2014 MEDIAN HANDBOOK

FDOT

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATON
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SYSTEMS PLANNING

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1.0 Medians and their Importance for Safety

A restrictive median with well-designed median openings is one of the most important tools to create a safe and efficient highway system. The design and placement of median openings is an integral component of a corridor that manages access and minimizes conflicts.

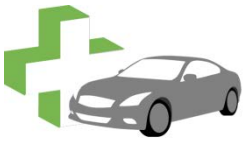
The AASHTO Green Book states, "A median is highly desirable on arterials carrying four or more lanes."

Medians are paved or landscaped areas in the middle of roadways that separate traffic traveling in opposite directions. Medians should be provided whenever possible on multi-lane arterial roadways. The documented benefits of raised medians are so significant that the Florida Department of Transportation (FDOT) requires medians for most new multilane facilities with over 40 mph in design.

Source : Plans Preparation Manual Volume 1 Chapter 2.2.2

This guide should help the professional with considerations for medians, median openings, and median design at intersections.

1.0.1 What are the Benefits of Medians?



Properly designed medians provide many benefits including:

Vehicular Safety — medians reduce crashes caused by traffic turning left, head-on and crossover traffic, and headlight glare, resulting in fewer and less severe crashes

Pedestrian Safety — restrictive medians provide a refuge for pedestrians crossing the highway. Fewer pedestrian injuries occur on roads with restrictive medians.

Operational Efficiency — medians help traffic flow better by removing turning traffic from through lanes. A roadway with properly designed medians can carry more traffic, which can reduce the need for additional through lanes.

Aesthetics – In addition to safety and operations, medians can improve the appearance of a corridor. If landscaped, the median can lessen water runoff and enhance air quality.

Restrictive medians help in both low and high traffic situations, but where traffic is high, the benefits are greater.

Properly implemented medians and median openings will result in improvements to traffic operations, minimize adverse environmental impacts, and increase highway safety. As traffic flow is improved, delay is reduced as are vehicle emissions. In addition, corridor efficiency/throughput and fuel economy are increased, and most importantly, crashes are less numerous and/or less severe.

1.1 How Medians Fit in with Access Management

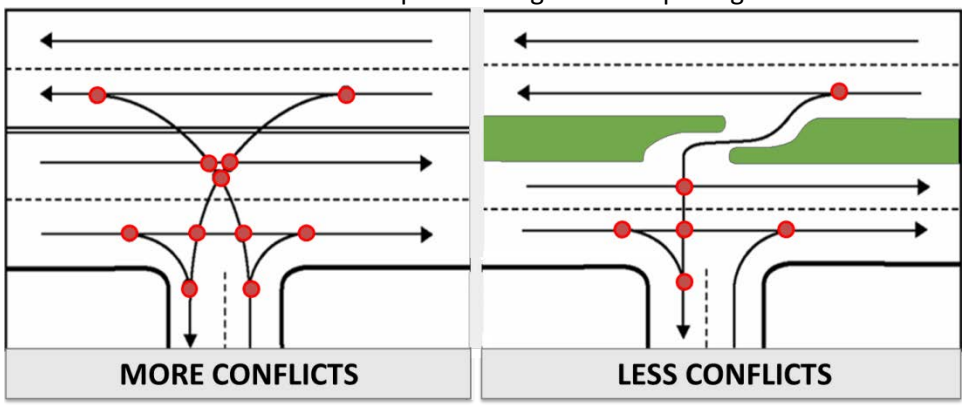
The location and design of medians and their openings will depend on the function of the roadway, to provide appropriate access to the driveways, intersections, traffic signals and freeway interchanges that connect.

1.1.1 What is the Function of a Median Opening?

In order to properly place and design median openings, you should consider the needed function of the opening

- Median openings can provide for cross traffic movement.
- Median openings can allow left turns and U-turns from the highway

Exhibit 1
Reduce conflict points using median openings



A typical median opening that allows all turns has numerous conflict points. One way to limit the number of conflicts is through the design of median openings. The example on the right is a “directional” median opening serving a side street that allows for left-turns from the major street but prohibits left-turns from the minor street. This is a design which greatly reduces the conflict points by limiting the number of allowed turning movements. Through use of restrictive medians, most driveways along the corridor become right-in/right-out driveways.

Exhibit 2
Separating conflict points benefits all modes of transportation

Of course, pedestrians, cyclists, and transit riders are all users of the roadway. When conflict points are well managed, all the users of the roadway benefit from a better environment.

1.1.2 The Location of Median Openings

The location of median openings has a direct relationship to operational efficiency and traffic progression.

To assure efficient traffic operations, full median openings should only be at locations which are thoughtfully placed along the corridor. If median locations are properly spaced when signalized, traffic will flow at efficient and uniform operating speeds.

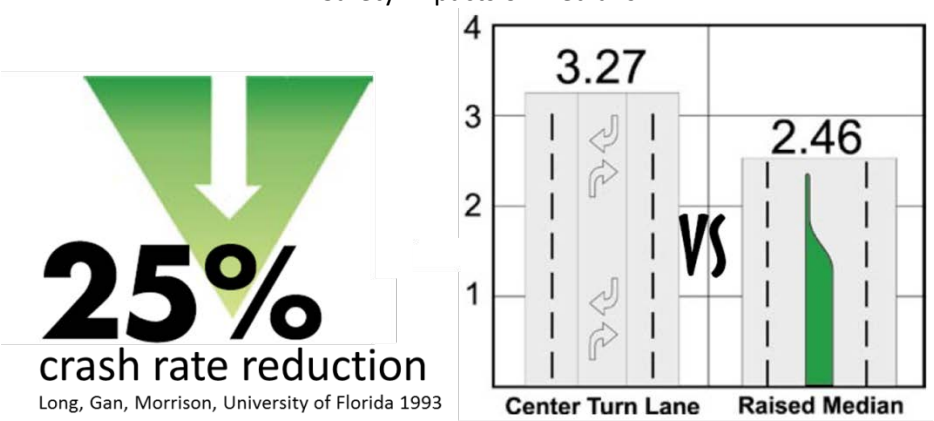
Full median openings should be limited to the following situations:

- Signalized intersections or those expected to be signalized.
- Intersections that conform to the adopted median opening spacing interval, or are separated from neighboring median openings so they will not interfere with the deceleration, queuing or sight distance of the full opening.
- Divided roadways where the traffic volume provides numerous opportunities for left-turns and crossing maneuvers from the intersecting access connection to be made with little or no delay.
- Decision sight distance to vehicles on the roadway is sufficient for
  (1) drivers to observe activity at the median opening and to proceed without decelerating if the median opening is unoccupied, and
  (2) for a driver making a left-turn into the roadway to do so without interference with traffic on the roadway.

1.1.3 Medians Increase Safety – Case Studies

Research has shown that restrictive medians have a significant safety benefit. In 1993, an evaluation of urban multilane facilities in Florida revealed that the crash rate for corridors with restrictive medians is 25% lower than those with center turn lanes. [1]

Exhibit 3
Safety Impacts of Medians



Before and After Study

Research performed in 2012 shows an improvement in safety when corridors were retrofitted with restrictive medians to replace center turn lanes (i.e. going from a 5-lane undivided section to a 4-lane divided facility, or a 7-lane undivided section going to a 6-lane divided roadway.)[2]

Raised medians improve safety for all modes of transportation

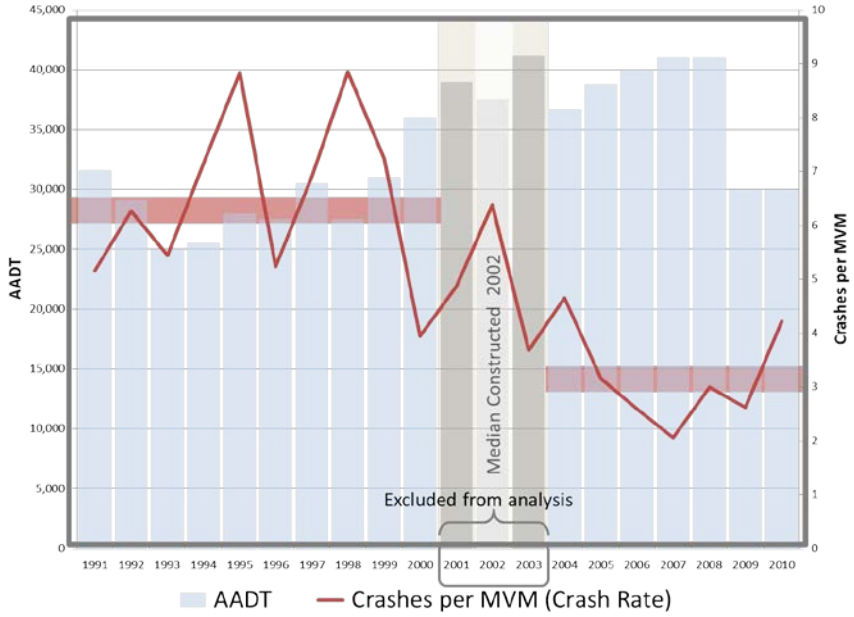
One of the case studies for this analysis was Apalachee Parkway in Tallahassee. Exhibit 4 shows that in 2002 a restrictive median was placed along a one and a half mile section of Apalachee Parkway. The research states, "Overall, a reduction of 48.1% in total crashes was observed in the three-year after period."

1
Safety Impacts of Selected Median and Access Design Features
Gary Long, Ph.D., P.E.,Cheng-Tin Gan, Bradley S. Morrison

2
Before and After Safety Study of Roadways Where New Medians Have Been Added
Priyanka Alluri, Albert Gan, Kirolos Haleem, Stephanie Miranda, Erik Echezabal, Andres Diaz, and Shanghong Ding

Exhibit 4

Before and After Safety Study of Apalachee Parkway Tallahassee Florida

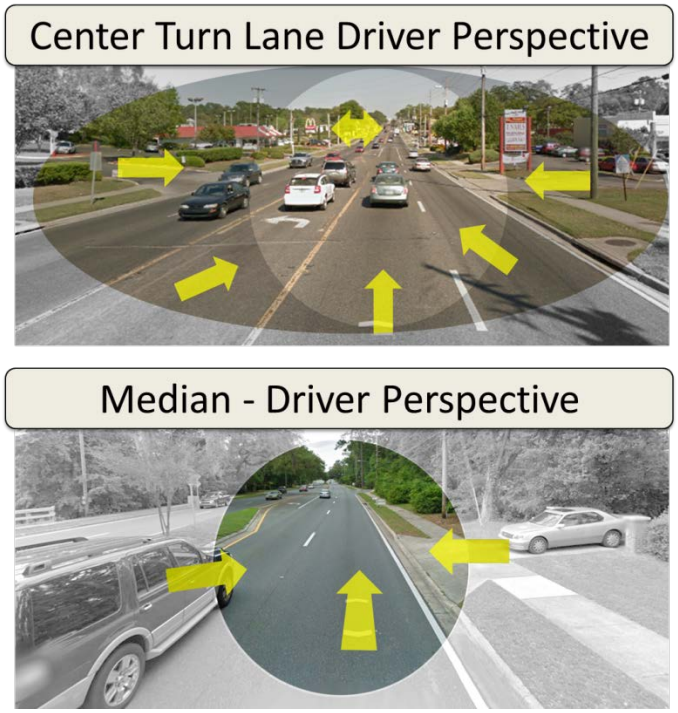


1.1.4 Driver Information Load

Medians make the road safer by minimizing the number of potential conflict points the corridor user must monitor at a single time. In the terminology of human factors research, "Driver Information Load" is decreased by having medians. An example is shown in Exhibit 5.

Exhibit 5

Comparison of driver information load for center turn lane and median



In the roadway with a center turn lane, the driver must scan the facility from numerous directions to monitor potential conflict points.

Exhibit 6

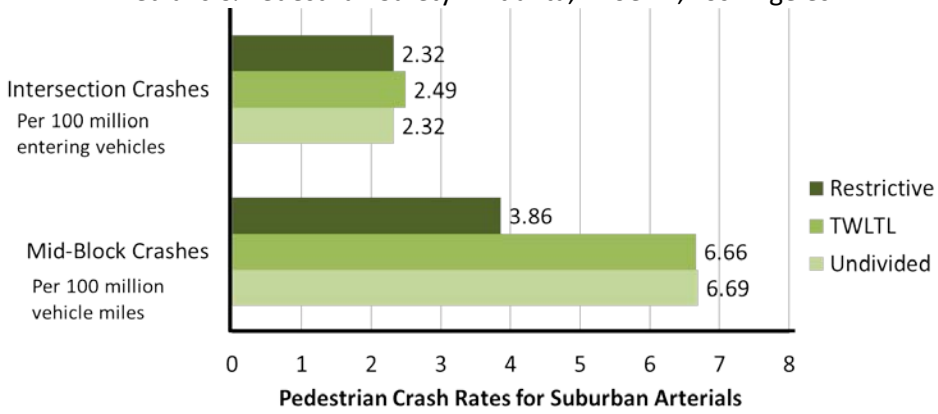
Pedestrian are more vulnerable in center turn lanes

The task of a pedestrian crossing the street is more challenging without a restrictive median. Pedestrians need to be aware of drivers in both directions and are not as visible to a driver traveling at a higher speed.

Other research has shown that the presence of restrictive medians makes the environment safer for pedestrians. Pedestrians were nearly half as likely to be involved in a mid-block crash on facilities with restrictive medians as shown in Exhibit 7. [3]

Exhibit 7

Medians & Pedestrian Safety – Atlanta, Phoenix, Los Angeles



Brian Lee Bowman, Robert L. Vecellio 1994 [3]

[3] Investigation of the Impact of Medians on Road Users - Brian Lee Bowman, Robert L. Vecellio 1994

1.2 The Highway Safety Manual

The Highway Safety Manual (HSM) is a scientifically based guide that predicts the impacts of safety improvements on the highway system. The HSM is a document of the American Association of State Highway and Transportation Officials (AASHTO). This document conclusively demonstrates the safety benefits of access management, especially the provision of restrictive medians. It also provides a method to use the safety impact projections to help promote restrictive medians, even when the construction or right-of-way costs are significantly greater.

The HSM Part C (Chapters 10-12) contains the information and procedure for this computation work.

1.2.1 Example Using Safety Performance Functions (SPFs)

Using the information in Chapter 12 of the HSM, the following example that demonstrates how it could be used to predict the safety benefits. You have been given the job of evaluated the benefits of a raised median. This example evaluates the safety benefits for converting a 5-lane section (two lanes in each direction with a center turn lane) into a 4-lane facility with a restrictive median. The corridor is one (1) mile in length and has annual average daily traffic (AADT) volume of 30,000 vehicles per day. Exhibit 8 graphs the relationship between the predicted crash frequency per mile and the AADT of different facility types. Exhibit 8 is based on the equations in the HSM called Safety Performance Functions (SPFs). These estimate the expected average crash frequency as a function of traffic volume and roadway characteristics (such as AADT, number of lanes, median width, intersection control, etc.).

Exhibit 8

SPF for urban highway 5-lane with center turn lane roadway segments

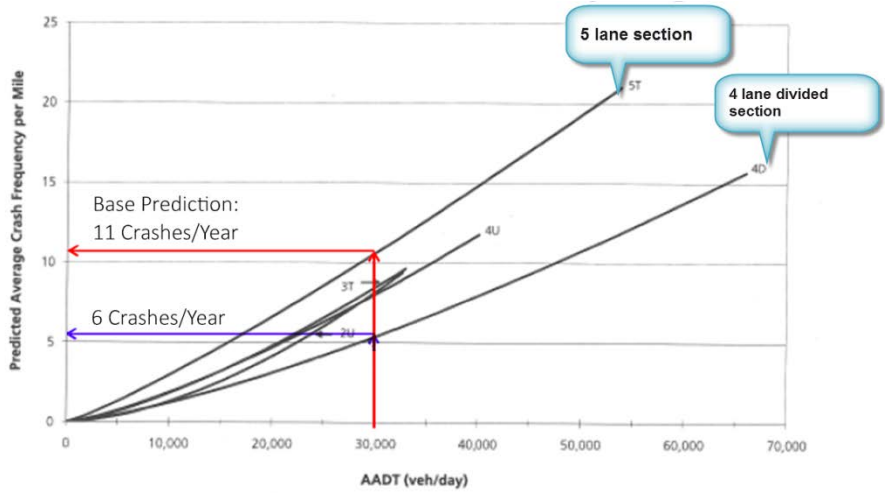


Figure 12-3. Graphical Form of the SPF for Multiple Vehicle Nondriveway collisions (from Equation 12-10 and Table 12-3)

Using the above method, adding a restrictive median is expected to reduce crashes by 5 per year (11-6 = 5).

Most corridor reconstruction safety project analyses are performed on a multi-year basis. Therefore, an examination of the cumulative safety benefits is more appropriate. We look at a longer view because the roadway improvement might serve the public for 15 to 20 years. A benefit-cost analysis provides more insight into the long-term benefits of restrictive medians.

1.2.1 Benefit/Cost Ratio Analysis

FDOT District 7 Office (greater Tampa area) completed an analysis on a resurfacing proposal. To improve the existing conditions, the District found that they would need to spend $2,200,000 for right-of-way to improve to a 4-lane roadway with restrictive medians compared to a projected cost of $600,000 to improve to a 5-lane roadway with TWLTL.

Exhibit 9 provides the estimated crash costs associated with the two alternatives using the methods in Chapter 12 of the HSM.

Exhibit 9
Estimated crash costs for different facility types

Crash Type	4-Lane Divided	5-Lane Center Turn Lane
Multi-Vehicle	$1,492,000	$2,856,000
Single Vehicle	$155,000	$235,000
Driveways	$561,000	$3,337,000
Total	$2,208,000	$6,428,000

The Benefit/Cost Ratio is found by calculating the difference between the benefits and costs of each alternative. In this example, taking the difference in crash costs divided by the extra right-of-way costs, you find the benefit cost ratio to be 2.64. This shows that the expenditure of the extra funds for right-of-way is well justified by the savings in crash costs over the 20 year period.

Exhibit 10
Calculate Benefit/Cost Ratio

Benefit/Cost Ratio: 4-lane Divided to 5 lane Center Turn Lane		
4-lane crash costs	$2,208,397	$4,219,132
5-lane crash costs	$6,427,529	
4-lane right of way costs	$2,200,000	$1,600,000
5-lane right of way costs	$600,000	
	B/C =	**2.64**

$$\mathbf{B/C} = \frac{\boldsymbol{Societal\ Benefit}}{\boldsymbol{Additional\ Cost\ to\ Build}} = \frac{\$\mathbf{4,219,132}}{\$\mathbf{1,600,000}} = \mathbf{2.64}$$

1.3 FDOT Policy on Medians and Median Openings

Median opening decisions are guided by the following principles:

- **Traffic Safety**
- **Traffic Efficiency**
- **Functional Integrity**

1.3.1 Rule 14-97

Administrative Rule Chapter 14-97 establishes the seven classifications for state highways that contain separation standards for access features. Essentially, FDOT determines which roads are the most critical to providing highly efficient, higher volume traffic. These facilities are classified with the highest standards.

Medians and median openings are regulated through the requirement for a restrictive median in certain classes. For those classes, spacings between median openings are regulated. The Access Management Standards and how these are measured are found in Exhibit 11. Class 1 applies specifically to freeways, so it is not included in this exhibit.

Exhibit 11

Access Management Standards From Rule 14-97

Class	Medians	Median Openings		Signal	Connection	
		Full	Directional		More than 45 mph Posted Speed	45 mph and less Posted Speed
2	Restrictive w/Service Roads	2,640	1,320	2,640	1,320	660
3	Restrictive	2,640	1,320	2,640	660	440
4	Non-Restrictive			2,640	660	440
5	Restrictive	2,640 at greater than 45 mph Posted Speed 1,320 At 45 mph or less Posted Speed	660	2,640 at greater than 45 mph Posted Speed 1,320 At 45 mph or less Posted Speed	440	245
6	Non-Restrictive			1,320	440	245
7	Both Median Types	660	330	1,320	125	125

It is critical to know what access classification and posted speed limit has been assigned to the highway/road segment under consideration and to determine what roadway features and access connection modifications are appropriate to adhere to the access management process. The Florida Transportation Information DVD is an easy to use resource to determine the access management classification and posted speed limits for all FDOT roads, as shown in Exhibit 12.

Exhibit 12

Florida Transportation Information DVD Access Management Classifications

The FTI DVD is available free from FDOT. Select Access Management from the View menu to display this screen.

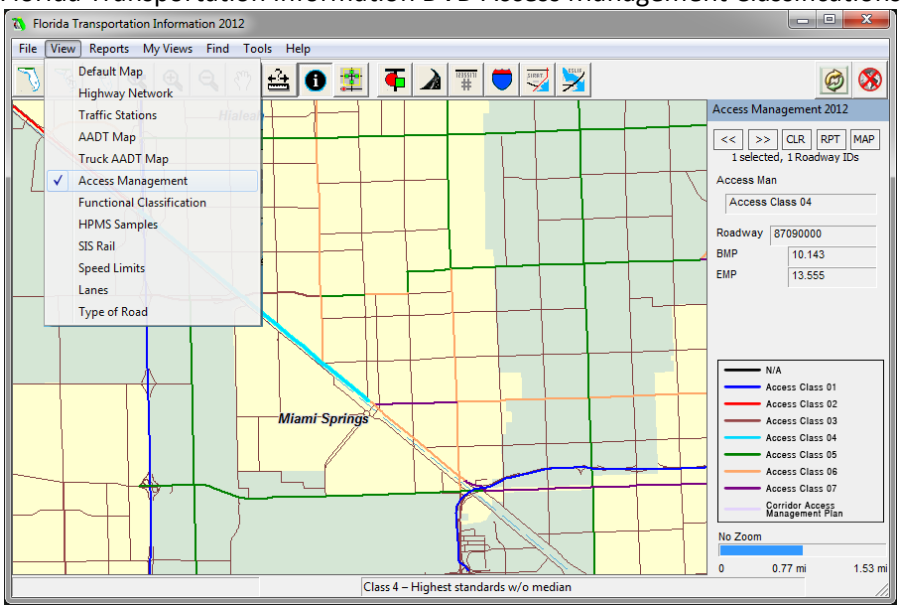
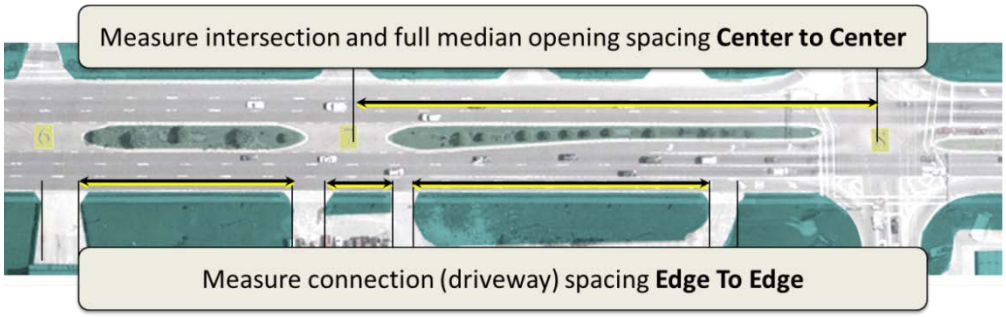
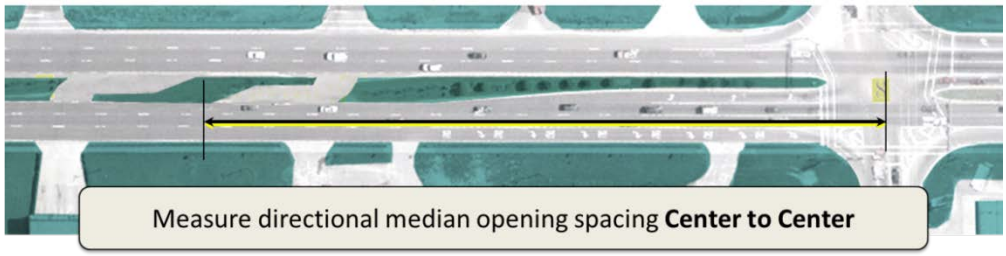


Exhibit 13 shows how to measure the distance shown in FDOTs standards. Full median openings are measured from the center of the median opening to the center of the next full median opening (or intersection.) Driveways are measured from one edge of a driveway to the nearest edge of the next driveway. Where a pair of directional median openings is used, the distance is typically measured from the center of a full median opening to the center of the pair of openings.

