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Arterials and Streets
Infrastructure and Operations

for Mobility, Access, and Community In Metropolitan Chicago

Part I: Pavement and
Part II: Access Management

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CMAP Congestion Management Process
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This paper analyzes potential strategies that may be deployed in northeastern Illinois on our arterial highway system. The purposes of the each strategy may vary, but the overall goal of such strategies would be to reduce vehicle delay, reduce crashes, facilitate economic development, improve reliability, and improve walkability and bikeability.

Physical and operational improvements to the arterial system can improve capacity, improve travel time reliability and reduce crashes. These strategies may require large capital outlay to facilitate, and may require a higher on-going commitment to supporting a cadre of qualified professionals to operate the facility.

For highways, the biggest investments are typically in pavement, structures, and drainage. However, good physical infrastructure is not sufficient to achieve our regional vision. Access management, “complete street” elements, technologies, and intersection operations will also be considered. Pavements and access management will be considered first, in this document. Successive documents will consider complete streets, technologies, and intersection operations. Drainage and structures are not a central theme of these papers, but will be considered as part of other discussions.

Part I. Pavements

Pavement designs are specific to the expected use and design life of a facility. Pavement structures begin with a gravel base resting on a native subgrade, fully cleared and grubbed. Substantial excavation is usually required, both for the pavement itself and associated drainage structures. Some subgrades (e.g., clay soils) require stabilization of the subgrade with Portland cement and/or a thick gravel base.

Asphalt concrete, often called simply “asphalt,” is comprised of a binder and aggregate. About 95% of roads in the United States are paved with asphalt.[1] Asphalt is usually installed in multiple layers. A thin, smooth asphalt surface is placed on top of a coarse asphalt base. Applying recent, better understanding of the chemistry of asphalt binders, which provide the waterproof cohesion of asphalt pavements, has provided a more durable, cleaner construction input.[2] Hot asphalt concrete pavement surfacings are expected to last 15-20 years, with an excellent ride quality, suitable for high-volume, high-speed roads.[3] A disadvantage of asphalt pavements is that the asphalt binder is a petroleum derivative, increasingly requiring specified, high-grade, imported petroleum.

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[1] Anderson, Youtcheff, and Zupanic: “Asphalt Binders.” In *Transportation in the New Millenium.* Transportation Research Board. http://onlinepubs.trb.org/Onlinepubs/millennium/00006.pdf Accessed July, 2008.

[2] Ibid.

[3] Federal Highway Administration, Central Federal Lands Highway Division. “Roadway Surfacing Options Photo Album.” Companion Document to Context Sensitive Roadway Surfacing Selection Guide. August, 2005. p. 37. Posted at http://www.pavementpreservation.org/toolbox/links/roadway-surfacing-photos.pdf

Portland cement concrete pavements, referred to as “concrete,” are composed of Portland cement, course aggregate, sand, and water. Chemicals are added to the concrete mix to control the setting and hardening processes and to improve workability and performance. Concrete is reinforced with treated steel bars.[4] Portland cement concrete surfacings are strong, durable, and have a long life (30-40 years). Portland cement concrete is suitable for high-volume, high-speed roads. However, concrete has a high initial cost.[5]

Other pavements are used on low-volume, low-speed roads. The region’s rural roads may include aggregates with slurry seals or chip seals. Also, some suburban communities are maintaining or are returning to brick pavements. For example, Huntley maintains Woodstock Street as a brick pavement (see Figure 1). Wilmette maintains a number of brick streets; additional asphalt-surfaced streets have a brick base.[6] In addition, Oak Park has recently installed a new brick street in the village’s downtown after many years of primarily asphalt infrastructure, and is converting existing asphalt streets to brick.[7] In Europe, “silent bricks” with a fine texture and porous top layer have been evaluated.[8] For brick pavements, typical forecast AADT is less than 500, with speeds less than 37 mph.[9] Other pavements include natural stone (AADT < 200, speed < 15 mph); porous unit pavers (AADT < 200, speed < 20 mph, with high maintenance requirements); and standard unit pavers (speeds < 50 mph).[10]

Figure 1. Village of Huntley’s Woodstock Street.

Photo: Dan Burden, Glatting Jackson/Walkable Communities

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[4] Portland Cement Association. “Cement and Concrete Basics.” http://www.cement.org/basics/concretebasics_concretebasics.asp. Accessed July, 2008.

[5] Federal Highway Administration, Central Federal Lands Highway Division. Op. cit., p. 55

[6] Village of Wilmette. “Brick Street Atlas.” http://www.wilmette.com/construction/2005/BrickLocations.pdf. Accessed July, 2008.

[7] Village of Oakr ParkPlanning Marion Street.

[8] Dutch Innovation Program on Noise Mitigation. “Pavement Noise Translator.” http://www.noiseinnovationprogramme.eu/data/files/algemeen/RAP-05.000188.pdf Accessed July 2008.

[9] Federal Highway Administration, Central Federal Lands Highway Division. Op. cit., p. 95.

