Traffic Engineering and Highway Safety Bulletin 19-02
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PARKING SAFETY

In This Issue...

MILITARY SURFACE DEPLOYMENT AND DISTRIBUTION COMMAND, TRANSPORTATION ENGINEERING AGENCY (SDDCTEA)

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Overview

Parking on military installations comes in many styles, shapes and sizes, from vertical structures, to various-shaped surface lots, to unimproved fields. Regardless of the type, if the proper design and planning principles are not met, problems can be compounded by an increase in crash potential. This bulletin will focus on common deficiencies related to safety and present methods to reduce crash potential for off-street and on-street parking. For information on parking lot design (i.e., parking lot layout and dimensions, parking stall layout and dimensions, setback requirements, and parking demand), refer to Chapter 17 of SDDCTEA's Pamphlet 55-17.

Off-Street Parking

Off-street parking facilities include parking lots, parking garages, and private driveways/lots. Given the widespread use of parking lots on military installations, they will be the focus of this section. Most safety issues in parking lots can be attributed to deficiencies in parking lot layout, signing and pavement markings, lighting, sight distance, drainage, pedestrian accessibility, etc. Distracted driving is also a growing concern in parking lots due to the ever changing technology available to drivers. In a National Safety Council public opinion poll from March 2016, 66% of drivers nationwide said they would make phone calls while driving through parking lots. Respondents also said they would:

- Program GPS systems (63%)
- Text (56%)
- Use social media (52%)
- Send or receive emails (50%)
- Take photos or watch videos (49%)

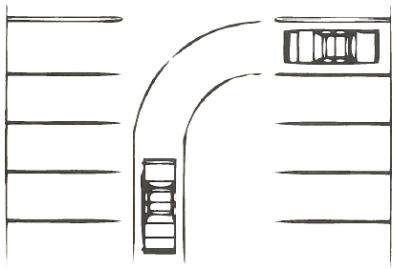
To minimize the growing number of crashes, it is important for designers to consider the many aspects that can attribute to an overall increase in parking lot safety. This section discusses those elements as they relate to safety and any additional requirements or guidelines that can help mitigate crashes.

Parking Lot Layout

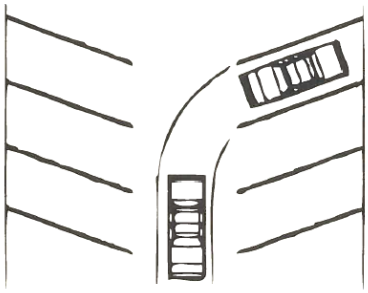
A parking lot should have circulation patterns that are as obvious and simple as possible to pedestrians, bicycles, and vehicles. The following sections discuss the advantages and disadvantages among various parking lot design elements in terms of safety.

Perpendicular vs. Angled Parking

Parking stalls can be oriented perpendicular (i.e., 90-degrees) to the driving aisle or at various angles (i.e., 30-degree, 45-degrees, and 60-degrees). While perpendicular parking is often the more efficient layout in terms of parking lot area per parking space, angled parking can be more efficient in terms of circulation and ease of parking. However, there is no clear advantage in terms of safety between either parking stall orientation.



