B.C. Community ROAD SAFETY **TOOLKIT**

Module 1:

Protecting people walking and cycling

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Disclaimer: This toolkit is designed to consolidate and disseminate knowledge about proven and promising road safety designs, strategies, and devices, rather than to provide technical knowledge.
A strong effort was made to find and incorporate the most valid and reliable research about the various strategies in the toolkit. However, the nature of road safety research is such that knowledge on road safety continues to change, and therefore any claims drawn from the research should be approached with a critical mind. Local road authorities wishing to implement any designs, strategies, and devices in this toolkit should do so under the guidance of trained and professionally-certified engineers and experts.

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Resource Kit

Protecting People Walking and Cycling: Our Most Vulnerable Road Users

This module is the first of what will ultimately be three modules of the BC Community Road Safety Toolkit. This first module focuses on road designs that work to better protect pedestrians and cyclists from motor vehicle-related injury. This module also contains information on strategies that encourage more people to walk, cycle and use public transit since shifting to these methods of transport decreases private car use and that, in turn, generates better road safety benefits.

Designing a road system that protects people who walk and cycle is vital because these road users do not benefit from the same measures that protect motor vehicle occupants, e.g., vehicle crumple zones, air bags, protected passenger compartments, etc. This important difference means that pedestrians and cyclists are much more likely to sustain serious injuries, including fatal injuries, when involved in a crash with a motor vehicle.

In British Columbia, pedestrian and cyclist fatalities represent 27 percent of all motor vehicle-related crash fatalities. And despite the fact that motor vehicle occupant fatalities decreased from 2006 to 2015, pedestrians and cyclist fatalities remained flat over this same time period. In order for British Columbia to achieve its goal of having the safest roads in North America by 2020, more work is needed to protect people who walk and cycle.

In order to use this module, please see the Resource Kit section, which contains::

- Defined terms;
- Evidence of effectiveness for each safety design, strategy, or device in Module 1; and
- Further resources containing additional information on each item in Module 1.

Separating Road Users in Physical Space

The road safety designs, devices and strategies in this chapter are intended to improve safety for people who walk and cycle—the vulnerable road user. By physically separating these road users from motor vehicle traffic, the possibility that these road users will be involved in a motor vehicle crash is greatly reduced.

Wider and Connected Sidewalks

Description

Sidewalks that are wide enough to accommodate all pedestrians will help foster a highly walkable city environment. An uninterrupted network of sidewalks will ensure that pedestrians can complete their trips without ever having to expose themselves to motor vehicle traffic by leaving the protective sidewalk space.

How it Works

Well-designed sidewalks create a dedicated pedestrian space that is unambiguously marked off from the roadway. The best sidewalks are wider, connected and as far from the roadway as possible.

Sidewalks should be wide enough to accommodate users who require extra space, including people in wheelchairs, those on mobility scooters and those pushing carts or strollers.

Narrowing roads and vehicle lanes, and removing vehicle lanes, can help create space for wider sidewalks.

Studies have shown that:

- Sidewalks can provide between a 50 and 88% reduction in vehicle-pedestrian crashes compared to locations without sidewalks.

Best results occur when:

- Sidewalks are built with at least a 2 metre-wide area (the "clear width") that is free of any obstructions such as trees and utility poles. Each additional "lane" of pedestrian travel requires a minimum of 0.7 metres of additional clear width;
- Sidewalk designs include buffers that place them as far away from the roadway as possible to reduce the likelihood of run-off-the-road vehicles striking people on the sidewalk. These buffers can be made of street furniture and landscaping, for example; and
- When there are raised crossings (e.g. along local streets), corner bulges (e.g. along collectors and major roads), and/or other physical treatments, as discussed in following sections.

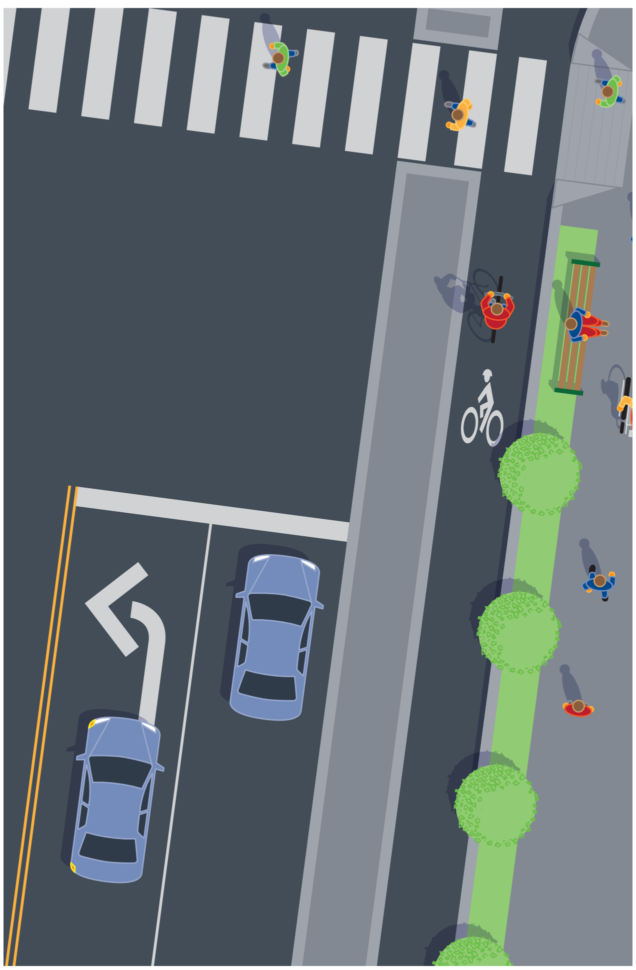
Advance Stop Lines

Description

An advance stop line consists of a line typically placed about 6 metres before a mid-block crosswalk on a school route. This encourages drivers to yield to pedestrians (i.e. especially younger students) well in advance of the crosswalk.

How it Works

By positioning drivers further back from the crosswalk, advance stop lines increase drivers' fields of vision and therefore improve drivers' ability to see pedestrians. Advance stop lines can also prevent situations where a vehicle that is stopped in the lane nearest the curb obstructs a pedestrian's view of an oncoming vehicle in the left lane. In addition, this safety feature reduces the likelihood of a vehicle hitting a person in the crosswalk in the event of a rear-end crash.



Studies have shown that:

- Advance stop lines are effective in increasing drivers' ability to see people attempting to cross the road;
- The likelihood of drivers yielding to pedestrians crossing can increase by approximately 60%; and
- The combination of a "Stop Here for Pedestrians" sign and advance stop line can increase the number of drivers yielding to pedestrians even more.

Best results occur when:

- In locations with a bicycle lane, there is a separate stop line for cyclists, which is placed immediately before the crosswalk. This will improve drivers' ability to see the cyclists;
- Advance stop lines are used in conjunction with "stop/yield for pedestrian signs" or, better still, with rectangular rapid flashing beacons (page 25);
- Advance stop lines are placed 6 metres before the crosswalk; and
- Advance stop lines are used in conjunction with safe crosswalk signalization (page 23), bicycle boxes (page 19) at signalized intersections and raised crossings (page 26).

Off-street Walking and Bicycle Paths

Description

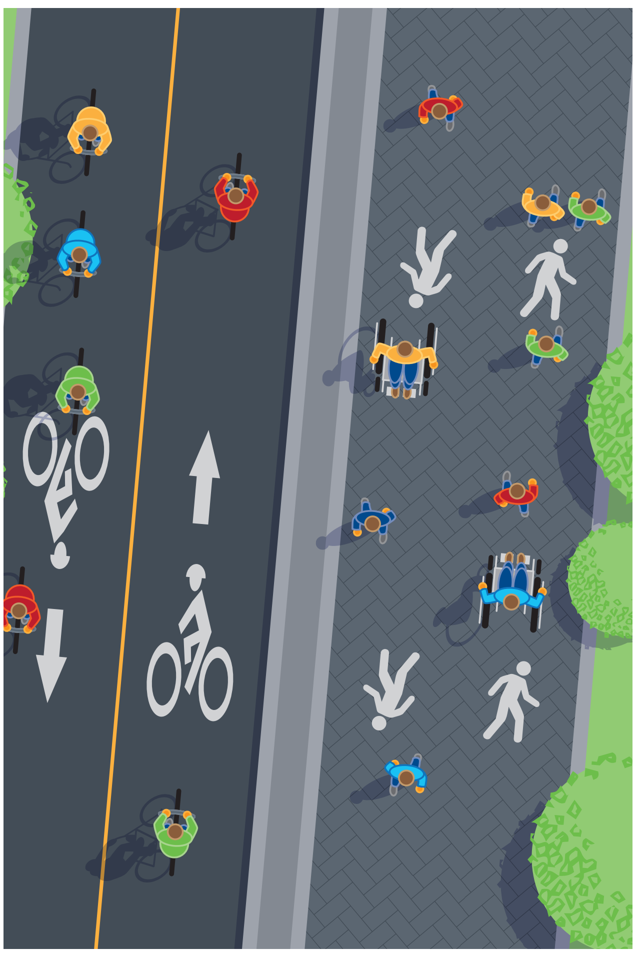
Off-street paths provide routes for walking and cycling away from streets and motor vehicle traffic. They are typically found in parks, alongside waterways, or in other quiet areas. They may be "multi-use" with people on foot and bicycle on a single path, or they may be designed as separate walking and bicycle paths.