[10] Ibid., p. 98 ff.

Pavement Management, Preservation, and Life-Cycle Costs

Good pavement design and pavement management both reduce long-term pavement costs. Most large agencies and many small agencies have implemented pavement management systems, a form of asset management, to facilitate better pavement conditions within constrained maintenance budgets. A sophisticated pavement management system consists of regular highway condition data collection, a database of collected information, and analytic capabilities. Analytic capabilities would include abilities to predict pavement life given likely loads, climate, and other factors; annual repair costs; and performance. These predictions involve feedback of historic data into the analyses.[11]

Pavement management systems have often been implemented on an agency basis. For example, the Illinois Department of Transportation maintains an extensive, well-developed pavement management system.[12] Alternatively, as in the San Francisco Bay area, pavement management has been approached from a regional perspective, including the participation of almost all counties and municipalities.[13] The system was put in place to encourage good management after a 1981 study demonstrated that Bay-area communities were spending only 60% of the funds necessary to properly maintain pavements.[14] Participation in a pavement management program became a prerequisite for state or federal funding under California law, with participation required by 1990.[15]

Pavement management research has shown that good design practices for construction projects have not been enough to assure good resource allocation, because maintenance budgets were focused on repairing streets in the worst condition. However, pavement management research showed that careful planning of maintenance could preserve pavements, preventing them from falling into poor condition and requiring much more expensive rehabilitation or reconstruction. As FHWA notes,

> *Successive years of collecting pavement condition data showed that it was far more economical to preserve roads than to delay repairs and reconstruct roads. The studies further showed that as traffic levels increase the costs of delaying repair work increased greatly. This suggested that the traditional practice of repairing the worst roads first is, in fact, a very expensive way to operate a highway system.*[16]

Preventive maintenance applies pavement treatments over the life of a pavement to maintain good condition, extend life, and minimize life-cycle costs. Examples of

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[11] Federal Highway Administration. *Pavement Management Primer.* P. 1. http://www.fhwa.dot.gov/infrastructure/asstmgmt/pmprimer.pdf

[12] Bham, Gharaibeh, Darter, Heckel, and Hall. "Illinois's Experience with Pavement Analysis and Management Systems." Transportation Research Board Paper 01-2970. http://www.mrutc.org/about/00486.pdf

[13] http://www.mtcpms.org/index.html. Accessed September, 2008.

[14] Metropolitan Transportation Commission. "About PMP." http://www.mtcpms.org/aboutus/index.html Accessed September, 2008.

[15] Metropolitan Transportation Commission. "Pavement Management Certification Listing." http://www.mtcpms.org/ptap/cert.html Accessed September, 2008.

[16] Metropolitan Transportation Commission. "Regional Streets and Roads Program.", http://www.mtcpms.org/index.html. p. 2

treatments for concrete include full-depth concrete repairs, joint sealing, crack sealing, pavement restoration, and spall repair. Asphalt pavement treatments include milling and overlays, crack treatments and filling. Recommendations as to the proper time, proper treatment, and application procedures for a given pavement and pavement condition have been developed and are available.[17] [18]

Design considerations are important in reducing life-cycle pavement costs. Standard design procedures consider pavement maintenance needs.[19] Several recent projects, including the I-290 and Dan Ryan Reconstruction Projects, have employed extended-life pavement experiments, increasing pavement depth to extend the service life of the pavement.[20] For I-290, IDOT stated that the goal of the project's pavement design was to "build a highway that will last at least 40 years before major repairs are needed; that is, double the current 20-year standard."[21]

Roadway and Lane Width

For urban, low-volume local roads (20-year projected average daily traffic less than 400), adopted national standards for total roadway width have been set at 20 to 28 feet for settings with less than two dwelling units per acre. For low-volume roads in areas with densities of 2.1 to 6 dwelling units per acre, the standard for total roadway widths is 28-34 feet.[22] These standards are sufficient for safe operation, two-way traffic, deliveries, emergency vehicles, and on-street parking consistent with residential uses; reduced widths can be instituted where parking is prohibited.[23] ***Adopting a narrow street standard for local streets reduces long-term maintenance costs of unnecessary pavement and reduce stormwater management expenses and impacts.***

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[17] Peshkin, Hoerner, and Zimmerman. *Optimal Timing of Pavement Preventive Maintenance Treatment Applications.* National Cooperative Highway Research Program Report 523. 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_523.pdf Accessed September, 2008.

[18] Federal Highway Administration. *Pavement Preservation Toolbox.* 2006. Posted at http://www.pavementpreservation.org/toolbox/start.html Accessed September, 2008.

[19] Illinois Department of Transportation, Division of Highways. *Bureau of Design and Environment Manual.* Chapter 54, Pavement Design. Posted at http://www.dot.il.gov/desenv/BDE%20Manual/BDE/pdf/chap54.pdf Accessed September, 2008.

