant place in transportation systems because they offer very convenient and comfortable high-speed travel at a very low cost. Generally they use less fuel than four-wheeled vehicles, and hence generate fewer greenhouse gas emissions¹. In some cities there is no public transportation system, and two-and-three-wheelers fill a critical gap in meeting the mobility needs of low and moderate income people serving as para-transit, moto-taxis, motor-rickshaw taxis, auto-taxis, and short-term rentals. As alternatives to personal motorization, their role in the transportation system needs to be recognized, while problems relating to the supply of such services should be mitigated.

Motorized and non-motorized two-and-three-wheelers are also highly efficient users of road space compared to four-wheeled vehicles, such as private automobiles. If all the current users of motorized two-and-three-wheelers were to switch to motorized four-wheeled vehicles, gridlock would increase significantly in many Asian cities.

Not all two-and-three-wheelers are the same. The social impacts of heavy, noisy, polluting, expensive, and fuel-inefficient two—and-three-wheelers are quite different from the effects of lighter, cleaner, quieter, fuel-efficient, and less expensive models. Policies should, therefore, affect not only modal choice but also vehicle choice within the two-and-three-wheeled motorized vehicle sector.

¹ The cumulative greenhouse gas emission from each type of vehicle is dependent on the percentage of the total number of each type of vehicle in the area under consideration. For instance, if there are many more three-wheelers than private four-wheeled vehicles in a given city, it is likely that the emissions from the three-wheelers will be higher. See the Hanoi example in 'Problems' section.

The economic impact of the two-and-three-wheelers should not be underestimated and under-regulated either. In some cities, both motorized and non-motorized two-and-three-wheelers are used as shared taxis. Improperly regulated, their use results in oversupply on some corridors and an undersupply on others, leading to destructive competition and unnecessary traffic congestion. Effective public management and regulation of commercial two-and-three-wheelers is necessary to ensure that the fleets remain in ample supply, that it serves the compact urban areas as evenly as possible, and that it provides clean, fair, and safe service without congesting the roads and undercutting the profitability of the business (i.e., where operators cannot afford to modernize their vehicles with cleaner engines). It is also necessary that regulation of commercial two-and-three-wheelers be coordinated with the regulation of the public transit system.

III. REGULATING TWO-AND-THREE-WHEELER USE

Principles

Ideally, regulation and optimization of any vehicle use should be based on a clearly defined *road classification system* and *vehicle classification system*. Historically, however, many cities in developing countries have not developed even a rudimentary road classification system – or if they have, it has been arbitrarily adopted from the developed countries without any real analysis of the local situation. In the absence of rational regulatory principles, city administrations have often based their regulatory decisions on mistaken impressions of political leadership.

Any analysis that intends to be the basis of functional road and vehicle classification systems – and thus of a functional regulatory process – should start with the understanding that roads are public space, and in modern societies public space is generally open and accessible to all. This right of access is critical to people’s ability to travel efficiently between their homes and places of work and commerce. However, this right does not historically extend free access to every possible vehicle and mode of travel because such access could compromise the safe, healthful, and efficient functioning of the public space. Governments, therefore, tend to retain ownership of the right of access to public space so that they can fully regulate its use for the greater social good and also fully control the nature of public investment in it.

Regulating and optimizing road use for the greater social good must reflect an understanding of different functions of different roads. For example, some roads are residential access streets, and their function may differ little from that of a playground or a front porch. Other roads primarily provide commercial access, and their function may be little different from that of the walkway in a shopping mall. At the other extreme, a road may be primarily used for hauling freight from a port onto an interstate highway system to distribute goods as quickly and as economically throughout the country as possible. It makes no more sense to have trucks speed through residential streets than have pedestrians walk on limited access expressways. For this reason, municipalities reserve the right to regulate access to different roads for different types of vehicles. Accordingly, any restrictions on vehicle use, especially as radical as bans, should be linked to the road classification system and based on optimizing the social benefits of the roads’ usage.

Restricting and Banning Two-and-Three-Wheelers

Some cities have banned various types of two-and-three-wheelers on specific roads and under specific conditions. Some of these bans have been based on legitimate concerns, while others have been based on lack of understanding and prejudice towards certain modes. As is the case with any policy, approach to bans should be rational, flexible, and in touch with the social reality of its application. A case in point is mode-specific economic restrictions and charging that have become an increasingly standard measure of traffic management in cities around the world. For example, such restrictions are now widely practiced and accepted in such Latin American cities as Bogota, Mexico City, and Sao Paulo, where motor vehicles with specific license plates are restricted on specific days. In Jakarta, private motor vehicles with less than three passengers are banned during peak hours on one primary arterial.

In Asia, it has been more common to ban, rather than restrict, both motorized and non-motorized two-and-three-wheelers. Politicians widely view them as a cause of traffic congestion, though there is generally no engineering basis for this view. Bans on access by motorized and non-motorized rickshaws, bicycles, and motorcycles in entire cities, zones, or on major arterials are quite common. Traditional (push or pull) rickshaws have mostly disappeared in Asia. Whether illegal or simply fallen out of favor, we are not sure. Calcutta is one of the few cities where traditional rickshaws continue to operate on a large scale, although there have been periodic attempts to ban them, too.

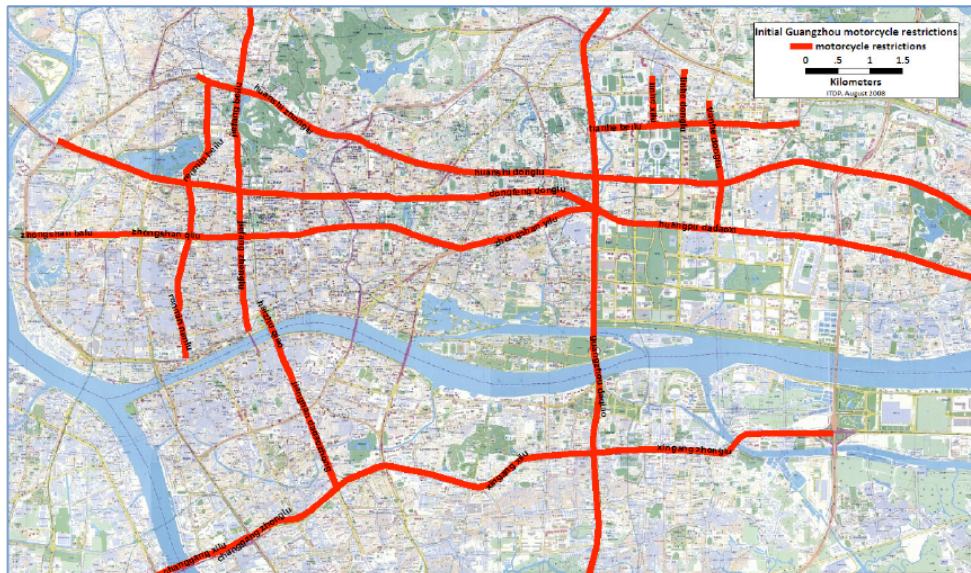
Cycle rickshaws face the most restrictions and are the subject of intense protest and debate in many countries. In China and Vietnam, cycle rickshaws generally operate in a legal limbo. They are not strictly legal or regulated in many cities, but they exist and are tolerated to varying degrees by local police. In Indonesia, Jakarta banned them in the late 1980s, then relaxed the ban with the economic crisis and the fall of Soeharto only to re-impose it in 1998 under Governor Sutiyoso. They remain legal and regulated in Yogyakarta and Solo. Though they are still popular on Yogyakarta's winding streets, cycle rickshaws have rapidly lost mode share to motorcycles and motorcycle taxis in recent years. In Surabaya, they are banned from primary and some secondary arterials but remain legal on most local streets. In India, they are still legal and nominally regulated in Agra, Hyderabad, Jaipur, Bharatpur, Mathura, Vrindavan, and several other cities in central India. They are either banned or, for some reason, not used in Ahmedabad, Mumbai, and Bangalore. Until 2007, cycle rickshaws were banned in New Delhi and allowed in Old Delhi where they were subsequently also banned by the Supreme Court to reduce traffic congestion. After having been unsuccessfully challenged in court, the ban remains in effect but is never enforced. Dhaka has begun to gradually ban cycle rickshaws from major arterials as well.

Just like their cycle counterparts, motor rickshaws are also banned in many Asian cities. Jakarta bans motor rickshaws on some primary and secondary arterials but not others. In China, they are not generally allowed, though they have sprung up as ancillary taxi services. Namely, in Shanghai motor rickshaw operators have taken advantage of a legal loophole and now operate as ambulatory vehicles for the disabled while providing, in fact, a general taxi service and being subject to occasional crackdowns. In most South Asian cities motor rickshaws are ubiquitous, legal, and imperfectly regulated as commercial vehicles.

Outright bans on bicycles are rare except in China, where they have been banned on a few major arterials in most major East Coast cities, effectively severing a large number of critical

travel links. On other roads, bicycles are legal, but Grade A cycling lanes have been replaced there with legal requirements to operate on congested sidewalks, effectively killing the mode.

Figure 2. Arterials Banning Cycle Rickshaws in Initial Phase of the Motorcycle Ban in Guangzhou, PRC



Motorcycles are legal in most of Asia. However, recently many Chinese cities have begun a progressive implementation of outright bans on motorcycles including lightweight electric bicycles, or e-bikes. Guangzhou is ahead of other Chinese cities in this respect, having entirely banned motorcycles and e-bikes throughout the city as of 1 January 2007. The motorcycle ban was implemented gradually over many years, with the first restrictions imposed more than 15 years earlier, in October 1991, and new motorcycle registrations limited to 500 per month. Restrictions on new registrations and usage of motorcycles were then extended temporally and geographically through different districts and roads, culminating in the complete citywide ban.

Motorcycle taxis exist in a number of Asian cities as well, though in many cases they operate in legal limbo and are subject to periodic crackdowns and control by criminal gangs. They have become particularly pervasive in Jakarta after the ban on cycle rickshaws. In China they often serve as feeders to bus and metro services.

The above examples make it clear that vehicle regulation in many Asian cities often lacks rational guidelines based on proper technical and legal classification systems. The following is an attempt to provide such guidelines, starting with a basic definition, with regard to two-and-three-wheelers in particular.

a. Basic Definition

A **bicycle** is any two-wheeled vehicle that is driven only by pedaling. An electrically assisted bicycle or e-bike is thus not a bicycle but an ultra-light motorcycle (see category I motorcycle below).

A **cycle rickshaw** is any three-or-four-wheeled passenger- or load-carrying vehicle driven only by pedaling. For the purposes of these recommendations, all becaks, pedicabs, and other local names for vehicles meeting this description will be called “cycle rickshaws”.

A **motorcycle** is any two-wheeled vehicle propelled by any type of power other than pedaling (including but not restricted to internal combustion engines and electric motors). For the purposes of these definitions, any two-wheeled motor-propelled vehicle, whether it is a single- or double-track one, will be considered a motorcycle. Thus the Segway PT and motorized scooters are here defined as motorcycles. This is important because, in the US, the Segway Corporation has attempted to obtain an “electric wheelchair” designation for their signature vehicle so that it could be allowed to operate on sidewalks where it has frequently been found a nuisance.

Motorcycles can be divided into the following sub-categories:

- i. Category I motorcycle (or ultra-light moped): has a maximum speed of 20 km/h, a maximum weight of 40 kg, and meets the most stringent air quality and noise standards.
- ii. Category II motorcycle (or moped): has an engine displacement of no more than 50 cm³, a maximum speed of 45 km/h, and a maximum weight of 65 kg.
- iii. Category III motorcycle: has an engine displacement of no more than 125 cm³, a maximum speed greater than 45km/h, and a maximum weight greater than 65 kg.
- iv. Category IV motorcycle: has an engine displacement of more than 125 cm³.

