2 Pedestrians at Multi-Modal Intersections

2.1 Intersection and Mid-block Crosswalk Treatments

Multiple Locations

Description

This section focuses on crosswalk treatments that will improve pedestrian safety and, in doing so, enhance pedestrian accessibility and mobility.

A crosswalk's primary function is to channelize pedestrians. Well-marked pedestrian crossings prepare drivers for the likelihood of encountering a pedestrian, and create an atmosphere of pedestrian walkability and accessibility. Marked crossings reinforce the location and legitimacy of a crossing. However, the California Vehicle Code requires vehicles to yield the right-of-way to pedestrians at any intersection where crossing is not prohibited (regardless of markings).[1]

Crosswalks are primarily located at intersections, where cars must stop anyway to wait for other vehicles travelling on the cross street. However, pedestrians often wish to cross at mid-block locations, particularly on long blocks and at locations with popular trip attractors. At these locations, mid-block crossing treatments are advisable to provide a seamless and safe walking environment.

Design and/or Operational Considerations

1. Intersection crossing treatments

Intersections are the primary crossing points for pedestrians. Although at signalized intersections cars are required to stop, pedestrian-vehicle collisions still occur, often as a result of drivers speeding or turning across the crosswalk.

Design solution: Decorative Crosswalks

Decorative crosswalks use distinctive patterns and pavement treatments to make the crosswalk more visible. They help define the pedestrian space and discourage vehicles from encroaching upon the pedestrian crossing area. They also help to beautify the streetscape and add a specific character to a neighborhood. One treatment that has been applied in Chinatown in Oakland as well as in Noe Valley and the Tenderloin in San Francisco is called Streetprint™. This treatment consists of a flexible, durable thermoplastic that is inset into asphalt pavement. Unique colors and patterns can be added according to the desired aesthetic. The inset process helps to protect the crosswalk from wear and ensure long-lasting color.

DuraTherm Crosswalk Treatment in Chinatown, Oakland

Design solution: Raised Intersections

Raised intersections help to designate areas with high pedestrian activity and slow down vehicle speeds. Raised intersections are whole intersections, including adjoining crosswalks, that are elevated three to six inches with ramps on all approaches (typically at a 4%-8% grade). Tactile treatments are needed at the sidewalk/street boundary so that visually impaired pedestrians can identify the edge of the street.

These treatments are designed to draw attention to the intersection and pedestrians while allowing vehicles to traverse the intersection safely, reducing vehicle speeds. They are ideal for application in commercial areas and business districts with high pedestrian flows.

[1] More information on the California Vehicle Code sections related to pedestrian right-of-way is available at http://www.walksf.org/vehicleCodes.html.

One potential consequence of raised intersections is that they can also slow transit speeds and increase wear and tear on transit vehicles. As a result, caution should be exercised when considering raised intersections along routes with high transit volumes, and if implemented, designs should ensure that transit impacts are minimized.

Raised intersections have been applied in the U.S. (Portland, OR, Cambridge, MA, and New York City) as well as internationally, including locations throughout the U.K. and Australia.

Raised intersection in Sale, England

Source: http://www.students.bucknell.edu/projects/trafficcalming/Library.html / Dr. Richard McGinnis

Raised intersection in Perth, Australia

Source: Gehl Architects

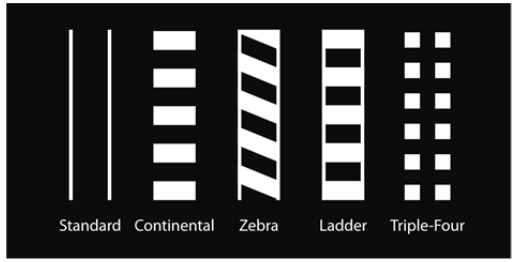
2. Mid-block crossing treatments

Mid-block crosswalk locations are determined by understanding pedestrian desire lines (i.e., the places people would like to walk). A person's decision of where to cross is affected by local land uses such as work places, hotels and commercial establishments, and the location of transit stops and vehicle and bicycle parking facilities. This information forms a basis for identifying locations for pedestrian crossing improvements and prioritizing such improvements, thereby creating a convenient, connected, and continuous walking environment. Once candidate crosswalk locations have been identified, appropriate treatments should be evaluated for each location.

Design solution: High Visibility Crosswalks

High visibility striping is a tool that brings attention to pedestrians crossing, typically at mid-block locations. It should be used in combination with other design treatments, like refuge islands, bulb-outs, and other active device enhancements for roadways with more than 4 lanes or speeds over 40 mph. They help to direct pedestrian traffic to specific locations. There are several treatments for high visibility markings, including the ladder, continental, and zebra designs. Communities should choose a preferred style to use in these circumstances so it is consistently applied. The City of Sacramento, for example, developed its own standard high visibility striping treatment for uncontrolled locations called the triple-four. The City has implemented this treatment citywide, involving three four-foot segments, two dashed lines on the outside with a clear space in the center to direct pedestrian traffic.

Example High Visibility Crosswalk Patterns



Design solution: Raised Crosswalks

Similar to raised intersections, raised crosswalks provide an elevated surface above the travel lane that attracts the attention of the driver and encourages lower speeds. It is useful in areas with high pedestrian activity by essentially raising the road surface (typically 3-6 inches or the height of the curb) over a short crossing distance. This treatment includes a flat area on the top that constitutes the crosswalk. This flat area may be made of asphalt, patterned concrete, or brick pavers. As with raised intersections, tactile treatments are needed at the sidewalk/street boundary so that visually impaired pedestrians can identify the edge of the street.

This treatment helps to reduce vehicle speeds and improve visibility of pedestrians by defining the crossing. The Pennsylvania Department of Transportation have found that raised sidewalks reduce vehicle speeds an average of 6mph. Research by Ekman and others has concluded that raised crosswalks at unsignalized crossings can be more effective than other traffic control devices because they control speed at the actual pedestrian crossing. However, similar to raised intersections, raised crosswalks can reduce transit travel speeds, and may not be appropriate along major transit routes, unless specific design treatments are included to minimize the effect to transit.