[20] John Fortmann, Illinois Department of Transportation. "Interstate 90/94 Dan Ryan Expressway Construction Project." Presentation. Posted at http://www.itre.ncsu.edu/ADC10/PDFs/2007_Summer_Conference/EnvAnalysisTour/Dan_Ryan_Expressway_Reconstruction.pdf P. 12

[21] Illinois Department of Transportation. "Extended Life Pavement/Auxiliary Lanes." http://www.dot.state.il.us/i290/lanes.html. Accessed September, 2008.

[22] American Association of State Highway and Transportation Officials (AASHTO). 2001. *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <= 400).* P. 20.

[23] Ibid., p. 19.

Figure 2. Narrow Local Street

Photo by Dan Burden Glatting Jackson/Walkable Communities

Figure 3. Wide Local Street

Photo by Dan Burden Glatting Jackson/Walkable Communities

Many local communities in metropolitan Chicago still require 40' local residential streets.[24] However, McHenry County has adopted a narrow street standard for conservation design.[25] Will County's subdivision ordinance also allows narrower

[24] For local streets, IDOT standards allow either following the ITE Recommended Practice *Guidelines for Residential Subdivision Street Design* IDOT BLRS Geometric Design Criteria (http://www.dot.il.gov/blr/manuals/Chapter%2032.pdf Figure 32-2H). Following the Geometric Design Criteria can result in local road widths of up to 48 feet (for local roads with parking and shared with bicycles – as local roads are).

[25] McHenry County. *McHenry County Subdivision Ordinance: Conservation Design Standards and Procedures.* Adopted February 19, 2008.

streets.[26] Chicago Wilderness and the Northeastern Illinois Planning Commission developed model subdivision ordinances for conservation design that include narrow residential streets.[27]

Arterial and collector street widths require as much attention as local streets. For many years, standard arterial lane widths were set at 12 feet, with "safety" being the reason asserted for the minimum width. However, engineers have indentified many safety benefits of reallocating space from 12' lanes to other urban and suburban cross-section needs. Harwood and Hauer note that these benefits include providing space for medians, bicycle lanes, curb parking, sidewalks, pedestrian buffers, and clear zones.[28].

A comprehensive review of safety data indicates that a nuanced approach to lane widths is necessary. For rural roads, crash rates are higher for nine- and ten-foot-wide lanes than for eleven- and twelve-foot-wide lanes. At less than 500 ADT, the accident modification factor (AMF) for 9-foot travel lanes in rural areas is 1.05 (a multiple of the base case – the base being 12-foot lanes). This AMF rises as rural ADT increases, so that the estimated AMF above 2000 ADT is 1.50. The difference between eleven-foot-wide lanes and twelve-foot-wide lanes in rural areas is not so great; even at higher ADT's, the AMF is 1.05.[29]

For urban roads, research is scarce about the relationship between lane width and crash rates. However, a recent, rigorous study of crashes and lane widths by Potts, Harwood, and Richard showed that, for roadway segments:

> there was no indication that the use of 3.0 or 3.3m (10- or 11-ft lanes) rather than 3.6m (12-ft) lanes for midblock segments led to increases in crash frequency. There are situations in which use of narrower lanes may provide both benefits in traffic operations, pedestrian safety, or reduced interference with surrounding development and space for geometric features that enhance safety, such as medians or turn lanes. The analysis results indicated that narrow lanes can generally be used to obtain these results without compromising safety.[30]

The authors recommended caution in using lane widths of 10 feet or less on four-lane undivided arterial segments, or nine-foot or less on four-lane divided arterial segments. Additionally, they recommended caution in using lane widths of less than 12 feet where

[26] Will County Subdivision Engineering. *Subdivision Ordinance.* Amended July 18, 2002. http://www.willcountylanduse.com/SubEng/SubEngDocs/subdivision_ord.pdf

[27] Chicago Wilderness and Northeastern Illinois Planning Commission. *Conservation Design Resource Manual: Language and Guidelines for Updating Local Ordinances.* 2003. http://www.chicagowilderness.org/pubprod/miscpdf/CD_Resource_Manual.pdf Accessed September, 2008.

[28] Harwood and Hauer, et al. *Methodology to Predict the Safety Performance of Urban and Suburban Arterials.* National Cooperative Highway Research Program Project 17-26 Final Report. March, 2007. Transportation Research Board, NCHRP Web-Only Document 129. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w129p1&2.pdf

[29] Ibid.