(Note: the categories cutout figures are up for discussion. Various countries have different categorization. Taipei, China, for example, divides motorcycles into three categories based on engine size: <50 cm³, 50-250 cm³, and >250 cm³. Improved international standardization is desirable.)

A **motor rickshaw** is any three-wheeled vehicle propelled by a motor, generally used for the commercial transport of passengers. Motor rickshaws should also be subdivided into three categories:

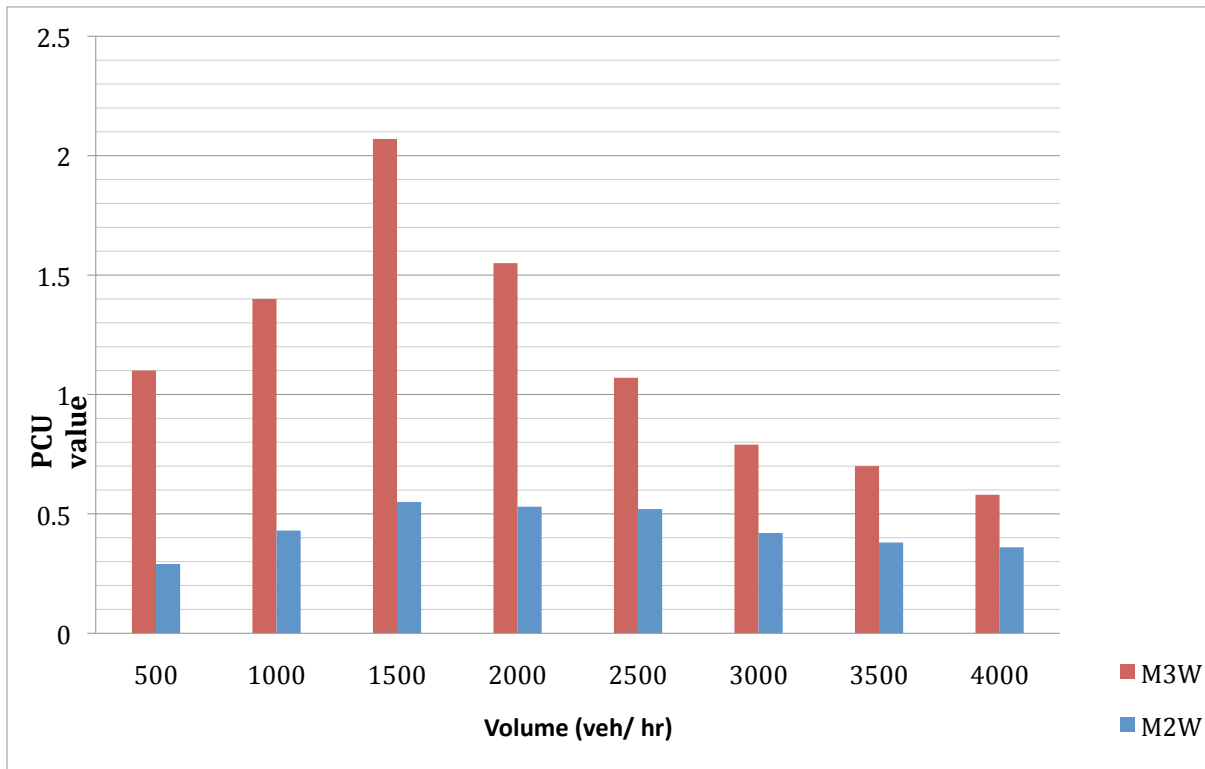
- i. Category I motor rickshaw: has a maximum speed of 20 km/h, a weight standard to be defined, and meets the most stringent air quality and noise standards (to be defined).
- ii. Category II motor rickshaw: has a maximum speed of more than 20 km/h but less than 45 km/h and a standard weight yet to be defined.
- iii. Category III motor rickshaw: has a maximum speed of more than 45 km/h and a maximum weight that has yet to be defined.

b. Restrictions and Traffic Congestion

The most typical explanation for categorical bans on two-and-three-wheelers in Asia is that they cause traffic congestion. Municipal authorities certainly need to retain the power to mitigate traffic congestion through restrictions on the use of specific vehicle types in specific locations or on specific lanes. Banning specific vehicle types under certain conditions may indeed be justified if a proper cost-benefit analysis were to prove that such a measure does mitigate congestion and reduce travel time. Such analysis always begins with the understanding that the congestion impact of a specific mode on a specific road depends on the operating characteristics of the mode such as maximum speed, passenger occupancy, and the load factor (passenger per vehicle), all of which vary according to local traffic conditions.

Standard tables listing the capacity characteristics of different modes and different Passenger Car Unit equivalents (PCUs) do not traditionally include much information regarding two-and-three-wheelers. What exists is rarely based on systematic empirical analysis. This scientific ambiguity lies behind some of the confusion regarding the congestion impacts of both motorized and non-motorized two- and three-wheelers. The following table assembles data available from different sources ("Transportation Strategies for Human Settlements in Developing Countries," 1984. (Nairobi: UN Habitat). Gallagher, R. 1992. The Rickshaws of Bangladesh (Dhaka: University Press Ltd., and other unpublished data).

Figure 3. PCU Values Observed at Various Volume Levels



Source: Arasan et al., Road and Transport Research, March 2008.

The wide ranges in PCU values for motorcycles and cycle rickshaws in the above table are largely the result of assumptions about whether the operator follows lane demarcations as well

as the load factor per vehicle. In North America, motorcycles are assumed to have no better capacity characteristics than single-occupancy motor vehicles because they tend to occupy a single lane and leave a large area around them for safety. By contrast, in India, where lane demarcation is rare and lane sharing and filtering to the front of the intersection are common, two-and-three-wheelers are found to have capacity characteristics that are roughly equivalent to bicycle, and three times as high as those of single-occupancy four-wheeled vehicles.

The PCU adopted for motorcycles in Malaysia is 0.75 for roundabout design and 0.33 for signal design (Ahmad, etc., 2000). In Vietnam it is 0.5 (Dao, etc., 2002). In Taipei, China, 0.33 is normally adopted as the official PCU value for transportation engineering. In mainland China, most traffic engineers assign a passenger car unit (PCU) equivalent of 1 to a cycle rickshaw, while in Jakarta it is standard to assign a PCU of 0.5 to cycle rickshaws. One study of a cycle rickshaw lane in Dhaka yielded 1000 passengers per meter per hour, or 3000 passengers per standard 3 meter lane width per hour, assuming 1.6 passengers on average (Gallagher, 1992). Because the cycle rickshaws measured were in homogenous rather than heterogeneous traffic, this is not a fair apples-to-apples comparison, so this measurement has been adjusted downwards.

In India, the PCU values of motorized two-and-three-wheelers range from 0.5 to 0.75 and from 1.2 to 2 respectively (the values are derived for the less than 5% and 10% or more mode share). However, research from Asia indicates that PCU for a vehicle type decreases with an increase in its own proportion in the traffic stream, suggesting that the Indian code needs to be revised.

Whenever a vehicle category is banned on specific routes, the existing passengers are forced to choose an alternative mode to reach their destination. This switch causes the traveler to use an alternative mode that is likely to be less optimal from the point of view of generalized cost, due to an increase travel time and cost. This shift, however, may have an aggregate positive impact as it may reduce the generalized cost for all other modes more than it increases the generalized cost to the operator of the restricted vehicle. Based on the above capacity ranges, the following can be concluded:

The only restriction measure that will successfully mitigate congestion is a restriction of access to specific lanes and streets by private, single-occupancy, four-wheeled motor vehicles and four-wheeled taxis.

Because the capacity characteristics of private cars carrying only one passenger is the worst, banning this type of travel mode will necessarily result in an aggregate social benefit because it will shift the passengers to an alternative mode that is a more efficient user of road space. The consequences of banning other vehicle categories are quite location-specific and thus much more difficult to predict.

In general, banning buses or pedestrians would almost never be a good idea from the congestion mitigation point of view. However, restructuring a bus route, for example, might dramatically increase the load factors per bus, reduce the number of buses per hour, and thus significantly reduce roadway congestion.

With regard to bans on all other vehicle categories, it is conceivable that there will be specific sets of circumstances where such restrictions will have an aggregate positive impact. Detailed

analyses of the motorcycle ban's impact on traffic congestion in Guangzhou and of the cycle rickshaw ban's impact on traffic congestion in Dhaka corroborate this point of view.

In Dhaka, the municipality banned cycle rickshaws in 2002 on the Mirpur Corridor, a major urban arterial. As is typical in many multi-purpose roads in Asia, the corridor served a combination of longer distance trips and shorter distance trips; hence it should be classified as a secondary arterial. The impacts of the ban were complex. Average travel times for primary work trips on the corridor fell by about 9 minutes (2004. "After Study on the Impact of Mirpur Demonstration Corridor Project," Barkat, A. et. al. Human Development Research Center, Dhaka Transport Coordination Board), but for non-work trips the travel time increased on average by 8 minutes (independent research by PATH Canada, 2005). Travel costs increased overall by about 9% (Barkat, 2004). The average displaced trip was 3 kilometers long, a distance well served by cycle rickshaw. There may have been some marginal net travel time savings, but they came at the expense of travel cost increases; thus the costs of the ban probably marginally outweighed any benefits.

This impact resulted because 25% of the former cycle rickshaw passengers shifted to walking. This population, which consisted predominantly of school children, mothers, and low-income garment workers, faced a doubling to tripling of their travel time, though their out-of-pocket travel expenses went down. This shift to pedestrian mode reduced roadway congestion in the short term both because pedestrians are more efficient users of road space than cycle rickshaws and because these trips take place partially on sidewalks rather than in the carriageway. Some 33% of the trips were shifted to buses, which were moving around 6000 passengers per three-meter lane, adding to reduced roadway congestion. Their door-to-door travel time increased slightly because waiting times for buses on the corridor are quite long, but their on-vehicle travel time decreased. Another 42% of the trips shifted to other forms of motorized transport, predominantly motor rickshaws, with similar capacity characteristics to cycle rickshaws. Thus, overall, the travel time benefit for motorists on the corridor was roughly similar to the added travel time imposed on the population now forced to walk, for roughly a zero net benefit.

Very few passengers shifted to private cars because they were too poor. However, within three years, the peak hour travel time benefit resulting from the removal of cycle rickshaws evaporated as the capacity was consumed by the growth of the private motor vehicle and taxi use of the road. These new motorists were disproportionately wealthier individuals who traded up from their motorcycle and taxi trips.

The ban also led to a 32% loss of net income by rickshaw pullers, who on average earned \$2 per day, with some of them earning less than \$1.25 per day, which is the World Bank's definition of poverty. Thus, while the ban clearly made a population of poor people worse off, it brought very marginal benefits. In our view, the optimal solution to traffic congestion in this case would have been to reduce the number of cycle rickshaws operating in the corridor by regulating their numbers through commercial licensing procedures; controlling other obstacles to smooth traffic flow like illegal vehicular parking and consideration of priority lanes for buses, ordinary cyclists, and possibly motorcycles could have also helped.

Banning cycle and motor rickshaws on any road with direct access to origins or destinations (1) disproportionately increases the generalized travel costs of low-to-moderate income populations; (2) leads to a loss of income among the poor; (3) creates only a marginal and

temporary improvement in travel times among general traffic. The following recommendation can be made.

Banning cycle or motor rickshaws on roads other than limited access freeways as a traffic mitigation measure is unlikely to be successful. Limiting the number of cycle (only cycle? – YES THIS NEEDS TO BE CHECKED) rickshaws through commercial vehicle regulation is a better way to proceed.

Bicycles and motorcycles are among the most efficient users of road space after buses and pedestrians. It is conceivable that under certain specific conditions banning bicycles or motorcycles will lead to slight reductions in traffic congestion, if the likely modal shift is towards greater bus ridership. In the past, Chinese officials frequently justified banning bicycles on key arterials on the grounds that it would lead to a modal shift primarily from bicycle to bus. This was, no doubt, largely true in the very short term, but over time the general trend of increased use of private cars has rapidly overwhelmed any traffic benefit of bicycle bans. Therefore, at present it is reasonable to conclude that

Banning bicycles as a traffic mitigation measure will not be successful.