How it Works

Off-street paths are located away from motor vehicle traffic, thus virtually eliminating the potential for crashes with motor vehicles.

Studies have shown that:

- Cycling injury risk can be reduced by 30 to 90%, compared to on-street riding with no cycling infrastructure.



Best results occur when:

- Off-street walking and bicycle paths provide convenient routes to and from popular destinations like grocery stores and other amenities. This can be done by connecting off-street paths to on-street routes with sidewalks and protected and connected bicycle lanes (page 12);
- Bollards, posts, street furniture, etc. are strategically and thoughtfully placed (or moved) well away from cyclists paths, so that people on bicycles have a smaller risk of crashing into them;
- Paths are well-maintained and free of uneven surfaces, holes, roots, leaves and gravel, all of which increase the risk of tripping or slipping, and increase crash risks for cyclists using the path;
- There are clear, unobstructed sight lines to ensure that people on bicycles have time to react to potential conflicts;
- Paths are well-lit, to reduce night time crash risks and improve personal security;
- There is separation between spaces for pedestrians and cyclists; and
- In places where walking paths or bicycle paths intersect with streets, raised crossings (page 26) and rectangular rapid flashing beacons (page 25) help ensure that drivers see people crossing the road and slow down.

Diversion of Motor Vehicle Traffic from Residential Roads

Description

Motor vehicle traffic diversion reduces or prevents drivers on major roads from entering local, mainly residential roads. This can be achieved by installing barriers and raised refuge islands that allow only pedestrians and cyclists to cross the major road. Diversion of motor vehicle traffic is also known as volume dispersion or traffic calming.

How it Works

This design prevents some or all motor vehicles from entering a local road, thus reducing conflicts between drivers and pedestrians and cyclists in residential areas.

It also has the potential to slow down drivers and reduce the amount of turning movements on roads, which simplifies the road environment for all road users.

Studies have shown that:

- Traffic diversion can reduce motor vehicle crashes by as much as 29%;
- Bicycle boulevards that include traffic diversion can reduce vehicle-cyclist crashes by as much as 63 to 70%; and
- Traffic diversion from residential streets is even more effective than traffic circles or speed humps in reducing crashes for people who cycle.

Best results occur when:

- Traffic diversion is implemented at intersections where bikeways cross major roads;
- The space between the curbs of the traffic diverter is sufficient for all types of bicycles (e.g., adult tricycles, cargo bicycles and bicycles with trailers) and for people who use wheelchairs to pass through easily; and
- The local road crossings are raised crossings.

Protected Intersections

Description

Protected intersections involve the implementation of a number of design features that minimize conflict between drivers and vulnerable road users by separating their intersection movements through space, and also through time.

How it Works

Protected intersections include four main features:

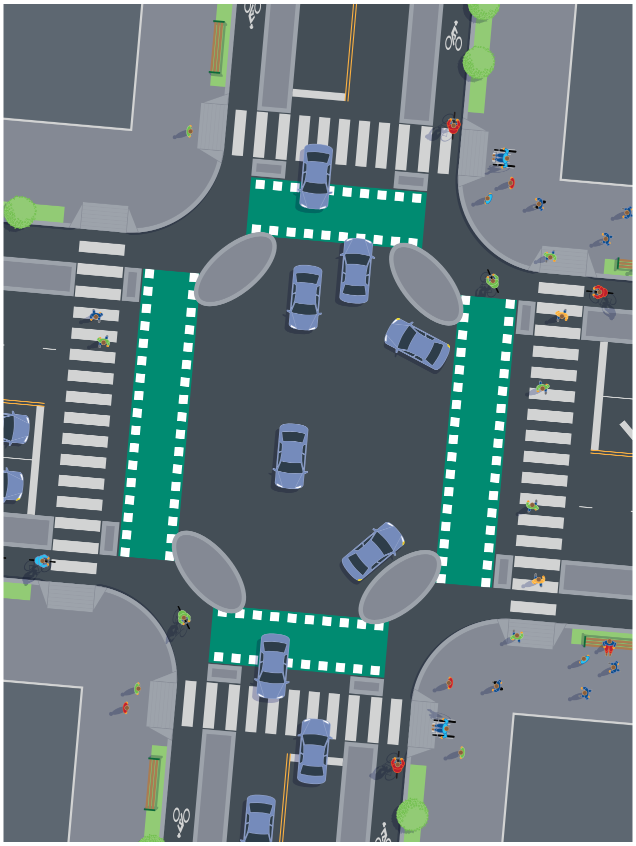
- Raised corner islands physically protect cyclists from right-turning drivers. With these islands, cyclists who are turning right do not interact with motor vehicle traffic at all if there is a protected bicycle lane on the cross street;
- The threshold between the sidewalk and the road is placed past the stop line for motor vehicle drivers. The effect is that pedestrians and cyclists are positioned in front of (rather than beside) drivers, which improves drivers' ability to see these vulnerable road users;
- The pedestrian crosswalk and cyclist crossing is placed at least 6 metres to the right of the right-most vehicle lane. This setback creates a refuge space for right-turning vehicles to stop outside of the traffic stream, and allows for better visibility of people biking and walking when they are about to enter the crosswalk or intersection bike lane; and
- Traffic signal timing is set to minimize conflicting driver movements when vulnerable road users cross the street. The most effective way of doing so is by implementing dedicated signal phases to prevent drivers from moving when pedestrians and cyclists are crossing, and vice-versa.
  An alternative is to use leading pedestrian/cyclist intervals (page 17) to give vulnerable road users a head start when they cross the road.

Studies have shown that:

- Crashes involving pedestrians and cyclists frequently occur when they are crossing intersections with the right-of-way and are struck down by drivers turning right or left. Protected intersections address this type of driver error effectively.

Best results occur when:

- Protected intersections are implemented at the intersection of major roads;
- This strategy is integrated with protected and connected bicycle lanes (page 12);
- At a signalized intersection, the zebra markings should be replaced with parallel lines for the pedestrian crossings;
- Where high percentages of large freight trucks are present, consider mountable aprons; and
- A local bylaw should be enacted to give legal meaning to elephant's feet.



Curb Extensions and Pedestrian Refuge Islands

Description

Pedestrians have the greatest risk of being struck down by a motor vehicle when they are crossing the street. Curb extensions and pedestrian refuge islands both work to reduce roadway crossing distances for people, allowing them to safely and more quickly reach the opposite side.

These safety designs are low-cost, increasing the opportunity for widespread implementation.

How it Works

Pedestrian refuge islands are protected spaces placed in the road, mid-way between opposite sidewalks, allowing pedestrians to cross in two stages. At each stage, people crossing the road only need to look in one direction for road traffic. This improves safety by simplifying the act of crossing.

Curb extensions are improvements that place the sidewalk further into the roadway. This reduces the total width of roadway that pedestrians and cyclists must cross. It also helps to physically align crossing pedestrians and cyclists with drivers' sight lines, which increases the visibility of these road users and encourages them to make eye contact with drivers.

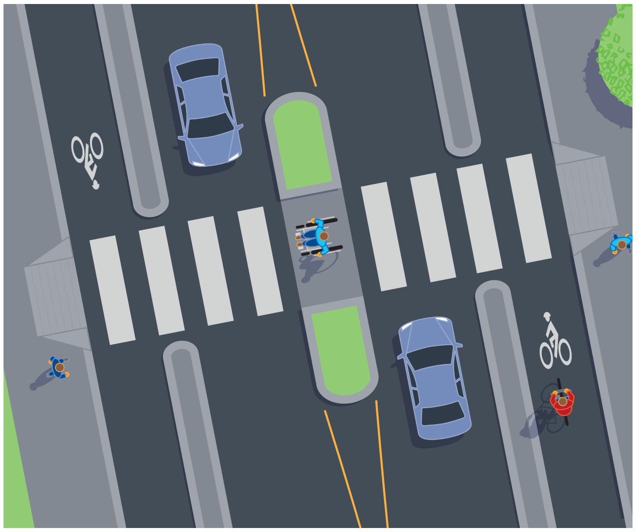
Curb extensions and refuge islands also make vehicle lanes physically narrower, which has the potential to slow down motor vehicle traffic.

Studies have shown that:

- Raised refuge islands have reduced vehicle-pedestrian crashes by 46% at marked crosswalks and by 39% at unmarked crosswalks; and
- Drivers are more likely to yield to pedestrians when the person is crossing from a curb extension.

Best results occur when:

- Curb extensions and pedestrian refuge islands are implemented jointly with safe crosswalk signalization (page 23);
- Refuge islands are wide enough to accommodate wheelchairs and bicycles, and provide enough room to protect people from being sideswiped by passing vehicles; and
- Such designs are implemented in areas with many children or older adults, as these individuals tend to walk slower and are more exposed at road crossings.



Offset Crosswalk

Description

An Offset Crosswalk is a raised refuge island which has been cut out in a zigzag pattern. This road crossing design is also known as a Danish offset, a Z-crossing, a corral crossing, or a two-stage crossing. The zigzag pattern of the refuge island directs pedestrians to face motor vehicle traffic before completing the second stage of their crossing.

Offset crosswalks have all the same advantages of raised refuge islands with the added benefit that they encourage pedestrians to look in the direction of oncoming traffic.