[30] Potts, Harwood, and Richard. Relationship of Lane Width to Safety on Urban and Suburban Arterials." *Transportation Research Record 2023.* Washington: Transportation Research Board. 2007. p. 81.

there are substantial volumes of bicyclists not accommodated by wide outside lane, bicycle lane, or paved shoulder.[31]

For intersection approaches, Potts, Harwood, and Richard found that, "with limited exceptions, there was no consistent, statistically significant relationship between lane width and safety for approaches to intersections on urban and suburban arterials."[32] The authors caution the use of lanes of ten feet or less for four-leg, stop controlled intersections, as well as the use of lanes less than twelve-feet-wide where substantial numbers of bicyclists share the road with motor vehicles (unless alternative facilities are provided).[33]

In cases where there are high bus and truck volumes, twelve-foot lanes may be supported by a 1994 study of bus crashes by Zegeer et al.[34] However, the 1988-1989 Illinois bus crash data analyzed in the study showed that buses accounted for only 0.2% of all crashes in the study period.[35] In addition, 2006 Illinois data for truck crashes indicates that, while more substantial in number, truck crashes are concentrated on state highways (including interstate highways). Thus, truck crash concerns do not provide a sound basis for widespread use of the twelve-foot lane standard on *all* roads, given the alternative treatments' safety benefits that are more clearly effective.[36] Conditions, including truck and bus volumes and crashes but also information about other modes, needs to be carefully evaluated for each specific site.

The Institute of Transportation Engineers (ITE) has proposed a recommended practice for lane widths as part of the *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities.*[37] The proposal recognizes that, in urban and suburban contexts, right-of-way is limited and should be allocated to accommodate all roadway users at the site, rather than using a cookie-cutter approach. The proposed practice recommends:[38]

- Consideration of 10-foot lanes for design speeds of 30 mph or less, and 11- 12-foot lanes at design speeds of 35-40mph;
- Design vehicle selection based on vehicle frequency.
- Balance design elements with available right-of-way;
- Consideration of adjacent element widths in selection of the width of an element (e.g., don't place a narrow bike lane next to a narrow motor-vehicle lane). First

[31] Ibid.
[32] Ibid.
[33] Ibid.
[34] Zegeer et al. "Commercial Bus Accident Characteristics and Roadway Treatments." *Transportation Research Record.* No. 1467. 1994.
[35] Ibid., p. 17.
[36] 2006 Illinois data for truck crashes show that tractor-trailers accounted for 16,064 crashes and 139 fatalities. Of these 16,064 tractor-trailer year-2006 crashes, 4,283 (26.7%) were on local roads and streets in urban areas; 4,179 (26.0%) were on urban interstate highways; and 5,151 (32.1%) were on other urban marked or unmarked state routes. The remaining crashes (2,451) were on rural highways and roads. Illinois Department of Transportation. *Illinois Crash Facts, 2006.* 2007. p. 39.
[37] Institute of Transportation Engineers. *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities.* An ITE Proposed Recommended Practice. 2006. p120.
[38] Ibid.

consider a wider bike lane; if a design vehicle or design speed justify, widen the travel lane.

Currently, policies and procedures make lane widths less than 12' a design exception, requiring additional engineering justification. These policies should be reconsidered to allow routine implementation of 11' lanes and, for lower-speed situations, even 10' lanes. Implementing such a routine procedure will facilitate more widespread implementation of other life-saving cross-section elements (e.g., medians, sidewalks).

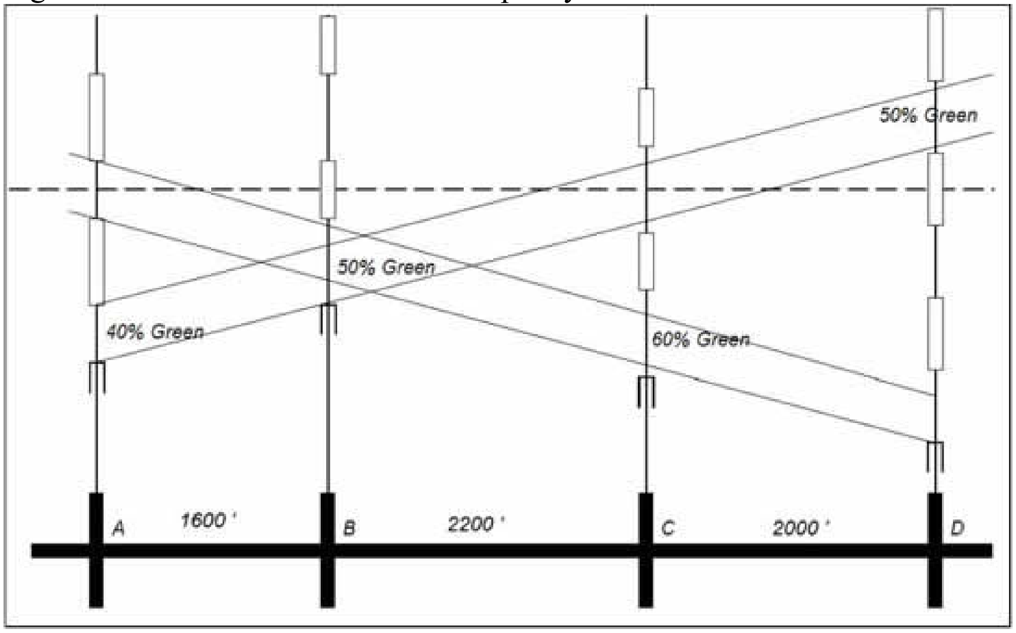
Number of Motor Vehicle Traffic Lanes

The number of motor vehicle traffic lanes has traditionally been treated as an engineering issue. To conserve resources, to reduce right-of-way costs, and to address community needs, the number of lanes on an arterial or collector road will increasingly need to be viewed as a planning issue.