Guangzhou is the only city for which we have data on the modal shift patterns that resulted from banning motorcycles. Traffic mitigation was not the cited reason for the ban. Two years before motorcycles were banned, they accounted for 20% of total trips. At the same time, walking accounted for 25%, buses for 30%, bicycles for 10%, cars for 5%, taxis for 5%, and other modes for 5% of total trips. After the ban, of the 20% motorcycle trips, 51% shifted to buses, 18% shifted bicycles, 18% shifted to cars or taxis, 9% shifted to walking, 2% shifted to the metro, and 2% shifted to other modes. Average traffic speeds on several major arterials that were measured before and after the ban showed a sharp decline. In the view of local traffic engineers, the motorcycle ban combined with gradually increasing car use to push the corridor close to an 80% saturation level, which led to sudden deterioration of road speeds. Based on this data, it can be concluded that

Banning motorcycles as a traffic mitigation measure will not be successful.

c. Vehicle Restrictions and Safety

Another reason that government officials often use as a justification for banning both motorized and non-motorized two-and-three-wheelers in specific locations is that the vehicles are unsafe both for the operator and others to operate. Indeed, in the cities where we have data, and where motorcycling is prevalent, motorcycles account for a disproportionate number of traffic fatalities. Particularly in China, motorcycles are banned in a growing number of cities in part for safety reasons.

Figure 4. Shared Street, Guangzhou, PRC: Motorbikes Integrate Well with Pedestrians, Cyclists, and Other Motor Vehicles on Streets Designed for Slow Speed.



It is important to understand, however, that safety conditions along any given roadway for any given vehicle are an aggregate of:

- a. the speed of traffic
- b. roadway design including visibility
- c. roadway condition
- d. operator behavior

When a pedestrian, a bicyclist, a motorcyclist or the user of a three-wheeler collide with a motor vehicle, there is a sharp increase in the likelihood that that the accident will be fatal at speeds over 40 km/h. At 30 km/h, there is about a 20% chance that the accident will lead to a fatality. At 50 km/h, the chance is 80%. Therefore, on any road with a speed limit of less than 30 km/h, there is no safety justification for banning any of the above-mentioned two-and-three-wheeler modes. The road must, of course, be designed to encourage travel at no more than 30 km/h. Ideally, road design should be based on their function, and any road providing direct access to any origins and destinations (that is any road other than a limited access highway) should be designed for safe operation by all of the vehicle categories allowed on that road link. There exist design solutions that allow for the operation of all vehicle types in the same right of way even at very high vehicle speeds.

Motorized accidents research in Delhi shows that accidents involving motorized three-wheelers most often involve other three-wheelers, followed by cars. Among the accidents involving two-wheelers, buses are the most frequent other vehicle involved, followed by cars, bicycles and other two-wheelers. While detailed analysis has not been done, it is the conflict between motorcycles and buses stopping for passengers or re-entering traffic that seems the most likely cause. One of the principal benefits of median busways is that they mitigate conflicts between buses and both motorized and non-motorized two-wheelers.

Malaysian Experience

- Motorcycles represent approximately 49.6% of traffic
- Motorcycles involved in 60 - 67 % of crashes
- Motorcyclists represent 50 - 57 % of deaths
- 33% of motorcyclists are involved in weaving
- 30% of helmet users not wearing helmet properly
- Only 24% of children are using a safety helmet
- Problem of motorcycle racing on public highway

Source: From presentation by Kulan K. C. Mani, Road Safety Research Centre, University of Putra Malaysia, at ASEAN Seminar, Viet Nam, March 2004, <http://www.grsproadsafety.org/knowledge-helmets-23.html>

Table 1. Conflicts of Two-and-Three-Wheelers with Other Vehicles in Delhi

	Car	Bus	2W	3W	Bicycle	Total
3W	24 %	17 %	17 %	25 %	17 %	100 %
2W	22 %	27 %	18 %	13 %	20 %	100 %

Source: Tiwari et al, *Accid. Anal. and Prev.*, Vol. 30, No. 2, pp. 207-215, 1998

Unsafe conditions can be either inherent in the design or a temporary condition. Both bicyclists and motorcyclists are highly vulnerable to deteriorated road conditions, debris on the road, burned out street lighting, and surface irregularities caused by roadway repairs. These temporary problems are best dealt with by proper road maintenance and warning signs to cyclists and motorists of temporary unsafe conditions, rather than via outright bans. Inherently unsafe designs on roads with speed limits of 40 km/h or above are sadly the rule rather than the exception in most countries. Intercity highways in developed countries are generally limited access highways with no direct access to adjacent properties, so restricting vehicle categories from these roads does not create an absolute obstacle to access to any property. In the case of developing countries, however, limited access highways are rare, and intercity highways frequently provide the only access to numerous properties. As a result, it is not unusual to see pedestrians, cyclists, and all manner of slow moving vulnerable road users walking along and crossing high speed intercity highways.

Certainly the preferable choice is to redesign the road for safe operation by all allowed modes. However, in the interim period, until the road is redesigned for safe operation, should operation and access by vulnerable users be banned?

If the primary risk is to the operator, and the risk is apparent to the operator, then a good case can be made for leaving the decision to the operator. All travel inherently involves some degree of risk, and the decision about risk is generally best left to the individual. Allowing bad road design to be a justification for banning vulnerable road users would establish a very dangerous

Vietnamese Experience

WHO (2004) stated that the main contributor to road crashes in Viet Nam is the rapid increase in the number of vehicles, particularly motorcycles, which increase by 10% every year. Nearly half of the motorcycle riders are not licensed, and three quarters don't comply with traffic laws. WHO further suggested that head injuries are the main cause of death among the riders of all two-wheelers. Helmets protect very effectively against such injuries. In order to reduce the fatalities, the Viet Nam government initiated the Helmet rule (Resolution 32), and preliminary results indicate that it was very successful.

“Over 80 percent of patients who arrive after traffic accidents were wearing a helmet. With all the patients with helmets who have head injuries, the trauma is much less critical. They have the same accident, but they're safe.” - Dr Nguyen Duc Hiep - <http://www.ipsnews.net/news.asp?idnews=41760>

precedent. Most of the roads in China which banned bicycles had well designed fully grade-separated cycling lanes of greater than 2.5 meters in width, or a Grade A level of service and excellent safety conditions, until these facilities were removed as a result of government decision. It would be absurd to ban bicycles on that route based on poor safety conditions when these poor safety conditions were created by an explicit policy hostile to non-motorized travel.

There may be unusual conditions on specific roads where circumstances lead to unexpected danger. An example might be a high-speed access ramp that leads to a local street that is not clearly visible to the operator. In general such conditions can be identified and mitigated through black spot analysis. They are better dealt with by warnings targeting vulnerable road users and by information regarding alternative routes rather than outright bans. Therefore,

Road conditions that are unsafe for the operators of both motorized and non-motorized two and three wheelers should be mitigated by changes in road design, visible warnings to at-risk operators, provision of alternative routes, and roadside information about these routes, rather than through outright bans on access.

If the primary risk is to other passengers and vulnerable road users, however, a stronger justification for restrictions exists. Category I motorcycles and bicycles, because of their light weight and slower operating speeds, are primarily placing their operators at risk, when the latter engage in unsafe behavior, not the operators and passengers of other vehicles. As such, normal bicyclists are not generally required to have an operating license and non-motorized cycle rickshaw operators are generally licensed primarily because they are commercial vehicles. There is some evidence that the sometimes erratic behavior of these non-motorized modes on mixed traffic roads may actually reduce the risk of fatal accidents for the remainder of the traffic by slowing down mixed traffic speeds, though it may lead to an increased level of minor accidents.

There are some streets and public spaces that are so narrow that even Category I motorcycles and bicycles are a nuisance. These include most sidewalks and other roads that have such high concentrations of pedestrian traffic where it is important to preserve the ambiance for strolling pedestrians and playing children. These areas should be designated as “pedestrian zones” or “sidewalks.” Generally, bicycles and Category I motorcycles must be walked by their operators in such zones. Nevertheless,

There is no convincing justification for banning Category I, II, or III motorcyclists, bicyclists, cycle rickshaws, or Category I, II, or III motor rickshaws on specific roads based on elevated levels of unsafe operator behavior among these modes.

While any vehicle operator may engage in driving behaviors that are unsafe for others, the operators of motorized two-and-three-wheelers are more frequently accused of unsafe behavior with some justification. Motorcycles are certainly one of the most dangerous forms of travel, accounting for a large share of traffic fatalities and injuries. It is very easy to track the number of cases where motorcyclists are the victims of the accident but harder to track those where motorcyclists are the cause of an accident or fatality. Nonetheless, they are frequently accused of being both.

It has been cited that the operators of motorized two-and-three-wheelers may engage in higher levels of unsafe behavior than the operators of alternative modes because:

1. These vehicles are somewhat easier to obtain and operate without a license and therefore harder to penalize for traffic infractions.
2. Their movements are harder to control by physical barriers.
3. They are particularly popular with younger drivers and lower income delivery service operators, who, in general, have poorer driving behavior.
4. Many small displacement and electric motorcycles as well as motor rickshaws have slower operating speeds than other vehicles, which encourages their operators to go the wrong way down one way streets where it cuts travel time.

The operation of a motorcycle with an engine displacement of more than 50 cm³ generally requires an operating license, and many countries are requiring licenses for smaller bikes as well. Yet it is quite typical for more than 30% of these vehicles to be operated without a license. It is also fairly typical for the operators of other motor vehicles to operate without a license in these countries, but the percentages of unlicensed vehicles are often higher among lower cost motorized two-and-three-wheelers. Unlicensed drivers are often harder to control through traffic fines. This is indeed a problem, but it is controllable through tighter enforcement without requiring complete bans on the mode.

Both motorized and non-motorized two-wheelers are quite agile and able to jump curbs, drive over medians, up pedestrian ramps, and engage in other activity that would be all but impossible for a three- or four-wheeler. This is only partially controllable through tighter enforcement and modifications in the design of infrastructure.

The age of the operator is something that can be controlled through changing the allowable driving age and tightening of enforcement. Legal driving age and the prevalence of crashes in particular age groups should be reviewed to inform the issuance of international standards. The tendency of both motorized and non-motorized two-and-three-wheelers to take shortcuts is particularly strong in Asia where there are many one way streets, a long-distance apart street grid, and very limited opportunities for crossing roads and turning around to reach specific destinations. The time penalty imposed on a passenger by the indirectness of route is directly proportional to the vehicle speed.

This problem can be best mitigated by allowing some two-directional movement on both sides of major carriageways in slow moving vehicle zones, and by creating frequent safe crossing possibilities. In addition, tighter control of illegal behavior can be managed. There may be some

streets or parts of streets where it is difficult to achieve safe and comfortable mingling of Category II motorcycles and motorized three-wheelers with more vulnerable road users. Such locations should be defined as bicycle lanes and restricted to Category I motorcycles and bicycles only. In general, then:

Banning bicycles, cycle rickshaws, motorcycles, or motor rickshaws, from specific streets because of frequent illegal behavior by some operators is discriminatory and should be avoided. Illegal activity is not exclusive to this class of vehicle, even if it is more typical among the operators of this vehicle type. The problem is better dealt with through improved design standards and tighter enforcement.

That being said, there are cities like Sao Paulo where so many motorbike operators engage in crime and socially unacceptable driving behavior that enforcement and other measures have proven impossible. These guidelines therefore reserve the right for the governments to ban vehicle categories if a sufficiently legitimate political mandate exists to do so.

d. Localized Noise and Air Pollution Issues

Most governments regulate the emissions of motorized two- and three-wheelers, and some also regulate their noise and speed. This general regulation will be discussed in a later section on overall emissions and noise regulation. This section will discuss only whether particular characteristics of specific areas may warrant banning certain categories of two-and-three-wheelers in those areas.

