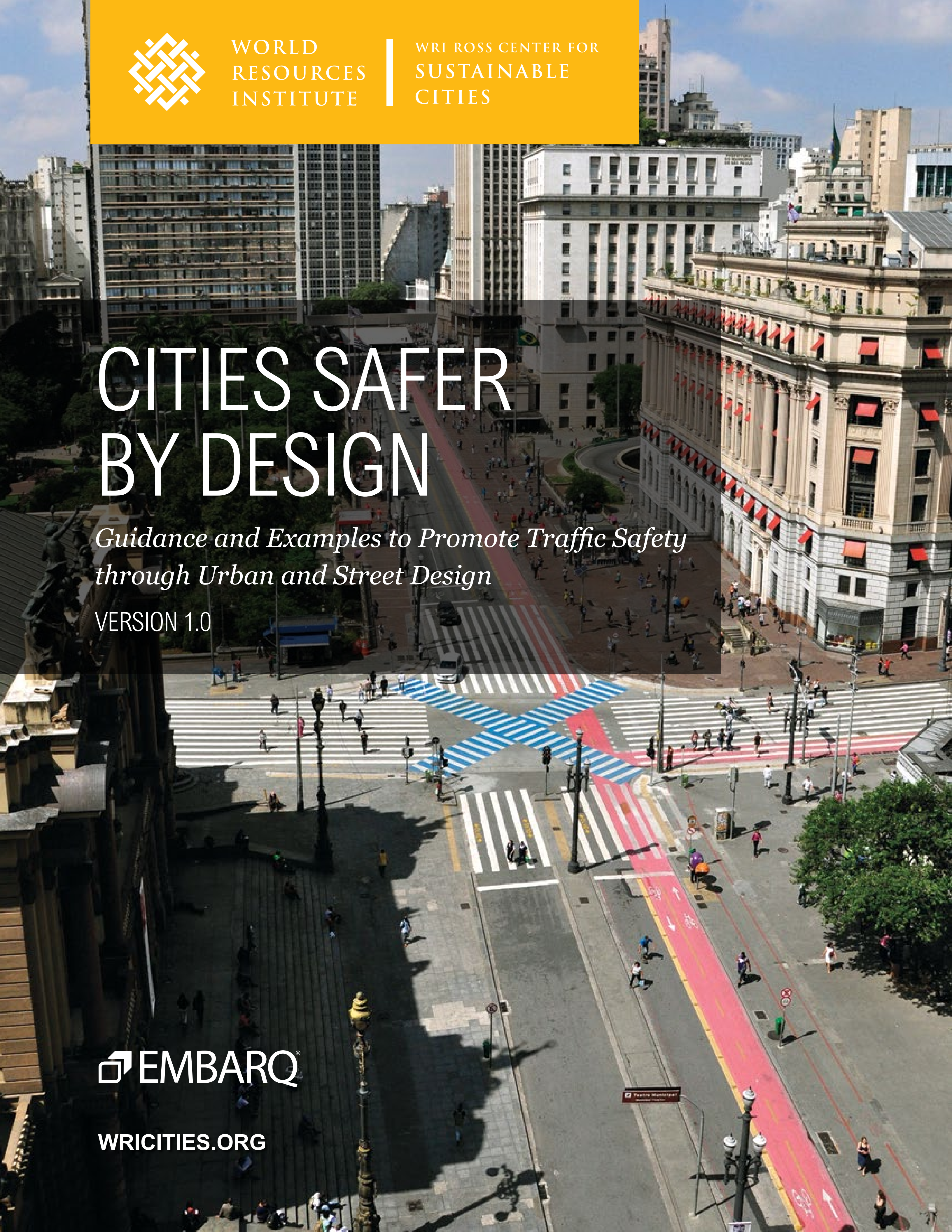
WORLD RESOURCES INSTITUTE | WRI ROSS CENTER FOR SUSTAINABLE CITIES

CITIES SAFER BY DESIGN

Guidance and Examples to Promote Traffic Safety through Urban and Street Design

VERSION 1.0



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BEN WELLE
QINGNAN LIU
WEI LI
CLAUDIA ADRIAZOLA-STEIL
ROBIN KING
CLAUDIO SARMIENTO
MARTA OBELHEIRO

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Design and layout by:
Jen Lockard
jlockard@ariacreative.net

TABLE OF CONTENTS

FOREWORD

Globally, 1.24 million people are killed in traffic crashes every year. This number is expected to keep rising as vehicle fleets grow, to become the 5th largest cause of death by 2030. The majority of these deaths happen in and around urban areas, disproportionately affecting vulnerable road users such as pedestrians and bicyclists. The percentage of the world's residents living in cities is also on the rise, from 50 percent in 2007 to 70 percent in 2030, making it vital for cities to address the need for safer streets. Traffic crashes also exact an economic toll. In some countries, such as India, the economic cost of traffic crashes equals 3 percent of the nation's Gross Domestic Product.

To address this alarming issue, the United Nations has declared a *Decade of Action* to address the challenges of traffic safety across the world, including through safer urban mobility and street design. As global cities look to reduce the threat of traffic deaths and injuries, there is a need for evidence-based solutions proven to improve safety and make cities livable, efficient and productive. Yet knowledge and global best-practices for creating safer cities are not well-documented in any global guide.

Cities Safer by Design collects this information into one resource addressing issues such as enhancing urban design to increase walkability, reducing vehicle speeds that threaten all road users, providing high-quality spaces for pedestrians and bicyclists, and improving access to mass transport. At WRI Ross Center for Sustainable Cities, we find that making urban travel safer is not only about health, but quality of life and creating sustainable, competitive, equitable and smart cities. Providing safe and convenient infrastructure opens up opportunities to all people. Walking and bicycling can thrive, helping curb emissions while offering active, healthy forms of transport. Mass transport can reach more people, helping cut vehicle emissions contributing to global warming and air pollution, while decreasing travel times. These solutions that benefit people also benefit the planet and economic development.

I encourage planners and policymakers to use this guide, and implement change in how they design and plan cities and streets. At WRI Ross Center for Sustainable Cities, our approach is to "Count it, Change it, Scale it." Cities can use the practices outlined in this guide to deliver change on the ground, informed by local context, and scale these solutions to improve traffic safety and quality of life.

Cities that are safer by design help create an urban world where everyone can thrive. Cities safer by design can save lives.

Andrew Steer
President
World Resources Institute


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EXECUTIVE SUMMARY

Many of the world's cities can become safer, healthier places by changing the design of their streets and communities. Where public streets have been designed to serve primarily or even exclusively private motor vehicle traffic, they can be made immensely safer for all users if they are designed to effectively serve pedestrians, public transport users, bicyclists, and other public activity.

This is currently not the case in many cities. Traffic fatalities account for 1.24 million annual deaths, with over 90 percent of global traffic deaths occurring in low- and middle-income countries (WHO 2013). Currently estimated to be the eighth leading cause of death worldwide, this is expected to become the fifth leading cause of death by 2030 at current trends. The majority of these fatalities are vulnerable road users—pedestrians and bicyclists in developing countries who are usually hit by motorized vehicles (WHO 2009).

These deaths can account for hefty tolls on economic development, with traffic deaths amounting to 3 percent of gross domestic product (GDP) in India and Indonesia, 1.7 percent in Mexico, 1.2 percent in Brazil, and 1.1 percent in Turkey (WHO 2013). Almost half of all traffic fatalities occur in cities; a larger proportion of serious road traffic injuries occur in urban areas and involve vulnerable road users (Dimitriou and Gakenheimer 2012; European Commission 2013).

This global health issue is being pushed by large underlying forces. Across the world—especially in places such as Brazil, China, India, Mexico, Turkey, and other emerging economies—people are buying private cars or motorcycles at a galloping pace. The world's car population has already passed 1 billion and is expected to reach 2.5 billion by 2050 (Sousanis 2014). The percentage of the world's residents living in cities will increase from 50 percent in 2007 to 70 percent in 2030 (UNICEF 2012). Urban land areas are expected to double by 2020 from 2000 levels (Angel 2012). Between considerable population and economic growth, there is enormous demand for new housing and urban expansion, with streets and the public space network linking everything together.

A common response to all of these issues is to build roads and design communities for automobiles. Yet this is just a short-term solution to ease traffic or improve safety only for drivers, and in time will only stimulate more growth in car use, a need for even more roads, and more overall traffic fatalities (Leather et al. 2011).

There is another path. Cities can design streets and the built environment to be safer, not only in new communities, but also by transforming existing neighborhoods and streets. Considering a comprehensive street network and the hierarchy of its users can reveal opportunities not only around critical transit corridors, but in the surrounding neighborhood streets. This is called a "safe system" approach to traffic safety. It sets targets and works to change the road environment to reduce injuries and fatalities (Bliss and Breen 2009).

Through its EMBARQ sustainable urban mobility initiative, WRI Ross Center for Sustainable Cities has created this guide to provide real-world examples and evidence-based techniques to improve safety through neighborhood and street design that emphasizes pedestrians, bicycling, and mass transport, and reduces speeds and unnecessary use of vehicles.

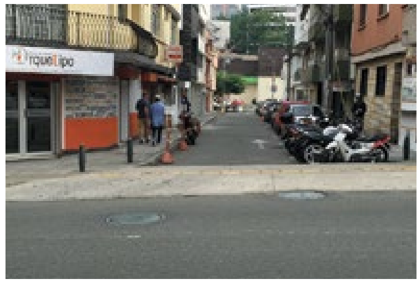
The guide provides an overview in chapter 2 on the current conditions for traffic safety in cities, the different groups of people impacted by safety, and what it means to make cities "Safer by Design" through urban and street design that improves safety for all road users.

The rest of the guide—chapters 3 to 8—provides descriptions of the different measures and elements that make up the key design principles to promote safety. These principles are composed of the following themes, and can be found in positive examples from cities across the world.

DESIGN PRINCIPLES

Beijing, China

Urban design that reduces the need for vehicle travel and fosters safer vehicle speeds
Develop mixed land uses, smaller blocks, ground-floor activities, and nearby public facilities that reduce overall exposure to traffic crashes from less vehicle travel.

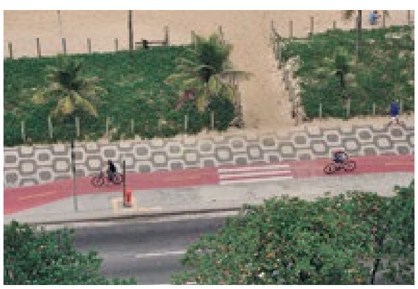


Medellín, Colombia

Traffic calming measures that reduce vehicle speeds or allow safer crossings
Integrate proven measures such as speed humps, chicanes, chokers, refuge islands, traffic circles, shared streets, and other street design applications that can reinforce safety.

Mexico City, Mexico

Arterial corridors that ensure safer conditions for all road users
Improve arterials and other main streets to ensure the safety of pedestrians, cyclists, mass transit as well as motor vehicle drivers through reduced crossing distances, lead pedestrian intervals, refuge islands and medians, safe turning movements, and lane alignments. Consistent designs should create a forgiving road environment with the least surprises for the road user, especially for vulnerable users.



Rio de Janeiro, Brazil

A network of connected and specially designed bicycling infrastructure
Design accessible, bicycle-friendly streets that include protected bike lanes or cycle tracks and connected networks. Pay special attention to reducing conflicts at junctions between cyclists and turning vehicles.

Istanbul, Turkey

Safe pedestrian facilities and access to public spaces
Provide quality space for pedestrians through sidewalks and street space, as well as access to parks, plazas, schools, and other key public spaces. Design these spaces to be attractive for pedestrians.

Ahmedabad, India

Safe access to mass transport corridors, stations, and stops
Improve access to transit, in part by avoiding physical barriers. Create a safe and secure interchange environment.

A Note on the Road-Testing Process

Version 1.0 allows for a "road test" to work with designers, auditors, project managers, policy makers, and other stakeholders involved in the way streets and communities are designed. During this road-test period, we will learn how the guide can be applied in cities and complete a review to improve it further.

This road test will include workshops, use in road safety audits and inspections, black spot (also known as hot spots, or high crash locations) treatment, and application to on-the-ground projects in coordination with city planners and officials. This process will occur across several countries and cities. It will seek out more examples that can explain real-world application of evidence-based measures, as well as additional evidence from different areas of the world to enhance the global understanding of safer design. Those interested in providing feedback, examples of good practices, and evidence can contact the project team through our email address: saferbydesign@wri.org.

How to Use this Guide

Cities Safer by Design provides an overview of how cities around the world can design communities and streets in a way that maximizes safety and health while promoting a more sustainable form of urban development. The guide can be used by designers, private and public developers, engineers, public health experts, city planners, policy makers, and others working to create plans and implement projects that include street and community design.

The guide can aid road safety audits and inspections. Planners and policy makers also can use it to inform how and what policies and projects ought to be created to enhance safety and improve quality of life, including urban mobility plans, transit-oriented development, city plans and regulations, and citywide pedestrian safety action plans.

The guide acts as a general direction on how to create the solutions that have been proven to be effective in creating a safe urban environment. However, cities and countries can be very different in their history, culture, design, development, policies, processes, and a variety of other factors. The guide focuses on the practices and characteristics of city planning and design that can be applied in a variety of situations, but local solutions and discretion should be taken into account, adapted and adjusted, measured and replicated. The current Version 1.0 of the guide will be further informed by a road-test process and subsequent version based on this process.

SUGGESTED INTERVENTION

DEFINITION/ DESCRIPTION

APPLICATION SKETCH

DESIGN PRINCIPLES

REAL PRACTICE PHOTO

BENEFITS

APPLICATION

EVIDENCE

TRAFFIC CALMING MEASURES | **3.3 Chicanes**

3.3 CHICANES

Chicanes are artificial turns created to slow traffic. They lead to a reduction in the width of the roadway, either on one side or on both sides or constructed in a zigzag, staggered pattern that directs drivers away from a straight line, which can reduce vehicular speeds on both one- and two-lane roads.

Figure 3.3 | **Chicanes Case**

A chicane in Istanbul, Turkey creates a safer neighborhood street, staggers parking to each side of the chicane, and can contain vegetation to improve aesthetics.

Design Principles

- Simple approach is to alternate on-street parking from one side of the street to the other on a one-lane road. This can be combined with curb extensions and raised crossings.
- On two-lane roads, such as an arterial in a residential area, staggered chicanes can be used by applying parking, central reserves turning lanes, etc. at various sections.
- Adequate space should be provided for pedestrians and bicyclists.
- Landscape must be designed not to disturb drivers' views.

Benefits

- Forces drivers to drive more slowly and with greater awareness, particularly at midblock locations.
- Can green and beautify the streetscape with trees and/or vegetation, improving environmental quality.
- Has minimal impact on emergency response vehicles compared to speed humps and other vertical deflection measures.

Application

- Can be useful on straight streets with long blocks combined with midblock crossings to enhance pedestrian safety.
- Useful on arterials passing through more residential or mixed land use areas that require safer speeds.
- Bicycles can have separate path next to sidewalk.
- Large vehicles can go through chicanes, particularly buses, as bus stops can be used as part of the speed reduction measure.

Evidence

- Available data for chicane schemes indicated a reduction in injury crashes (54 percent) and crash severity (UK Department for Transport 1997).

34 | WRI.org

Key Terms Defined

In this guide, we provide a number of measures and terms in each chapter. The definitions for these measures are provided in each summary of the item. A few terms appear throughout the document, including:

Crash frequency models. Crash frequency models also are referred to as safety performance models or accident prediction models. These models consist of statistical analysis that aims to predict the safety performance of an entity (e.g. street, intersection, neighborhood), using variables that account for exposure (traffic volumes, pedestrian volumes) and risk factors (intersection geometry, signal control, block sizes etc.). These models often use a Poisson or negative binomial distribution.

Exposure. In the context of road safety, exposure is defined as the state of being exposed to risk. The measure of exposure aims to indicate the likelihood that certain segments of the population could be involved in crashes. It is based on the amount of time, volume, or distance. In the context of crash models, exposure may include total motorized traffic volumes (vehicle kilometers traveled, or VKT; annual average daily traffic, or AADT), or travel volume of pedestrians and cyclists.

Lead pedestrian interval. A signal configuration under which pedestrians get the green light several seconds before traffic going in the same direction. This can help avoid conflicts between pedestrians and right-turning traffic, by making pedestrians more visible.

Risk. In terms of traffic safety, risk can have different meanings. It can be a situation involving exposure to danger, injury, or loss that may involve several factors such as perception, propensity, and reward (e.g. crossing the street faster at midblock). It can also refer to an injury rate that takes the number of injuries or crashes over the amount of exposure, or over the population. Lastly, risk can refer to perception of risk or the propensity to take risk.

Road safety audit (RSA). RSA is a qualitative evaluation of safety conditions for a roadway or transport project that is currently in the design phase, carried out by an experienced road safety auditor. Unlike an RSI, an RSA evaluates the design drawings, not just the infrastructure.

Road safety inspection (RSI). RSI is a qualitative evaluation of safety conditions along an existing roadway, carried out by an experienced road safety auditor. A road safety inspection can help identify issues not evident in the study area crash data, based on the auditor's expertise, best practices, and more systemic studies.

Traffic calming. The combination of street designs and traffic rules that deliberately reduces vehicle speeds by designing and building interventions (e.g. speed humps, raised crossings, chicanes) to improve safety for all road users, especially pedestrians and cyclists.

Transit-oriented development (TOD). A type of community development that includes a mixture of residential, commercial, office, and public facilities to maximize use of public transport. It often incorporates design features to encourage walking and cycling. A TOD neighborhood typically has a center with a transit station or stop, which is surrounded by relatively high-density developments that are generally within a radius of 400 to 800 meters, or one-quarter to one-half mile.

Vulnerable road users. A collective term for a group of road users who have a high injury or casualty rate, mainly pedestrians, bicyclists, and motorcyclists. Vulnerability is defined in a number of ways, such as by the amount of protection in traffic or by the amount of task capacity (e.g. the young and the elderly).


723
106

TRAFFIC SAFETY FOR PEOPLE

Traffic safety has much to do with the interaction among people, the street environment, and vehicles, and creating quality of life in cities.

Sustainable urban development or transit-oriented development is defined here as the urban-built environment that involves compact, mixed land uses, access to high-quality mass transport, and streets that reduce traffic speeds and limit vehicle presence in key areas. This provides opportunities for walking and bicycling rather than driving to school, the park, the store, work, the doctor, family and friends, and other daily activities. As the New Climate Economy explains, these places are connected, compact, and coordinated (NCE 2014).

Promoting sustainable urban development can have a strong and positive relationship with traffic safety. This comes from two key safety issues: exposure and risk. Sustainable urban development practices can (a) *reduce exposure* by preventing the need for vehicle travel, thus preventing a crash before a trip would even begin; and (b) *diminish risk* by encouraging safer vehicle speeds and prioritizing pedestrian and bicyclist safety.

Taking full advantage of these potential safety benefits requires close coordination of transport and land use planning, and implementation, as well as ongoing data analysis, assessment, and performance measurement.

This chapter describes what it means to have cities that are safer by design, and includes the following:

- Traffic fatality rates in selected cities globally
- Background on the different user groups of cities and why traffic safety is important
- Evidence supporting the design principles of *Cities Safer by Design*
- Data analysis and assessment tools for deploying these design principles
- Key performance measures to consider in evaluating interventions.

1.1 Traffic Safety Across Selected World Cities

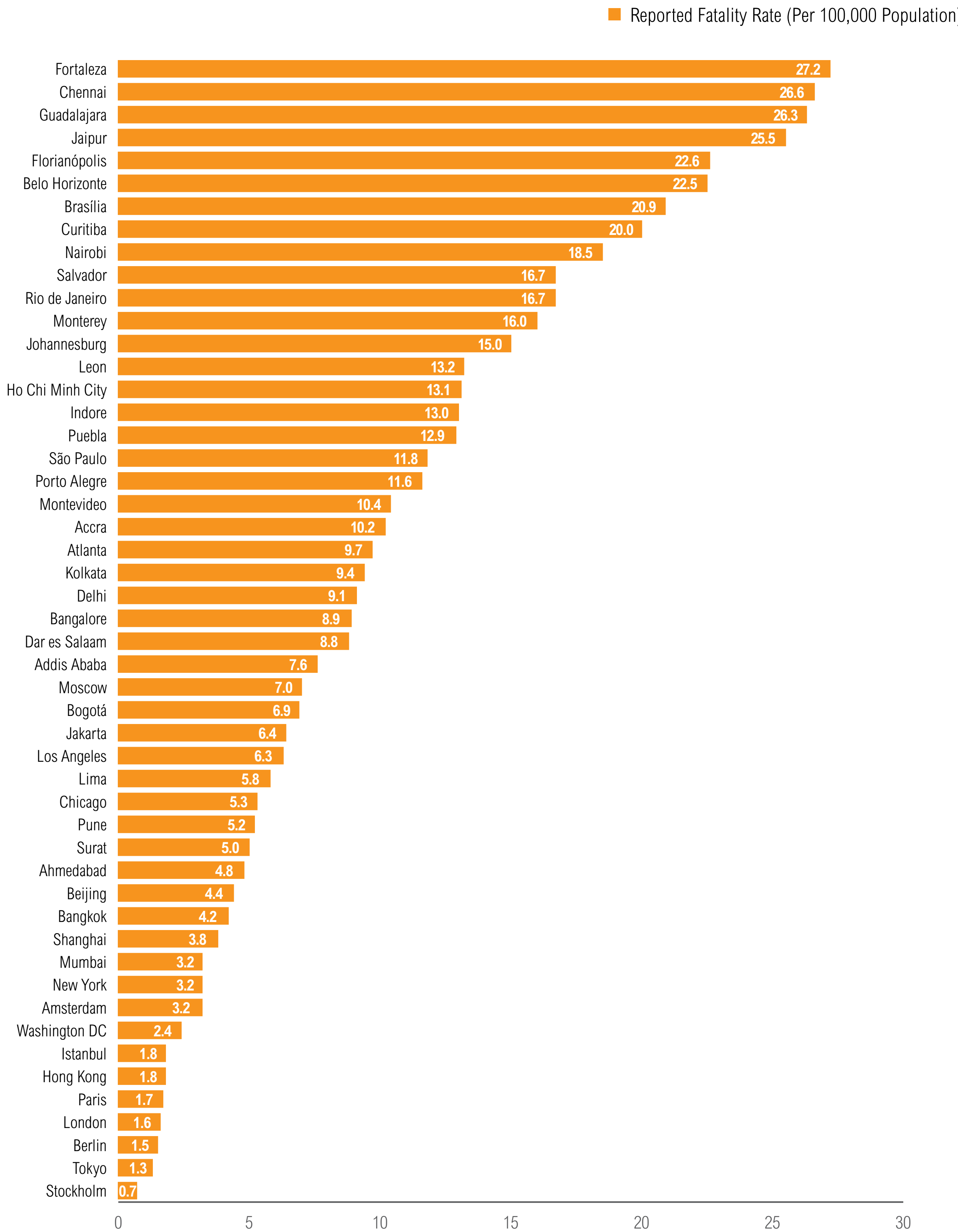
How many traffic fatalities are occurring in the world's major cities? While the World Health Organization (WHO) provides country-level statistics and information on how policies and practices are being addressed in its *Global Status Report on Road Safety*, data at the city level has not been collectively presented on a global scale. Providing better information on how cities compare across the world can help inform where and how different cities can approach improving traffic safety and the data used to do so.