Arterial traffic flows in urban areas are interrupted to accommodate conflicting flows. Typically, traffic is controlled with stop signs and traffic signals. For arterials, operations at fixed points, e.g. signal locations, are the primary capacity constraint. At standard-operation highway traffic signals, through-traffic flows are only a fraction of overall capacity, because of the need to accommodate left-turns and the other approaches of an intersection. So a through movement may have a green signal only 40% of the time. Furthermore, as illustrated in Figure 4, to facilitate progressive flows between signalized intersections, the effective windows of time when through movements can proceed in platoons may be limited to the minimum, or critical, value along a corridor.

Figure 4 shows the impact of signal operations on arterial traffic flow, in a space-time diagram. Platooned vehicles can only progress through the signalized intersections (A,B,C, and D) in a narrow band of time for each green cycle.

Figure 4. Simple Arterial Time-Space Diagram, Showing Effect of Progressed Signalized Intersections on Arterial Capacity.



Source: Federal Highway Administration. http://ops.fhwa.dot.gov/publications/signal_timing/03.htm

Thus, more lanes are needed to move a given level of traffic through a standard intersection than through a non-intersection cross-section. But because of the need to carry a uniform cross-section between intersections, to facilitate platooning of vehicles for progressive traffic flow, additional lanes necessary for standard intersections are often extended between the intersections.

The bottom line is that ***to minimize the number of through traffic lanes in a given cross-section for a given traffic volume, adjacent intersection operations must be made much more efficient.*** Innovative intersection operations facilitating such improvements will be discussed in an accompanying paper.

Median Treatments

An arterial median separates oncoming traffic, provides space for left-turning vehicles outside of the through traffic stream, and improves pedestrian safety by providing a refuge from moving traffic. Medians are either open, typically providing a continuous left turn lane, or channelized to separate road users and manage access. Channelization also facilitates landscaped medians, providing an opportunity for highway beautification and improved stormwater management.

Continuous Two-Way Left-Turn Lanes. Open medians providing continuous two-way left turn lanes are common in suburban Chicago. National study has indicated that, when implemented for safety purposes, such treatments are most effective in rural areas. Expected crash reductions for rural areas are 36% for total crashes, 35% for injury crashes, and 47% for rear-end crashes.[39] More research is needed to evaluate safety effects in urban areas; careful selection of applications is recommended.[40]

Sometimes two-way left turn lanes are an alternative to adding additional traffic lanes. Though a three-lane cross section does not specifically address delays relating to signal operations upstream or downstream, the three-lane cross section substantially reduces delays from turning vehicles compared to a two-lane cross section, and is not substantially different than a four-lane cross-section below 15,000 ADT.[41] Still, above 8,000 ADT, four-lane cross-sections have lower delay than three-lane cross-sections. The effectiveness of alternative cross-sections is also a function of the land use intensity and driveways per mile.[42]

An example of a two-lane to three-lane conversion as an alternative to a four-lane cross-section occurred in 1981 in Downers Grove. Downers Grove had proposed to add two through traffic lanes to Fairview Avenue. The proposal was scaled back to only add a continuous left turn lane. The three-lane alternative allowed for the retention of a parkway and many street trees, and was a successful safety improvement appropriate for the projected 16,000 AADT. In this case, crashes fell from 55 in a six-month period before the improvement to 29 after the improvement, a reduction of 47% that came despite higher volumes and higher crashes rates village-wide.[43]

Road Diets. In some cases, in a strategy called a "road diet," communities are converting four-lane cross-sections to three-lane cross-sections. Urban and suburban communities may find this strategy attractive to reduce excessive vehicle speeds and speed variability in existing four-lane cross sections with appropriate volumes. Road diet case study analyses by Knapp et al showed that, for volumes of 8,400 up to 24,000 ADT, 85th percentile speeds fell, typically less than 5 mph, but speeding more than five mph above the posted limit sometimes fell dramatically.[44] Studies of crash reduction effects of road diets have given mixed results. While some studies have shown safety benefits of road diets, the most statistically rigorous analysis to date has shown no discernible change in the number of crashes.[45,46] Experience of communities nationwide indicates that road