The first point to be made is that:

Category I motorcycles, bicycles, and non-motorized vehicles by definition generate minimal emissions and noise, so there is no environmental or noise justification for banning them anywhere.

A citywide tailpipe emission and fuel standard must reflect an understanding that the health risk of an emission is a function of the number of people exposed to concentration of pollutants in specific locations. The tighter the overall tailpipe emission and fuel standard, the lesser the health risk for large numbers of people in high concentrations of pollution.

Pollution and noise from motorized two-and-three-wheelers are frequently quite severe and worse than pollution and noise from cars (Table 2). It is therefore possible that concentrations of these vehicles on specific streets are exposing significant populations of urban residents and office workers to unhealthful levels of particulates and other emissions. In an East-West Center study measuring the exposure to pollutants while on a motorbike, walking, in a car, and in a bus in Hanoi, Viet Nam, the exposure reached $580\mu\text{g}/\text{m}^3$, $495\mu\text{g}/\text{m}^3$, $408\mu\text{g}/\text{m}^3$, and $262\mu\text{g}/\text{m}^3$ respectively (Saksena, et.al. 2006).

In an ideal world, municipal authorities would be required to ensure that concentrations of unhealthful emissions would not be allowed anywhere in the city where a part of the population faces significant risk of exposure. In practice, the regulation of ambient air quality even in developed countries is done only at the municipality-wide level, and the mitigation measures are often quite general in nature rather than site specific.

Table 2. Motorcycle Share of Total Transport Emissions in Selected Asian Cities

City	VOC	CO	PM	NOx	CO ₂
Ho Chi Minh City, Vietnam	90%	70%	No estimate	12%	40%
Delhi, India	70%	50%	No estimate	No estimate	No estimate
Bangkok, Thailand	70%	32%	4%	<1%	No estimate
Dhaka, Bangladesh	60%	26%	42%	4%	No estimate

Source: Mezler 2007

However, this is gradually changing with the introduction of new tools for modeling site-specific emission concentrations. Therefore, the following recommendation is legitimate:

If a city or part of a city is not in compliance with an internationally or nationally recognized ambient air quality or noise standard, municipal authorities are justified in banning any vehicle types in the non-compliance area if the ban brings the area back into compliance with the norm.

An example of this recommendation in effect is the current air regulation policy in Mexico City. If the city finds itself in sufficient and sustained violation of the ambient air standard, the municipality begins placing restrictions on the use of certain types of vehicles. Ideally, the problem of air quality in Mexico City can best be avoided by instituting general and tight enough tailpipe emission and fuel standards.

e. Commercial Vehicle Regulation

The bans on cycle rickshaws in Dhaka, Bangladesh, and other places, as well as the bans on motorized rickshaws and motorcycle taxis elsewhere are sometimes justified on the grounds that there is an oversupply of them in relation to the demand for their services. As a result, there are many idle cycle rickshaws or motor rickshaws occupying scarce road space and generating needless pollution and congestion. This is a legitimate concern that is as true of the cities with unregulated taxi fleets as it is of the cities with a multitude of cycle rickshaws. Whenever a commercial transportation service, whether it be taxi, cycle rickshaw, bus or minibus, is completely unregulated, the result is an overconcentration of services and vehicles along the most lucrative routes, and a scarcity of services on the less popular ones and in peripheral areas.

This problem is generally overcome if the competition for specific segments of the market for these services is limited by the issuance of commercial operating licenses and sometimes by linking the operating license to specific zones or routes. The problem is also partially solved by providing designated waiting areas for the vehicles and not allowing them to cruise for passengers. Normally, if the operators themselves are involved in setting the number and location of services that are appropriate to a given area, they will be more or less self-regulating because they would like to limit competition in order to maximize their own profits. The oversupply of a commercial transport service on a particular route does not, however, constitute a justification for outright banning of the vehicle. Therefore:

Restricting the number of cycle rickshaws, motorcycle taxis, or Category I – III motor rickshaws on where and whether they are allowed to cruise for passengers and on where and whether they are allowed to park is necessary to protect the public interest, but

these specific restrictions are a better alternative than outright bans of the vehicles on specific streets or in specific zones.

f. Restrictions based on Local Consensus

Roads in any city are regulated by different levels of government. Intercity roads are generally provincial or national roads, major urban roads are generally under the municipality, and local streets are sometimes under the municipality and sometimes controlled by sub-municipal governments. Streets with only local access functions may be controlled by local ordinances that are passed by sub-governmental bodies to satisfy the desires of the community. This could lead to bans on any vehicle category for a variety of reasons. In Jakarta, for example, the Governor banned cycle rickshaws throughout the city, and motor rickshaws in some areas, but some of the district governments and local villages inside Jakarta wanted to retain them for local trips. Other areas wanted cycle rickshaws banned locally even before the blanket ban was imposed because they blamed cycle rickshaw operators for petty criminality or simply felt the rickshaws were an eyesore. In general, the city may often wish to tolerate even noisy motorcycles or motor rickshaws on major roads, but some local neighborhoods may want to ban them because they disrupt the neighborhood's tranquility. Some neighborhoods would even like to ban pedestrians and cyclists who do not reside in the neighborhood for security reasons, gating their communities off even if the streets are marked as public roads. The degree to which local control should be allowed to make decisions about modal access to local streets is an open question, but certainly:

Access to roads should be determined by the appropriate level of government. Local access streets should be controlled by the most localized form of government, secondary and primary arterials by the municipality, primary arterials that are part of a provincial road network should be governed by the provincial government, and roads that are part of the national road network should be governed by the national government.

If, for any reason, the opinion of the majority of residents or the duly elected representatives of this appropriate level of government is to ban certain categories of vehicles in specific locations, this opinion needs to be taken into consideration.

g. Road Pricing

The less space-efficient the vehicle, the more its operator has to pay for its use in the public space. Two- and three-wheelers can be made less attractive on short urban trips, where walking or pedal-powered bicycles provide convenient alternatives, by raising the cost of operating motorized vehicles. The rationale for raising the cost of driving above current practices is that cars and powered two-and-three-wheelers should be made to (1) pay for their full social cost and (2) pay a premium for the use of the very scarce public space/right-of-way resources in urban settings.

Regarding road pricing, the first goal should be to improve knowledge of the nature and cost of the various externalities linked to the use of each transport mode, particularly personal motorized vehicles including two-and-three-wheelers. Emission of pollutants and greenhouse

gas, construction and maintenance of road and parking infrastructure, consumption of public space resources, noise, strains on the emergency services and health care, urban sprawl inducement, and more should be legitimately taken into account. Currently, simpler road pricing models, used in Taipei, China and Singapore, are based on emissions (Taipei, China) and on maintaining the peak efficiency rate of roads (Singapore), respectively. These models should be evaluated for their replicability across the region.

A strict periodical environmental certification of each vehicle following emission tests should be a basic policy. Vehicles not meeting the assigned standards should be set to pay higher, graduated fee or simply be banned from the streets. Such policy should be coordinated with safety inspection and maintenance, as well as traffic law enforcement. Road pricing is still a young technology, both in the West and in the East, but a number of precedents, nonetheless, present learning opportunities.

In Germany, a truck toll doubled the rate of scrapping highly polluting old trucks while having no impact on shipping rates. In London, congestion relief and emission-based charges have been implemented within the city center zone. The cleanest vehicles pay no fee. A daily flat fee is enforced via high-tech cameras and registration number tags. About half of the collected revenue ends up funding the fee collection process. Many exemptions, however, undermine the London model. For instance, the charging system is too complex to be directly replicable in developing countries in any short or medium term, not to mention the need for an in-depth analysis of the local situation before such measures are replicated in a developing world context.

In Stockholm, the charge is per entry and depends on time. So far, Singapore's system has proved the most efficient: it cut motor vehicle traffic by about 45% in the center while only about 5% of the system's revenues are spent on collecting the fees. The system relies on tollgates, transponders, a fully automated GPS system, and cooperation of private banks. Each vehicle is fitted with a transponder, at the cost of about \$150 per vehicle, covered by the Authority for the Vehicles in Service at the time of initial implementation of the system. Toll prices are adjusted every three months to maintain the peak efficiency rate of the road's operation. Motorcycles pay a 0.5 PCU fee.

The other promising technology is the embedding of GPS chips in the frame of each motor vehicle allowed on the road. Currently offered by only a few firms such as Canada's Skymeter and a subsidiary of Deutsche Telefon, the chips cost around \$200 a unit for a whole region. However, this price is likely to drop sharply as chips begin to be mass-produced. Countries in Asia should implement policies that will allow them to take full advantage of this technology when its cost and availability will allow, without compromising on the complete privacy. Systems that are easily readable by automated equipment should be implemented as soon as feasible even if they are of no immediate use, so as to facilitate future steps.

In the meantime, transposition of technologies, practices, and policies to developing countries is possible but probably entails identifying a spectrum of locally appropriate regulatory solutions rather than a one-size-fits-all solution. While, technologically simpler models such as those deployed in Singapore in the 1970s before electronic congestion charging and those currently in place in Taipei, China, are available, they still require fairly well-organized institutional frameworks for rigorous implementation.

The first step to implementation of an effective road pricing system is systematic and comprehensive motor vehicle registration that includes all motorized two-and-three-wheelers. Weak registration and maintenance requirements, which have characterized many developing countries in Asia, must be strengthened. Furthermore, **innovative road pricing should also encourage the use of two-and-three-wheelers that have lower weight, operate at slower speeds, and generate fewer emissions and less noise.**

h. Other Objections to Two-and-Three-Wheeler Operations

With respect to the problem of labor exploitation in commercial operations (taxi, freight, etc.), sociological studies and interviews with cycle rickshaw drivers indicate that the population operating these vehicles generally has limited alternative employment opportunities. These opportunities tend to include day labor at construction sites, seasonal agricultural work, and factory work. In India, where the research was conducted, almost all laborers preferred operating a cycle rickshaw to the alternative forms of employment available to them because they found the work less strenuous, did not have to report to a boss, had huge personal freedom, and generally received much better pay. Technological innovation in the design of cycle rickshaws has significantly reduced the strain imposed on the operator. The emergence of cycle rickshaws even in developed cities like New York, Berlin, and San Francisco, where they are mostly operated by college students or professionals wanting to have fun and make a few extra dollars, also indicates that this mode of work is not inherently exploitative. Objection to cycle rickshaw employment on the grounds that it makes village-city migration less controllable is irrelevant to the issues of traffic regulation. From the point of view of this objection, all low-level urban employment would have to be banned in order to control village-city migration effectively. Presently, it seems reasonable to believe that:

There is nothing inherently exploitative about employment in the non-motorized commercial vehicle sector, and, in many ways, employment in this sector is preferable to available alternatives. Giving potential workers more, rather than fewer, employment opportunities will always be to their benefit, so long as there is nothing inherently dangerous or unhealthy about the employment option. While neither perfectly safe nor perfectly healthy, employment in the non-motorized commercial vehicle sector is as good as or better than other generally available options.

The issue of the operators' criminality is a real problem in some cities. For commercial activities such as taxi operation this problem can often be handled by tightening regulation of this commercial vehicle category. Forcing all operators using a particular waiting area to be licensed and registered, for example, is generally sufficient to eradicate criminality in this sector. For bicycle and motorcycle-assisted theft, data from Guangzhou indicates that 41% of purse snatches are perpetrated from motorcycles. This was a major factor behind banning motorcycles in the city and a major reason why the public sentiment expressed in public hearings often favored the ban.

Persistent criminality among motorized two-wheeler users has been addressed by categorical bans in this vehicle type, but there should be other ways of addressing this problem that do not infringe the civil liberties of law-abiding two-wheeler users.

i. Modal Targets

Some cities and countries precisely define mode share targets in their overall planning guidance. London has passed planning guidance indicating that the mode shares of both bicycling and motorized two-wheelers should be increased. Many Chinese cities have undertaken a reduction of the modal share of powered two-and-three-wheelers (See Annex 2). Guangzhou has set this mode share to zero as of January 2007.

