Course Code: CE 455
Course Title: Traffic Engineering and Management

Lecture 8: Urban bypass

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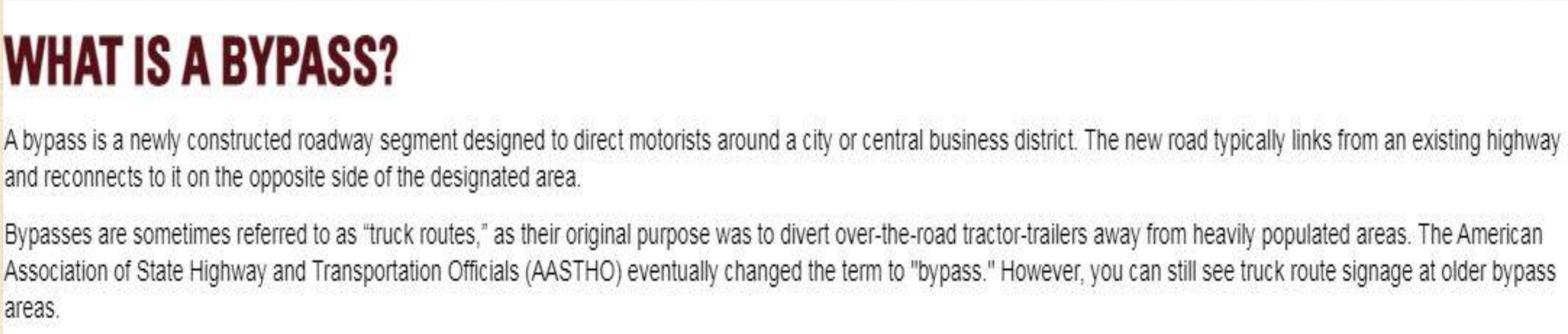
Outline

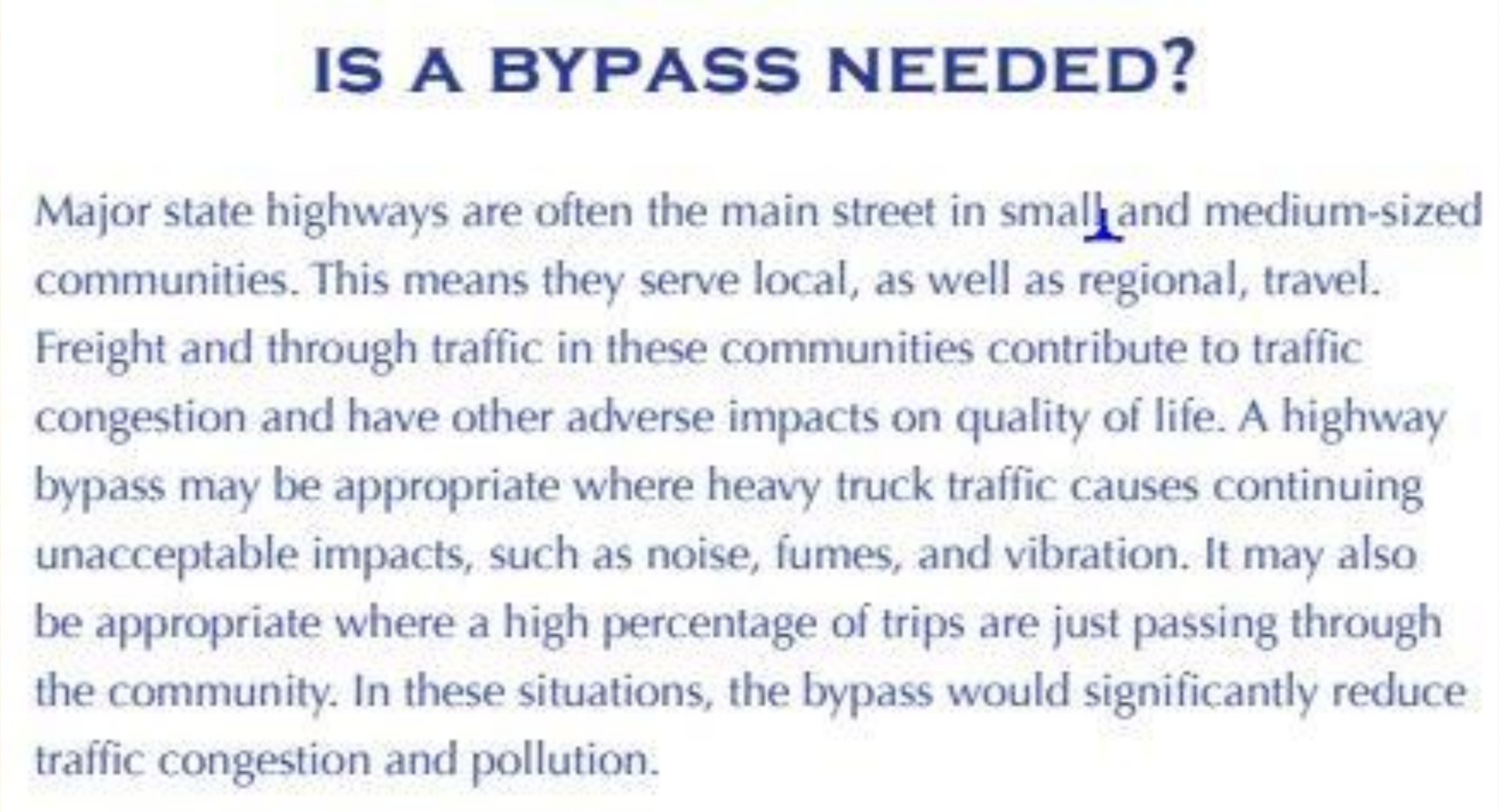
- Bypass: Definition
- Necessity of bypass facilities
- Affecting land use pattern,
- Economic implications,
- Potential issues related to a bypass
- Access control
- Equipment for bypass construction
- Difference between access management in rural and urban roads
- Access control and road geometry
- Access management manual



WHAT IS A BYPASS?

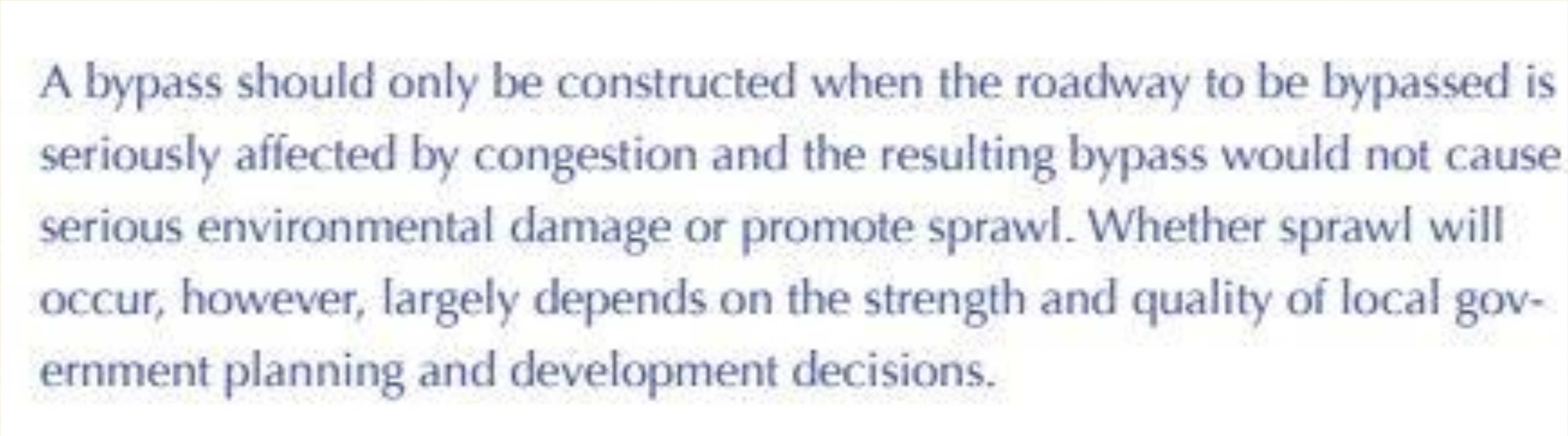
A bypass is a newly constructed roadway segment designed to direct motorists around a city or central business district. The new road typically links from an existing highway and reconnects to it on the opposite side of the designated area.

Bypasses are sometimes referred to as “truck routes,” as their original purpose was to divert over-the-road tractor-trailers away from heavily populated areas. The American Association of State Highway and Transportation Officials (AASTHO) eventually changed the term to "bypass." However, you can still see truck route signage at older bypass areas.

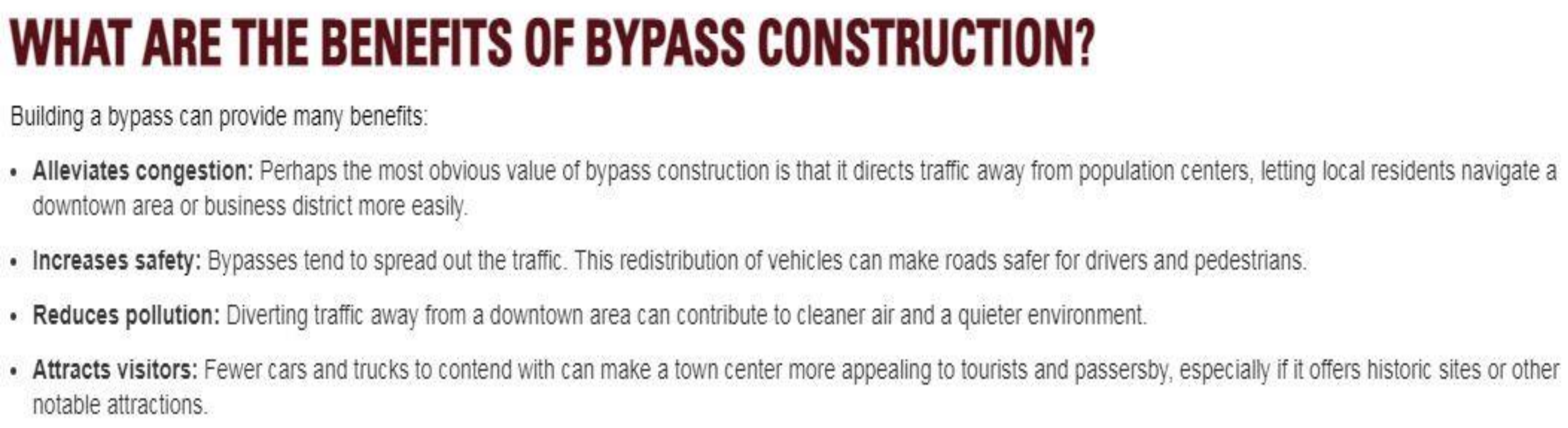


IS A BYPASS NEEDED?

Major state highways are often the main street in small and medium-sized communities. This means they serve local, as well as regional, travel. Freight and through traffic in these communities contribute to traffic congestion and have other adverse impacts on quality of life. A highway bypass may be appropriate where heavy truck traffic causes continuing unacceptable impacts, such as noise, fumes, and vibration. It may also be appropriate where a high percentage of trips are just passing through the community. In these situations, the bypass would significantly reduce traffic congestion and pollution.



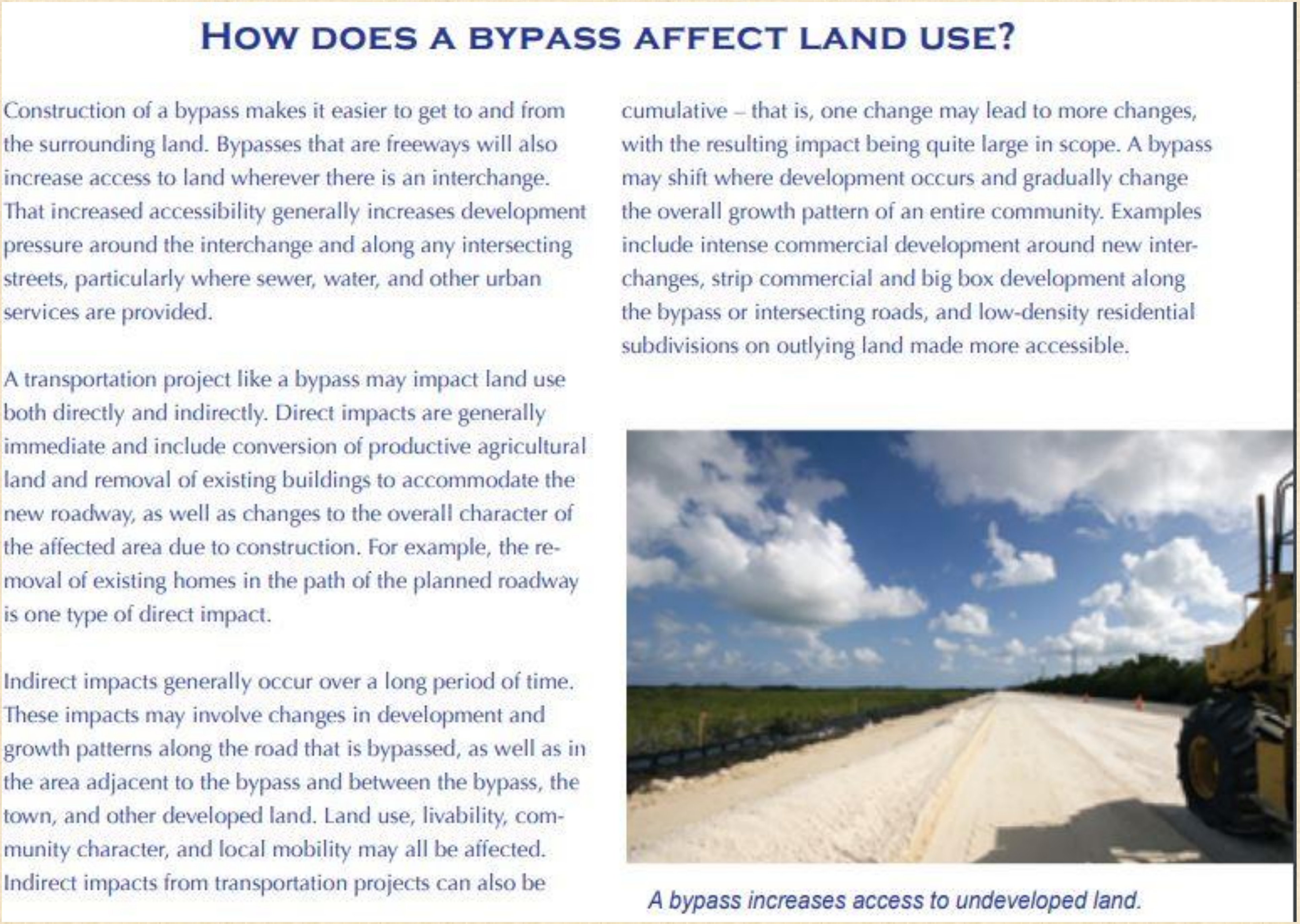
A bypass should only be constructed when the roadway to be bypassed is seriously affected by congestion and the resulting bypass would not cause serious environmental damage or promote sprawl. Whether sprawl will occur, however, largely depends on the strength and quality of local government planning and development decisions.



WHAT ARE THE BENEFITS OF BYPASS CONSTRUCTION?