How it Works

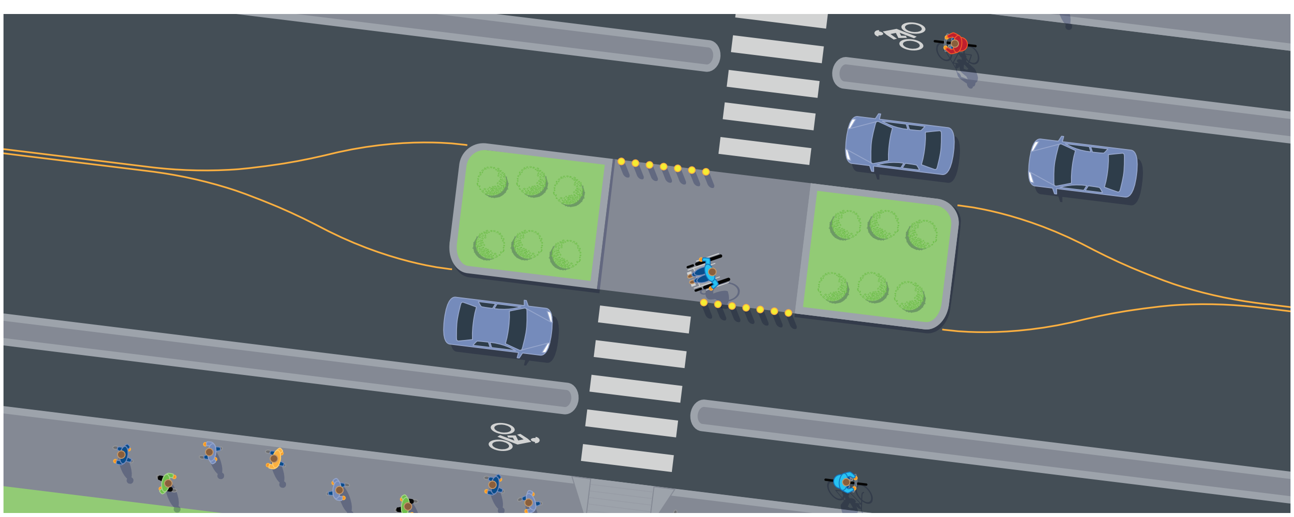
The offset crosswalk works by providing pedestrians and cyclists with a refuge when crossing the street at a mid-block location. By nudging them to face oncoming road traffic, pedestrians are more likely to accurately judge the speed and distance of oncoming vehicles and to make eye contact with drivers. This helps to improve drivers' yielding behaviours and encourages pedestrians to wait for safe gaps in traffic.

Studies have shown that:

- Offset crosswalks contribute significantly to drivers' yielding behaviour; and
- They aid in reducing the number of pedestrians who find themselves trapped in the middle of the street, and may even help to encourage pedestrians to refrain from crossing at dangerous locations.

Best results occur when:

- The offset crosswalk is large enough to accommodate numerous and varied road users with specific needs or large objects, including: people using strollers; people using wheelchairs or mobility scooters; and people with bicycles, including larger tandems, cargo bikes, tricycles and bicycles pulling trailers;
- Railings or tactile signs are used to assist people with visual limitations to realign themselves to the roadway prior to continuing their crossing; and
- If bicycles are also intended to use this mid-block crossing, then a wider refuge is needed, as well as wider, curved corners and elephant's feet.



Protected and Connected Bicycle Lanes

Description

A protected bicycle lane (also known as a cycle track or separated bicycle lane) runs alongside a street, but is physically separated from motor vehicle traffic and is distinct from the sidewalk. Protected bicycle lanes can be one- or two-way. The bicycle lane can be at street level, higher up at the sidewalk level, or at a level in-between the two.

Connected bicycle lanes ensure that the network of lanes is uninterrupted, so that cyclists do not need to leave the lane's protective space in order to reach their final destination.

How it Works

The main feature of a protected bicycle lane is a physical barrier that prevents motor vehicles from entering the dedicated road space set aside for cyclists. The barrier can be a raised curb, jersey barriers, bollards, plantings, or motor vehicle or bicycle parking.

Protected bicycle lanes can be integrated with on-street motor vehicle parking by placing the bicycle lane on the sidewalk side of a parking lane. Drivers moving in or out of parking spaces do not interact with cyclists, and the motor vehicles also act as a barrier that helps protect cyclists.

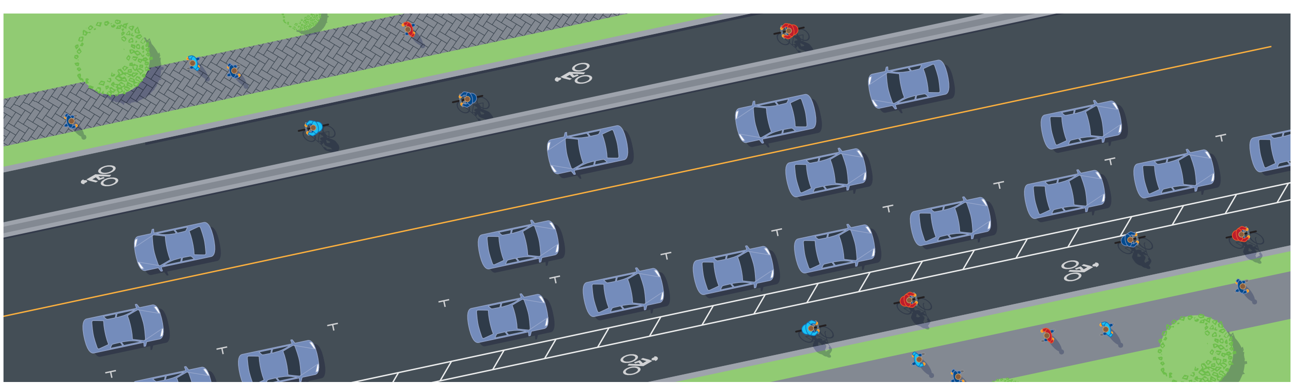
Injuries caused by "dooring" (when cyclists are injured as a result of car doors opening) are eliminated when the bicycle lane's design fully separates cyclists from parked vehicle spaces.

Studies have shown that:

- The effectiveness of protected bicycle lanes varies but, if implemented well, can reduce vehicle-bicycle crashes resulting in injuries by as much 90%; and
- One-way protected bicycle lanes on both sides of a street are a significantly safer design than a single two-way protected bicycle lane on only one side of the street, especially where they cross intersections and driveways.

Best results occur when:

- Protected bicycle lanes are installed along streets with high motor vehicle volumes and faster speeds (i.e., arterial roads and collector roads);
- They are implemented in conjunction with raised crossings (page 26) to help extend protection to intersections;
- A buffer zone for opening car doors is included in the design if protected bicycle lanes are installed on the sidewalk side of a vehicle parking lane; and
- One-way bike paths on different streets, or on different sides of the same street, are prioritized over two-way bike paths on the same street. Two-way paths lead to highly complex intersections, and introduce greater risks to cyclists when they cross driveways and alleys.



Road Diets and Complete Streets

Description

"Road diets" are changes to a street's design where one or more motor vehicle travel lanes are removed. Commonly, this occurs when a 4-lane street is reduced to a 2-lane street and pedestrian and cycling facilities are added to make it a "complete street." A complete street is one that accommodates and protects all road users in proportion to their risk.

How it Works

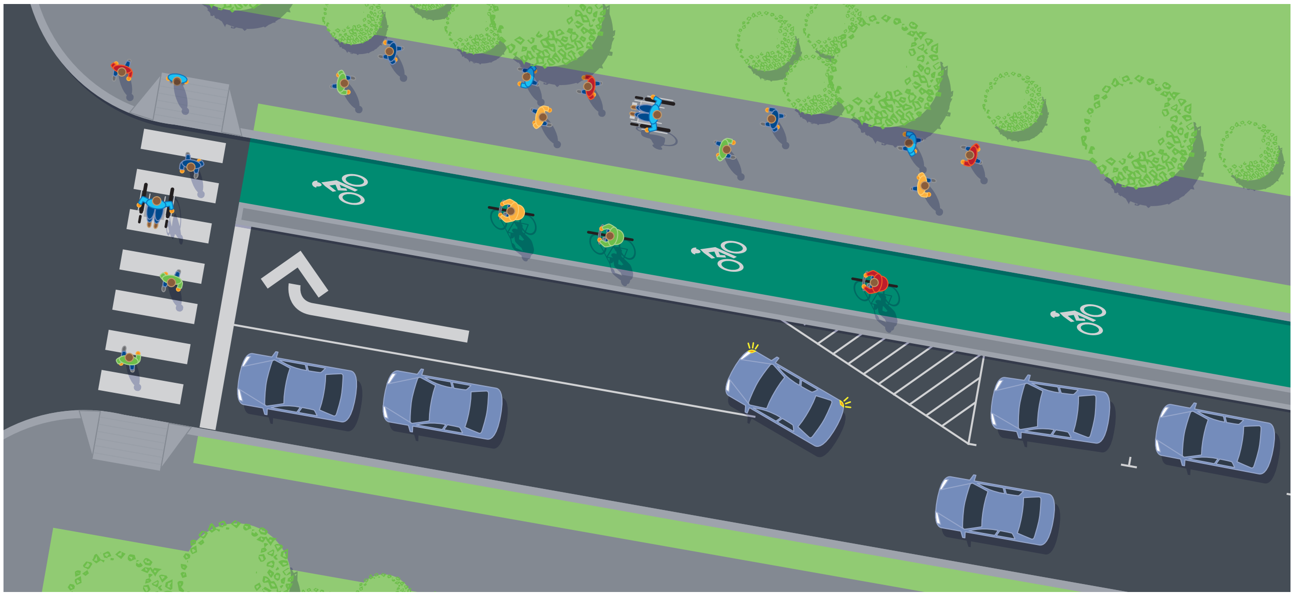
Reducing the number of motor vehicle travel lanes and/or implementing complete street conversions makes the street more of a "drive-to" destination (where drivers travel more slowly and attentively) rather than a "drive-through" corridor (where drivers travel faster and less attentively). It also attracts more pedestrian, bicycle and public transit-oriented traffic. Its destination nature creates a calmer, slower, safer and more attractive venue—a place where people are more likely to want to walk around, enjoy the setting and visit local businesses.