EMBARQ collected data on reported traffic fatalities in cities worldwide. The data come almost entirely from government sources, at either the national or city level (Welle and Li 2015). As with country-level figures, there may be significant variation in terms of underreporting, follow-up with hospitals, data reliability, and other issues. Some cities and countries may not have developed a system based on international standards and local context to provide an accurate number of traffic fatalities. This is why some cities with better data collection and reporting may show higher numbers of fatalities than others.

Data from higher income countries are generally more reliable, so many of the cities outside the more developed regions may have much higher fatality rates than reported. For example, WHO estimates that on the country level Ethiopia may have nearly six times more traffic deaths than reported, and in India the estimate is nearly two times the reported deaths (WHO 2013). Li et al. (2006) estimated that the fatality rate in Shanghai in 2003 was 14.18 per 100,000 inhabitants. Others, such as those in Brazil, may appear at the top of the chart because of better crash reporting systems, though they still have very high fatality rates.

Improved crash data practices by cities are clearly needed, as is deeper research on injuries. A WHO publication—entitled *Data Systems: a road safety manual for decision-makers and practitioners* (2010)—provides more information on improving such systems. It is also difficult to compare cities when data quality and reporting is uneven, and there is no generally accepted methodology developed to benchmark differences in safety levels between cities and overcome differences in size, function, and morphology (Jost et al. 2009). An expanded effort to analyze the status of traffic safety in the urban context would allow cities to compare themselves more along these multiple factors and analyze their own systems.

Figure 1.1 | **Reported Traffic Fatalities Per 100,000 Inhabitants in Selected World Cities**



Source: EMBARQ technical note (Welle and Li 2015).
Note: Actual fatalities may vary for some cities with poor crash reporting systems.

1.2 Nearly All Urban Dwellers are Affected by Traffic Safety in Cities

The level of safety is partly contingent on the way people use the city and embark on their daily activities. Many different types of people are impacted by traffic safety. While there are numerous groups of people affected by traffic safety, some key groups to consider include the following:

Children. Road crashes are the leading cause of death among young people ages 15–29, and the second leading cause of death worldwide among young people ages 5–14 (WHO 2003). In Brazil from 2008–12, for instance, 4,056 children died in traffic crashes. Can children safely walk or bicycle to school, parks, and playgrounds? Can they bicycle on city streets?

The poor. People from lower socioeconomic backgrounds are more likely to be involved in traffic crashes, and often live in areas with low-quality infrastructure (WHO 2003). Are streets designed to protect and help those with lower socioeconomic status achieve access to upward mobility without a disproportionate threat of serious injury or death?

How is traffic safety in your city? How do people use the city and are they safe in doing so?

Elderly and the disabled. Older pedestrians and cyclists can account for up to 45 percent of pedestrian fatalities and up to 70 percent of cyclist fatalities (Oxley et al. 2004). Is there safe mobility for the elderly and disabled? Are the elderly accounted for in street design standards and processes?

Men and women. When analyzing safety by gender, there can be different levels of real or perceived safety. Traffic deaths are the leading cause of death globally for young men, and women and men have been shown to perceive traffic safety differently (DeJoy 1992).

Commuters and workers. Most workers spend anywhere from 30 to 60 minutes or more traveling to and from work—a time when they are at risk for falling victim to traffic crashes while trying to earn a living. Can commuters expect a safe trip to and from their work?

Customers. Research has shown that pedestrian and other crashes are associated with the location of retail land uses, at the places where people are going to buy clothes, food, and other consumer goods (Wedagamaa, Bird, and Metcalfe 2006). Can shoppers and errand-runners complete their activities in a safe place, and can they reach shopping areas safely?

Citizens. Those living in dense urban centers need space for civic activities and cultural enrichment, but they can encounter poor traffic safety conditions trying to access parks, plazas, libraries, and special events. Is the city a safe space for recreation and interaction, events and leisure?

Visitors. Road crashes are the single greatest annual cause of death of healthy U.S. citizens traveling abroad. This is likely the case for tourists from all countries (Association for Safe International Road Travel (ASIRT)(n.d.). Can tourists and traveling businesspeople safely arrive and find their way to sites and meetings?

1.3 Creating a Safer System for All People: Reducing Exposure and Risks

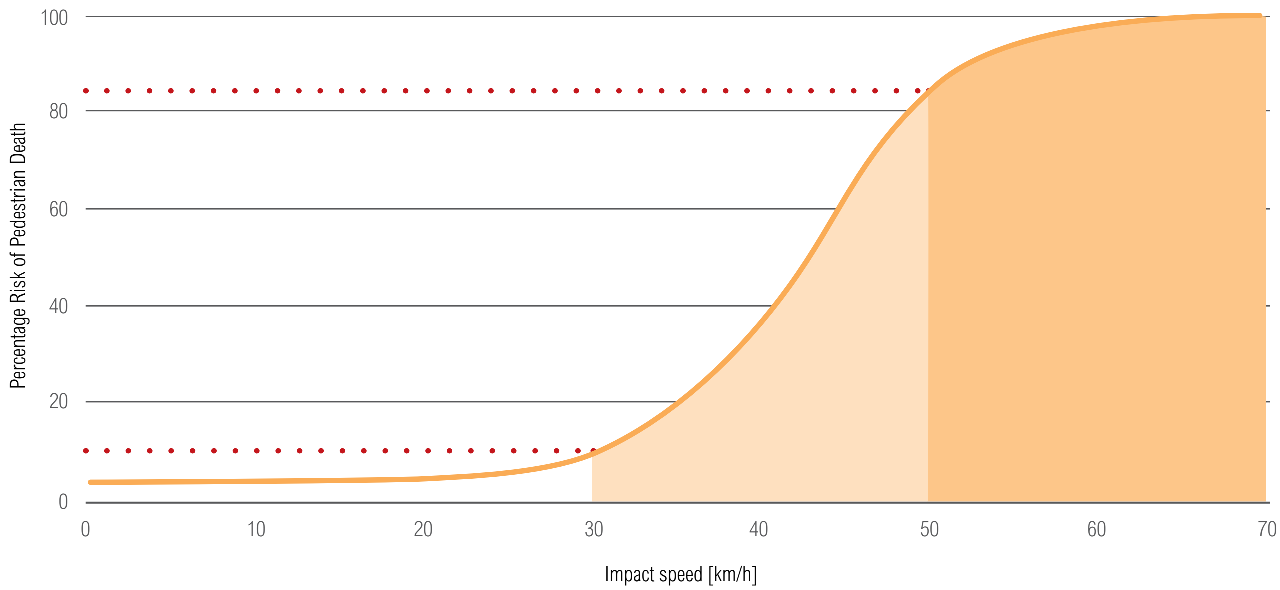
Looking closer within cities reveals that safety and design go hand in hand. The safest cities in the world for traffic safety include Stockholm, Berlin, Hong Kong, and Tokyo (see figure 1.1). These cities and others with lower levels of traffic crashes and deaths share certain characteristics.

Safer cities tend to be ones with extensive mass transport, good conditions for walking and cycling, and fewer cars on the road driving short distances at safer speeds, which lower the energy levels inflicted from vehicle impact. Data confirms there are fewer fatalities in places with fewer vehicle miles traveled and those promoting mass transport, walking and cycling, thus reducing overall exposure (Duduta, Adriazola, and Hidalgo 2012). These cities also have comprehensive traffic safety plans, which at their core pay attention to reducing vehicle speeds to make them safe for walking and cycling, in addition to providing good infrastructure for these modes. The approach is called safe systems (Bliss and Breen 2009).

This guide provides design principles to help achieve this safer environment. It can be explained under the following interconnected categories found in research on urban and street design.

- **Connected and compact urban design.** Cities can be safer when they have more compact and connected urban form that reduces the need for driving and fosters shorter trips. In a study from the United States, urban sprawl—places with less density, long blocks, and a lack of street connectivity—has been "directly related to traffic fatalities and pedestrian fatalities" (Ewing, Schieber, and Zegeer 2003). For every 1 percent change toward a more compact and connected urban form, all-mode traffic fatality rates fell by 1.49 percent and pedestrian fatality rates fell by 1.47 to 3.56 percent. In fact, densely populated New York City had the least fatalities, while the most sprawling areas of Atlanta and elsewhere the highest. Other research shows that this is because people drive less in the compact, mixed-use areas and that connected urban form tends to lead to lower vehicle speeds (Ewing and Dumbaugh 2010).
- **Safer vehicle speeds.** Enhancing safety depends on lowering vehicle speeds and reducing conflicts. Lower automobile speeds, especially those below 30 kilometers per hour (km/hr), have been found to drastically lessen the risk of fatalities (Rosen and Sander 2009). The fatality risk for pedestrians with vehicles traveling at 50 km/hr is more than twice as high as the risk at 40 km/hr and more than five times higher than the risk at 30 km/hr (figure 1.2). For example, bringing traffic speeds down to safer levels can be achieved through a set of evidence-based traffic calming measures (Bunn et al. 2003).
- **Managing arterials.** Ensuring safety is especially true with arterial corridors. Pedestrian-scaled retail configurations have been associated with fewer fatal crashes as opposed to layouts of big box stores with large parking lots along busy urban arterials (Dumbaugh and Rae 2009). Research from Mexico has shown that most crashes are likely to occur on wide arterials; similar findings are shown in New York City and elsewhere (Chias and Cervantes 2008; NYC DOT 2010). Rather than being built for the quick movement and flow of vehicles, putting pedestrians and bicyclists at high risk, cities can ensure safer design of complex intersections that involve multiple modes of transport and limit motor vehicle speeds to 40 km/hr, especially in mixed land use areas. Roads with higher speeds ought to be separated entirely from pedestrians, cyclists, and corresponding mixed land uses.
- **Walking, bicycling, and mass transport emphasized.** Cities with lower levels of vehicle travel have connected networks of high quality walking, bicycling, and mass transport infrastructure. Cities can make bicycling practical and safe, reducing injury rates as bicycling increases (Duduta, Adriazola, and Hidalgo 2012). U.S. and European cities with higher rates of bicycling have fewer overall traffic crashes. These cities also have good cycling infrastructure, high street connectivity and compact urban form (Marshall and Garrick 2011). On the flip side, there is evidence that bicycling rates are declining in places such as China and India—as road space is commandeered for automobiles, it becomes more dangerous to undertake this activity (Yan et al. 2011).

Figure 1.2 | **The Relationship Between Pedestrian Safety and the Impact Speed of Vehicles**



Note: The above figure shows the relationship between pedestrian fatalities and vehicle impact speed published by the OECD (2006). Some recent studies show a similar relationship, but account for sample bias to find slightly lower risks in the 40 to 50 km/hr range. (Rosen & Sander 2009, Tefft 2011, Richards 2010, Hannawald and Kauer 2004) There are not, however, studies from low- and middle-income countries where things like vehicle type, emergency response time and other characteristics may influence this relationship. In any case, there is clear evidence to support policies and practices that lower vehicle speeds to 30 km/hr where pedestrians are commonly present, and no more than 50 km/hr on non-grade separated streets.

When rebuilding a road to promote safer conditions, the introduction of Bus Rapid Transit has been shown to reduce traffic crashes on urban roads, in addition to providing a safer in-vehicle experience than motor vehicle drivers (Duduta, Adriazola, and Hidalgo 2012). Global research shows that cities with higher shares of mass transport use have fewer traffic fatalities (Litman 2014).

Taken together, these key considerations can reduce the need for vehicle travel exposure to traffic while lessening the risk of injury for everyone, especially pedestrians and cyclists.

Policies are beginning to embody this framework for a safer city. Mexico City's Mobility Law and policies recommended by the European Traffic Safety Council are providing a hierarchy of modal priority that begins with pedestrians, followed by cyclists, mass transport, and lastly, automobiles, to address concerns such as safety and sustainability ahead of moving only motorized traffic (ETSC 2014).

The cities with the best road safety records in the world incorporate sound design of their streets for pedestrians, cyclists, and mass transport to further reduce exposure and risk. Gothenburg, Sweden, for example, has introduced extensive traffic calming and car restriction measures, and significantly reduced the number of traffic fatalities over the past twenty-five years (Huzevka 2005).

This is especially important given the large numbers of pedestrians and bicyclists on the road. In most Latin American cities, walking comprises around 30 percent of all trips (Hidalgo and Huizenga 2013). Asian cities have historically high rates of walking, biking, or mass transit. Unfortunately, the unsafe conditions for walking and cycling may be pushing people toward car use.

Cities nevertheless have an opportunity to create places that are safe for all residents and reverse the trend of growing traffic fatalities.

BOX 1.1 | THE AVOID-SHIFT-IMPROVE PARADIGM

Changing the current paradigm involves a process by which cities can limit vehicle travel while maximizing safety for those who are traveling. A framework for this approach is the Avoid-Shift-Improve paradigm (Dalkmann and Brannigan 2007). The framework was created as a way to reduce carbon emissions from transport, but it can also be adapted to traffic safety. Cities can find synergies in policies to address both climate change and traffic safety. In terms of traffic safety, this means avoiding unnecessary vehicle trips, shifting trips to safer, less threatening modes, and improving the existing environment and operations to be safer for all road users.

Avoid unnecessary trips to prevent traffic fatalities and injuries, by creating an urban development pattern that is compact, walkable, and accessible by mass transport and contains mixed land uses.

Shift trips to safe or less threatening modes from automobile travel by creating high quality transit and compact development, allowing people to safely walk and bike.

Improve the design and operation of urban development to maximize safety of all trips, by slowing speeds and protecting pedestrians and bicyclists.

BOX 1.2 | THE 5Ds AND PRINCIPLES FOR TRANSIT-ORIENTED DEVELOPMENT

An urban form framework that reduces driving and encourages walking and biking is described as the "5Ds" of *density*, *diversity*, *design*, *destination*, and *distance* (Ewing and Cervero 2010). *Density* refers to the number of housing units or quantity of office space per hectare, or built density. *Diversity* is a measure of land use mix, based on the hypothesis that people are more likely to walk in areas with a mix of shops, offices and housing, rather than in single use suburban neighborhoods. The third dimension, *design*, refers to the quality of the pedestrian environment, number of street trees, presence of street furniture, etc. *Destination* refers to the ability or convenience of accessing different trip destinations from a point of origin, such as to major commercial and employment centers. The last factor, *distance*, refers to the proximity of public transport to reach destinations. This definitive study found that people tend to walk and use transit more and drive less in areas with better pedestrian facilities, such as wider sidewalks, more transit stops, and a good combination of the characteristics that define the 5Ds.

EMBARQ Mexico has developed guidelines to promote the 5Ds and transit-oriented development in a manual for the Mexican context that can be applied in other developing countries. The manual identifies the following key elements in shaping overall development: (1) quality, safe facilities for non-motorized transport; (2) high-quality public transport; (3) active and safe public spaces; (4) mixed land uses; (5) active street life; (6) management of automobiles and parking; and (7) community participation and security.

1.4 Analyzing Traffic Safety in Cities

Data can dramatically help cities create a safer system and deploy the design principles presented in this guide. Cities with traffic crash data collection systems in place can review and analyze the information for a variety of uses, including creating policy goals, identifying the most dangerous streets and locations (known as black or hot spots), and learning how streets can be designed safely.

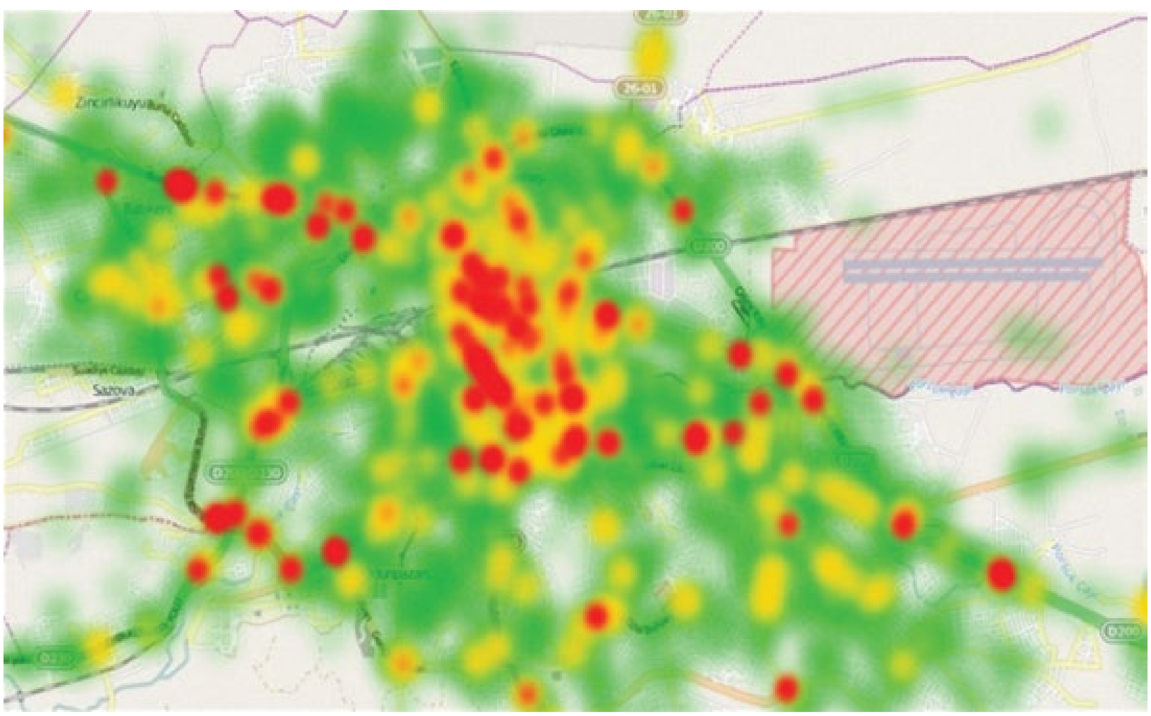
Cities can establish a process to inspect high-risk areas and make appropriate changes to improve safety. New York City, for example, analyzed pedestrian crashes citywide and targeted street design changes toward high-risk corridors (NYC DOT 2010). In Turkey, EMBARQ Turkey has helped five municipalities identify black spots and recommend traffic calming and other design changes based on road safety inspections.

Data can be used to provide evidence about what makes a city safer, including before and after measurements of road design changes and crash frequency models comparing different street designs within a city.

1.5 Performance Measures

Hand in hand with data analysis, improving traffic safety in cities relies on successfully measuring the performance of various interventions. According to the World Bank, periodic monitoring and evaluation of traffic safety targets and programs are

Figure 1.3 | **Traffic Crash Locations Can Be Analyzed Using "Heat Maps"**



The heat maps shown here from Turkey use PTV Visum Safety software to identify street corridors or neighborhoods for design, enforcement, or other targeted actions to improve safety. These maps can address pedestrian or bicycle crashes, areas around schools, and other more specific topics.

essential to assess performance and are integral to a safe system approach to traffic safety (World Bank 2013).

There are a variety of factors to consider in evaluating the progress of traffic safety policies and projects. Decision makers, engineers, and planners instituting traffic safety plans and measures within community and street design can consider the following key indicators in monitoring and evaluation.

Final safety outcomes. These include deaths and injuries recorded by police, hospitals, health authorities, or other sources of such information. A common indicator is the number of traffic fatalities per 100,000 inhabitants, which is ideal for comparing jurisdictions or for monitoring progress over time. A common form of measurement counts those killed or seriously injured, abbreviated as KSI.

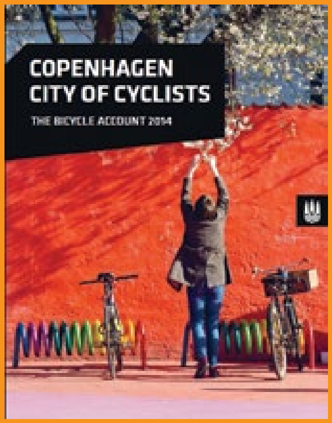
Exposure. Kilometers traveled by mode, traffic volume by mode, mode share of trips or commuting trips.

Risk. Traffic crashes, fatalities, and injuries over mode or passenger distance traveled. Traditional engineering has often focused on reducing crash frequency per VKT, which can lead to a bias toward treatments that improve car occupant safety. Instead, cities can treat all the modes fairly and focus on locations that are especially prone to produce fatalities or serious injuries.

Infrastructure and Design. Includes the number of safety engineering treatments per section of street network, characteristics of community design that reduce speed or offer good conditions for walking, cycling and mass transport facilities and volume, and average vehicle speeds by road type.

Perceptions. Perceived safety of bicycling and walking, percent of residents who feel safe crossing the street, percent of residents satisfied with pedestrian, cycling, and public transport facilities.