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[39] Persaud et al. *Safety Evaluation of Installing Center Two-Way Left-Turn Lanes on Two-Lane Roads.* FHWA Report Number FHWA-HRT-08-042. December, 2007.
[40] Ibid.
[41] Hummer and Lewis. Operational Capacity of Three-Lane Cross Sections. *Operational Capacity of Three-Lane Cross-Sections.* Center for Transportation Engineering Studies, Department of Civil Engineering, North Carolina State University. April, 2000. [Available from National Technical Information Service.] pp. 32-39.
[42] Ibid.
[43] John McCree, (Illinois Department of Transportation). "Two-Way Left Turn Lane." *Illinois Municipal Review.* July 1987. p.12. Posted at http://www.lib.niu.edu/1987/im870712.html. Accessed September, 2008.
[44] Knapp, Giese, and Lee. "Urban Four-Lane Undivided to Three-Lane Roadway Conversion Guidelines." In *Proceedings of the 2003 Mid-Continent Transportation Research Symposium.* Ames: Iowa State University. 2003. p. 2. Posted at http://www.ctre.iastate.edu/PUBS/midcon2003/KnappConversion.pdf. Accessed September, 2008. In two cases, excessive speeding fell 60-70%.
[45] Ibid.
[46] Huang, Stewart, and Zegeer. "Evaluation of Lane Reduction 'Road Diet' Measures on Crashes and Injuries." *Transportation Research Record 1784.* Transportation Research Board, 2002.

diets can be applied comfortably to roadways up to 20,000 ADT; above this traffic volume, communities have been more cautious.[47] Overall, "road diet" evaluations should consider the characteristics of each unique situation, including consideration of excessive vehicle speeds, crashes, and non-motorized safety. Road diets can be expected to have traffic calming effects, reducing excessive speeds, above 8,000 ADT.

Figure 5 shows how a road diet may facilitate adding bike lanes to existing pavement.

Figure 5. Road Diet, Showing Bicycle Lanes.

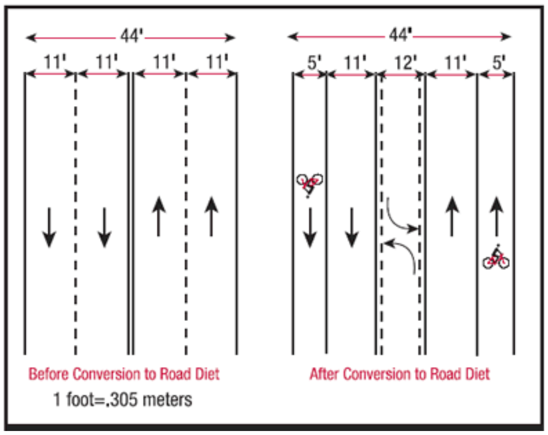

Image: Huang, Stewart, and Zegeer, Op. cit.
Posted at http://www.tfhrc.gov/safety/hsis/pubs/04082/index.htm

Raised Medians. Raised medians provide access management and channelize conflicting traffic movements, thus improving safety. Medians also improve pedestrian safety by providing a refuge from moving traffic.

Raised medians improve motorist safety. Raised medians reduce the number of conflict points. Gluck, Levinson, and Stover estimated that urban highways with non-traversable medians had a crash rate per million VMT that was 38% lower than undivided highways.[48] Rural raised medians also improved safety over rural undivided highways.[49]

In many cases, two-way left-turn lanes can be converted to raised medians. A literature review and empirical models also demonstrated that **raised medians have a significant safety benefit over two-way left turn lanes**.[50] For empirical data, accident rates for roadways with raised medians were 5.17 crashes per million VMT, 28% less than the rate of 7.25 per million VMT for roadways with two-way left turn lanes.[51] Of seven safety

[47] Burden and Lagerwey. *Road Diets: Fixing the Big Roads.* Walkable Communities, Inc. 1999. p. 2. Posted at http://www.walkable.org/download/rdiets.pdf. Accessed September, 2008.
[48] Gluck, Levinson, and Stover. *Impacts of Access Management Techniques.* National Cooperative Highway Research Program Report 420. National Academy Press. 1999. p. 3.
[49] Ibid., p. 4.
[50] Ibid., pp. 72-76.
[51] Ibid., p. 74.

models using a variety of traffic levels, six also showed a substantially lower crash rates for raised median roadways compared to two-way left-turn lanes.[52]

Raised medians provide significant reductions in delay compared to undivided highways. Travel delay for raised medians is similar to that of two-way left turn lanes, though raised medians may have somewhat higher delay than two-way left turn lanes for very-high-volume roads. Detailed tables are presented in Tables 2-13 to 2-15 in *NCHRP Report 395*[53]. Table 1, below presents a sample of this information from *NCHRP Report 410.*

Table 1. Annual Delay to Major Street Left-Turn and Through Vehicles (Hours/Year)

Driveways/Mile	**Undivided**	**Two-Way Left-Turn Lane**	**Raised Median**
		ADT 22,500	
30	2,200	1,300	1,300
60	2,200	1,400	1,400
90	2,200	1,400	1,400
		ADT 32,500	
30	7,100	3,000	3,100
60	7,800	3,200	3,500
90	8,000	3,200	3,400

Source: Reproduced from Gluck, Levinson, and Stover. *NCHRP Report 410.* Table 65. This example of results from *NCHRP Report 395* assumes 10% left turns per 1320-foot segment.