Evidence of Effectiveness

- Studies have shown that complete street projects have been successful in reducing motor vehicle crashes by between 19 and 47%, depending on the characteristics of the implementation site.

Best results occur when:

- A buffer zone for opening car doors is included in the design if protected bicycle lanes are installed on the sidewalk side of a vehicle parking lane;
- Local governments conduct a transportation planning review of the potential for road diets to negatively impact nearby residential areas;
- The transportation planning review takes into account that some trips will be converted to other modes, as has commonly been found when road capacity is reduced and the availability of pedestrian and bicycle routes improves. Where analysis suggests short-cutting might occur, road diets and complete streets can be combined with area-wide traffic calming to protect adjacent neighborhoods; and
- There is continued evaluation of the overall net impact in affected areas.



SMARTer Growth Neighborhood Design

Description

SMARTer Growth neighborhoods (also known as Fused Grid and SMART Growth) are a system-based land use and transport development design policy. They locate residents near services (schools, shops, offices) in compact, connected, and coordinated neighborhoods that are walkable, bike-friendly and transit-oriented with car-free, green cores. Keeping through traffic to perimeter roads means local roads inside these SMARTer Growth neighborhoods can be designed for low speeds (30 km/h max), low volumes, and local access only, which then naturally results in a safer pedestrian/bike environment for all ages and abilities.

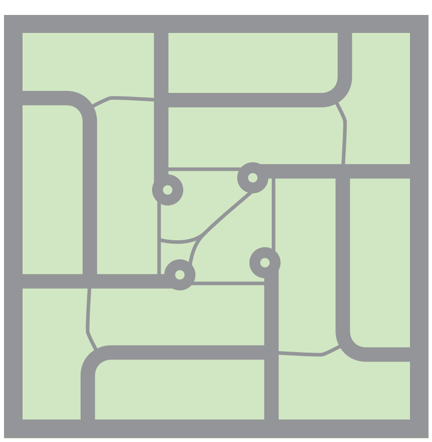
SMARTer Growth design principles have been used for decades in large and small cities in the Netherlands. In Canada, the City of Kelowna has begun retrofitting existing communities based on fused grid principles. The City of Stratford, Ontario, and the neighbourhood of Saddlestone, Calgary, have also adopted the fused grid concept as a core design plan for new developments.

How it Works

Perimeter roads generally have high-quality transit services, which maximize the attractiveness of not driving and help reduce the risk of motor vehicle crashes by reducing the number of private vehicles.

The use of roundabouts and 3-way intersections helps eliminate severe crash types (e.g., right-angle crashes). The discontinuous grid, as well as the traffic-calmed local roads, reinforces slow driver speeds. Pedestrian and bicycle routes are located such that road crossings are minimized.

The SMARTer Growth design results in increased social equity (more accessibility to amenities, places of work, services and active transport opportunities for all residents).



Studies have shown that:

- Motor vehicle crash rates declined by up to 60% in SMARTer Growth neighbourhoods compared to other types of road layouts; and
- SMARTer Growth principles suggest capital costs are comparable to conventional development patterns, but with lower ongoing life-cycle costs. These costs would be additionally offset by the safety benefits of reduced crashes and injuries and in the long term by the improved health of residents.

Best results occur when:

- All parts of the SMARTer Growth neighbourhood system design are implemented: high-quality transit services, the discontinuous grid and continuous peripheries; bicycle and pedestrian routes, and nearby amenities; and
- SMARTer Growth neighbourhood plans are integrated with policies and plans for transit-oriented development (page 30).

Separating Road Users in Time

It is not always possible to create complete physical separation between vulnerable road users and motor vehicles. Another effective way of reducing the possibility of motor vehicle crashes is to have different types of road users move through the same space, but at different times.

Pedestrian Scramble Intersections

Description

A pedestrian scramble intersection (also known as a "Barnes Dance", exclusive pedestrian phase, or all red intersection) involves configuring an "all-red" phase for drivers and an exclusive and concurrent "WALK" phase for pedestrians in all directions, including diagonally.

The pedestrian scramble first emerged in the late 1940s in many North American cities, including Vancouver, Denver and Kansas City, but these were later removed because of a greater value placed on driver speeds and vehicle throughputs at that time. Today, pedestrian scrambles are returning to cities around the world.

How it Works

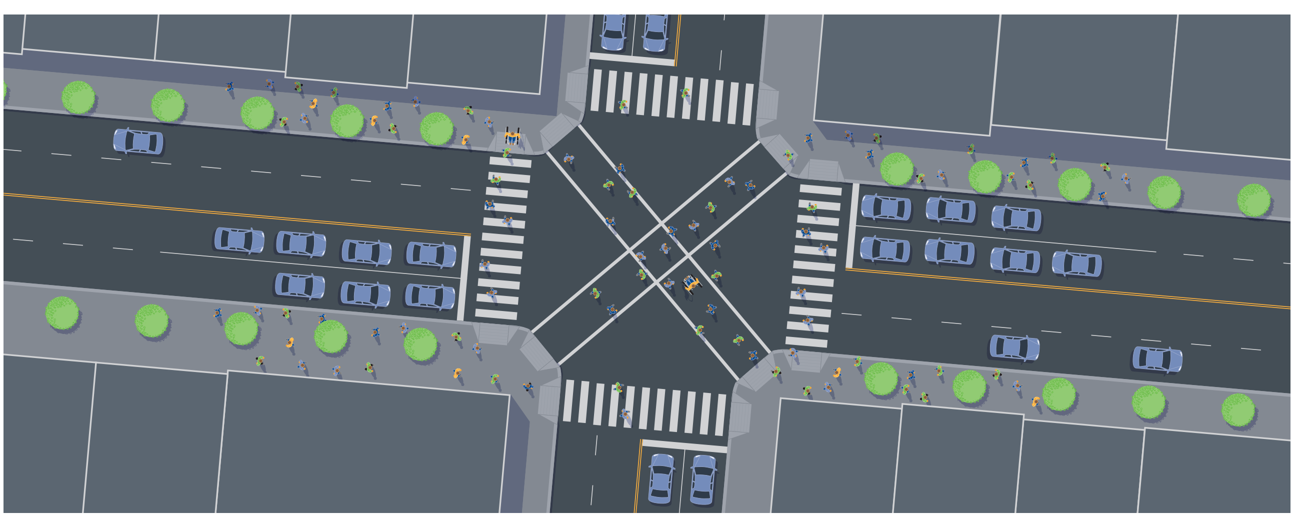
This strategy eliminates concurrent movements for different types of road users at intersections, which otherwise are more likely to lead to deaths and injuries for pedestrians crossing at intersections—locations that remain one of the most dangerous for people who walk.

Studies have shown that:

- Pedestrian scramble intersections can achieve a reduction in vehicle-pedestrian crashes of all severities in the range of 34 to 51%.

Best results occur when:

- Pedestrian scrambles are implemented based on criteria such as higher pedestrian volumes and the effectiveness of pre-existing traffic control measures;
- These types of intersections are implemented alongside a public information campaign about their use and effectiveness, because this type of intersection is relatively novel for most Canadian towns and cities;
- Drivers are prohibited from making right-turns-on-red, in order to completely eliminate all conflicting movements between motor vehicles and pedestrians;
- The needs of a variety of people with different types of disabilities are taken into account. For people with visual limitations, audible signals and other accessible pedestrian signal features will improve comfort and safety; and
- Bicycle volumes are low, or well managed during the scrambles.



Leading Pedestrian Intervals

Description

Leading pedestrian intervals, also known as advanced green for pedestrians, are re-programmed intersection signal phases that provide pedestrians with a head start of 3 to 7 seconds (or longer) over drivers, reducing the potential for driver-pedestrian conflicts and crashes.

Given this is a proven and low-cost safety design, it should be strongly considered for widespread implementation.

How it Works

Countless driver-pedestrian crashes take place at intersections in the moments just after the signal light has changed to green for vehicles and "WALK" for pedestrians. During this time, both drivers and pedestrians enter into the intersection. By providing an exclusive pedestrian advance phase, pedestrians are more visible to drivers because they are already in the intersection when drivers begin to move.

If the leading pedestrian interval is long enough, some pedestrians can even reach the safety of the opposite sidewalk before drivers begin to move.

A variation of leading pedestrian intervals is called a leading cyclist interval, which makes use of signal heads with bicycle symbols to allow cyclists to begin crossing the intersection before motor vehicles.