BOX 1.3 | COUNTING REAL AND PERCEIVED SAFETY



Every other year the city of Copenhagen undertakes an account of bicycling in the city, measuring a range of factors from the number of bicyclists to residents' opinions about whether they would ride if they could feel safer. A key feature of the account is that it makes a distinction between actual safety and the sense of safety in traffic. The city notes that "actual safety refers to the number of serious casualties involving cyclists in Copenhagen. Sense of safety refers to the individual's subjective perception of how safe it feels to cycle" (City of Copenhagen 2010). The city's account notes that both factors are crucial in its effort to become the world's best city for bicycling, and it uses these and other key indicators to continuously monitor and evaluate the performance of bicycling in the city. Cities such as Minneapolis and more recently Bogotá have introduced bicycle accounts to evaluate and measure progress toward their goals. Similar accounts can be used for monitoring pedestrian activity and safety, in addition to evaluations of street redesign, seen in New York City's "Measuring the Street" report.

KEY URBAN DESIGN ELEMENTS

Building safer cities for pedestrians and cyclists doesn't only mean improving streets. Urban design plays an important role in creating a safer travel environment. Cities can facilitate development that allows more people to use mass transit, walking, and bicycling and limit unnecessary motor vehicle trips.

Safer urban design can help reduce motor vehicle speeds and provide a safer and more user-friendly street network for pedestrians. The faster a driver goes, the more difficult it is for her or him to avoid hitting a pedestrian in their path. This is the case with large blocks, which encourage faster speeds, due to uninterrupted travel that allows vehicles to accelerate more freely while requiring more time to stop. Shorter block faces and narrower street widths can reduce speeds, provide more walkable conditions, and greatly reduce the chances of pedestrian death and injury. Some research shows that certain small block patterns with more four-way junctions may actually lead to more traffic crashes, but in this case the smaller street configurations still lead to fewer fatalities and injuries (Dumbaugh and Rae 2009).

Street network connectivity, which measures the directness of pedestrian and/or vehicle routes, is a key element in community design. Pedestrians and cyclists can find more direct routes in a more connected street network or grid as opposed to disconnected, cul-de-sac, or superblock networks that can discourage walking and bicycling.

This chapter describes specific key elements of urban form that, especially when taken together, can lead to increased safety:

- Block size
- Street connectivity
- Street widths
- Access to destinations
- Population density

BOX 2.1 | PLANNING FOR SAFE WALKING & CYCLING

Cities can foster the development of safer conditions for all road users through planning that prioritizes mass transport, pedestrians, and bicyclists.

Comprehensive or long-range plans. Cities can embrace the principles identified in this chapter within their major plans and zoning regulations, including clear and predictable standards and expectations for safety of a high quality public realm and a hierarchy that prioritizes pedestrians, bicyclists, and mass transport.

Local area plans. Cities can prepare local area plans that may provide guidance on community and street design for particular neighborhoods, such as transit station areas, development corridors, or other new or existing areas for urban development.

Transport and mobility plans. Citywide transport or mobility plans can take into account the needs of all road users by planning and setting goals, such as safety for vehicles, bicycle and pedestrian networks, and mass transit services (APA 2006). They can also set targets for desired modal splits. Several cities have created their own specific bicycle or pedestrian plans. These plans can set a hierarchy of road users and map existing and future cycling and pedestrian networks—through areas such as neighborhood streets and arterials, parks, off-street trails on rail corridors or waterfronts, boulevards, shared streets, pedestrian-only streets, and other public spaces that can be linked together in a connected web for direct and safe travel.

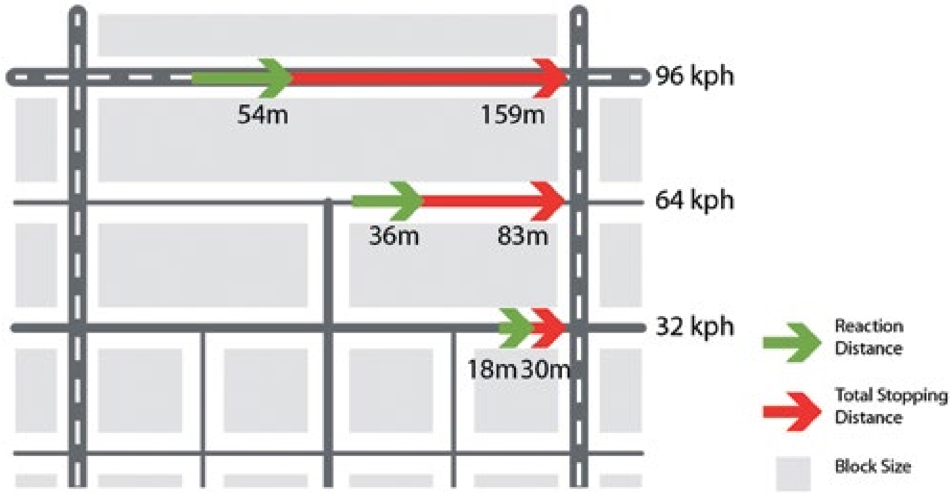
Strategic traffic safety plan. Cities can create specific plans to address traffic safety through a comprehensive approach that addresses a shared ownership between road users and designers to create a safer system. The plans can include ambitious targets to reduce traffic fatalities and serious injuries. For example, Copenhagen has its own Traffic Safety Plan for the city, and New York City recently released its Vision Zero Action Plan.

Street design guides. Many cities create their own pedestrian and cycling master plans accompanied by a tailored set of street design guidelines for the local context. This guide provides a general overview of the different tools cities can use to create a safer city by design, and can consider creating their own specific design guide for their problems, needs, opportunities, and strengths. Examples include the Abu Dhabi Urban Street Design Manual or the New York City Street Design Guide, which provides detailed information on everything from basic sidewalk designs to traffic calming measures to bicycling lanes and street fixtures.

2.1 BLOCK SIZE

Longer block faces allow higher vehicle speeds, placing pedestrians at higher risk.

Longer street blocks are unsafe for pedestrians. Long blocks commonly have crosswalks only at intersections, indirectly encouraging unsafe midblock crossings. Long blocks also encourage higher vehicle speeds due to fewer junctions that interrupt travel. More junctions mean more places where cars must stop and pedestrians can cross.



Note: Assumes 2 seconds reaction time and vehicle deceleration rate of 3.4 m/s².

Design Principles

- For a high degree of walkability, block lengths of 75 to 150 meters are more desirable.
- If blocks are scaled to automobiles (200–250 meters) or superblocks (800 meters or more), midblock crossings and pass-throughs are recommended every 100–150 meters, either signalized or using raised crossings or speed humps before crossings.

Benefits

- Shorter block faces reduce the incentive for crossing in midblock, since the distance to the nearest intersection is shorter.
- Smaller blocks and more frequent stops at intersections will reduce vehicle speeds.
- Smaller blocks and compact communities help reduce travel distance to jobs, services, and entertainment by providing more cut-through paths in all directions, thus facilitating travel by walking or cycling, and minimizing dependency on motorized travel.

Application

- Streets may be added to reduce block face lengths, and in large blocks pass-throughs and other pedestrian/bicycle connecters can be considered.
- Care should be taken to provide safer intersection designs or T-junctions to reduce conflicts as four-armed junctions are more prone to traffic crashes.
- For newly built areas, smaller block sizes are recommended. Zoning codes can require shorter blocks and a street hierarchy.

Evidence

- Evidence from China has shown that the long blocks of typical urban development (superblocks) encourage midblock crossing on arterials, a high-risk area for pedestrian fatalities (Tao, Mehndiratta, and Deakin 2010).
- Evidence from Guadalajara, Mexico shows that the total length of all approaches to intersections and the number of injurious and fatal crashes at intersections are significantly related (Duduta, Lindau, and Adriazola-Steil 2013).
- Research shows that while smaller blocks can lead to more traffic crashes (not considering other street designs), they lead to fewer fatal crashes and injuries due to lower speeds (Dumbaugh and Rae 2009).

Figure 2.1 | **Block Size Case**

The smaller block sizes in the central areas of Shanghai foster a more walkable street network, as opposed to large superblocks that allow higher vehicle speeds and result in more dangerous mid-block crossings by pedestrians.

2.2 CONNECTIVITY

Connectivity refers to the directness of links and the density of connections in a street network. A highly connected network has many short links, numerous intersections, and minimal dead-ends. As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations and creating more accessibility (Victoria Transport Policy Institute 2012). It affects the need to travel and the attractiveness of walking and cycling.

Comparison in 800-meter radius walking catchment in different street connectivity scenarios (compact grid vs. sprawling suburb).

Design Principles

- Create multiple links for pedestrians and cyclists through an interconnected street network.
- Plan new subdivisions based on pedestrian and cyclist movement before the road network is fixed.
- Ensure pathway networks connect with arterial networks to travel longer distance (particularly relevant for cycle use) and that non-arterial streets connect.
- Balance with distinct design by function, associated speed classification and reduced accessibility, especially in residential areas.

Figure 2.2 | **Connectivity Case**

Many Mexico City neighborhoods have a connected street network, which makes walking more direct and convenient.

Benefits

- A dense network of streets can disperse traffic rather than concentrate it on arterials, so that traffic is more spread out and can be scaled accordingly.
- Excellent connectivity actively seeks to discourage car use by making local trips easier and more pleasant by foot.
- A connected network has more intersections making it easy to reach a destination in a reasonably direct route (Frumkin, Frank, and Jackson 2004).

Application

- The higher density and more mixed use there is, the more connected the streets should be.
- In existing areas that lack connectivity, new streets or pathways can be considered to increase direct pedestrian routes.
- In the ideal situation, street layout should offer a high level of connectivity that prioritizes direct walking routes while limiting the number of 4-armed junctions, which have more conflict points. In layouts resembling more perfect grids, however, traffic calming and diversion can be used to achieve this effect.

Evidence

- Meta-analysis shows street connectivity to be one of the most important factors in fostering walking and reducing vehicle travel (Ewing and Cervero, 2010).
- Three and four legged intersections have been shown to have a greater frequency of crashes, though less severity in fewer fatalities and serious injuries. Appropriate traffic calming measures can help ameliorate this issue, leading to a safer overall system (Dumbaugh and Rae 2010).

2.3 VEHICLE/TRAVEL LANE WIDTH

Street width often means the roadbed width, which is the distance between curb edges on opposite sides of a street, or, where no curbs exist, from pavement edge to pavement edge. The width of space allowed for vehicle travel on streets greatly influences pedestrian crossing distance and the roadway width potentially available for other uses, such as bike lanes, parking lanes, or landscape curb extensions. This is separate from the width of the space between buildings or the total public right of way, including sidewalks and other areas not dedicated to vehicles.

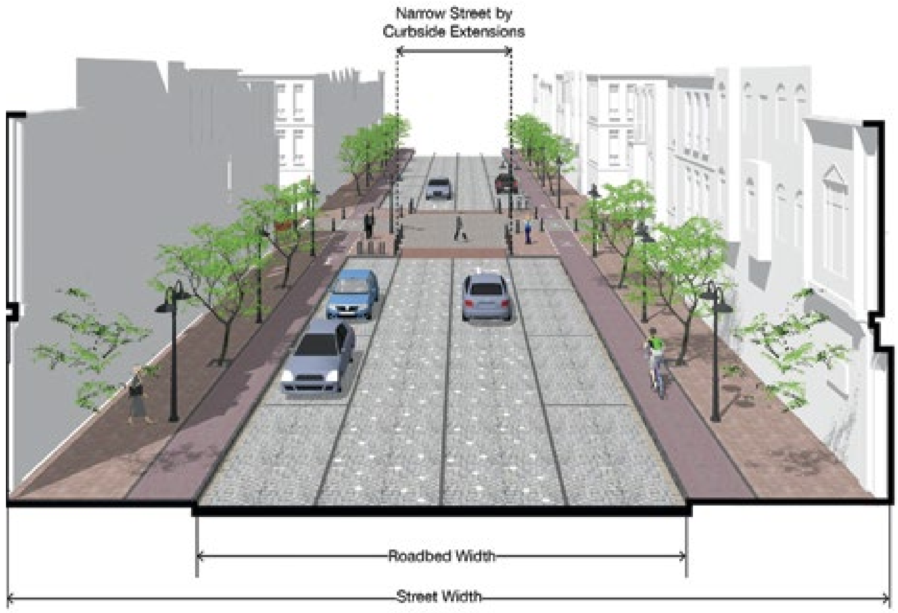


Illustration showing the different aspects of street width.

Design Principles

- Minimize vehicle travel lane width to prioritize pedestrians.
- Provide sidewalk on both sides of street wherever possible.
- Provide appropriate width for building and land use function.
- Minimum street widths needed to support all road users.

Benefits

- Reduced street widths will shorten pedestrian crossing distance and exposure to cars.
- Narrow streets slow traffic by increasing drivers' perception of impediments to motion, and mitigate the potential severity of crashes.
- On-street parking and street trees visually narrow the street for those traveling along it, and can help lower vehicle speeds.

Application

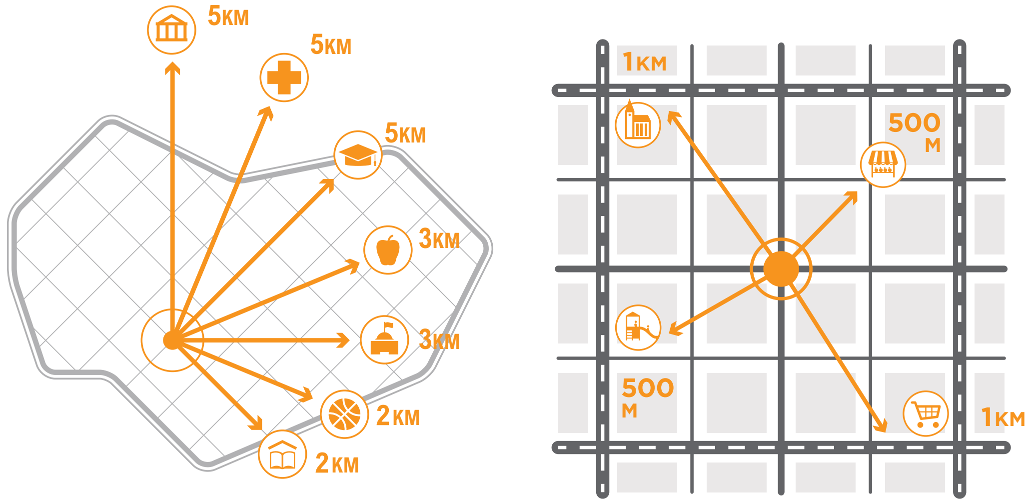
- A street hierarchy may regulate widths in city code or regulation, and may need to be changed to reflect safer designs.
- In places where private owners control sidewalk areas, efforts can be made to make them responsible for sidewalk design and maintenance according to city regulations, or they can be taken over by the city.
- Curb extensions can reduce width and crossing times.
- Signals should allow ample pedestrian crossing time.
- Care should be taken for cyclists on more narrow streets.

Evidence

- Evidence from Mexico City shows that as the maximum pedestrian crossing distance at an intersection increases by 1 meter, the frequency of pedestrian crashes increases by up to 3 percent (Duduta et al. 2015). Each additional lane (another measure of street width) also increases crashes at all severity levels (Duduta et al. 2015).
- The most significant relationship to injury crashes was found to be street width and street curvature. As street width widens, crashes per mile per year increase exponentially. The safest residential street width is 7.5 meters (Swift, Painter, and Goldstein 1997).

2.4 ACCESS TO DESTINATIONS

Pedestrian destinations or points of interest are normally places that people find useful or interesting or where employment, retail, and leisure uses concentrate. High-quality networks should be provided particularly between key destinations such as residential areas, schools, shopping areas, bus stops, stations, and places of work.



Destinations and points of interest.

Design Principles

- Neighborhoods should be designed to include transit, parks, schools, stores, and other uses within walking distance, considering a .5-km catchment area for these activities.
- Complement with safe pedestrian and bicycle routes to nearby destinations such as schools, parks, and retail.
- Provide residential densities that support local facilities (over 30 dwellings/hectare may sustain basic walking distance facilities).

Figure 2.4 | **Access to Destinations Case**

Nearby cafes, shops, and public spaces in the Coyoacan neighborhood of Mexico City encourage walking and reduce the need for vehicle travel.

Benefits

- A variety of destinations in local and neighborhood clusters encourage people to meet and have public facilities and services close to home, saving time and money.
- Mixed uses can improve street vitality. Lighting, flexible use of buildings, and crime prevention through urban design encourage more nighttime activity.
- There is a sense of community ownership and responsibility for the public realm (Tolley 2003).

Application

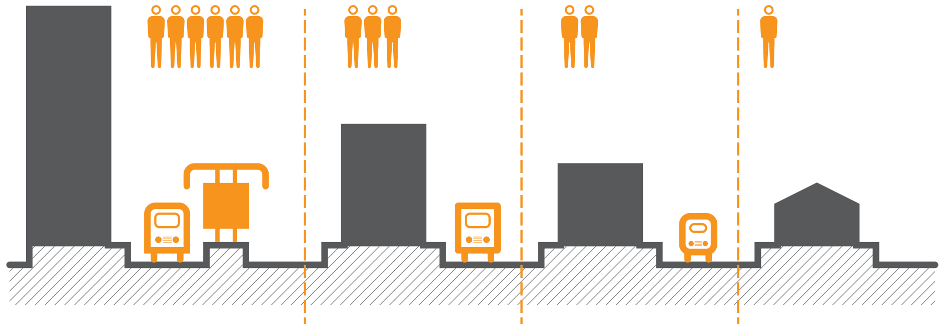
- In downtown and other commercial locations, buses and trams should be able to set down and pick up passengers as close as possible to main destinations.
- City plans can set goals for access to transit, parks, and retail nodes.

Evidence

- Urban sprawl, typically used to describe more car-oriented areas and longer distances to destinations, was directly related to traffic fatalities and pedestrian fatalities in a study of 448 United States counties in 101 metro areas (Ewing, Shieber, and Zegeer 2003).
- A meta-analysis on travel and the built environment found that vehicle kilometers traveled is most strongly related to measures of accessibility to destinations, meaning that efforts to increase destination accessibility can decrease vehicle travel and improve overall safety (Ewing and Cervero 2010).

2.5 POPULATION DENSITY

Population density refers to day and nighttime population per square kilometer or other unit area. Density is not directly related to safety, but can play a role in complementing other design factors. Locating more people within walking distance of services, public facilities, and transport can help reduce the need for driving.



Greater population densities can help support mass transit and nearby uses.

Design Principles

- Density alone is not an indicator of traffic safety in cities, but rather can be used with other community design elements in this guide to increase walking and cycling and reduce motorized travel.
- Dense communities should be coupled with safe street designs that protect pedestrians and cyclists.
- Areas around mass transport stations and corridors can be targeted, especially those within a half-kilometer catchment area of stations.

Benefits

- Creates demand and support for mass transport, parks, retail, and services.
- In contrast to more sprawling land uses, density reduces the need for more infrastructure such as roads and sewers.
- Helps reduce the need for vehicle travel and supports walking and bicycling.

Application

- Population and household density can be combined with other urban form elements such as street connectivity, proximity to destination, and mixed uses. If not, density may contribute to less safe conditions by not complementing the concentration of people with measures that reduce car speeds and foster safer walking.
- Local plans and regulatory codes may need adjusting to accom-modate desired population densities.

Evidence

- Urban sprawl, typically used to also describe places without a compact urban form, was directly related to traffic fatalities and pedestrian fatalities in a study of 448 United States counties in 101 metro areas (Ewing, Shieber, and Zegeer 2003).
- Dumbaugh and Rae (2009) found that for an increase in density of 100 persons / square mile, there was a 6 percent reduction in injurious crashes and a 5 percent reduction in all crashes, after controlling for VMT, street connectivity, and land use.
- A meta-analysis from 10 separate studies showed population/ household density was linked to increased walking and mass transport use as well as reduced vehicle travel (Ewing and Cervero 2010).

Figure 2.5 | **Population Density Case**

Cities such as Tokyo, near the Shibuya station here have developed high density residential and commercial areas around rail and other mass trans-port stations, fostering less motor vehicle use. Tokyo has one of the lowest traffic fatality rates in the world.

TRAFFIC CALMING MEASURES

Lower automobile speeds, especially those below 35 km/hr, have been found to drastically lessen the risk of fatalities (Rosen and Sander 2009). Creating safer streets when cars are present means balancing the inherent tension between vehicle speeds and the safety of pedestrians, cyclists, and motor vehicle occupants alike (Dumbaugh and Li 2011).

A number of street design interventions have been found to reduce traffic speeds and improve safety. Called "traffic calming," most of these actions can actually improve the visual aesthetics of streets (Bunn et al. 2003).

Measures we present in this chapter involve physically altering the road layout or geometry to actively or passively slow traffic. The measures can result in more attentive driving, reduced speeds, reduced crashes, improved conditions for bicycling, and greater tendency to yield to pedestrians. They also have been found to improve traffic safety in developing cities, such as Beijing (Changcheng et al. 2010). These measures are especially important around shopping areas, schools, parks and recreational areas, places of worship, and community centers. They can be applied as a network of measures in what is called area-wide traffic calming.

Traffic calming can complement other considerations in this guide regarding arterials, pedestrian and bicycling conditions, and community design. For example, reduced speeds can open up the possibility for shared streets, street plazas, wider sidewalks, bicycle lanes and other features, and alternatively, designing for pedestrians and cyclists will open up opportunities for reducing speeds.

Traffic calming measures presented in this chapter include the following:

- Speed humps
- Speed cushions
- Chicanes
- Chokers
- Curb extensions
- Raised pedestrian crossings
- Traffic circles
- Roundabouts

3.1 SPEED HUMPS

Speed humps are raised pavement that can reduce speeds to a certain limit based on the height and length of the hump. Humps are artificial elevations on the roadway. A hump is often designed as part of a circle, a trapeze, or as a sinusoidal curve. Speed humps can be designed for different target speeds, and are not limited to low traffic streets. Ideally, speed humps will enable vehicles to travel at a target speed consistently along a road, rather than slowing down and speeding up before and after each hump.

Design Principles

- The geometry of a speed hump determines the speed at which traffic will travel over it: those with larger area-to-width ratios have more drastic slowdown effect (see figure 4.2).
- Length typically ranges from 3.7 to 4.25 m. Heights range from 7.5 to 10 cm.
- Often placed in a series, spaced 100 to 170 meters apart.
- Humps in a series must be properly spaced to encourage driving at constant target speed and to avoid noise from braking and acceleration immediately before and after each device.
- Must be sufficiently marked, optionally with signage. At a minimum, an advance warning sign before first hump in series.
- Humps constructed as raised pedestrian crossings have level ramps and a level surface.