Raised crosswalks have been installed in El Cerrito, CA, Sacramento, CA, Cambridge, MA, Bellevue, WA and Boulder, CO. Raised crosswalks are also common in the U.K., Sweden and France.

Raised crosswalk in Boulder, CO

Raised crosswalk in Sterling, Scotland

Source:
http://www.students.bucknell.edu/projects/trafficcalming/Library.html / Dr. Richard McGinnis

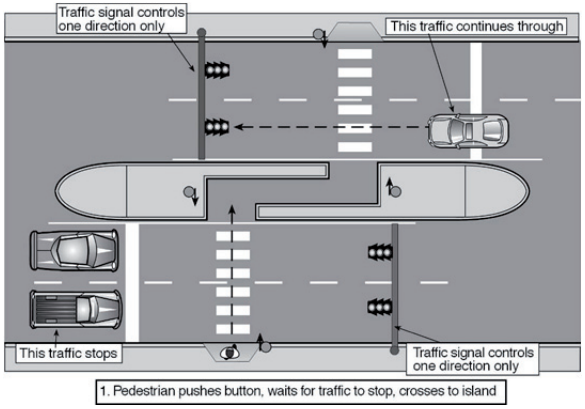
Design solution: Staggered Crosswalks

Often on wide streets, crosswalks are divided into two parts with a median or island in the center of the roadway. In these situations, crosswalks on either side of the median can be staggered such that a pedestrian crosses half the street and then must walk a short distance and facing traffic to reach the second half of the crosswalk. This configuration provides pedestrians with a better view of oncoming traffic and allows drivers to clearly see pedestrians. It also reduces the crossing distance for pedestrians by allowing them to cross half the street at a time and provides more flexibility for signal coordination. Staggered crosswalks can be designed to accommodate bicycles by providing sufficient space and width for bicyclists to comfortably maneuver across the off-set crossings. This treatment has been applied in numerous locations in San Francisco, including some crossing locations on upper Market Street, and King Street between 4th and 2nd Street.

Staggered crosswalk in Bristol, United Kingdom

Source: Pedestrian and Bicyclist Safety and Mobility in Europe report, Federal Highway Administration

Pedestrian refuge island with staggered crosswalks



Design solution: Pedestrian Crossings at Transit Boarding Islands

In locations with center-running transit, transit boarding islands are located in the middle of the road: typically two islands are provided, one on each side of the center-running transit. In certain circumstances it may make sense to use these islands as locations for pedestrians to cross the street in addition to accessing transit. In order to enhance pedestrian safety, several design features must be incorporated. First, marked crosswalks or raised crosswalks (as mentioned above) should lead from the curb to each transit boarding island. Second, the area designated for pedestrian crossing across the transit right-of-way, between the two islands, should be clearly marked.

An example of this type of configuration can be seen along the Diagonal tram line in Barcelona. This is a center-running tram on a highly-trafficked street. Signalized crosswalks lead to each boarding island from either side of the street. The trams run in both directions between the boarding platforms. At most stops, at the edge of the boarding platforms is a signalized crossing for pedestrians between the two platforms. The majority of the tracks are surrounded by a grass, but the locations designated for pedestrian crossing are paved and often highlighted in a red brick color with a tram icon painted along with an arrow, alerting pedestrians to look for trams approaching from that direction.

Barcelona tram crossing and platform

Photo credit: Mireia Roca-Riu

Crosswalk across Barcelona tram line (tram platform is to the left)

Source: ITDP / Michael Kodransky

Barcelona tram crossing with markings for pedestrians

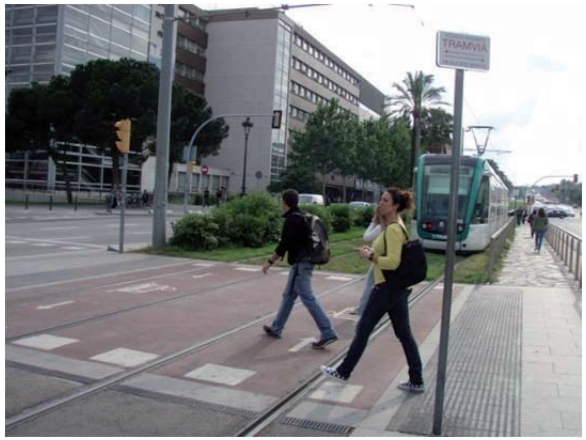


Photo credit: Mireia Roca-Riu

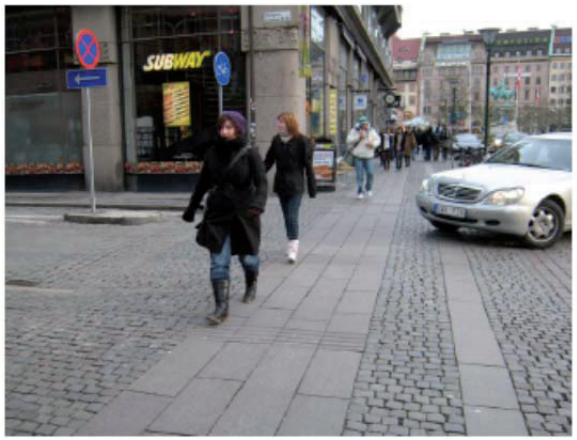
Barcelona tram crossing and platform

Photo credit: Mireia Roca-Riu

3. Continuous Sidewalks

By taking sidewalks across side streets the pedestrian landscape becomes more comfortable with fewer interruptions. This treatment is primarily used on stop-controlled, low-volume cross-streets without transit. Continuous sidewalks may be more challenging to implement across high-volume cross-streets that are controlled with signals and carry buses, trucks and emergency vehicles.