Building a bypass can provide many benefits:

- **Alleviates congestion:** Perhaps the most obvious value of bypass construction is that it directs traffic away from population centers, letting local residents navigate a downtown area or business district more easily.
- **Increases safety:** Bypasses tend to spread out the traffic. This redistribution of vehicles can make roads safer for drivers and pedestrians.
- **Reduces pollution:** Diverting traffic away from a downtown area can contribute to cleaner air and a quieter environment.
- **Attracts visitors:** Fewer cars and trucks to contend with can make a town center more appealing to tourists and passersby, especially if it offers historic sites or other notable attractions.



HOW DOES A BYPASS AFFECT LAND USE?

Construction of a bypass makes it easier to get to and from the surrounding land. Bypasses that are freeways will also increase access to land wherever there is an interchange. That increased accessibility generally increases development pressure around the interchange and along any intersecting streets, particularly where sewer, water, and other urban services are provided.

A transportation project like a bypass may impact land use both directly and indirectly. Direct impacts are generally immediate and include conversion of productive agricultural land and removal of existing buildings to accommodate the new roadway, as well as changes to the overall character of the affected area due to construction. For example, the removal of existing homes in the path of the planned roadway is one type of direct impact.

Indirect impacts generally occur over a long period of time. These impacts may involve changes in development and growth patterns along the road that is bypassed, as well as in the area adjacent to the bypass and between the bypass, the town, and other developed land. Land use, livability, community character, and local mobility may all be affected. Indirect impacts from transportation projects can also be cumulative – that is, one change may lead to more changes, with the resulting impact being quite large in scope. A bypass may shift where development occurs and gradually change the overall growth pattern of an entire community. Examples include intense commercial development around new interchanges, strip commercial and big box development along the bypass or intersecting roads, and low-density residential subdivisions on outlying land made more accessible.

A bypass increases access to undeveloped land.

WHAT ARE THE ECONOMIC IMPLICATIONS OF A BYPASS?

Many preconceptions exist about the effect of a bypass on a community's economy. Some view a new bypass and the access it brings to undeveloped land as an opportunity for economic growth. Others believe that there will be a decline in sales and decreased business activity in town, particularly along the bypassed route. The reality is more likely to be a redistribution of economic activity from the downtown area toward the bypass. Many businesses will likely be national chains.

Economic activity along the bypassed route is likely to change. For example, a downtown, along with its valuable infrastructure and local businesses, may experience increased vacancy rates as new, national chain stores develop adjacent to the bypass. The new chain stores often attract more growth to the bypass, and require the community to pay for supporting infrastructure and services, such as connector roads, sewer and water lines, and fire and police protection. In addition, more local dollars spent at new national chain stores mean fewer dollars kept locally. Most profits go to owners and shareholders located outside of the community, often in other states. Some small businesses that rely on customers from pass-by traffic or those that offer goods and services sold cheaper by national chains will close, affecting both the local economy and community character.

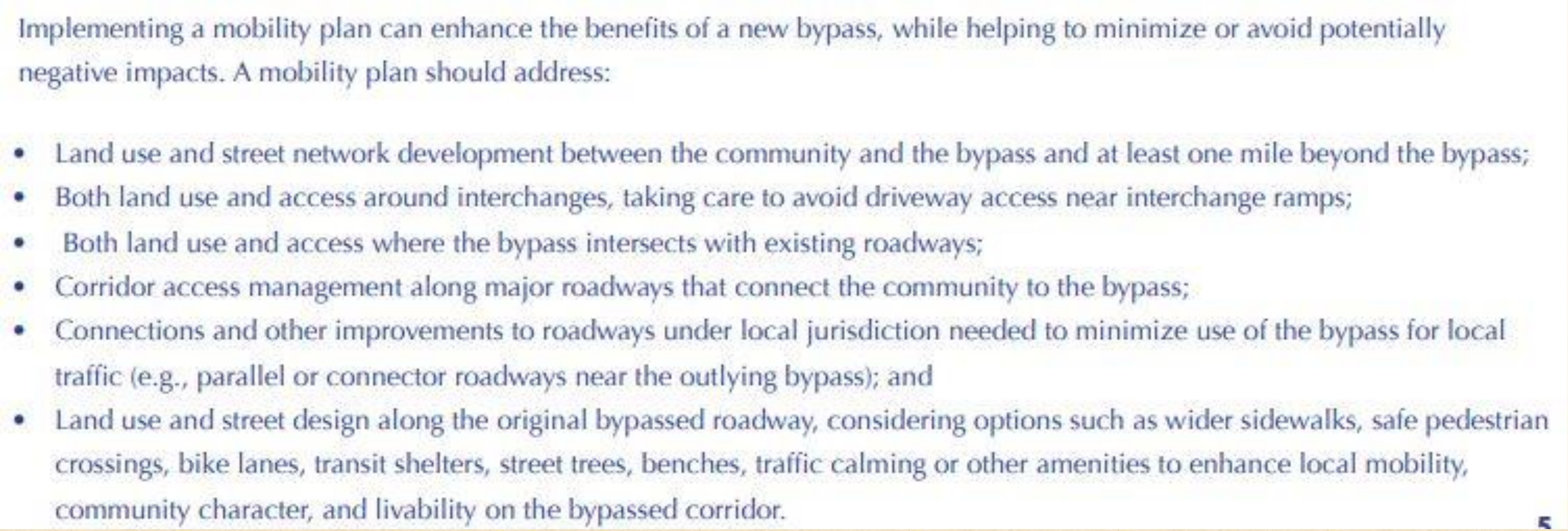
Such potential impacts warrant detailed analysis, not only of economic impacts to businesses, but also of the infrastructure and service cost/benefit to the community. Unfortunately, most economic studies only uncover regional shifts in economic activity, due to lack of data at the local level. Therefore, they may not bring to light important local impacts, such as changes in type of ownership or openings and closings of local businesses.

Questions to ask

- *Has there been or will there be a study to determine the economic impact of a bypass on the community?*
- *Will such a study examine the potential change in downtown business customers?*

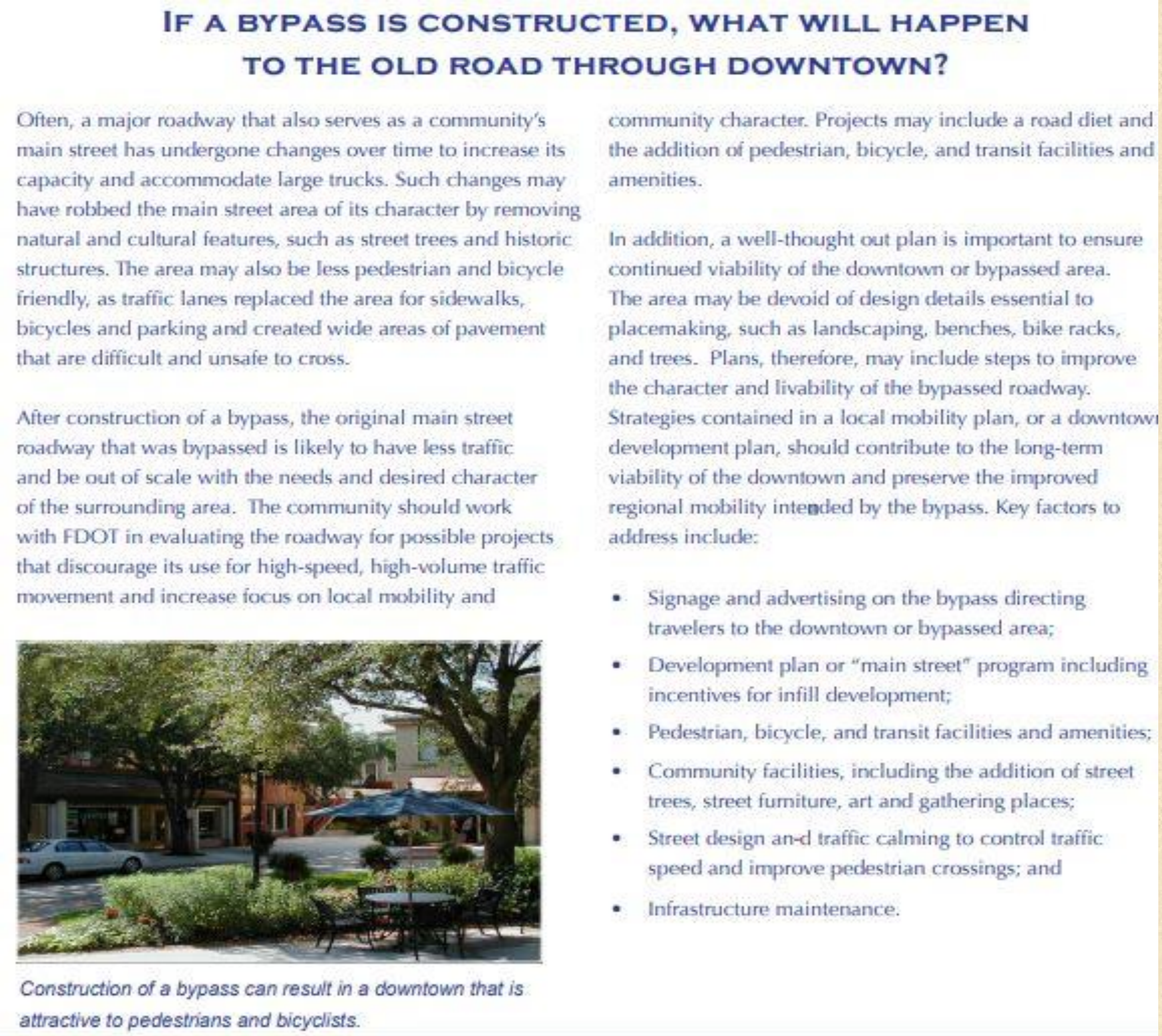
Livability in small communities may be hindered by heavy traffic and congested roads.

How can potential issues related to a bypass be resolved?



Implementing a mobility plan can enhance the benefits of a new bypass, while helping to minimize or avoid potentially negative impacts. A mobility plan should address:

- Land use and street network development between the community and the bypass and at least one mile beyond the bypass;
- Both land use and access around interchanges, taking care to avoid driveway access near interchange ramps;
- Both land use and access where the bypass intersects with existing roadways;
- Corridor access management along major roadways that connect the community to the bypass;
- Connections and other improvements to roadways under local jurisdiction needed to minimize use of the bypass for local traffic (e.g., parallel or connector roadways near the outlying bypass); and
- Land use and street design along the original bypassed roadway, considering options such as wider sidewalks, safe pedestrian crossings, bike lanes, transit shelters, street trees, benches, traffic calming or other amenities to enhance local mobility, community character, and livability on the bypassed corridor.



IF A BYPASS IS CONSTRUCTED, WHAT WILL HAPPEN TO THE OLD ROAD THROUGH DOWNTOWN?

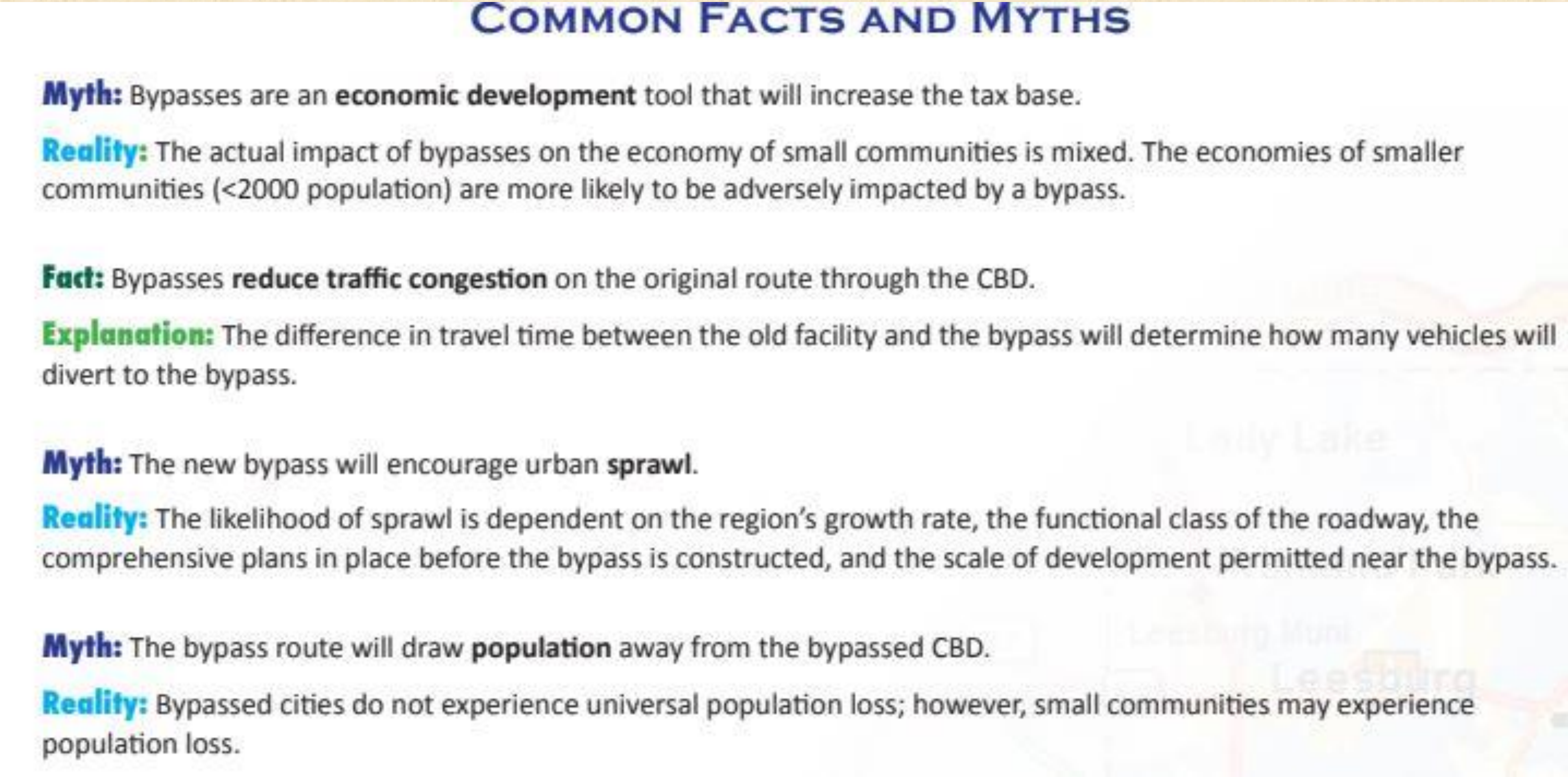
Often, a major roadway that also serves as a community's main street has undergone changes over time to increase its capacity and accommodate large trucks. Such changes may have robbed the main street area of its character by removing natural and cultural features, such as street trees and historic structures. The area may also be less pedestrian and bicycle friendly, as traffic lanes replaced the area for sidewalks, bicycles and parking and created wide areas of pavement that are difficult and unsafe to cross.

After construction of a bypass, the original main street roadway that was bypassed is likely to have less traffic and be out of scale with the needs and desired character of the surrounding area. The community should work with FDOT in evaluating the roadway for possible projects that discourage its use for high-speed, high-volume traffic movement and increase focus on local mobility and community character. Projects may include a road diet and the addition of pedestrian, bicycle, and transit facilities and amenities.

Construction of a bypass can result in a downtown that is attractive to pedestrians and bicyclists.