Benefits

- Reduce vehicle speeds, and enhance pedestrian/crossing and cyclist safety.
- Low in cost and require minimum maintenance.

Application

- Speed humps are frequently used on residential and local streets to reduce speeds, but can be used on arterials as well.
- Do not use if sight distance is limited and/or if the street is on a steep grade.
- Humps are more appropriate at midblock than at an intersection, unless designed as a raised crossing.
- Can be considered as part of greater area-wide traffic calming.
- Bus passenger comfort should be accounted for where speed humps are applied on certain bus routes. Speed cushions may alternatively allow buses to pass with limited disturbance to passengers.

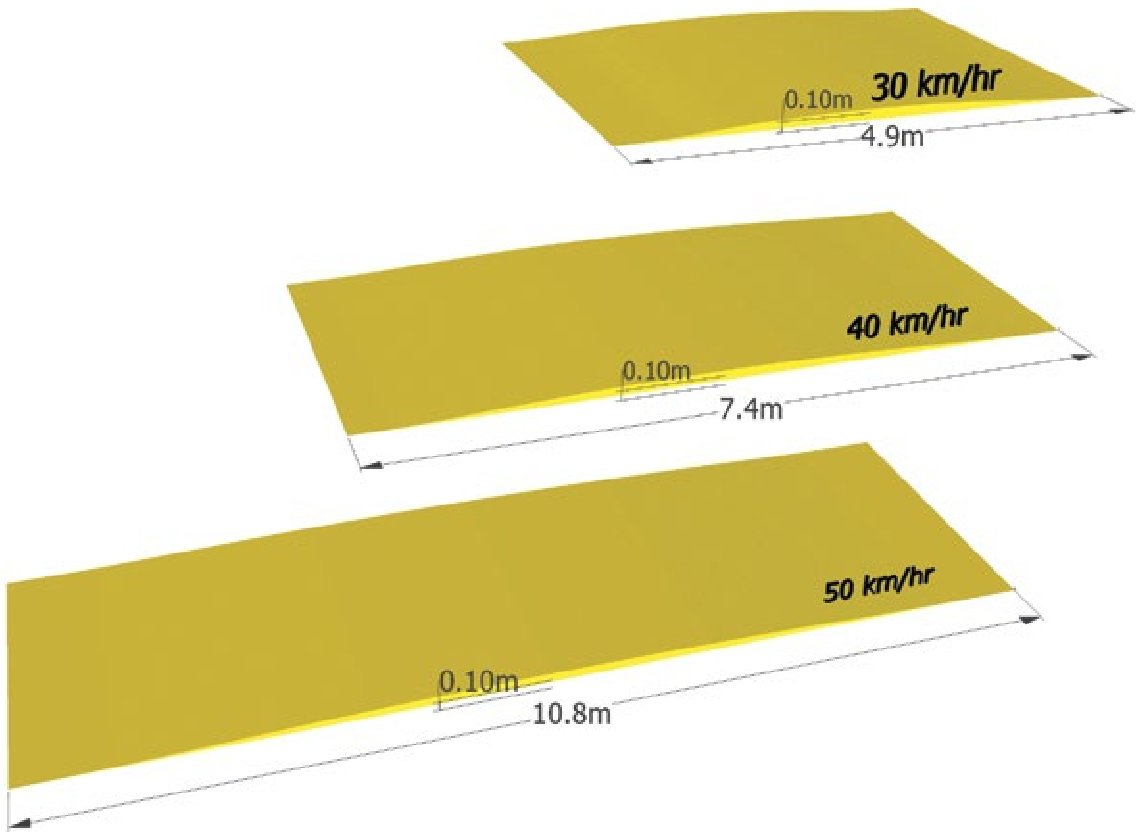
Evidence

- Studies from Norway show that humps reduce the number of injury crashes, for a given amount of traffic, by around 50 percent.
- Traffic volume goes down where humps are introduced. Studies show that on average, the reduction in traffic is around 25 percent.
- On average, newly installed humps reduce mean vehicle speeds from 36.4 to 24.4 km/hr (Elvik, Hoye, and Vaa 2009).

Figure 3.1.1 | **Speed Humps Case**

A speed hump in Mexico City near a school slows neighborhood traffic.

Figure 3.1.2 | **Speed Humps Can Be Designed for Different Speeds**



3.2 SPEED CUSHIONS

Speed cushions are traffic calming devices designed as several small speed humps installed across the width of the road with spaces between them. Speed cushions force cars to slow down but are different from a speed hump as they can better allow movement of larger vehicles—such as buses or ambulances—by straddling the cushions.

Speed cushions can allow wide-axle vehicles to pass over the cushion to increase comfort for bus passengers.

Design Principles

- Speed cushions are narrower than the lane width and are rectangular or square in shape.
- The basic design of speed cushions is very much like the speed hump, except the additional modifications to accommodate for wider vehicle width of cars. The width of each cushion is designed intentionally so that the wider axle of emergency vehicles or buses can pass but that the smaller passenger vehicles must ride over the raised area.

Benefits

- Slows down vehicle speed and contributes to the reduction in the number and severity of crashes.
- Avoids excessive discomfort or damage to emergency vehicles and buses by making separations in the hump.
- Less costly than speed humps, while most cities report them to be just as effective.
- Easy to install, remove and maintain; some come pre-made.

Application

- Can be designed for speeds from 20 to 50 km/hr.
- Permanent speed cushions and humps are generally made of asphalt. Rubber models are more temporary and can be removed or replaced easily.
- Residential streets, school zones, and playground zones are also recommended to install speed cushions to slow traffic speed and enhance safety.

Evidence

- Experience in the United States has shown that speed cushions exhibit similar effectiveness in terms of controlling speed as speed humps of equal height and length.
- The presence of speed cushions, however, has little effect on controlling the speed of two-wheel motorized vehicles, which can pass between speed cushions (Berthod 2011).

Figure 3.2 | **Speed Cushions Case**

A speed cushion in Paris, France slows traffic before an intersection, providing greater protection for pedestrians.

3.3 CHICANES

Chicanes are artificial turns created to slow traffic. They lead to a reduction in the width of the roadway, either on one side or on both sides or constructed in a zigzag, staggered pattern that directs drivers away from a straight line, which can reduce vehicular speeds on both one- and two-lane roads.

Figure 3.3 | **Chicanes Case**

A chicane in Istanbul, Turkey creates a safer neighborhood street, staggers parking to each side of the chicane, and can contain vegetation to improve aesthetics.

Design Principles

- Simple approach is to alternate on-street parking from one side of the street to the other on a one-lane road. This can be combined with curb extensions and raised crossings.
- On two-lane roads, such as an arterial in a residential area, staggered chicanes can be used by applying parking, central reserves turning lanes, etc. at various sections.
- Adequate space should be provided for pedestrians and bicyclists.
- Landscape must be designed not to disturb drivers' views.

Benefits

- Forces drivers to drive more slowly and with greater awareness, particularly at midblock locations.
- Can green and beautify the streetscape with trees and/or vegetation, improving environmental quality.
- Has minimal impact on emergency response vehicles compared to speed humps and other vertical deflection measures.

Application

- Can be useful on straight streets with long blocks combined with midblock crossings to enhance pedestrian safety.
- Useful on arterials passing through more residential or mixed land use areas that require safer speeds.
- Bicycles can have separate path next to sidewalk.
- Large vehicles can go through chicanes, particularly buses, as bus stops can be used as part of the speed reduction measure.

Evidence

- Available data for chicane schemes indicated a reduction in injury crashes (54 percent) and crash severity (UK Department for Transport 1997).

3.4 CHOKERS

Chokers are curb extensions that narrow a street by widening the sidewalks or placing planting strips, effectively creating a pinch point along the street. They lead to a reduction in the width of the roadway, vehicular speeds, and pedestrian crossing distance.

Design Principles

- Chokers can be created by bringing both curbs in, or they can be done by more dramatically widening one side at midblock locations.
- Reduce a two-lane street to one lane through a choking point in a neighborhood setting, requiring motorists to yield to each other. In order for this to function effectively, the width of the travel-way cannot be wide enough for two cars to pass: 3.5~3.75 meters is generally effective.
- Can be combined with on-street parking, as would be the case for a one-way street with a choker that visually and physically narrows the road bed.
- When space permits, more functional designs on the extended curb, such as those with landscape elements or community facilities such as seating or bicycle parking, can be used whenever possible.

Benefits

- Slower vehicle speeds at a mid-point along the street can improve pedestrian crossing safety.
- Narrows overly wide midblock areas of streets.
- Add room along the sidewalk or planting strip for landscaping or street furniture.
- Reduce cut-through traffic.
- Reduce pedestrian crossing distance at a midblock location.

Application

- Chokers are only appropriate for low-volume, low-speed streets.
- Care should be taken to ensure that street furniture and landscaping do not block motorists' view of pedestrians.
- Consult with local fire and sanitation departments before setting width to ensure passage of service/emergency vehicles.
- Consider how bicycles will pass through area, such as placing cycle track between choker and sidewalk.

Figure 3.4 | **Chokers Case**

Chokers in London squeeze cars into a passage that requires them to reduce speeds. Chokers tend to extend farther into the street than regular curb extensions, aimed more at slowing traffic than reducing crossing distance of pedestrians.

Evidence

- Speeds have typically been reduced on average by 4 percent for two-lane chokers and 14 percent for one-lane chokers (Institute of Transportation Engineers 2013).
- Minor decrease in traffic for two-lane and 20 percent reduction for one-lane chokers (Institute of Transportation Engineers 2013).

3.5 CURB EXTENSIONS

Curb extensions are extensions of the sidewalk, usually at intersections that improve pedestrian visibility and reduce crossing distances. An expansion of the curb line into the lane of the roadway adjacent to the curb (typically a parking lane) for a portion of a block, either at a corner or midblock, can reduce speeds of turning vehicles and offer protection to pedestrians.

Design Principles

- Curb extension width is typically slightly less than the width of the parking lane.
- When space permits, more functional curb extension designs, such as those with landscape elements or community facilities such as seating or bicycle parking, can be used whenever possible.
- Ensure that angles between turning cars and bicyclists allow visual contact between these road users.
- Identify where parking spaces and lanes can be removed or reduced to allow for curb extensions.

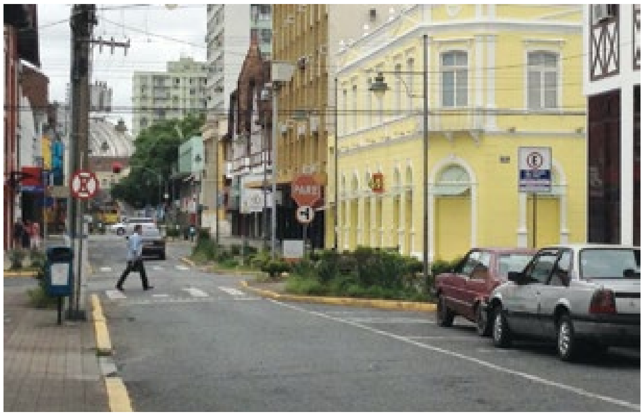


Figure 3.5 | **Curb Extensions Case**

A curb extension in Joinville, Santa Catarina, Brazil on a one-way street shortens the pedestrian crossing distance and creates green infrastructure to capture storm water and beautify the street.

Benefits

- Calms traffic by physically and visually narrowing the roadway.
- Slows turning vehicles and shortens crossing distance, reducing pedestrian exposure and minimizing signal time.
- Creates space that may be used to locate street furniture, bike parking, etc.
- Physically prevents illegal parking near intersections and crossings.

Application

- Curb extensions should typically be used where there is a parking lane and near bus stops.
- Midblock extensions provide an opportunity to enhance midblock crossings.
- Extensions can be areas for landscaping or water management, though care should be taken to ensure that street furniture and landscaping do not block motorists' view of pedestrians.
- Cannot be used where curbside travel (including bus, bicycle, or general traffic) lane exists, such as those created through peak-period parking restrictions.
- Expand length to provide seating areas and landscaping, and expand pedestrian space.

Evidence

- Evidence from Latin American cities shows that the chance of a vehicle collision and pedestrian crash increases by 6 percent for every additional 1 meter of pedestrian crossing distance (Duduta et al. 2015).

3.6 RAISED INTERSECTIONS/ CROSSINGS

Raised crossings are elevations of the road that slow cars as pedestrians cross, either at the intersection or a midblock location. The intersection area is raised to the same level as the surrounding pavement. Ramps are constructed on the access to the raised intersection area. Raised intersections can be combined with pavement widening, as well as bollards on the edge of the pavement to separate pedestrians and vehicles.

Design Principles

- Slope of entrance ramps for motorized traffic can be steep or shallow, depending on target speeds, but normally raised to the vertical level of the curb.
- Use different paving materials to further draw attention to raised intersections.
- Appropriate warning signs and roadway markings should accompany raised crossings.

Benefits

- Vertical elevation at the entry to intersection helps reduce vehicle speeds.
- Midblock raised crossings compel drivers to travel at a lower speed and enhances the safety of pedestrians crossing to the opposite side of a street.
- Improves drivers' awareness of presence of pedestrian crossings.
- Visually turns intersection into a pedestrian-oriented zone.
- Bicycle friendly.
- Enhances pedestrian environment and crossing safety.

Application

- Ideally suited for stop-controlled intersections with a high volume of pedestrian crossings and low target vehicle speeds, such as transit stops, commercial areas, residential neighborhoods, or schools.
- Also applicable to stop-controlled intersections with a high rate of pedestrian crashes or speeding issues.
- Well-suited for crossings of intersecting streets on arterials to slow traffic entering and exiting the arterial and prioritize the safe movement of pedestrians.

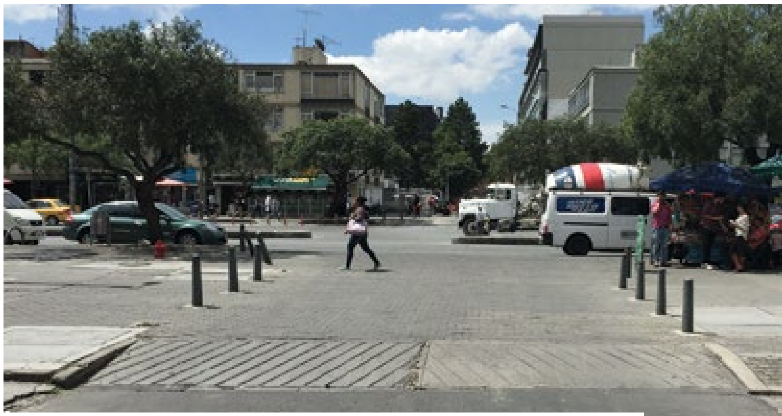


Figure 3.6 | **Raised Intersections/Crossings Case**

A raised crossing in Bogotá helps give priority to pedestrians and protects them from turning vehicles on an arterial street. These treatments are useful for junctions with neighborhood streets and can be combined with bicycle lanes.

Evidence

- Reduction in midblock speeds typically up to 10 percent (Institute of Transportation Engineers 2013).

3.7 TRAFFIC CIRCLES

Traffic circles or rotaries are generally circular central islands in the middle of an intersection. Entering traffic must typically alter direction and speed to avoid the island, creating a circular flow in one direction. In most applications, traffic circles replace the stop lights and traffic signs that regulate flow in other intersections.

Design Principles

- Traffic circles are designed according to the existing geometry of the intersection.
- Traffic circles should be large enough that vehicles entering the intersection must slow down and change course, but they should not significantly alter the path of travel for pedestrians or bicyclists.
- Traffic circles should maintain sufficient space for pedestrian crosswalks, and crossings should retain a linear path of travel.
- The circle should be designed to allow larger vehicles to runover their outer edge.
- Signage should be included to indicate the direction of circulation and to clearly show that there is a traffic circle.

Figure 3.7 | **Traffic Circles Case**

A traffic circle located in the Hipódromo neighborhood of Mexico City, Mexico calms traffic, provides a space for greenery, and reduces conflict points through eliminating left turns.

Benefits

- Traffic circles are effective at reducing traffic speeds at intersections, as well as the number and severity of collisions.
- More appropriate for streets with one lane in each direction, and can be problematic if applied to multiple lane streets.
- Especially when installed in a series, traffic circles also provide an overall traffic calming effect along the entire street corridor.
- Improve traffic flow efficiency for intersections that handle a high number of left turns.
- Improve the community environment with landscaping within circles.

Application

- Traffic circles tend to be small and for lower capacity areas.
- Traffic circles are often used in cities with street grids and can also be used to create streets shared with bicycles.

Evidence

- A study of 119 residential traffic circles installed in the city of Seattle between 1991 and 1994 found that reported crashes in those areas declined from 187 before installation to 11 after installation, and injuries declined from 153 to 1 in the same period (Mundell 1998).

3.8 ROUNDABOUTS

Roundabouts reduce conflict points at four-armed intersections and slow traffic. A roundabout is a road intersection with circulatory traffic. The traffic passing through the intersection is regulated in one direction anti-clockwise (in countries driving on the right) around a circular traffic island placed in the center.

Design Principles

- Normally used to replace a signalized intersection that is experiencing medium traffic volume and congestion.
- Curves and runover areas on the edge of the island should accommodate larger vehicles such as trucks that require a longer turning radius.
- Needs to be constructed to accommodate the needs of pedestrians and bicyclists through measures such as raised crossings, clear markings, and protection for cyclists.
- The roundabout should have no more than two lanes.
- Forces traffic from all approaches to make a slight detour around the central island. If one of the approaches can continue in a straight line, the roundabout is less effective.

Benefits

- Provides good traffic management where the existing intersection is large, complex, or has more than four approach legs.
- Reduces vehicular speeds and the severity of crashes.
- Reduces conflict points, eliminating left turns—a primary cause of crashes.
- Enhances pedestrian safety when used at appropriate intersections.
- Can green and beautify the streetscape with trees and/or plantings, improving environmental quality.
- Provides for safer U-turn possibility.

Application

- Roundabouts are generally not appropriate if traffic volumes are extremely high, or where pedestrian volume is very high. Signalized roundabout arrangements can be introduced as a potential solution in specific situations. Consultation with experts on roundabout design should be sought first.
- Street widths and/or available right-of-way need to be sufficient to accommodate a properly designed roundabout.
- Applicable to intersections having existing all-way stop control, at least three approaches, high vehicle turning volumes, or left-turn conflicts.

Evidence

- Roundabouts reduce the number of injury crashes by 10 to 40 percent, depending on the number of legs and the previous form of traffic control, though this should not be considered for high vehicle and pedestrian volume areas.
- A reduction of 70–90 percent has been found for fatal and serious injury crashes (both from Elvik, Hoye, and Vaa 2009).

Figure 3.8 | **Roundabouts Case**

A roundabout in Copenhagen, Denmark includes a bicycle lane.


10318

ARTERIAL CORRIDORS AND JUNCTIONS

Urban arterials are the most common location for severe pedestrian and motor vehicle collisions, given the volume of road users and often higher speeds of vehicles. These streets are often designed first for motor vehicles rather than pedestrians and bicyclists. The relatively high speeds on arterials exacerbate the severity of injuries that occur on these streets.

The condition can be worse in low-and-middle-income countries, where signalization and crossing design may not consider pedestrians and bicyclists, features such as median refuge islands are missing, turning movements are not considered, vehicle design speeds are high, and road striping can be unbalanced or confusing.

There are some key considerations for arterials and higher volume corridors that can impact safety. This includes designing crossings that consider how pedestrians move, providing medians and refuge islands, and ensuring lane balance—meaning a road will not have two lanes on one side of an intersection and three on the other. There are also considerations about how junctions (also called intersections) are signalized and designed to reduce crossing distance.

New development can limit the number of arterials and ensure they are designed for safer conditions and preference toward pedestrians and cyclists, while existing arterial streets can often be reoriented toward the more efficient movement of mass transport, pedestrians, and bicycles.

The needs of all road users should be considered on streets where vehicle, pedestrian, and bicycle traffic are mixing. The following basic considerations for arterial corridors and junctions are discussed in this chapter:

- Major arterial considerations
- Crossings
- Signalization
- Medians
- Median refuge islands
- Lane balance

BOX 4.1 | COMPLETE STREETS

On streets with mixed traffic—motor vehicles, pedestrians, and bicyclists—all road users have to be considered in designing safer streets. In places such as the United States and Mexico, the concept of Complete Streets has been used to think about streets that are holistically safer for everyone. This concept is based on the principle of shared public space and use. It focuses on safe access, an attractive streetscape, and effective mobility for all street users, including pedestrians, bicyclists, motorists, and transit riders of all ages, gender, and abilities.

The Complete Streets concept puts a priority on active transport, making it easier for people to cross the street, walk to shops, and bicycle. They are also designed around efficient street networks and context-sensitive solutions, allowing buses to run on time and making it safe for people to walk to and from transit stations. Complete Streets coordinate all street elements—infrastructure, paving, street furniture, signage, lighting, trees, and vegetation—for the use, enjoyment, and understanding of the public realm.

Notwithstanding the variety of street types a city has, the Complete Streets concept aims to offer as many possible choices for safe transit as possible to the widest range of users, seeking a balance in their levels of service. Complete Streets must then be designed with the following in mind:

- **Accessibility first.** Streets that focus on accessibility before vehicle flow and capacity are Complete Streets, accessible to everyone.
- **Inclusive design.** Streets that favor the most vulnerable users lead to fair and democratic Complete Streets.
- **Safety principles.** Streets that care for the comfort and well-being of its users through smart design produce safe Complete Streets.
- **Effective for all citizens.** Streets that take into account impacts, benefits, and externalities for all users of the city are Complete Streets.
- **Urban integration.** Streets that take into account the street's multifunctionality, compatibility, and diversity of use are truly integrated Complete Streets.
- **Continuity.** Streets that are envisioned not only in a plan or street section, but consistent in space and time along their corridor, are enduring Complete Streets.