Continuous sidewalk in Malmo, Sweden



Credit: Gehl Architects (request original JPG from Gehl)

A gently sloped side street provides access across a continuous sidewalk along the main traffic corridor. Copenhagen, Denmark

Credit: Gehl Architects (request original JPG from Gehl)

Potential Market Street Application

These solutions help to address the following issues:

- **Defining the pedestrian realm:** These treatments help to define the pedestrian realm, providing safe, well-marked locations for pedestrians to cross the street. Continuous sidewalks may be suitable for the north side of Market Street which has more frequent crossing interruptions.
- **Managing vehicle speeds:** Installing raised crosswalks and intersections can help reduce vehicle speeds thus enhancing pedestrian safety; however this desired outcome may also result in lower transit speeds, which would not be desirable.
- **Calming bicyclist speeds in pedestrian areas:** Raised crosswalks and intersections can also have the effect of reducing bicycle speeds in pedestrian areas.
- **Improving pedestrian access:** Since Market intersections are wide, installing mid-block crosswalks and improving intersection crossings can improve pedestrian safety and access. Providing safe crossings to and between transit boarding platforms also improves access, both for accessing transit and for crossing the street. New mid-block crossings should be designed as to minimize the potential effect on transit travel times. For example, if implemented in conjunction with a new signal, the signal should be timed and coordinated with adjacent signals to minimize the chances that transit vehicles would have to stop at the mid-block signal.

Other Information

The cost of raising an entire intersection can be expensive, depending on size, drainage issues and aesthetic features such as pavement texturing and color.

Local emergency services and transit service should be considered when determining placement of raised intersections and raised sidewalks since these can cause slight delay for emergency and transit vehicles (4-6 second delay).

References

For more information on applications of the above measures in Europe see:

- *International Scan Summary Report on Pedestrian and Bicyclist Safety and Mobility,* June 2009, http://www.fhwa.dot.gov/environment/bikeped/pbssummary062409.pdf

For more information on decorative pavement, see:

- https://www.integratedpaving.com/index.cfm

For more information on raised intersections see:

- http://www.trafficcalming.org/raisedintersections.html

For more information on San Francisco specific design guidelines related to the measures listed above see:

- San Francisco Better Streets Plan, http://www.sf-planning.org/ftp/BetterStreets/proposals.htm

2.2 Minimizing Pedestrian Exposure to Vehicle Traffic

Multiple Locations

Description

A primary strategy for enhancing pedestrian safety and creating a comfortable and attractive walking environment is minimizing pedestrian exposure to vehicle traffic. This includes providing a buffered area between the sidewalk zone and moving traffic, minimizing the amount of time pedestrians spend in the roadway and reducing conflict points at uncontrolled locations. Some cities have gone as far as removing vehicle traffic on certain streets to create pedestrian and transit malls. On streets with vehicle traffic, barriers can be added to protect pedestrians from moving traffic and to channelize pedestrians to optimal crossing points.

Design and/or Operational Considerations

1. Channelizing pedestrians

Café seating, landscaping, and where appropriate, rails and fencing can be used to channel pedestrians and ensure that they cross at designated locations.

Design solution: Sidewalk Café Seating

On wide sidewalks, café seating can be placed on the sidewalk along the street, allowing pedestrians to pass between the storefronts and café seating. Café seating also serves to channelize pedestrians at designated crossing locations. In addition, outdoor seating helps to make the street a more lively and attractive place to be. This strategy has been applied in many cities in Europe, including Barcelona and Edinburgh. Most recently, San Francisco's Pavement to Parks project has replaced on-street parking spaces with public "parklets".

Sidewalk café seating in Madison, WI

Source: www.pedbikeimages.org / Eric Lowry

Sidewalk café seating in San Francisco

Design solution: Landscaping

Landscaping such as shrubbery and street trees along the edge of the sidewalk zone also serves as a barrier between pedestrians and motorized traffic and can reduce mid-block crossings. It is important to provide landscaping in a way that does not hinder movement along the sidewalk or access to transit stops or stations. San Francisco has specific guidelines for type, size, location, spacing and maintenance of street trees. This strategy has been applied in cities throughout the US, Europe and Australia.

Street trees in Los Angeles

Street trees, café seating and street furniture in Bethesda

Design solution: Street furniture

Street furniture, including benches, fountains, newspaper racks and garbage or recycling containers can also be used as a barrier to street traffic. Street furniture also provides additional comfort to pedestrians and enhances place making within the pedestrian realm. It is important to locate street furniture in a way that it does not conflict with the pedestrian travel path.

Street trees and street furniture as barrier in Copenhagen

Source: Gehl Architects

Design solution: Bollards

Bollards are a low cost treatment for protecting pedestrians from moving traffic and are particularly effective at stopping vehicles that are out of control from encroaching onto the sidewalk. Retractable bollards are also available for locations where vehicle or emergency access is occasionally needed.

Decorative bollards used as barrier in Bilbao, Spain

Source: Gehl Architects

2. Minimizing crossing distances

Minimizing pedestrian crossing distances will reduce the amount of time pedestrians are in the street, and thus reduce potential conflicts with vehicles.

Design Solution: Curb Extensions

Also known as bulb-outs, this measure consists of an extension of the curb into the street, making the pedestrian space (sidewalk) wider. Curb extensions provide a larger space for pedestrians to wait before crossing an intersection and prevent cars from parking near the crosswalk. By extending the sidewalk into the street, they create shorter crossing distances for pedestrians and smaller vehicle turning radii at intersections. Bulb-outs have been applied in many locations including Boston, Philadelphia and San Francisco.

Bulb-out in Bainbridge Island, Washington

Source: www.pedbikeimages.org / Carl Sundstrom

3. Discouraging vehicle encroachment in pedestrian space

Vehicles are often tempted to pull up to the edge of the intersection, encroaching upon the crosswalk. This presents a hazard to pedestrians in the crosswalk.

Design Solution: Advanced stop bar

Advanced stop bars are lines placed in advance of marked, signalized crosswalks. They increase pedestrian visibility to motorists, reduce the number of vehicles encroaching on the crosswalk and improve general pedestrian conditions on multi-lane roadways. It is also a low-cost treatment.