Studies have shown that:

- Leading pedestrian intervals can achieve a 59% reduction in vehicle-pedestrian crashes at intersections.

Best results occur when:

- Right-turns-on-red are prohibited, as this will ensure that pedestrians have exclusive use of the intersection space during the interval phase; and
- Other safety features are installed alongside the leading pedestrian interval, including advance stop lines for cars (page 6), curb extensions and pedestrian refuge islands (page 10) and safe crosswalk signalization (page 23).

Adequate Pedestrian Crossing Times and Signal Cycle Lengths

Description

Short "WALK" signal times for pedestrians and long green phases for drivers can make it more likely that pedestrians will attempt to cross against the signal. This strategy involves programming signalized intersections to cycle through all the signal phases faster to increase turnover and increasing the length of time that crossing pedestrians have a "WALK" signal on some crossings.

How it Works

At signalized intersections on major roads, it is common to have green signals for vehicles that last longer than 90 seconds. This can be frustrating for people who arrive early in a cycle and wish to cross the major road, as they will have longer to wait until they are given a "WALK" signal, thereby encouraging some pedestrians to make risky crossing decisions.

At the intersections of major and more minor roads, sufficient time for pedestrians to cross the major road can be attained by ensuring a more equal balance in the length of time for the green signal on the two intersecting streets. By reducing the cycle length and increasing pedestrian signal crossing times, pedestrians are encouraged to wait for the "WALK" signal instead of trying to find gaps in the road traffic. Shorter cycle lengths can also be used to reduce drivers' speeds and improve road capacity when combined with a coordinated signal timing plan.

However, there is a balance when adjusting crossing times and cycle lengths, as allowing more time to cross may increase the total cycle length.

Studies have shown that:

- Increasing minimum green time for drivers at signal-controlled midblock crosswalks increases the rate of pedestrians crossing against the signal, which can lead to a greater risk of crashes; and
- Timing pedestrian signals based on a 1.2 metres per second walking speed does not give sufficient time to cross for 90% of pedestrians who use assistive walking devices. Optimal signal time is set for pedestrians moving at 0.8 to 1.0 metres per second.

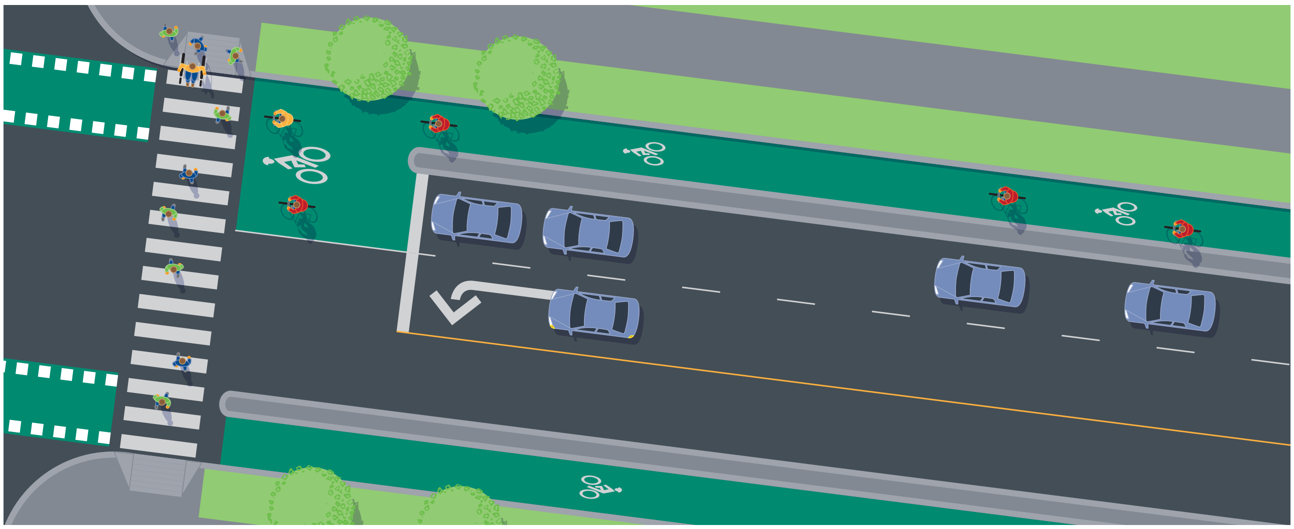
Best results occur when:

- Increased crossing times are prioritized in areas where there is a high concentration of pedestrians, especially children and older pedestrians;
- Signal cycle lengths vary from 60 to 90 seconds in urban areas. This can be achieved by reducing the length of the green signal for drivers on major roads; and
- Crossing distances are shortened using curb extensions and pedestrian refuge islands (page 10) in order to address the challenge of wide streets.

Bicycle Boxes and Two-stage Left-turns

Description

A bicycle box is an area that is a right-angle extension of the bicycle lane positioned in front of motor vehicles at a signalized intersection. It allows cyclists to move ahead of motor vehicle traffic when there is a red light, which gives them space to safely and more comfortably clear the intersection.



A two-stage left turn (also known as the "Copenhagen left") involves bicycle boxes on the outside edges of the intersection, but out of the path of drivers on the cross-street. At the first stage, left-turning cyclists move through the intersection to a bicycle box at the opposite-right end of the intersection, and then turn to face the desired direction of travel. At the second stage, cyclists pass through the intersection as part of the through-traffic and do not have to cross the path of oncoming through-traffic. A two-stage left-turn could be facilitated by a bike box, but better treatment is the protected intersection described elsewhere.

How it Works

Bicycle boxes assist cyclists by separating them from motor vehicle in time and helping to:

- Increase drivers' ability to see cyclists at the red light and reinforce cyclists' right-of-way;
- Group cyclists together and allow them to move first with the green light, reducing delays for them and for drivers since they clear the intersection together;
- Prevent "right-hook" crashes where motor vehicles turn right and crash into cyclists who are moving straight through an intersection;
- Position cyclists out in front of vehicles' exhaust fumes, making it more pleasant to cycle; and
- Keep cars further away from the sidewalk and crosswalk, which benefits pedestrians.

Two-stage lefts prevent cyclists from having to turn across opposing through-traffic, making it simpler and safer to complete left-turns. A variation of the two-stage left at T-intersections is the jug-handle-left, which consists of a "bicycle bay" or protected waiting area cut out of the right-side curb. Cyclists can position themselves in this protected location and either wait for a safe gap in traffic or, in the case of a signalized T-intersection, wait for a green light.

Bicycle Boxes and Two-stage Left-turns, continued

Studies have shown that:

- Bicycle boxes can reduce the overall number of conflicts between cyclists and drivers at intersections and increase drivers' yielding behaviour to cyclists.

Best results occur when:

- Both cyclists and drivers are aware of the purpose of bicycle boxes and how to use them, which requires public education;
- The bicycle lane leading up to the bicycle box is sufficiently long to allow cyclists to safely filter through to the front of the queue;
- The bicycle box itself is large enough for cyclists to move away from drivers and to feel comfortable using the box; and
- Bicycle boxes are used in conjunction with advance stop lines (page 6).

Safe Bus Stop Placement and Design

Description

The bus stop is the first point of contact between the passenger and the bus service. Designing safe bus stops requires appropriate spacing, placement and layout of the stops. This can help reduce the risk of crashes, improve personal security for transit users and improve the transit system's efficiency.

Safe Bus Stop Placement and Design, continued

How it Works

Improperly designed bus stops can increase road safety risks by creating visual obstructions between different types of road users. They may also create more complex environments that increase the potential for conflict between road users. Well-designed bus stops help reduce risk by:

- Creating clear sight lines so that all road users can see and react safely to one other;
- Simplifying road user movements or separating those movements through space and time; and
- Reducing transit riders' vulnerability by loading and unloading passengers at the safest locations.

A floating bus stop (also called a bus stop bypass) is an innovative bus stop design that helps reduce crash risks to cyclists by allowing them to pass buses away from motor vehicle traffic. Floating bus stops include a curb extension, as well as a bicycle lane wrapped behind the area where passengers board or step off the bus. This design allows transit vehicle drivers to pull up to the bus stop without blocking the bicycle lane, which would otherwise force cyclists to move to the left of the bus and enter the motor vehicle traffic stream.

Studies have shown that:

- There is a strong correlation between the presence of bus stops and crashes involving pedestrians. This may be due to higher volumes of pedestrian traffic, but may also be related to the visual obstructions created by buses. It is therefore important that bus stop design and placement pays specific attention to safety.

Best results occur when:

- Bus stops should be well-lit to improve safety and personal security and increase the likelihood of use, especially at night time;
- There is an adequate "landing pad" at the bus stop, which is a stable, level and slip-resistant surface to facilitate passenger boarding and stepping down;
- Information on transit schedules is made available;
- Bus stops provide shelter from inclement weather, excessive heat and direct sun; and
- Careful thought is given to the placement of the bus stop. The following should be considered:
    - Placing bus stops on the far side of an intersection is the safest option in most cases, as it minimizes the possibility that stopped buses will visually obstruct traffic signals, road signs and crossing pedestrians;
    - Where a high-volume destination (e.g., a shopping mall or connecting bus route) is located on the near side of an intersection, the safest option may be to position the bus stop nearest to that location. This reduces the need for pedestrians to cross the intersection in order to reach their destination; and
    - It may be desirable to place bus stops at mid-block locations on very long blocks, especially if there is a popular destination in a mid-block area. To ensure that people who have to cross the road at a mid-block location can do so safely, crosswalks should be positioned such that the bus passes the crosswalk before reaching the stop. This will prevent the bus from obstructing sight lines between pedestrians and drivers.