4.1 ARTERIALS

Urban arterials generally have more travel lanes and higher speeds, compared to neighborhood or local streets, and most intersections are signalized. Urban arterials are major and minor thoroughfares that carry higher traffic volumes. These streets often have surface transit routes, retail, and high numbers of pedestrians and cyclists. Prioritizing the safety and comfort of pedestrians, cyclists, and transit is key to achieving mobility goals for all road users in cities.

Arterial with central median, restricted left turns, and dedicated bus lane.

Design Principles

- When arterials enter areas where pedestrians, cyclists, and a mix of land uses are present, the road should be designed for speeds safe for pedestrians, ideally 30 km/hr. Pedestrian fatality risk will start to increase rapidly when the street is designed for 40 km/hr speeds (see p. 16).
- Apply traffic calming through curb extensions, speed humps or cushions, raised crossings on intersecting streets, median refuge islands, narrow lanes, etc. Use signal timing, pedestrian refuges, crosswalks, and other measures to create safe and convenient crossings and routes between transit stops and surrounding destinations.
- Cross-section design elements for the arterial typology include traffic travel lanes, medians, plantings, and sidewalks, with a lane width generally no more than 3 to 3.2 meters to maximize safety.
- Bus services should primarily be directed along arterial and collector streets, as these will be the most direct routes between destinations with the greatest number of connections.
- Arterial and collector streets through intensively developed neighborhoods may also sustain retail/commercial activity, particularly on corner locations and around transport nodes.

Benefits

- Better designed arterials improve mobility for all road users, making walking, bicycling, and access to mass transit safer and more comfortable, as well as encouraging daily physical activity and less reliance on vehicles.
- Enhancing the street as a public space may lead to economic benefits to retail along the corridor.
- Arterials designed for more transport modes than motor vehicles can manage congestion over time by allocating space more efficiently to pedestrians, cyclists, and mass transport, which can move more people with less space.

Application

- Where more intense levels of pedestrians, cyclists, and a mix of land uses are present, the road should be designed for lower speeds.
- Couple design with coordinated traffic lights and photo enforcement.
- Speed, pedestrian safety, and land uses along arterial and collector streets should be addressed at the community planning and street design levels.

Evidence

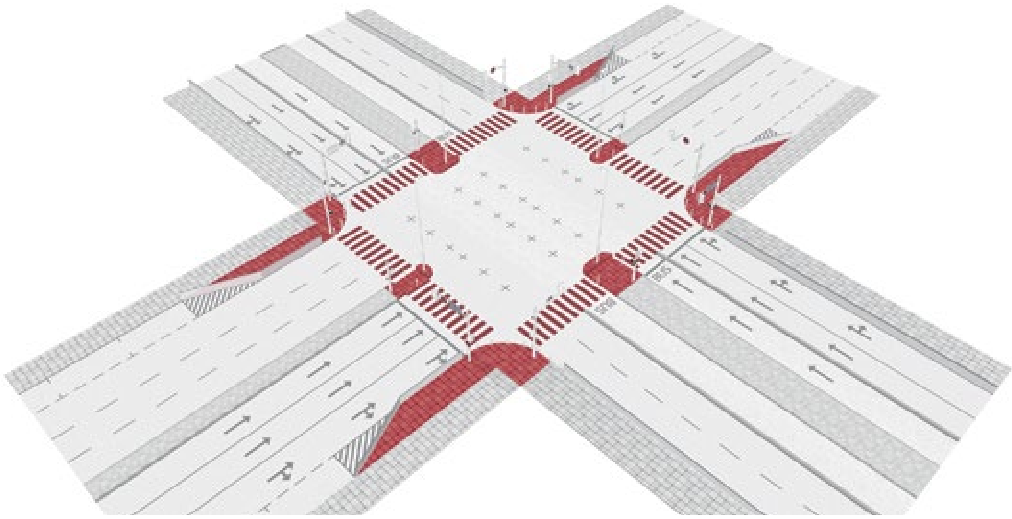
- A nationwide study from the U.S. shows that more than 50 percent of all pedestrian fatalities occurred on arterial roads in urban areas compared to 14 percent on local roads or streets. Maximizing pedestrian safety on arterials will greatly improve overall pedestrian safety (FHWA Safety 2010).
- A study of urban streets in Tokyo and Toronto found that both narrow (less than 2.8m) and wider (over 3.2~3.4m) designs have proven to increase crash risks with equal magnitude (Masud Karim 2015).

Figure 4.1 | **Arterials Case**

Avenida Ing. Eduardo Molina in Mexico City—an arterial with dedicated bus lanes, protected bike lanes, rebuilt sidewalks, and a green central median at some segments—accommodates mass transport, mixed vehicular traffic, bicycling, and walking.

4.2 PEDESTRIAN CROSSINGS

Multimodal intersections operate with pedestrians, bicycles, cars, buses, and trucks, and in some cases trains. The diverse uses of intersections involve a high level of activity and shared space. Crossings should be direct and as short as possible for pedestrians to safely reach the other side of the street. The goal is to minimize pedestrian exposure and to provide a safer, marked area for when they are exposed.



Providing curb extensions and median refuges decrease crossing distance and reduce exposure to moving vehicle traffic.

Design Principles

- Crossings should allow for directness, locating the crossing close to the junction and following the line of pedestrian movement.
- At the curb, a ramp at a reasonable grade or level grade should be provided to the sidewalk; fixed objects should not impede the pedestrian path.
- In a controlled junction, provide a stop line before the crossing. If uncontrolled, consider traffic calming measures to improve pedestrian safety when crossing.
- Minimize conflicts between modes, such as segregated cycle lanes, pedestrian refuge islands, and low-speed right turns.
- Provide good visibility through proper sight distance triangles and geometric features that increase visibility, such as curb extensions.
- Design for slow speeds at critical pedestrian-vehicle conflict points, such as corners, by using smaller curb return radii or low-speed right-turn lanes.
- Ensure intersections are fully accessible to the disabled and hearing and sight impaired. Provide flush access to crossings, visual and audio information about WALK/DON'T WALK phases, and detectable warnings underfoot to distinguish pedestrian from vehicular areas.

Figure 4.2.1 | **Pedestrian Crossings Case**

An intersection in São Paulo, Brazil prioritizes the crossing of pedestrians with an "all red" dedicated signal phase for pedestrians to cross in all directions. Such crossing configurations are useful in high pedestrian volume areas and also can help prevent conflicts between left-turning vehicles.

Benefits

- Improving safety along arterials can address problems where crashes are most common—where numbers of pedestrians and cyclists are present, yet vehicles are traveling at higher speeds.
- Arterials often act as edges to adjacent neighborhoods; safer arterials may better connect these areas.
- Mass transit stations are often located along major arterials; making them safer may improve transfer times and the user experience.

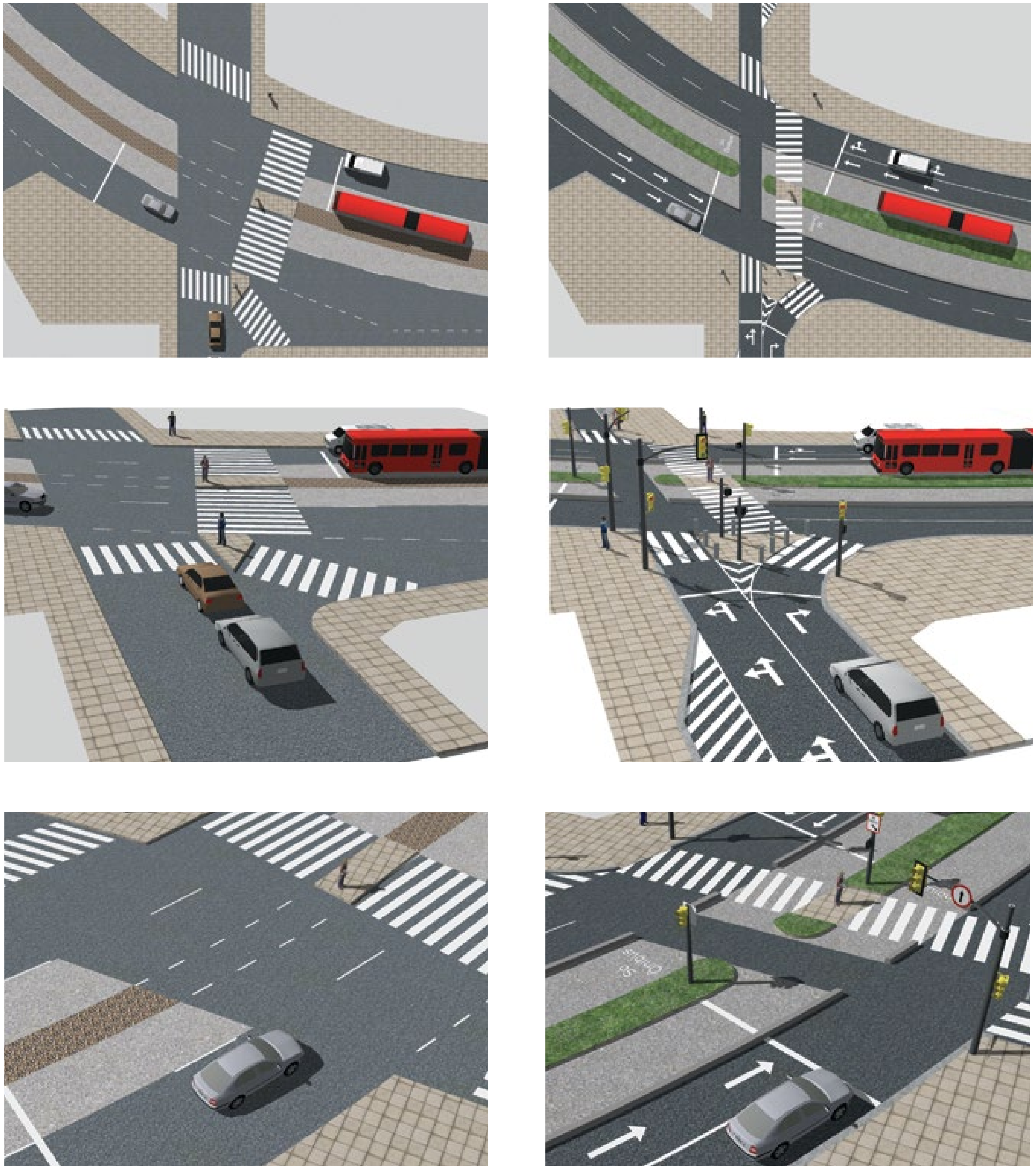
Application

- Every intersection should be carefully designed or audited to ensure pedestrian and bicycle crossing safety.
- Curb ramps should be used to facilitate crossing for wheelchair users, people pushing strollers, bicyclists, and others.
- Measures such as raised crossings, curb extensions, and median refuge islands can be combined to enhance crossing safety.

Evidence

- A before-after study of intersection improvements in Beijing found that crosswalk striping—along with bus stop redesign, pedestrian barrier construction, increased illumination, and new signals—increased both real and perceived pedestrian safety (Wang et al. 2009).

Figure 4.2.2 | **A Before and After of Crossing Designs, Creating Direct and Shorter Paths**



4.3 MEDIANS

Medians are barriers in the center portion of the street or roadway separating different lanes and traffic directions. The widths and design of medians can vary greatly. They can range from narrow concrete curbs to tree-lined promenades to landscaped boulevard medians.

Central median refuge, seen on a 4-lane road; applicable to two-lane roads as well.

Design Principles

- Allow for wide enough median for pedestrians to find refuge (at least 1.5 meters), and more in case of adjacency to a dedicated bus or tram lane, for stations.
- Landscaping in medians should not obstruct the visibility between pedestrians and approaching motorists.
- Medians should not visually distract drivers.

Figure 4.3 | **Medians Case**

A central median with trees in Addis Ababa helps green the street, prevent conflicts between vehicles and provides a refuge for pedestrian crossings. The pedestrian refuge area should be at-grade to improve pedestrian comfort and accessibility. While this road lacks other features that could improve pedestrian conditions, the median provides a basic level of safety.

Benefits

- Reduces the risk of left-turn and vehicle head-on collisions.
- Enhances pedestrian safety by reducing crossing distance and providing space for pedestrians crossing the street at phases.
- Provides space for street trees and other landscaping design, which also helps reduce speeds by visually relieving drivers' fatigue and visual monotony.

Application

- Most useful on high-volume, four-lane or more roads, as well as two-lane arterials.
- Continuous medians may not be the most appropriate treatment in every situation. In some cases, they can increase traffic speeds by decreasing the perceived friction through separating traffic flow directions.
- Medians may also take up space that can be better used for wide sidewalks, bicycle lanes, landscaping buffer strips, or on-street parking.
- Medians can be used for walking and bicycling if vehicle speed and volume is limited, though junctions should be carefully designed to avoid conflicts on left turns.
- Include planted areas and stormwater source controls within medians wherever possible.

Evidence

- Evidence from crash frequency models in Latin American cities suggests that medians can reduce crashes, including severe crashes, by 30–40 percent (Duduta et al. 2015).

4.4 MEDIAN REFUGE ISLANDS

Pedestrian refuge islands are short segments of median used at pedestrian crossings for pedestrian refuge. Medians or pedestrian refuge islands are designated places in the middle of the street for pedestrians who cross a street midblock or at intersections.

Central median refuge without a continuous median.

Design Principles

- Medians should be wide enough to provide refuge to pedestrians at crossings: 1.5 meters minimum; 1.8 meters or greater preferred.
- Illuminate or highlight islands with signs and reflectors to better inform drivers.
- Medians should be at street level, protected by bollards or curbs. Pedestrians, especially those with strollers or disabilities, will often go around refuge islands if they do not have ramps.

Benefits

- Enhances crossing safety by allowing pedestrians to deal with only one direction of traffic at a time.
- Reduces pedestrian crossing distance, aids in decreasing vehicle speeds, and raises greater attention of drivers to the existence of a pedestrian crossing.
- Provides extra space for unsafe U-turn conditions.
- Calms traffic, especially left turns and through movements, by narrowing roadway at intersection.

Application

- Can be combined with curb extensions, chicanes, or other measures along a corridor.
- Care should be taken to maintain bicycle crossing access.
- Should be considered at unsignalized crossing points.

Evidence

- This kind of facility has been demonstrated to decrease the percentage of pedestrian crashes and casualties by 57–82 percent in the U.S. (FHWA Safety 2013).

Figure 4.4 | **Median Refuge Islands Case**

A median refuge island gives pedestrians a safer place to wait for crossing in Paris. Islands can be used at signalized or unsignalized junctions, as well as mid-block.

4.5 SIGNAL CONTROL

Traffic signal control at intersections separates different flows of traffic from each other, and can improve vehicle and pedestrian safety at intersections. Traffic signal control can be time-controlled (phase change after a given time, regardless of the traffic volume) or actuated by vehicles, bicyclists, or pedestrians. Special signal times for pedestrians and bicycles can be provided.

Signal poles at intersection.

Design Principles

- Each pedestrian green phase should allow sufficient time for a pedestrian to complete the crossing (using a pedestrian speed of 1.2 m/s); with more frequent green phases provided, fewer pedestrians will cross against the signal.
- Left-turn phases can reduce conflicts but should be applied carefully as pedestrians may cross during this phase (in drive-on-the-right countries).
- Right turns on a red light (in drive-on-the-right countries) should be evaluated based on local conditions and traffic volume before permitted.
- Signals should be coordinated to help control vehicle speeds.
- If using button- or sensor-activated pedestrian signals, minimize the wait time after actuation.

Benefits

- Enhances pedestrian safety by signalizing their crossing, assuming that pedestrian wait time is addressed appropriately.
- Can be used to prioritize public transport and bicycles; provides lead intervals for pedestrians and bicyclists.

Application

- Junctions with high traffic flows are required to be signalized.
- An exclusive pedestrian or bicyclist phase, or lead pedestrian interval (a head start) will improve crossing for these vulnerable users.
- All-red time can further enhance pedestrian crossing safety.

Evidence

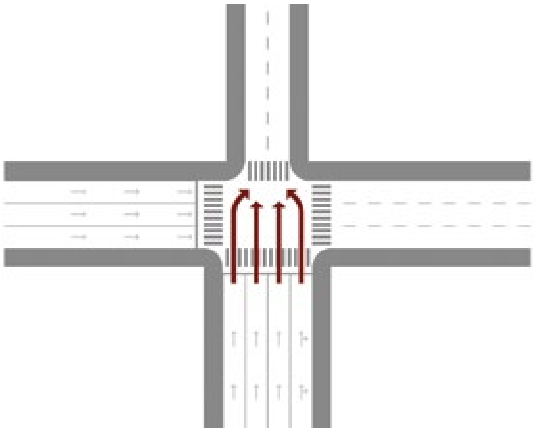
- Traffic signal control reduces the number of crashes by around 15 percent at T-junctions and around 30 percent at crossroads (Elvik, Hoye, and Vaa 2009).
- Signalized pedestrian crossings reduce the number of injury crashes by around 5 to 10 percent (Elvik, Hoye, and Vaa 2009).
- When lead pedestrian intervals, or early release signals for pedestrians were provided in a U.S. study, odds of conflict with turning vehicles were reduced by 95 percent in the beginning walk period (Van Houten et al. 2000).

Figure 4.5 | **Signal Control Case**

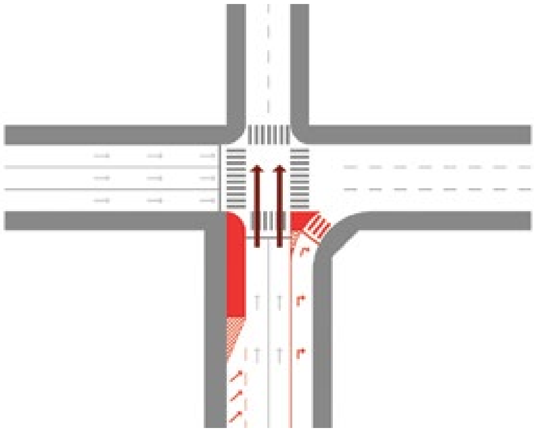
A Lead Pedestrian Interval from Washington, D.C. shows the walk signal for pedestrians to begin 3 or more seconds before the green phase for vehicles.

4.6 LANE BALANCE

To avoid traffic conflicts through an intersection, there should be a balance in the number of lanes entering and exiting the intersection. Lane imbalance occurs when the number of lanes entering an intersection along any given approach or turning movement is larger than the number of lanes exiting the intersection along that same movement (i.e. continuing straight, turning left, etc.).



Example of how lane imbalance (above) can be addressed by taking out lanes on one approach, or creating turn-only lanes (below).



Design Principles

- Determining the number of entry and exit lanes requires study of road capacity and proportion of left and right turn traffic.
- All lanes shall be in alignment through intersection, with a maximum of a 0.6m shift in a hardship situation only.
- For right-turn-on-red permitted intersection (drive-on-the-right countries), the right-turn traffic should be counted into the exit lanes.

Benefits

- Avoids possible crashes caused when vehicles converge on fewer lanes, as some drivers may react to this by changing lanes suddenly.

Application

- In some cases, lane imbalance can be solved by designating some lanes as turn-only. For example, if a street has four lanes entering an intersection, but only three lanes after the intersection, one of the lanes on the approach could be designated as right-turn or left-turn only.
- One lane can be turned into on-street parking to reach a balance at the coming intersection.

Evidence

- Many traffic crashes are reported to occur at the exit of an intersection when vehicles are converging onto fewer lanes.

Figure 4.6 | **Lane Balance Case**

On this street in New York City, the number and symmetry of lanes are aligned on both sides of the junction.

BOX 4.2 | MOTORCYCLES AND A CITY SAFER BY DESIGN

Many cities face the pressing challenge of growing motorcycle fleets and significant increases in motorcycle-related traffic fatalities. Latin America's motorcycle deaths tripled in the 2000s—most evident in places like Brazil and Colombia (Rodrigues et al. 2013). In Malaysia—where motorcycles make up roughly half of the country's vehicle fleet—two- and three-wheelers make up 59 percent of its nearly 7,000 annually reported traffic deaths. Similar trends are occurring in India, Vietnam, Indonesia, and other countries worldwide.

Motorcyclist behavior is one problem that, when changed, can reduce traffic deaths—especially through laws and campaigns for helmet wearing, driver education, and licensing (Passmore et al. 2010). With this guide focused on design solutions to traffic safety, are there specific infrastructure considerations when it comes to motorcycles? There is a need for more research and attention to motorcycle safety design solutions, and how they impact other modes of transport such as mass transport and bicycling. Though research is limited, we present an overview here of some infrastructure and mobility issues.

Street design for motorcycle safety
Some infrastructure has been shown to be effective at reducing motorcycle crashes, such as exclusive motorcycle lanes on trunk roads in cities in Malaysia—a practice that has been replicated in Indonesia and the Philippines (Radin Umar 1996; Radin Umar, Mackay, and Hills 1995; Sohadi et al. 2000). It isn't known if these exclusive lanes are appropriate in other locations, or on urban streets other than the primary roads. Barranquilla, Colombia created some exclusive lanes but little evidence is available on their effect. In São Paulo, the results of exclusive lanes have been described as mediocre, though the city did see a reduction in crashes when it banned motorcycles on the central lanes of a main expressway (Vasconcellos 2013). In London, the city opened bus lanes to motorcyclists and found that crashes increased in a first trial, but did not significantly increase after a second trial (York and Hopkins 2011).

Research seems to show that the measures that improve safety for all road users also apply to motorcyclists, such as reducing speeds through traffic calming and limiting vehicular traffic. One reason motorcycles are so dangerous is that they zig-zag in between and around cars, moving unpredictably at higher speeds. A study from Malaysia found that an increase in the speed at which vehicles approach signalized intersections is associated with more motorcycle crashes, and that more motorcycle crashes occur at signalized intersections located within commercial areas (Harnen et al. 2004). Slowing all vehicles to safer speeds before signalized intersections—particularly in retail areas—may do a great deal to improve motorcycle safety.