Similar to advanced stop bars are advanced yield lines, which are markers (typically a series of while triangles or “shark’s teeth”) which are placed in advance of marked, unsignalized crosswalks. This helps alert drivers to look for pedestrians crossing the street, giving them more time to react and stop if a pedestrian is crossing.

Potential Market Street Application

These solutions help address the following issues:

- **Minimizing the time pedestrians spend in the street:** Bulb-outs reduce crossing distances and minimize the amount of time pedestrians are in the roadway.
- **Reducing conflict points:** Seating, landscaping, fencing and rails channel pedestrians to designated crossing points, reducing mid-block crossings and the number of locations where vehicles and pedestrians may conflict.
- **Enhancing the pedestrian experience:** Barriers separate pedestrians from moving traffic, providing a safer, calmer environment, minimizing hazards from moving vehicles.
- **Increasing pedestrian visibility:** curb extensions and advanced stop bars help bring motorist attention to pedestrians crossing the street, providing them with more time to react to avoid conflicts.

Other Information

Café seating and other sidewalk uses should be considered in partnership with private businesses.

References

Better Streets Plan, City and County of San Francisco, December 2010: http://www.sf-planning.org/ftp/BetterStreets/proposals.htm

Pedestrian and Bicyclist Safety and Mobility in Europe, US Department of Transportation, Federal Highway Administration, 2010, http://www.international.fhwa.dot.gov/pubs/pl10010/ch00.cfm

2.3 Minimizing Pedestrian/Bicycle Conflicts

Various Locations

Description

An often-overlooked issue is minimizing pedestrian-bicycle conflicts. Pedestrians and bicyclists are often grouped into the same category but are actually quite different regarding mobility and speed. In some ways, minimizing pedestrian-bicycle conflicts can be similar to minimizing pedestrian-vehicle conflicts. As bicycles become more experienced, their awareness of pedestrians may decrease. Therefore, efforts to improve bicycle mobility while maintaining pedestrian safety are key. Attention should be paid to providing separate facilities for these modes, calming bicycle speeds and limiting conflicts.

Design and/or Operational Considerations

1. Intersection treatments

Crosswalks at intersections are the primary crossing points for pedestrians. Bicycles, like motorized vehicles, are required to stop at signalized intersections. However, since bicycles span the realm between motorized and human-powered modes, they may be more inclined to encroach into the crosswalk than cars. Therefore, it is important to clearly delineate which space at the intersection is reserved for each mode.

Design solution: Bike Boxes

A bike box is a reserved area for bicyclists between the pedestrian crosswalk and an advanced stop bar, where motorized vehicles are required to stop. The area is typically painted a distinguishing color and marked with a bicycle stencil. The bike box provides a place for bicycles to wait for traffic green light without encroaching on pedestrians in the crosswalk or being next to stopped cars. Once the light turns green, bicycles may proceed before cars. Bike boxes also minimize left-turning conflicts between bicycles and cars.

Bike boxes are common in several countries in Europe including the Netherlands, Denmark and the United Kingdom. Most European traffic signal systems display a short simultaneous red and yellow indication before the green phase to alert queued traffic in advance of the green phase and to alert bicyclists that entering the bike box just before the green phase will likely result in a conflict with releasing traffic. There is no U.S. equivalent of the advance simultaneous red and yellow indication to provide a cue that the signal is changing.

Several U.S. cities are experimenting with bike boxes including Cambridge, MA; Columbus, OH; New York, NY; Portland, OR; and San Francisco, CA. Bike boxes were recently implemented at several intersections along Market Street. Bike boxes tend to be most effective to bicycles arriving at the intersection during the red signal phase and wishing to turn left. They may pose comfort and safety concerns for inexperienced bicyclists who arrive at the intersection during the green phase and wish to turn left. Bike boxes benefit pedestrians by separating the bicycle waiting space from the pedestrian crossing space, thus reducing pedestrian-bicycle conflicts while pedestrians are in the crosswalk.

New bike box on Market Street

Source: StreetsblogSF / Bryan Goebel

Bike box in London

Source: Pedestrian and Bicyclist Safety and Mobility in Europe report, Federal Highway Administration

Design solution: Advanced Stop Bars and Limit Lines

Advanced stop bars are white lines placed between four and twenty feet in advance of marked crosswalks at signalized intersections. While their main purpose is to encourage motorists to stop further in advance of the marked crosswalk to avoid encroaching on the pedestrian space, they can also be used for bicyclists as well (although not as effective as a bike box). This strategy has been applied in Sacramento, CA and St. Petersburg, FL.

Advanced limit lines as described in *the Minimizing Pedestrian Exposure* section, and "yield here to pedestrians" signage can help to reduce bicyclists encroaching on pedestrians at unsignalized crossing locations.

Advanced stop bar

Design solution: Bicycle Signal Heads

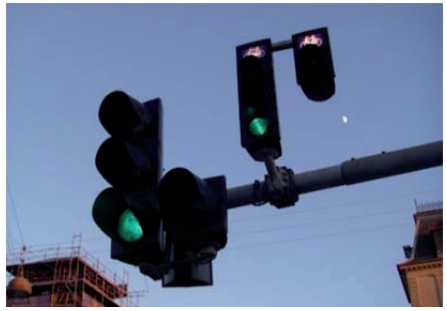
Bicycle signal heads (see the Cycle Tracks case study) can be used at signalized intersections to indicate a bicycle signal phase. This can help separate bicycle movements from conflicting motor vehicle or pedestrian movements.

Bicycle signal heads in the US typically use standard three colored lenses: green, yellow and red, and display a bicycle image. This strategy has been implemented in the United States in locations such as the Fell and Masonic intersection in the Panhandle of San Francisco, Long Beach, New York City, and is common internationally in Europe and China.

Bicycle crossing with bicycle signal head in Stuttgart, Germany

Photo credit: Nicole Foletta, Fehr & Peers

Traffic light for both cars and bicycles in Copenhagen, Denmark



Source: Gehl Architects

Design solution: Curbside Markings

At crossings where pedestrians cross a bicycle path, a marker can be placed on the ground, alerting pedestrians to look both ways for bicyclists. This can help raise pedestrian awareness of bicycles in the area and provide more time to react to potential conflicts.