Other cities in China have established planning guidelines encouraging cycling for distances of 6 km or less for cities with a population of one million and above, and 10 km for cities with population below one million. They also set planning guidance for the modal share relationship between cycling and public transit. In the context of China, this was done in an effort to reduce the modal share of cycling and increase the modal share of public transit. However, no modal targets were set either for taxis or private four-wheeled motor vehicles, which makes it impossible to justify the effort to reduce cycling share in favor of public transit from the traffic congestion mitigation point of view. **It is imperative that modal targets include all vehicle types; it is also advisable that guidelines for vehicle use be defined based on the relation between city size and travel distance.**

j. Segregating Motorized Two-and-Three-Wheelers and Integrating Them Into General Traffic

Only a few cities in the world have attempted to segregate motorcycles from the general traffic. Special motorcycle lanes have been built in Taipei, China, Malaysia, Brazil, mainland China, and a few other countries. The purpose of this segregation has been to improve the capacity of the roadway and to reduce accidents. The capacity of a road can increase when motorcycles are provided with special lanes and enjoy special treatment at intersections because they can move far more passengers per lane than private cars and because they start faster than most traffic at signalized intersections.

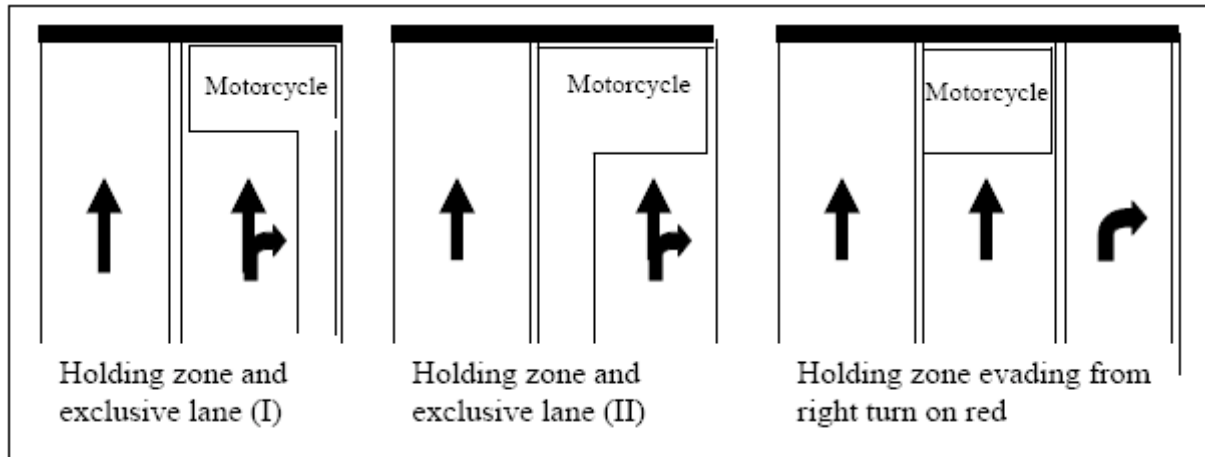
Experience from Taipei, China

Taipei, China, is one of the few countries to have built special motorcycle infrastructure and studied its impact. Taipei, China's segregated motorcycle lanes are, for the most part, separated from regular traffic only by painted lines. There are no physically separated motorcycle lanes in there except over certain bridges and for short sections on the approaches to bridges.

Chinese experts (Hsu, 2006) defined a design parameter called the "disarray rate" which is the amount of meters of lateral movement per every 10 meters of forward travel by the average vehicle. Studies indicate that the "disarray rate" is highest when the modal share of motorcycles is between 35% and 65% of the total traffic. Above or below this percentage, the disarray rate drops significantly.

The disarray rate has several noteworthy characteristics. First, it tends to slow down traffic speeds, and slower speeds lead to fewer fatal accidents. Further research is necessary, however, before a direct correlation between a higher disarray rate and higher levels of traffic

Figure 5. Motorcycle Turning Lanes



fatalities can be established. It is very likely that higher disarray rates lead to higher numbers of minor accidents but fewer fatalities due to its depressing influence on vehicle speeds. It is also noteworthy that the disarray rate actually drops when the modal share of two-wheelers in mixed traffic increases above 50% to 60%. Beyond this level, then, the benefits of creating segregated lanes for motorbikes drops. Third, the disarray seems to occur regardless of whether and how road lanes are demarcated. A high disarray rate means that the road lane demarcation has become meaningless. Based on this knowledge, we arrive at the following tentative principles:

- 1. For roads where motorcycles and three-wheelers constitute over 50% of the vehicle modal split there is no point in separate lane demarcation.**
- 2. A segregated motorcycle lane may be called for if there are more than 1000 motorcycles per hour and if motorcycles represent between 10% and 60% of traffic.**
- 3. Roads with an intended operational speed of 40 km/h or less should be designed for safe integration of traffic at slow speeds rather than segregate different forms of traffic into special lanes.**

The location of a motorcycle lane with respect to mixed traffic is a matter of debate. The Taipei, China design guidelines offer three options (see Figure 5 below). Motorcycles can: (I) have a special lane adjacent to the curb; (II) have a special lane between a mixed traffic curb lane and a car lane; (III) share a somewhat wider than normal curb lane with mixed traffic. Design II is generally preferable because it has the advantage of avoiding conflicts with right turns, stopping vehicles like buses and taxis, and pedestrians and cyclists in the curb lane.

Where present, the motorcycle lane in Taipei, China, is generally accompanied by a holding box at the junction if the number of waiting motorcycles per signal phase is greater than 10, or 800 motorcycles per hour. Because motorcycles can start much faster than a regular vehicle, they clear the intersection faster than other vehicles. The space of the holding zone must be 0.8 meters wide by 2 meters long per waiting motorcycle per signal phase. The motorcycle holding area can extend across multiple mixed traffic lanes so long as it does not disrupt the function of

Table 3. Effect of Head Start Holding Zone, Before and After Study

Before and after study, effect of head start holding zone	Motorcycle traffic		Car traffic	
	Before (without holding zone)	After (with holding zone)	Before (without holding zone)	After (with holding zone)
Saturation flow (vph)	7668 motorcycle/hr (using the data of the first 6 sec of green time)	11040 motorcycle/hr (using the data of the first 6 sec of green time)	1492 car/hr (curb mixed lane)	1801 car/hr (curb mixed lane)
			1901 car/hr (inner car lane)	1950 car/hr (inner car lane)
Delay effect	reduce 4.8 sec/motorcycle in after case		reduce 4.3 sec/car in after case	

Source: Hsu, 2006

any allowed right and left turning movements. By allowing motorcycles to move to the front of the traffic cue, the efficiency of the junction is increased. Tests of roads with the head start holding zone for motorcycles in Taipei, China, indicated an average reduction of delay by 4.8 seconds per motorcycle and 4.3 seconds per car.

Studies of motorcycle accidents in Taipei, China, indicate that the majority are one of two types: sideswipe collisions along roadways caused generally by lane switching behavior, and both head-on and sideswipe collisions at intersections involving left-turning motorcycles.

Motorcyclists tend to drive down the space between the curb lane and the mixed traffic lane adjacent to it, whether or not this space is marked as a motorcycle lane. When they reach the intersection, they will proceed forward until they reach a storage area if one has been provided. If the road is two lanes or less, they are generally allowed to turn left by moving across the road and to the front of the left-turn lane.

However, this movement of motorcycles from the right to the left-turn lane (in India, Malaysia, Singapore, and Indonesia, the movement would be from the left to the right) sometimes leads to accidents. To minimize the number of left-or-right turning accidents while maintaining simple and efficient signal phasing, some intersections have banned left turns by motorcycles and require them to make a two-phase turning movement. Hsu (2006) recommends this configuration if there are 200 or more left-turning motorcycles per signal phase and three or more mixed traffic lanes.

If direct left-hand turns are banned, motorcyclists wishing to turn left must proceed through the intersection during the green phase and then wait in a specially designated waiting area ahead of the pedestrian crosswalk in front of the perpendicular traffic. This design introduces some additional delay for motorcycles reaching the intersection during the red phase. If a motorcycle reaches the traffic signal during the red phase, it must proceed to the perpendicular road and wait through the entire signal phase to turn left, while motorists can make a direct left turn. In cities without strict enforcement capacity, such left-turn configuration tends to lead motorcyclists to make illegal left-turns to save time.

Table 4. Motorcycle Traffic Management in Taipei, China

Time	Countermeasure	Location	Comments
1984	Two-stage left turn regulation set up	Taipei	Now spread to whole country
1997	Helmet wearing duty imposed	Whole country	With extreme enforcement
1997	Headstart waiting zone set up at the stop line	At three locations in Taipei	Now spread to the whole country
1999	New design of motorcycle-exclusive lane at city center introduced	Taipei	A new era for motorcycle traffic begins ???
2002	Enforcement against violating motorcycles stepped up?	whole country	???
2002	Motorcycle classification changed to four classes	whole country	For the first time 150cc motorcycles are included
2002	All-day running headlight for motorcycles introduced	Part of road sections in Taipei area	

Source : A comparative study on motorcycle traffic development in some Asian countries – case of Taiwan, Malaysia, and Vietnam - Dr. Ing. Hsu, Tien-Pen et al.

Figure 6. Two-stage left turn for motorcycles

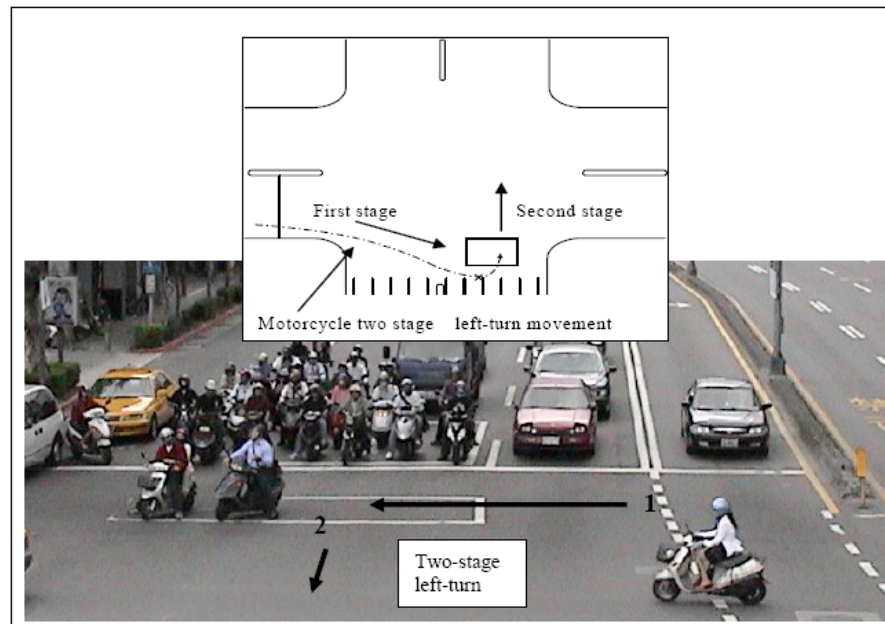
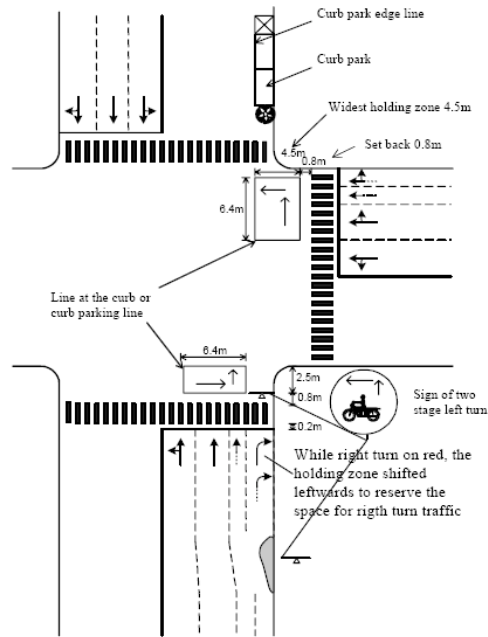


Figure 7. Motorcycle waiting area at intersection



The motorcycle waiting area in Taipei allows approximately 0.8 meters of width and 2.3 meters of length for each turning motorcycle. This solution eventually reduced motorcycle accidents at intersections after having initially increased them at crosswalks between motorcycles and pedestrians. To avoid such a setback, the waiting area must be properly sized, and the pedestrian crosswalk needs to be set back from the junction by the full length of the turning box and an additional 0.8 meters.