In addition, a well-thought out plan is important to ensure continued viability of the downtown or bypassed area. The area may be devoid of design details essential to placemaking, such as landscaping, benches, bike racks, and trees. Plans, therefore, may include steps to improve the character and livability of the bypassed roadway. Strategies contained in a local mobility plan, or a downtown development plan, should contribute to the long-term viability of the downtown and preserve the improved regional mobility intended by the bypass. Key factors to address include:

- Signage and advertising on the bypass directing travelers to the downtown or bypassed area;
- Development plan or "main street" program including incentives for infill development;
- Pedestrian, bicycle, and transit facilities and amenities;
- Community facilities, including the addition of street trees, street furniture, art and gathering places;
- Street design and traffic calming to control traffic speed and improve pedestrian crossings; and
- Infrastructure maintenance.



COMMON FACTS AND MYTHS

Myth: Bypasses are an **economic development** tool that will increase the tax base.

Reality: The actual impact of bypasses on the economy of small communities is mixed. The economies of smaller communities (<2000 population) are more likely to be adversely impacted by a bypass.

Fact: Bypasses **reduce traffic congestion** on the original route through the CBD.

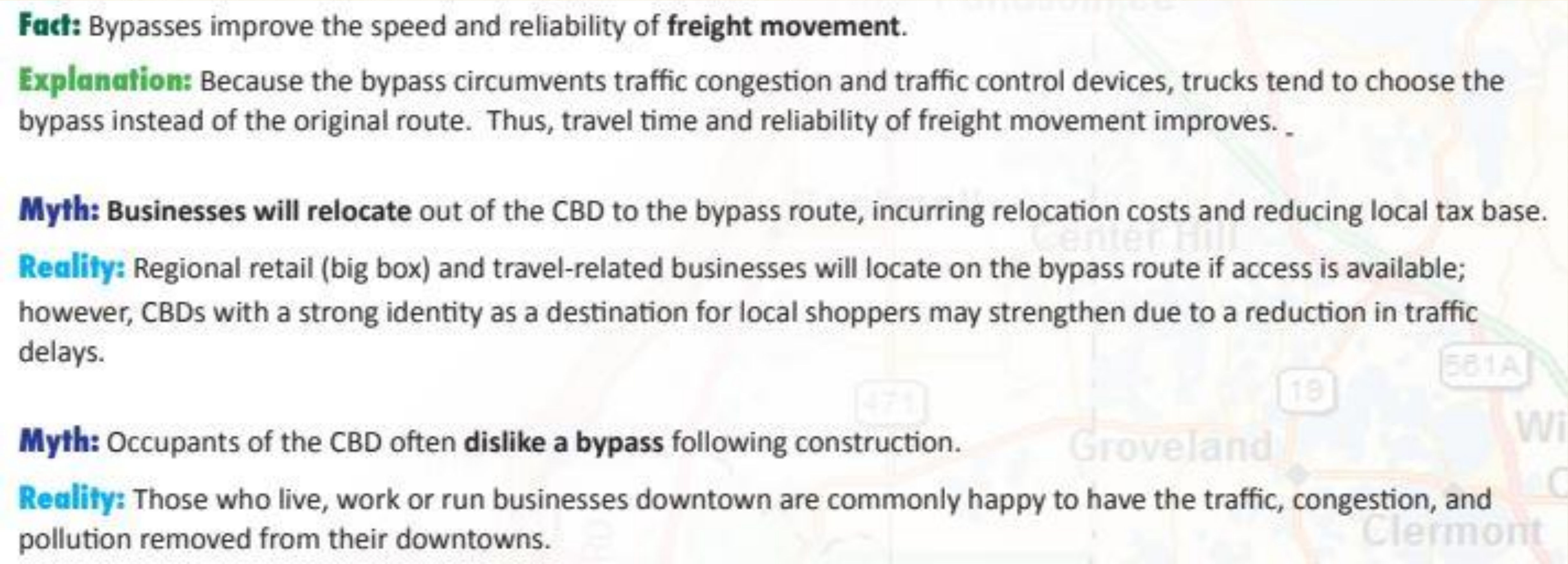
Explanation: The difference in travel time between the old facility and the bypass will determine how many vehicles will divert to the bypass.

Myth: The new bypass will encourage urban **sprawl**.

Reality: The likelihood of sprawl is dependent on the region’s growth rate, the functional class of the roadway, the comprehensive plans in place before the bypass is constructed, and the scale of development permitted near the bypass.

Myth: The bypass route will draw **population** away from the bypassed CBD.

Reality: Bypassed cities do not experience universal population loss; however, small communities may experience population loss.



Fact: Bypasses improve the speed and reliability of **freight movement**.

Explanation: Because the bypass circumvents traffic congestion and traffic control devices, trucks tend to choose the bypass instead of the original route. Thus, travel time and reliability of freight movement improves.

Myth: **Businesses will relocate** out of the CBD to the bypass route, incurring relocation costs and reducing local tax base.

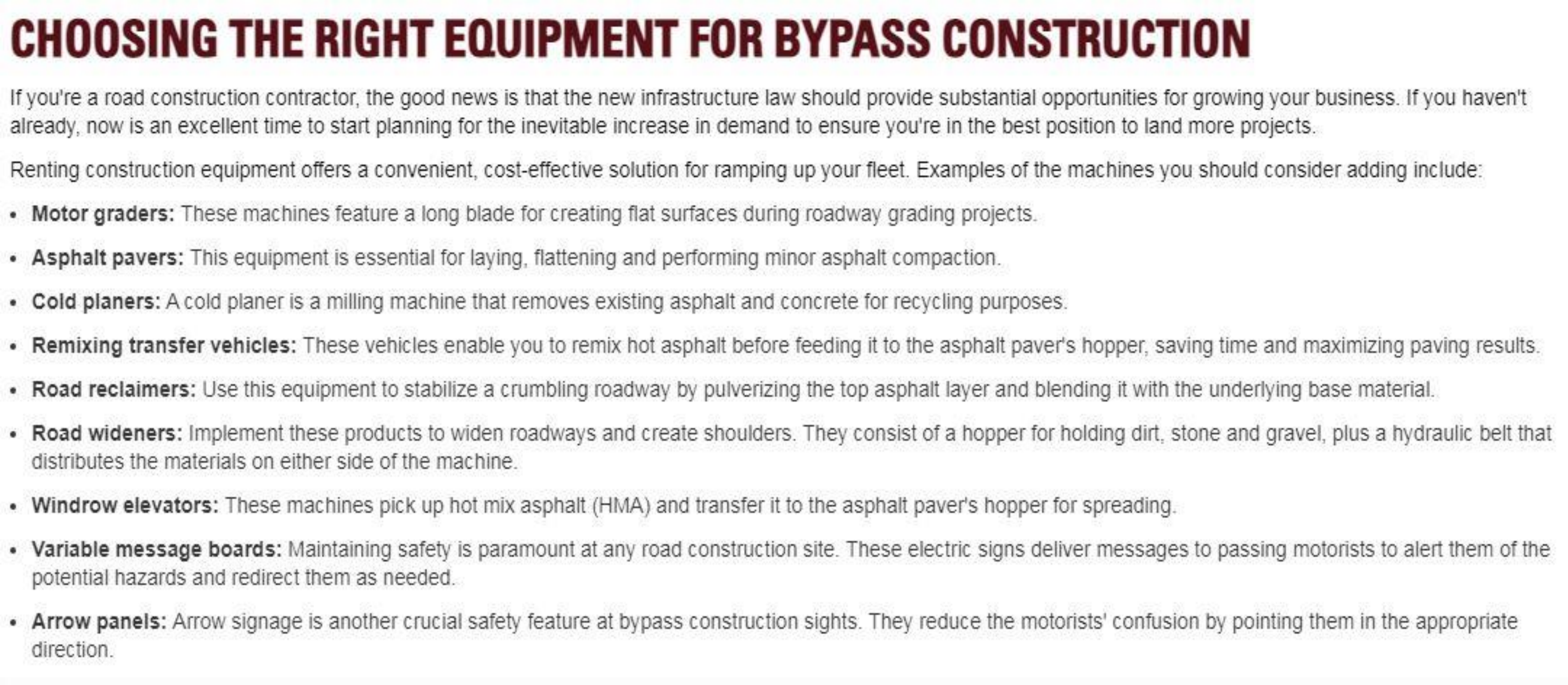
Reality: Regional retail (big box) and travel-related businesses will locate on the bypass route if access is available; however, CBDs with a strong identity as a destination for local shoppers may strengthen due to a reduction in traffic delays.

Myth: Occupants of the CBD often **dislike a bypass** following construction.

Reality: Those who live, work or run businesses downtown are commonly happy to have the traffic, congestion, and pollution removed from their downtowns.

Access Management

Managing access to major roadways can reduce crashes by 50%, increase available roadway capacity, and reduce travel time and delay. Access management is critical along all major roadways - especially those that intersect with a bypass or other limited access highway.

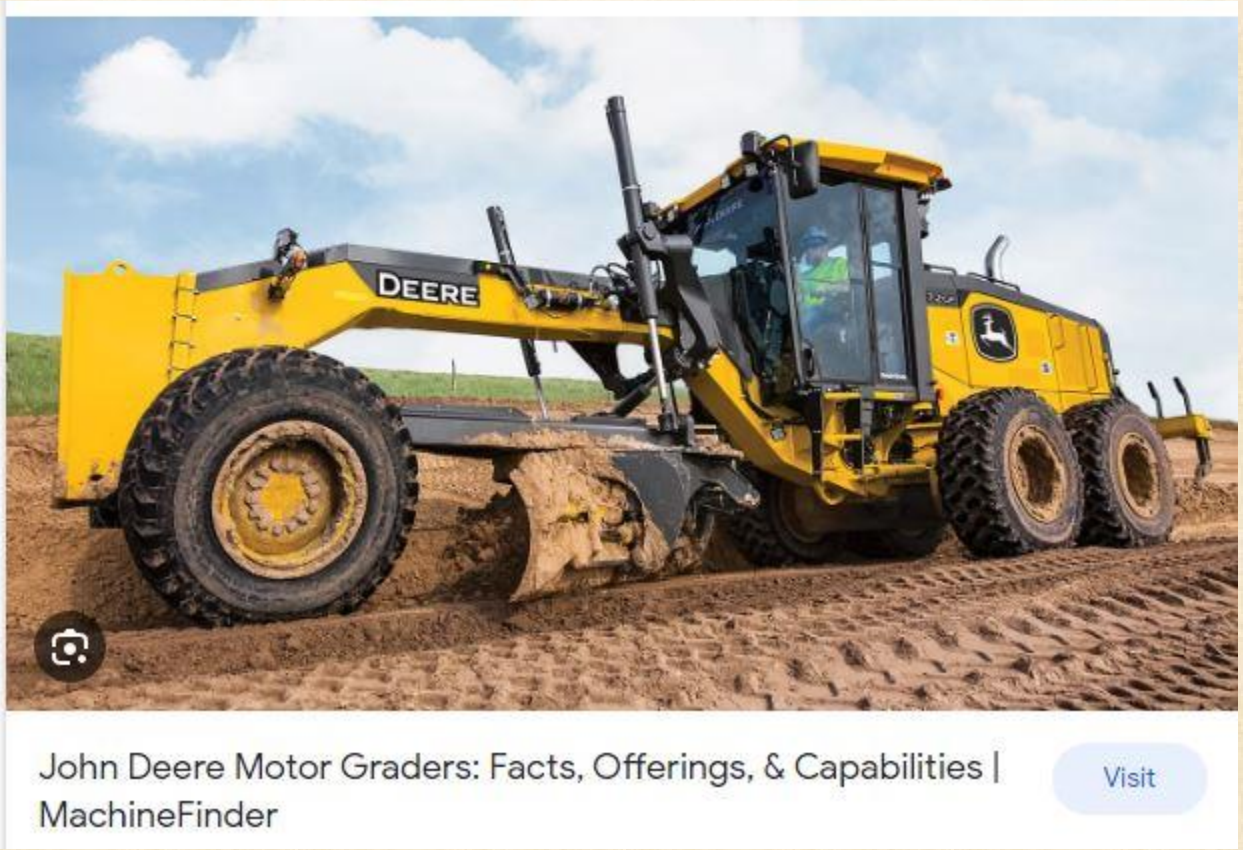


CHOOSING THE RIGHT EQUIPMENT FOR BYPASS CONSTRUCTION

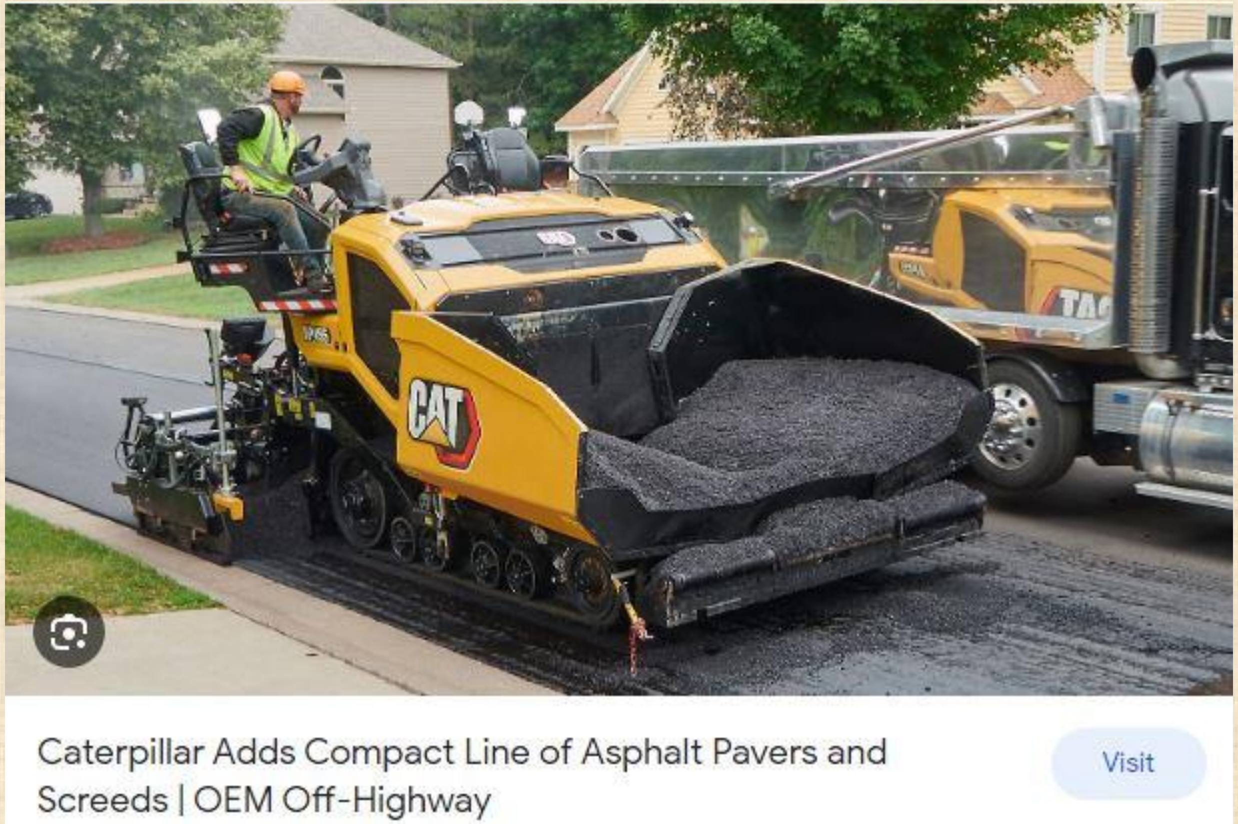
If you're a road construction contractor, the good news is that the new infrastructure law should provide substantial opportunities for growing your business. If you haven't already, now is an excellent time to start planning for the inevitable increase in demand to ensure you're in the best position to land more projects.