FHWA has also issued strong support for medians for pedestrian safety purposes:

> ***Background:***
> *Providing raised medians or pedestrian refuge areas at pedestrian crossings at marked crosswalks has demonstrated a 46% reduction in pedestrian crashes. Installing such raised channelization on approaches to multi-lane intersections has been shown to be particularly effective. At unmarked crosswalk locations, medians have demonstrated a 39% reduction in pedestrian crashes. Medians are especially important in areas where pedestrians access a transit stop or other clear origin/destinations across from each other.*
>
> ***Guidance Statement/Application:***
> *Raised medians (or refuge areas) should be considered 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 ADT) and intermediate or high travel speeds. Medians/refuge islands should be at least 4 feet wide (preferably 8 feet 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.*[54]

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[52] Ibid., pp 78-79

[53] Bonneson and McCoy. *Capacity and Operational Effects of Midblock Left-Turn Lanes.* National Cooperative Highway Research Program Report 395. National Academy Press. 1997. pp. 25-27.

[54] Jeffrey Lindley, FHWA Associate Administrator for Safety. *Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures.* July 10, 2008. Posted at http://safety.fhwa.dot.gov/policy/memo071008.htm

Raised medians provide not only a pedestrian refuge, but a location for landscaping as well. See Figure 6. Ground cover should be short, though trees can also be added. Irrigation is often required for landscaped medians.

Figure 6. Highway with Raised, Planted Median.

Photos by Dan Burden Glatting Jackson/Walkable Communities. Note provision for U-turning Vehicles.

Business Access and Exposure. Raised medians improve highway capacity and business exposure at the expense of some reduction in access.[55] Access to adjacent businesses is frequently an issue for raised medians. For most businesses, service, quality and price are all more important than access considerations, but access is of high importance for a substantial number of businesses.[56] Based on a survey of business representatives in four national case studies, Bonneson and McCoy concluded that, according to such representatives, "a conversion from an undivided cross section to either a raised-curb median (with openings every 330 feet) or a two-way left turn lane *will* improve arterial traffic conditions and business conditions (i.e., property values, access, and sales). In contrast, business owners believe that the conversion from either a raised-curb median (with openings every 330 feet) or a two-way left-turn lane to a raised-curb median with openings every 660 feet *will not* improve business conditions."[57] Thus, raised medians' trade-off between accessibility on the one hand versus mobility and safety on the other can be reduced by the design of the medians. Overall, median implementation is beneficial, but will need to consider site-specific access, traffic, and cost issues.[58]

Median construction and, in particular, the spacing and layout of median openings is a focus of "access management," the subject of the next section of this paper.

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[55] Gluck, Levinson, and Stover. Op. cit., pp. 79-80.

[56] Bonneson and McCoy. Op. cit., pp. 123-128.

[57] Ibid., p. 132

[58] Right-of-way and construction costs, in 1996 dollars, for undivided highways, highways with two-way left turn lanes, and highways with raised medians are estimated by Gluck, Levinson, and Stover, op. cit., on p. 55.

Part II. Access Management

The Transportation Research Board's *Access Management Manual* defines access management as "the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway."[59] Access management manages parcel ingress and egress to improve arterial and collector traffic flow. The challenge of access management is to assure mobility on arterial highways while providing sufficient access to assure prosperous businesses in planned commercial and mixed-use districts. Modern reliance on functional classification of roadways to guide access management has not been sufficient to provide sufficient access with regional mobility. New techniques and strategies are necessary to provide such benefits.

Access management "limits and consolidates access along major roadways, while promoting a supporting street system and unified access and circulation systems for development."[60] Access management accomplishes this through implementation of the following ten principles:

1. Provide a specialized roadway system.
2. Limit direct access to major roads.
3. Promote intersection hierarchy.
4. Locate signals to favor through movements.
5. Preserve the functional areas of intersections and interchanges.
6. Limit the number of conflict points.
7. Separate conflict areas.
8. Remove turning vehicles from through-traffic lanes.
9. Use nontraversable medians to manage left-turn movements.
10. Provide a supporting street and circulation system.[61]

Access management is implemented through the following governmental tools:

1. Policies, directives, and guidelines
2. Access management regulations
3. Acquisition of access rights
4. Land development regulations
5. Development review and impact assessment
6. Geometric design.[62]

A detailed program of how to implement access management is in the TRB's *Access Management Manual.* In this discussion of access management as a regional planning strategy, we will review the principles of access management, discussing challenges where appropriate. We will review particularly important elements applicable in a land use-transportation planning context. Lastly, we will summarize the benefits of access management.