Experience from Other Countries

In many Indian cities, roads do not have graphically demarcated lanes because of the high number of junctions and high levels of mixed traffic on any typical collector/feeder Indian road. Such a traffic setup leads to high levels of merging, diverging, and weaving, and never allows people to follow lane discipline. On streets with a wide variety of modes, it leads to traffic self-adjustment that results in slow speed but higher capacity flow ratios than it would have been the case if the road were divided into separate lanes. Rural National Highways of India provide continuous paved 1.5-meter wide shoulders for slow moving traffic such as two-wheelers, while service roads do the same for two-wheelers and other slower vehicles in urban stretches. The decision to allocate these facilities rests with the National Highway Authority of India and its designers.

Some cities in India have tried separate lanes for motor rickshaws. Bangalore began enforcing lane segregation for motorized three-wheelers on M G Road in 2002 and gradually extended the measure to 12 major arterial roads, including the busy K G Road.

Eventually, the measures became unpopular with motor rickshaw drivers and their customers because they ended up slowing down motor rickshaws and thus significantly restricted their

usage. The system was not optimized and did not offer the same flexibility to overtake slow and stationary vehicles that mixed traffic conditions permitted. The separate motor rickshaw lanes were initially designed to allow overtaking but proved too narrow to make it possible in most real life conditions. Drivers were frequently forced to move in one line at the speed of the slower vehicles ahead and come to a stand when the lanes were obstructed by disabled vehicles or those picking up and dropping off passengers. Delays in service resulted in customers' turning to other modes. The motor rickshaw lanes were still in effect as of June 2007.

Experience from Malaysia suggests that motorcycle lanes, provided in many places, are working very effectively in reducing accidents (rear end and sideswipe). The first lane was provided in the 1970s. Since then Malaysia has taken the lead in developing strategies to sustain motorcycle flow. In the 1990s, they started the "Headlight-On" campaign. They have initiated both "exclusive" and "inclusive" lanes (paved shoulders). Research by Radin et al². indicates that an exclusive motorcycle lane needs a control width of 3.81 meters (inclusive of marginal 0.38 meter stripe at both edges of the road) for two riders to travel side by side comfortably at a speed of 70 km/h. This value was higher than the 3.5 meters adopted by the Ministry of Works. International Road Access program suggests that motorcycle lanes should be at least 1.8 meters wide (for each direction).

The Malaysian Design Guidelines (Arahan Teknik Jalan 8/86, 1986. *A Guide On Geometric Design of Roads*, Jabatan Kerja Raya (JKR), Malaysia) state:

"In areas where there is usually a high proportion of motorcyclists, the volume may be so substantial as to affect the smooth flow of traffic. In such instances, the provision of separate and exclusive motorcycle lanes should be considered. The general warrants for determining the need for an exclusive motorcycle lane are:

- (i) the total volume of traffic exceeds the provided lane capacity and*
- (ii) the volume of motorcycles exceeds 20% of the total volume of traffic."*

The table below gives the width of exclusive lanes for different traffic volumes.

Table 5. Malaysian Guidelines for Separate Motorcycle Lanes

Volume of motorcycle/hr	Width of MotorCycle Lane (m)	
1000 – 1500	2.0	2.5
1500 – 2000	2.5	3
> 2000	3	3.5

Source: Arahan Teknik Jalan 8/86, 1986. *A Guide On Geometric Design of Roads*, Jabatan Kerja Raya (JKR), Malaysia

The Malaysian Design Guidelines further suggest: *"When the volume of motorcycles exceeds 30 percent of the total volume of traffic at the particular intersection at the peak hour or when an at-grade intersection treatment does not provide a smooth flow or adequate safety to the motorcyclists, grade separated intersection treatment should be considered. These can be easily incorporated at roundabout and other intersections with the provision of underpasses*

² <http://www.miros.gov.my/publications/DeterminationOfComfortableSafeWidthInAnExclusiveMotorcycleLane.pdf>

(box culvert type). The type of the underpass must have a 2.5m clearance with a maximum slope of 10 percent. They should be lighted to give better visibility and safety during the night time.”

There is a need to review these guidelines as it is very difficult for two-wheelers to access slopes as high as 10%. The guidelines also suggest a design speed of 60 km/h or less where there are physical constraints. However, at this design speed, the guidelines also recommend a design radius of 15 meters which would make it impossible to sustain that speed without causing accidents.

Figure 8. Motorcycle Lane in Kuala Lumpur



Source: Horizon Gitano

In the Philippines, a bill³ that seeks to establish motorcycle lanes along busy roads and streets across the country to minimize motorcycle accidents has been filed in the Senate. The bill requires construction of 1.5 meter lanes on both sides of the road for exclusive use by motorcycles. The bill seeks an appropriation of P10 million to construct the lanes. However, the bill is pending in the Senate, and it is unclear whether it will be passed.

In Brazil, a different configuration was tested: an exclusive motorcycle lane was incorporated into the high-speed lane along the central median along Avenida Sumare and Avenida Paulo VI in Sao Paulo. Most motorcyclists in the country work for delivery services and tend to travel at recklessly high speeds in the high-speed lanes. The road selected for the test had a modest volume of motorcycles (300 per hour). One year later, 95% of the motorcyclists used the exclusive lane, and 60% of them approved of it because they thought it was safer. However, the special motorcycle lane did not reduce accidents. Accidents along the corridor doubled, mainly because pedestrians, misled by the fact that cars stuck in traffic were not moving, did not cross

³ http://www.senate.gov.ph/press_release/2008/0310_estradaj1.asp

in the correct places and were hit by motorcycles traveling in the exclusive lane. Furthermore, cars were prohibited from turning left, but did so anyway, also causing accidents.

k. Segregating Non-Motorized Two- and-Three-Wheelers from and Integrating Them into General Traffic

Because bicyclists generally move at slower speeds and thus are more vulnerable road users, they are more frequently given fully segregated facilities, primarily for safety reasons. Bicycle facilities are generally divided into several types. Segregated bicycle paths are fully separated from mixed traffic, mainly by painted markings on the road. Regular bicycle paths may have no special road treatment and just be marked as a relatively safe and useful route for cyclists. Most design manuals recommend segregated bicycle paths based on a combination of observed speeds on the road and observed average daily traffic (ADT) volumes. On facilities where traffic speeds are less than 40 km/h, no separation is necessary. On facilities with speeds between 40 and 60 km/h, the necessity of separation depends on the traffic flow. At 40 km/h, separate bike facilities can be justified if there are more than 6000 passenger car units (PCU) per 24 hours. At over 60 km/h, separated facilities are virtually always recommended with any significant volume of traffic.

Some US planners have tried to develop Bicycle Level of Service (BLOS) definitions that take into account several other road factors such as the amount of curbside vehicular parking, pavement condition, the level of heavy goods traffic, and other factors (see Barsotti and Kilgmore, for instance). Since these definitions do not depend on bicycle volumes, they would require construction of dedicated bicycle lanes on a huge number of roads. Such practice would certainly be desirable, but it is rarely followed outside the Netherlands and Denmark.

The Dutch guidelines provide for the use of bicycle lanes by a certain amount of light-duty motorcycles. Prior to 1999, the bicycle lanes were open to "light" motorcycles or mopeds, specifically to those with the engine displacement of less than 50 cm³, and a certain amount of three-wheelers. This changed in 1999 when all motorcycles were obliged to use the mixed traffic lanes. In the United States, the US Highway Capacity Manual suggests that a bicycle lane needs to be a minimum of 1.8 meters wide to allow one cyclist to pass another. China also has some guidelines governing the development of cycling infrastructure, though they are not frequently heeded. Currently, there are three types of bicycle road facilities China: special bicycle road, segregated bicycle lane, and painted bicycle lane. Chinese regulations require fully segregated bicycle roads with bicycle volumes over 10,000 per hour and physically segregated bicycle lanes for volumes of 5000 bicycles per hour. These are volumes that do not exist outside China and are rare in China, except on a few major urban arterials. The guidelines are, therefore, rarely used, and traffic engineers simply tend to use their judgment.

Chinese guidelines recommend a network of segregated bicycle lanes. These guidelines include a density of one bicycle road every 1 – 3 kilometers, one segregated bicycle lane every 400 – 600 meters, and one painted bike lane or branch road and path to residential apartment buildings every 150 – 200 meters. Chinese guidelines recommend that a bicycle lane be 1 meter wide, adding 0.25 meters where such a lane is next to a curb or median. For two-way bicycle roads, the minimum width is 3.5 meters. Where there are other types of non-motorized traffic, the minimum width in one direction shall be 4.5 meters. Planning guidance assumes that a bicycle lane will handle 1500 bicycles per meter of the lane width and 1000 per hour at the intersection, though these parameters are rarely used in the actual bicycle infrastructure design.

Figure 9. A One-Way, Fully Grade Separated Bicycle Lane on a Major Two-Way Thoroughfare



They are also very rarely used when determining the allocation of an available right of way between segregated facilities for bicycles, motorcycles, and mixed traffic. Therefore, these guidelines demand serious further analysis.

Bicycle lanes in China generally have a maximum speed limit of 20 km/h, according to the regulations. To US cyclists, this seems slow, and the standard design speeds between links in the US are closer to 25 km/h. The US highway capacity manual suggests that a 1.2 to a 1.8 meter wide facility may not saturate until 2600 bicycles per hour.

Bicycle lanes tend to be focused on primary and secondary arterials using the following configurations:

1. A One-Way Paint-Only Bicycle Lane on One Side of a One-Way Road Between a Parking Lane and the Mixed Traffic Lane.

This type of bicycle lane, which is typical in many cities, has the distinct disadvantage of being easily occupied by double parked vehicles and exposing the cyclist to "dooring" by passengers getting out of taxis and parked cars. There is debate among cycling experts as to whether this type of bicycle has any utility. Painting the lane in a different color increases motorists' awareness of the lane and improves enforcement.

This classic Chinese style major segregated bicycle lane, as seen here in Hangzhou (Figure 10), provides a very secure, comfortable riding environment between intersections. It passes behind bus shelters to avoid conflicts between buses and cyclists. Parking is not generally allowed along major Chinese arterials, so conflicts with parked vehicles are not a problem. Such fully segregated cycling lanes need to terminate well before the junction and be brought adjacent to the mixed traffic lanes or else there will be visibility problems and conflicts between turning vehicles and cyclists.

Figure 10. Bicycle Lane, Hangzhou, PRC



Source: Karl Fjellstrom

2. A One-Way, Segregated or Partially Segregated, Street Level or Partially Elevated Bicycle Lane on One Side of a One-Way Road Between the Sidewalk and First Mixed Traffic Lane Where no Parking is Allowed.

This configuration, as shown in Santiago (left) works fine as there are no conflicts between parking vehicles and cyclists. The shown bicycle lane has a physical barrier that prevents motorists from entering and double-parking inside the bike lane, but also allows bicyclists to leave the lane in case of an obstruction.