Exhibit 13

How to apply spacing requirements from Rule 14-97





Where a pair of directional median openings is used, the distance is measured from the center of a full median opening to the center of the pair of openings.

1.3.2 Multi-lane Facility Median Policy

Multi-lane facility median policy is an integral part to roadway access management

All multilane Strategic Intermodal System (SIS) facilities shall be designed with a raised or restrictive median. All other multilane facilities shall be designed with a raised or restrictive median except four-lane sections with design speeds of 40 mph or less.

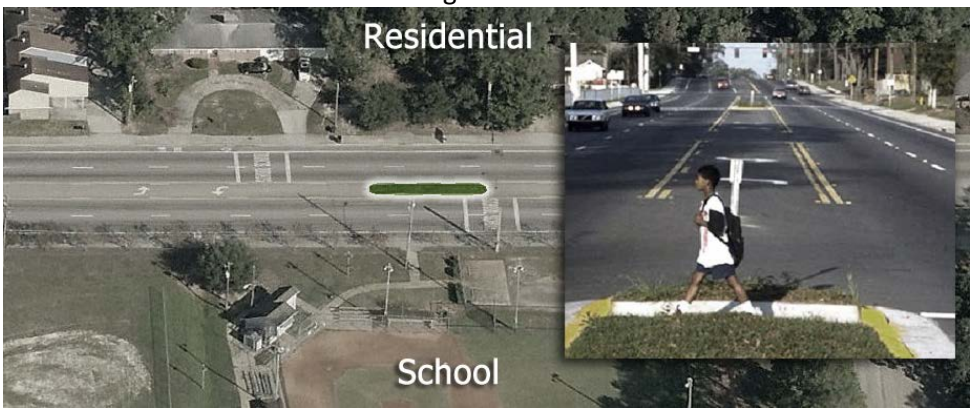
Facilities having design speeds of 40 mph or less are to include sections of raised or restrictive median for enhancing vehicular and pedestrian safety, improving traffic efficiency, and attainment of the standards of the Access Management Classification of that highway system.

Multilane Facility Median Policy
Topic #625-000-007 January 1, 2013
Plans Preparation Manual, Volume I
Design Geometrics and Criteria 2.2.2.

Since 1993, the **Multi-lane Facility Policy** essentially directs all FDOT multilane projects over 40 mph in design speed to have some restrictive median treatments.

It also directs our designers to find ways to use restrictive medians in all multi-lane projects, even those below the 40 mph design speed. An example of a small pedestrian refuge that could be used on a 5-lane section is shown in Exhibit 14.

Exhibit 14
Pedestrian refuge on a 5-lane section



What is the impact of redirecting left turns?

One of the impacts of these standards is the concentration of more left turn and more U-turns. This requires careful planning of well designed, well placed median openings. In response to this, FDOT created the Median Opening and Access Management Procedure.

1.3.3 Median Opening and Access Management Procedure: 625-010-021

Adhering to the median opening spacing standards of Rule 14-97 can, at times, pose a practical problem. Therefore, FDOT developed a process to analyze deviation from the standards found in the Rule. The process allows project managers/permits staff a 10% deviation from the standards for full median openings and gives complete flexibility to project managers/permits staff on decisions involving directional median openings as long as they meet minimum traffic engineering standards for storage, deceleration, sight distance, and maneuverability. All deviations greater than 10% for full median openings must go to the District Access Management Review Committee (AMRC) for further study and recommendation. For minor deviations:

- Decisions can be made by a responsible engineer
- 10% deviation for "full" openings allowed
- Directional openings are decided on a "case-by-case" basis

It is important to note that even deviations of less than 10% might be problematic and create operational issues. Districts can follow a more strict decision making policy and process.

Each District has an AMRC to consider deviations from Rule 14-97 standards. The decisions of the AMRC are guided by the following principles of the process:

Decision making principles

- **Traffic Safety**
- **Traffic Efficiency**
- **Functional Integrity**

1.3.4 Recommended Queue Storage Requirements

A critical measure for adequate median opening design is left-turn lane queue storage.

Site or project specific projections of queue storage should be used at all critical intersections. Due to the variable nature of left-turn demand, actual volumes should be collected and reviewed in many cases. Designs should also include a factor of safety to account for any uncertainty in demand. [4]

Queue Storage

Where left turn volume is unknown and expected to be minor [5]

- Urban/suburban minimum = 4 cars or 100 ft.
- Rural/small town minimum = 2 cars or 50 ft.

[4] Median Opening and Access Management Procedure (FDOT) Topic No.: 625-010-020
[5] Plans Preparaton Manual Vol. 1- 2.13.2 Queue Length for Unsignalized Intersections

1.3.5 Conditions for More Flexibility

The process also gives guidance for where flexibility should be considered. These would be favorable conditions for approving an deviation of a median opening: [6]

- Opportunities to alleviate significant traffic congestion at existing or planned signalized intersections.
- Opportunities to accommodate a joint access serving two or more traffic generators.
- Existence of control points that cannot be relocated such as bridges, waterways, parks, historic or archaeological areas, cemeteries, and unique natural features.
- Where strict application of the median opening standards in 14-97.003(1) Figure 2, would result in a safety, maneuvering, or traffic operational problem.
- Where directional opening would replace existing full service median opening.

1.3.6 Conditions for Less Flexibility

Limited Flexibility

The following conditions may provide less flexibility for deviation from the standards:

- Full median openings and signals
- Median openings in a high crash segment or intersection, unless a safety benefit can be clearly shown
- Situations where circulation can be provided through other alternatives

Unfavorable Conditions

These unfavorable conditions provide less flexibility for deviation from the standards:

- Openings in functional area of intersection
- High crash locations
- Where alternatives exist
- Where any unsignalized intersection would be unsafe (such as close to the Interchange at SR 436 and I-4 in Altamonte Springs shown in Exhibit 15)

Other Considerations and priorities

Other considerations that would influence the decision where median openings would be located include:

- Where strict adherence would cause safety problem
- Where a directional would replace a “full” opening
- Emergency vehicle openings

[6] Median Opening and Access Management Procedure (FDOT) Topic No.: 625-010-020

Exhibit 15

Interchange of SR 436 and I-4 in Altamonte Springs

1.3.7 Retrofit Multi-lane Multilane Roadways with Center Turn Lanes

Retrofit center turn lanes with medians

All 7 lane (6-lane roadways with a two-way center turn lane) roadway sections should be given the highest priority for retrofit.

Existing 5 lane sections and those facilities over 28,000 in daily traffic should be given high priority for retrofit.

1.3.8 Florida Statute 335.199 – Public Involvement

Effective November 17, 2010, a new Florida Statute had impacts on the way the FDOT works with the public in regards to median changes. Generally, whenever the FDOT plans to add a median, or close a median opening, new requirements not present in our previous standards must be followed.

Overarching Principle

FS 335.199

"Whenever the Department of Transportation proposes any project on the State Highway System which will divide a state highway, erect median barriers modifying currently available vehicle turning movements, or have the effect of closing or modifying an existing access to an abutting property owner, the Department shall notify all affected property owners, municipalities, and counties at least 180 days before the design of the project is finalized."

FS 335.199 Requirements

- Notify, in writing, the Chief Elected Official of the City and/or County as well as property owners
- Conduct at least one public hearing
- Local governments should notice impacted property owners at least 180 days before the design of the project is finalized.

Further guidance has been provided, and is expected to change with time and experience. The following is guidance written in December 2010:

Brian Blanchard's guidance on SB 1842 regarding changes to medians: December 21, 2010

> Senate Bill 1842 requires the Department to notify all affected property owners and local governments when it proposes projects on the State Highway System that will divide a state highway, erect median barriers modifying currently available vehicle turning movements, or have the effect of closing or modifying an existing access to an abutting property owner. The notification must occur at least 180 days before the project design is finalized. Related to these projects, the bill requires FDOT
>
> (a) to consult with applicable local government on its final design and allows the local government to present alternatives to relieve impacts to commercial business properties;
>
> (b) to hold at least one public hearing to determine how the project will affect access to businesses and the potential economic impact of the project on the local business community; and
>
> (c) to take all comments into consideration in final design of the project.
>
> Brian Blanchard SB1842

This bill applies to any proposed work program project beginning design on or after November 17, 2010. The language of the bill states "whenever the Department of Transportation proposes any project**", so this language does not apply to permit applications. However, for permit applications that affect medians and median openings,** the effected people and businesses should be informed and involved by the permittee as soon as possible.

This provision requires at least one public hearing (advertised and recorded). Many times the decision whether to construct a median is made during the Planning and/or Efficient Transportation Decision Making (ETDM)/Project Development & Environment (PD&E) Phases of a project. During these phases of a project, the FDOT works with a community with an emphasis on their participation in the decision-making process concerning the project's need and basic concepts. These phases involve local government representatives, public input, business interest input as well as other interested parties along the corridor and others outside the corridor. The ETDM/PD&E phases document these activities for major projects throughout. As this phase progresses, stakeholder input is sought and may involve multiple mailings, meetings and workshops depending on the scope of the project. **This process will not change and in most cases will satisfy the 180 day hearing requirement. Since only major studies like an EIS, EA, and major Type 2 Categorical Exclusions are required to have a formal hearing, a hearing during the final design phase shall be conducted when one hasn't been conducted during the ETDM/PD&E phase**.

For on-going design projects, additional outreach to the community is provided through implementation of our Community Awareness Plans, which include notification of property owners and occupants.

If a final design plan has been inactive (on-the-shelf) for a time long enough for major changes in roadside business ownership and occupancy, FDOT staff will work with the new owners and residents to inform them of the upcoming changes and allow for a dialogue before construction begins.

The Department will continue to provide property owners Access Management Notices with project plans and Chapter 120, Florida Statutes rights. The Access Management Review Committees will also continue to meet to provide property owners the ability to voice their concerns before the Department.

1.3.9 Other FDOT Criteria and Standards

Other FDOT documents containing important standards and criteria for medians and median opening design are:

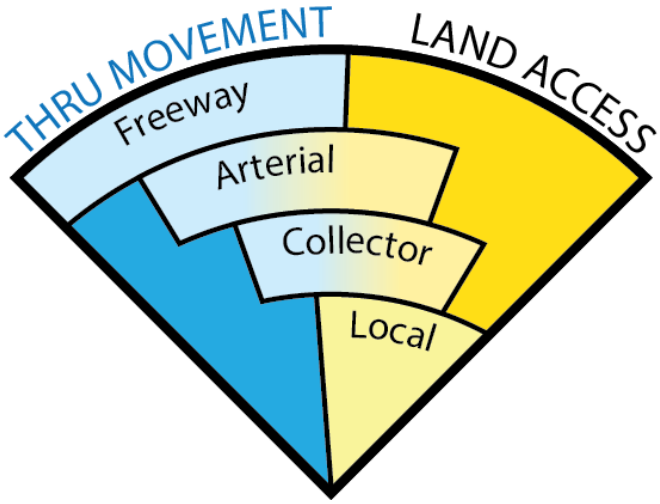
- Plans Preparation Manual
- Standard Index Design Standards
- Florida Highway Landscape Guide

2.0 Importance of Roadway Functional Classification

Highway functional classification means classifying highways with respect to the amount of access or movement they are to provide and then designing and managing each facility to perform that function.

> "A prominent cause of highway obsolescence is the failure of a design to recognize and accommodate each of the different trip levels of the movement hierarchy." AASHTO Green Book (Chapter 1)

Exhibit 16
Balancing through movement and land access



There is no clear distinction between each of the functional classes or direct correlation to define a corridor as a local, collector, or arterial facility. The four basic functional classes represent a continuum of facilities that range from unrestricted access (no through traffic) to complete access control (no local traffic). Applying the principles of access management through well-designed medians and median openings will improve the function of corridors by maximizing the facility's ability of the roadway to safely move people and goods through the heart of the system.

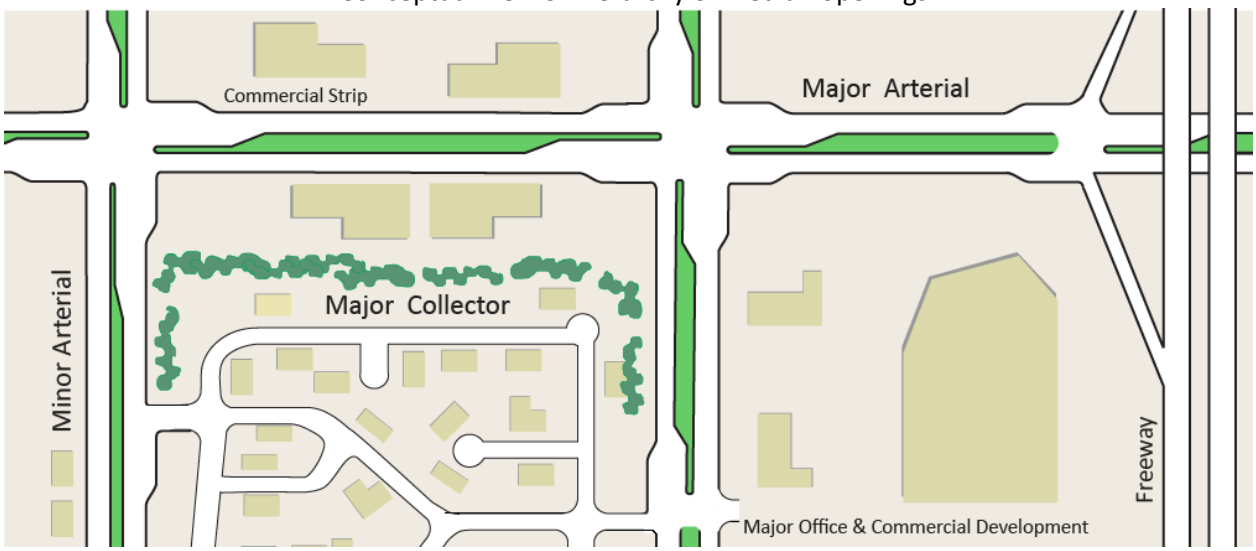
An important access management principle is that facilities should ideally not connect directly to another facility with a significantly higher functional classification. For instance, a local road may be connected to a major collector, and a major collector may be connected to a minor arterial, but a local road should generally not connect directly a major arterial.

> *"The extent and degree of access control is thus a significant factor in defining the functional category of a street or highway."* AASHTO Green Book 2011

2.0.1 Hierarchal Priority of Median Openings

In keeping with the principles of functional design adopted by the AASHTO Green Book, the choice of which opening is to be closed in order to resolve inadequate median opening spacing requires that the hierarchy or prioritization of the median openings be established.

Exhibit 17
Conceptual view of hierarchy of median openings



- Major arterial-to-major arterial (signal spacing can have large impact on interchange area)
- Arterial to large development (consider impacts if signalization needed later) Directional openings are desired unless impractical.
- Directional openings at two public and/or private connections.

Other U-turn/left-turn ingress should normally be given priority over left-turn movements out (egress) because ingress capacity is typically higher and produces less hazardous conflict than the left-turn out (egress) movement.

Source: Adapted from the course material notes of Virgil Stover.

For more information on roadway hierarchy:

- AASHTO Green Book, Chapter 1.
- Transportation and Land Development, Stover/Koepke

2.1 Median Opening Placement Principles

The basic concept used in median opening location and design is avoidance of unnecessary conflicts which result in crashes.

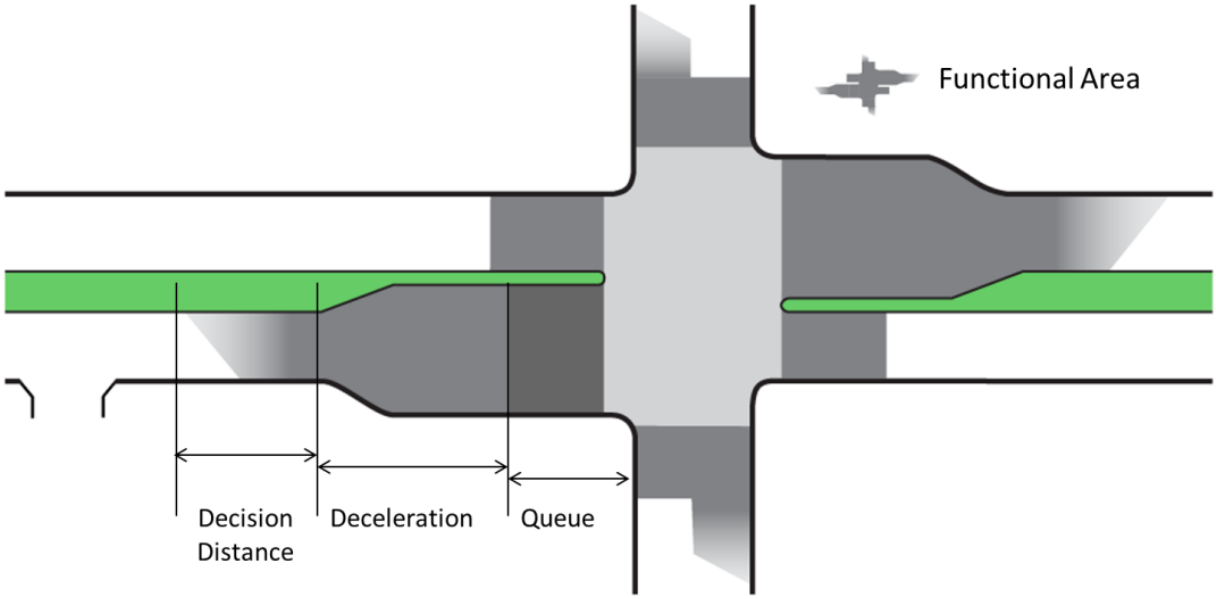
The unsignalized median opening is essentially an intersection. Properly designed, it will have an auxiliary lane allowing the left-turning vehicles to decelerate without interfering with the through movements of the leftmost through lane.

Important: The outside through lane is where most high speed traffic operates. Therefore, the potential of high speed crashes is the greatest in the through lanes. Before median opening placement is determined, it is important to know what speed, maneuvering distances, and storage requirements the project requires.

2.1.1 Placement Principles

- Follow the spacing criteria in Rule 14-97 as close as possible.
- Median openings should not encroach on the functional area of another median opening or intersection as shown in the following exhibit.

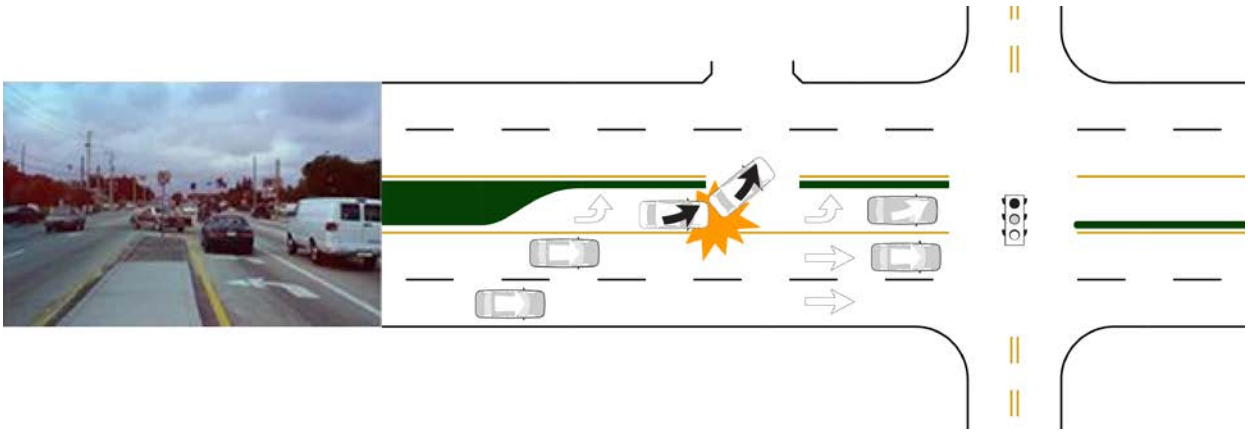
Exhibit 18
Functional area of an at-grade intersection



"Driveways should not be situated within the functional area of at-grade intersections."
AASHTO Green Book, Chapter 9, 2011

Exhibit 19

Median openings that allow traffic across left-turn lanes should not be allowed



A median opening within the physical length of a left-turn lane or lanes as illustrated in Exhibit 19 can create a safety issue. Such an opening violates driver expectancy.