Curbside marking of bicycle crossing

Source: Gehl Architects

2. Transit stop configuration

Pedestrian-bicycle conflicts can occur at transit stops if not configured appropriately. If the bicycle space is not well-defined, bicyclists may try to pass transit vehicles on the right side while pedestrians are boarding or alighting, potentially causing collisions. The bicycle space should be separated from the pedestrian space to avoid conflicts.

Design solution: Bikeway Definition and Routing

Bike facilities should be specifically designated, either by providing a physically separated bike lane (cycle track) or painting the bicycle lane a distinct color. In some cases, these facilities can be routed around transit platforms to avoid conflict.

Separating the space designated for each mode will bring order to the street and reduce confusion. Many European countries, including Denmark and the United Kingdom, have implemented colored bicycle lanes to designate the bicycle right-of-way. Furthermore, an innovative strategy of routing the bike lane around the back side of the bus stop to avoid conflicts has been implemented in various locations including Stockholm, Sweden. Routing bikeways behind bus stops can increase bicycle and pedestrian conflicts, and should be designed to slow bicycle speeds and minimize conflicts. This is of particular concern for the frail elderly and visually impaired.

Colored bicycle lane in Copenhagen

Source: ITDP / Michael Kodransky

Bike lane routed around bus stop in Stockholm

Source: ITDP / Michael Kodransky

Colored bicycle lane through intersection in Copenhagen

Source: Gehl Architects

Bike lane to right of bus stop in Copenhagen

Source: Gehl Architects

Pedestrian-bicycle conflicts can be a result of bicyclists speeding and not paying attention to pedestrians. Slowing bicycle speeds can help reduce conflicts.

Design solution: Raised Crosswalks

Beyond improving pedestrian safety, raised crosswalks (see Intersection and Mid-Block Crosswalk Treatments) can also aid in “bicycle calming” by slowing bicycle speeds and therefore reducing pedestrian hazards. However, raised crosswalks can reduce transit travel speeds, and may not be appropriate along major transit routes, unless specific design treatments are included to minimize the effect to transit.

Design solution: Textured Pavement

In areas used by both bicycles and pedestrians, the area designated for pedestrians can be textured while the area designated for bicycles is smoother. Subtly textured pavement does not hinder pedestrians while bicycles will prefer the smoother pavement, thus helping to channelize and segregate bicycles. However, textured pavements can by a hindrance to wheelchair users or other mobility devices, which can be slowed or made uncomfortable by the texture. This strategy has been applied in Sweden.

bicycles in Sweden

Source: Charles Alexander, Fehr & Peers

Defining bicycle right-of-way on Market Street and properly routing bicyclists around transit boarding platforms can help to provide order on the street. These solutions can help to address the following issues:

- **Defining bicycle space:** Bike boxes and physically separated bike lanes both help to define the bicycle space. These treatments discourage bicyclists from encroaching on pedestrian areas. These facilities also help pedestrians and motorized vehicles become more aware of bicycles and bicycle space.
- **Calming bicycles in pedestrian areas:** Raised crosswalks and textured pavement help to slow bicycles and reduce potential conflicts with pedestrians.
- **Managing modal separation:** Defining the space designated for each mode will help street users of all modes interact in a safe manner.

References

For more information on **Bike Boxes** see:

- Pedestrian and Bicyclist Safety and Mobility in Europe, US Department of Transportation, Federal Highway Administration, 2010, http://www.international.fhwa.dot.gov/pubs/pl10010/ch00.cfm
- William Hunter, Evaluation of an Innovative Application of the Bike Box. University of North Carolina Highway Safety Research Center. Prepared for U.S. Department of Transportation, Federal Highway Administration. Publication Number FHWA-RD-00-141, August 2000.

For more information on **Advanced Stop Bars**, see:

- Retting, R., and R. Van Houten. "Safety Benefits of Advance STOP Lines at Signalized Intersections: Results of a Field Evaluation." *ITE Journal*, September 2000.
- TRL Project Report 181- Advanced Stop Line for Cyclists: The Role of Central Cycle Lane Approaches and Signal Timings.

For more information on **Bike-Bus Interaction** see:

- Austroads (2005). "Bus-Bike Interaction within the Road Network." Austroads Publication No. AP-R266/05. Sydney, Australia. Available on-line at: http://www.wsdot.wa.gov/NR/rdonlyres/8458A9D7-0654-4C93-A545-ADA8F35856D5/0/05BusBike.pdf

For more information on **Bicycle Signal Heads** see:

- http://nacto.org/cities-for-cycling/design-guide/bicycle-signals/bicycle-signal-heads/

2.4 Corner Geometries

Multiple Locations

Description

Intersections along Market Street are complicated since the streets north of Market intersect the street diagonally. Several intersections have an odd number of approaches, which can make crossing the street difficult to navigate for pedestrians. Innovative adjustments of corner geometries can make these intersections less daunting. In general, corners with a smaller radius are more comfortable for pedestrians since they reduce vehicle speeds.

Design and/or Operational Considerations

1. Geometries for skewed intersections

Market Street's unique geometry calls for tailor-made solutions to enhance the pedestrian experience.

Design solution: Curb Extensions/ Bulb-outs

Curb extensions (see Minimizing Pedestrian Exposure to Vehicle Traffic) are extensions of the curb into the street, making the pedestrian space wider and street crossing distances shorter. These extensions provide a larger space for pedestrians to wait before crossing an intersection and prohibit cars from parking near the crosswalk. They are highly beneficial in areas with significant pedestrian activity.

Typical curb extensions should only be used where there is a curbside parking lane. Curb extensions can extend to the width of the parking lane but should not encroach on bicycle lanes.

According to the San Francisco Better Streets Plan, corner bulb-outs should extend at least five feet beyond the extension of the corner property line before beginning to return to the prevailing curb line, and the width should be determined by the adjacent lane. The NYCDOT's Street Design Manual recommends curb extensions be two feet less than the width of the parking lane.