Perpendicular Parking



Angled Parking

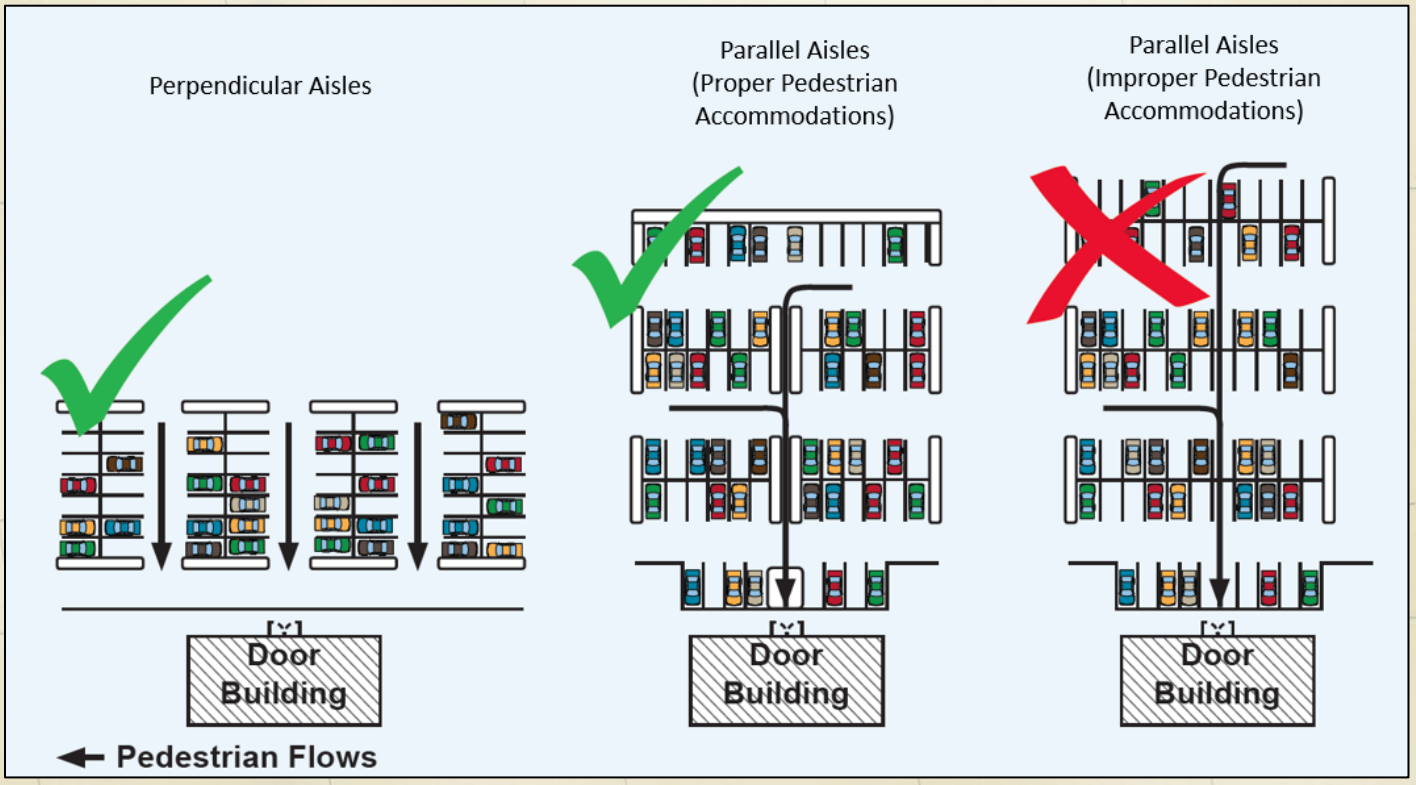
One-Way vs. Two-Way Driving Aisles

For two-way traffic flow, parking spaces perpendicular to the aisles provide the most efficient design. For one-way aisles, angled parking is desirable since the footprint can be reduced by utilizing the advantage of easy pull-in and pull-out that angle parking provides. In terms of safety, the one-way driving aisle is preferred since it can reduce conflicts between vehicles backing out of a stall and vehicles traversing the driving aisle. When designing a parking lot with one-way driving aisles, consideration should also be given to the inconvenience of one-way aisles. Typically, one-way driving aisles are most appropriate for parking lots that have a high turnover rate, meaning a greater likelihood of finding an empty stall before reaching the end of the aisle (such as a Commissary or Exchange where people are coming and going continuously).

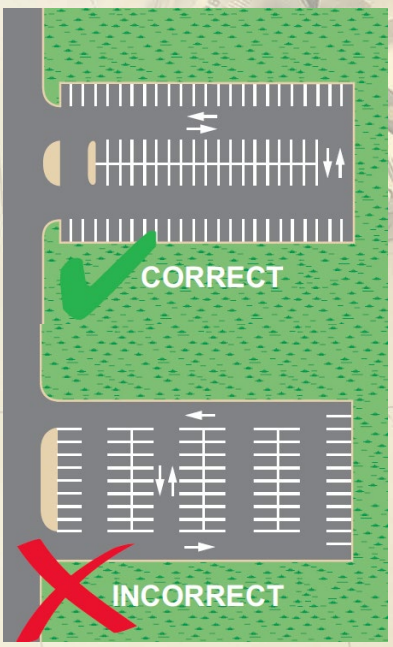
Driving Aisle Orientation

Figure 1 illustrates the relationship between pedestrian flows and driving aisle orientation. As shown in the figure, aligning the driving aisles perpendicularly to a building provides the shortest desired walking lines to the front doors of the building. It also avoids requiring pedestrians to walk through bays of parked cars to reach a building destination. However, driving aisles perpendicular to a building should not be less than 130 feet since this would not be an efficient use of space. In this case, the aisles should be oriented parallel to the building, but pedestrian pathways should be incorporated to facilitate pedestrian flow.

Figure 1 Pedestrian Flows and Driving aisle Orientation



The perpendicular driving aisle orientation is typically safer since pedestrians are encouraged to walk along the driving aisle to travel between their vehicle and the building rather than crossing the driving aisles. Additionally, the perpendicular orientation usually results in shorter aisles compared to the parallel orientation which can reduce speeding within the parking lot. The drawback of the perpendicular orientation, as shown to the right, is the increase in conflict points with vehicular traffic at the ends of the aisles and the number of times a motorist may circulate through the driving aisles to find a parking space. If parallel aisles are used, pedestrian conflicts should be reduced with the inclusion of pedestrian pathways as shown in center example within figure 1, and vehicle speeding may need to be reduced with the installation of speed humps.



Signing and Pavement Markings

Parking lots are not required to follow the Manual on Uniform Traffic Control Devices (MUTCD); however, circulation roads around the parking lots are required. Although parking lots do not have to adhere to the MUTCD requirements, traffic control devices in place cannot be incorrectly applied. SDDCTEA recommends all signing and pavement markings follow the MUTCD guidelines. Below are some example MUTCD guidelines.