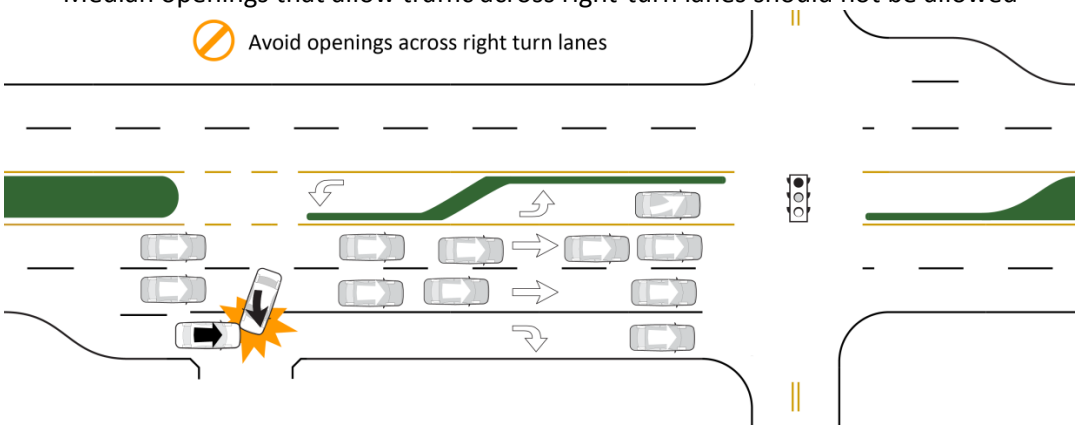
Avoid these movements

Median openings that allow the following movements should be avoided:

- across exclusive right turn lanes
- across regularly forming queues from neighboring intersections

Exhibit 20

Median openings that allow traffic across right-turn lanes should not be allowed



Avoid openings across right turn lanes due to the danger of queues accumulating across the opening area. When vehicle performs a left-turn across regularly forming queues, some queued drivers known as “Good Samaritans” often provide a gap to allow for the right-turning vehicle to cross oncoming traffic while drivers in other lanes do not provide a gap, causing an angle crash.

Exclusive right-turn lanes are most appropriate under the following conditions:

1. No median openings interfere,
2. The right-turn lane does not continue across intersections, and
3. No closely spaced high volume driveways

2.1.2 Avoid Median Opening Failure

Median opening failure can occur when critical components of the opening are not designed appropriately. This is usually due to the inadequate space for left-turn storage. This can result in excessive deceleration in the through lane, because vehicles are queued in the area of the left-turn lane needed for deceleration. Additionally, an inadequate left-turn lane can lead to vehicle queues extending into the through lane creating amore hazardous situation. Exhibit 21 illustrates this issue.

Exhibit 21
Examples of median opening failure

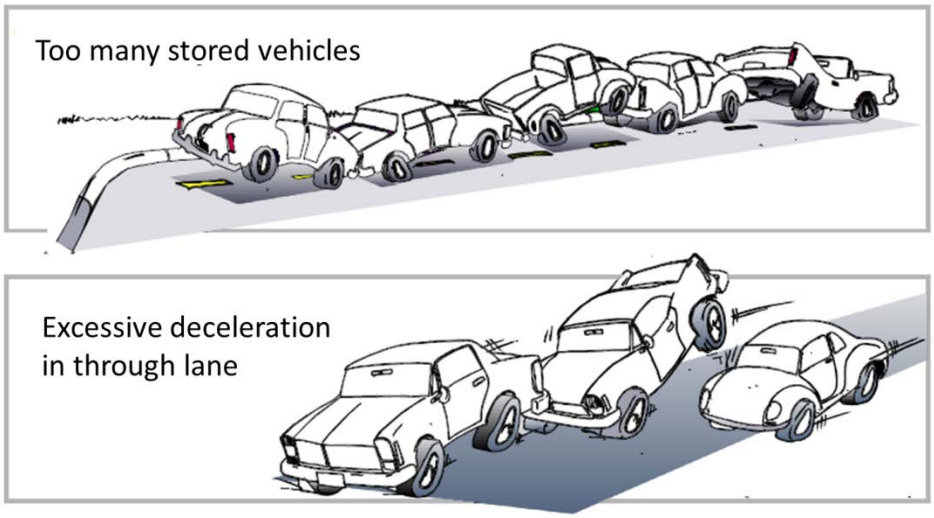
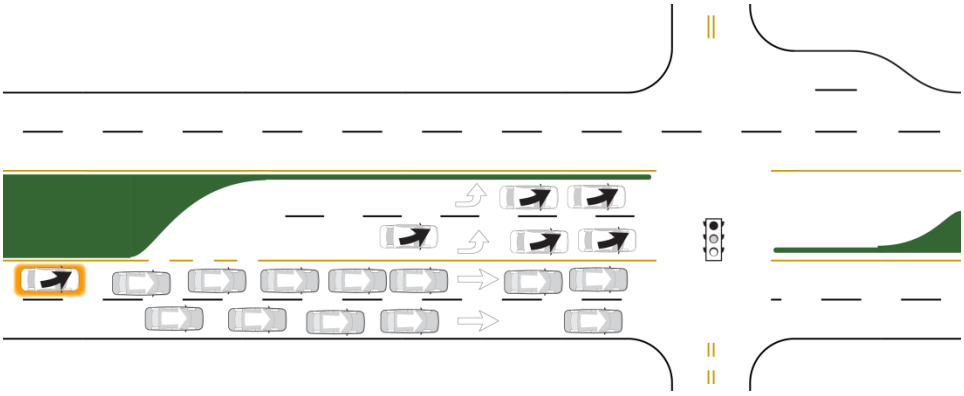


Exhibit 22
Through lane queue blocks entry into the left-turn lane

Watch out for this problem



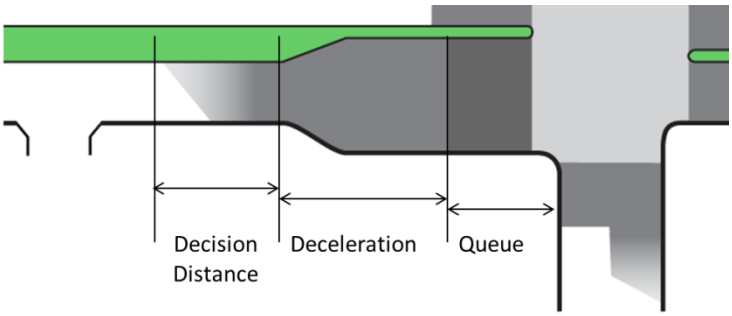
When the queue in the through traffic lane spills past the left-turn lane, turning vehicles are trapped in the queue, as illustrated in Exhibit 22. The left-turning vehicles are not able to move into the turn bay until the queue advances and often miss the left-turn signal phase which negatively impacts intersection efficiency. Dual left turn lanes may be more prone to this problem.

2.2 Parts of the Functional Area of an Intersection

The intersection functional area consists of three basic elements:

1) Distance traveled during decision time,
2) Maneuver-deceleration distance, and
3) Queue-storage distance.

Exhibit 23



2.2.1 Decision Distance

The perception-reaction time required by the driver to make a decision varies. For motorists who frequently use the corridor this may be as little as one second or less. However, unfamiliar drivers may not be in the proper lane to execute the desired maneuver and may require three or more seconds.

Suggested decision distances are shown in Exhibit 24.

Exhibit 24
Suggested Decision Distance

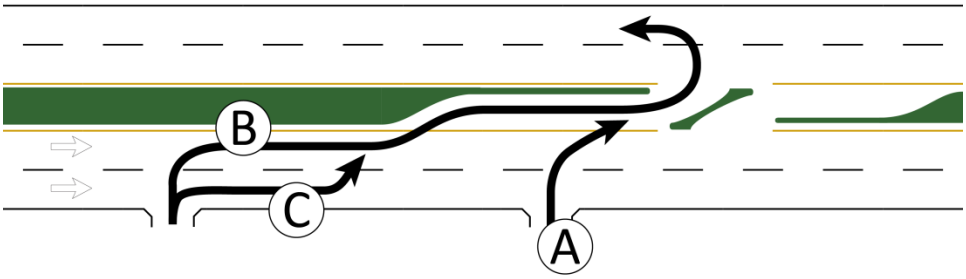
Area	Seconds	35 MPH	45 MPH	55 MPH
Rural	2.5	130 ft	165 ft	200 ft
Suburban	2.0	100 ft	130 ft	160 ft
Urban	1.0	50 ft	75 ft	100 ft

For more information on decision time: AASHTO Green Book or the Florida Intersection Design Guide 2013

2.2.2 Right Turn Weave Distance (Right Turn Weave Offset)

Vehicles turning right from a downstream driveway will need distance to weave if they are turning left at the next opening. Exhibit 25 shows the potential weaving patterns from having driveways close to median openings.

Exhibit 25
Weaving Patterns



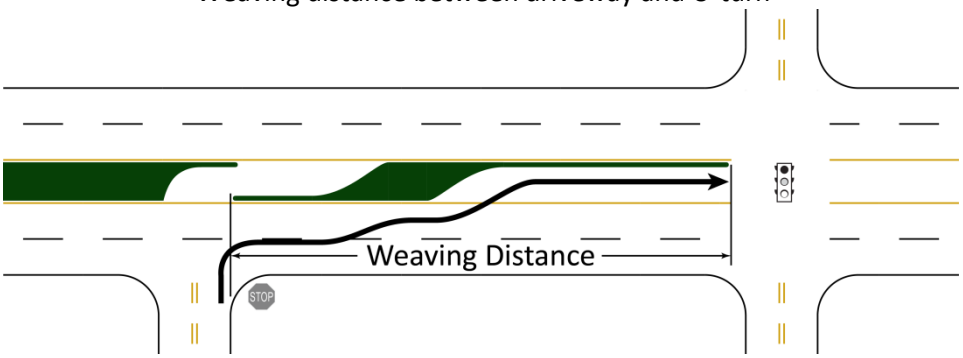
A Short separation:
Drivers select a suitable simultaneous gap in all traffic lanes and then make a direct entry into the left-turn/U-turn lane.

B Long separation, low volume approaching from the left:
Drivers select a simultaneous gap in all traffic lanes, turn right, and make a direct entry maneuver into the left through lane

C Long separation, high volume or low volume and high-speed traffic from the left:
Drivers wait for suitable gap, turn right, accelerate and make a lane change maneuver, then decelerate as they enter the left-turn lane. [7]

A study by the University of South Florida gives some guidance for the needed weaving distance needed. Exhibit 26 shows the "weaving distance." (University of South Florida, 2005). [8]

Exhibit 26
Weaving distance between driveway and U-turn



Although the study focused on the weaving made by vehicles positioning for a U-turn, the recommended distances are the same as weaving distance for left-turn and U-turns. The research highlights that the more through lanes a facility has, the longer the weaving distances are from

[7] NCHRP 420 Impacts of Access Management Techniques - 1999

[8] Determination of the Offset Distance between Driveway Exits and Downstream U-turn Locations for Vehicles making Right Turns Followed by U-turns –University of South Florida, November 2005 - Jian John Lu, Pan Liu, and Fatih Pirinccioglu

the driveway to the median opening. Exhibit 27 shows some recommended distances.

Exhibit 27
Recommended Weaving Distances

Turn Location	*Number of Lanes*	*Weaving Distance (ft.)*
Median Opening	*4*	*400*
	6 or more	*500*
Signalized Intersection	*4*	*550*
	6 or more	*750*

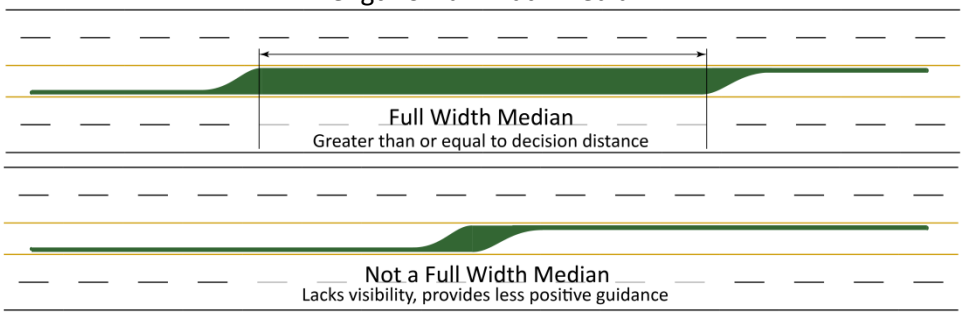
Source: (University of South Florida, 2005) [8]

2.2.3 Full Width Median

Where at all possible, the length of the full width median should be as long as possible. The median will be more visible to the driver. This also gives more space for traffic signs and landscaping.

Rule of thumb: the full width median should be greater than or equal to the decision distance

Exhibit 28
Length of full width median



2.2.4 Maneuver-Deceleration Distance

The Maneuver-Deceleration Distance consists of two components:

1) the taper, and
2) the deceleration

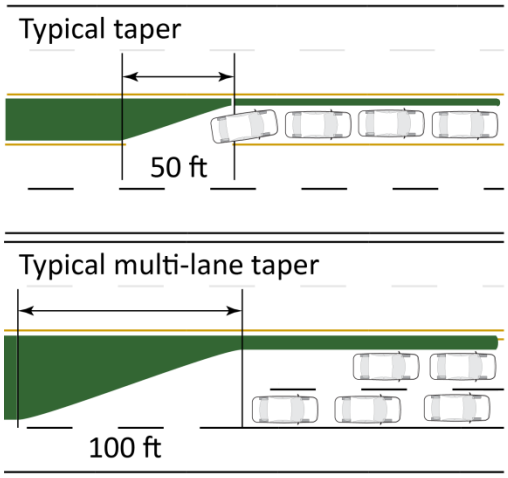
Taper

Taper — The taper is the portion of the median opening that begins the transition to the turn lane. FDOT Standard Index 301 contains the standards for this feature.

Design standards for left-turn lanes are available from several sources, most of which determine the base their rate of taper length from the approach speed; the faster the speed, the longer the taper. The FDOT

does offer standards for the design of left turn lanes. The FDOT Design Standards Index 301 dictates the use of a 4:1 ratio, or 50 ft, for bay tapers on all multilane divided facilities regardless of speed. This may appear to be an abrupt transition area for free-flow conditions, however, most urban areas will benefit from a longer storage area for queued vehicles. It also provides a better visual cue to the driver for the turn lane.

Exhibit 29
Recommended Taper



- More storage
- Less chance of a vehicle blocking through lane

Typically 50 ft
(or 100 ft for dual-left-turn lane taper)

Additional Taper Designs can be found in the AASHTO Green Book.

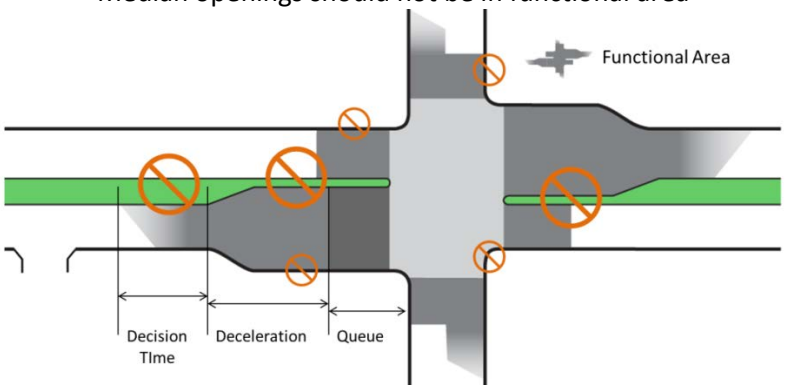
Deceleration

Total Deceleration

Minimum standards for the distance needed to properly slow a vehicle down and bring the vehicle to the storage portion of the median opening, or deceleration distance, is found in FDOT Standard Index 301. This distance is measured from the beginning of the taper to the end of the queue storage portion.

The standards found in the Standard Index however should be considered a minimum because research has shown reactions vary considerably with drivers. And in many cases, more space may be needed.

Exhibit 30
Median openings should not be in functional area



Design Speed

The **design speed** is the speed used to make critical decisions on the roadway design features. The AASHTO Green Book defines the design speed as:

> "Design speed is a selected speed used to determine the various geometric design features of the roadway… In selection of design speed, every effort should be made to attain a desired combination of safety, mobility, and efficiency within the constraints of environmental quality, economics, aesthetics, and social or political impacts."
>
> "Once selected, all of the pertinent features of the highway should be related to the design speed to obtain a balanced design. Above-minimum design values should be used where practical, particularly on high speed facilities."
>
> AASHTO GREEN BOOK

Entry Speed

When considering medians and median openings, the greatest use of design speed is for determining the length of right- and left-turn lanes. FDOT Standard Index 301 identifies that design speed and the related entry speed are the basis for determining the minimum length of the turn lane for deceleration and stopping behind the turn lane queue.

Exhibit 31
Deceleration Distances from the FDOT Design Standard Index 301

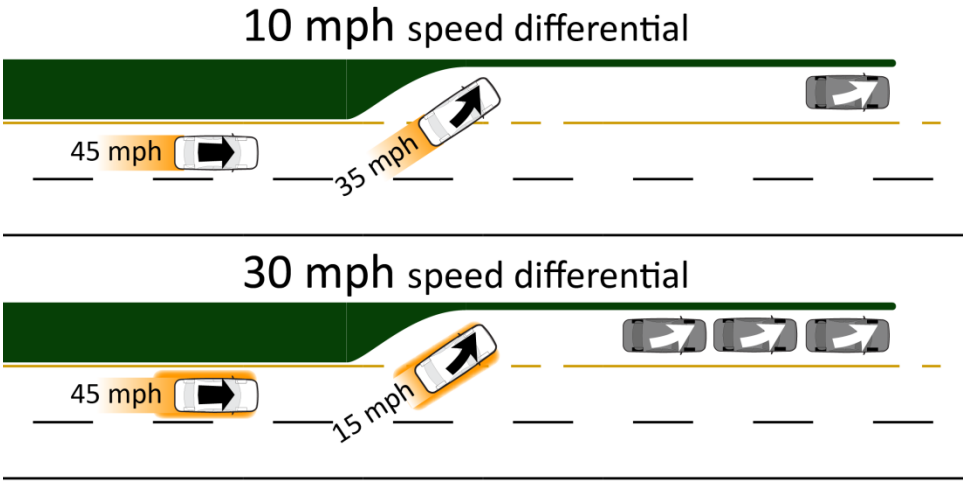
Design Speed (mph)	Entry Speed (mph)	Total Deceleration (ft)
35	25	145
45	35	185
50 Urban	40	240
50 Rural	44	290
55 Rural	48	350

Design Standards Index 301

Total Deceleration Distance

The turn bay should be designed so that a turning vehicle will develop a speed differential (through vehicle speed minus the entry speed of turning vehicle) of 10 mph or less at the point it clears the through traffic lane and enters the turn lane. The length of the turn lane should allow the vehicle to come to a comfortable stop prior to reaching the end of the expected queue in the turn lane.

Exhibit 32
Excessive Deceleration



If the turn lane is too short, or queued vehicles take up too much of the deceleration portion of the turn lane, excessive deceleration will occur in the through lane. This creates a high crash potential.

Non-Peak Hour Speeds

Non-Peak Hour speeds are also important considerations since around 80% of the daily traffic takes place outside of the peak hours at that time, usually at higher speeds. Turning volumes are lower at those times which will make queuing requirements smaller.

For more information on speed definitions:

- Design Speed, Operating Speed, and Posted Speed Practices, NCHRP Report 504, 2003
- AASHTO Green Book

2.2.5 Queue Storage

Turn lanes must include adequate length for the storage of traffic waiting to perform a turn. This is also called turn lane queue length.

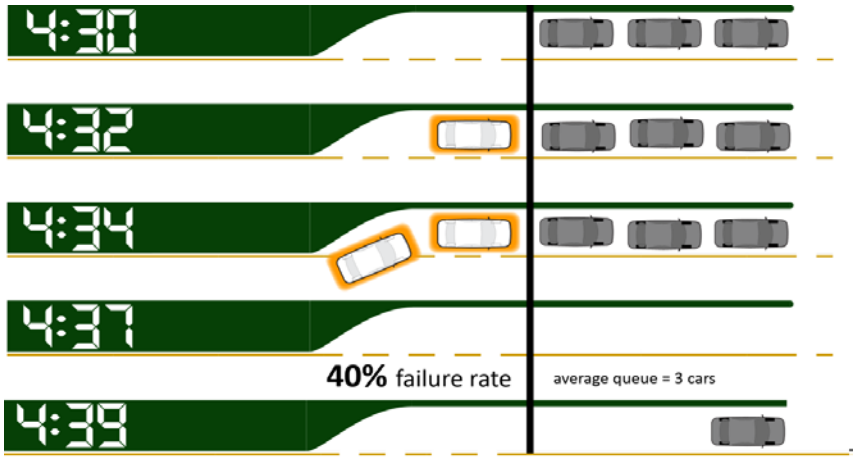
Where a specific queue study does not exist, FDOT will typically require a 100 ft. queue length (four passenger cars) in an urban/suburban area and a 50 ft. (two passenger cars) queue length in rural or small town areas with expected low volumes of left turns. Deceleration distance needs to be added to the queue storage to determine the full turn lane length requirements.

Sources:

- Plans Preparation Manual Vol. I - 2.13.2 Queue Length for Unsignalized Intersections
- Median Opening and Access Management Decision Process (FDOT) Topic No.: 625-010-020

Alternatively, for calculating purposes, the AASHTO Green Book suggests the use of a virtual 2 minute interval for unsignalized locations. Exhibit 33 illustrates that where an average queue is 3 vehicles, the actual queue will probably be over 3 vehicles much of the time.

Exhibit 33
How can designing to the average fail?



The technique used to analyze this distribution of queue length is the Poisson Distribution. The Poisson Distribution is used to predict randomly occurring discrete events such as queues. Using this statistical technique we see that building queue storage to fit the average demand will result in the median opening "failing" 30% to 40% of the time.

Design queues are usually 1.5 to 2 times the average.

Exhibit 34
Estimated queue storage for unsignalized median openings

Lefts per Hour	Estimated Queue in feet
30	50*
40 – 50	75 *
60 – 70	100
80 – 90	125
100 – 110	150
120 – 140	175
150+	200

** Only use less than 100 ft in small towns, rural areas, or where you expect low volumes in the future*

Assumptions: 120 second interval, approximate probability of turn lane length success is 90%

Exhibit 34 contains the recommended queue storage length of as variety of left turn lane volumes. The recommendations were based on a 90% turn lane length success rate. You must consider the historic variability of these numbers, as well as the inherent inaccuracies of traffic projection models when making your recommendation.