Typical curb extension in Bainbridge Island,WA

Source: Carl Sundstorm

In some situations, including skewed intersections, extended bulb-outs may be called for. The Better Streets Plan states that extended bulb-outs should use special paving or edge treatments to distinguish the space as a plaza space separate from the through travel area.

In Portland, Oregon, W Burnside St. intersects with NW 13th St., SW 13th St., and Stark St., creating a 5-way intersection. The curb between SW 13th Ave. and SW Stark St. was extended out to W Burnside St., creating a pedestrian refuge and reducing crossing distances. Though the shape of the extension may look abnormal, it creates a solution specific to the intersection. Similar curb extensions were applied at several intersections along Burnside Street in Portland.

In addition, the redesign of Broadway in New York City features curb extensions at multiple skewed intersections at Times Square, Madison Square Park, and Union Square.

Tailored curb extension in Portland

Source: Google Earth

Design solution: Converting Pork Chop Islands to Curb Extensions

Pork chop islands allow vehicles to make right turns at higher speeds in advance of the intersection. This design requires that pedestrians cross multiple sections of roadway and can introduce more conflict points on urban streets. Extending the sidewalk area to the pork chop island provides additional space for pedestrians, reduces turning radii for vehicles and can also improve pedestrian safety.

The northwest corner of Broadway and Columbus Avenue in North Beach was recently transformed into a pedestrian plaza and art installation by extending the sidewalk to an area which was previously a pork chop island.

Existing pork chop island at Turk Street and Market Street

Source: Google Earth

Pork chop island conversion in North Beach

Source: Google Earth

Potential Market Street Application

As a diagonal street, Market Street has many skewed intersections. Curb extensions could help to simplify some of these intersections and improve pedestrian safety. This helps to address the following issues:

- **Make intersection more pedestrian-friendly:** Extending the curb helps to improve sight lines between pedestrians and vehicles. It also provides more space for pedestrians.
- **Reduce crossing distance:** Curb extensions reduce the crossing distance, thus reducing the amount of time pedestrians spend in the roadway. This can have a benefit on signal operations by reducing the time necessary for pedestrian phases.
- **Reduce points of conflict between pedestrian and vehicles:** converting pork chop islands to curb extensions reduces the exposure time for pedestrians in the roadway.

References

For more information on **Curb Extensions** see:

- Ewing, R, *Traffic Calming, State of the Practice*, Report No. FHWA-RD-135. ITE under contract with US DOT, FHWA, Washington DC, 1999.
- Better Streets San Francisco: http://www.sf-planning.org/ftp/BetterStreets/proposals.htm
- Broadway: Union Square Report, New York City DOT: http://www.nyc.gov/html/dot/downloads/pdf/20100610_broadway_union_square.pdf

2.5 Sight Lines

Multiple Locations

Description

A sight line is an unobstructed line-of-sight between an observer and a point of concern. Sight lines are particularly important in urban planning. Sight lines to key transit stations, wayfinding signage and destinations help pedestrians navigate the street environment. Furthermore, line-of-sight between pedestrians and approaching vehicles is key to minimizing collisions.

Design and/or Operational Considerations

1. Enhancing line-of-sight

Line-of-sight provisions must be made from both the vehicle and pedestrian perspective in order to improve safety. Line-of-sight considerations should also be made for pedestrians to aid in wayfinding.

Design solution: Curb Extensions

Curb extensions (see Corner Geometries) are extensions of the curb into the street, making the pedestrian space wider and street crossing distances shorter. Though the curb extension mentioned in the previous section was more extreme, often times more subtle extensions, or bulb-outs, are added to enhance the pedestrian space. These improve the visibility between pedestrians and drivers by elevating the pedestrians, allowing the pedestrians to stand further into the street-space, and prohibiting vehicles to park on the street corner, which could otherwise potentially obstruct the line-of-sight. Curb extensions or bulb outs have been applied in multiple cities including Boston, Philadelphia, Berkeley and even San Francisco.

Curb extension in Madison, WI

Source: Dan Burden

Design solution: Staggered Crosswalks

Staggered crosswalks (see Intersection and Mid-Block Crosswalk Treatments) are crosswalks which are staggered on either side of a pedestrian median island such that a pedestrian crosses one direction of traffic, turns towards the next crosswalk and then negotiates the second crosswalk. These provide pedestrians with a direct view of oncoming traffic from the median in the middle of the street. They also make pedestrians more visible to drivers.

Design solution: Mirrors

Several cities in Europe have placed mirrors at intersections to improve visibility. In Bern, Switzerland, convex mirrors have been attached to traffic signal or utility poles at specific intersections. These mirrors enable truck drivers to more easily see bicycles and pedestrians and vice-versa. It also helps pedestrians and bicycles scan the roadway behind them. In Malmö, Sweden, large mirrors have been placed at crossings where visibility is poor to help people see what is happening around the corner.

Convex mirror in Bern, Switzerland

Source: Pedestrian and Bicyclist Safety and Mobility in Europe report, Federal Highway Administration

Design solution: Removing Clutter from the Sidewalk

Unnecessary clutter should be removed from the sidewalks, particularly at corners, to improve sight lines. Additionally, street furniture and trees should be strategically located so as not to interfere with pedestrian movement or views.

Potential Market Street Application

These solutions help address the following issues:

- **Allow all road users to see each other:** These strategies help make pedestrians more visible to motorists and also help pedestrians see approaching vehicles.
- **Give road users more time to react to potential conflicts:** Being able to see other road users in advance will help everyone anticipate potential conflicts and allow more time to react to dangerous situations.

References

For more information on applications of these measures in Europe, see:

- Pedestrian and Bicyclist Safety and Mobility in Europe, US Department of Transportation, Federal Highway Administration, 2010, http://www.international.fhwa.dot.gov/pubs/pl10010/ch00.cfm

For more information on **Curb Extensions** see:

- Ewing, R, *Traffic Calming, State of the Practice*, Report No. FHWA-RD-135. ITE under contract with US DOT, FHWA, Washington DC, 1999.
- *Canadian Guide to Neighbourhood Traffic Calming*, Transportation Association of Canada, Ottawa, Ontario, December 1998.