- For good visibility, repaint markings as needed, and replace old signs.
- Old or conflicting pavement markings should be eradicated completely; black paint should not be used to cover old markings
- Retroreflective pavement markings should be used to ensure full visibility during nighttime or adverse weather conditions.
- The retroreflective sheeting type for all regulatory, warning, and guide signs shall be Type III or better per the DOD Supplement to the MUTCD.
- Avoid wide driving aisles or driveways that are not delineated with pavement markings as they can cause confusion for motorists.
- For one-way driving aisles, it is important to use directional arrows to ensure that motorists do not travel in the wrong direction; for larger parking lots that have end islands, DO NOT ENTER (R5-1) and ONE-WAY (R6-1) signs can be posted to further enforce the direction of the driving aisles.
- Parking space markings should be white in color and a minimum of 4 inches wide. Blue lines may supplement the white parking stall markings for accessible stalls, but only on the accessible parking space side of the white markings.

Pavement Marking Colors

Given that parking lots do not have to adhere to MUTCD standards, pavement marking colors can vary. Some sites utilize yellow markings while others use atypical colors to distinguish employee parking from customer parking. SDDCTEA commonly encourages the use of white markings. Note that white markings must be used for on-street parking as required by the MUTCD.

Stop Control in Parking Lots

The improper use of stop control can result in poor circulation within the lot, confusion for motorists and pedestrians, and increased crash potential. In parking lots, use the following guidelines for stop control.

- At the ends of aisles in parking lots, the word STOP shall not be used on the pavement unless accompanied by a stop line.
- At the ends of aisles in parking lots, a STOP sign is not necessary. A stop line and legend can be used to indicate stop control. If a raised island is provided, then a STOP sign should be installed on a breakaway post to further establish right of way.

Lighting

Lighting in parking lots plays a critical role in maximizing visibility between motorists and pedestrians since pedestrians typically walk next to vehicle driving aisles.

Below are some guidelines for light fixtures in parking lots.

- Locate light fixtures away from traffic aisles and parking stalls wherever possible. Light poles are ideally located in islands and protected by raised curbing.
- When light poles are within parking rows, locate the poles at the junctions of adjacent stalls, and install them on top of a 3-foot high concrete base to avoid accidental knockdowns. While this practice is acceptable in parking lots, high concrete bases should not be used adjacent to parking lot circulation roads where speeds are higher. If used, clear zone requirements must be met or the light pole should be installed on a breakaway support. Pole heights range from 20 to 50 feet high or more.
- Poles and light fixtures should be in scale and accommodating to the setting and surrounding area, while providing adequate illuminance of the parking lot.

The table below lists the illuminance and uniformity ratio requirements for parking lots according to the Illuminating Society of North America's (IESNA) *Lighting for Parking Facilities*, RP-20-14 publication. The procedures for taking lighting measurements can be found in IESNA's *Guide for the Photometric Measurement of Parking Areas*, LM-64-01 publication.

Location	Time of Day	Minimum Horizontal Illuminance*	Minimum Vertical Illuminance**	Maximum: Minimum Uniformity Ratio***
Drive Aisles/Parking Areas (Asphalt Surfaces)	Pre-curfew	5 lux	2.5 lux	15:1
	Post-curfew	2 lux	1 lux	15:1
Drive Aisles/Parking Areas (Concrete Surfaces)	Pre-curfew	10 lux	5 lux	15:1
	Post-curfew	2 lux	1 lux	15:1
General Transaction Areas (i.e., drop-arm gate access, guard booth access, etc.)	Pre-curfew	10 lux	5 lux	15:1
	Post-curfew	2 lux	1 lux	15:1

* Horizontal illuminance describes the amount of light landing on a horizontal surface
** Vertical illuminance describes the illuminance landing on a vertical surface, such as a wall or pedestrian
*** The uniformity ratio is the ratio of the maximum illuminance to the minimum illuminance; this applies to both vertical and horizontal illuminance measurements

Criteria for parking structures, pedestrian areas, and roadways can be found in UFC 3-530-01, Interior and Exterior Lighting Systems and Controls. Refer to Chapter 21 of SDDCTEA's Pamphlet 55-17 for more information on lighting.