Increasing the Visibility of People Who Walk and Cycle

Pedestrians and cyclists have greater safety risks because their small mass makes them vulnerable to heavy and fast-moving vehicles, they do not benefit from the same protective vehicle designs as motor vehicle occupants, and their small size makes them less visible to drivers. The safety designs in this chapter are designed to increase the visibility and conspicuousness of vulnerable road users, which encourages drivers to drive more cautiously.

Safe Crosswalk Signalization

Description

At some crosswalks, it is necessary to press a push-button to activate the pedestrian crossing. An alternative design for intersections of two major roads or two smaller roads is called "pedestrian recall", which is when the "WALK" signal coincides with most of the duration of the green light for drivers, changes to a flashing "DON'T WALK" signal several seconds before the light turns yellow and ultimately reverts to the solid "DON'T WALK" signal at the same moment that the light for drivers turns yellow.

Another design for intersections of major and local roads is called "rest-in-walk", which is when the traffic signal on the major road stays green and the pedestrian signal indicates "WALK" until a vehicle or a pedestrian arrives from an intersecting minor road. In order to cross the major road, pedestrians must activate a push button.

Other safe crosswalk signalization designs include automated pedestrian detection systems and accessible pedestrian signals for people with visual limitations.

How it Works

Pedestrian recall and rest-in-walk signals work by reducing or eliminating the need for pedestrians to activate the pedestrian crossing signal themselves. This helps ensure that pedestrians cross when they have a "WALK" signal.

Automated pedestrian detection systems are used to activate the "WALK" signal when a pedestrian reaches the crossing. Like pedestrian recall, this eliminates the need for pedestrians to manually activate the crossing signal.

An accessible pedestrian signal uses audible sounds for people with visual limitations to help indicate when it is safe to cross. Technologies that utilize vibrating panels to physically and audibly symbolize the "WALK" signal provide additional prompts for pedestrians with visual limitations.

Studies have shown that:

- Pedestrian recall and rest-in-walk increase pedestrians' compliance with crossing signals; and
- Automated pedestrian detection systems have been found to reduce the number of conflicts between drivers and pedestrians.

Best results occur when:

- Safe crosswalk signals are programmed to minimize delays for pedestrians and cyclists;
- Crossings with high pedestrian volumes throughout most of the day use pedestrian recall because of their lower implementation and maintenance costs. This also promotes regularity and predictability for all road users and helps reinforce pedestrians' right-of-way;
- Each accessible pedestrian signal is mounted on its own pole corresponding to each separate crossing, instead of on a single pole. This reduces confusion for people with visual limitations over which crosswalk has the "WALK" signal. Where two systems are installed on a single pole, messages that verbally name the road with the "WALK" signal are most effective;
- Rest-in-walk systems are used in areas with low volumes of pedestrian traffic crossing a corridor;
- Automated detection is used on major bicycle routes to improve convenience and compliance by cyclists; and
- Safe crosswalk signalization is combined with leading pedestrian intervals (page 17), curb extensions and pedestrian refuge islands (page 10) and raised crossings (page 26).

In-street Yield to Pedestrians Crosswalk Signs

Description

Yield-to-pedestrian signs are typically positioned on sidewalks at un-signalized road crossings to alert drivers about the likely presence of pedestrians on the road.

Conversely, "in-street pedestrian crosswalk signs" are regulatory yield signs that are placed in the middle of the crossing to emphasize the possible presence of pedestrians in the crosswalk. These signs are typically installed along the centre line of the road at the crosswalks, but can also be located on lane edge lines or in medians.

This is a low-cost safety feature, increasing the opportunity for widespread implementation.

How it Works

In-street pedestrian crosswalk signs can be bolted to the pavement or used as portable devices placed by crossing guards during peak pedestrian activity. The signs aim to raise driver awareness of the presence of the crossing and may have a traffic calming effect by giving a visual impression of narrower travel lanes at the crossing.

Studies have shown that:

- In-street pedestrian crossing signs can lead to a 13 to 46% increase in drivers yielding to pedestrians at the crosswalk.

Best results occur when:

- The signs are used on two-lane, low-speed roadways;
- They are installed at school crosswalks on local roads; and
- The signs are used in conjunction with curb extensions and pedestrian refuge islands (page 10), as these road design features make pedestrians and cyclists more visible to drivers before they begin crossing.

Rectangular Rapid Flashing Beacons

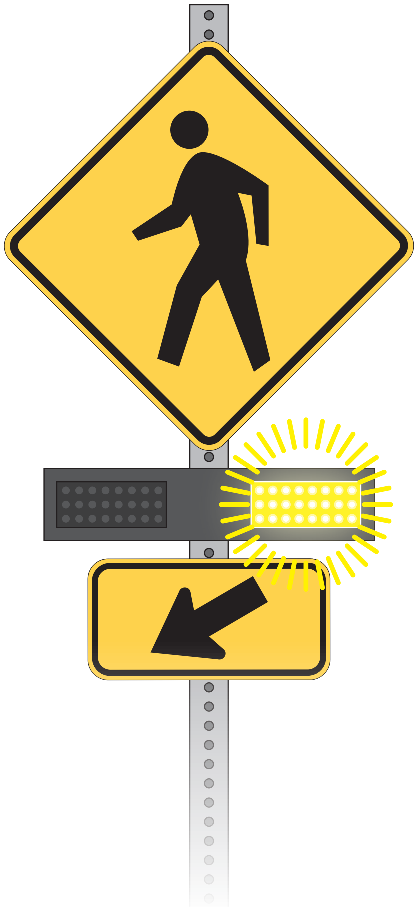
Description

Rectangular rapid flashing beacons are a form of warning amber flashing beacon used at un-signalized pedestrian crosswalks to support the regulatory crosswalk signs and pavement markings. They use a high-intensity rapid and irregular flash pattern to capture drivers' attention.

The beacons are activated by pedestrians, either manually by way of push-button control at the side of the road, or automatically by way of automated pedestrian detection systems (page 23).

How it Works

The bright, rapid and irregular flash patterns of this beacon are more noticeable to drivers than traditional flashing warning lights. This safety device elicits a stronger response from drivers, making them more likely to slow down and yield. The flashing lights, which are active only when people are crossing, also clearly signal to drivers when someone is in the crosswalk.



Studies have found that:

- Rectangular rapid flashing beacons can increase the number of drivers yielding to crossing pedestrians by 52 to 77% after implementation.

Best results occur when:

- Locations for implementing rectangular rapid flashing beacons are chosen using a warrant system, which scores each site based on set criteria, thus allowing municipal planners to prioritize appropriately. As of November 2016, a warrant system is being developed by the Transportation Association of Canada to ensure consistency in design and installation of rectangular rapid flashing beacons across Canada.

Raised Crossings

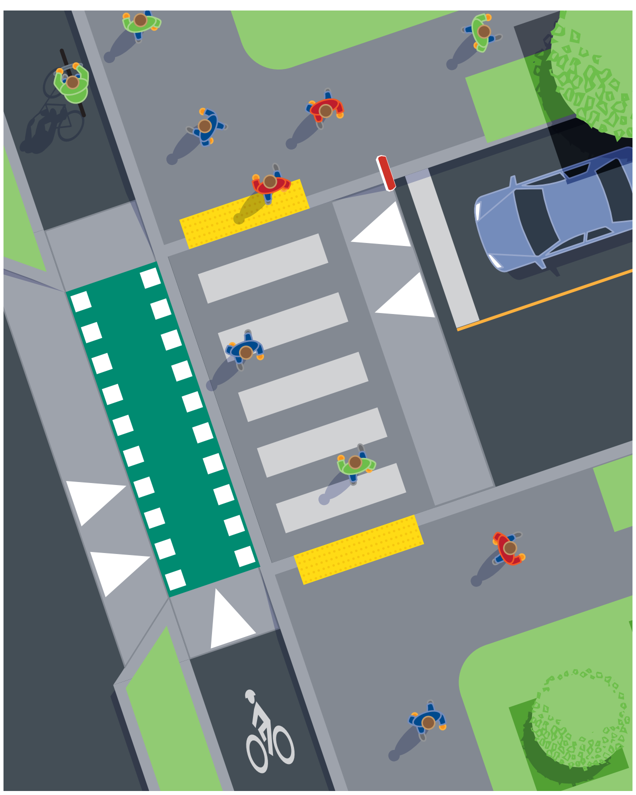
Description

People on foot or on bicycle crossing a road often have the right-of-way, but this is not intuitive in typical North American road design. Raised crossings are crosswalks that are flush with the sidewalk, rather than the road, and help to make people crossing more conspicuous to drivers.

How it Works

In order to help draw drivers' attention to pedestrian traffic and help make the right-of-way clear, raised crossings use the same materials as the sidewalk and bikeway, instead of those used for the road. Their purpose is to slow motor vehicles, improve the visibility of vulnerable road users, and encourage more drivers to yield to people crossing on foot or by bicycle.

An added benefit of this safety design is greater ease of crossing for people with mobility or balance challenges (including people using walkers, wheelchairs, mobility scooters, etc.), because they do not need to step down from the curb.