Renting construction equipment offers a convenient, cost-effective solution for ramping up your fleet. Examples of the machines you should consider adding include:

- **Motor graders:** These machines feature a long blade for creating flat surfaces during roadway grading projects.
- **Asphalt pavers:** This equipment is essential for laying, flattening and performing minor asphalt compaction.
- **Cold planers:** A cold planer is a milling machine that removes existing asphalt and concrete for recycling purposes.
- **Remixing transfer vehicles:** These vehicles enable you to remix hot asphalt before feeding it to the asphalt paver's hopper, saving time and maximizing paving results.
- **Road reclaimers:** Use this equipment to stabilize a crumbling roadway by pulverizing the top asphalt layer and blending it with the underlying base material.
- **Road wideners:** Implement these products to widen roadways and create shoulders. They consist of a hopper for holding dirt, stone and gravel, plus a hydraulic belt that distributes the materials on either side of the machine.
- **Windrow elevators:** These machines pick up hot mix asphalt (HMA) and transfer it to the asphalt paver's hopper for spreading.
- **Variable message boards:** Maintaining safety is paramount at any road construction site. These electric signs deliver messages to passing motorists to alert them of the potential hazards and redirect them as needed.
- **Arrow panels:** Arrow signage is another crucial safety feature at bypass construction sights. They reduce the motorists' confusion by pointing them in the appropriate direction.



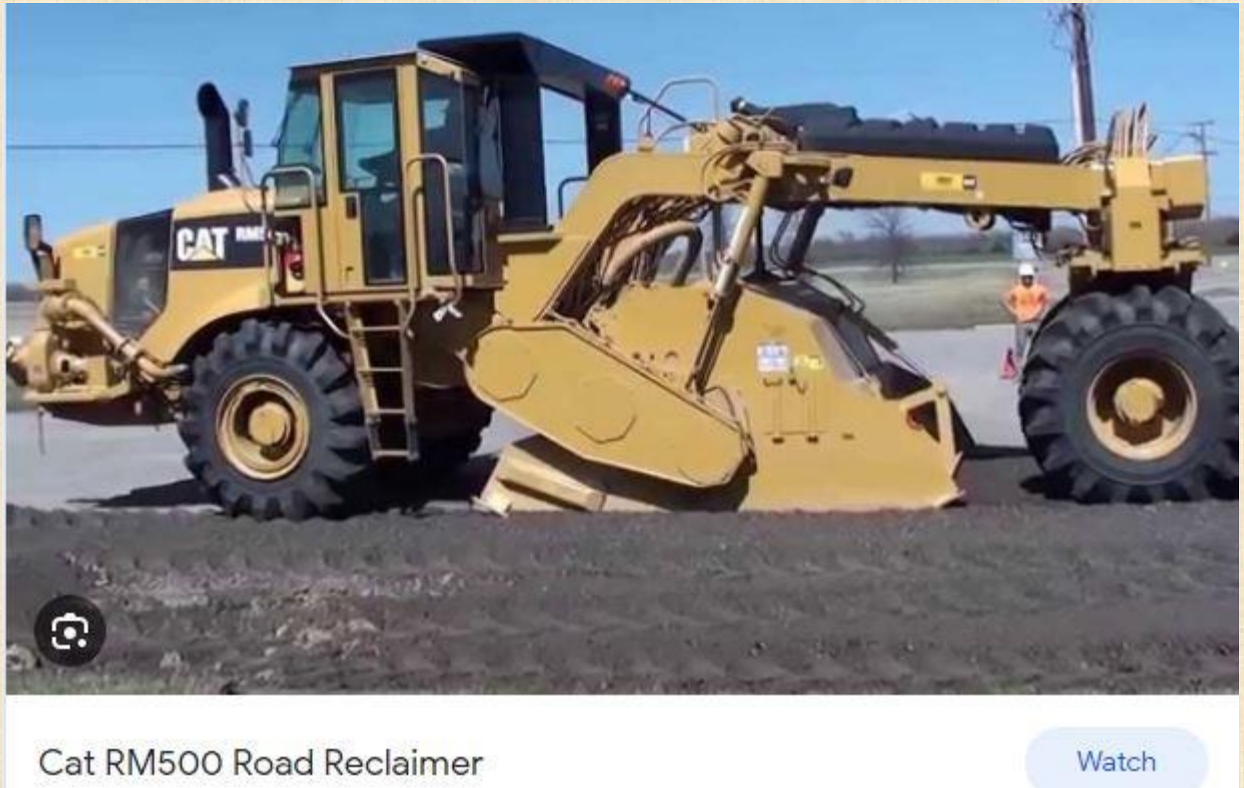
John Deere Motor Graders: Facts, Offerings, & Capabilities | MachineFinder



Caterpillar Adds Compact Line of Asphalt Pavers and Screeds | OEM Off-Highway

Cold Planers and Concrete Recycling | The Cat Rental Store

Remixing Transfer Vehicles Rentals | Wagner Rents



Cat RM500 Road Reclaimer

Road Widener | Road Shouldering Attachment for Skid Steers & Wheel Loaders

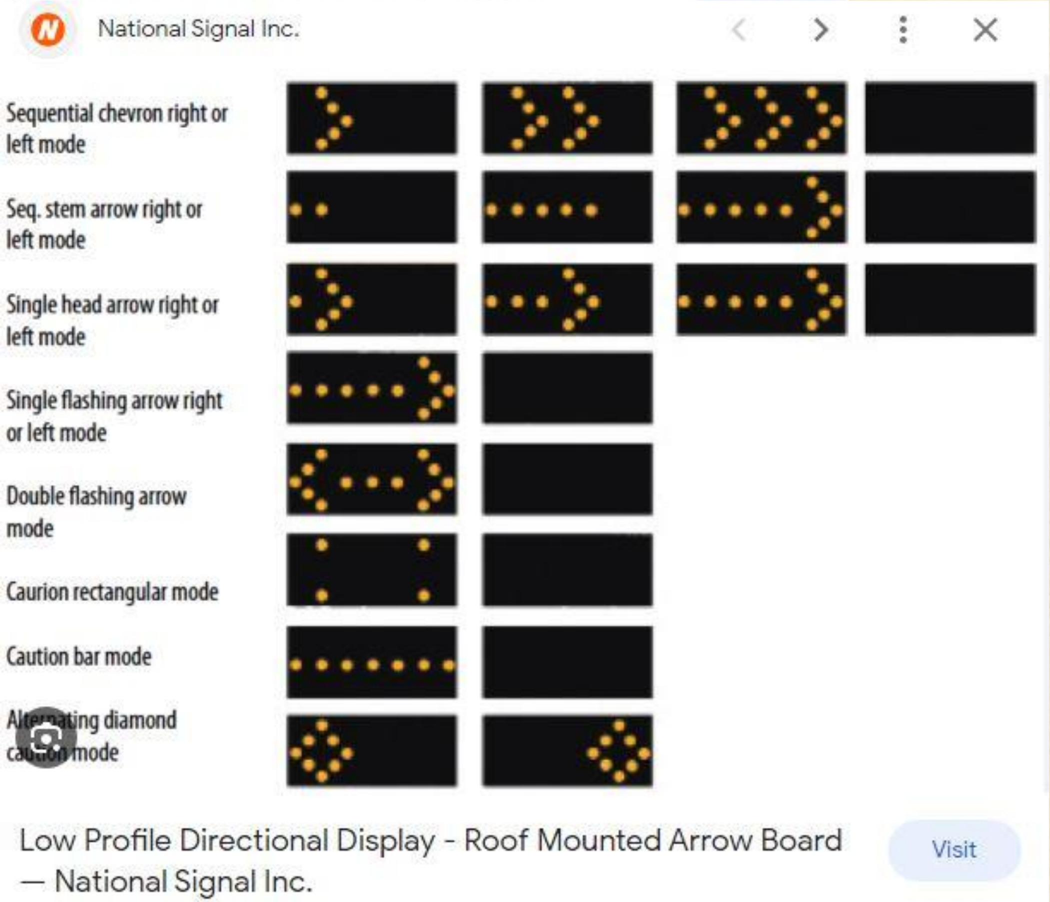
Windrow Elevators from top manufacturers available | Ritchie

Message Signs

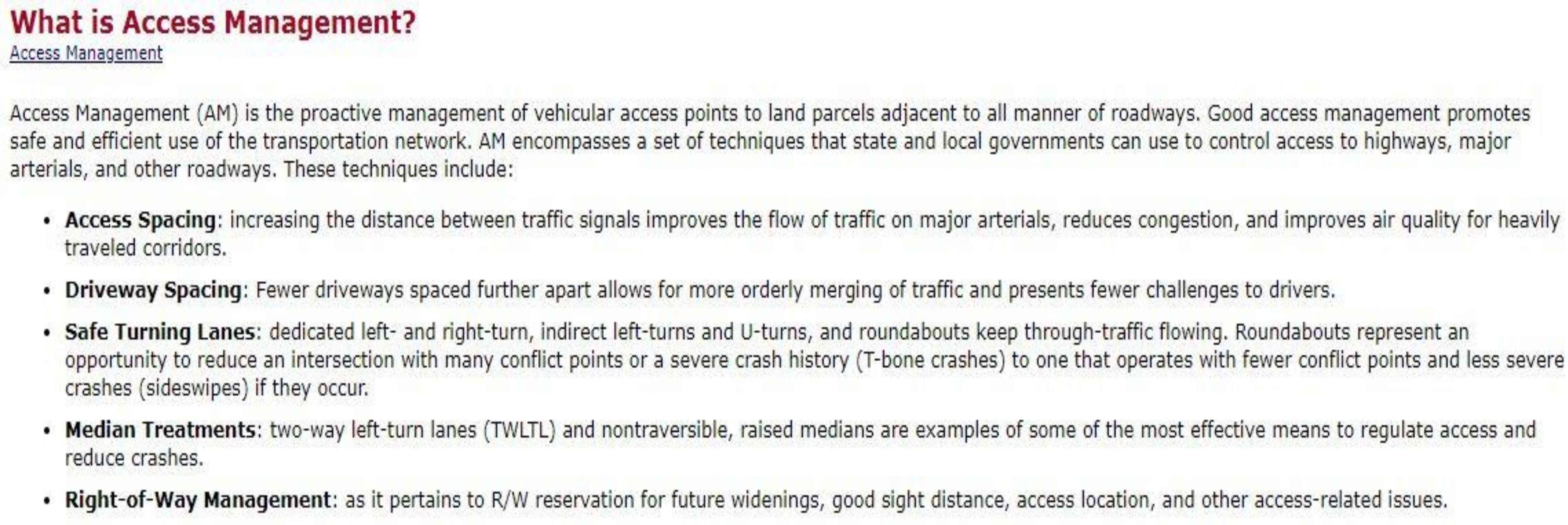
Variable-message sign - Wikipedia

Arrow Panels | H-CPC

Arrowmaster M90 Arrow Board - Traffic Safety Supply Company



Low Profile Directional Display - Roof Mounted Arrow Board — National Signal Inc.

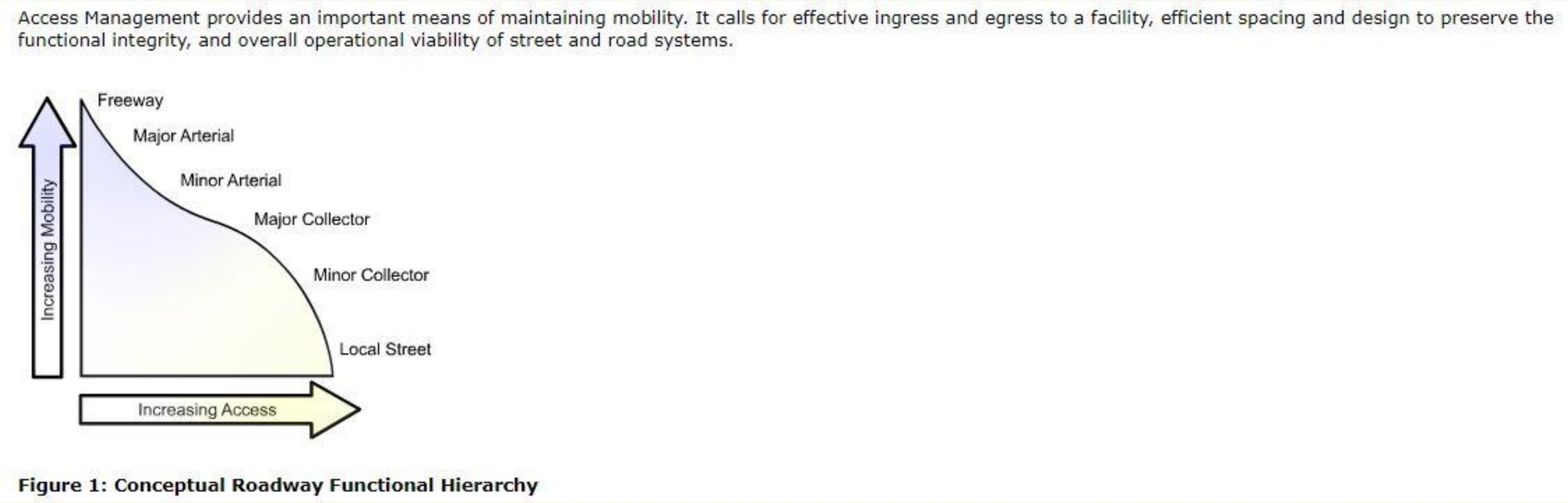


What is Access Management?