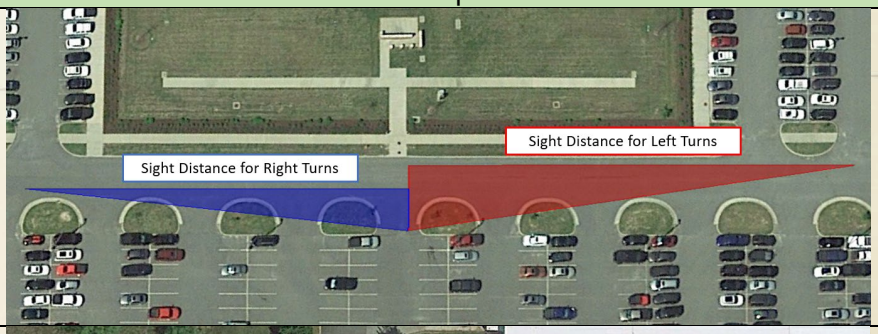
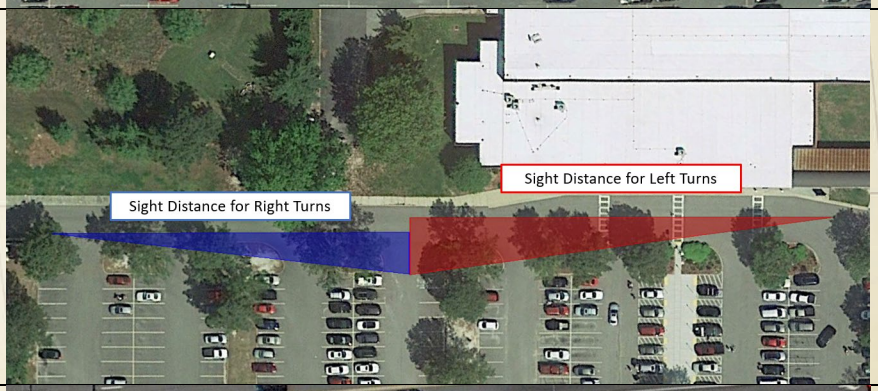
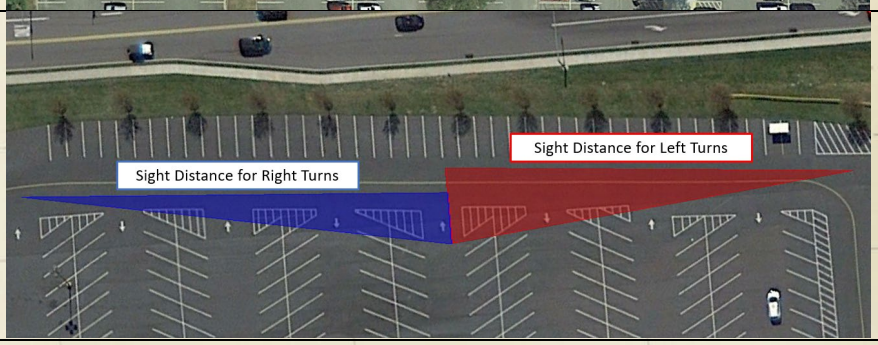
End Islands and Landscaping

Space at the end of each aisle should be kept clear of parked vehicles to allow turning motorists a clear view down the cross aisle. Mark this area with either white paint or a raised traffic island. Adequate sight distance must be provided within parking lots, particularly at the intersections of access aisles with cross aisles or a roadway. Proper sight distance should be provided for the form of traffic control present, with consideration for prevailing vehicle speeds. As parked cars may limit sight distance, a correctly sized end island provides a buffer from parking for proper sight distance and refuges for pedestrians. SDDCTEA recommends an island width of no less than 10 feet. If plantings are used within the islands, ensure that they are low height plantings to not limit sight distance. Periodic trimming is important to ensure that they remain at low heights.

The table to the right shows the minimum sight distance required for a left turn or a right turn from a driving aisle to a cross aisle or roadway; these values assume stop control at the end of the aisle and a level grade throughout. If no speed limit is posted on a cross aisle or roadway, a design speed of 25-mph should be used. These required sight distance values, coupled with the position of the stopped vehicle (assumed to be 19.5 ft from the edge of the roadway) and the travel lanes on the cross aisle or roadway, form a sight triangle. This sight triangle must not be obstructed by parked vehicles or landscaping in order to ensure that the sight distance requirements are met. The figure below illustrates the impact of obstructions such as parked vehicles or landscaping on sight distance.

Roadway or Cross Aisle Speed (mph)	Required Sight Distance for Left Turn from Access Aisle (feet)	Required Sight Distance for Right Turn from Access Aisle (feet)
25	280	240
30	335	290
35	390	335
40	445	385
45	500	430
50	555	480
55	610	530
60	665	575

Figure 2 End Island Sight Distance Illustrations

Notes	Example
Sight distance requirements are met. The end islands provide a sufficient buffer between the roadway and parked vehicle. There are no trees or shrubbery obstructing the sight triangle.	
Sight distance requirements are not met. The end islands provide a sufficient buffer between the roadway and parked vehicle. However, the trees planted within the end islands obstruct the sight triangle.	
Sight distance requirements are not met. The painted end islands do not provide a sufficient buffer between the roadway and parked vehicle.	

Source: Google Earth

Drainage

Source: www.universalseal.net

Provide positive drainage of surface water in parking lots. The possibility of flat spots, ponding, and accumulating water is a hazard for both vehicle and pedestrian movements, particularly in cold climates where freezing may lead to icy spots. Recommended minimum pavement grades are 1.0 percent for asphalt surfaces and 0.5 percent for concrete surfaces.

Pedestrian Accommodation

Typical unsafe driving behavior in parking lots includes vehicles not slowing when passing pedestrians in driving aisles or not slowing for pedestrians within unmarked or marked crosswalks. Typical unsafe pedestrian behavior includes pedestrians taking the shortest path across parking lots and often cross where there are no pedestrian accommodations. For example, instead of crossing access aisles, cross aisles, or roadways at right angles, pedestrians tend to walk diagonally; this provides more opportunities for motorists to interact with pedestrians.