The length of 25 feet is an average distance, front bumper-to bumper of a vehicle in queue. If the queue is comprised mostly of passenger cars, this distance provides for an average distance between vehicles of about one-half car length.

If 10% or more trucks or large vehicles are expected, the average queue length, should be increased as follows:

Exhibit 35
Adjustment for Trucks

Percent Trucks	Average Storage Length per Vehicle
Over 10%	30 ft
Over 20%	35 ft

Source: Adapted from Transportation and Land Development, Stover and Koepke

Use Caution Near Railroad Crossings

Use caution to assure that queues will not be placed over downstream railroad crossings. Railroad crossings should not be anywhere near the functional area on an intersection.

For more information on queues, storage, and projecting left turns:

- AASHTO Green Book
- FDOT Project Traffic Forecasting Handbook, Statistics Office

2.2.6 Median Opening Spacing

The spacing of median openings will be the sum of the following factors for both directions of the roadway.

How all these factors impact the spacing of openings

- Deceleration
- Queue storage
- Turning or control radii (usually 60 ft)
- Perception/reaction distance or full width of median
  (The length of the median which is not a part of the turn lanes or the taper. These sections provide for visibility, buffer and landscaping opportunity.)

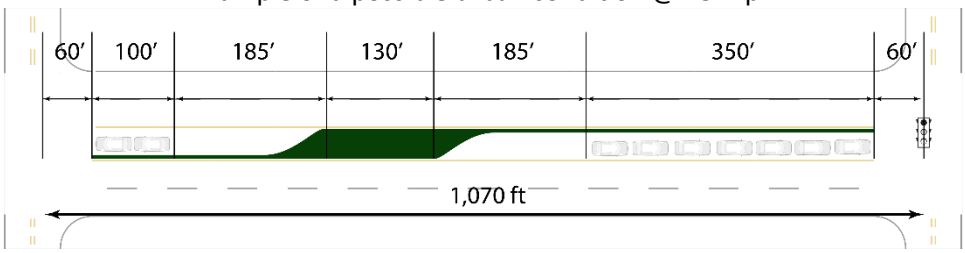
Exhibit 36 shows a possible example. In this case you have a signalized intersection on one end and an unsignalized opening at the other end. The signalized intersection has been designed for 45 mph deceleration and a queue of 350 ft. Because we want to have some small area for landscaping and improved night time visibility, we have included 130 ft full width median. This example shows even if the facility were a Class 7 roadway where 660 ft would be the standard, the median opening spacing would need to exceed the standard criterion. On the other hand during a reconstruction project, if this facility were a Class 5 roadway where the standard spacing is 1,320 ft, the designer may justify a shorter spacing. In all cases, the design should provide adequate spacing between median openings and handle the expected operations (queuing, deceleration, decision, and visibility).

Design speed – 45mph urban location

Left Turn Queue Storage (Signalized)	= 350 ft
Deceleration	= 185 ft
Left Turn Queue Storage (Unsignalized)	= 100 ft
Deceleration	= 185 ft
Full width median	= 130 ft
Turn Radii	= 60 ft
TOTAL	1,070 ft

Exhibit 36

Example of a possible urban condition @ 45 mph



Longer median opening provides space for:

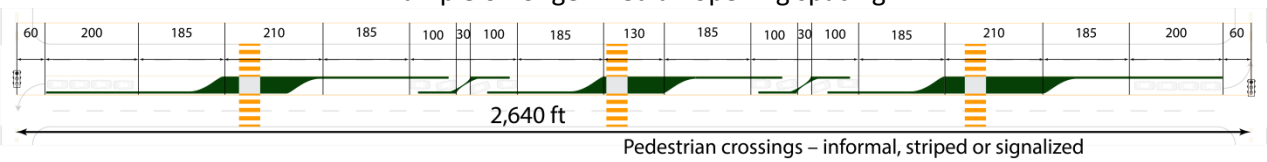
- Safety
- Operations
- Flexibility
- Traffic Progression
- Pedestrian refuges
- Aesthetics

Exhibit 37 depicts median opening spacing that allows for numerous pedestrian crossing opportunities.

(both formal and informal)

Exhibit 37

Example of longer median opening spacing



Longer spacing between median openings provides multiple opportunities for vehicle and pedestrian to benefit, both formal and informal.

2.3 Median Openings near Freeway Interchanges

Administrative Rule 14-97, the main rule on access management standards, considers interchange areas differently than other portions of a corridor. These areas may require spacing of median openings at greater distances than required by the individual access management class of the arterial.

Interchange Areas 14-97.003 1. (i) 3.

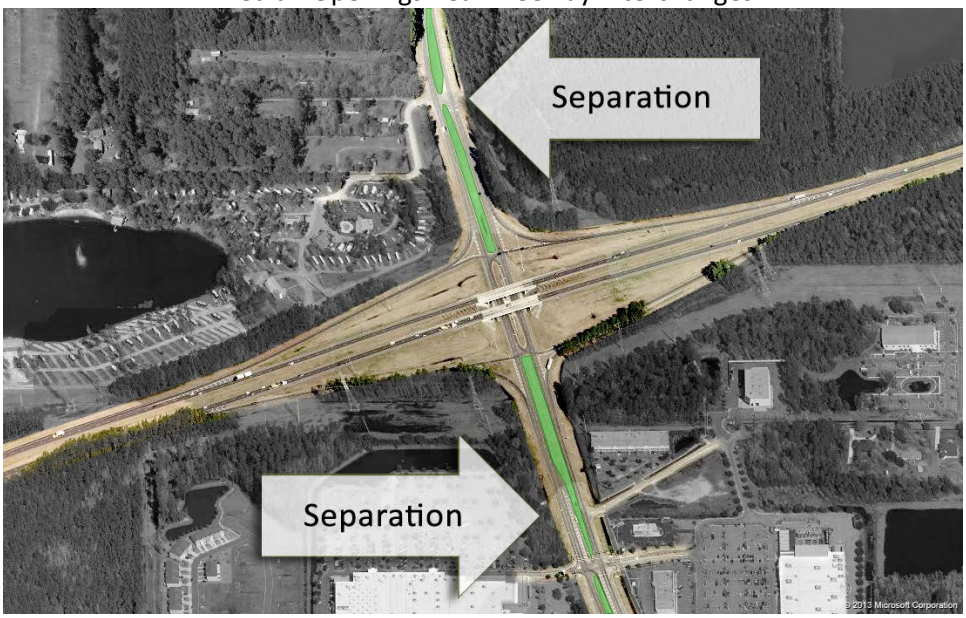
The standard distance to the first full median opening shall be at least 2,640 ft as measured from the end of the taper of the off ramp.

Interchange Areas 14-97.003 1. (i) 4.

Greater distances between proposed connections and median openings will be required when the safety or operation of the interchange or the limited access highway would be adversely affected. Based on generally accepted professional practice, FDOT makes this determination when the engineering and traffic study projects adverse conditions.

The standards in Rule 14-97 are difficult to achieve in many cases. Therefore, FDOT relies upon generally accepted professional practices and model to analyze and design the separation of median openings.

Exhibit 38
Median Openings near Freeway Interchanges

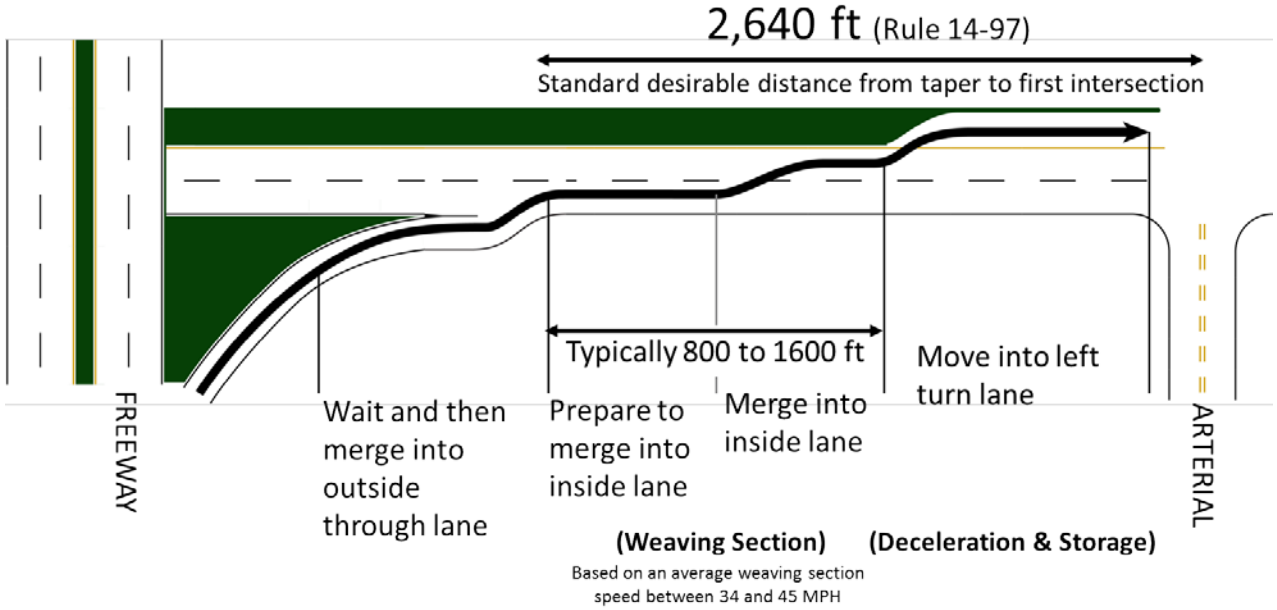


2.3.1 At unsignalized interchange ramps

What distance is needed from a freeway ramp terminal to the first median opening?

Drivers may make erratic maneuvers in areas where there is a limited separation between the off-ramp and the median opening. Desirable conditions would permit a driver to accelerate, merge into the outside traffic lane, select an acceptable gap in order to merge into the inside lane, move laterally into the left-turn lane, and come to a stop as shown in Exhibit 39. The desired distance needed between an unsignalized freeway off-ramp and median opening at first signalized intersection is 2,640 ft.

Exhibit 39
Distance between an off-ramp and first signalized intersection



Experience shows that most urban situations fall within 800 ft to 1,600 ft of conflicting weaving movements within the arterial weaving section, during the peak hour. If a lower average speed through that section is acceptable (35 mph) the weave section may be as low as 400 ft.

Jack Leisch – Procedure For Analysis And Design Of Weaving Sections 1985 and Robert Layton Interchange Access Management Background Paper 2 - 1996

Though not a specific FDOT requirement, we have included Exhibit 40 from the State of Oregon for access management near freeway interchanges. A designer may choose to reference these standards as a starting point to the decision-making process.

Example access spacing at interchange areas – developed for Oregon DOT for educational purposes.

Exhibit 40
Example Access Spacing At Freeway Interchanges
(Oregon State University Transportation Engineering)

	Area Type		
	Fully Developed Urban (35 mph)	Suburban (45 mph)	Rural (55 mph)
	Two-lane Cross Roads		
First Access (ft)	750	990	1,320
First Major Signalized Intersection (ft)	1,320	1,320	1,320
	Four-lane Cross Roads		
First Access from Off-Ramp (ft)	750	990	1,320
First Median Opening	990	1,320	1,320
First Access Before On-Ramp	990	1,320	1,320
First Major Signalized Intersection (ft)	2,640	2,640	2,640

***Source**: Adapted from Interchange Access Management Discussion Paper #4 by Robert Layton - Oregon State University 2012*
http://teachamerica.com/MHB/12-5-interchange-access-management.pdf

This is not a substitute for FDOT standards. Although it is not consistent with the requirements in FDOT Plans Preparation Manual (PPM) Chapter 2.14 "Interchanges and Median Openings/Crossovers", Exhibit 40 summarizes the Oregon State University research developed for Oregon DOT. This can be a good example and starting point for access management near freeway interchanges.

Signalized On and Off Ramps: If the ramp is signalized, this weaving distance will need to be determined by a signal spacing analysis or other methods and standards.

2.4 Median End Treatments

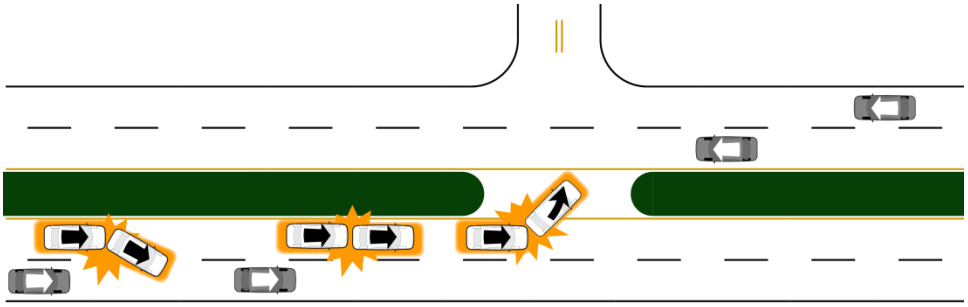
The median end design for an urban arterial should be designed for a passenger vehicle while assuring it can accommodate a larger design vehicle. Alternative median end designs include: semicircular, symmetrical bullet nose, asymmetrical bullet nose, half-bullet nose, **but remember: always use turn lanes.**

The only new openings that should be provided without turn lanes would be for official or emergency use only.

The "bullet nose" median opening requires a vehicle to make a left turn from a through lane interfering with the through traffic. This will result in a situation with a high potential for rear-end crashes as shown in Exhibit 41.

Exhibit 41
Potential crash problems when left-turn is made from the through traffic lane

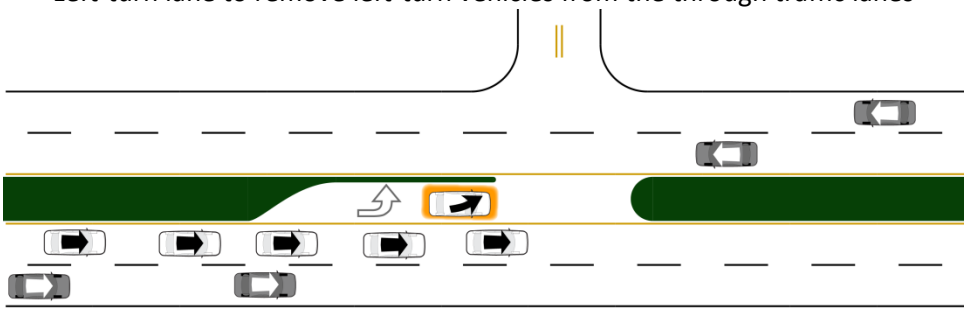
The **problem**
of no turn lanes



The most common method in which left-turning vehicles can be removed from a through traffic lane is to install a left-turn lane (see Exhibit 42). The lane should be of sufficient length to allow for adequate maneuvering distance plus queue storage as discussed earlier in Chapter 2. The total deceleration length, including the taper, should be sufficient to allow the turning vehicle to decelerate from the speed of through traffic to a stop plus queue storage. Existing bullet nose median openings should be replaced with an adequate left-turn lane.

Exhibit 42
Left-turn lane to remove left-turn vehicles from the through traffic lanes

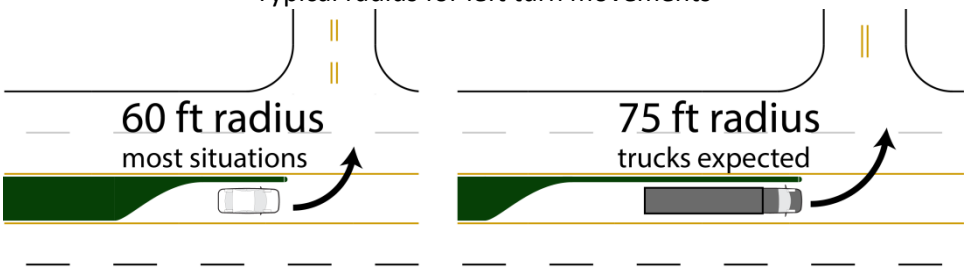
Solution
Add a turn lane



2.5 Median Opening Left Turn Radius

FDOT has historically used 60 ft for most situations and 75 ft when significant truck volumes are expected for left-turn or control radii.

Exhibit 43
Typical radius for left turn movements



The Florida Intersection Design Guide contains the following guidance:

Exhibit 44
Control Radii for Minimum Speed Turns

	Control Radius (ft)			
	50 (40 min)	60 (50 min)	75	130
Predominant	P	SU-30	SU-40 WB-40 WB-62	WB-62FL
Occassional	SU-30	SU-40 WB-40	WB-62FL	WB-67

Table 3-13 Florida Intersection Design Guide 2013

For more guidance on radius design:

- Florida Intersection Guide

2.6 Median Opening Length

Median opening length is governed by the:

- Turning or control radii
- Side street geometrics
- Median (traffic separator) width
- Intersection skews
- Intersection legs

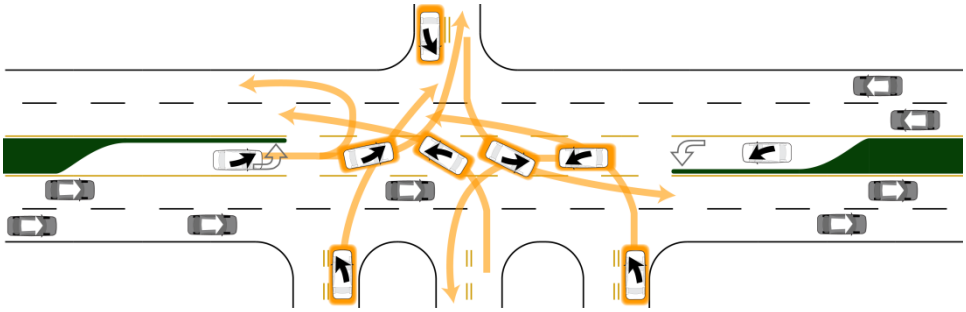
An excessively wide median opening will store multiple vehicles in an unsignalized full median opening while they are waiting to complete a maneuver. Excessively wide openings result in multiple conflicts for both the turning vehicles and through traffic. The situation shown in Exhibit 45 is a common occurrence at wide full median openings on high volume roads during peak periods. This often occurs in areas that experienced significant development and growth in traffic volumes since the median opening was originally constructed.

The presence of several vehicles in the median opening results in impaired sight distance, especially when one or more of the vehicles is a pickup, van or RV. Signalization should be considered only if the median opening meets the criteria of a signal warrant analysis.

Exhibit 45

Vehicles stopped in excessively wide median opening

Problem



Solution

Alternative solutions to the problem are:

1. Reconstruct the unsignalized full opening as a more restrictive median opening.
2. Close the median opening.
3. Directionalize the median opening.

Which solution is selected, as well as the design of the restrictive movement if used, will depend on several factors including the proximity to other median openings, alternative routes, traffic volumes, and crash experience.

For more information on median opening length:

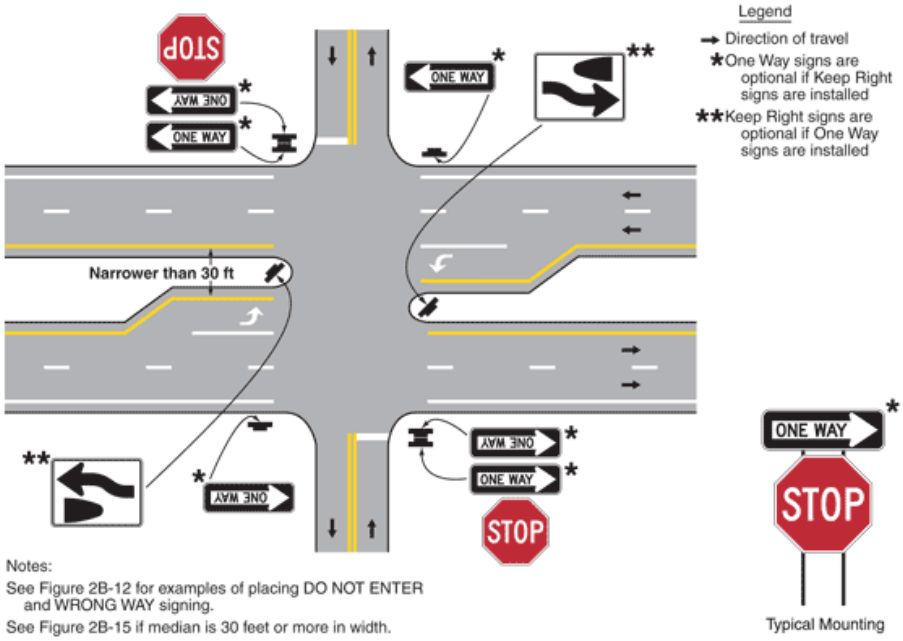
- AASHTO Green Book Median Openings Section of "At-Grade Intersections"

2.7 Pavement Markings and Signing

The Manual on Uniform Traffic Devices (MUTCD) contains guidance on the type and placement of signs and traffic control devices at median opening areas. FDOT also provides guidance for signing and pavement markings in the FDOT Standard Index 17000 series.

Exhibit 46

M.U.T.C.D Figure 2B-16



For more information on pavement markings and signing:

- Manual on Uniform Traffic Devices (MUTCD)
- FDOT Standard Index 17000 series

2.8 Retrofit Considerations

When resurfacing, or altering a segment of a roadway within the State Highway System (SHS), it is recommended that all medians, median openings, and driveways be assessed to determine see if it is appropriate to retrofit any of the median characteristics.

2.8.1 Assessing the Need to Close/Alter/Maintain a Median Opening

Adapted from "Guidelines for Median Opening Placement and Treatment Type"

FDOT D5 1996

For the initial assessment of the existing median opening, the design requires data collection and analysis. A 4-step process (as provided in the literature indicated in the side bar) should provide adequate information for decision making on whether to close/alter/or maintain an existing median opening.