Access Management

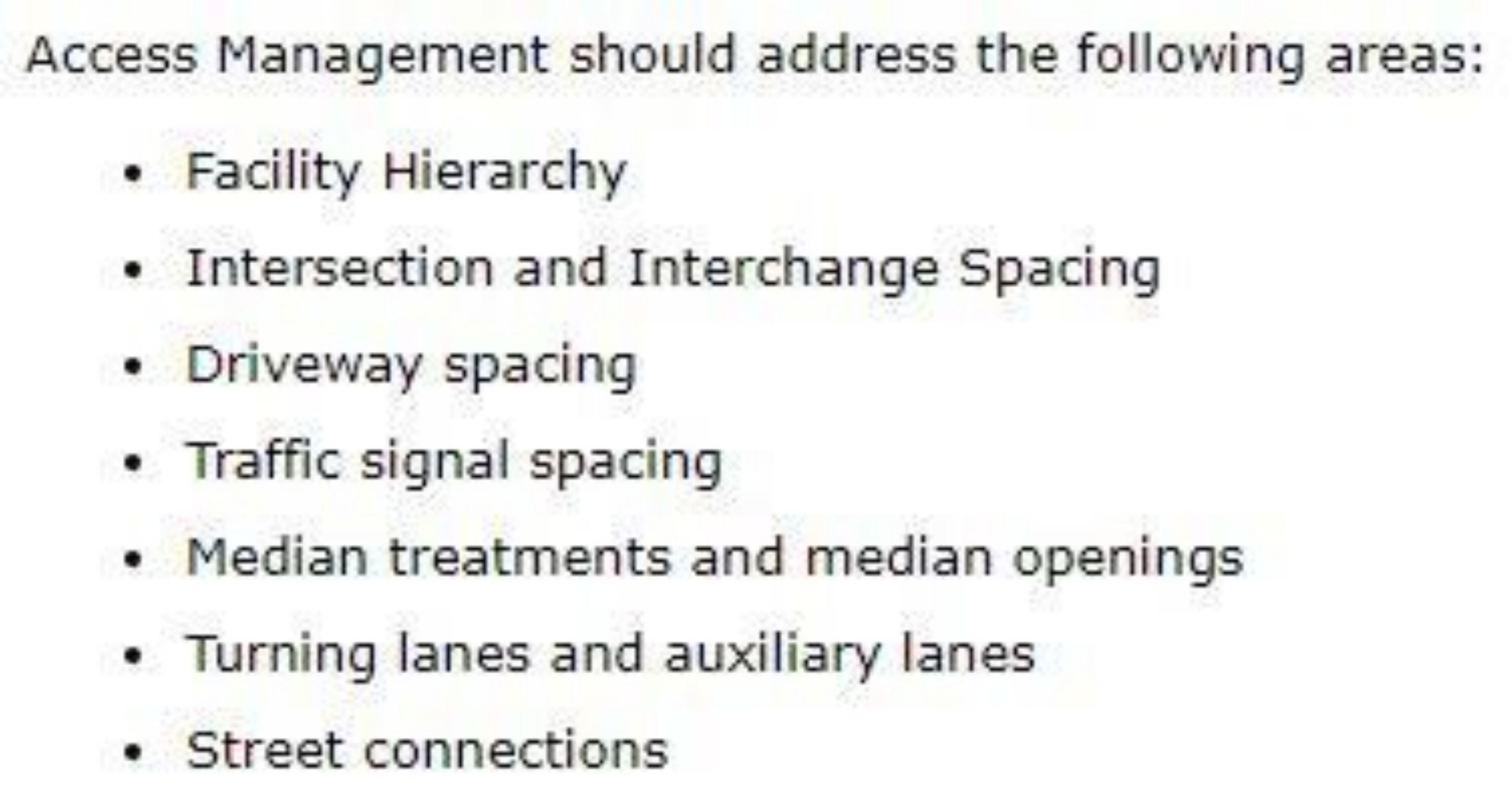
Access Management (AM) is the proactive management of vehicular access points to land parcels adjacent to all manner of roadways. Good access management promotes safe and efficient use of the transportation network. AM encompasses a set of techniques that state and local governments can use to control access to highways, major arterials, and other roadways. These techniques include:

- **Access Spacing**: increasing the distance between traffic signals improves the flow of traffic on major arterials, reduces congestion, and improves air quality for heavily traveled corridors.
- **Driveway Spacing**: Fewer driveways spaced further apart allows for more orderly merging of traffic and presents fewer challenges to drivers.
- **Safe Turning Lanes**: dedicated left- and right-turn, indirect left-turns and U-turns, and roundabouts keep through-traffic flowing. Roundabouts represent an opportunity to reduce an intersection with many conflict points or a severe crash history (T-bone crashes) to one that operates with fewer conflict points and less severe crashes (sideswipes) if they occur.
- **Median Treatments**: two-way left-turn lanes (TWLTL) and nontraversible, raised medians are examples of some of the most effective means to regulate access and reduce crashes.
- **Right-of-Way Management**: as it pertains to R/W reservation for future widenings, good sight distance, access location, and other access-related issues.



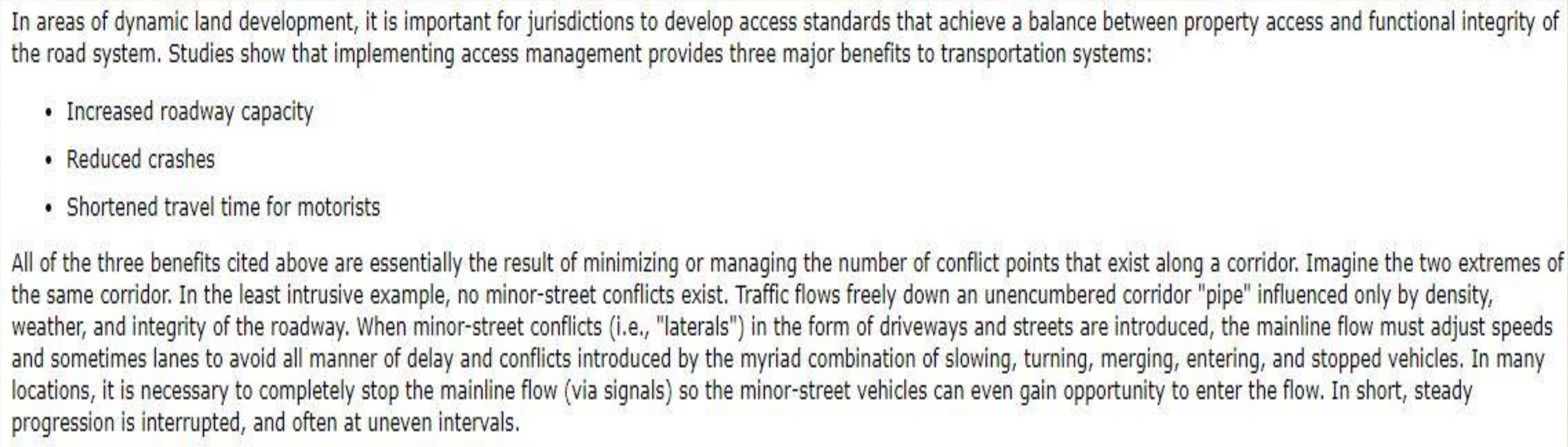
Access Management provides an important means of maintaining mobility. It calls for effective ingress and egress to a facility, efficient spacing and design to preserve the functional integrity, and overall operational viability of street and road systems.

Figure 1: Conceptual Roadway Functional Hierarchy



Access Management should address the following areas:

- Facility Hierarchy
- Intersection and Interchange Spacing
- Driveway spacing
- Traffic signal spacing
- Median treatments and median openings
- Turning lanes and auxiliary lanes
- Street connections

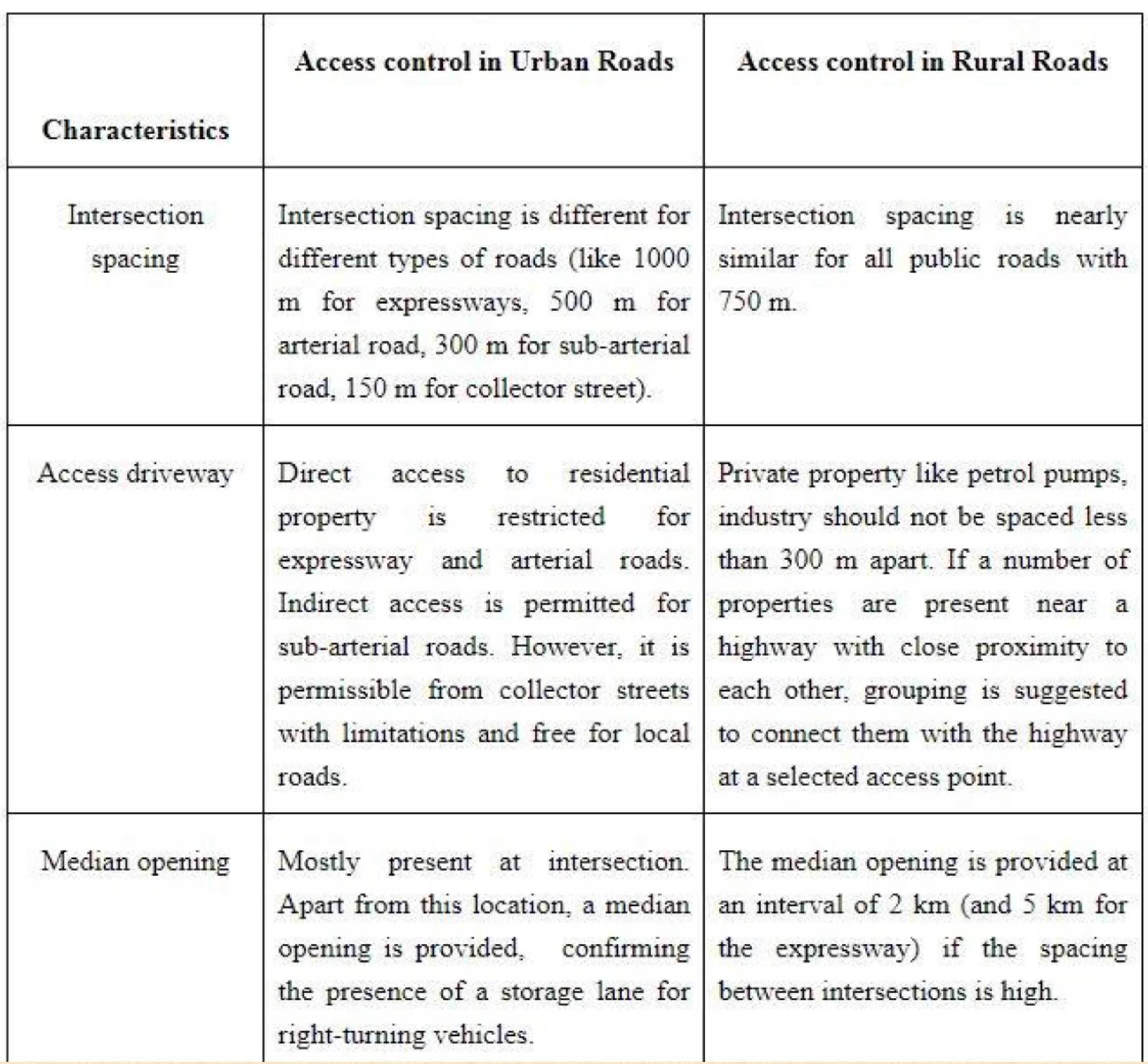


In areas of dynamic land development, it is important for jurisdictions to develop access standards that achieve a balance between property access and functional integrity of the road system. Studies show that implementing access management provides three major benefits to transportation systems:

- Increased roadway capacity
- Reduced crashes
- Shortened travel time for motorists

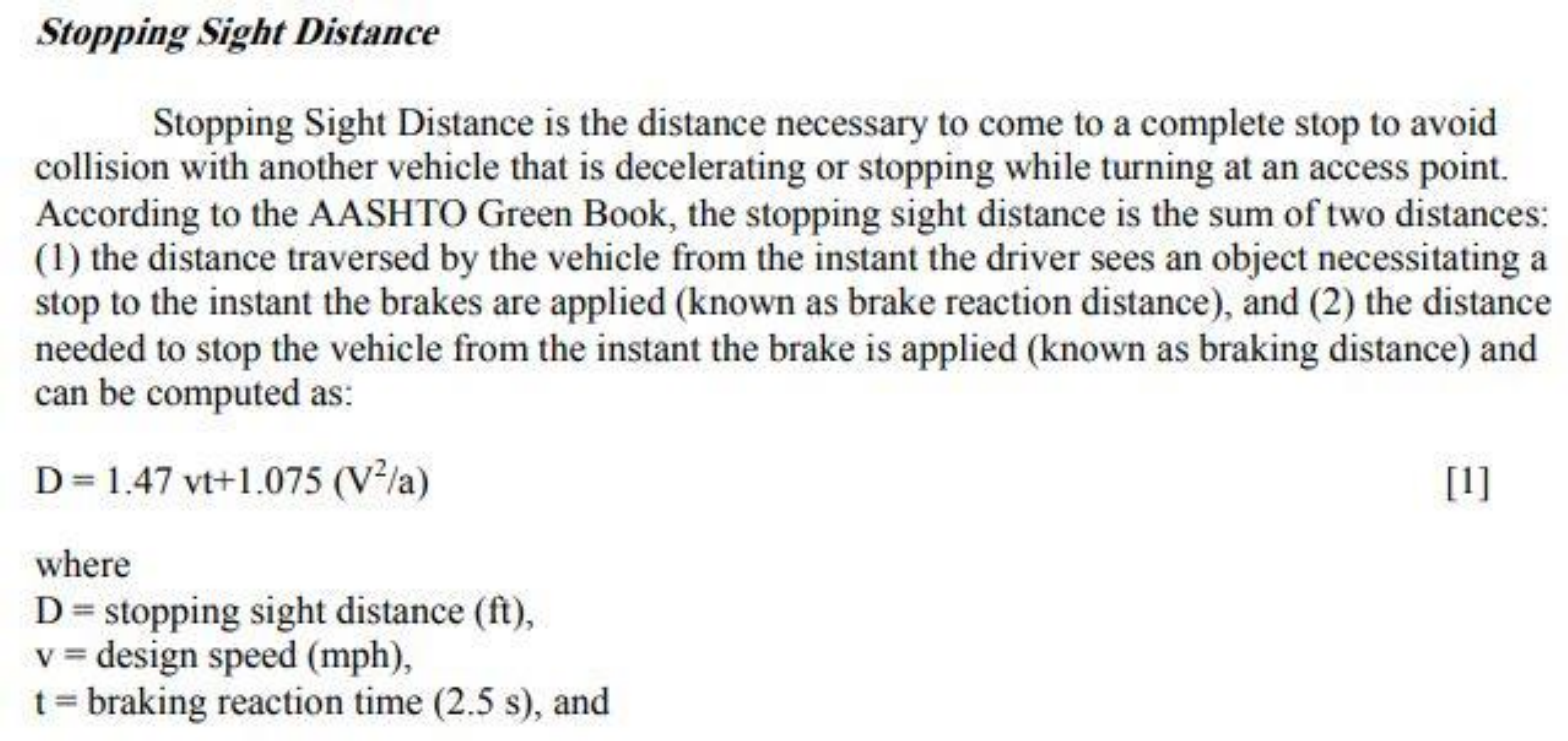
All of the three benefits cited above are essentially the result of minimizing or managing the number of conflict points that exist along a corridor. Imagine the two extremes of the same corridor. In the least intrusive example, no minor-street conflicts exist. Traffic flows freely down an unencumbered corridor "pipe" influenced only by density, weather, and integrity of the roadway. When minor-street conflicts (i.e., "laterals") in the form of driveways and streets are introduced, the mainline flow must adjust speeds and sometimes lanes to avoid all manner of delay and conflicts introduced by the myriad combination of slowing, turning, merging, entering, and stopped vehicles. In many locations, it is necessary to completely stop the mainline flow (via signals) so the minor-street vehicles can even gain opportunity to enter the flow. In short, steady progression is interrupted, and often at uneven intervals.

Difference between Access control on Urban and Rural Roads



Characteristics	Access control in Urban Roads	Access control in Rural Roads
Intersection spacing	Intersection spacing is different for different types of roads (like 1000 m for expressways, 500 m for arterial road, 300 m for sub-arterial road, 150 m for collector street).	Intersection spacing is nearly similar for all public roads with 750 m.
Access driveway	Direct access to residential property is restricted for expressway and arterial roads. Indirect access is permitted for sub-arterial roads. However, it is permissible from collector streets with limitations and free for local roads.	Private property like petrol pumps, industry should not be spaced less than 300 m apart. If a number of properties are present near a highway with close proximity to each other, grouping is suggested to connect them with the highway at a selected access point.
Median opening	Mostly present at intersection. Apart from this location, a median opening is provided, confirming the presence of a storage lane for right-turning vehicles.	The median opening is provided at an interval of 2 km (and 5 km for the expressway) if the spacing between intersections is high.