The one-way cycle lane in Delhi (right) is higher than the roadway, separated from it by a planting strip, and also semi-depressed from the sidewalk to indicate to pedestrians that it is a cycling lane. This facility works well where cycling volumes are reasonably high, pedestrian volumes are modest, and mixed traffic is not terribly congested.



Figure 11. Bicycle Lane, Santiago de Chile.



Figure 12. Delhi Bicycle Lane Along BRT Corridor Source: ITDP

3. A One-way Bicycle Lane on One Side of a One-Way Road Between the Parking Lane and the Sidewalk.

This configuration, which is increasingly popular in both the US and Europe, allows the parked vehicles to become an additional protective barrier between the bicycle lane and the roadway, preventing vehicles from double-parking across the bicycle lane. The lane must be sufficiently wide to prevent passengers exiting parked vehicles from “dooring” the cyclist. A reasonable volume of cyclists is necessary to keep such lanes from being occupied by vendors (Figure 13).



Figure 13. Bicycle Lane, Copenhagen.

4. A One-or-Two-Way, Sidewalk-Level Bicycle Lane on One or Both Sides of a Major Road.

This segregated bicycle lane is typical of the cycling infrastructure built in Bogota during the Penalosa administration. On some arterials, this two-way bike lane is only on one side of a major road, making access difficult to the other side of the major road. In other locations, a two-directional bicycle lane exists on both sides of the major road, providing excellent access to adjacent properties. High curb heights, bicycle lanes at sidewalk level, and protective bollards at the junctions prevent motorists from parking on the bicycle lane and provide a safe trip for a contra-flow bicycle lane. Where the pedestrian or bicycle volumes are high, however, this sort of design can lead to very slow bicycle speeds, and many cyclists may decide to use the mixed traffic lanes instead. Surface treatment also matters. Cyclists do not like to ride on brick, stone, or other rough

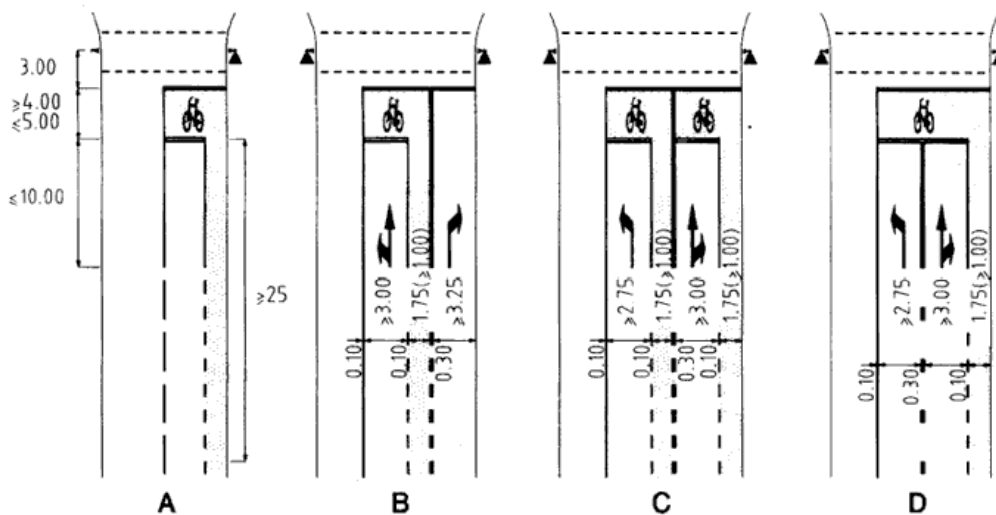


Figure 14. Bicycle lane in Chengdu, PRC
Photo: Karl Fjellstrom

surfaces, as they create vibration that does not affect pedestrians. The new bicycle lane in Chengdu, pictured above (Figure 14), is used by pedestrians, while cyclists continue to use the road.

Standard Dutch and US treatment of cycling facilities at intersections tend to have the bicycle lane feed into a box at the front of the traffic to allow cyclists to clear the intersection before motor vehicles because they can generally start faster than motor vehicles. Some cities are using a "leading pedestrian interval" to give cyclists a five- to ten-second cyclist and pedestrian only green phase at the beginning of each cycle to allow them to clear the intersection before motorists.

Figure 15. Cycling turning models



Notes: A = Standard model; B = Right-turning model; C = Left-turning model; D = Left turning model w/o a separate green phase (CROW Manual 1993)

The above approach brings cyclists into the junction and treats them in a manner quite similar to the treatment of motorcycles in Taipei, China. The bicycle lane is sometimes painted through the intersection and located between the right-turn lane and the first straight-only lane (Figure 15).

The other option is to pull cyclists out of the intersection and have them cross with pedestrians. This practice tends to slow down cycling speeds and is considered discriminatory by cycling advocacy organizations, though some engineers consider it safer on larger, higher-speed roadways with low volumes of cycling traffic.

In China, there are no specific design guidelines for bicyclists at junctions, but there are standard practices. Segregated curbside bicycle lanes generally continue all the way to the junction. This presents no problems for bicyclists turning right or going straight, though they have to pay attention to the right-turning vehicles.

The major design problem for high volumes of bicyclists on high traffic roads is to negotiate turns across lanes in the opposite direction (i.e. left turn in the right-side driving countries and

Figure 16. Cyclists at Traffic Intersections in Chengdu, PRC



vice versa). At major intersections in China, the default planning practice is to force cyclists to make a 270° turn.

In the photo of Chengdu above (Figure 16), cyclists are supposed to stop at a red light behind the crosswalk at the lower right, but in practice often stop in the green circle, as there is a free right turn. When the light changes to green, cyclists wishing to go left pass through the intersection, then stop in the red circle, and wait for a red traffic signal.

When the signal changes, they cross with pedestrians. This approach works well in the context of very high volumes of bicycle flow. Such junctions as pictured in Figure 16 are processing more than 1000 bicycles per hour in one direction. The high volume of cyclists on the road slows down right-turning traffic. If there were few bicycles, the very wide turning radius for the free right turn would create dangerous conflicts between the right-turning vehicles and cyclists.

In the case of the Delhi BRT and bicycle lane designs, the free right turn was removed, and the turning radius for vehicle turns was tightened to slow turning speeds. The removal of the free left turn (i.e. right in the right-side driving world) was possible because no provision was made for a turning lane.

I. Controlling Motorcycle Access to Bicycle Lanes

Building a bicycle lane in a corridor with high levels of motorcycle traffic requires special attention. The standard, road-level bicycle and cycle rickshaw lane on the ring road in Yogyakarta (Figure 17) is fully occupied by illegal motorcycle traffic during the peak hours.



Figure 17. Yogyakarta Bicycle Lane Frequently Occupied by Motorbikes



Figure 18. Delhi Bicycle Lane Occupied by Motorcycles and Other Two-Wheelers

Along the New Delhi BRTS corridor, bicycle lanes are being occupied by motorcycles and even some three-wheelers during peak hours. Some bollards placed at the junctions were destroyed within months of the system's opening.

There are a number of physical designs and devices which can be employed to restrict motorcycle access to bicycle lanes and pedestrian areas (Figure 19; Figure 20).

These measures, however, also create nuisances for cyclists, pedestrians, and particularly for disabled people, shoppers with carts, and parents with children in strollers.

Figure 19. Motorcycle-Proof but Pedestrian, bicycle, and Wheelchair-Accessible Gate in Paris, France Photo: Luc Nadal



Figure 20. Motorcycle Control Devices



Upper left: Changsha, China; Upper right: Changzhou, China; Middle left: Fuzhou, China; Middle right: Xiamen, China; Lower left: Wuhan, China; Lower right: Kyoto, Japan.

Photos: Karl Fjellstrom

The following rules of thumb should be considered when designing measures to exclude motorcycles from cycling facilities:

- 1. The higher the volume of bicycles, the lower the risk of motorcyclists' encroachment on cycling facilities.**

2. The lower the level of congestion in the mixed traffic lanes, the lower the risk of motorcycles using the cycling lanes.

3. Motorcyclists are most likely to enter bicycle lanes at the last curb-cut before the junction, where traffic tends to back up.

Therefore, our recommendations are as follows:

1. If bicycle volumes on a given road are greater than 1000 per hour, no physical design measures for keeping motorcycles off bicycle lanes are necessary.

2. If mixed traffic lanes are not congested (average speeds are above 15 km/h), no physical measures for keeping motorcycles off bicycle lanes are necessary. All effort should be made to minimize mixed traffic congestion.

3. If motorcycle volumes are less than 100 per hour, no physical measures for keeping motorcycles off bicycle lanes are necessary.

4. Designing roads with motorcycle lanes may reduce the risk of motorcycles using designated bicycle lanes.

5. If traffic is congested (average speeds are lower than 15 km/h) and bicycle volumes are below 1000 bicycles per hour, then some form of barriers should be used to prevent motorcycles from using bicycle lanes.

6. Physical barriers preventing motorcycles from entering bicycle lanes should be in two primary locations: at the junctions and along the corridor.

7. The barrier must be built along the corridor and made narrow enough (between 250 and 500mm) to fit between the motorcycle's wheels. This barrier will be impossible to cross because it will hit the motorcycle's exhaust tube and engine block. .

8. At major traffic junctions and any local access street curb cuts adjacent to major junctions where traffic tends to back up, bollards or other physical barriers should be close enough to prevent all but very small motorcycles from passing the barrier.

9. If volumes of cyclists are high, physical barriers need to be designed in such a way that they do not congest bicycle traffic?.

In addition, new rules at the junction access points need to be strictly enforced for a year until the traffic behavior conforms to the intended use. Fines should not be imposed in locations where doing so would obstruct traffic in the bicycle lane.

However, if the government decides to allow cycle rickshaws, Category I motorcycles rickshaws, electric bicycle rickshaws, Segways, electric scooters, and other "intermediate vehicles" onto bicycle lanes, the facilities should be designed with sufficient width to avoid obstructions. Cycling lanes can either offer a superior, congestion-free means of access in an otherwise congested traffic system, or they can be sub-standard facilities which no vehicle would choose to use unless no safe alternative existed. Access to a Grade A cycling facility that

offers quality, congestion-free access to desirable locations should be used to encourage socially desirable travel modes, that is modes that are cleaner, quieter, and less threatening to pedestrians and vulnerable road users.

Electric bicycles under 40 kg and with operating speeds of no more than 20 km/h are fully compatible with bicycles, and there is no reason to ban them from cycling facilities. Heavier, noisier motorcycles are less compatible, but mopeds and light motorcycles with engine displacement of 50 cm³ or less and maximum speed of 30 km/h are compatible with bicycles in most conditions, though cyclists may view them as a nuisance.

Cycle rickshaws and electric-assisted cycle rickshaws of the type are reasonably compatible with bicyclists and light motorcycles. They obviously require additional road width to maintain a C or above Level of Service. The bike lanes to the right that were built in Lima initially attracted some three-wheelers, effectively blocking the entire lane for all other cyclists.

The bicycle lanes in Bogota and New Delhi are currently closed to cycle rickshaws and were not designed to accommodate their presence. The designers intentionally placed the bicycle lanes at the same height as the sidewalks, often as much as 25 cm above the roadway level to prevent illegal car parking on the bicycle lane. They also designed the curb cuts at steep angles and the bollards close together to inhibit use by motorcycles and cars, which also restricted access by cycle rickshaws and wheelchairs. By contrast, the Malioboro Rd in Yogyakarta, Indonesia, was designed with a special lane for non-motorized vehicles. The lane is wide enough to accommodate both moving and parked cycle rickshaws (becaks), bicycles, and delivery carts. Cycle rickshaws there are mainly used in commercial areas for distances under 3 km.

Design specifications should be based on the existing traffic. If there is a relatively large volume of mixed slow moving traffic, then the lane use is likely to be reasonably self-regulating, as is the case in Yogyakarta, pictured below (Figure 21). If such traffic volume is uncommon, then this sort of facility will be easily occupied by motorcycles, heavier motorized three-wheelers, and even cars.