1. Determination of major cross streets and major driveway locations
2. Data Collection
    - Identification of all existing signalized intersections, as well as those locations scheduled for signalization in the near future
    - Elimination of intersections from consideration for signalization (based on proximity to other signalized intersections)
    - 24-hour bi-directional approach counts on each leg of each intersection
    - Other pertinent traffic data includes;
        - Traffic count locations for vehicle classification and volume to develop traffic characteristics
        - Planned development in the corridor
        - Locations of schools, school crossings, and school zones
        - Locations of facilities/design characteristics that serve emergency vehicles
        - Locations of land uses which have special access requirements (bus terminals, truck stops, fire stations)
        - Existing pedestrian crossings, parks, or other pedestrian generators
        - Existing and proposed bicycle facilities
        - Recent (3 years) crash data, especially individual crash reports

3. Analysis
    - Preliminary signal warrant analysis using existing volumes
    - Determine if (proposed) signal spacing is adequate using progression analysis
    - Verify that existing signals still meet the warrants
    - Intersection and arterial capacity analyses based on anticipated roadway improvements to determine overall corridor level of service (using projected design-year data)
4. Recommendations
    - Provide a list of existing signalized intersections which are expected to continue to meet the warrants for signalization
    - Develop a list of intersections which are candidates for future signalization that will still provide adequate spacing between signalized intersections
    - Provide roadway segments where median openings are not recommended (site specific reasoning), as well as noting all existing median openings being closed or modified
    - Recommendations for median opening locations and treatment type

Once the recommendation has been made to close/alter/or maintain an existing median opening, the following sections provides guidance on how to proceed with that decision.

2.8.2 Deciding to Close a Median Opening

The following criteria provides guidance on a recommendation to close an existing median opening:

- Narrow median width (<14 ft or less than length of design vehicle) where left turning vehicles cannot be protected during a two-stage left turn (move to median and then proceed left when the appropriate gap becomes available for the left turn vehicle.
- A combination of high volume left- turn out movements coupled with high through and left- turn in movements, significantly reducing making the availability of available gaps.
- High volume of left-out movements onto the major roadway (AADT >27,000 AADT or existing crash data)
- Disproportionate share of angled crashes involving the left-out turning movement
- Provision of an appropriate place for the displaced left-turn to make U-turns

Driveway consolidation and median opening alterations that would improve traffic conditions as a result of a plan that includes median closure(s).

2.8.3 Deciding to Alter a Median Opening

Adapted from Virgil Stover's course notes

The following design/traffic criteria provides guidance on the alteration of an existing median opening:

Narrow median (12 – 14 ft.)

- Replace a full median opening with a directional opening for left-turns from one direction only

Median (>14 ft.)

- Replace a full median opening with a directional opening for left-turns from both directions

2.8.4 Deciding to Keep a Median Opening

When all the data has been analyzed and negative impacts on the adjacent roadway are considered minimal, the decision to keep a median opening placement and/or type would be justified.

2.8.5 Construct a New Median on an Existing Roadway

On a 5-lane or 7-lane roadway with center turn lane;

- Replace the center turn lane with a raised median to restrict movements to right-in/right-out only
- Install a raised median with a directional median opening. Where the center turn lane width is 14 ft. or more, the directional opening may be designed for left-turns from both directions on the roadway. Where the center turn lane is less than 14 ft. wide, the directional opening should be designed for left-turns from one direction only. Consideration as to the choice as to which connection will have left-turn in movements ins and which will not include:
    a) Alternative access
    (the directional median opening given to the property not having alternative access, or the less extensive alternative), and
    b) Traffic generation
    (the directional opening going to the property generating the most traffic).

See Vergil Stover's "Access Connections on Opposite Sides of Roadway" (2008)

2.8.6 Considerations for Resurfacing, Restoration, and Rehabilitation (3R) Projects

When a 3 R project is planned for a corridor, many features of the facility are analyzed. Some of the most important considerations involve access management. These may include:

- Radius improvements at side road driveways due to evidence of off-tracking
- Close abandoned driveway in urban/curb & gutter section to improve ADA accessibility/sidewalk
- Correct driveways that do not meet design standards*
  (i.e. slopes too steep, documented dragging or damaged driveway and/or asphalt on roadway)
- Construct new transit/bus amenities*
  (bus bays, pads for bus shelters, bus stop pads, etc.)
- Construct new turn lanes to meet projected need*
- Lengthen/revise existing turn lanes at signalized intersections due to documented operational issues. Any intersection could be revised as needed based on verified crash history*

*To remain in resurfacing projects at the engineer's discretion

Source: *FDOT Roadway Design Guidance 04/05/2012 "List of Optional Items to Review on RRR Projects"*

- www.dot.state.fl.us/officeofdesign/CPR/ProjectScopingfor3RWork.shtm

2.9 Rural Median Opening Considerations

Unsignalized intersections in rural areas can often lead to some of the most dangerous points of conflict due to generally higher speeds and reduced enforcement of proper driver behavior. Crash data in rural areas has shown a higher proportion of right angle crashes and injury rates compared to more urbanized areas. It is in the best interest of the travelling public to limit the number of through movements across major roadways from minor roadways. The following sections provide suggestions to improve safety on rural facilities on the SHS.

2.9.1 Realigning Minor Roadway Intersections

Where an unsignalized intersection in a rural area experiences a high crash rate, due to a minor roadway crossing a major roadway, it is recommended (when sufficient right- of- way exists) that one of the access points to/from the minor roadway be re-aligned so that a 4-way intersection is modified to create two (2) 3-way intersections, ideally spaced approximately ¼ mile part or more. Refer to Exhibit 47 and Exhibit 48.

Exhibit 47

Vergil Stover's paper "Access Connections"

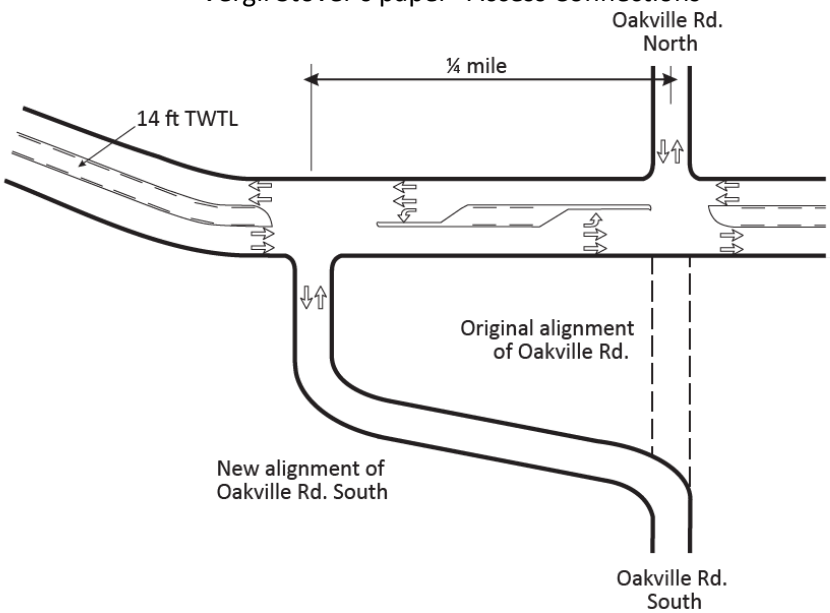
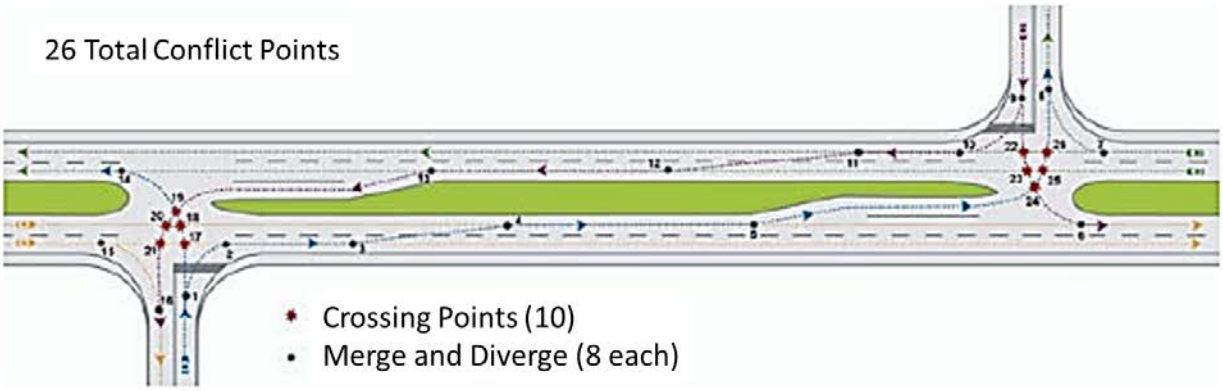


Exhibit 48

NCHRP Report 650 – Figure 65. Conflict-point diagram for offset T-intersection



2.9.2 Restricted Crossing U-Turn Intersection (RCUT)

Where an unsignalized intersection in a rural area experiences a high crash rate, due to a minor roadway crossing a major roadway, it is recommended (when right of way is limited) that the full median opening be converted to a directional median opening. This will force the through vehicle (on the minor roadway) to make a right turn followed by a U-turn and ultimately making a right turn (back onto) at the minor roadway.

Considerations need to be made so that the design vehicle has enough room to make the required right turns and U-turn. Even if right of way allows the re-alignment of the minor roadway, the directional median opening may be the preferred treatment.

Exhibit 49

Conflict point diagram for Restricted Crossing U-Turn Intersection, or RCUT)

For more information on RCUT:

- www.fhwa.dot.gov/publications/research/safety/09059/
- teachamerica.com/ai14/

2.10 Special Rural Highway Treatments

2.10.1 Advance Warning of Oncoming Vehicles on Rural Highways

Innovative treatments of problematic intersections in rural settings have proven to be beneficial in reducing the number of accidents that result in injuries and fatalities. Even though an intersection meets all FDOT guidelines and design standards, certain situations could result in higher than expected conflicts. All geometrics and hazards should be considered when attempting to improve the safety of an intersection and no one method may offer the desired results. It is recommended that FDOT staff should consider innovative treatments if all other design options have been exhausted.

2.10.2 Vehicle Actuated Flashing Beacons for 2-Stage Crossing

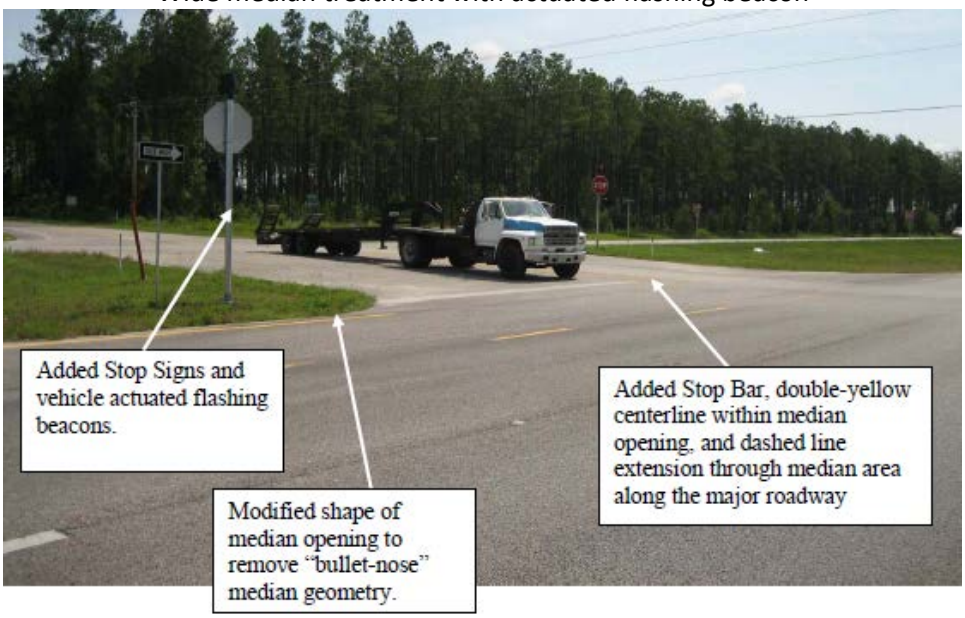
This treatment option may be considered when an extraordinarily wide median results in an increased observance of accidents occurring at the far end of the intersection (before fully crossing the intersection but after traversing the median). The root of the problem lies in a deceptively long acceptable gap in traffic in order to safely cross the entirety of the intersection. One option is to break the 1-stage crossing maneuver into a 2-stage crossing maneuver by placing a 2nd set of stop signs within the median.

This treatment option includes the placement of continuously flashing beacons on the existing stop signs of the intersecting roadway. Due to an exceptionally wide median, distance is sufficient to store at least 1 vehicle. Please note the design vehicle, as in many situations a large vehicle may need to use this intersection. A second set of stop signs are placed within the median, thereby making this intersection crossing a 2-stage maneuver. Additionally, on the 2nd set of stop signs, it is recommended that loop sensors are placed within the median to activate flashing red beacons on the stop signs as well as flashing yellow beacons in advance of the intersection on the major roadway.

The following example is located along SR 20 and CR 234 in Alachua County, Florida.

Exhibit 50

Wide median treatment with actuated flashing beacon



Safety Improvements at Unsignalized Intersections (2008)
FDOT Traffic Operations Research Study

Exhibit 51

Flashing beacon on minor street

Safety Improvements at Unsignalized Intersections (2008)
FDOT Traffic Operations Research Study

Exhibit 52

Loop Sensors and Flashing Yellow Beacons

Google Earth image

Note: painting and loop detectors within median pavement. The loop sensors activate flash red beacons on the stop signs within the intersection as well as flashing yellow beacons place ahead of the intersection on the major roadway.

Exhibit 53

Loop sensors and flashing yellow beacons

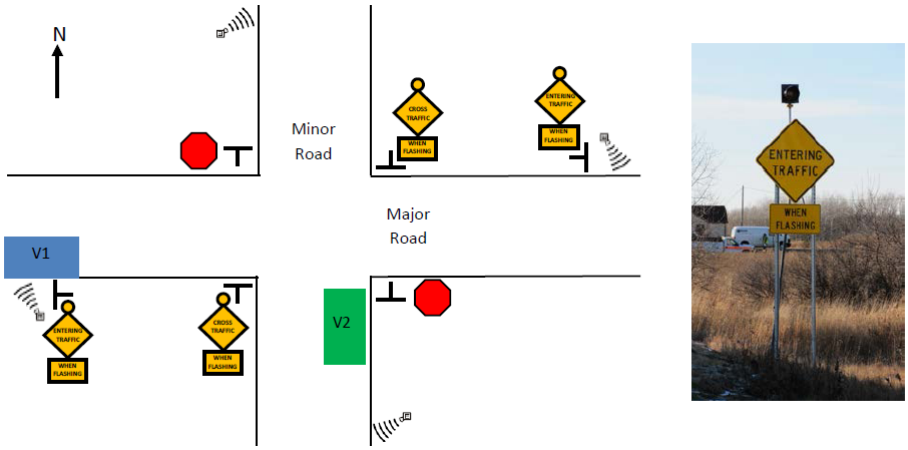
Exhibit 54

2.10.3 Rural Intersection Conflict Warning System

Another innovative idea designed to alleviate traffic crashes, has been developed by the Minnesota Department of Transportation. Their system warns motorists if a vehicle is approaching the intersection from either direction. As a vehicle on the minor roadway approaches the major roadway, a red flashing beacon will warn the motorist if vehicles on the major roadway are approaching the intersection. Alternately, as a vehicle on the major roadway approaches the minor roadway, a yellow flashing beacon will warn the motorist if there are vehicles approaching the intersection. This system requires loop sensors in advance of the intersection from each direction.

Exhibit 55

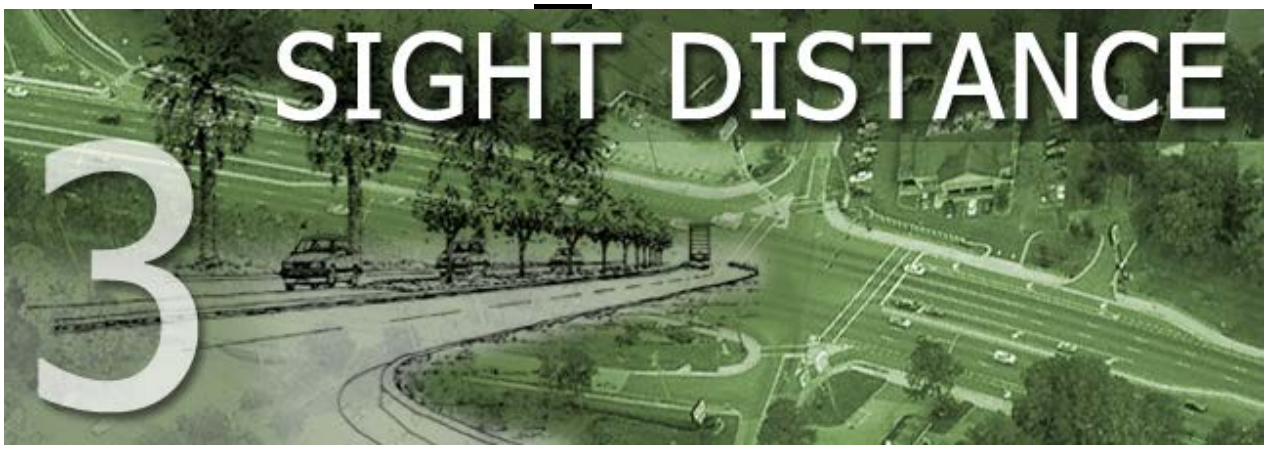
Intersection conflict warning system concept



Rural Intersection Conflict Warning Systems Deployment – Concept of Operations (2012) Minnesota DOT

Additional resources:

- MnDOT webpage on "Rural Intersection Conflict Warning System" www.dot.state.mn.us/guidestar/2012/rural-intersect-conflict-warn-system/
- Link to MnDOT "Concept of Operations" www.dot.state.mn.us/guidestar/2012/rural-intersect-conflict-warn-system/documents/RICWSConOps.pdf
- FDOT's research on "Innovative Operational Safety Improvements at Unsignalized Intersections" www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_C8K21_rpt.pdf
- Development of Guidelines for Operationally Effective Raised Medians and the Use of Alternative Movements on Urban Roadways
  D. Li G. Liu H. Liu K. Pruner K. R. Persad L. Yu X. Chen Y. Qi
  Full report 2013 :
  d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-6644-1.pdf



3.0 Introduction to Sight Distance Concepts

This chapter addresses sight distance concepts related to unsignalized median openings and facility connections. The majority of the chapter contains discussion of the assumptions relating to stopping and intersection sight distances. The AASHTO Green Book is the basis for much of the Florida Design Standards. Right-turn and passing sight distance is not addressed in the chapter as they are not typically an element in median opening location and design.

Highways must be designed to provide sufficient sight distance so that drivers can control and safely operate their vehicles. The following sight distances are of concern on median and median opening decisions, both urban and rural:

- **Stopping Sight Distance:** The distance necessary for the driver to safely bring a vehicle to a stop.
- **Intersection Sight Distance:** The distance necessary for drivers to safely approach and pass through an intersection.

Several factors that contribute to determining stopping sight distance and intersection sight distance include:

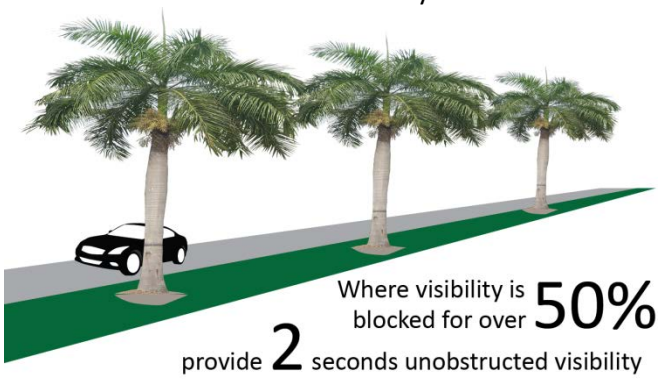
- **Height of Eye** - In determining sight distance, the height of the eye of the person who must stop or pass through the intersection is assumed to be a certain measure. This assumption has significant bearing on such issues as the placement of landscaping which might obstruct the view of the vehicle at the assumed height. FDOT defines this height as 3.5 ft.
- **Height of Object** - AASHTO and FDOT assumes a determined height of object for intersection sight distance. This will allow the driver to view the headlights of an oncoming passenger car. This height is defined as 0.5 ft above the road surface by FDOT.
- **Area Size of Vehicle** – Florida DOT has developed criteria for sight distance that allows a 50% “Shadow” control for sight distance. This

means that if a driver can see at least 50% of the visual area of a vehicle it is considered "visible."

- **Time of Visibility –** Where visibility is blocked by over 50%, FDOT will allow for two seconds unobstructed visibility.

Exhibit 56
Area Size of Vehicle

Exhibit 57
Time of Visibility



3.0.1 Stopping Sight Distance

Sight distance is the length of roadway ahead visible to the driver. The minimum sight distance available on a roadway should be sufficient to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. The sight distance at every point along the highway should be, at a minimum, the distance required for an operator or vehicle to stop in this distance.

Exhibit 58
Minimum Stopping Sight Distance

For application of stopping sight distance, use an eye height of 3.5 ft and an object height of 0.5 ft above the road surface

Design Speed	Minimum Stopping Sight Distance (feet)
35	250
45	360
55	495
60	570
65	645

Source: FDOT Plans Preparation Manual Vol. I Table 2.7.1

3.0.2 Intersection Sight Distance

FDOT Design Standard Index 546 specifies the following sight distances for right- and left-turns at intersections on multi-lane facilities with medians. These distances should be considered minimums. Exhibit 59 presents an example at 45 mph with a 22 ft median width.