Pedestrian Crossing Laws

The majority of states require motorists to yield to pedestrians crossing at uncontrolled crosswalks while others (nine states and the District of Columbia) require motorists to stop for pedestrians crossing at uncontrolled crosswalks. **These laws apply to all roadways including parking lots.**

SDDCTEA recommends using marked crosswalks when they are warranted and where the majority of pedestrians are expected to cross. Although there are typically low levels of crosswalk usage in parking lots, several measures can be used to increase the safety and usage of marked crosswalks. Refer to chapter 13 of SDDCTEA's Pamphlet 55-17 for more information. Where pedestrian crossing volumes do not warrant a marked crosswalk, markings should not be installed. Motorists must still yield to or stop for pedestrians when crossing an intersection whether a marked crosswalk is provided or not, and pedestrians will typically be more vigilant when crossing at an unmarked location.

It is important to anticipate the most common pedestrian activity patterns during the design stage of a parking lot layout to reduce pedestrian activity at unsafe locations. Accommodating these patterns during the design stage will address pedestrian needs efficiently and mitigate crash potential.

Pedestrian Zones

One way to reduce crash potential between pedestrians and vehicles in a parking lot is to separate areas with high pedestrian traffic from areas with high vehicular traffic. Given that the entrance and exit points to a building are the main pathways for pedestrian travel, the area between a building's front and the parking area is typically the area with the highest amount of pedestrian traffic. Figure 3 the following page shows two examples of parking lots that were designed with a roadway adjacent to the front of the building.

Figure 3 Pedestrian-Vehicle Conflict Areas

Source: Google Earth

Design the parking lot so that the building's front and the roadway (i.e., outside circulatory roadway, street, or highway) are on opposite ends of the parking lot. For existing parking lots with a roadway adjacent to the building's front, provide alternate access points and routes if necessary, and close the roadway to vehicular traffic to create a pedestrian zone. This will not only mitigate vehicle-pedestrian crashes, but also improve operations within the parking area since motorists would not have to experience delays when yielding to pedestrians crossing the roadway. Note that the building's front should still be accessible to emergency vehicles; signing can be used to restrict all vehicles but emergency vehicles at both sides of the parking lot. If it is not possible to restrict access to the front of the building, traffic calming measures such as speed humps or raised crosswalks should be used to reduce speeds.

Pedestrian Pathways

Typically, pedestrians traverse the parking lot via the driving aisles (when a pedestrian pathway is not designated). Although this is preferable to traveling between parked vehicles and crossing the aisle, this type of pedestrian movement presents a safety concern because motorists traveling along the aisle or backing out of a parking stall can have difficulty seeing pedestrians in the driving aisle due to parked vehicles obstructing their view. Where possible, the main internal pedestrian routes should be enhanced with a 5-foot wide walking area between parking stalls as shown in the two figures below.

A raised concrete sidewalk is the preferred design for the pedestrian pathway since the curbing improves pedestrian safety by physically defining the border between the pedestrian pathway and the parking area. However in areas adjacent to accessible parking spaces, or in parking lots where strollers or shopping carts are commonly used, the sidewalk should be flush with the pavement level for ease of access between the parking lot and the walkway. In these cases, curb stops should be added to the parking spaces adjacent to the pedestrian pathway so parked vehicles do not encroach the pathway. Note that ABA-compliant curb ramps with a 5'x5' landing area should be provided wherever the pathway intersects an accessible aisle. Trees, shrubs, or shade structures can be placed along the pathway to encourage pedestrian usage and increase overall aesthetics. The landscaped area can also provide a buffer between the parking stalls and pathway to prevent vehicles from overhanging into the pathway. In the absence of a buffer, wheel stops should be installed to prevent vehicles from overhanging into the pathway. Although these pathways are recommended between all parking stall rows, they should at least be used between the rows that align with the main entrances or exits of the building's front. Figure 4 and figure 5 show examples of a typical pedestrian pathway between rows of parking stalls.