Access control and road geometry



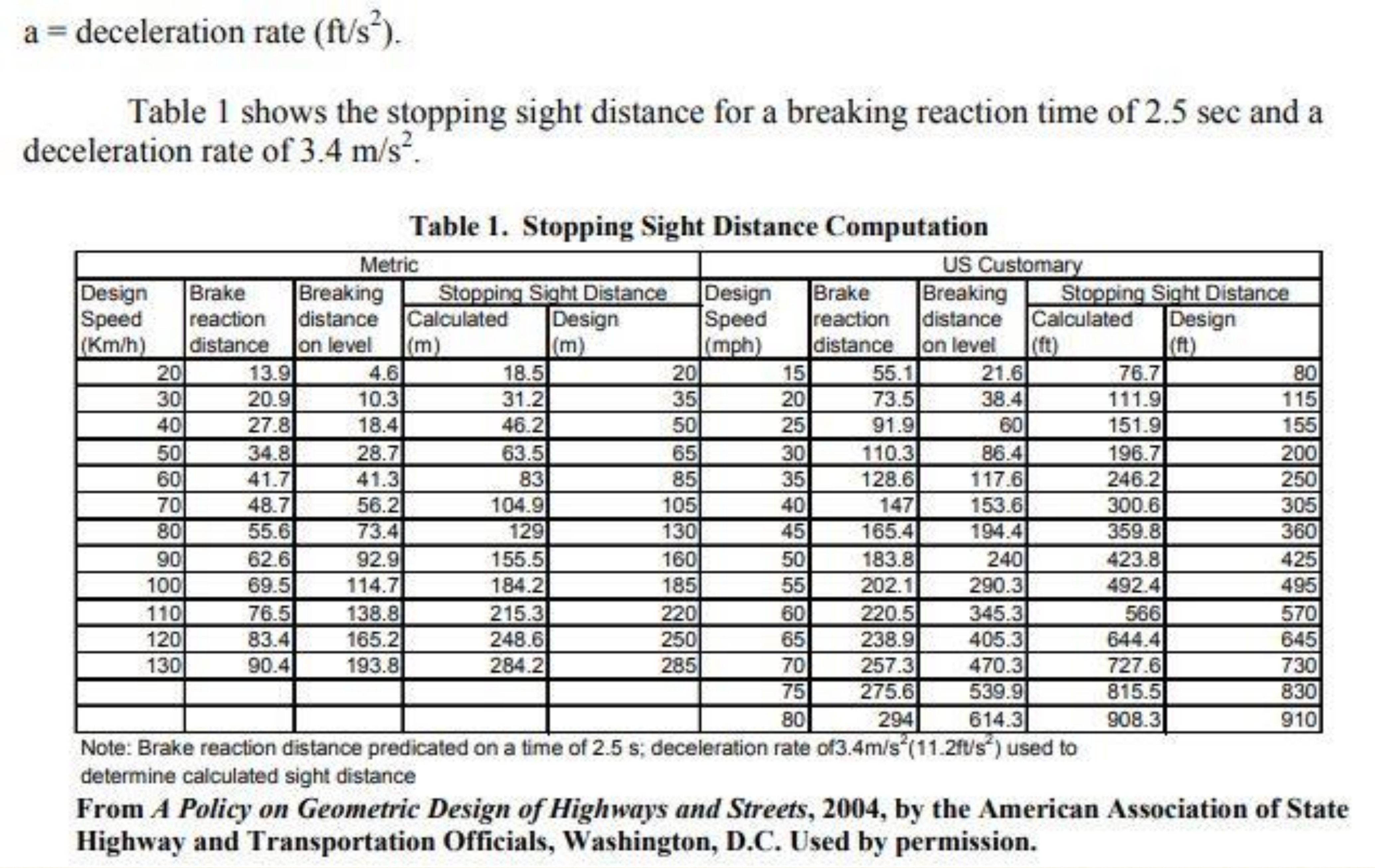
Stopping Sight Distance

Stopping Sight Distance is the distance necessary to come to a complete stop to avoid collision with another vehicle that is decelerating or stopping while turning at an access point. According to the AASHTO Green Book, the stopping sight distance is the sum of two distances: (1) the distance traversed by the vehicle from the instant the driver sees an object necessitating a stop to the instant the brakes are applied (known as brake reaction distance), and (2) the distance needed to stop the vehicle from the instant the brake is applied (known as braking distance) and can be computed as:

$$D = 1.47\,vt+1.075\,(V^2/a) \qquad [1]$$

where

D = stopping sight distance (ft),
v = design speed (mph),
t = braking reaction time (2.5 s), and



a = deceleration rate (ft/s^2).

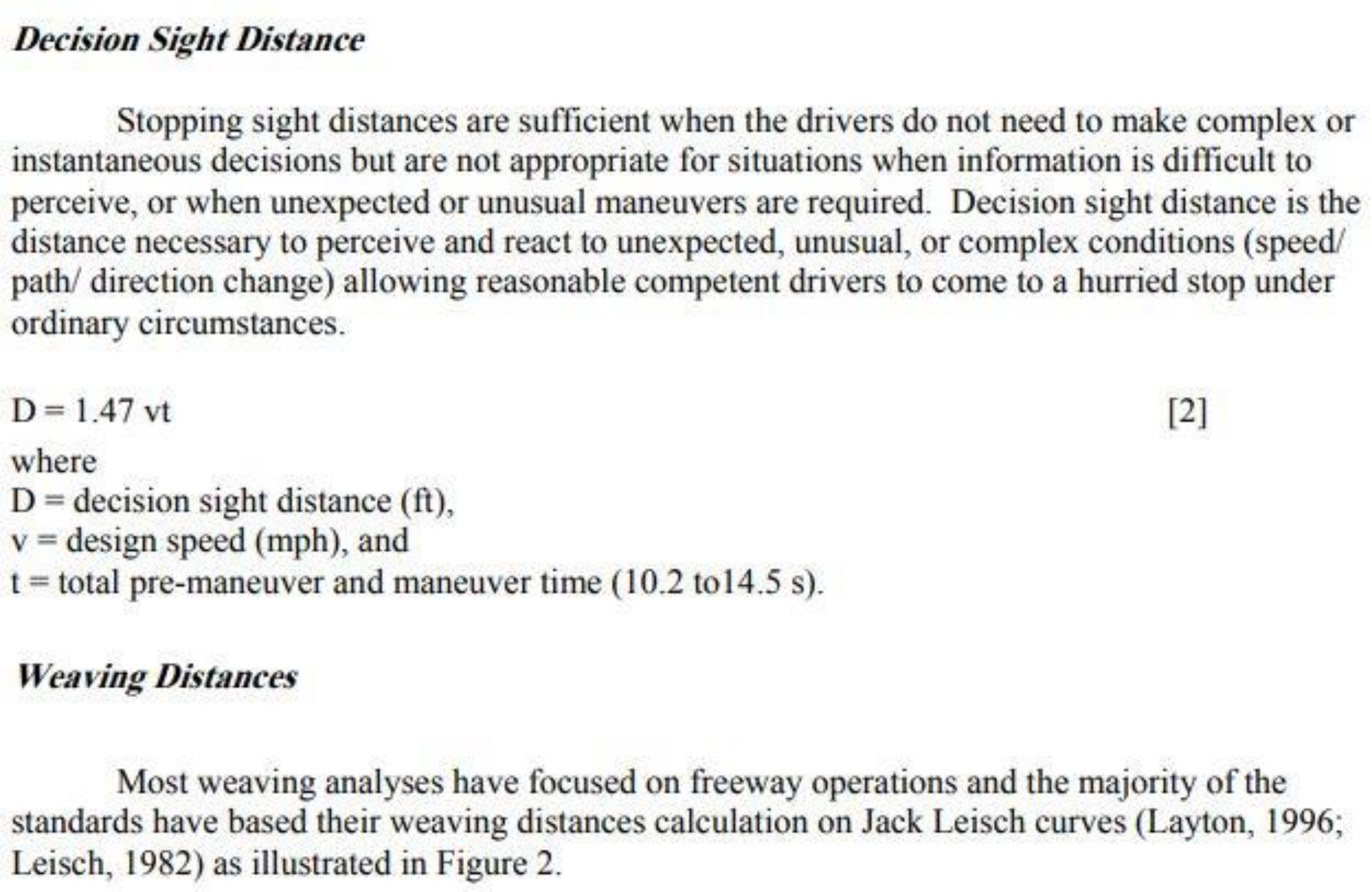
Table 1 shows the stopping sight distance for a breaking reaction time of 2.5 sec and a deceleration rate of 3.4 m/s^2.

Table 1. Stopping Sight Distance Computation

Metric					US Customary				
Design Speed (Km/h)	Brake reaction distance	Breaking distance on level	Stopping Sight Distance		Design Speed (mph)	Brake reaction distance	Breaking distance on level	Stopping Sight Distance	
			Calculated (m)	Design (m)				Calculated (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147	153.6	300.6	305
80	55.6	73.4	129	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.3	566	570
120	83.4	165.2	248.6	250	65	238.9	405.3	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	830
					80	294	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of3.4m/s^2(11.2ft/s^2) used to determine calculated sight distance

From *A Policy on Geometric Design of Highways and Streets*, 2004, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used by permission.



Decision Sight Distance

Stopping sight distances are sufficient when the drivers do not need to make complex or instantaneous decisions but are not appropriate for situations when information is difficult to perceive, or when unexpected or unusual maneuvers are required. Decision sight distance is the distance necessary to perceive and react to unexpected, unusual, or complex conditions (speed/ path/ direction change) allowing reasonable competent drivers to come to a hurried stop under ordinary circumstances.

$$D = 1.47\ vt \qquad [2]$$

where

D = decision sight distance (ft),
v = design speed (mph), and
t = total pre-maneuver and maneuver time (10.2 to14.5 s).

Weaving Distances

Most weaving analyses have focused on freeway operations and the majority of the standards have based their weaving distances calculation on Jack Leisch curves (Layton, 1996; Leisch, 1982) as illustrated in Figure 2.

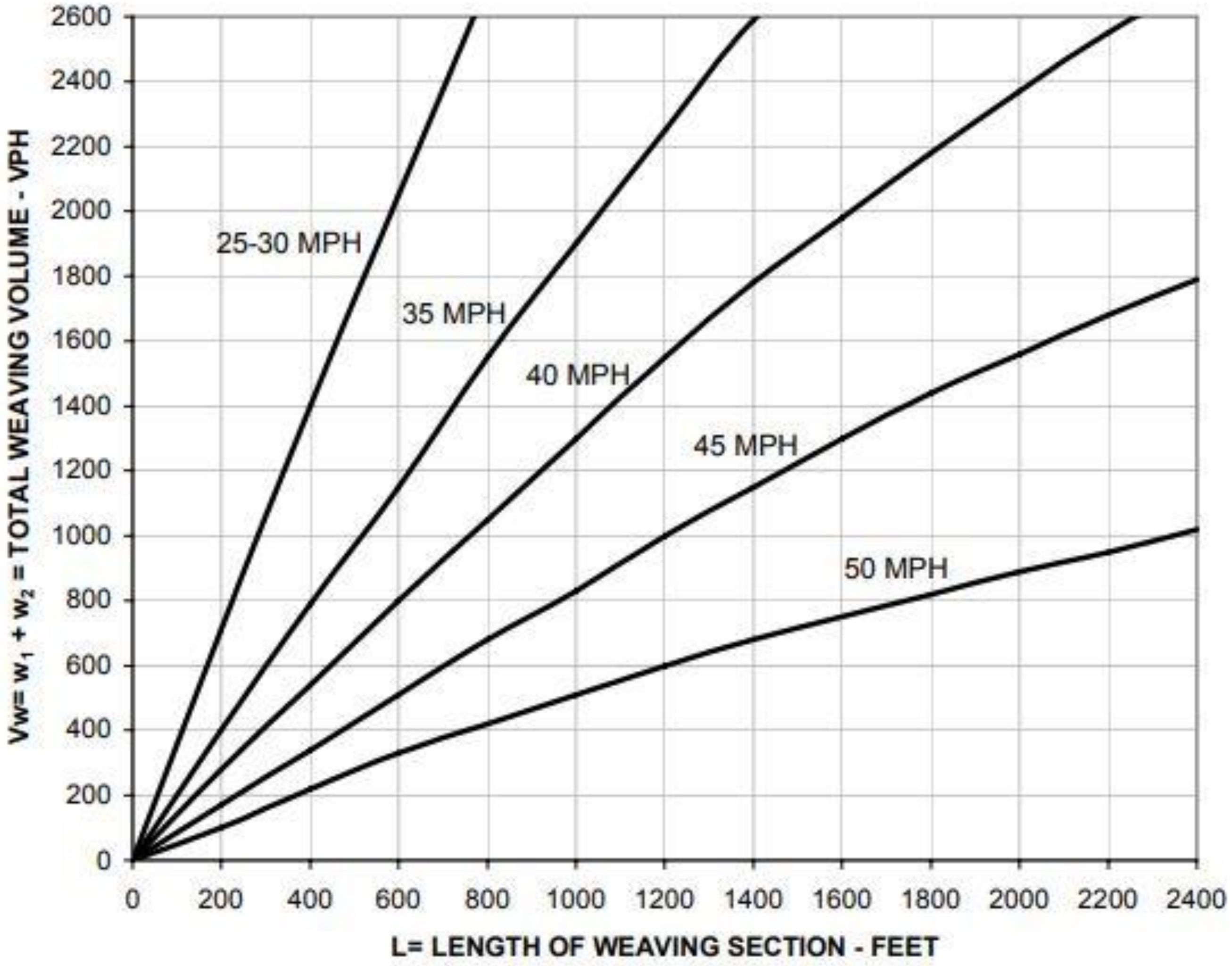
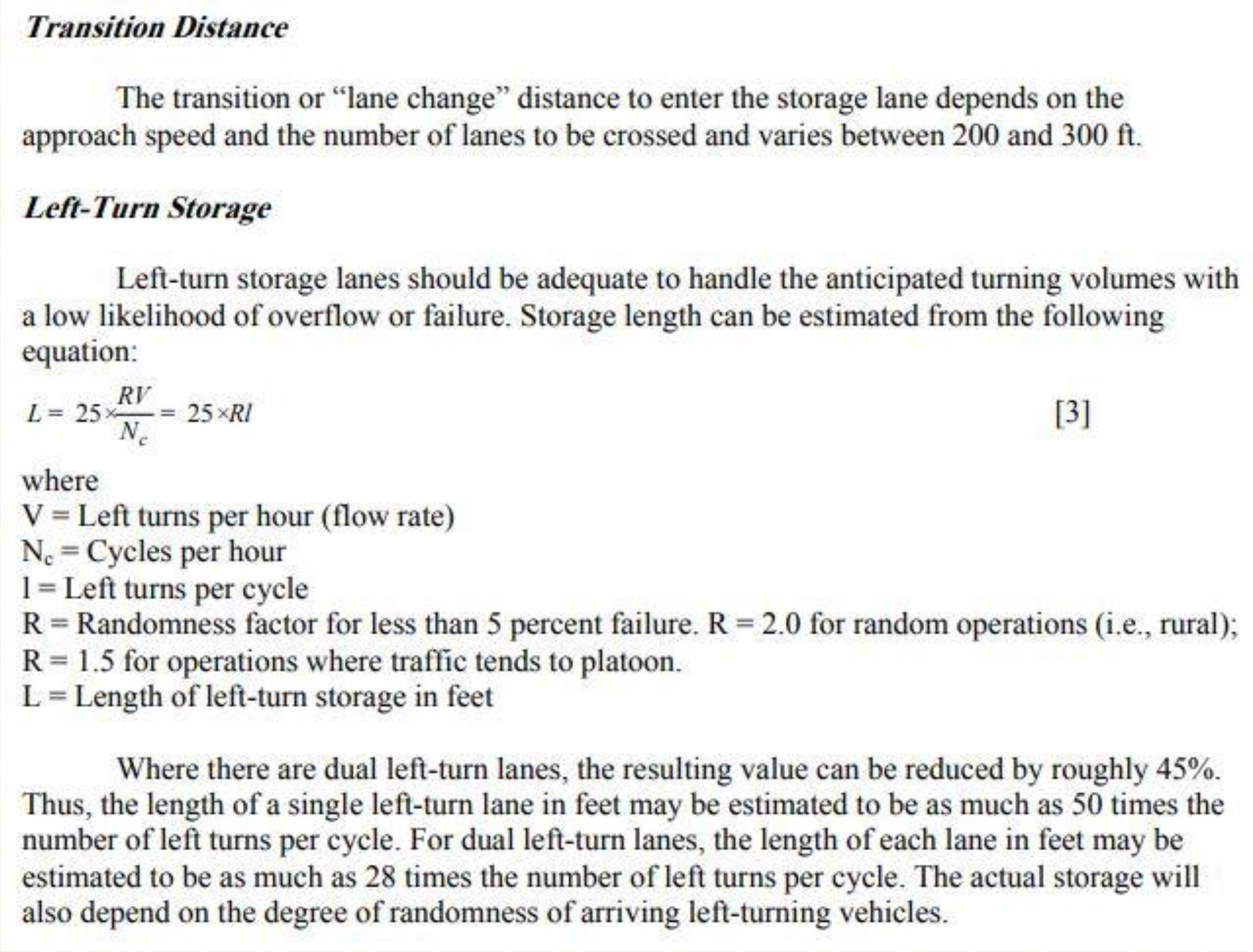


Figure 2. Analysis of Service Road Weaving Conditions (Layton, 1996)

Table 2 shows the weaving distances for different weaving volumes and speeds. According to Leisch, for normal conditions, weaving distances of 700 ft to 800 ft are required for two-lane roads and 1200 ft to 1600 ft will usually be adequate for multilane roads.