Addressing the larger issue of urban mobility
Motorcycles are a preferred option for many to get from one point to another where public transport is very poor quality, inaccessible, or nonexistent. In Hanoi, for example, a study showed that employment opportunities are much less accessible by public transport than by motorcycle or car, which explains why Hanoians "like" to use motorcycles instead of public transport (Nguyen et al. 2013). In addition, in Brazil, many travelers use motorcycles instead of public transport due to lower costs or the poor quality of public transport in their city—finding that overall motorcycle operating costs were 25 percent lower than bus fares (Vasconcellos 2013). And in Pune, India an EMBARQ India study showed that two-thirds of two-wheeler riders surveyed said they used public transport prior to using two-wheelers (Pai et al. 2014). The same study indicated that motorcycle riders would shift to public transport if it were made more reliable, comfortable, frequent, and clean.

Moreover, because many urban trips are short, providing safer bicycling and walking facilities or connecting these modes to mass transport can give residents alternative mobility options. The guidance in this report may help achieve this, but there is much more research needed in order to determine exactly how motorcycle safety can be addressed in terms of infrastructure and mobility.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PEDESTRIAN SPACES AND ACCESS TO PUBLIC SPACE

Nearly all trips begin and end with walking. But pedestrians have often been overlooked when planning for transport.

WHO reports show that each year, more than 270,000 pedestrians lose their lives on the world's roads (WHO 2013). Pedestrians are most at risk in urban areas due in part to the large amount of pedestrian and vehicle activity occurring and concentrated in cities (Zegeer and Bushell 2012). This is especially the case in developing countries, where urbanization is speeding up. For example, due to the growing parking demand in rapidly motorizing countries, sidewalks are commandeered for parking and public space converted into parking lots, pushing pedestrians into the street. Many cities' sidewalks are poorly maintained or not maintained at all. In India, statistics show that the pedestrian fatality share is over 40 percent in metropolitan areas like New Delhi, Bangalore, and Kolkata (Leather et al. 2011).

Any plan to address safety needs to address pedestrian safety. The European Traffic Safety Council, for example, recommends policies of modal priority for road users, particularly in urban environments, and that a hierarchy based on safety, vulnerability, and sustainability place pedestrians at the top, followed by cycling and public transport (ETSC 2014; Paez and Mendez 2014).

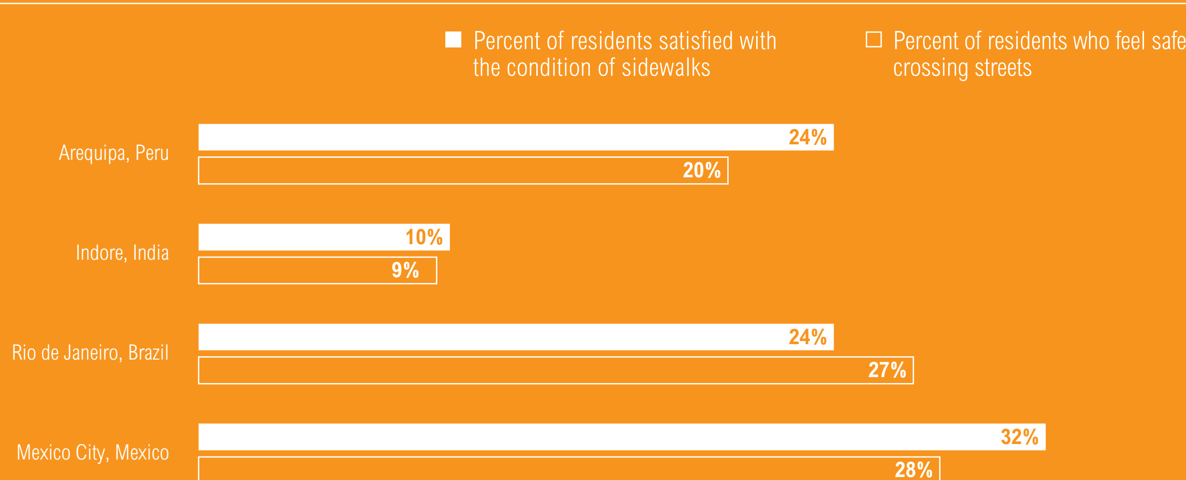
Walking also has great health and environmental benefits. It reduces the incidence of non-communicable diseases, is nearly carbon-emissions free, and pedestrians support street-level retail businesses. This chapter aims to provide some basic guidance on how streets and public spaces can be provided and designed to foster a safer pedestrian environment. The following sections are covered:

- Safer sidewalks
- Shared streets
- Pedestrian streets and zones
- Safe access to places to learn and play
- Open streets, or ciclovias
- Street plazas

BOX 5.1 | RESIDENT PERCEPTIONS OF SAFETY AND SIDEWALKS IN FOUR CITIES

EMBARQ conducted household surveys in 2010 and 2011 on the conditions of the built environment in the catchment areas of four forthcoming BRT corridors in four cities around the world. Though the results may have regional differences and local issues that impact numbers, the consistent theme across all of them is that few residents feel safe from traffic on city streets or are satisfied with the condition of sidewalks (figure 1.5). Providing safer community and street designs through transit-oriented development around these corridors is one way that could improve the perception of safety and opinions of pedestrian facilities.

Sidewalk Conditions and Street Crossing Safety Satisfaction in Four Cities



5.1 THE BASICS OF SAFE SIDEWALKS

Sidewalks, pavement, or footpaths are portions of a street between the curb lines and the buildings for use by pedestrians. A well-equipped sidewalk accommodates pedestrian use and street furniture, as well as landscaping elements, including light poles, signs, fire hydrants, benches, mail boxes, newspaper boxes, parking meters, trash cans, etc.

Basic sidewalks provide a separate area for pedestrians without parked cars.

Design Principles

- Sidewalks should be level or sloped to accommodate those with disabilities.
- Sidewalks should provide adequate space for pedestrian movement and activity, at the very least 1.5–1.8 meters wide for low-volume areas and 2.5 meters wide and up for higher volume areas. If the walkway is adjacent to the curb, minimum sidewalk width should be 2.10 meters. (See Table 6.1 for more information on volumes and minimum widths.)
- Provide enough space in the "transit zone" for a clear through-route.
- Provide space in a building or lot "frontage zone" to account for doors, signage, vegetation, etc.
- Provide an "elements and furnishing zone" that can include trees, vegetation, trash cans, benches, tables, bollards, or additional space.
- Curb ramps are necessary to allow wheelchairs or strollers to enter or exit a pedestrian crossing.

Benefits

- Provides space for pedestrian traffic, free of vehicle conflicts.
- Fosters social space for people to sit, shop, eat, meet, and socialize.
- Provides a variety of benefits, including basic mobility, consumer cost savings, cost savings (reduced external costs), efficient land use, community livability, improved fitness and public health, economic development, and support for equity objectives.

Application

- Sidewalks should always be provided on both sides of the streets whenever possible, except exclusive vehicle corridors.
- In developing countries, cars or vendors often commandeer sidewalks for parking; bollards and strict enforcement programs can alleviate this issue. City regulations may not also dictate consistent provision of sidewalks, or may require private property owners to provide them. These are political considerations that may need to change, or be considered in applying design principles.

Figure 5.1.1 | **Safe Sidewalks Case**

These before and after photos show the sidewalk of a street in São Paulo that was reconstructed to remove obstructions and uneven steps, and improve access, continuity, and appeal. The project was part of the Calçadas Verdes e Acessíveis (Green and Accessible Sidewalks) project.

Figure 5.1.2 | **Safe Sidewalks Case**

A sidewalk in Mexico City provides the basic comforts of even pavement, segregation from the street and trees, and is designed to prevent vehicles from commandeering the space.

- Shared streets don't have separate sidewalks but a mix of vehicles and pedestrians (see 6.2).
- Sidewalks can be combined with other traffic calming measures (see chapter 4).

Evidence

- Evidence from the U.S. shows that pedestrian crashes are more than twice as likely to occur in places without sidewalks; streets with sidewalks on both sides have the fewest crashes (Smart Growth America 2010).

Table 5.1 | **Sidewalk Widths for Different Pedestrian Capacities**

CAPACITY IN PERSONS PER HOUR		
ALL IN ONE DIRECTION	IN BOTH DIRECTIONS	MINIMUM WIDTH OF SIDEWALK IN METERS
1220	800	1.50
2400	1600	2.00
3600	2400	2.50
4800	3200	3.00
6000	400	4.00

Source: UNEP (2013), CSE (2009).

5.2 SHARED STREETS

Shared streets often are referred to as "pedestrian-priority streets", "home zones", or "woonerfs." The street is shared by all users, designed to foster safety. Shared streets are designed to dramatically slow traffic through treatments such as brick paving, planters, and curves, in order to give priority to pedestrians over motorists and create awareness among all users.

Design Principles

- Sidewalks and curbs are generally not used in shared streets, with fixed objects such as planters and trees acting as traffic calming measures to form chicanes, chokers, and other design measures to prioritize pedestrians.
- Enhanced paving, alternating pavers, and street furnishings within the street can be used.
- Plants and landscaping should be utilized to further improve the quality of walking.
- Maximum design vehicle speeds should stay at most around 15 km/hr.

Benefits

- Give priority to pedestrians and bicyclists; enhance walking and bicycling safety by slowing vehicular speeds.
- Allow active land uses and ground-floor activities to foster a healthy public realm.
- Encourage street activities—such as sitting, eating, shopping, meeting, and socializing—that are adaptable to different times of day, week, or year.
- Maintain vehicular access while emphasizing pedestrian space.

Application

- Can be gradually implemented so that road users will be progressively familiarized with the changes to the road environment.
- Should be considered on narrow streets where there is a lack of space for sidewalks and vehicle lanes, or where there is significant pedestrian and bicycle activity.
- Should be considered on streets close to major pedestrian destinations, such as retail, waterfront, parks, plazas, transit hubs, schools, etc.
- Recommended on local streets to encourage walking and cycling, and recreational uses within neighborhoods.

Evidence

- Results of crash investigations in the Netherlands indicate that converting streets to woonerfs leads to a reduction of approximately 50 percent in the number of crashes on them (Kraay and Bakker 1984; Wegman 1993).
- Evidence from shared streets in Seven Dials, London shows that—based on two years of 'before and after' monitoring—casualties fell from 71 in the period before the street was remodeled to 40 afterwards—a drop of 43 percent (Gould 2006).

Figure 5.2 | **Shared Streets Case**

The streets of Rio de Janeiro's favelas often function well as shared streets, and though they may lack some traffic calming features of traditional shared streets, when upgraded can contain such features. EMBARQ research shows residents feel safer from traffic here than in the formalized city.

5.3 PEDESTRIAN STREETS AND ZONES

Pedestrian streets also are referred to as “pedestrian malls”, “auto-free zones”, or “car-free zones” that are reserved for pedestrian use only. All automobile traffic may be prohibited on pedestrianized streets and zones, except delivery trucks at night or another period of day, and emergency vehicles.

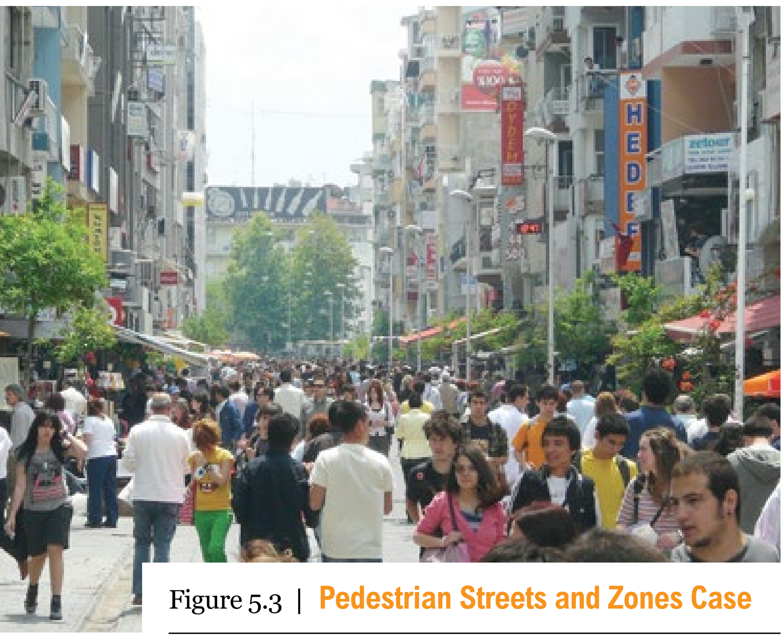


Figure 5.3 | **Pedestrian Streets and Zones Case**

A pedestrian street in Izmir, Turkey provides a place to shop and be out in the city safely away from vehicle traffic.

Design Principles

- Pedestrian streets should be interesting, safe, convenient, and appealing. Ground-floor activities are greatly encouraged to attract pedestrians.
- Street furniture, paving treatments, lighting, and landscaping are important design elements to improve the walking environment. Features such as benches arranged in groups in small rest areas and pocket gardens improve user experience and attractiveness.
- Paving materials can be designed to better improve the walking environment and attractiveness.
- Provide enhanced safety features for pedestrians at the buffer area of the pedestrian zone and at intersecting streets where motor vehicles are present and additional traffic and safety issues can emerge.

Benefits

- Little or no car use resulting in less vehicular traffic.
- Creates the best possible conditions for pedestrians’ free movement and road safety.
- Has aesthetic, economic, and social benefits, improving access to retail and improving air quality.

Application

- Pedestrian streets are most beneficial where there are heavy pedestrian activities, retail or mixed development, high pedestrian volume, and accessible mass transport.
- Access for emergency and evacuation services should be maintained at all times. Delivery vehicles can be allowed during the early morning or overnight.
- Cyclists (unless dismounted) usually are prohibited on pedestrian streets or provide a special zone for cyclists.

Evidence

- Complete pedestrianization can reduce crashes by 50 percent or more, though buffer areas may see an increase in crashes, unless extra measures are taken (Elvik, Hoye, and Vaa 2009).
- Evidence from Istanbul shows pedestrianization increased retail sales, resident perception of traffic safety and air quality, and walking rates (Cörek, Öztas and Aki 2014).

5.4 SAFE PLACES TO LEARN AND PLAY

Zones around children's playgrounds, parks, schools, and community centers are areas that require special attention to pedestrian safety. Children are more vulnerable than adults to collisions with motor vehicles, because their activities and movements are more unpredictable.

Design Principles

- Traffic calming devices should be considered to further slow vehicular speeds around children and school zones.
- School sites, playgrounds, parks, recreational zones should be accessible by pedestrians and bicycles from all directions.
- Surrounding streets should be equipped with good conditions for walking and cycling, as well as designated school-bus loading zones.
- Parking should be limited to encourage more walking and bicycling.

Benefits

- Emphasizes child and student safety, special considerations taken to enhance play and school zones.
- Improves student pedestrian safety along school trip routes.
- Enhances walking and cycling environment; encourages more physical activity and reduces driving speeds.

Application

- Areas around schools and playgrounds require special attention to road safety. Some special limitations of children—such as eye height, peripheral vision, and lack of judgment—should be taken into consideration.
- Plans for safe routes to school should follow a timeline strategy to execute improvements.

Evidence

- In Seoul, Korea, crashes decreased by 39 percent in school zones after improved design and traffic calming measures were put in place (Sul 2014).

Figure 5.4 | **Safe Places to Learn and Play Case**

This narrow street in a school zone in Seoul has a clearly marked roadway (here translated as "school zone—slow down—30km/hr") and sidewalk protection fences, creating a safe walking environment for children.

5.5 OPEN STREETS

Ciclovias—also referred to as "Ciclovias recreativas" in Latin American countries—temporarily open streets exclusively for people for cycling, skating, walking, jogging, or other activities. Open streets are a recent initiative that shows promise in addressing the global concern about lack of physical activity and in providing safe recreational places on weekends.

Figure 5.5 | **Open Streets Case**

Participants play basketball on a street closed to automobiles as part of Raahgiri Day in Gurgaon, India.

Design Principles

- Collect information on routes, street conditions, neighborhoods, and populations that are included in the program, and include the community in the selection of routes.
- Consider areas with higher population densities, lack of public spaces, arrange for handling traffic on intersecting streets.
- Allow for programmed activities as well as walkers, joggers, and bicyclists.

Benefits

- Promotes physical activity and contributes to chronic disease prevention, such as being overweight or obese.
- Contributes to social capital development and improvement in the population's quality of life.
- Encourages the use of public space for recreation, creates a socially cohesive environment.
- Promotes efficient modes of transportation like walking and cycling.
- Decreases exposure to air and noise pollution and motor vehicle emissions.
- Promotes social inclusion, social interaction, and equality.
- Provides opportunities for economic revitalization of communities.

Application

- Open streets worldwide are often conducted on weekends or holidays across the entire year.
- The length of streets occupied for open streets varies depending on the local condition.
- Complementary programs, activities, or temporary businesses are also encouraged to increase the attractiveness of the program.

Evidence

- Survey results from Bogotá, Colombia show that open streets participants report feeling safer on open streets (Sarmiento et al. 2010).

5.6 STREET PLAZAS

Street plazas— also referred to as "pedestrian plazas" or "pocket parks"—are abandoned small residual urban or road areas that were converted into public spaces.

Mexico street plaza.

Design Principles

- Place in residual space that is or would be underoccupied or misused by cars (can be both road space or lot space), commonly at diagonally connecting streets.
- The residual space commonly has a minimum area between 100 m^2 and 400 m^2. It must be visible from the street, easy to get to, and preferably near commerce and public transportation. Total accessibility and safe access must be provided to the street plaza as well as protective pedestrian components that keep cars out.
- The components used to create the plaza can be low cost and removable. Pavement treatments are done with colorful designs, over which street furniture is placed depending on its context and intended use (rest, amusement, exercise), along with lighting and vegetation of high resistance and low maintenance.

Benefits

- Acts as community gathering place, and encourages pedestrian activity.
- Betterment of the streetscape through vegetation.
- Provides shorter crossing distances.

Application

- They should preferably be located in zones lacking public spaces with higher pedestrian flows and retail stores, but can be located even as extensions of parks or plazas on adjacent streets.
- Can be low-cost and temporary and followed by permanent installation.

Evidence

- New York has shown a decrease of 16 percent in speeding and a 26 percent reduction in injury crashes along streets that contain pedestrian plazas (New York City Department of Transportation 2012).

Figure 5.6.1 | **Street Plazas Case**

A street plaza in Coyoacan, Mexico City provides public space for people, helps calm traffic and reduces pedestrian crossing distance.

Figure 5.6.2 | **Street Plazas Case**

A variant of the street plaza is the parklet (a term used in the United States and Brazil). Seen here in São Paulo, parklets are part traffic calming (sharing characteristics with curb extensions and chokers) and part public space improvement. This parklet in São Paulo was created by taking away vehicle parking spaces and was built to be level with the sidewalk with seating and greenery.

BOX 5.2 | NYC PUBLIC PLAZA PROGRAM

Streets make up approximately 25 percent of New York City's land area and yet, outside of parks there are few places to sit, rest, socialize, and to enjoy public life. To improve the quality of life for New Yorkers, the City creates more public open space by reclaiming underutilized street space and transforming it into pedestrian plazas.

In addition to the plazas shown on this page, there are twenty-six plazas that are in some phase of planning, design, or construction with three additional plazas expected each year. The most high-profile pedestrian plazas are improving quality of life and safety for New Yorkers and tourists at Times Square, where the City is preparing to make permanent the public space enhancements that were installed as part of a six-month pilot during the summer of 2009.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BICYCLE INFRASTRUCTURE

Bicyclists require special attention in street design as they are one of the most vulnerable users in terms of traffic fatalities and injuries, yet an increase in safety and usage can lead to greater health and environmental benefits.

Bicycling in many cities is a main form of transport. Asian cities once had a great legacy of bicycling, but this is on the decline in China and increasing in the United States and other developed European countries. Research has shown that U.S and European cities with higher rates of bicycling have fewer overall traffic crashes, and these cities are also home to connected streets and advanced networks of bicycle lanes, off-street paths, ample bike parking, and bicycle sharing systems. This chapter will be focusing on some key issues in providing safer conditions in a bicycle system, using examples and evidence from both the developed and developing countries. The following sections will be included:

- Bicycle networks
- Bike lanes and cycle tracks
- Off-street trails
- Shared bicycle street
- Bicycle safety at intersections
- Bike safety at bus stops
- Bicycle signals

Evidence shows that the crash rate for cyclists is six to nine times as high as for car users (Bjornskau 1993). The risk may be even higher in developing countries due to underreporting. Evidence also shows that through better street design, bicycle injuries and crashes can be greatly reduced. While protected bicycle lanes seem to improve safety through numbers by giving users a perceived security and increased safety between junctions, paying special attention to junction design is crucial for real gains in safety. This includes improving the visibility between cyclists and vehicle drivers and addressing conflicts at junctions with proper markings and signalization. Combining these measures will ensure a safer, more pleasant, and ultimately more successful bicycling system.

6.1 BICYCLE NETWORKS

The needs of bicyclists should be considered throughout the road network. A well-connected bicycle network should consist of interconnected bike lanes, cycle tracks, traffic-calmed streets with priority for bicycles, and special considerations at junctions and intersections, which are designed to prioritize cyclists' needs.

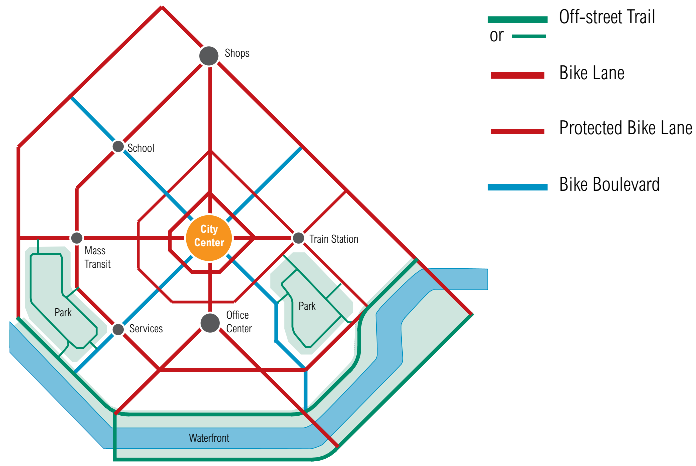


Diagram of a bike network that connects important destinations.