Figure 4 Pedestrian Pathway Design

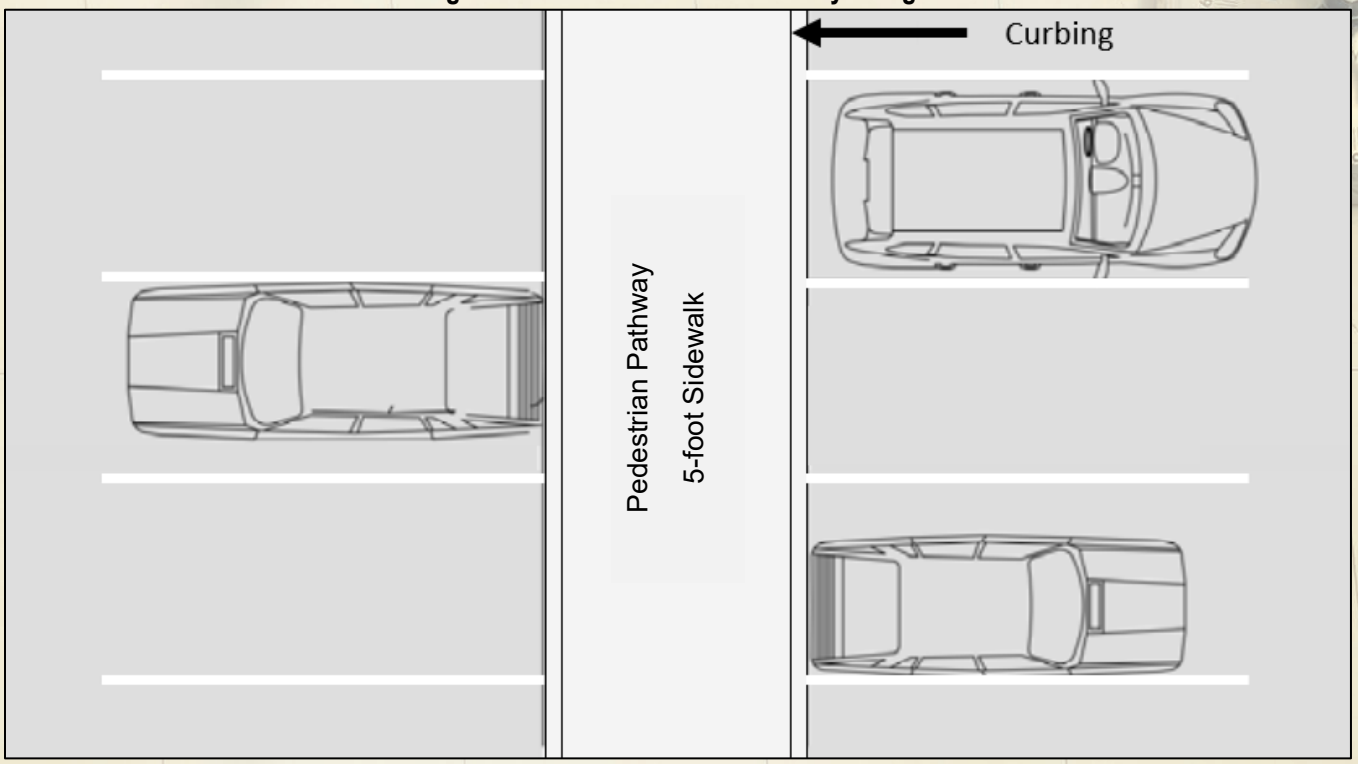


Figure 5 Pedestrian Pathway Example Photo

Source: City of Vaughan Policy Planning Department (Canada)

On-Street Parking

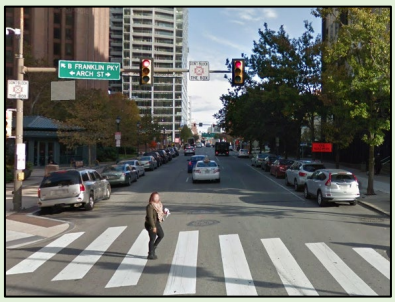
In general, the study of the safety effects of on-street parking reveals that any on-street parking decreases through capacity, impedes traffic flow, and increases crash potential. UFC 3-201-01 'Civil Engineering' states that the use of on-street parking is discouraged and that parking spaces should be provided primarily by off-street parking areas or structures. As a general rule, on-street parking should only be used to supplement off-street parking or in situations where off-street parking is not feasible. Note that since on-street parking is open to public travel, the standards for pavement markings in section 3B.19 of the MUTCD must be followed.

On-Street Parking and Roadway Type

On-street parking is not desirable on arterial or collector roads that are designed to move high traffic volumes at moderate or high speeds. On lower speed roadways, such as residential streets, on-street parking is acceptable because it "calms" traffic and thus reduces vehicle speeds.

On-street parking can be divided into three main categories: parallel parking, angle parking, and perpendicular parking. Figure 6 shows a safety summary and the advantages and disadvantages of each parking type.

Figure 6 On-Street Parking Types

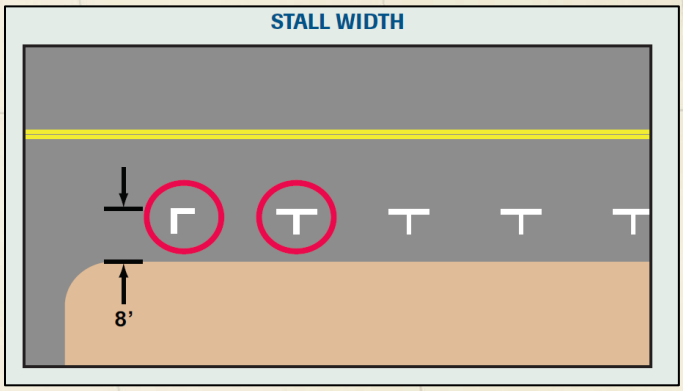
Parking Type	Parallel Parking	Angle Parking	Perpendicular Parking
Example			
Safety Summary	Parallel parking is the most common type of on-street parking and is generally preferred for safety and operational considerations.	Angle parking, while not preferable to on-street parallel parking and should be discouraged, is allowable under certain conditions. The implementation of back-in parking can address some of the safety concerns of angled parking.	Perpendicular parking, while common in parking lots, is highly discouraged on streets. SDDCTEA does not recommend this type of on-street parking under any circumstances. All instances of perpendicular parking should be eliminated or replaced with parallel or angle parking.
Advantages	• Good visibility when re-entering the roadway • Empty parking spaces can be easily identified	• Less time required for parking maneuver • Provides more parking per unit of curb length than parallel parking • Driver and passengers exit vehicle outside of the traveled way	**NOT RECOMMENDED**
Disadvantages	• Driver and passengers may have to exit their vehicle into the traveled way • The parking maneuver takes more time than angle parking • Some drivers must execute maneuver multiple times • Interruption of through movement depending upon width of cross section	• The driver leaving the space has limited visibility to the rear • Empty spaces are hard to detect by approaching drivers resulting in stop and go movements • Through drivers decrease speed in anticipation of conflict movements (can be advantageous for traffic calming)	**NOT RECOMMENDED**