Exhibit 59
Sight Distance Example

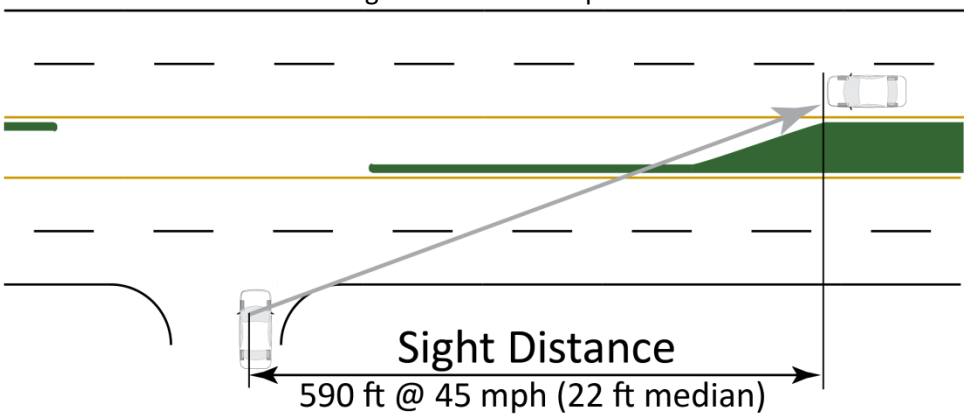


Exhibit 60
Intersection Sight Distance for Passenger Vehicle (P)

Design Speed (mph)	*Intersection Sight Distance (ft)*	
	22 ft Median	***25-64 ft median****
35	460	330
45	590	430
55	720	530
60	780	570

* If the median width is sufficiently wide enough for the design vehicle to pause in the median (vehicle length plus 6 feet) then the passenger car (P) can make the maneuver as a two-step process by pausing in the median

Source: FDOT Design Standard Index 546

3.0.3 Sight Distance for U-turns

U-turns are more complicated than simple turning or crossing maneuvers. Sight distances in Exhibit 62 for U-turns were calculated for automobiles with the following assumptions:

- "P" vehicle (Passenger vehicle)
- 2.0 seconds reaction time
- Additional time required to perform the U-turn maneuver
- Begin acceleration from 0 mph only at the end of the U-turn movement (this is conservative)
- Use of speed/distance/and acceleration figures from AASHTO Green Book.
- 50 ft clearance factor

Exhibit 61
U-turn Sight Distance

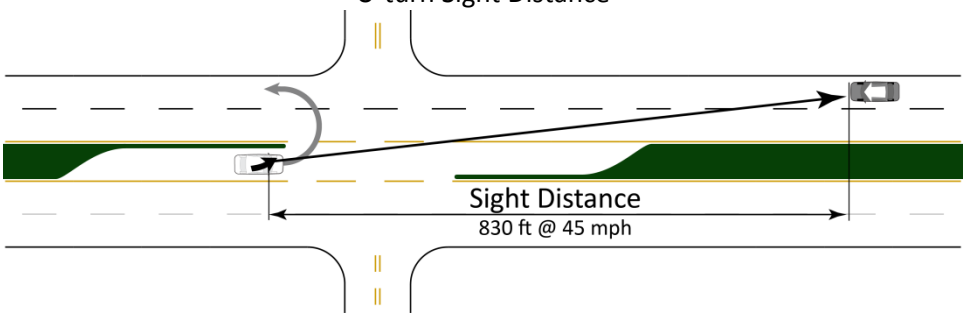


Exhibit 62
Sight distance for U-turn an unsignalized median opening

Speed (mph)	*Sight Distance (ft)*
35	520
40	640
45	830
50	1,040
55	1,250
60	1,540

3.0.4 Sight Distance for Left-Turn into Side Street

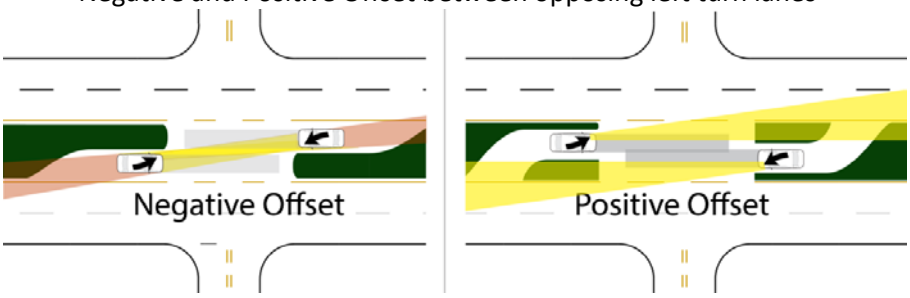
In most cases, the right-turn sight distance from the side street/connection would control the sight distance of this area. If the intersection has sufficient sight distance to allow a right-turn maneuver from the side street, the sight distance should have sufficient sight distance for the left-turn maneuver from the side street.

3.0.5 Left Turn Lane Offset

This is further defined in Section 2.13.3 of the FDOT Plans Preparation Manual.

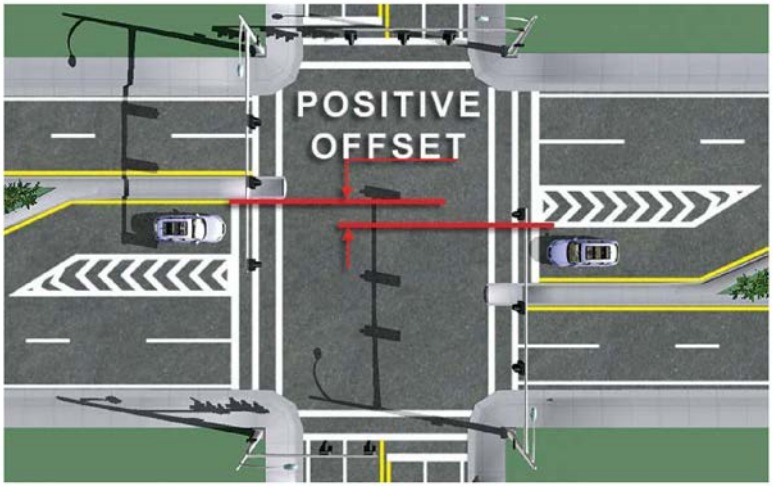
Vehicles turning left from opposing left-turn lanes restrict sight distance for both vehicles unless the lanes are sufficiently offset. Offset is defined as the lateral distance between the left edge of a left-turn lane and the right edge of the opposing left-turn. When the right edge of the opposing left turn is to the left of the left edge of the left turn lane, the offset is negative. If it is to the right, it is a positive offset as shown in Exhibit 63.

Exhibit 63
Negative and Positive Offset between opposing left turn lanes



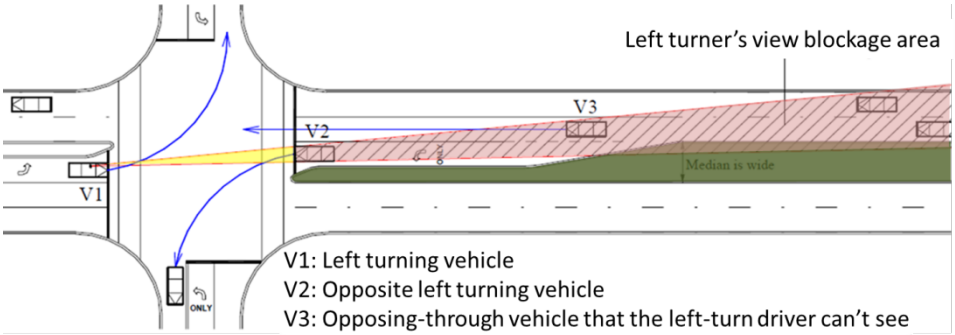
Source: Plans Preparation Manual Vol. I, 2.13.3

Exhibit 64
Offset Left-turn Lane



Source: 2001 Highway Design for Older Drivers and Pedestrians FHWA

Exhibit 65
Offset Left-turn Lane



Desirable offsets should all be positive with a recommended minimum 2-foot offset when the opposing left turn vehicle is a passenger car and a recommended minimum 4-foot offset when the opposing left turn vehicle is a truck. In both cases, the left-turn vehicle is assumed to be a passenger car.

On all urban designs, offset left-turn lanes should be used with median widths greater than 18 ft. A 4 foot wide traffic separator should be used when possible to channelize the left-turn movement and provide separation from opposing traffic. On rural intersections where high turning movements occur, offset left-turn lanes should also be considered.

On median widths 30 ft or less, an offset left-turn lane parallel to the through lane should be used and the area between the left-turn lane and the through lane where vehicles are moving in the same direction should be channelized with pavement markings. On medians greater than 30 ft, a tapered offset should be considered.

Exhibit 66
Example of Positive Offset

Source: FHWA

Exhibit 67
Example of Positive Offset

For More Information on Offset Design:

- District 1 Access Management Unsignalized Median Opening Guidelines
- Transportation Research Record #1356

3.1 Landscaping and Sight Distance Issues

Two important FDOT documents address landscaping as they relate to medians:

- FDOT Design Standard Index #546 (Sight Distance)
- "Florida Highway Landscape Guide"
  FDOT, Environmental Management Office

The **Landscape Guide** states the importance access management in providing good visibility and landscaping opportunities:

When the number of median openings and driveway connections are reduced, a greater area is generally available for landscaping.

"Access management is the management of vehicular access to the highway. This includes ingress to the highway, egress from the highway and median openings on divided highways. A well-designed highway with good access management can be aesthetically pleasing. It provides the landscape architect greater opportunity in the development of practical and efficient landscape plans. When the number of median openings and driveway connections are reduced, a greater area is generally available for landscaping. The reduction of median openings and driveways also reduces the number of locations that must meet clear sight requirements. This allows greater flexibility in the landscape plan. Therefore, any plan for landscaping a highway should consider access management."

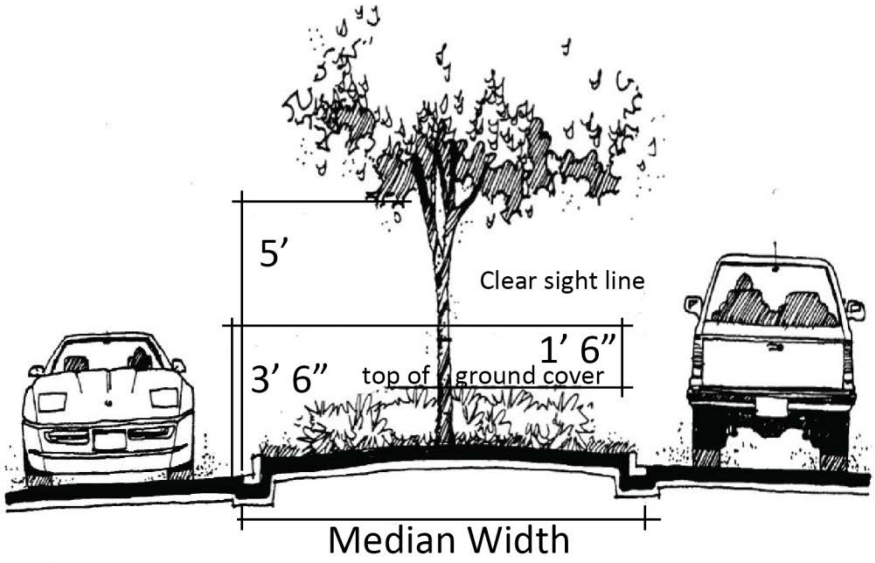
FDOT LANDSCAPE GUIDE

3.1.1 Major Criteria for Decisions on Sight Distance and Planting Area

- **Sight Distance** - for left-turns as stated in FDOT Design Standard Index #546
- **Stopping Sight Distance** for absolute clear area
- **Tree Caliper** – 4 – 11 in. and greater than 11 in. to 18 in.
- **Tree Spacing** - as stated in FDOT Design Standard Index #546
- **Area Size of Vehicle Seen** - 50% coverage or 2 seconds of complete visibility
- **Horizontal Clearance** - as stated in Standard Index 700 and Plans Preparations Manual
- **Clear sight window** criteria - see Exhibit 68.

The same standards are used for both signalized and unsignalized intersection because the traffic signal could malfunction of operate in flash mode during some hours of the day.

Exhibit 68
Clear Sight Window



Source: *Adapted from Standard Index 546 (2013) and the Florida Highway Landscape Guide, Environmental Management Office, 1995*

The spacing of trees is based on the design speed and the caliper or diameter of the tree trunk. Once the caliper of the mature tree trunk is over 18", the driver can completely lose sight of the other vehicle, therefore, the spacing of the trees increases dramatically to allow a complete 2 second view between trees.

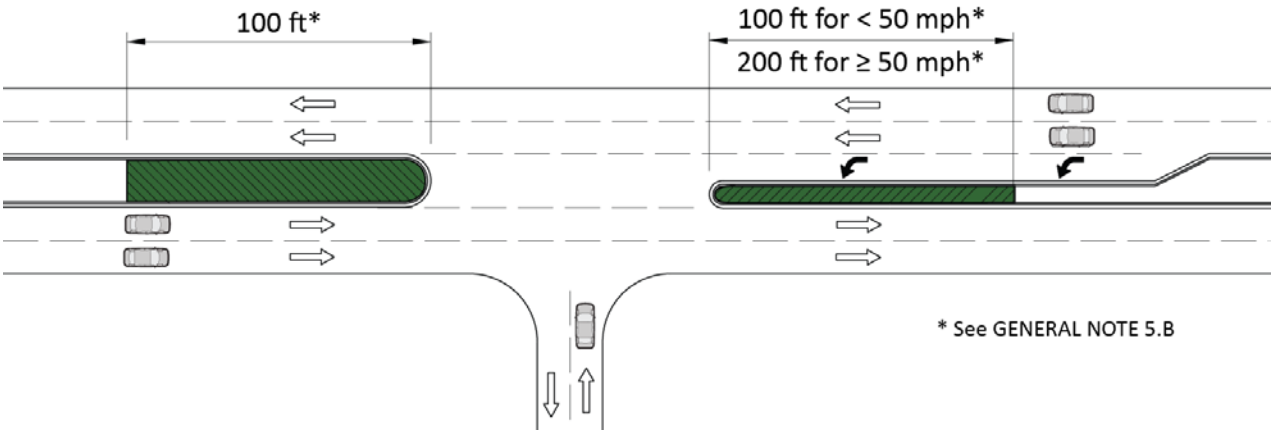
Exhibit 69
Spacing of trees (in ft) from Index 546 (45 mph)

	Feet between trees	
Speed	**> 4 ≥ 11 in. Diameter**	**> 11 ≥ 18 in. Diameter**
30	22	91
35	27	108
40	33	126
45	40	146
50	45	165
55	52	173
60	60	193

FDOT Design Standard Index 546 also has important direction on areas that should never have any landscaping except low groundcover. At a minimum, low groundcover should be used in areas to allow for clear stopping sight distance or to the start of the turn lane taper (whichever is the longest measure).

Exhibit 70

Special areas limited to ground cover (45 mph)



Adapted from Standard Index 546

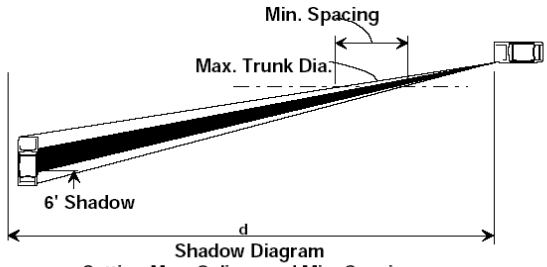
No trees shall be permitted within 100 ft (<50 mph) or 200 ft (≥50 mph) of the restrictive median traffic separator nose.

Exhibit 71

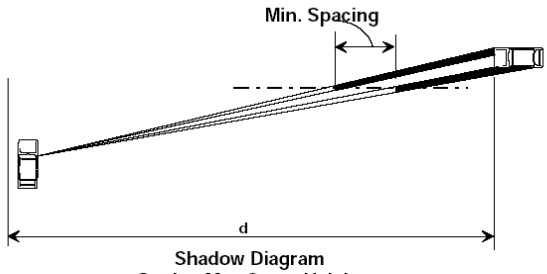
Trees In Median

Intersection Sight Corridor And Outside Clear Zone

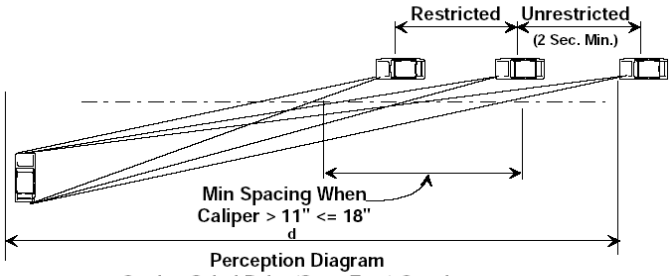
(6' Horizontal Clearance), Curb And Gutter



Shadow Diagram
Setting Max. Caliper and Min. Spacing

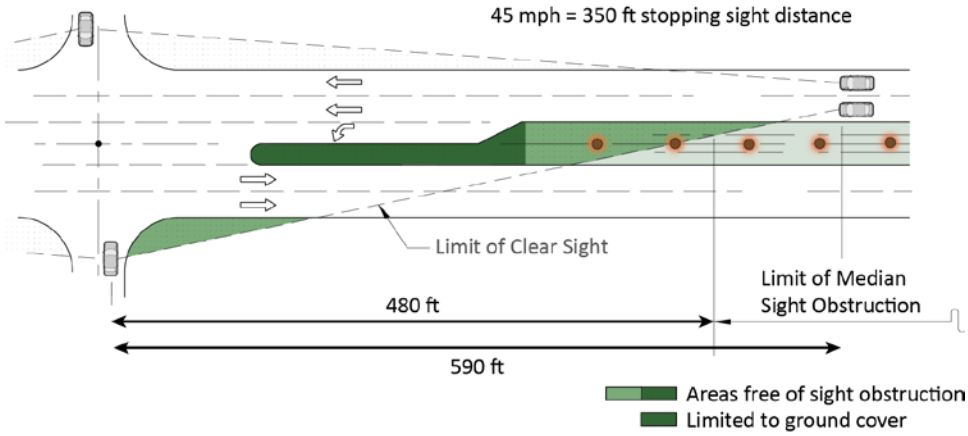


Shadow Diagram
Setting Max.Cover Height



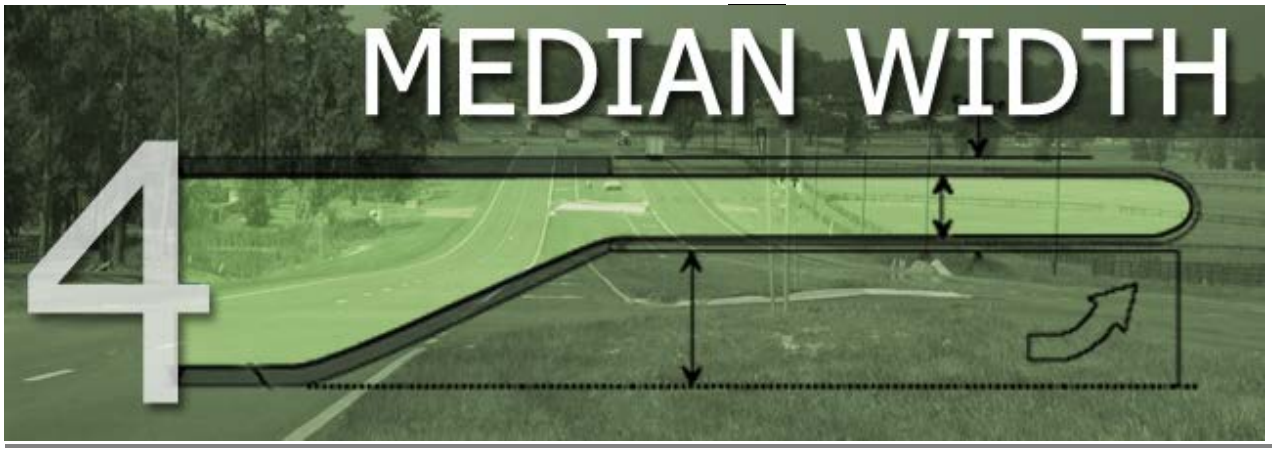
Perception Diagram
Setting Sabal Palm (State Tree) Spacing

Exhibit 72



For more information on landscaping and sight distance:

- Florida Highway Landscaping Guide, FDOT - Environmental Management Office (1995)
- Standard Index #546 (Sight Distance at Intersections)



4.0 Function Determines Median Width

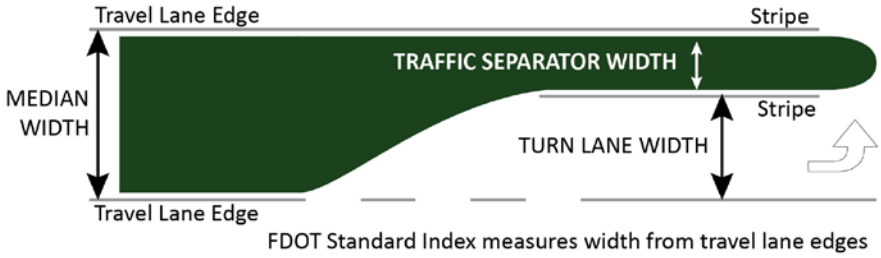
The appropriate median width should be determined by the specific function the median is designed to serve. Concerns which affect median width on roadways having at-grade intersections include the following:

- Separate opposing traffic streams
- Pedestrian refuge
- Left-turns into side streets
- Left-turns out of side streets
- Crossing vehicle movements
- U-turns
- Aesthetics and maintenance

4.1 Anatomy of Median Width

Median width in most urban situations should accommodate turning lanes and a separator. The width of both the left-turn lane and separator are critical to the operations of the median opening. Exhibit 73 shows the traffic separator "nose." (FDOT Standard Index 301 & 302)

Exhibit 73
Anatomy of Median Width



Important Point: Never use the gutter space as part of your turn lane width.

Exhibit 74
Median and Turn lane Width

4.1.1 Minimum and Recommended Widths

Exhibit 75
Minimum Median Width

Minimum Median Width from FDOT Plans Preparation Manual	Width (ft)
40 mph and less *(Reconstruction Projects)*	15.5*
45 mph (Reconstruction Projects)	19.5*
45 mph and less	22
When greater than 45 mph	40

*On reconstruction projects where existing curb locations are fixed due to severe right of way constraints.

Exhibit 76
Recommended Median Width

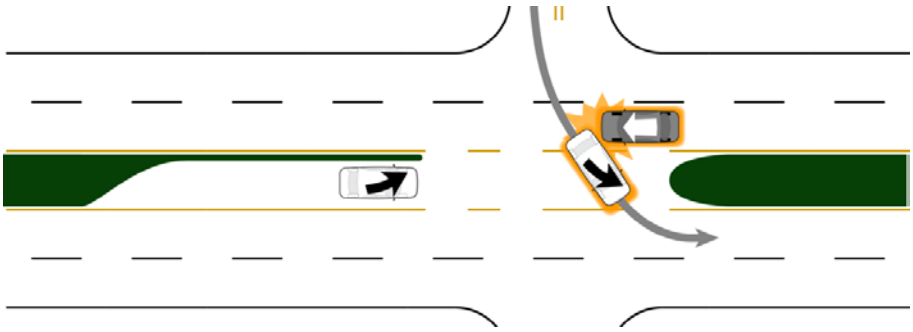
Recommended Median Width	Width (ft)
4 lane highways with medians expecting significant U-turns and directional median openings with excellent positive guidance	30 for single left turn lanes 42 for dual left turn lanes
6 lane highways with medians expecting significant U-turn and directional median openings with excellent positive guidance	22 for single left turns 34 for dual left turn lanes

Where left turns are not expected due to terrain or land use, a median as narrow as 6 ft can help channelize traffic and provide more positive guidance and prevent unwanted left turns.