For more information on **Staggered Crosswalks** see:

- Bacquie, P., Egan, D. and Ing, L., “Pedestrian Refuge Island Safety Audit,” Compendium of Papers, ITE Spring Conference, Monterey, California, March 2001.

2.6 Optimizing Signal Timing and Traffic Control for Pedestrians

Various Locations

Description

Various traffic signal timing techniques can be used to improve and prioritize pedestrian crossings at intersections, give people more time to cross the street, and pedestrians more visible to motorists.

Design and/or Operational Considerations

1. Signal timing adjustments

Signalized intersections provide a dedicated walk phase for pedestrians to cross the street, and should be timed to allow sufficient time for pedestrians to cross safely. The standard for walking speeds at signalized intersections has recently changed from four feet per second to 3.5 feet per second to more accurately reflect the average pedestrian walking speed and aging population. The 2009 Federal MUTCD requires this reduction, though it has not yet been adopted by the California version of the MUTCD (CA MUTCD). A slower walking rate of 2.8 feet per second is recommended in areas with a high number of children, older adults, or disabled pedestrians crossing. San Francisco has surpassed this standard and is moving towards a policy of using a walking rate of 2.5 feet per second to time signalized intersections. In general, shorter cycle lengths and longer walk intervals provide better service to pedestrians and encourage better signal compliance. Various levels of signal timing for pedestrians are available at signalized intersections. The following signal timing treatments support pedestrian activity, and are recommended in areas with high pedestrian volumes, although not all of these treatments are appropriate in all circumstances.

Design solution: Pedestrian Scrambles

Scrambles allow pedestrians to cross in all directions at an intersection, including diagonally, during an exclusive pedestrian phase. In order to accommodate pedestrians with vision impairments, the scramble phase should be accompanied by an audible signal to indicate the walk interval.

During the signal phase when the pedestrian indication permits pedestrians to cross diagonally, the vehicle indications display red on all approaches of the intersection. However, pedestrians are typically not allowed to cross during phases when vehicles have a green signal. This enables right-turning vehicles to turn without having to wait for pedestrians to cross. This arrangement effectively separates the conflicts between right-turning vehicles and pedestrians by giving them each a distinct, dedicated phase to move through the intersection.

In areas with high pedestrian volumes, right-turning vehicles often have difficulty turning, and in some circumstances long queues can form. Separating the movements through a scramble could help queues of right-turning traffic dissipate more quickly.

This treatment gives ultimate flexibility to pedestrians, speeds pedestrian crossings for those crossing more than one leg of the intersection and reduces vehicle turning conflicts. However, scrambles may not be appropriate for every intersection along Market Street due to geometry issues and potential effects on transit delay.

The total waiting plus crossing times for pedestrians should be evaluated when considering pedestrian scrambles.

Pedestrian scrambles have been applied at many locations both locally and internationally including the Financial District of San Francisco, Oakland, New York City, Osaka (Japan) and Tokyo (Japan).

Pedestrian Scramble in Osaka, Japan

Photo credit: Nicole Hervol, Fehr & Peers

Pedestrian scramble in Chinatown, Oakland

Pedestrian scramble sign

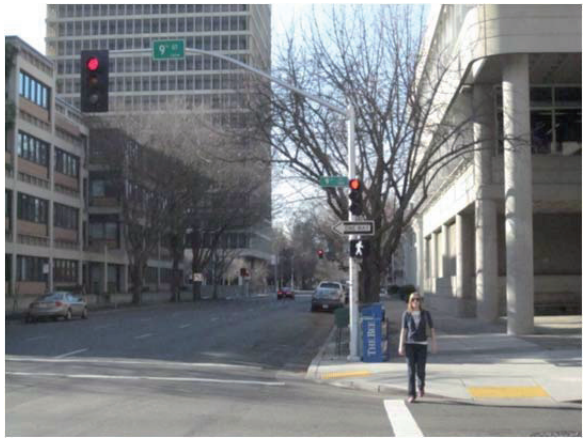
Design Solution: Leading Pedestrian Interval

In situations where a pedestrian scramble is not appropriate or feasible, an alternative signal treatment is a leading pedestrian interval (LPI). LPIs provide a pedestrian walk signal three or more seconds before the green signal indication for vehicles. This gives pedestrians a head start and helps to establish their place in the crosswalk. LPIs help to make pedestrians more visible to motorists approaching the intersection and therefore more likely to yield to them. In order to accommodate pedestrians with vision impairments, the LPI should be accompanied by an audible signal to indicate the walk interval. This treatment does not give pedestrians as much separation from vehicle traffic as a pedestrian scramble, but can help to increase pedestrian visibility and therefore, conflicts with vehicles. In New York City, studies have demonstrated reduced conflicts for pedestrians.

This treatment has already been applied at several intersections along Market Street and could be considered at additional locations.

In addition to San Francisco, LPIs are used in multiple cities including New York City, St. Petersburg, FL, Boston, MA, and Philadelphia, PA.

Leading pedestrian interval



2. Turning movement restrictions

Design Solution: No Right Turn on Red

Restricting vehicle right turns during the red signal phase can also enhance pedestrian safety. Although all vehicles are required to yield to pedestrians in the crosswalk, right-turning vehicles may encroach upon pedestrians in the crosswalk or may not be alert to pedestrians in the intersection. A “no right turn on red” restriction prohibits cars from turning right when the light is red. The restriction is typically indicated by posting a sign, which can also include time of day restrictions if applicable. The restriction can also be indicated in the traffic signal. In areas with high right turning volumes, the no right turn on red

restriction can cause longer queues for vehicles and buses.

In the United States it is always legal to turn right at a red light unless there is a sign or indication otherwise, with the exception of New York City, where it is forbidden to turn right at a red light unless otherwise indicated. The origin of right turn on red allowance was as an air quality compliance measure. Contrary to the United States, it is illegal to turn right at a red light in any European Union country unless there is a sign or signal indicating otherwise.