Source of Images above: Google Earth

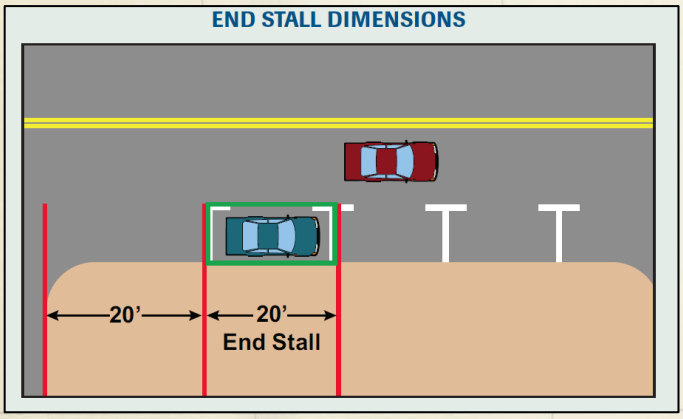
Parallel Parking

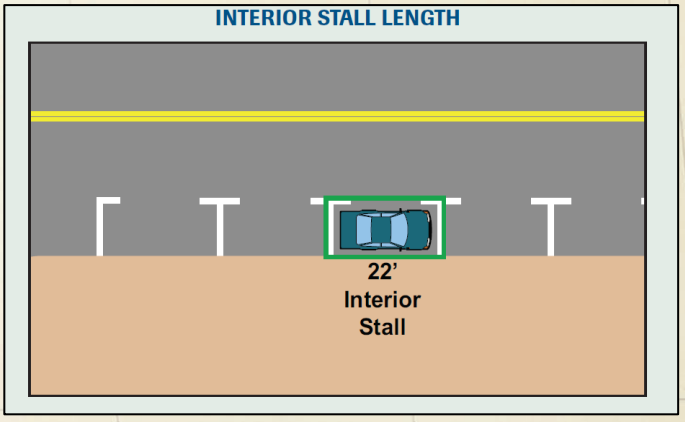
To mitigate crash potential at parallel, on-street parking locations, SDDCTEA recommends the following practices:

1. **Delineate the parking spaces with white pavement markings.** This maximizes the capacity of on-street parking and allows for more uniform spaces which makes it easier for motorists to identify empty spaces when attempting to park. Parallel parking stalls should be defined by white lines extending perpendicular from the curb, for a distance of 8 feet. Generally, end stall lines are L-shaped and interior stall lines are T-shaped.

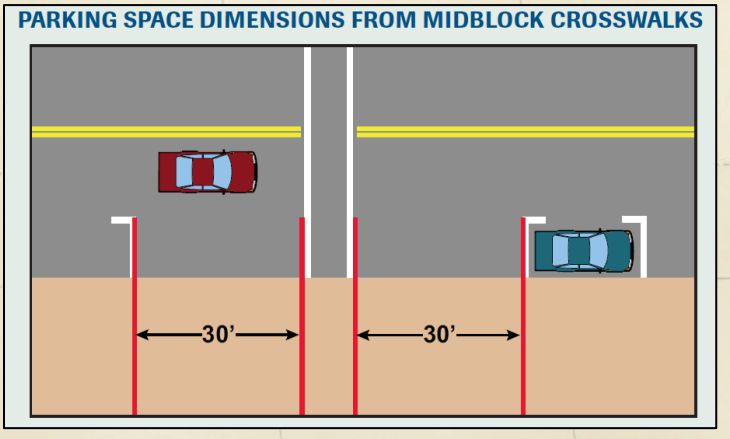


2. **Utilize a 20-foot end stall and a 22-foot interior stall to allow for sufficient maneuvering room.** There should also be a minimum of 20 feet between an end stall and a curb opening or intersection, assuming there is no marked crosswalk and there is no sidewalk leading to an implied (i.e., unmarked) crosswalk.





3. **Apply a 30-foot buffer zone between stalls and crosswalks.** This maximizes visibility between pedestrians and motorists and applies to crosswalks located at intersections and midblock.



As an option to the 22-foot interior stalls, a 12-foot buffer can be applied between spaces, at every other space. These buffer zones should consist of a white rectangle with white interior striping oriented in the direction of travel. While this reduces the parking capacity along the roadway, it can reduce delays and crash potential since motorists spend less time hindering through traffic while finding or maneuvering into a parking space. Note that the parking stalls can be reduced to 18-feet since the maneuvering space is provided in the buffer zone.