Studies have shown that:

- Raised crossings can reduce vehicle-pedestrian crashes resulting in injury by as much as 46% and reduce vehicle-bicycle crashes resulting in injury by as much as 51%; and
- Raised crossings are more protective than speed humps which have sometimes been shown to increase crashes for cyclists.

Best results occur when:

- This safety feature is installed at the intersections of local roads with major roads, and placed across the local road. It may also be used in parking lots and at the intersection of two local roads;
- Raised crossings are set back approximately 6 metres from the major road. This increases the space between drivers who are turning right onto the local road and people who are crossing the local road. As a result, drivers are better able to see pedestrians after turning, and all road users have more time and space to react safely when there is a conflict;
- Tactile warning strips and other highly vivid methods of demarcating the sidewalk and the roadway are used at raised crossings. This helps all people, and in particular those with visual limitations, to distinguish between the sidewalk and the roadway; and
- Raised crossings are used in conjunction with protected and connected bicycle lanes (page 12).

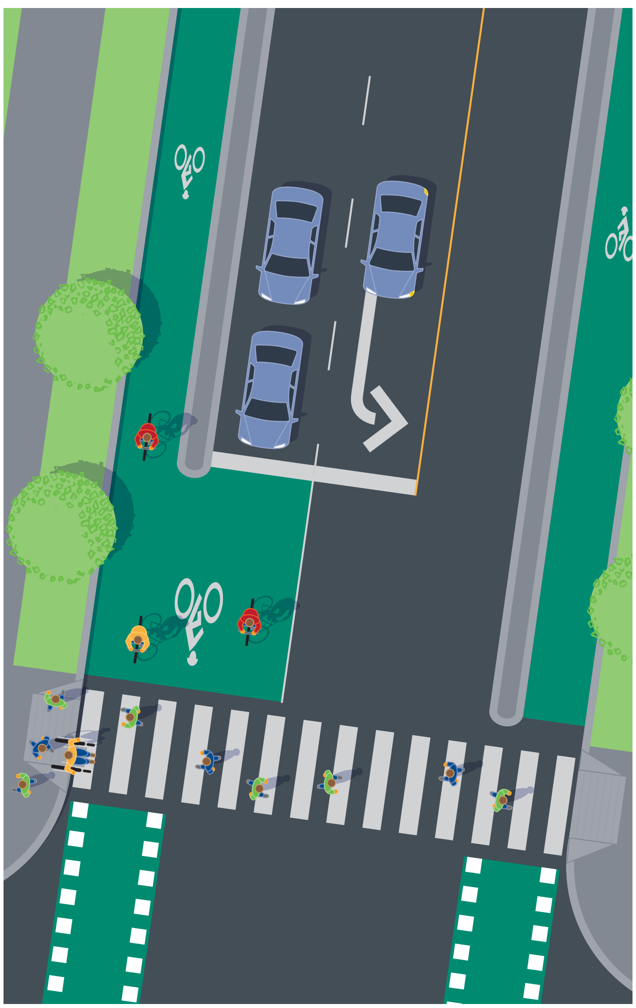
Coloured Bicycle Lanes

Description

In North America, green or blue pavement colouring has been used to define bicycle lane treatments, bicycle boxes (page 19), or locations where bicycle lanes cross intersections. Changes in colour or vivid paint patterns can also be used to draw more attention to specific locations where cyclist movements interact with motor vehicle traffic, for example in front of driveways or where drivers need to move into a dedicated right-turn lane. White stencils and pavement arrow markings help to reinforce the proper use of these facilities.

How it Works

Coloured bicycle lanes increase the visibility of the lane to drivers, highlight the presence of cyclists and reinforce the right-of-way for cyclists. Coloured bicycle lanes have also been shown to increase the number of cyclists who follow the delineated paths.



Studies have shown that:

- Coloured bicycle lane treatments can improve the number of drivers yielding to cyclists by 12 to 20%.

Best results occur when:

- Coloured bicycle lanes are used in conjunction with high-friction, skid-resistant pavement materials; and
- They are used on relatively calm, lower-speed roads. Where speeds and vehicle volumes are high, cycling facilities should be completely separated from adjacent motor vehicle traffic through the installation of protected and connected bicycle lanes (page 12).

Improving Safety through Green Transportation Options

The following strategies are best practices that will benefit vulnerable road users. They are primarily intended to create a safe and friendly environment for people who walk, cycle and take public transit, and to encourage more people to do so. Encouraging more people to use these forms of transport can also help make the roads safer by reducing the number of private vehicles using the road system.

Priority Signalling and Right-of-way for Buses

Description

Priority signalling for buses involves the use of remote sensors and computer controls on a single traffic signal or an entire traffic signal network to give the equivalent of green signals to buses at intersections. Bus lanes, high occupancy vehicle (HOV) lanes and queue jumpers are all forms of right-of-way priority for buses that allow them to move about more safely and efficiently.

How it Works

Bus lanes are dedicated lanes which ensure that public transit vehicles are always able to efficiently move on roads, even when those roads are congested. HOV lanes work in a similar way, though they are also permitted for use by private vehicles that have a minimum prescribed number of occupants. Local road authorities can designate bus and HOV lanes either on an ongoing around-the-clock basis, or operate them only during peak traffic times when buses would benefit most.

Queue jumpers are areas at intersections that allow buses to pass stopped traffic. They can often be created by removing on-street parking near the intersection, or by utilizing a right-turn lane.

Priority signalling for buses is a special signal phase that allows buses to move through the intersection while all other traffic, including through-traffic in the same lane as the bus, has a red phase. This phase is often represented as a vertical white bar on black background, and is activated for a short period (5 to 7 seconds) immediately prior to the green phase. This signal mode can be combined with a dedicated bus lane or a queue jumper to allow buses to position themselves at the front of the queue at intersections.

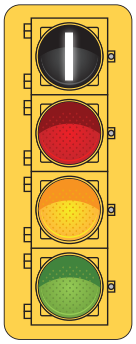
Priority signalling and right-of-way for buses are strategies that increase transit efficiency, reduce travel time and delays for transit users and improve the convenience and attractiveness of taking public transit.

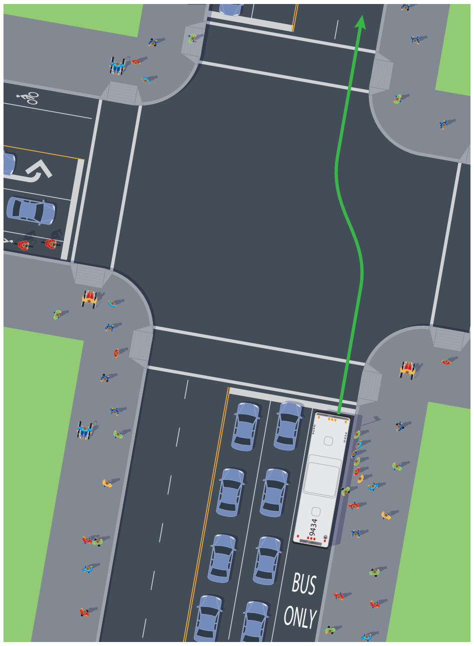
Studies have shown that:

- After the implementation of a major bus priority lane in a city in Japan, there was a reduction in the number of private vehicles using the road, queue lengths at red lights were shortened and congestion was reduced;
- Cities in the Netherlands had improvements in bus schedule adherence where priority signalling was used; and
- Overall, there are decreases in serious crashes where priority signalling for buses is used.

Best results occur when:

- Priority bus signals and lane networks are implemented along with safe bus stop placement and design (page 20); and
- Side transit-ways—which are bus lanes completely separated from adjacent traffic—are implemented where possible.





Transit-oriented Development

Description

Transit-oriented Development (TOD) is an urban planning concept which seeks to promote the use of public transportation through integrating transport and land use policy. The idea is to improve access to transportation centres by making them accessible to all forms of transport, and specifically improving access for people who walk and cycle. This allows people to more easily combine transport modes within a single trip.

How it Works

TOD focuses on the environmental characteristics that improve the access of public transportation by walking or cycling. These characteristics are:

- High population density;
- Mixed residential and commercial land uses;
- Pedestrian-friendly urban design; and
- Proximity to transit.

Developing neighbourhoods by focusing on these characteristics encourages individuals to use transit because they can access it more easily. Furthermore, as the TOD takes place in high-density areas, there is typically enough demand to support more frequent transit service which, in conjunction with the ease of access to transit, creates a positive feedback loop as individuals use public transportation more frequently because the service is reliable and easily accessible.

Studies have shown that:

- Individuals who choose to live in the vicinity of TODs are typically more likely to use public transit.

Best results occur when:

- A public transport hub or location that is frequently-serviced by public transit should be located within walking distance (ideally a 10-minute walk, or a 750 metre radius) from any home in the TOD area. For cyclists, this distance can be increased to 2 to 3 kilometres;
- Adequate bicycle parking is provided, including rentable bicycle lockers that ensure bikes can be kept secure for the duration of the day and night; and
- Adequate facilities are provided for people travelling to public transit hubs by car, including "park-and-ride" facilities, "kiss-and-ride" facilities where people can be safely and conveniently dropped off, and/or designated carpool parking.