No turn on red sign

Potential Market Street Application

These solutions help to address the following issues:

- **Making pedestrians more visible:** Pedestrian scrambles make drivers more aware of the pedestrian space since the entire intersection is dedicated to pedestrian crossing. LPI's allow pedestrians to enter the crosswalk before drivers are given a green light, helping to make drivers more alert of their presence.
- **Preventing vehicles from encroaching upon pedestrian space:** Giving priority to pedestrians at intersections will help to reinforce driver behavior that is considerate of pedestrians.
- **Reducing pedestrian crossing distances and time:** The pedestrian scramble allow pedestrians to cross the street in a diagonal direction, reducing travel time from the typical configuration in which pedestrians must cross in two signal phases.
- **Reducing vehicle turning conflicts:** All of the treatments mentioned restrict vehicle turning movements, thus reducing potential conflicts and improving pedestrian safety.

Other Information

The cost to adjust signal timing is very low.

References

For more information on **Pedestrian Scrambles** see:

- Bechtel, A.K., MacLeod, K.E. and Ragland, D.R., "Pedestrian Scramble Signal in Chinatown Neighborhood of Oakland, California: An Evaluation," *Transportation Research Record*, Issue No. 1878, Transportation Research Board, 2004.

For more information on **Leading Pedestrian Intervals** see:

- http://streetswiki.wikispaces.com/Leading+Pedestrian+Travel

For more information on Pedestrian Traffic Control Devices see:

- http://www.walkinginfo.org/engineering/crossings-signals.cfm

2.7 Optimizing Pedestrian Access to Bus Stops & Subway Portals

London, San Francisco

Description

Providing good pedestrian access to bus stops and subway portals can encourage transit ridership. Once transit riders arrive at their destination they become pedestrians, therefore it is important o provide to formalize the connection between transit and pedestrian origins or destinations . Clear, easy to find transit stops and stations with minimal obstacles are key to enhancing the transit experience.

Design and/or Operational Considerations

1. **Improving wayfinding and access to stations and destinations**

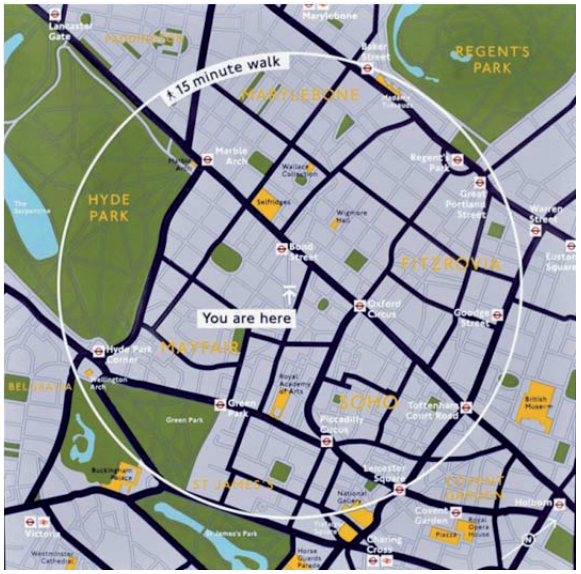
Safety risks are heightened when pedestrians are not oriented with their surroundings. When pedestrians are distracted or looking for directions they may accidentally wander into the path of a bicycle or motorized vehicle. Therefore, helping pedestrians to orient themselves, especially when in a new location, can help enhance pedestrian safety.

Design solution: Wayfinding Signage

Wayfinding refers to the process of orienting oneself and determining a path to reach ones destination. Wayfinding signage can be extremely helpful to those trying to find their way, especially when in a new or unfamiliar location. Transport for London recently implemented new wayfinding maps at tube stations providing the following:

- An easy-to read map that is oriented to the users point of view
- 5 and 15 minute walking distances
- 3D drawings of key shops and buildings in the area

Wayfinding sign in London



Reproduced with permission from Transport for London

Wayfinding sign in London

Reproduced with permission from Transport for London

Wayfinding sign in London

Reproduced with permission from Transport for London

Design solution: Delineate queue at bus stop

At bus stops that regularly experience lines during peak periods, queuing areas can be delineated to bring order to the queue and keep the sidewalk area clear for pedestrians passing by. This strategy has worked well for BART by painting queuing areas on the platform. The painted areas also remind boarding passengers to make room for alighting passengers. If implemented, queuing areas should indicate that bus lift users have priority for boarding. Passenger queuing may be a challenge to implement on Market Street's surface stops where multiple routes share the same stops.

BART queuing area

Source: Nicole Foletta, Fehr & Peers

Design solution: Clear pedestrian right-of-way

Obstacles surrounding transit stops and stations should be relocated to provide a clear walking path. Street furniture should also be strategically located so as not to interfere with pedestrian traffic.

Potential Market Street Application

Wayfinding signage should be located at key Muni/ BART station entrances which provide information about the surrounding area. Queuing areas could be marked at highly used Muni bus stops. Effort should be made to remove unnecessary clutter from Market Street and provide direct walking paths for pedestrians to bus stops and BART stations. For example, newspaper racks in several locations on Market Street could be moved or relocated to improve pedestrian access. These measures help to address the following issues:

- **Orienting pedestrians:** Wayfinding signage helps pedestrians feel more comfortable and helps them plan an appropriate route to their destination. Maps could indicate locations of transit portals, including elevators. Elevators with LED lights indicating their status (working or not working) would be highly beneficial. Real-time arrival information at BART and Muni street entrances (including elevator) would be beneficial, similar to the information provided at Muni shelters today.
- **Minimizing obstacles:** Clearing the pedestrian right-of-way helps to ensure that pedestrians will have a direct path to access transit stops and stations.

References

For more information on wayfinding, see: Transport for London:
http://www.tfl.gov.uk/microsites/interchange/82.aspx

Pedestrian Safety Guide for Transit Agencies, US Department of Transportation, Federal Highway Administration, February 2008,
http://safety.fhwa.dot.gov/ped_bike/ped_transit/ped_transguide/