Transition Distance

The transition or "lane change" distance to enter the storage lane depends on the approach speed and the number of lanes to be crossed and varies between 200 and 300 ft.

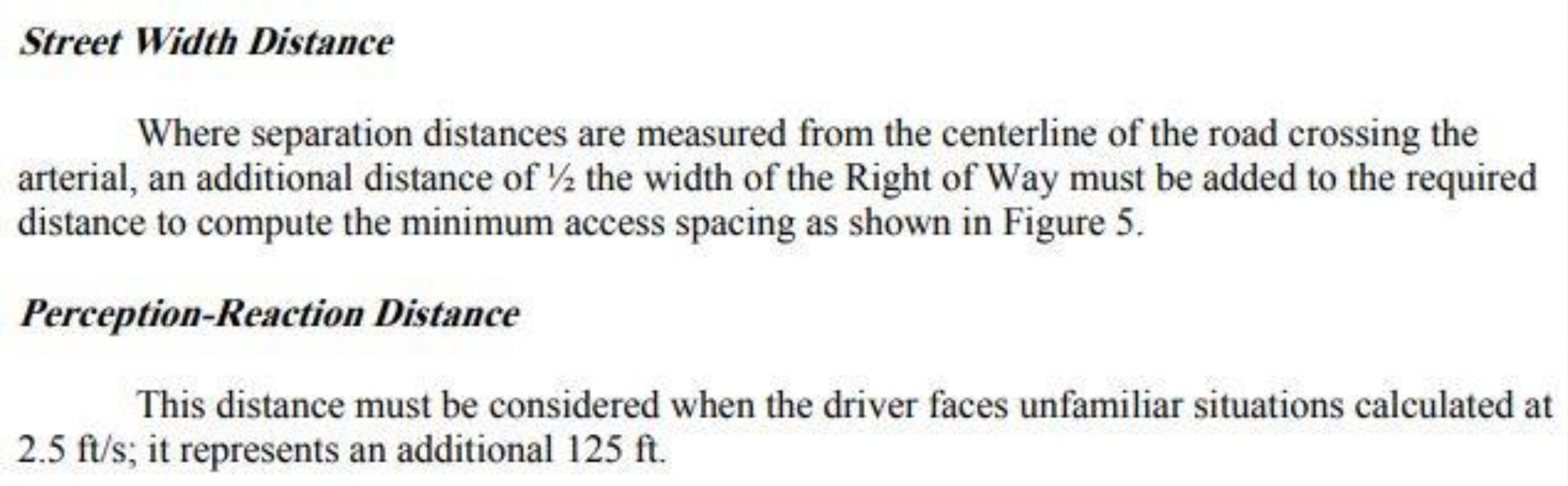
Left-Turn Storage

Left-turn storage lanes should be adequate to handle the anticipated turning volumes with a low likelihood of overflow or failure. Storage length can be estimated from the following equation:

$$L = 25 \times \frac{RV}{N_c} = 25 \times Rl \qquad [3]$$

where
V = Left turns per hour (flow rate)
N_c = Cycles per hour
l = Left turns per cycle
R = Randomness factor for less than 5 percent failure. R = 2.0 for random operations (i.e., rural);
R = 1.5 for operations where traffic tends to platoon.
L = Length of left-turn storage in feet

Where there are dual left-turn lanes, the resulting value can be reduced by roughly 45%. Thus, the length of a single left-turn lane in feet may be estimated to be as much as 50 times the number of left turns per cycle. For dual left-turn lanes, the length of each lane in feet may be estimated to be as much as 28 times the number of left turns per cycle. The actual storage will also depend on the degree of randomness of arriving left-turning vehicles.



Street Width Distance

Where separation distances are measured from the centerline of the road crossing the arterial, an additional distance of ½ the width of the Right of Way must be added to the required distance to compute the minimum access spacing as shown in Figure 5.

Perception-Reaction Distance

This distance must be considered when the driver faces unfamiliar situations calculated at 2.5 ft/s; it represents an additional 125 ft.

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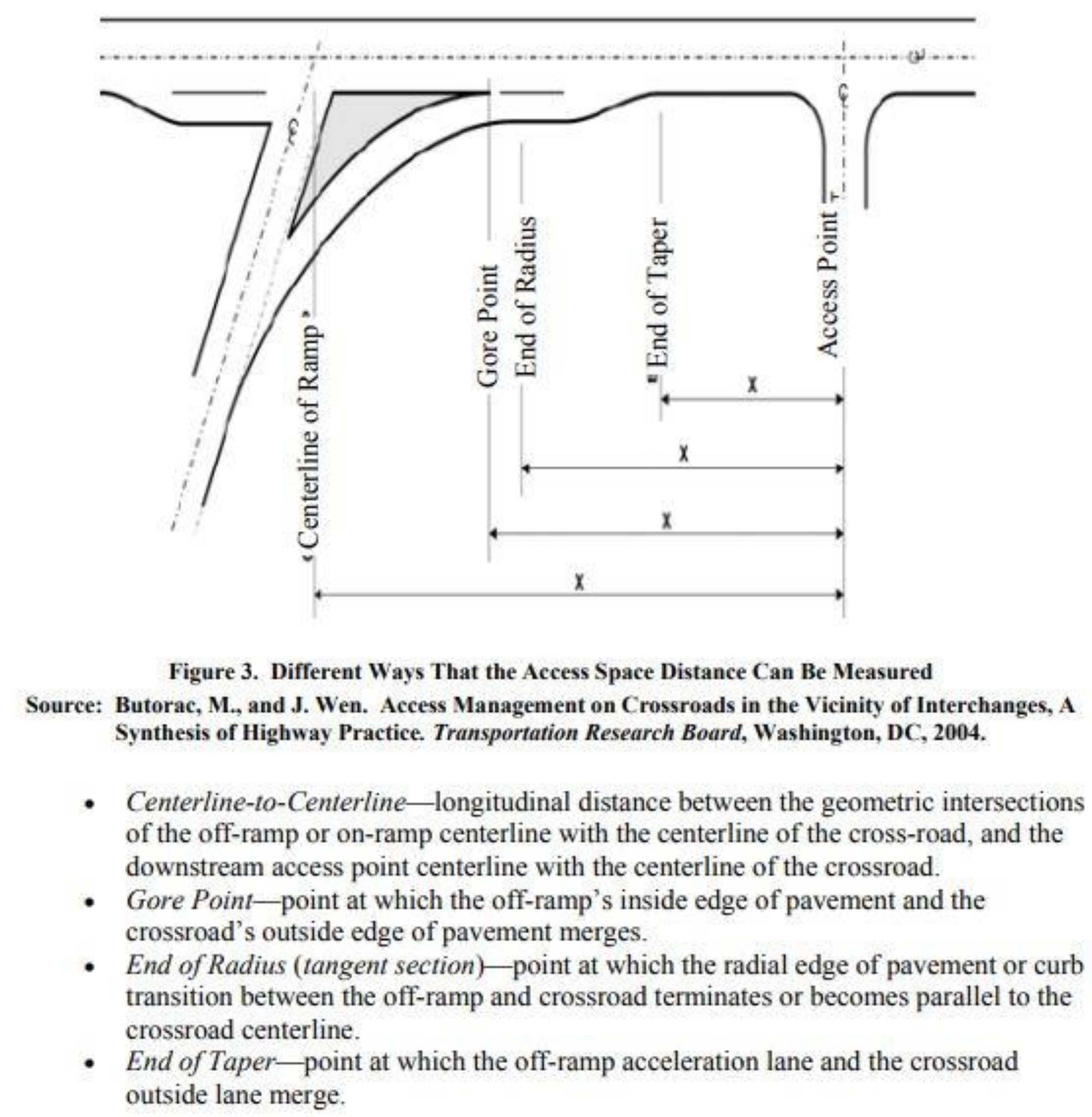


Figure 3. Different Ways That the Access Space Distance Can Be Measured

Source: Butorac, M., and J. Wen. Access Management on Crossroads in the Vicinity of Interchanges, A Synthesis of Highway Practice. *Transportation Research Board*, Washington, DC, 2004.

- *Centerline-to-Centerline*—longitudinal distance between the geometric intersections of the off-ramp or on-ramp centerline with the centerline of the cross-road, and the downstream access point centerline with the centerline of the crossroad.
- *Gore Point*—point at which the off-ramp's inside edge of pavement and the crossroad's outside edge of pavement merges.
- *End of Radius* (*tangent section*)—point at which the radial edge of pavement or curb transition between the off-ramp and crossroad terminates or becomes parallel to the crossroad centerline.
- *End of Taper*—point at which the off-ramp acceleration lane and the crossroad outside lane merge.

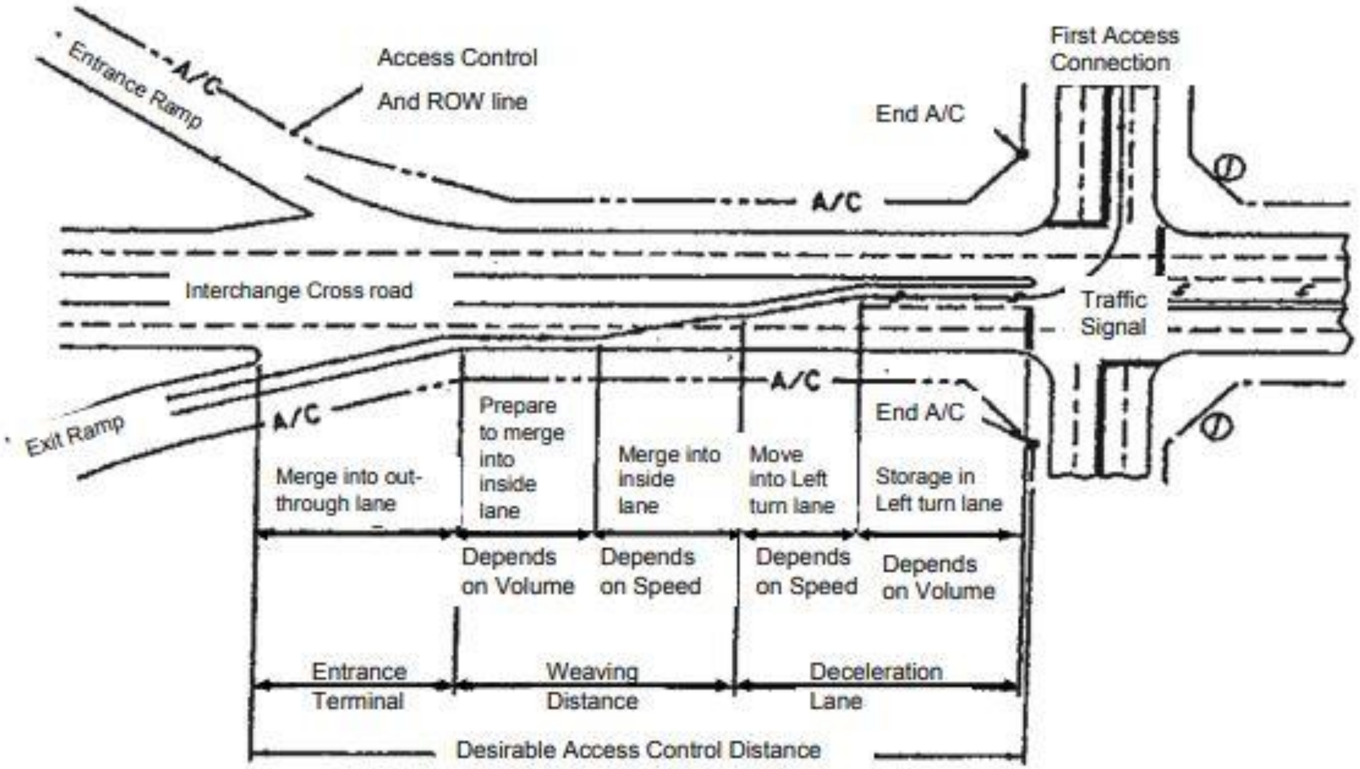


Figure 4. Free Flow Ramps Entering and Exiting From Cross Road

From *A Policy on Geometric Design of Highways and Streets*, 2004, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used by permission.

For diamond interchanges or other interchange forms without free-flow ramps (the first access may either be controlled by a traffic signal or stop signs), the desirable access control distance on the crossroad includes:

- Distance required for advance guide signs, progression
- Storage lengths of traffic turning at the first access.