Where left turns are not expected due to terrain or land use, a median as narrow as 6 ft can help channelize traffic and provide more positive guidance and prevent unwanted left turns.

A critical function of many medians is to protect vehicles turning left. Exhibit 77 shows how a narrow median cannot provide this protection.

Exhibit 77
Movements in a narrow median



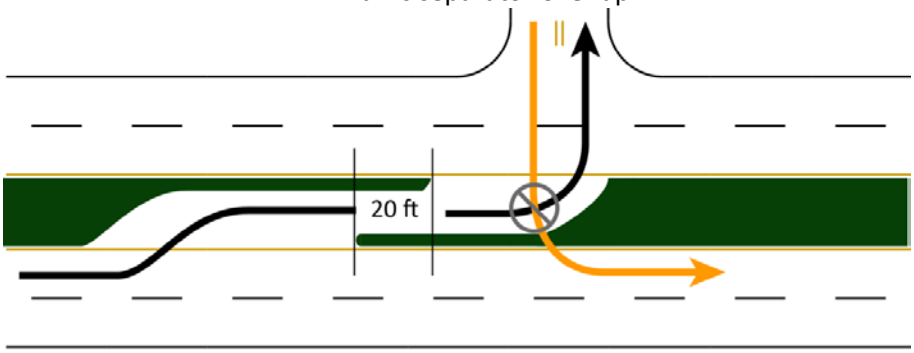
4.1.2 Directional Median Opening Channelization

FDOT Design Standards (Standard Index 527 - "Directional Median Openings") contains much guidance on the design, channelization, and striping of directional openings. The standards found in the Design Standards and the FDOT Plans Preparation Manual will be the major authority for the details of channelizing directional median openings.

Preventing wrong-way movements

A critical function of many medians is to protect vehicles turning left. In order to discourage unwanted movements in a directional median opening, provide a 20-foot section of traffic separator overlap as shown in Exhibit 78.

Exhibit 78
Traffic separator overlap



A 30-foot median width provides many desirable aspects that should be considered:

30 ft median benefits

- Greater flexibility in the choice of lane widths and separation width at double left-turn, full median openings.
- Additional width for landscaping the overlapping "traffic separators" at directional median openings, depending on width.
- Permits separate vertical and/or horizontal alignment of the two roadways.

The FDOT Plans Preparation Manual - Section 2.16.4 (Medians) also provides the following guidance on the benefits of a wider median:

> The minimum median width for four-lane and six-lane high-speed urban and suburban arterial highways may be reduced to 30 ft (inclusive of median shoulders) as opposed to 40 ft minimum required in Table 2.2.1. A 30-foot median provides sufficient width for a 30-foot clear zone. This median width also allows space at intersections for dual left turn lanes (11-foot lanes with 4-foot traffic separator), and directional median openings using 4-foot traffic separators. When this is done neither a Design Exception nor Design Variation is required.
>
> FDOT PLANS PREPARATION MANUAL

For more information on turn lane width:

- Plans Preparation Manual Table 2.1.1

4.1.3 Minimum Traffic Separator Width at Intersections

The minimum width of a median traffic separator "nose" has commonly been 4 ft. AASHTO indicates that "*…the minimum narrow median width of 4 ft is recommended and is preferably 6 to 8 ft wide." (AASHTO Green Book).* The FDOT Design Standards identify 4, 6 and 8.5 ft wide traffic separators as standard widths; however, where right-of-way is limited, narrower median traffic separators have been used.

For more information on traffic separators:

- Standard Index 302

4.1.4 Traffic Separator Visibility at Intersections

Narrow median traffic separator noses can be difficult to see, especially at night and in inclement weather. Reflectorized paint provides minimal visual enhancement as it rapidly loses its limited reflectivity. Reflectorized traffic buttons and/or reflectorized pylons help but are not a significant feature to provide good "target value." Carefully selected landscaping is often the most effective way to provide good median/median opening visibility. A minimum traffic separator width of 6 ft (preferably 8.5 ft) is needed for the median traffic separator nose to be of sufficient width to make it highly visible. Landscaping of the median traffic separator nose to provide visibility is especially important where longer left-turn lanes are present. Obviously, the choice of vegetation and the landscaping design must ensure that sight distance is not obstructed.

Exhibit 79
Traffic pylons

4.1.5 Minimum Median Width for Pedestrian Refuge

In order for a median to be considered a pedestrian refuge, the minimum median width must be at least 6 ft, but preferably at least 8.5 ft. Exhibit 80 depicts a median of adequate width to be considered a pedestrian refuge.

Exhibit 80
Pedestrian refuge in unmarked median

4.1.6 Minimum Median Width for U-turns

See Chapter 5 for complete analysis

U-turns should not be permitted from the through traffic lane because of the potential for high speed, rear-end crashes and significant detrimental impacts on traffic operations. All left-turns and U-turns should be performed from a left-turn/U-turn lane.

Exhibit 81 shows that extremely wide medians are needed for a U-turn by large vehicles. Even a standard passenger car cannot make a U-turn on a 4-lane divided roadway with curb and gutter and commonly used median traffic separator nose widths. A very high percentage of the automobile fleet is intermediate and smaller than the "P" design vehicle. Small or intermediate vehicles can complete a U-turn on a 4-lane divided roadway with curb and gutter and a 6 foot median traffic separator nose.

The design P-vehicle can make a U-turn on a 4-lane divided roadway with a 6 ft. median traffic separator nose by “flaring” the receiving roadway.

- See Chapter 4.2 and Refer to AASHTO Green Book, Chapter 2, for the minimum turning radii for common vehicle types.
- See Chapter 5.3 for a more complete discussion of truck U-turns

5.0 AASHTO Guidance on Width and U-turns

U-turns should not be permitted from the through traffic lane because of the potential for high speed, rear-end crashes and serious detrimental impact on traffic operations. All left-turns, and U-turns should be made from a left-turn/U-turn lane.

The AASHTO Green Book provides guidance on the relationship between median width and U-turn movements. Unfortunately, the figure in the Green Book shows the U-turn movements made from the inside (left) lane. This is contrary to the basic principle of providing accommodations for left turns to be made in auxiliary lanes rather than through lanes. Therefore, the designer should include at least 12 additional feet to the median width for this purpose. Exhibit 81 presents the AASHTO Green Book figures with 12 ft added for a better guide to median width and U-turns. In order to provide median width sufficient for a passenger car (P) to make a U-turn from the left-turn lane to the outer through lane, it would require 30 ft. If you cannot provide 30 ft, then the car will encroach on to the shoulder. This is acceptable as long as this encroachment has been built into the design by way of a bulb out or additional pavement. When designing for 6 lane facilities, 20 ft of median width will usually provide sufficient space for the U-turn for the P vehicle.

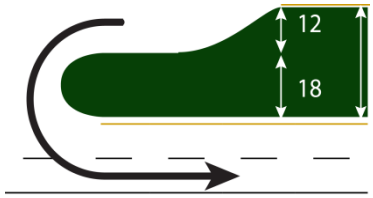
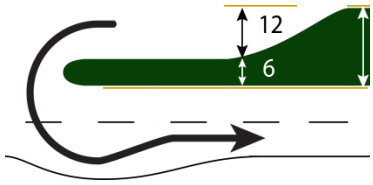
Please Note: *The "P" vehicle is approximately the size of a luxury car or a Chevy Suburban. Therefore, many vehicles in today's passenger car fleet can make tighter U-turns.*

Exhibit 81 shows that extremely wide medians are needed for a U-turn by large vehicles. Even a standard passenger car cannot perform a U-turn on a 4-lane divided roadway with a minimum recommended 18 foot median curb and gutter and commonly used median traffic separator nose widths. However, a very high percentage of the automobile fleet is

intermediate and smaller than the "P" design vehicle. Small or intermediate vehicles can complete a U-turn on a 4-lane divided roadway having curbs and gutters and a 6 ft median traffic separator nose.

The design P-vehicle can make a U-turn on a 4-lane divided roadway with a 6 ft. median traffic separator nose by “flaring” the receiving roadway. See Chapter 4.2 and Refer to AASHTO Green Book, Chapter 2, for the minimum turning radii for common vehicle types.

Exhibit 81
Minimum width of median for U-turn on 4 lane road

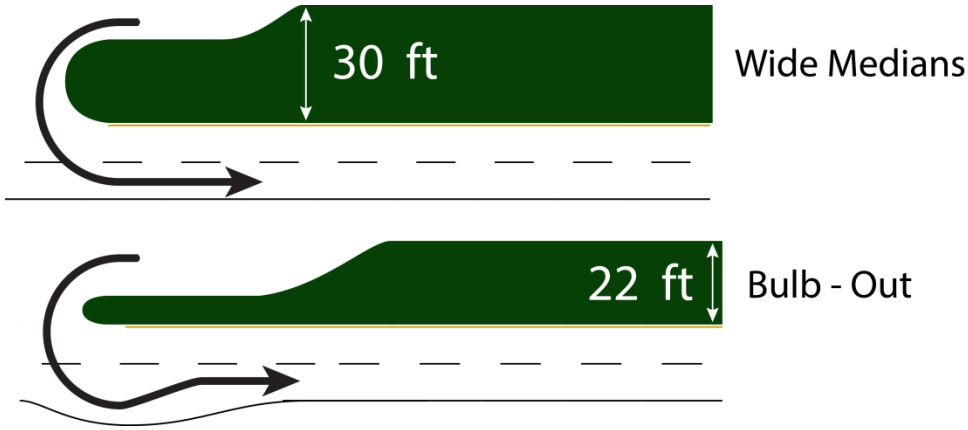
	Passenger P	Single Unit SU
	30	63
	18	53

Source: Adapted from AASHTO Green Book (with added 12ft for turn lane width)

5.1 Design Options for U-turns

In order to accommodate U-turns, the following options are available:

Exhibit 82
U-turn Options



Traffic, land use, and terrain will play important roles in the decision on their implementation.

5.1.1 U-turn Flare Design Examples

The design P-vehicle can make a U-turn on a 4-lane divided facility with a 6 ft median by "flaring" the receiving pavement area via a bulb out or radius return as illustrated in Exhibit 83 and 84.

Exhibit 83
U-turn Alternatives

Design for P-vehicle U-turn with extended flare (point out extended flare)

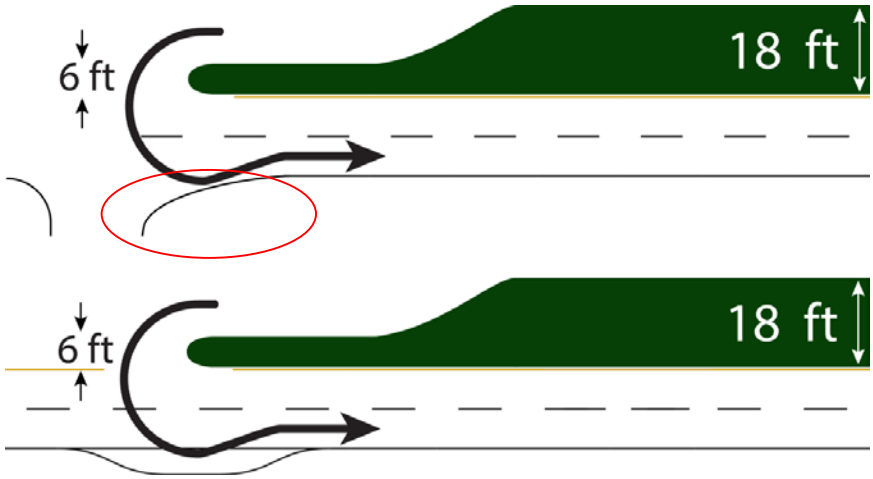
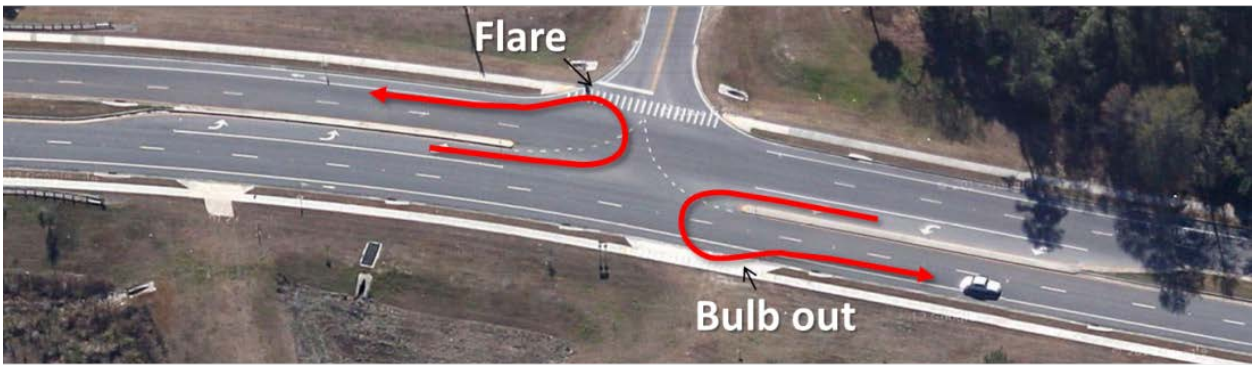


Exhibit 84
Median opening with both bulb out and flare to accommodate U-turn



5.2 Truck U-turns

The extremely wide median that is required for buses and trucks to make a U-turn makes it impractical to design for these vehicles except in special cases. The need for U-turns by large vehicles can generally be avoided in the following ways:

- Bus and truck delivery routes can be planned to eliminate the need for U-turns on a major roadway.
- Driveways can be adjusted and on-site circulation designed to eliminate the need for U-turns by trucks.

Local governments can avoid the need for U-turns by large vehicles through their subdivision and site development ordinances.

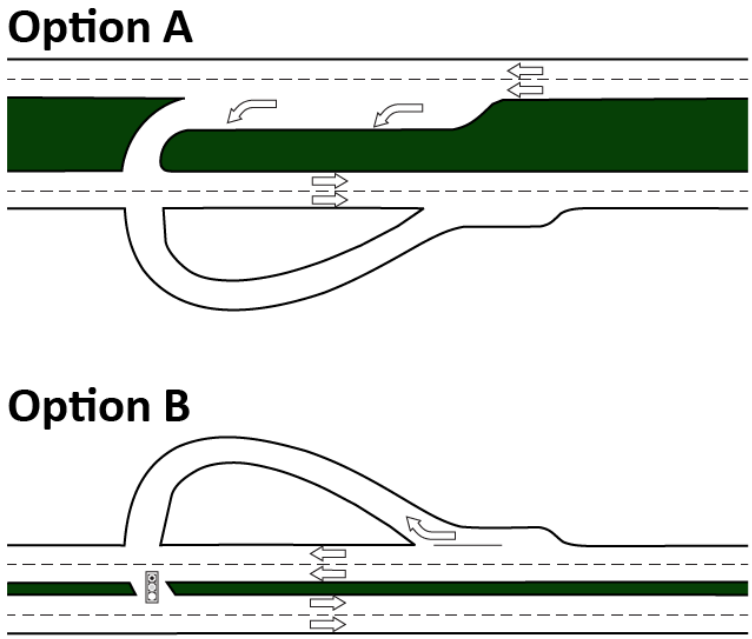
These special designs will probably only be necessary at, or near, truck facilities, major industrial areas, or truck staging areas.

Exhibit 85
Truck U-turn in Williston Florida

5.2.1 U-turn Alternatives for Large Vehicles - Jug Handles

Exhibit 86

Jug handle designs for large vehicles



Jug handles are a roadway design feature to accommodate U-turns (and left turns) for large vehicles. In most cases Option "B" would need a signal. Option "A" has the following desirable operational features.

- The U-turning vehicle is stored in the median parallel to the through traffic lanes.
- A suitable gap is needed in the opposing traffic stream only.
- After completion of the U-turn the driver can accelerate prior to merging into the through traffic lane.

These options require more right of way than most standard highway designs, but it may be more cost feasible where public land is available.

Exhibit 87

Jug-handle at a Miami horse race track specifically designed for horse trailers

5.3 U-turn Locations

Consider the location of U-turns in context with the transportation network.

5.3.1 U-turn at Signalized Intersections

U - turns can be made at a signal when:

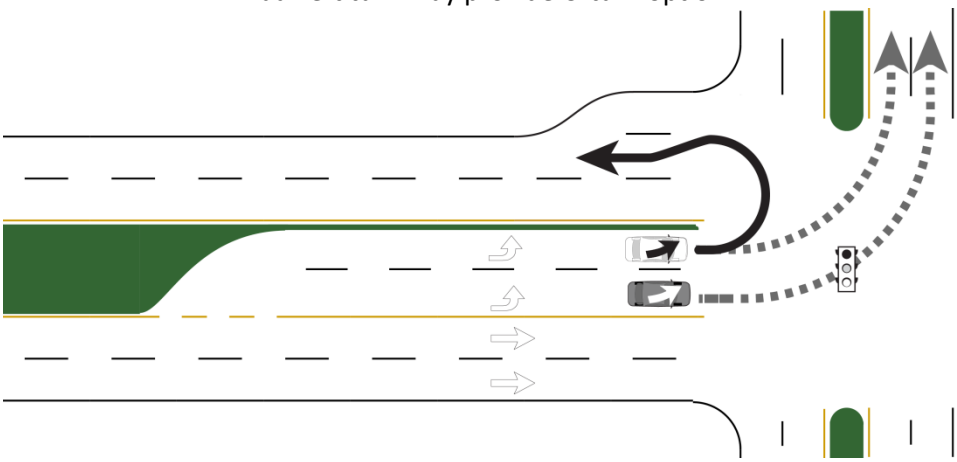
- Median is of sufficient width
- Low combined left-turn plus U-turn volume at signalized single left-turn lane

You should note:

- Consider "right-on-red" restrictions for side streets
- Signal operation including right-turn overlaps
- U-turns take more time to clear the intersection than left turns

Where medians are of sufficient width to accommodate dual left-turn lanes, an excellent option is to allow U-turns from the inside (left-most) left-turn bays as illustrated in Exhibit 88.

Exhibit 88
Dual left turn may provide U-turn option



5.3.2 U-turns in Advance of a Signal

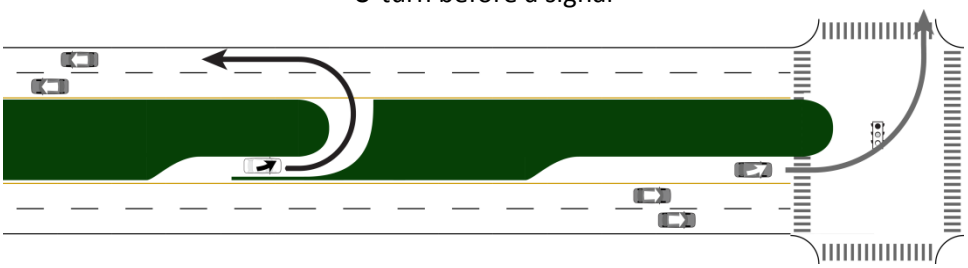
A U-turn in advance of a signalized intersection will result in two successive left-turn lanes as illustrated in Exhibit 89. However, unless there is a substantial length of full median width, drivers may mistakenly enter the U-turn lane when desiring to perform a left-turn at the downstream signalized intersection. Motorists may perform abrupt re-entry maneuvers into the through traffic lane to escape the U-turn lane. Over 100 ft of full median width would help to alleviate this problem. If 100 ft is not possible, signage or other pavement markings can be used to help guide the motorist.

Indications that you should consider a U-turn opening before a signalized intersection are:

- High volume of left turns currently at signalized intersection
- Many conflicting right turns
- Where a gap of oncoming vehicles would be beneficial at a separate U-turn opening
- Where there is sufficient space to separate the signalized intersection and U-turn opening

A study on U-turns by the University of South Florida has shown that having U-turns made before a signalized intersection can greatly decrease delay at the signalized intersection.

Exhibit 89
U-turn before a signal



Source: Safety and Operational Evaluation of Right Turns Followed By U-turns as an Alternative to Direct Left Turns, Dr. John Lu, University of South Florida

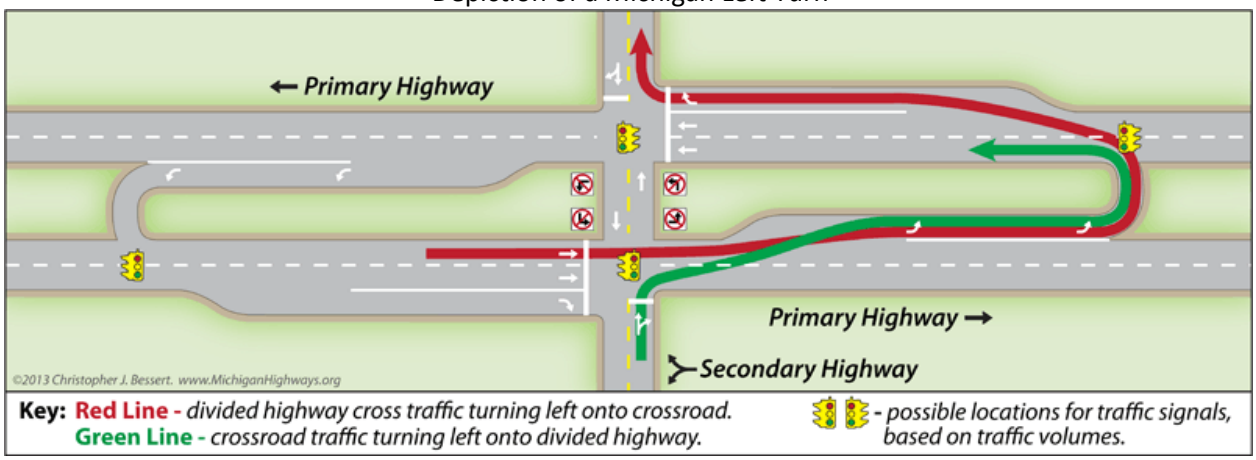
Exhibit 90
Directional opening before a signalized intersection

Locating the U-turn after a traffic signal has the same operational issues as the U-turn located before a signal. These are sometimes called “Michigan U-turns” or “Michigan Left Turns.”

5.3.3 U-turns after a Signal

Locating the U-turn after a traffic signal has the same operational issues as the U-turn located before a signal. These are sometimes called "Michigan U-turns" or "Michigan Left Turns", due to their origination in Detroit, Michigan in the early 1960's. While this type of turn is still common in the state of Michigan, there have been recent implementations of Michigan Lefts throughout the country.