Source: Google Earth

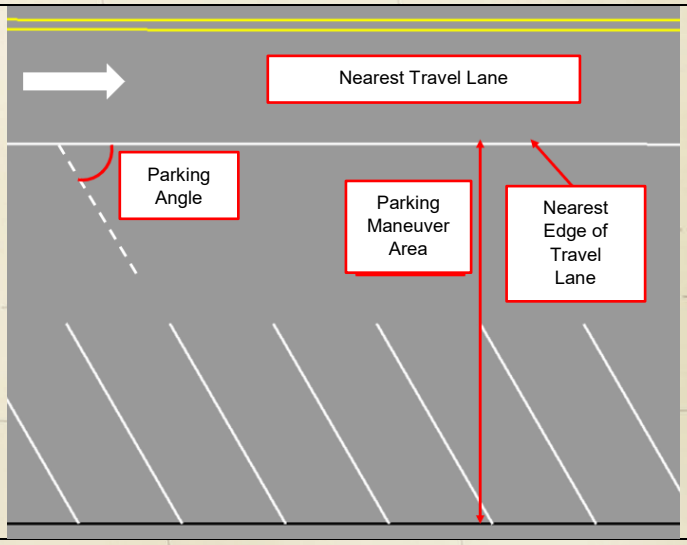
Angle Parking

As discussed previously, on-street angle parking is not preferable to parallel parking and should be discouraged. If an installation requests to use angle parking, a qualified engineer should determine that parked vehicles would not adversely affect the available intersection sight distance and additional travel lanes are not required for the existing traffic volumes to achieve a satisfactory level of operation. When implementing angle parking, the following practices should be used to mitigate crash potential.

1. **Utilize the parking angles and minimum parking maneuver areas shown below.** Following the guidelines below ensure safer and more efficient maneuvering into and out of the angled spaces.

Parking Angle*	Minimum Parking Maneuver Area**
30-degrees	26-feet
45-degrees	30-feet
60-degrees	37-feet

* The angle that vehicles on the nearest travel lane need to turn to the right to park in the center of a parking stall.
** The perpendicular distance between the right edge of the nearest travel lane and the front edge of the parking stalls.



2. **Implement back-in angle parking.** Back-in angle parking requires the motorists to enter the parking stall by pulling past the parking stall and backing into the stall rather than entering the stall head on. This makes angle parking similar to parallel parking, but with fewer maneuvers. The advantages associated with this type of parking are shown below.

    a. Less maneuver space required.
    b. No blind backing into traffic.
    c. Better visibility of bicycles.
    d. Curbside loading.
    e. Vehicle doors open towards curb.
    f. Easy and safe exit from space.
    g. Improves ability to locate an empty parking stall.

If using back-in angle parking, install special BACK-IN ANGLE PARKING ONLY signs along the roadway. (This would be a modified parking-series sign with green legend and border on a white background.).

Source: City of Wauwatosa, Wisconsin

Summary of Best Practices

In general, provide off-street parking as opposed to on-street parking whenever possible to reduce crash potential. To maximize safety with off-street parking, use the following practices.

Off-Street Parking

- Incorporate one-way driving aisles to reduce conflicts but ensure that pavement markings and/or signs are used to inform motorists of the correct travel direction.
- Align the driving aisles perpendicularly to the building unless this would result in aisles less than 130 feet in length; in this situation, the aisles should be oriented parallel to the building to efficiently utilize the available space and pedestrian pathways should be incorporated to facilitate pedestrian flow.
- Ensure that signs and pavement markings are properly maintained and meet the MUTCD's retroreflectivity requirements.
- Follow the guidelines in SDDCTEA's Pamphlet 55-17 when designing lighting systems to maximize visibility between motorists and pedestrians.
- Provide an end cap (i.e., clear space) at the end of each driving aisle with either white paint or a raised end island.
- Ensure that low-height landscaping is used to avoid obstructing the line of sight within the parking lot.
- Provide adequate grading of surface lots to minimize the possibility of low or flat spots.
- Use marked crosswalks when they are warranted and where the majority of pedestrians are expected to cross.
- Design the parking lot so that the building's front and the roadway (i.e., outside circulatory roadway, street, or highway) are on opposite ends of the parking lot. For existing parking lots with a roadway adjacent to the building's front, provide alternate access points and routes if necessary, and close the roadway to vehicular traffic to create a pedestrian zone.
- Where possible, enhance the main internal pedestrian routes with a 5-foot wide walking area between parking stalls.

On-street parking is not desirable on arterial or collector roads that are designed to move high traffic volumes at moderate or high speeds, but can be used on lower speed roadways, such as residential streets, to calm traffic. To maximize safety with on-street parking, use the following practices.

On-Street Parking

- Avoid perpendicular parking entirely; only utilize parallel or angle parking.
- Parallel parking
  - Delineate the parking spaces with white pavement markings
  - Utilize a 20-foot end stall and a 22-foot interior stall to allow for sufficient maneuvering room.
  - Apply a 30-foot buffer zone between stalls and crosswalks.
- Angle parking
  - Utilize a 30, 45, or 60-degree parking angle with a 26, 30, or 37-foot maneuver area, respectively.
  - Implement back-in angle parking with the proper BACK-IN ANGLE PARKING ONLY signs posted along the roadway to inform motorists.

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WEBSITE: http://www.sddc.army.mil/sites/tea for pamphlets, bulletins and studies

Reference List

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