Design Principles

- Provide bicyclists the most direct possible routes and a continuous right-of-way.
- Should be coherent and not interrupted by intersections or building sites.
- Separate from high-speed motorized traffic. Special considerations and clear visibility to bicycles should be given at intersections and junctions.
- Consider bikeway typology/hierarchy, from off-street trails to shared streets to protected bike lanes on streets.
- Establish wayfinding tools, signalization, and integration with other transport modes.
- Provide ample bike parking.
- Safety of bicycle networks can also be enhanced by signalizing.

Benefits

- A well-connected bicycle network can provide bicyclists a continuous biking route without disruption.
- A well-designed bicycle network can ensure bicycle safety and reduce crashes and fatalities.
- A sound bicycle network and adequate biking facilities or programs will encourage biking use and physical activities, as well as reduce vehicle travel and environmental impacts.

Application

- Lane markings, lane widths, and waiting and loading areas on main roads need modifying to help cyclists.
- Special consideration of bicycle routes should be given at bus stops and stations to avoid conflicts.
- Introduce bicycle facilities on main roads whenever possible, such as bike lanes, stopping areas, and separate traffic signals at junctions.
- Provide bicycle parking facilities and renting/sharing system.
- Ensure all retail, business, leisure destinations, and public spaces are accessible by bicycle.
- Bike sharing/renting program should be considered to promote bicycle use.

Evidence

- Cities such as Copenhagen, New York City, and Minneapolis have witnessed significant decreases in the rate of fatalities and injuries for cyclists after building a network of safer bike infrastructure over the years (Duduta, Adriazola-Steil, and Hidalgo 2012).

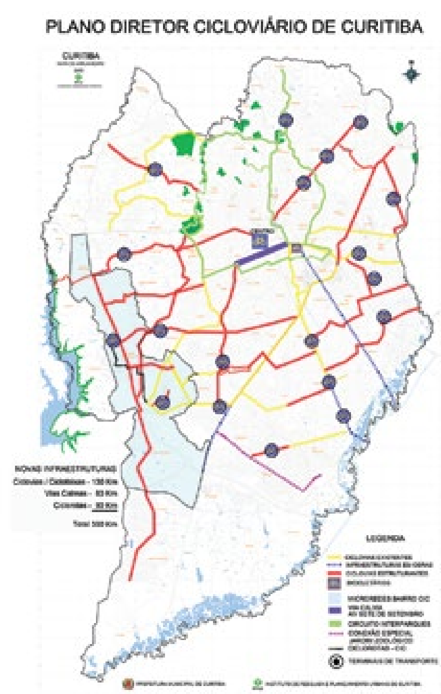


Figure 6.1 | **Bicycle Networks Case**

Curitiba, Brazil has more than 120 km of bicycle lanes and paths, traversing both green areas and city streets. The city is planning another 200 km, linking destinations, transport nodes, and residential areas in a consolidated network.

6.2 BIKE LANES AND CYCLE TRACKS

A portion of the street in one or both traffic directions is designated for exclusive bike use by pavement markings (bike lanes), or a curb or median (cycle tracks). Protected bicycle lanes are intended to physically separate cyclists from motorized traffic and to ensure cyclists mobility and a feeling of security when traveling.

Cycle tracks separated from car traffic through physical barrier.

Design Principles

- Recommended bike lane normal minimum width adjacent to sidewalk curb of 2.2 meters and a 1.7-meter bare minimum if planners see the facility as improving safety and comfort for cyclists. Where an adjacent parking lane does not exist, 1.5 meters may be sufficient if adjacent traffic speeds are low.
- Bidirectional lanes are not preferred but could be considered if they would prevent crossing movements or space is limited. Safety can be enhanced through limited intersections, special signal control for bicycles, traffic calming at intersections, raised bicycle crossings at some intersections, and addressing vehicle accesses. Bidirectional lane widths should be a minimum of 2.5 meters.
- A bike lane next to a parking lane should be located in the inner side of the parking lane to protect bicyclists from motor traffic.
- In high- and medium-volume streets, use physical barriers or buffer zones between bike lane and motor lane but relieve barriers before junctions with right-turning traffic.
- Place on right side on a one-way street (right-side direction countries).

Benefits

- Separated bike lanes enable bicyclists to ride comfortably apart from moving vehicles aside from intersections, providing perceived safety that increases bicycling rates.
- Protected lanes place bicyclists farther away from vehicle exhaust.

Application

- Protected bicycle lanes are safer in between intersections, but can pose problems at intersections when motor vehicles and bicycles can conflict. Care should be taken to increase visibility and decrease conflicts at these points.
- Paint pavement to differentiate, especially at high traffic intersections.
- Bidirectional can be considered on one-way vehicle streets in contraflow configuration with consideration of intersection safety.
- Protected lane is provided by a buffer of some kind, which varies by local context but could include small "armadillo" humps, a linear curb, a raised cycle path, plastic bollard posts within a painted area, or other tools that provide a physical protection.
- Can be at roadbed level, or on level between roadbed and side-walk but preferably not on same level as sidewalk as this infers shared space of pedestrians and cyclists.

Evidence

- Bike lanes lead to small changes in the number of injury crashes. The mean estimate of 4 percent reduction of injury crashes is statistically significant (Elvik, Hoye, and Vaa 2009).
- A new cycle track in New York has reduced speeding rates from 74 percent to 20 percent. Crashes and injuries of all kinds dropped by 63 percent (Schmitt 2013).

Figure 6.2 | **Bike Lanes and Cycle Tracks**

A one-way cycle track from Mexico City protects bicycles with physical barriers and markings where the barriers give way at a vehicle access point.
Bottom: Cycling infrastructure seen here in Shanghai, China provides physical separation from motor vehicles through a fence. Pedestrians are also kept from entering the area.

6.3 OFF-STREET TRAILS

A path is provided in an off-street location that is exclusive to bicycles and pedestrians. Off street trails are sometimes called greenways or green routes and located on linear corridors, parks, utility or former rail corridors, along streams or waterfronts.

An off-street trail that segregates bicyclists and pedestrians to reduce conflicts.

Figure 6.3.1 | **Off-Street Trails Case**

A bidirectional lane along the edge of a park in Belo Horizonte, Brazil allows the adjacent path to be solely devoted to pedestrians. The bicycle lane is protected from motor vehicle traffic with concrete separators. Bidirectional lanes are most applicable when along corridors such as parks and waterfronts where turning conflicts are fewer.

Figure 6.3.2 | **Off-Street Trails Case**

This off-street bike trail on the edge of a park in Bogotá, Colombia provides separate paths for pedestrians and cyclists, helping to reduce conflicts between the users.

Design Principles

- Segregate bicycle traffic from pedestrian traffic using a striped line or separate path, providing at least 3.0m for a bidirectional bicycle lane and 1.5m for the pedestrian path.
- Junctions or points of conflict with vehicles should be designed carefully to reduce vehicle speed, control the approach to the junction, and provide appropriate signage.
- Ideal for streams and waterfronts, abandoned rail corridors, utility corridors, or plan as part of an interconnected parkway system.
- Closure of streets can be used to create bicycle greenway.
- Connect to on-street bicycle and pedestrian routes.

Benefits

- Can lead to greater connectivity of cycling and pedestrian paths.
- May provide economic benefits for surrounding development.
- Segregated completely from traffic for safer experience.

Application

- Ensure separation of cyclists and pedestrians, but if not possible, limit speeds of bicyclists and give pedestrians priority.
- Provide ample lighting and security features.
- Avoid sharp curves.

Evidence

- Clearly marked, bike-specific paths were shown to provide improved safety for cyclists compared to mixed-user bike paths (Reynolds at al. 2009).
- Off-street bike paths were found to be one of the safest bicycle routes in Vancouver, Canada (Teschke et al. 2012).

6.4 SHARED BICYCLE STREET

Shared bicycle streets—also known as bicycle boulevards—are low-vehicle-volume and low-speed streets that have been optimized for bicycle travel through treatments such as traffic calming, vehicle reduction and redirection, signage and pavement markings, and intersection crossing treatments.

A shared bicycle street, bike boulevard design with road markings and traffic calming measures.

Design Principles

- Locate on streets with low traffic volumes designed for vehicle speeds between 20 and 30 km/hr, with an ultimate maximum of 40 km/hr.
- Use traffic calming measures to limit the volumes and speeds of motor vehicles.
- Introduce traffic reduction measures such as diverters, traffic circles that restrict or prevent vehicles from passing through all junctions but allow cyclists.
- Prioritize intersection treatment to create safer crossings and reduced conflict with fast-moving vehicles, such as bicycle boxes, signaling, traffic calming for perpendicular traffic, median refuge islands, etc.
- Prioritize bicycle travel by the use of pavement markings and signage.

Benefits

- Can make better use of low-volume traffic and neighborhood streets.
- Homeowners and the local community may benefit from the safer, quieter, and pleasanter environment created by shared bicycle streets.

Application

- Bicycle boulevards should provide connectivity to key destinations such as schools, employment or commercial centers, recreational facilities, and transit.
- Shared bicycle streets, as they contain mixed traffic, require careful attention to keep motor vehicle speed safe for cycling. They may not improve safety if this is not addressed along the corridor and at intersections with major streets.
- Better integrated with green storm water treatments, public art, landscaping and street trees, pedestrian amenities, and end-of-trip facilities (adequate and safe bike parking).

Evidence

- Evidence from Berkley, CA shows that collision rates on bicycle boulevards are two to eight times lower than those on parallel, adjacent arterial routes. The difference is highly statistically significant (Minikel 2012).

Figure 6.4 | **Shared Bicycle Street Case**

A fietsstraat (bike way) in the Netherlands has pavement markings and signage of a bike boulevard.

6.5 BICYCLE SAFETY AT INTERSECTIONS

A safer intersection for bicyclists may include elements such as colored pavement, markings, bike boxes, bicycle signals, and simultaneous green phases for cyclists. Special attention to bicycle facilities at intersections and driveways should be given to maintain visibility of the bicyclists to motorists and to reduce the risk of turning conflicts with motor vehicles.

An intersection enhances the view between drivers and cyclists as they approach the intersection, and a two-step left-turn box.

Design Principles

- Minimize the potential conflict points at intersections, and ensure low motor vehicle speeds at approaches, using raised crossings, speed humps or other treatments.
- Eliminate any curbside parking spaces at least 10 meters before intersection to help ensure visibility between drivers and cyclists.
- Set back stop line for motor vehicles ideally by 5 meters to provide visibility of bicyclists (sometimes this area is marked in form of painted box); stop line for bicycles should be just behind the pedestrian crossing.
- Two-step left turns where cyclists approach the opposite corner, turn, and then proceed straight are regarded as safer than allowing cyclists to make left-turning movements from the left side of the vehicle travel lane. A bicycle box can be provided in front of the pedestrian crossing of the intersecting street to provide space for bicyclists to queue for left turns. (See page 73 for more).
- Bidirectional lanes are considered less safe as they involve unpredictable movement of cyclists, especially at intersections. If these facilities are to be implemented, special traffic calming, such as raised bicycle crossings, speed humps, or other features should be applied at intersections, in addition to signal control that eliminates conflicts with turning vehicles.

Benefits

- Intersections are where bicyclists come most into conflict with motorists, so increasing visibility and protection of bicyclists improves both comfort and safety.
- Good conditions for bicyclists can improve delineation between pedestrians and cyclists.
- Raised crossings, median refuges reduce motor traffic speed at the intersections.

Application

- Intersections should be designed to fit each particular space and designed with the needs of traffic at this location.
- Bike boxes usually are used at signalized intersections with high volumes of bicycles, especially where bicycle left-turns and motorist right-turns often conflict.
- Colored paving and markings are recommended to increase bicyclists' presence.
- Bike boxes may be combined with a separate bicycle signal phase to allow bicyclists to cross the intersection ahead of motorists.

Figure 6.5 | **Bicycle Safety at Intersections Case**

An intersection in Amsterdam is designed to show visibility between cyclists and vehicles, with the parking lane gradually eliminated to improve visibility between motorists and bicyclists.

BOX 6.1 | LEFT TURNS ON STREETS WITH BICYCLE LANES

Left turns are one of the more complicated movements at intersections, and it is important to know the varying safety aspects of certain designs.

Some guidance, such as the NACTO Urban Bikeway Design Guide from the United States, outlines bicycle boxes where cyclists are placed ahead of cars to make a left turn (NACTO 2013). Similarly, manuals from Ireland and the Netherlands describe an option where cyclists weave into a feeder lane for a left turn, though this places cyclists at risk while turning (CROW 2007; NTA 2011).

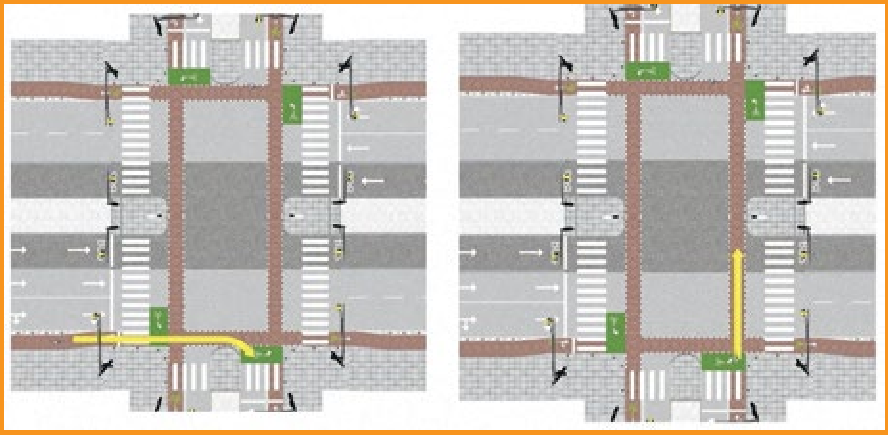
A safer design may be found in two-step turns. Guidance from the Netherlands indicates that two-stage left turns are one option that can reduce the conflicts (CROW 2007). A national-level guide for Mexican cities also suggests this design (ITDP 2011). Research from China also shows the two-step design to be beneficial (Wang et. al 2009). One problem is that this can leave cyclists in a subjectively unsafe situation waiting in the street. As such, NACTO suggests that bicyclists be placed in line with a curb or parking area. The Irish bicycling guide echoes this, saying the "stacking area" must be clearly visible and not obstruct crossing pedestrians or straight ahead cyclists. A frequent signal cycle may entice cyclists to wait in a design that requires two steps.

Lastly, the Netherlands' CROW 2007 indicates that simultaneous green signal phases exclusive to cyclists can be provided to allow bicycle left turns on all arms of an intersection. This may be ideal for high cyclist-volume intersections, though it could increase waiting times for all road users. Again, a quick signal cycle may relieve this issue.

More research is needed on the safety effects of these interventions and the impacts of whatever facility is put in place ought to be measured.

Two-Step Left Turn Design Example

Cyclists should continue straight along the road on a green light, stop in the queue box to the right and wait for the light to change before proceeding on the other street.



Evidence

- Seventy-seven percent of cyclists felt bicycling through the intersections was safer with bike boxes, and bike boxes reduce motor vehicle encroachment at intersections by almost 20 percent (Monsere and Dill 2010).
- Improving intersection design to provide two-step left turns resulted in a reduction in safety conflicts between motor vehicles and bicyclists by 24 percent in Beijing (Wang et. al 2009).
- A study from Finland and another from the Netherlands found that speed-reducing countermeasures (e.g. raised bicycle crossings) improved drivers' visual search patterns in favor of the cyclists coming from the right, giving more time to notice cyclists (Summala et al. 1996; Schepers et al. 2011).

6.6 BIKE SAFETY AT BUS STOPS

Bicyclists conflict with pedestrians embarking and disembarking at bus stops. Special design should accommodate the needs of both. A bike path behind bus stops can help avoid collisions between bicyclists and bus passengers, though if this is not provided priority should be given to pedestrians in some form.

Bike path design should accommodate the needs of both bicyclists and pedestrians at a bus stop.

Figure 6.6 | **Bike Safety at Bus Stops Case**

A bus station bypass in Rio de Janeiro, Brazil that raises the bicycle lane to the sidewalk level while bypassing the bus waiting area.

Design Principles

- Ensure easy access to bus stops for people with reduced mobility.
- Design can place bike lanes at the same level of sidewalk or bike lanes at street level with curb cuts enabling better pedestrian passage to the bus platform area.
- Design and markings should ensure that cyclists slow down and give way to pedestrians crossing in shared spaces.
- Bike lanes should be widened at the curves so that cyclists don't risk falling.
- The minimum width of the embarking/waiting area is 3m and the recommended length is 20m.

Benefits

- Reduce crash risks for both pedestrians and bicyclists at bus stops.
- Guarantee an easy access for bus users while accommodating a bicycle lane around a bus stop.

Application

- If it is prohibitive to raise the bicycle lane to the pedestrian pavement grade or to bring the lane behind the station area, then paint or markings could mark the pedestrian priority area.
- Waiting area sizes may need to be adjusted to match the passenger boarding and alighting volume at bus stops.

Evidence

- Studies have shown that collisions between cyclists and pedestrians result in significant injuries, and that increased controls of shared spaces may reduce the burden on pedestrian injury, particularly older pedestrians (Chong et al. 2010). Reducing this conflict at bus stops is one area that may be considered.

6.7 BICYCLE SIGNALS

Bicycle signals make crossing intersections safer for bicyclists by clarifying who and when to cross an intersection and by giving bicyclists priority crossing by signal phasing. Push buttons, bike boxes, and colored pavement and markings may be combined with bicycle signals to enhance bicycle crossing safety.

Bicycle signals can be clearly placed to inform when cyclists can cross.

Design Principles

- The bicycle signal head should be placed and designed so it is visible to bicyclists and not visible to motorists, as motorists may head start upon seeing the bicycle signal.
- Bicycle signal shall be used in combination with an existing conventional traffic signal at the intersections.
- Use three-lamp signal so cyclists can distinguish it from pedestrian signals.

Benefits

- Provides priority to bicyclists at intersections; the pre-green for cyclists will increase their visibility.
- Avoids bicyclist and motorist conflicts at the intersection by separating the crossing movement into phases.

Application

- Recommended at intersections with a high volume of crossing bicycles.
- Give bicyclists advanced green (e.g. a leading crossing interval) where bicyclists turning movements are high.
- Useful at complex intersections that may otherwise be difficult for bicyclists to cross.
- Useful at intersections close to schools and universities.

Evidence

- Evidence from Portland, OR shows that bicycle signals can reduce the number of bicycle/vehicle collisions (Thompson et al. 2013).

Figure 6.7 | **Bicycle Signals Case**

A bicycle signal is provided along this protected bicycle lane in Istanbul, Turkey.

BOX 6.2 | BICYCLE SHARING

Introducing new bicycle infrastructure can help enhance bicycling rates and provide residents the choice to use a form of transport that is incredibly healthy when considering the physical activity benefits. Cities can go beyond safer bicycling lanes to also provide the bicycles themselves through bicycle sharing, which has found success in low- and middle-income countries such as China and Mexico.

One of the most notable is Mexico City's Ecobici bike sharing program, which was launched in 2010 and today has an estimated 73,000 users and 27,500 daily trips over 4,000 bikes and 275 stations. In China, the systems are the largest in the world. The bicycle share system in Hangzhou, China has 66,500 bicycles operating from 2,700 stations. Globally, there are now over 500 cities with bicycle sharing systems in place (Hidalgo and Zeng 2013).

Studies of bicycle sharing are showing a potential in providing health benefits. A study of users of Barcelona's bike sharing system showed that there was near-zero percent increase in risk associated with exposure to air pollution and traffic crashes, but that over twelve lives were saved per year from the physical activity of people switching to more active transport (Rojas-Rueda et al. 2011). A review of bicycle share systems in the United States, Canada, and Europe reveals that bicycle share riders have a lower rate of crash risk than the average bicyclist (Kazis 2011). Experts have noted that this may be because bicycle-share bicycles move at lower speeds, are sturdier, are designed to keep riders in an upright position, have built-in lighting, and are often taken for short trips that may limit exposure.

Further study is needed regarding the safety aspect of bicycle sharing—especially those in Latin America and China—being instituted in countries with higher rates of traffic crashes. It is also important that cities interested in introducing bicycle sharing take actions to improve the safety of infrastructure on streets.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SAFE ACCESS TO TRANSIT STATIONS AND STOPS

Well-designed public transport is a key component of safer city streets. High-quality public transport provides the safest form of mobility possible, moving more people, more safely than other modes (ETSC 2003; Elvik and Vaa 2009). In many cities, especially in low- and middle-income countries, however, informal mass transport with little oversight (Restrepo Cadavid 2010) is perceived to be unsafe and generally associated with an increased risk of crashes.

For public transport to have a positive impact on safety, it requires a well-organized system and priority. Our research shows that when cities give this priority, they have a better safety impact than conventional or informal transit. Data from the implementation of Bus Rapid Transit (BRT) systems—such as Macrobus in Guadalajara, Transmilenio in Bogotá, and the Janmarg in Ahmedabad—show a significant reduction in crashes and fatalities on their respective corridors.

Research at EMBARQ has focused on identifying risk factors and common crash types on such transitways to provide safer design guidelines. The main safety risks on transit corridors depend on its geometric design rather than the type of technology used (bus or rail) or the region of the world it is in. Most recommendations in this chapter focus on bus systems, which are more widely implemented around the world and are relatively easier to upgrade than other modes. More detailed guidance can be found in the WRI report entitled *Traffic Safety on Bus Priority Systems*.

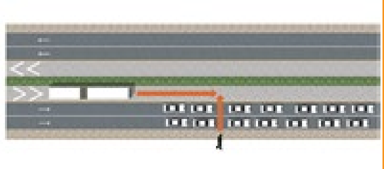
Though recommendations discussed here and in other chapters of this guide can also be applied to the design of access points for other public transport, more research is needed on how cities can foster safer access and movement within an integrated transport system.