Figure 21. Shared Cycle Rickshaw and Bicycle Lane, Malioboro Rd, Yogyakarta, Indonesia



m. When Should Bikes, Rickshaws, Category I Motorcycles, Segways, or Other Light Vehicles Be Allowed to Operate on Sidewalks

As part of their efforts to reduce the mode share of bicycles in favor of public transit, many Chinese cities began converting former bicycle lanes to mixed traffic lanes and relegating bicycles to the sidewalk. In some cases, bicycles can operate on facilities shared with pedestrians, and in other cases, as in the photo below (Figure 22), it is inappropriate.



Figure 22. Sidewalks in Hefei, PRC Photos: Karl Fjellstrom

As a rule, bicyclists do not like to ride on the sidewalk, and pedestrians do not like bicycles on the sidewalk. If there are any significant number of pedestrians or obstacles on the sidewalk, lack of curb cuts, debris, parked vehicles, or street vending activity, speeds will be too slow to reach a C level of service.

Nevertheless, there may be a few cases where shared facilities for bicyclists and pedestrians are acceptable. There are also some slow motorized devices that may be considered for use on sidewalks. The inventor of Segway, a motorized scooter, strongly believed that it belongs on the sidewalks with pedestrians. He created a very powerful lobby and convinced many state governments across the US to allow Segways to operate on sidewalks, sometimes masking the legislation by classifying his invention as an electric wheelchair. Various advocacy groups, supporting the disabled and pedestrians, fought this legislation which was passed in many states, with the exception of New York State and a few others where sidewalks tend to be heavily congested. Our position is that their speed and flow characteristics are similar to bicycles; hence, they should operate on the same facilities as bicycles, whereas on crowded sidewalks, they are a nuisance.



Figure 23. Segway

n. Integration with Bus Rapid Transit Systems

As a rule, the lower the bus frequency, the more difficult it is to maintain the exclusivity of the bus lanes. With frequencies below one bus every two minutes, keeping motorcycles and bicycles off the bus lanes is difficult, particularly in the off-peak hours when bus frequencies tend to drop even lower. Also, high volumes of motorcycle traffic make the task even harder. Using solid barriers is the only effective option.

It may well be the case that a given road has to accommodate more than 1000 motorcycles per hour and 2000 passengers per direction at the peak time. In such a case, it is debatable whether exclusive motorcycle lanes are still a good idea or not. In both Delhi and Jakarta, where motorcycle lanes have never been integrated into busways, and motorcycle levels are greater than 1000 per hour per direction, there are frequent problems with motorcycles cutting into the bus lanes. This can be somewhat controlled by police regulation.

In 2008, London conducted a small-scale trial allowing motorcycles to use bus lanes in the borough of Westminster. The authors of the trial-based study found that the accident and conflict analyses were not conclusive. The safety of motorcycles that were permitted to use bus lanes did not appear compromised in comparison to that of motorcycles that were not. However, safety appeared reduced if there was a traffic-intensive side road along the bus lane, or if taxis and buses were maneuvering towards and away from the curb along a section of the lane. The authors also expressed concerns for cyclist and pedestrian safety – in particular, where a greater percentage of motorcycles were speeding (a known cause of accidents and serious injuries) and when other road users and pedestrians came into contact with fast motorcycles while expecting only slower vehicles.

Based on these reports, Mayor Livingston, citing the protection of vulnerable pedestrians and cyclists, opted to wait for more conclusive research. This decision was reversed by newly elected Mayor Boris Johnson, who campaigned on a series of pro-motorcycles measures and ordered the Transport for London's (TfL) bus lanes to be opened to motorcycles of all sizes. TfL announced an 18-month trial allowing motorcycles, mopeds, scooters and tricycles - but not those with sidecars - to travel in TfL-controlled bus lanes from 5 January 2009, to be followed by recommendations to the mayor on whether to make the measure permanent. This trial excludes the majority of bus lanes which run on the borough-controlled roads.

Riding bicycles on bus lanes is also problematic. For example, Curitiba's bus lanes, and in fact Curitiba's road system, was not designed for bicyclists. Nonetheless, cycling in Curitiba has increased to nearly 5% of the mode share, and much of the cycling activity takes place in the bus lanes, particularly during off-peak periods. Thus it appears reasonable to enable bus lanes to accommodate a certain number of cyclists, particularly in dense urban areas where actual bus speeds are below 40 km/h and especially: (1) if there are no cycling facilities along or parallel to a BRT corridor; (2) if the mixed traffic lanes are heavily congested or unsafe; (3) if traffic regulations enforcement is weak.

In fact, bus lanes designed to accommodate both bicycles and buses do exist. Paris, for instance, has 118 kilometers of shared bus and bicycle lanes shown below (Figure 24). A bus and bicycle shared lane is somewhat wider than a standard bus lane so that buses and bicycles could pass one another comfortably. If buses and motorcycles are to share a lane, it is particularly important for bus stops to be located at sufficient distance from intersections so that

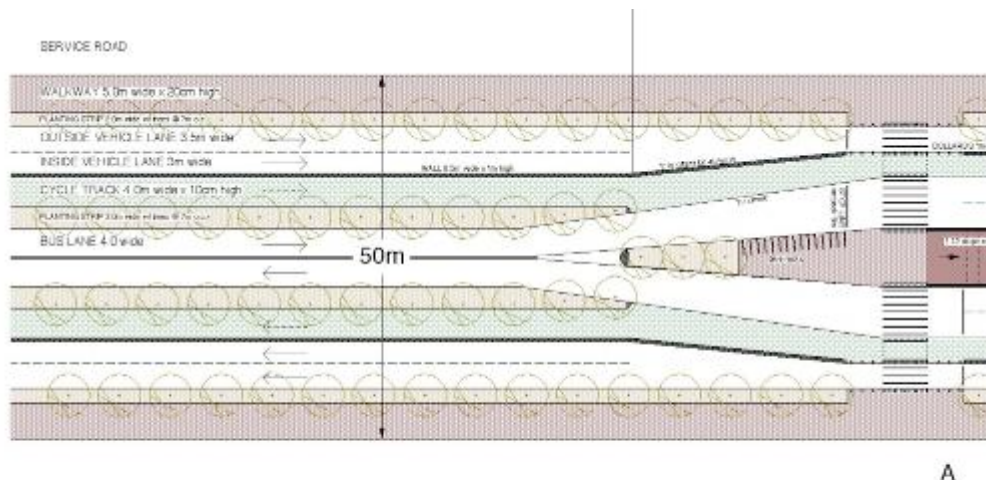


Figure 24. Shared Bus and Bicycle Lanes

Left: Paris, France by Luc Nadal Right: Sydney, Australia by Karl Fjellstrom

waiting motorcycles and bicycles could not disrupt boarding and alighting.. It is also particularly important that the bus lanes be wide enough at station stops to allow motorcycles to pass without disrupting the functioning of the bus stop. In the case of a BRT lane with increased speed, consideration should be given to the risk that drivers may not see cyclists well enough. Low floor buses would not present this danger.

It may be possible to adjoin motorcycle lanes to a median bus lane on higher speed sections of the road, but no examples of this configuration have been tested to date. The design below was developed as a central median bicycle lane adjacent to the busway. The advantages of such a design are that it would allow for a minimization of turning conflicts and other roadside conflicts between motorcycles and pedestrians, cyclists and other modes. It might also increase the road's capacity. The design was rejected because of concerns about having cyclists adjacent to high speed mixed traffic. For motorcycles, however, the speed difference is negligible. Some slight modifications of the design might make it feasible. The main concern that this design presents for the motorcycle use is the risk of motorcycle-pedestrian conflicts at the crosswalk, which might be controllable either through signalization or speed bumps. Intersection designs for this median motorcycle lane concept have not been developed.



Typical Bus Rapid Transit Station
Morogoro Road, Dae es Salaam, Tanzania

ITDP w/ input from LOGIT & ICE
June 2006

MINIMUM SIZING REQUIREMENTS
FOR DISCUSSION ONLY

The main problem in busway design is finding sufficient road width for passing lanes at the bus stops. It is conceivable that the passing lane could be partially shared with a motorcycle lane. This might create dangerous conditions. Though most BRT system designers do not like the idea of allowing other forms of traffic onto the busway because it degrades the image of the BRT system, there may be specific cases when shared motorcycle and bus lanes can be considered; for example, when bus frequency is below 2 per minute, motorcycle mode share is between 20 and 60%, and the right of way is constrained for short segments.

o. Access Regulation Principles

Based on the above discussion, the following general access regulation principles are proposed for discussion (they should be treated by road users as the law if no location-specific signage instructs otherwise):

1. Bicycles, cycle rickshaws, Category I motorcycles, and Category I motor rickshaws should be allowed on all streets except for limited access highways and streets or facilities designated as pedestrian zones or sidewalks.
2. No motorcycle of any category or any other motor vehicle are allowed to operate on sidewalks and inside pedestrian zones.
3. Bicycles and cycle rickshaws are not allowed to operate on sidewalks or inside pedestrian zones unless the operator is walking the vehicle, the sidewalk is specifically designated as a "shared use facility," if the operator of the bicycle is under 14 years of age, or if the operator is an adult accompanying a child under 14 years of age.
4. Operation by pedestrians, bicycles, cycle rickshaws, Category I and II motorcycles, and Category I and II motor rickshaws can be banned on limited access highways if the ban does

not create a severance problem. A significant severance problem is any popular origin-destination pair that has to be diverted by a distance greater than 400 meters.

5. Category I motorcycles are allowed to operate on cycle lanes.

6. Bicycles and Category I motorcycles should be encouraged to use any infrastructure specially designated as a bicycle lane, but it should not be made illegal for them to operate in the mixed traffic lanes.

7. No category of vehicle other than buses can operate inside a bus lane unless specifically designated.

8. Cycle rickshaws and Category I motor rickshaws can use all infrastructure designated as a bicycle lane unless specifically prohibited, in which case they can use the mixed traffic lanes.

9. Category III and above motorcycles and Category II and above motor rickshaws cannot operate on infrastructure designated as a bicycle lane and must operate in mixed traffic lanes. The trend is also to ban Category II motorcycles from cycling lanes.

Specific circumstances may warrant exceptions to the principles outlined above.

Throughout the world, there are examples of bans on certain categories of vehicles on specific streets, in specific zones, or throughout an entire city. Possible justifications for these bans include the following:

1. The category is the specific cause of traffic congestion.
2. The category causes specific hazards to both the operators and other road and public space users.
3. The category generates excessive noise and pollution.
4. Vehicles in the category are in unnecessary numbers and cause needless congestion.
5. The form of labor is demeaning and exploitative to the driver.
6. The use of vehicles in the category increase crime, either because some of the operators are criminals or because the vehicle makes criminals difficult to pursue and, for that reason, is favored by them.

p. Parking of Two-and-Three-Wheelers in BRTs, Metro, and Bus Stations

In China none of the existing BRT systems, even with extremely high two-wheeler volumes such as those in Beijing, Kunming, Changzhou, Hangzhou and Jinan, have included any provision for bicycle or e-bike parking in the BRT station design. The first BRT system in China to include bicycle parking in its design is Guangzhou's BRT, due to open in February 2010. Bogota and Brisbane both included bicycle parking in the BRT station designs, and Japanese subway and

rail systems routinely include advanced bicycle parking facilities. Generally, special bicycle parking facilities do not include provision for motorcycles. Highly mechanized bicycle parking systems (such as the underground “bike ATMs” in Tokyo) or those requiring lifting the bicycle (such as in Bogota) preclude motorcycles and heavier e-bikes.

Bicycle, e-bike, and motorcycle parking at or near BRT stations (or metro stations) is important because these modes can all potentially increase the reach and market share of a bus, BRT, or metro system by reducing access times and removing the need for what might otherwise be a paid transfer to another public transport mode. The issue of motorcycle parking at transit stops, therefore, deserves more attention, especially in cities with large motorcycle and e-bike volumes.