Safe Parking Lot Design for Pedestrians and Cyclists

Description

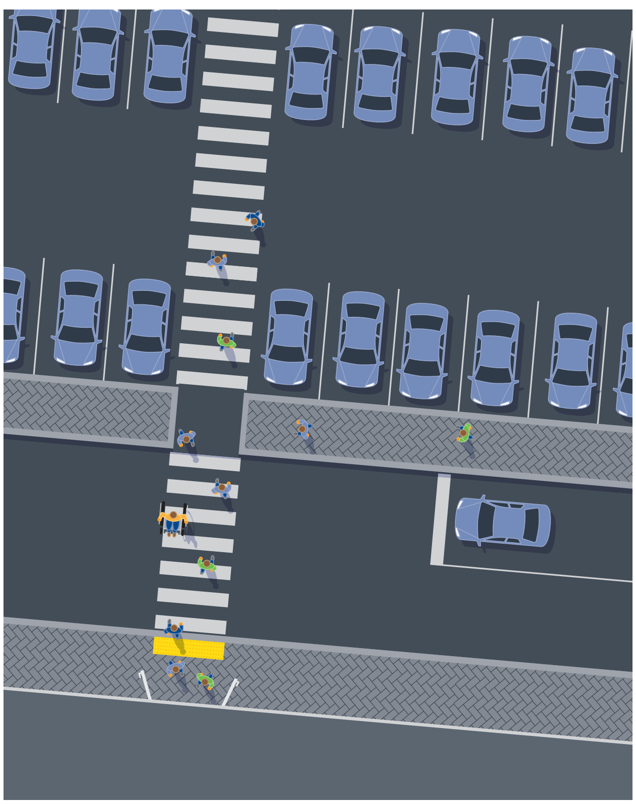
Parking lots are areas with complex interactions and strong potential for conflicts between road users. Safe parking lots use design features that allow for the unbroken safe movement of pedestrians and cyclists. The parking lot driveways should also ensure safe access/egress for all road users.

How it Works

Many of the strategies discussed in this toolkit can be used to design safe parking lots. Safe parking lots separate different types of road users from one another, reduce driver speeds and have unobstructed sight lines. This helps alleviate the unpredictability of the parking lot environment.

Studies have found that:

- Parking lots are locations where pedestrians often get struck by motor vehicles, and there are greater risks of serious crashes for younger pedestrians (aged 15-19 years) and older pedestrians (aged 65 years and over).



Best results occur when:

- There is at least one uninterrupted pedestrian route between the main building entrance and the sidewalk/roadway to help ensure more pedestrians and vehicle are kept separated;
- Curb extensions wrap around and extend away from parking lot entrances/exits to provide much improved visibility;
- Raised Crossings (page 26) are used at parking lot entrances to slow down drivers and improve their ability to see pedestrians;
- Coloured Bicycle Lanes (page 27) are placed across the face of a parking lot entrance to signal to drivers that there may be cyclists present. Bicycle lanes may also extend from the roadway into the parking lot;
- Speed bumps are placed at regular intervals to slow drivers' speeds;
- Tactile warning strips and other highly visible methods of demarcating the sidewalk and roadway are used at raised crossings;
- Adequate lighting is installed to ensure safety and security. Lighting along pedestrian and cyclist paths is scaled appropriately for these road users to help mark their path from a distance; and
- Good quality bicycle parking installations are provided in sufficient quantity and in visible areas close to building entrances. Bicycle parking should not obstruct pedestrian pathways.

Defined Terms

Arterial roads: higher-capacity roads used to move large volumes of traffic.

Collector roads: low-to-moderate capacity roads that allow traffic flow within larger neighbourhoods and distribute motor vehicle traffic between arterial roads and local roads

Local road authority: the local public body that has authority to install and maintain traffic control devices (i.e., road signs and signals), and install road safety infrastructure.

Local roads: roads that primarily serve local neighbourhood traffic, provide connections within communities, provide access to residential properties, and usually have on-street parking.

Major roads: arterial roads and collector roads.

Pedestrian: a person travelling by foot, skateboard/longboard, roller skates, push scooters, or any other small-wheeled form of transport, or using mobility assistance devices like wheelchairs or electric scooters. This toolkit uses the terms "pedestrians" and "people who walk" interchangeably.

Sight lines: the distance in any direction where different road users can easily see one another.

Signalized intersection: an intersection where road user movements are controlled by traffic lights.

Vulnerable road user: anyone outside of a motor vehicle including pedestrians, cyclists, people using mobility assistance devices (i.e., people who use wheelchairs, mobility scooters, etc.), and motorcyclists. These road users do not benefit from vehicle protections like crumple zones, airbags, and a protected passenger compartment. For the purposes of this toolkit, vulnerable road users also refers to skateboarders and longboarders, people using push scooters, and people using in-line skates.

Separating Road Users in Physical Space

Wider and Connected Sidewalks

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These posts by North American transport designer Nick Falbo and by Bicycle Dutch provide helpful videos, photos, and descriptions of how these intersections are designed:

- http://www.protectedintersection.com
- https://bicycledutch.wordpress.com/2011/04/07/state-of-the-art-bikeway-design-or-is-it/
- https://bicycledutch.wordpress.com/2011/05/05/state-of-the-art-bikeway-design-a-further-look/
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Curb Extensions and Pedestrian Refuge Islands

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- People for Bikes "pro" and "con" guide to many different ways to create physical separation: http://www.peopleforbikes.org/blog/entry/wonktastic-chart-rates-15-different-ways-to-protect-bike-lanes
- Design Manual for Bicycle Traffic (often called the CROW Manual) available for purchase in English: http://www.crow.nl/publicaties/design-manual-for-bicycle-traffic
- Ontario Ministry of Transportation's Traffic Manual: http://www.raqsb.mto.gov.on.ca/techpubs/eps.nsf/0/825810eb3ddd203385257d4a0063d934/$FILE/Ontario%20Traffic%20Manual%20-%20Book%2018.pdf

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SMARTer Growth Neighborhood Design

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Pedestrian Scramble Intersections

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Increasing the Visibility of People Who Walk and Cycle

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Further Resources

NACTO has two useful resources, one on raised crossings and one on raised intersections:

- http://nacto.org/publication/urban-street-design-guide/intersections/intersections-of-major-and-minor-streets/
- http://nacto.org/publication/urban-street-design-guide/intersections/minor-intersections/raised-intersections/

The following resource describes Dutch designs for raised crossings. It complements the NACTO resources above by explicitly including cycling facilities.

- https://departmentfortransport.wordpress.com/2012/08/21/continuous-paths-across-minor-junctions/

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Safe Parking Lot Design for Pedestrians and Cyclists

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R3133

Acknowledgements

The BC Community Road Safety toolkit would not have been possible without the work and dedication of the following individuals:

Amanda Watson, City of Vernon

Barbara Thomas, Municipality of North Cowichan

Chuck Hutchinson, BC Ministry of Transportation and Infrastructure

David Hill, Insurance Corporation of British Columbia

Dotan Amit, Ministry of Public Safety and Solicitor General

Dragana Mitic, City of North Vancouver

Dr. Emily Newhouse, Vancouver Coastal Health Authority

Erin Anderson, Ministry of Public Safety and Solicitor General

Dr. Gordon Lovegrove, University of British Columbia

Heather Andreychuck, City of Prince George

Joy Sengupta, BC Ministry of Transportation and Infrastructure

Dr. Kay Teschke, University of British Columbia

Liliana Quintero, City of Vancouver

Mark Donnelly, Trucking Safety Council of British Columbia

Mark Ordeman, WorkSafeBC

Mavis Johnson, Canadian Traffic Safety Institute

Neil Arason, Ministry of Public Safety and Solicitor General

Patrick Glanc, Ministry of Public Safety and Solicitor General

Dr. Paul de Leur, Insurance Corporation of British Columbia

Raheem Dilgir, TranSafe Consulting Ltd.

Richard Campbell, BC Cycling Association

Ryan Khan, Ministry of Public Safety and Solicitor General

Steve Haywood, BC Ministry of Transportation and Infrastructure

Zahra Hussein, Vancouver General Hospital

In addition to the above list of individuals, many of whom also provided peer review, the following individuals contributed to the toolkit by peer reviewing some of its sections for quality and accuracy:

Arno Schortinghuis, BC Cycling Coalition

Donna Chan, City of Richmond

Joanna Domarad, City of Calgary

Dr. John Morrall, Canadian Highways Institute Ltd.

Kliment Kuzmanovski, City of Surrey

Dr. Meghan Winters, Simon Fraser University

Megan Oakey, Provincial Health Services Authority

Mirjana Petrovic, City of Surrey

Richard Campbell, BC Cycling Coalition

Steve Chou, City of Vancouver

Toby Lewis, City of Vancouver

Finally, the following individuals completed a full in-depth peer-review of the entire toolkit:

Dotan Amit, Ministry of Public Safety and Solicitor General

Erin Anderson, Ministry of Public Safety and Solicitor General

Joy Sengupta, BC Ministry of Transportation and Infrastructure

Dr. Kay Teschke, University of British Columbia

Linda Phillips, BC Ministry of Health

Mavis Johnson, Canadian Traffic Safety Institute

Neil Arason, Ministry of Public Safety and Solicitor General

Dr. Paul de Leur, Insurance Corporation of British Columbia

Raheem Dilgir, TranSafe Consulting Ltd.

Ryan Khan, Ministry of Public Safety and Solicitor General

February 2018