This chapter illustrates how safety can be improved on bus priority corridors by improved design of:

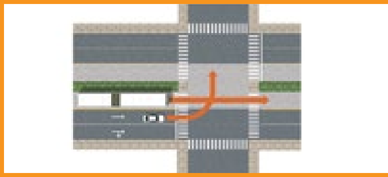
- Intersections
- Midblock pedestrian crossings
- BRT /Busway Stations
- Terminals and transfer stations
- Midblock bus stops

BOX 7.1 | COMMON BUSWAY/BRT CRASH TYPES

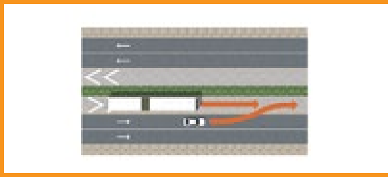
In its publication *Traffic Safety on Bus Priority Systems*, EMBARQ provides guidelines for creating safer bus corridors based on research from around the world. Part of the data analysis from this research revealed common types of crashes along bus corridors. This includes the following:



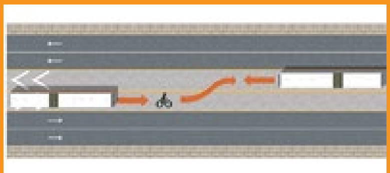
1. Pedestrians in the bus lane
Pedestrians may cross through slow or stalled mixed traffic only to be struck by a bus travelling on a dedicated bus lane. Bus drivers also have little time to react as their view of pedestrians crossing through traffic is often obstructed by the vehicles on the road. This type of crash usually results in fatal injuries.



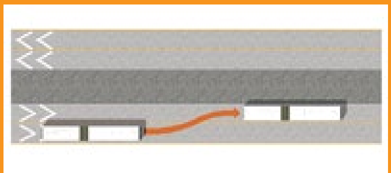
2. Left turns across a bus lane
This is one of the most common types of collision between buses and general traffic when median bus lanes are used. If left turns at intersections are not restricted or controlled, a vehicle when making a left turn cuts across the bus lane and can be struck by a bus going straight through the intersection.



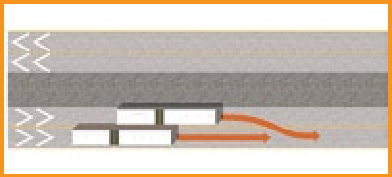
3. General traffic in bus lanes
This is a common crash type when dedicated bus lanes are provided. The lack of a physical barrier between bus lanes and general traffic lanes can allow other vehicles to illegally enter the bus lanes and collide with buses.



4. Crashes between buses and cyclists
Cyclists sometimes use dedicated bus lanes, because they perceive them to be safer than mixed traffic lanes but can face serious injury when hit by fast moving buses. Cyclists sometimes also attempt evasive maneuvers into other lanes when buses approach, which may cause them to be hit by a vehicle from the opposite direction or lose control and hit the dividers. At curbside bus stops, buses merging into mixed traffic may potentially be dangerous to cyclists.



5. Rear end collisions at a bus stop or station
This occurs when a bus is lining up behind another bus at a station platform but is coming in too fast and collides with the bus in front.



6. Crashes between buses at stations
These crashes occur on multi-lane busways with express lanes. Buses leaving the station and merging onto the express lane collide with buses in the express lane, either traveling through or attempting to access the station. A collision with an express bus is more severe as they travel at higher speeds.
Source: Duduta et al. 2015

7.1 INTERSECTIONS WITH BUS CORRIDORS

The key to ensuring safety on any bus corridor is to keep streets narrow and design simple, tight intersections. The size and complexity of intersections are key predictors of higher crash frequencies on bus corridors.

Four-way intersection with a median bus way.

Four-way intersection with curbside bus lanes.

Design Principles

- Left turns across median busways are particularly associated with increased crashes between buses and other vehicles and should be restricted.
- Provide a protected signal phase and dedicated turn lane where left turns cannot be avoided. General traffic should not be allowed to merge with the bus lane.
- As with left turns across median busways, right turns across curbside bus lanes also require the same consideration.
- With curbside bus lanes, if a separate turn lane for general traffic is provided, buses waiting at the intersection could block a pedestrian's view of turning traffic. A better option in this case is to allow general traffic to share the bus lane before turning right.
- Pedestrian cross times should be sufficient to cross the width of the street. We recommend a walking speed of 1.2 meters/second to determine the length of the pedestrian green phase.
- Keep the number of signal phases to a minimum and the signal configuration simple.

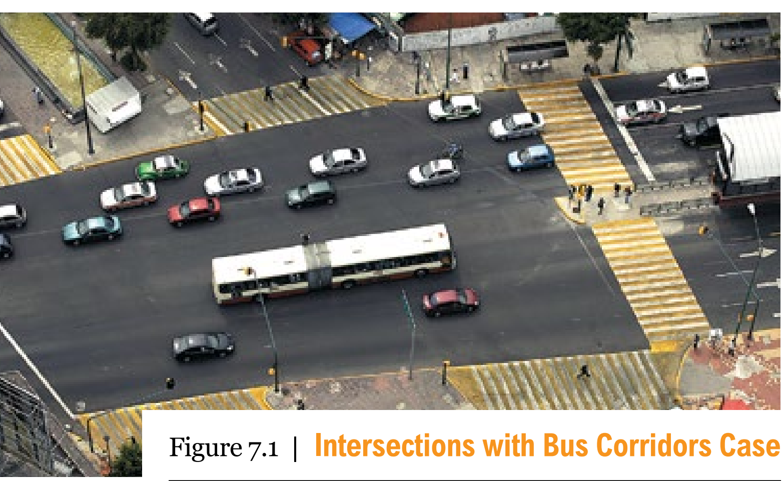


Figure 7.1 | **Intersections with Bus Corridors Case**

Mexico City's BRT corridor on Avenida Insurgentes includes a ban on left turns at intersections, leading to fewer conflicts and crashes.

Benefits

- Segregating traffic flows minimizes potential conflicts among buses, other vehicles, pedestrians, and bikes.
- Removing left turns avoids one of the most dangerous turns at an intersection.
- A simple signal configuration with fewer signal phases can reduce wait times for buses as well as pedestrians and other traffic. This improves bus performance and reduces the incentive for pedestrians to cross on red.
- Narrow streets and tight intersections can reduce pedestrian exposure and calm traffic.

Application

- An alternative to left turns across a busway at an intersection is to replace them with a loop. This substitutes the left turn with three right turns (or in some cases with one right and two lefts). This alternative is feasible if block sizes are less than 150–200m, reducing the length of the detour, and if the loop road is capable of handling the extra traffic.
- Special signals for buses are recommended that are distinguishable from regular signals.
- Left turns can be allowed but at fewer intersections.
- A physical separation between bus lanes and other traffic lanes will improve system performance by preventing collisions with other vehicles or pedestrians.

Evidence

- EMBARQ's crash frequency models suggest that each additional lane entering an intersection increases crashes by 10 percent. Simpler intersections are the safest (Duduta et al. 2015).
- Evidence from Bogotá, Mexico City, and Guadalajara show that allowing mixed traffic to enter a bus lane is a safety risk and results in increased collisions with buses (Duduta et al. 2015).
- Each added left turn movement at an intersection may increase pedestrian crashes by 30 percent and vehicle collisions by 40 percent (from EMBARQ models for Mexico City and Porto Alegre).
- Median busways have shown both a higher impact on safety as well as better operational performance (Duduta et al. 2015).

7.2 MIDBLOCK CROSSINGS

Pedestrian midblock crashes are the most important safety issue on a bus corridor. Busways can become a barrier to pedestrian access if sufficient midblock crossings are not provided. This can also increase the chances of pedestrians crossing without any protection or even jumping over barriers, increasing the likelihood of crashes. Well-designed mid-block crossings can mitigate these crashes and improve safety.

Midblock crossing on an urban arterial.

Design Principles

- Crossings should be provided frequently enough so that pedestrians are not prone to cross illegally (see page 23 on block size), though physical barriers such as fencing or vegetation may be needed to direct pedestrians to crosswalks if this is not possible.
- Signal timing should allow pedestrians to cross the street in one phase.
- Pedestrian volumes depend on adjacent land uses and must be considered in the design.
- Crosswalks near shopping malls, religious or educational buildings may experience larger demand.

Benefits

- Well-designed midblock crossings can improve both pedestrian safety as well as accessibility without sacrificing busway performance.
- Medians and refuge islands reduce the unprotected distance a pedestrian must cross by more than half.

Application

- All crossings on urban arterials should be signalized and at grade. Speed humps can further increase the likelihood that drivers stop at crossings. Staggered crossings should be provided so that pedestrians are facing the direction of traffic while crossing. Staggered crossings also provide more waiting space if pedestrians are unable to cross in a single phase.
- On narrower streets with single lanes in each direction, chicanes and other traffic calming measures can be used depending on the level of signal compliance in that city.
- Pedestrian bridges are effective only on freeways where high speeds do not allow safe at-grade crossings. Guardrails or fences to prevent pedestrians from entering the roadway are necessary, and care should be given to ensure that these measures effectively move people to the pedestrian bridge.
- The distance between signalized crosswalks on city streets should not exceed 300 meters.
- Bollards should be placed at crossings to protect pedestrians as well as to prevent illegal U-turns across the busway.

Evidence

- Ninety-three percent of pedestrian crashes in Porto Alegre occurred at midblock locations as opposed to intersections (calculated from 2011 crash data).

Figure 7.2 | Midblock Crossings Case

A midblock crossing on a busway in Juiz de Fora, Brazil includes a marked, raised crossing and signalization in a 25 km/hr segment that allows safer passage.

7.3 BRT/BUSWAY STATIONS

Station design can prevent dangerous traffic movements and improve accessibility and operations. Stations and their surrounding areas have higher pedestrian volumes due to traffic moving to and from stations. This increases the risk of crashes involving pedestrians. Stations near intersections also need to be designed to allow buses to wait or turn at intersections.

Pedestrian access to a median BRT station.

Design Principles

- Closed stations near intersections can use controlled access points to direct pedestrians to signalized crosswalks.
- Overcrowding on platforms, crosswalks, medians, or refuge islands can encourage pedestrians to walk along the road or cross illegally. Station design must take into account the expected volume of passengers to reduce the likelihood of overcrowding.
- Station design can also prevent collisions between buses. Lowering speed limits at stations and providing longer merging areas can reduce crashes.

Figure 7.3 | **BRT/Busway Stations Case**

Stations of the MOVE BRT in Belo Horizonte BRT are accessible via clearly marked crossings, signalization, and a ramp into the station that is set back so that passengers can see coming and going vehicles as they exit the station.

Benefits

- Improving station capacity and accessibility can improve system performance on the whole as well as safety.
- Regardless of the type of system, closed stations with high platforms can reduce dangerous pedestrian movements like jaywalking.
- Bike boxes and marked bike lanes can facilitate a bicyclist's left turn at signalized intersections.

Application

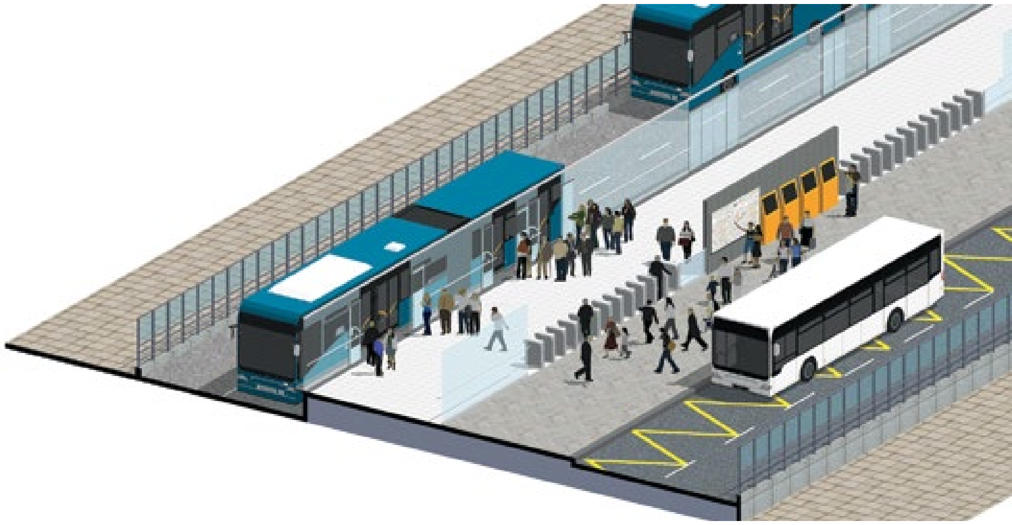
- Guardrails between lanes can prevent jaywalking. Guardrails on platforms should extend along the entire length of the station, be at least 1.7 meters high, and resistant to damage.
- Platform doors that open only when a bus has docked at the station are a good safety feature if they are well-designed and maintained.
- A station speed limit of 30 km/hr can give drivers more time to react.
- Where express lanes are used, a merging area for buses should be provided to allow buses to reach a sufficient speed before merging.
- A waiting space for one bus can be provided before the station to allow a bus to wait for the bus ahead to depart before pulling in and docking.

Evidence

- Busway stations in Porto Alegre, Brazil had a higher incidence of pedestrian crashes than other locations after accounting for other differences (Diogenes and Lindau 2010).

7.4 TERMINALS AND TRANSFERS

The safest transfers between two routes or modes are when passengers do not have to leave the station platform. Integrated transfer points are ideal, but they require a lot of space. In denser cities, transfers may happen across an intersection, requiring design considerations similar to those discussed in the previous sections.



Transfer between a high floor BRT line and conventional bus service.

Design Principles

- Direct routes to passenger destinations are the ideal case. Passengers wait for the bus route that they want to take and can avoid transfers. However, this option is operationally complex.
- Where possible, transfers between modes and routes should happen on the same platform.
- Transfers at intersections with signalized crosswalks can allow connectivity between adjacent stations or routes.
- Traffic turn movements that conflict with pedestrian access at stations should be prohibited.

Benefits

- Effective and convenient transfers between modes and routes will encourage more passengers to use the system.
- Design of access points to a terminal can minimize conflicts between buses and ensure safe pedestrian access.
- Well-designed transfer points allow for effective integration of different transportation modes.

Application

- Raising the street level on one side of a platform can allow both low-floor and high-floor buses to use the same platform.
- Transfers across an intersection to nearby stations on different routes should use bridges or underpasses if possible for seamless transfers.
- Altering routes can allow multiple routes to use the same station; however, this may require intersections to be designed for different bus turns.

Evidence

- Our data have shown that people are considerably safer when they are in the bus or on the station platform than when they are walking to and from the station. Same-platform transfers are the safest (Duduta et al. 2015).
- EMBARQ studies also show that major transfer stations are the locations with the highest number of crashes on many public transport systems due to the large volumes of traffic and increased exposure for pedestrians (Duduta et al. 2015).

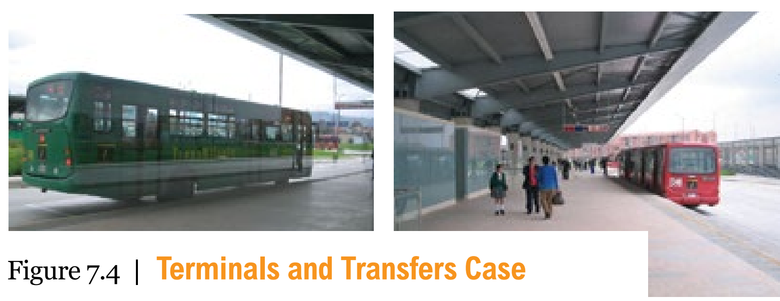


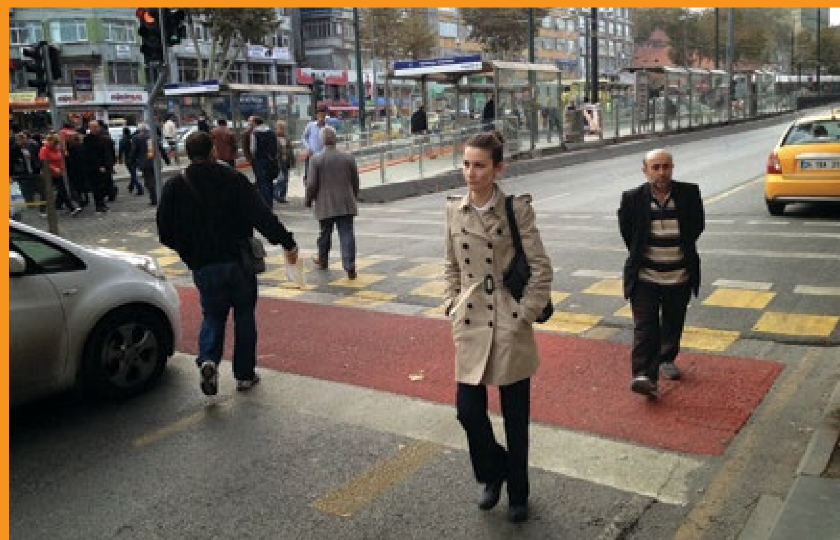
Figure 7.4 | **Terminals and Transfers Case**

Images show transfers between the Transmilenio BRT and a feeder bus on two sides of the same platform.

BOX 7.2 | SAFETY ON TRAM/LIGHT RAIL CORRIDORS

This chapter primarily focuses on access to bus stations and does not provide key elements for designing safer tram or light rail corridors or access to these stations. Trams can take on a wide spectrum of route types. Some are completely separated from traffic in underground tunnels or along heavy rail or waterfront corridors. Others are placed along or in the middle of city streets. While this publication does not include detailed guidance on trams, a review of research on street design shows the main issues involve (a) conflicts between vehicles and trams; and (b) pedestrian safety, especially regarding station access.

Vehicle conflicts: mixed traffic is least desirable. Streetcars running at grade on-street have been identified as the least desirable design for light rail systems due to potential conflicts with other modes of transit, which can impede traffic, limit transit speed and reliability, and pose safety risks to both vehicles and pedestrians (Richmond et al. 2014). Dedicated lanes prevent these conflicts and can be ensured through physical barriers such as guard rails or fences that will prevent pedestrians and vehicles from entering the track area. Conflicts also can be found at intersections, especially where turning vehicles may be crossing the path of the tram. This requires separate signals for turning vehicles, though banning left turns would go further in reducing the chance of a tram hitting a turning vehicle (Pecheux and Saporta 2009).



A raised crossing in Istanbul helps give priority to pedestrians at an access point to a tram station.

Pedestrian safety. Another large issue with trams is the conflict between vehicles and pedestrians, particularly at station areas. A study from Sweden showed that three-quarters of those injured in bus and tram incidents sustained their injuries at bus or tram stops, or at pedestrian crossings (Hedelin, Bunketorp, and Björnstig 2002). Measures to improve safety include reducing vehicle speeds through speed humps, raised pedestrian crossings, or other traffic calming measures, shortening crossing distances, and ensuring clear visibility at station entries and exits. Horns or bells can alert pedestrians of a coming train. Among other interventions, arms can close off the track area to prevent pedestrians from crossing when trains are passing (Cleghorn 2009).

More research is needed, particularly statistical analysis on the design features that can maximize safety for tram corridors. Many of the issues found with trams appear to be similar to those seen with BRT (Duduta et al. 2015). In any event, road safety audits and inspections are important and will give designers important information in improving traffic safety.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CONCLUSION

The design of city streets and neighborhoods can impact the health and safety of residents.

Across the world, cities have choices to make in how they shape neighborhoods and design streets. Will these choices lead to the pedestrian and bicycle accommodating streets of Copenhagen or the more car-dependent, freeway-oriented past of Atlanta?

Combined with efforts to improve vehicle impact technologies, improved regulations for seatbelt use and drunk-driving laws, safer street and urban design can be provided in new massive housing developments or redevelopment, new cities and urban growth areas, and in rethinking existing streets.

Spread-out cities in the U.S., Canada, and Europe that developed in the late twentieth century are reviewing their own policies, which have promoted a spread-out city with higher traffic fatalities. This realization, however, has taken several decades while a place like Copenhagen is seeing the benefits of 50 years of work to reclaim the city for people. Sustainable urban development—focused on walking, bicycling, and access to mass transport, compact development, mixed land uses, nearby parks and public space, and safely designed roads that slow cars and forgive human error are the key to making this happen.

Urban road safety should be integrated into urban mobility and other city plans—alongside environment, energy, and mobility concerns—within a long-term and sustainable vision. Both authorities and citizens should realize the choices to be made and diligently work together to implement them.

Continuous safety performance monitoring and research is needed to acquire the necessary knowledge to support decision making. Cities need to create their own solutions, catered to their own local context, and measure them to obtain the desired impact.

This report is meant to guide cities on the basic elements of how to make community and street design safer so cities can create these solutions, and measure them for replication. In this pilot version, a variety of solutions and evidence is provided, along with examples to road test in cities. The next version will incorporate all of the reviews and input received over this road-test process. This guide also hopes to inspire the creation of local- or country-level guidance that can better reflect the context of those places—and reduce traffic fatalities and serious injuries. By doing so, cities can become not only safer for all their residents, but healthier, more sustainable places to live.

Urban road safety should be integrated into urban mobility and other city plans—alongside environment, energy, and mobility concerns—within a long-term and sustainable vision.

Seven Things a City Can Do to Improve Travel Safety

1. Tap into the expertise of all road users. To build a successful safe and friendly city, consultations with all the road users are imperative. Different users are the experts on their own needs.

2. Engage multiple sectors. Government cannot do it alone. Encourage public and private partners from multiple sectors to take part in the effort to be more inclusive of all road users, both as a business opportunity and a moral imperative. Museums, theaters, grocery stores, banks, pharmacies, churches, and block associations can all be leaders in creating safe and friendly cities.

3. Recognize that a safe travel environment is a contributor to the economy.

4. Ensure that pedestrians, bicyclists, transit and bus passengers know about existing opportunities and resources.

5. Adopt a "safe-in-everything" approach to community planning and the design process. Redesign street intersections with the safety of all road users in mind. Focus on areas near shops and services and on areas with high rates of pedestrian injuries. Add public seating on streets in accordance with location recommendations from pedestrians.

6. Advocate for improvements in public transportation. Focus on making transportation safe, accessible, and welcoming to all users. Good lighting, clear signage, and courteous drivers can be just as important as having an appropriate infrastructure in place.

7. Increase accessibility to opportunities that promote health and socialization. Expand efforts to make parks, walking trails, swimming pools, beaches, recreation centers, and public events accessible and welcoming to all groups. Offer fitness and recreational programming designed for and of interest to all users.

8. Last but not least, plan for safety through mobility plans, city plans, traffic safety action plans, and other plans to prioritize safety in city designs.

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AUTHORS

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WORLD
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10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

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