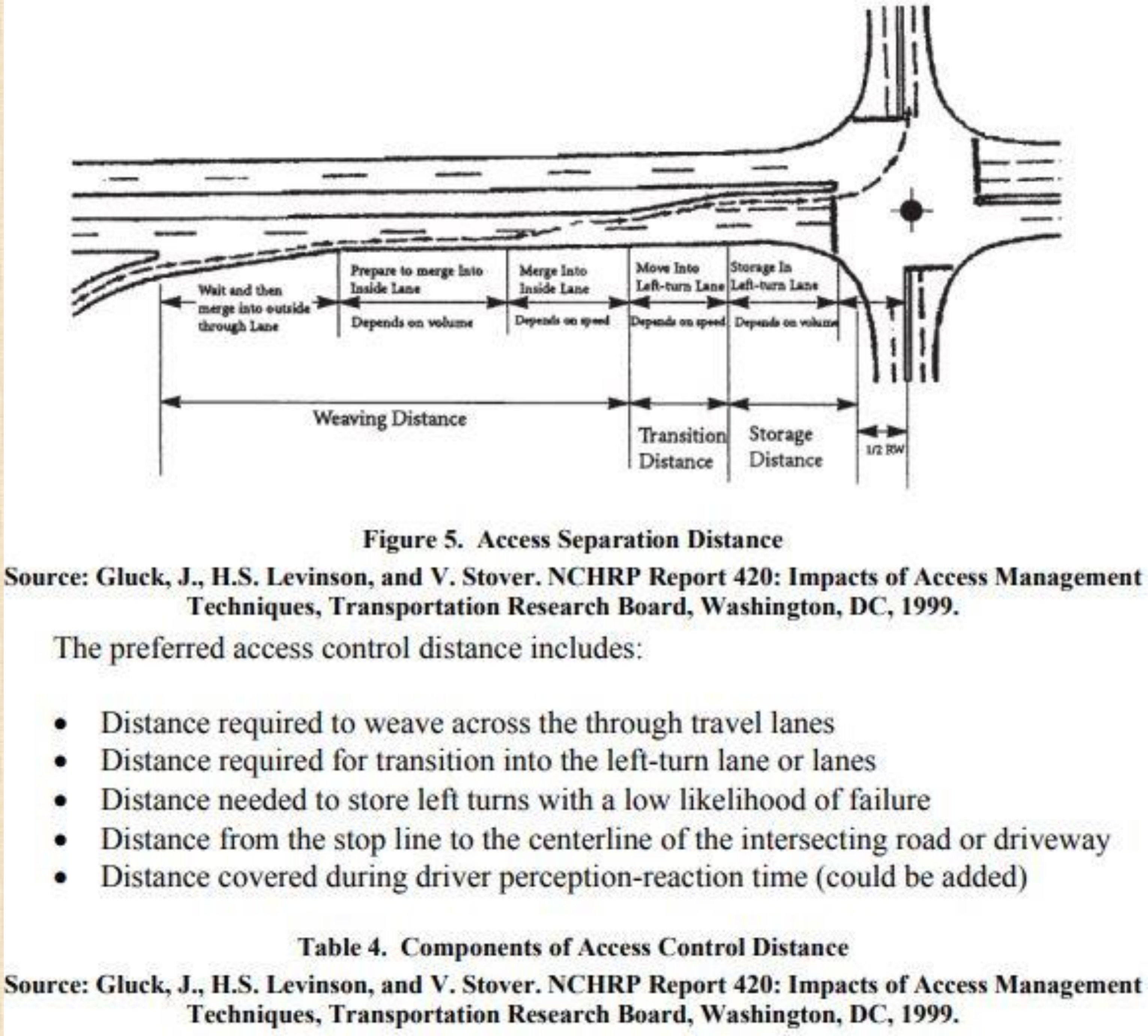


Figure 5. Access Separation Distance

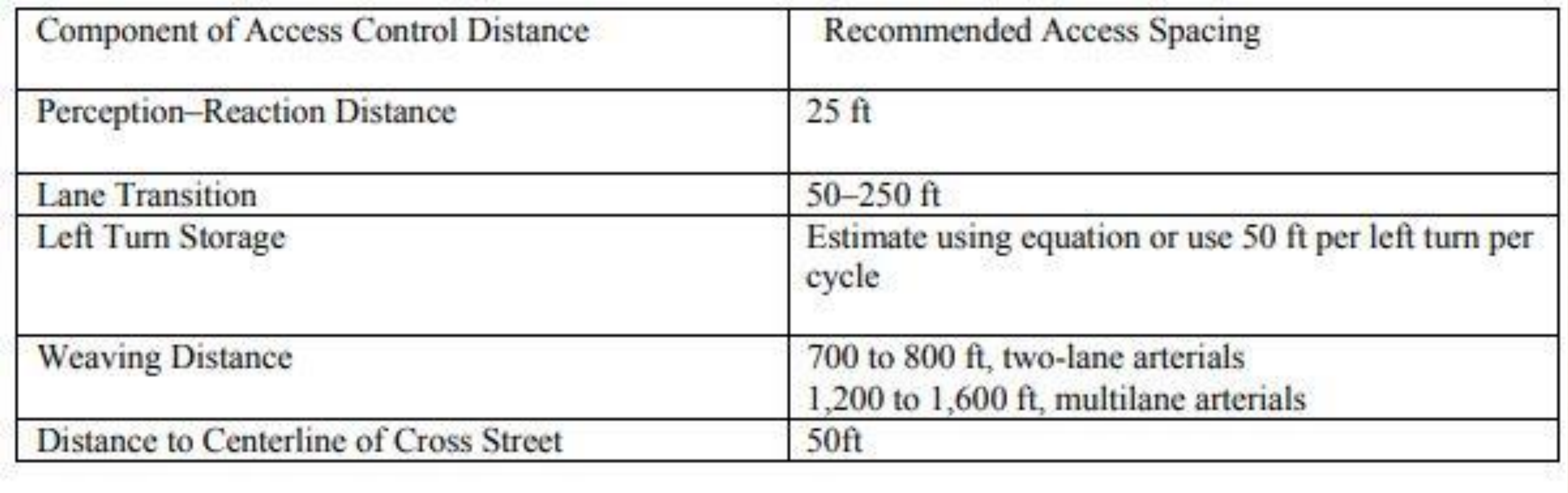
Source: Gluck, J., H.S. Levinson, and V. Stover. NCHRP Report 420: Impacts of Access Management Techniques, Transportation Research Board, Washington, DC, 1999.

The preferred access control distance includes:

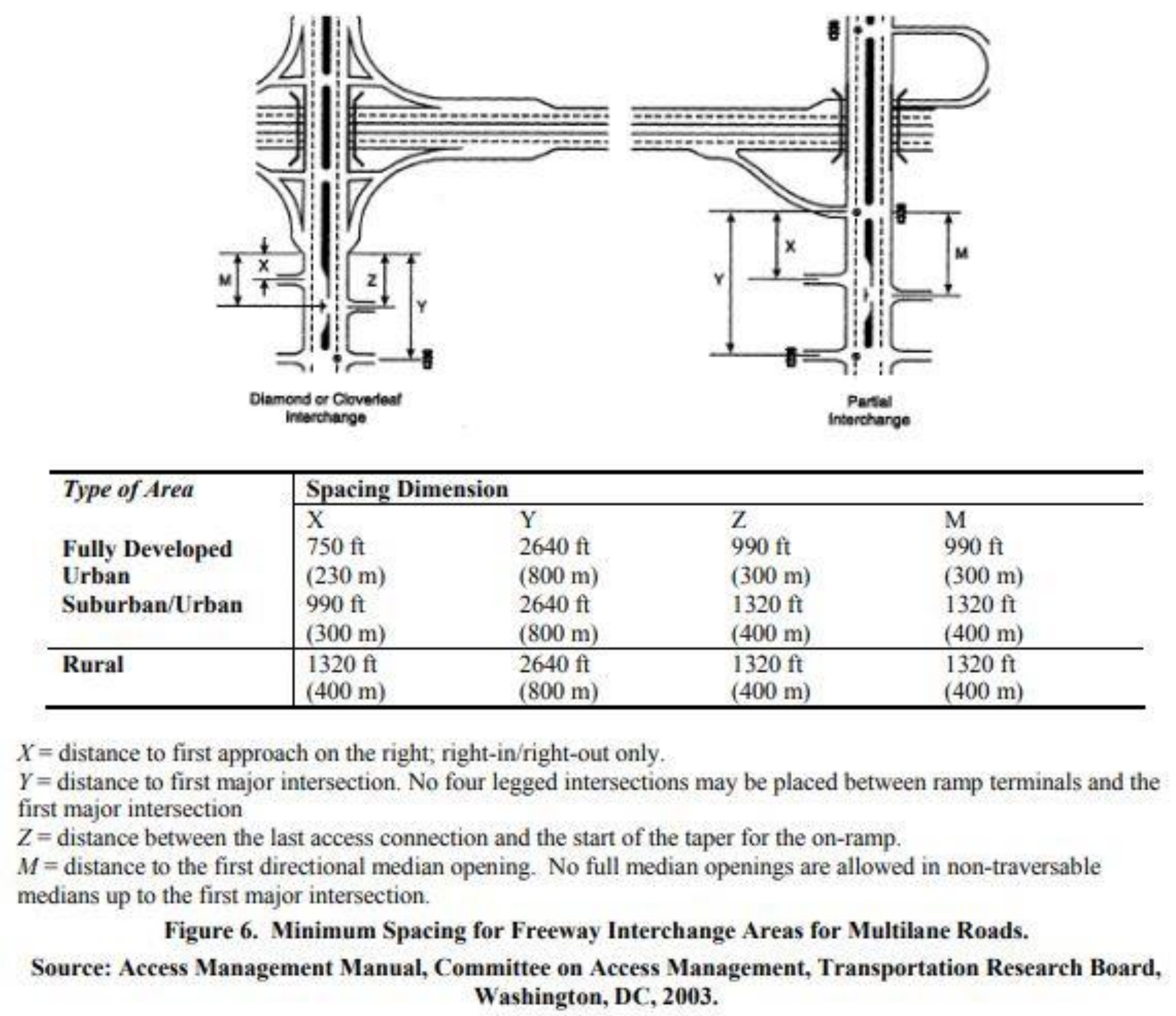
- Distance required to weave across the through travel lanes
- Distance required for transition into the left-turn lane or lanes
- Distance needed to store left turns with a low likelihood of failure
- Distance from the stop line to the centerline of the intersecting road or driveway
- Distance covered during driver perception-reaction time (could be added)

Table 4. Components of Access Control Distance

Source: Gluck, J., H.S. Levinson, and V. Stover. NCHRP Report 420: Impacts of Access Management Techniques, Transportation Research Board, Washington, DC, 1999.



Component of Access Control Distance	Recommended Access Spacing
Perception–Reaction Distance	25 ft
Lane Transition	50–250 ft
Left Turn Storage	Estimate using equation or use 50 ft per left turn per cycle
Weaving Distance	700 to 800 ft, two-lane arterials 1,200 to 1,600 ft, multilane arterials
Distance to Centerline of Cross Street	50ft

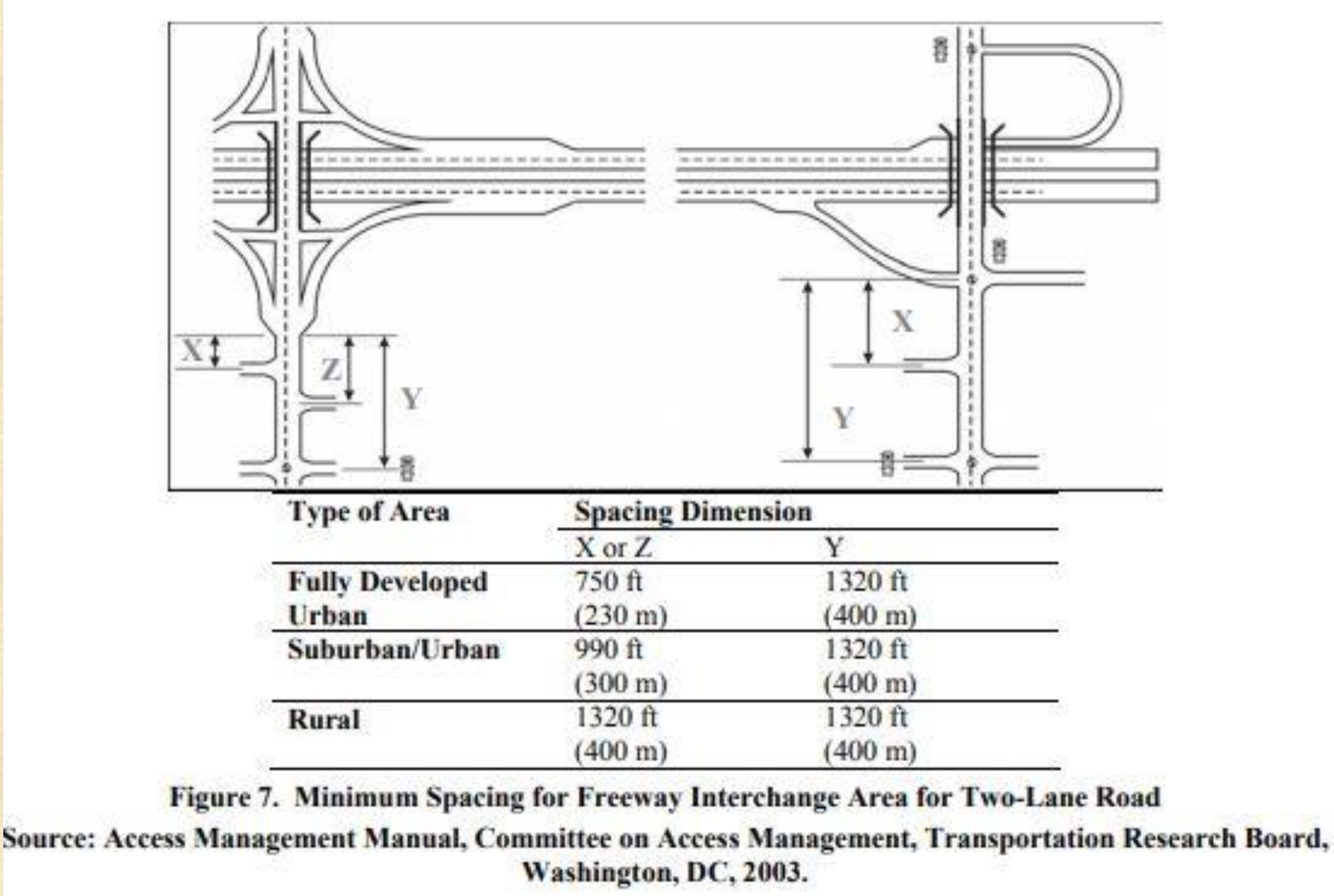


Type of Area	**Spacing Dimension**			
	X	Y	Z	M
Fully Developed Urban	750 ft (230 m)	2640 ft (800 m)	990 ft (300 m)	990 ft (300 m)
Suburban/Urban	990 ft (300 m)	2640 ft (800 m)	1320 ft (400 m)	1320 ft (400 m)
Rural	1320 ft (400 m)	2640 ft (800 m)	1320 ft (400 m)	1320 ft (400 m)

X = distance to first approach on the right; right-in/right-out only.
Y = distance to first major intersection. No four legged intersections may be placed between ramp terminals and the first major intersection
Z = distance between the last access connection and the start of the taper for the on-ramp.
M = distance to the first directional median opening. No full median openings are allowed in non-traversable medians up to the first major intersection.

Figure 6. Minimum Spacing for Freeway Interchange Areas for Multilane Roads.

Source: Access Management Manual, Committee on Access Management, Transportation Research Board, Washington, DC, 2003.



Type of Area	Spacing Dimension	
	X or Z	Y
Fully Developed Urban	750 ft (230 m)	1320 ft (400 m)
Suburban/Urban	990 ft (300 m)	1320 ft (400 m)
Rural	1320 ft (400 m)	1320 ft (400 m)

Figure 7. Minimum Spacing for Freeway Interchange Area for Two-Lane Road

Source: Access Management Manual, Committee on Access Management, Transportation Research Board, Washington, DC, 2003.