Exhibit 91
Depiction of a Michigan Left Turn



Source: michiganhighways.org

Exhibit 92
Michigan Left Turn in Holland, MI

There are potential benefits associated with the implementation of a Michigan Left. The Michigan Department of Transportation (MDOT) has found that Michigan Lefts allow for a 20 to 50 percent greater capacity than direct left-turns. This has led to reduced average delays for left-turning vehicles and through-traffic. Michigan Lefts have also been found

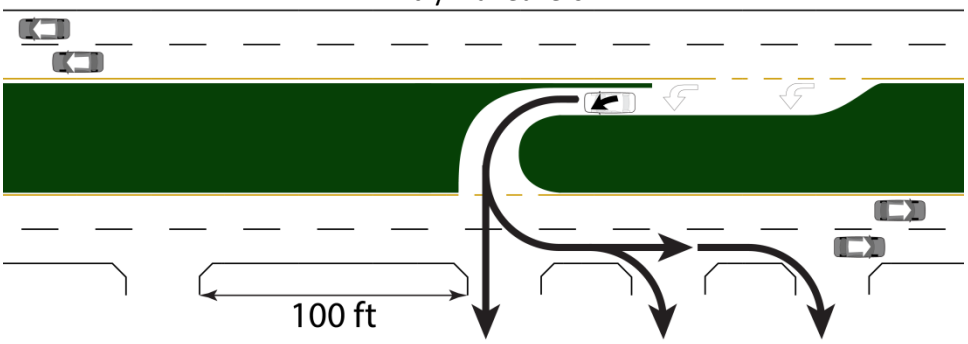
to be safer for pedestrians looking to cross the roadway. Vehicular safety is also increased, MDOT found significant crash reductions.

Typically, there is ¼ mile spacing between the intersection and the left turn. According to MDOT, while there are no absolute traffic volume requirements for the use of a Michigan Left, they have traditionally been implemented on state roads with average traffic volumes of at least 10,000 vehicles per day.

5.3.4 U-turns location in relation to driveways

Access connections should be located directly opposite or downstream from a median opening as illustrated. The nearest driveway access should be located more than 100 ft upstream from the median opening to prevent wrong way maneuvers as seen in Exhibit 93.

Exhibit 93
Entry maneuvers



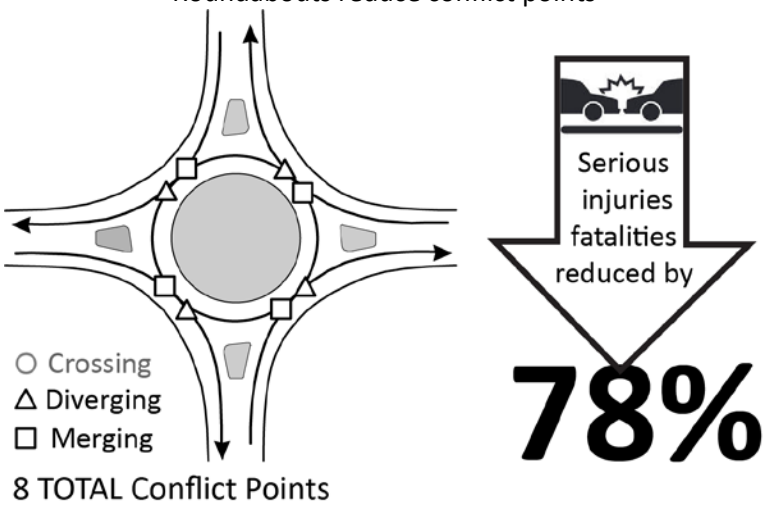
Additional Resources:

- Synthesis of the Median U-turn Intersection Treatment, Safety, and Operations Benefits
- Median U-turn Intersection
- Restricted Crossing U-turn Intersection
- Displaced Left-Turn Intersection
- Quadrant Roadway Intersection
- Alternative Intersections and Interchanges Symposium http://www.teachamerica.com/AI14

6.0 Roundabouts and Access Management

Roundabouts can provide many benefits when included as part of an overall access management strategy. Roundabouts achieve one primary principal of access management by reducing the number of conflict points. The result is that serious injuries/fatalities are significantly reduced.

Exhibit 94
Roundabouts reduce conflict points



Source: safety.fhwa.dot.gov/provencountermeasures/fhwa_sa_12_005.htm

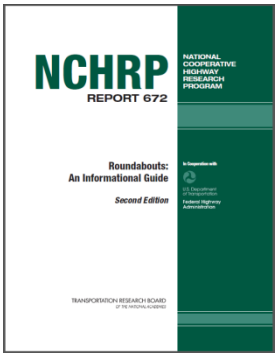
Roundabouts are ideal for providing U-turn opportunities, and when designed in series, they help create an integrated system of moving traffic safely and efficiently, with potentially better traffic flow and access to adjacent businesses.

This chapter will provide guidance to help you determine whether a roundabout is an appropriate access management tool for a specific application.

Traffic flow through a roundabout is especially sensitive to small geometric changes. Some considerations that must be addressed for successful implementation are:

- Good deflection at the entry of a roundabout
- Truck movements
- Public acceptance/awareness

Because many minor crashes can be avoided by a careful review of initial designs by designers with significant roundabout experience, peer review of all designs is highly recommended.



NCHRP Report 672

Roundabouts are one of the select few FHWA proven safety countermeasures, and FHWA offers Peer-to-Peer (P2P) assistance to transportation professionals interested in considering them as an option. The FHWA Safety P2P Coordinator will determine your specific questions or issues and match you with the best peer for your case.

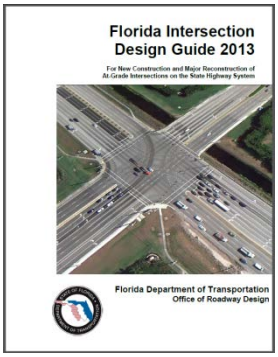
NCHRP Report 672, *Roundabouts: An Informational Guide* covers all aspects of roundabout design in more detail. This chapter provides some general guidance to help you consider whether a roundabout is a good choice, and how it could be implemented.

The Florida Intersection Design Guide provides more guidance and a checklist to evaluate whether conditions are appropriate for a roundabout.

www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG.shtm

Roundabouts should be considered as an alternative to all the other traffic control modes - FDOT Intersection Design Guide.

> Due to substantial safety characteristics, and potentially significant operational and capacity advantages, the modern Roundabout is a preferred traffic control mode for any new road or reconstruction project. Roundabouts should be considered as an alternative to all the other traffic control modes.
>
> Florida Intersection Design Guide



FIDG 2013

> Roundabouts by nature encourage lower speeds on the approach to, and within the circulatory roadway, thereby enhancing safety characteristics. The numbers of vehicles that are required to come to a complete stop at a roundabout are significantly less than at a conventional intersection, thereby reducing delay. Because entering vehicles are required to yield to vehicles within the circulatory roadway, sight distance is critical to entering vehicles, while approaching vehicles should not be given the appearance of a linear path. World-wide experience has shown that there are a few conditions under which roundabouts may not perform well enough to be considered as the most appropriate form of control. These factors must be examined carefully as a part of the justification process.
>
> Florida Intersection Design Guide

6.1 Roundabout Considerations

At a minimum, roundabouts should accommodate school buses, moving vans, garbage trucks, fire trucks, and other emergency vehicles. Truck aprons around the circular island allow for larger trucks to safely make all turning movements. When properly designed, the geometric design of roundabouts reduces the speed of vehicles approaching, using, and exiting the roundabout. Because vehicle speed is reduced, the differential among all users speed is also lowered.

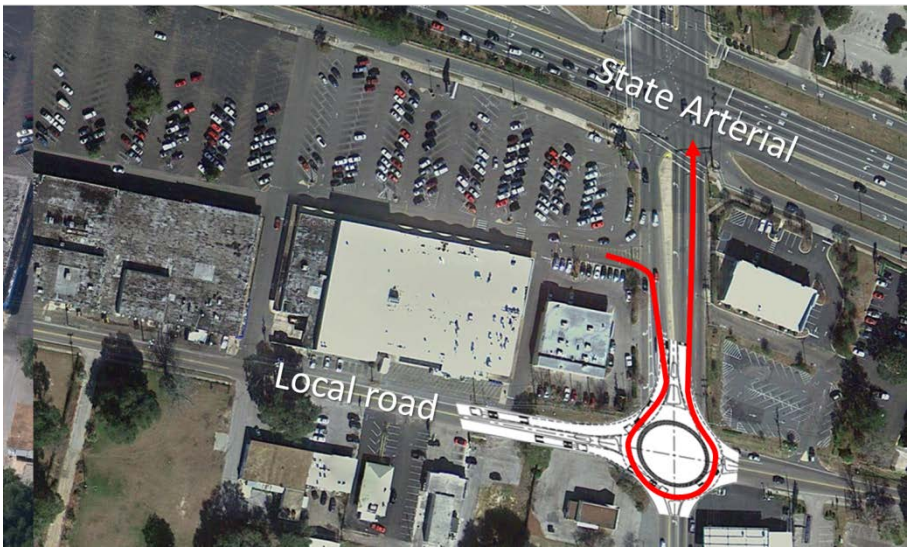
Exhibit 95
Roundabout category comparison (adapted from NCHRP 672)

	Single lane	Multi-lane
Total entering traffic volumes	Up to 25,000	Up to 45,000
Entry speed	20 to 25 mph	25 to 30 mph
Typical inscribed circle diameter	90 to 180 ft	150 to 300 ft

6.1.1 How Roundabouts can be used for U-turns

Roundabouts allow U-turns within the normal flow of traffic, which often are not possible at other forms of intersection. Isolated roundabouts can be used to solve a variety of problems. The use of a roundabout can also change access management patterns, changing side street and driveway access spacing needs and requirements. Exhibit 96 shows how a roundabout would facilitate access to the arterial from this shopping center, where the median opening was closed.

Exhibit 96
Example of proposed roundabout near arterial



6.1.2 Adjacent Median Opening Locations near Roundabouts

The operational characteristics of a roundabout are very different than an intersection. The slower speeds and traffic queues provide more flexible turning opportunities that would typically disrupt a signalized intersection.

Directional median openings could be considered **after** exiting a roundabout. The ease of making a U-turn suggests reduces the need for median openings prior to roundabouts. Since speeds are lower before and after roundabouts, the design and location of median openings will depend on the specific location. Exhibit 97 shows a directional median opening constructed near the exit leg of this Arizona roundabout.

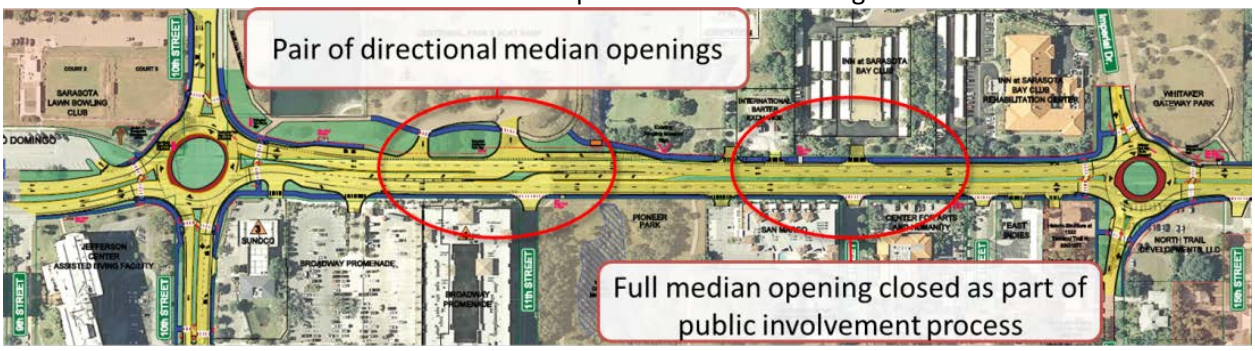
Exhibit 97
Directional median opening after a roundabout

Exhibit 98 shows a series of two roundabouts in Sarasota approved in 2013. Signalized intersections and several median openings were included in alternatives to be considered. An extensive public involvement process resulted in a single pair of directional median openings between two roundabouts that allow direct access to the park and 11th Street. All other movements are accommodated by U-turns at the two roundabouts.

Exhibit 98
Existing conditions for Sarasota

Exhibit 99

Proposed roundabout design for Sarasota

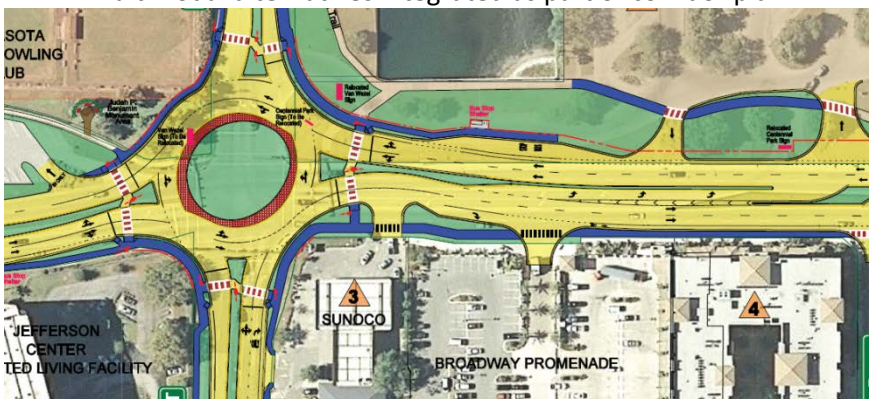


[View Sarasota Roundabout Website]

Exhibit 100 shows that the splitter island has been extended to form a continuous median for this corridor. Excellent bicycle and pedestrian amenities include a transit shelter and multi-use recreational trail. The median forms a pedestrian refuge along the entire corridor, and positive guidance for all vehicular movements.

Exhibit 100

Multimodal alternatives integrated as part of corridor plan



Below is an example of how a series of roundabouts was used to improve traffic flow and safety on a commercial corridor.

Exhibit 101

Golden Colorado businesses helped by roundabouts and medians

Source: [teachamerica.com/RAB11/RAB1111Isebrands/player.html]

7.0 Medians Help Pedestrians

Although medians have significant benefit for vehicle operations, they are also beneficial for pedestrians. Pedestrians are permitted to travel along all non-limited access facilities. Therefore, considerations for pedestrian safety and mobility should be included in median design decisions.

Pedestrian Safety — restrictive medians provide a refuge for pedestrians crossing the highway. Fewer pedestrian injuries occur on roads with restrictive medians.

Pedestrian Mobility – when pedestrian crossing treatments are incorporated into restrictive medians, a complete pedestrian network is provided resulting in improved connectivity.

Pedestrians, transit riders, and cyclists are all users of all non-limited access facilities. Note that bicyclists, for design purposes, are considered vehicles when operating within the roadway and pedestrians when operating within the sidewalk area. When conflict points are well managed as part of a comprehensive approach, all users of the roadway benefit from improved safety and operations.

Multi-lane facility median policy is an integral part to roadway access management

The **Multi-lane Facility Policy** directs our designers to find ways to use restrictive medians in all multi-lane projects, even on facilities with those below the 40 mph design speed.

An example of a small pedestrian refuge that could be used on a 5-lane section is shown in Exhibit 102.

Exhibit 102
Pedestrian refuges on a 5-lane section

Source: John McWilliams, South Florida

7.1 Proven Safety Countermeasures

7.1.1 Pedestrian Refuges Islands in Urban and Suburban Areas

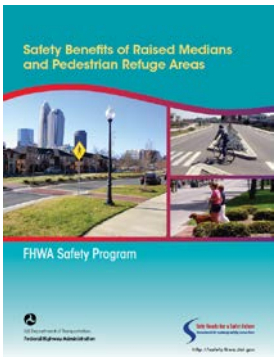
Midblock locations account for more than 70 percent of pedestrian fatalities. This is where vehicle travel speeds are higher, contributing to the larger injury and fatality rate seen at these locations. More than 80 percent of pedestrians die when hit by vehicles traveling at 40 mph or faster while less than 10 percent die when hit at 20 mph or less. Installing such raised channelization on approaches to multi-lane intersections has been shown to be especially effective. Medians are a particularly important pedestrian safety countermeasure in areas where pedestrians access a transit stop or other clear origins/destinations across from each other. Providing raised medians or pedestrian refuge areas at marked crosswalks has demonstrated a 46 percent reduction in pedestrian crashes. At unmarked crosswalk locations, medians have demonstrated a 39 percent reduction in pedestrian crashes.

Exhibit 103

Angled cut-through in Bainbridge, WA (from FHWA Medians Brochure)

Source: safety.fhwa.dot.gov/provencountermeasures/fhwa_sa_12_011.htm

7.1.2 Pedestrian Crashes can be Reduced



Safety Benefits of Raised Medians and Pedestrian Refuge Areas

FHWA Safety Program

Pedestrian crashes account for about 12 percent of all traffic fatalities annually. Over 75 percent of these fatalities occur at non-intersection locations. On average, a pedestrian is killed in a motor vehicle crash every 120 minutes and one is injured every 8 minutes.[9] Many of these crashes are preventable. By providing raised medians and pedestrian refuge islands, we can bring these crash numbers down, prevent injuries, and save lives.

Providing raised medians or pedestrian refuge areas at pedestrian crossings at marked crosswalks has demonstrated a 46 percent reduction in pedestrian crashes. At unmarked crosswalk locations, pedestrian crashes have been reduced by 39 percent.[10] Installing raised pedestrian refuge islands on the approaches to unsignalized intersections has had the most impact reducing pedestrian crashes.

[9] NHTSA, Traffic Safety Facts 2008 Pedestrians, NHTSA, Washington, DC, 2009.

[10] Lindley, J., Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures FHWA, Washington DC, July 2008.

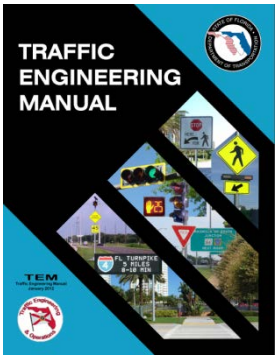
7.1.3 Midblock Crossing Locations

The Federal Highway Administration (FHWA) strongly encourages the use of raised medians (or refuge areas) in curbed sections of multi-lane roadways in urban and suburban areas, particularly in areas where there are mixtures of a significant number of pedestrians, high volumes of traffic (more than 12,000 vehicles per day) and intermediate or high travel speeds.[8]

FHWA guidance further states that medians/refuge islands should be at least 4 ft wide (preferably 8 ft wide for accommodation of pedestrian comfort and safety) and of adequate length to allow the anticipated number of pedestrians to stand and wait for gaps in traffic before crossing the second half of the street.[8]

On refuges 6 ft or wider that serve designated pedestrian crossings, detectable warning strips complying with the requirements of the Americans with Disabilities Act must be installed.[11]

7.1.4 Installation Criteria



Traffic Engineering Manual

FDOT's Traffic Engineering Manual (TEM) (Section 3.8) provides installation criteria for marked mid-block crosswalks.

> Placement of mid-block crosswalks should be based upon an identified need and not used indiscriminately. Important factors that should be considered when evaluating the need for a mid-block crosswalk include:
>
> (a) Proximity to significant generators
>
> (b) Pedestrian demand
>
> (c) Pedestrian-vehicle crash history
>
> (d) Distance between crossing locations
>
> *FDOT Traffic Engineering Manual*

Any marked crosswalk proposed at an uncontrolled location across the SHS must be reviewed and approved by the District Traffic Operations Engineer prior to installation. A full engineering study documenting the need for a marked crosswalk based upon the location of significant generators, demand, crashes, and distances to nearest crossing locations provides the basis for the determination. Refer to the TEM for detailed criteria for each facet of this evaluation.

[11] Lindley, J., Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures FHWA, Washington DC, July 2008.

7.1.5 Treatments

The TEM also provides standards for the appropriate treatments for marked mid-block crossings. The determination of the appropriate treatments is generally based upon pedestrian volumes, vehicular volumes, distances to adjacent traffic signals, etc. The TEM outlines 3 primary treatment options for midblock crossings beyond an appropriately signed and marked crosswalk:

1. Traffic Signal – a conventional full traffic signal installed at a mid-block location. Consideration for traffic signal warrant and spacing criteria must be addresses as part of this option.

2. Pedestrian Hybrid Beacon – this treatment is also referred to as a High-Intensity Activated Crosswalk Beacon or HAWK beacon. This treatment provides for signalized, protected pedestrian crossings while minimizing disruption to vehicular traffic flow. Pedestrian hybrid beacons must meeting specific warrant criteria for installation as outlined in the TEM. This is a common option in locations where a full traffic signal is not warranted by pedestrian volumes demand are more intense warning treatment.

3. Supplemental Beacons – The TEM provides two (2) options for supplemental beacons: flashing yellow warning beacons and rectangular rapid flashing beacons (RRFBs). Conventional flashing yellow warning beacons installed as part of regulatory or warning signs provides additional emphasis on the crossing location. Note that the TEM requires that these beacons be activated by a pedestrian to increase the effectiveness of the treatment. RRFB's are also pedestrian actuated and quickly flash alternating warning lights in a "wig-wag" pattern.

Exhibit 104

Rapid Rectangular Flashing Beacon in Miami

In addition to these treatments, other enhancement tools are available to the designer to further enhance midblock crossings. These enhancements include, but are not limited to supplemental pavement markings/signage and in-street lighting. Note that all marked mid-block crossings must meet the ADA Standards. The TEM provides guidance for the application of these supplemental enhancements.

Key Resources

- A Review of Pedestrian Safety Research in the United States and Abroad, p. 85-86
  http://www.walkinginfo.org/library/details.cfm?id=13
- Pedestrian Facility User's Guide: Providing Safety and Mobility, p. 56
  http://katana.hsrc.unc.edu/cms/downloads/PedFacility_UserGuide2002.pdf
- Guide for the Planning, Design, and Operation of Pedestrian Facilities, American Association of State Highway and Transportation Officials, 2004 [Available for purchase from AASHTO]
  https://bookstore.transportation.org/item_details.aspx?id=119
- Pedestrian Road Safety Audits and Prompt Lists
  http://www.walkinginfo.org/library/details.cfm?id=3955
- FHWA Office of Safety Bicycle and Pedestrian Safety
  http://safety.fhwa.dot.gov/ped_bike/
- Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations, p. 55
  http://www.walkinginfo.org/library/details.cfm?id=54
- Handbook of Road Safety Measures
  http://www.cmfclearinghouse.org/study_detail.cfm?stid=14
- Analyzing Raised Median Safety Impacts Using Bayesian Methods
  http://www.cmfclearinghouse.org/study_detail.cfm?stid=213