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[59] Committee on Access Management. *Access Management Manual.* Transportation Research Board. 2003. p. 3
[60] Ibid., p. 7.
[61] Ibid., pp 8-9.
[62] Ibid, pp. 7-8

Principle 1: Provide a Specialized Roadway System

Functional Classification. Functional classification is the foundation for access management.[63] With functional classification, appropriate access management strategies can be developed for each class, then applied to each roadway or roadway segment.[64]

Federal procedures differentiate procedures for urban, small urban, and rural areas.[65] Illinois procedures adopt consistent classes within these areas. Illinois-defined functional classes are shown in the following table:

Table 2. Illinois Roadway Functional Classes

Urban Functional Classes	Non-Urban Functional Classes
• Interstate • Freeways and Expressways • Other Principal Arterials • Minor Arterials • Collector • Local Road or Street	• Interstate • Other Principal Arterials • Minor Arterials • Major Collector • Minor Collector • Local Road or Street

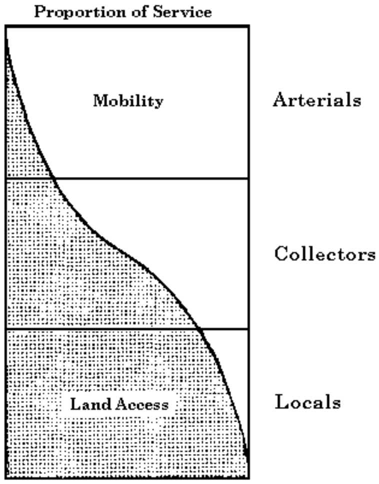
Source: Illinois Department of Transportation
http://www.dot.state.il.us/iris/Item-057.pdf accessed October, 2008.

Functional classification groups roads into classes by the character of the roadway and its relationship to other roads in the roadway network. Such classification allows channelization of long-distance, higher speed travel onto appropriate facilities.[66] Such channelization also allows regional resource allocation to be clearly directed to higher-classified roads.

Figure 7 shows the theoretical framework for the modern highway system's functional classification system and its relationship to access management. Access is managed such that it is the emphasis for local and collector streets, but is increasingly controlled and limited for higher-classed roads. Arterial design and operation are established to provide minimal land access but substantial mobility. Local streets, on the other hand, provide land access but minimal regional mobility. Collectors are intermediate, often providing linkages between arterial highways and local streets.

[63] Committee on Access Management, op. cit., p. 71.
[64] Ibid.
[65] Federal Highway Administration. *Highway Functional Classification: Concepts, Criteria, and Procedures.* March 1989. pp II-5 – II-7
[66] Federal Highway Administration. *Highway Functional Classification: Concepts, Criteria, and Procedures.* p. II-1.

Figure 7. Federal Highway Administration's Relationship of Functionally Classified Systems in Serving Traffic Mobility and Land Access.



Source: FHWA Functional Classification Guidelines. http://www.fhwa.dot.gov/planning/fcsec2_1.htm

Access Classification. In establishing classifications that are useful for access purposes, the following should be considered:

- Level of importance of roadways within the jurisdiction;
- Characteristics of system roadways;
- Land use and growth management goals;
- Current and potential future presence of pedestrians, bicycles, and transit.[67]

Federally- and state-defined functional classes may or may not adequately address the factors listed above**. Thus, a separate access classification for arterial and collector roadways is strongly recommended.** The *Access Management Manual* notes that "during the development of transportation plans, the basic roadway functional classifications are modified and expanded for planning purposes. Access categories should be internally consistent with agency transportation plans."[68] These classifications typically include the "degree of urbanization, presence or absence of a median, and speed. Factors used to differentiate the degree of urbanization include development intensity, traffic volume, intersection frequency, and speed conditions."[69]

Addressing urbanization in an access classification scheme allows access management to directly address central business district issues appropriately. Subcategories are suggested for central business districts and main street environments. Here, signal operations for closely spaced intersections, on-street parking, transit, and pedestrian needs are integral elements of a traffic environment that is necessarily low-speed. Full consideration of the needs of such areas facilitates maintaining consistent policies for other areas.[70]

[67] Committee on Access Management, p. 72.
[68] Ibid.
[69] Ibid.
[70] Ibid., pp 73-74.

An example of such a detailed access classification scheme has been developed in Oregon. There, as part of the Oregon Highway Plan, "special transportation areas," "urban business areas," and "commercial centers" have been designated along the highway system state-wide, consistent with the Plan's Land Use and Transportation Policy.[71] These areas are defined as follows:

- *Special Transportation Areas (STAs)* are designated districts of "compact development located on a state highway within an urban growth boundary in which the need for appropriate local access outweighs the considerations of highway."[72] A limited number of designated freight routes are excepted, and always have a mobility emphasis.[73]
- *Urban Business Areas (UBAs)* are those areas where auto-oriented development exists, but where the Oregon Highway Plan seeks to "encourage redevelopment and reinvestment in urban areas" and to shift urbanized land use to reduced auto-dependence. Urban Business Area designation and applicable regulation is automatic where the highway is already a low-speed urban road (speed limits of 35 mph or less). For roads with speed limits higher than 35 mph, road segments may be designated UBAs with ODOT and local jurisdiction approval of a management plan. Thus, the impact is to concentrate urban development and urban transportation in areas where highway speeds are already low or where there is a plan to manage land use, mobility, and access together.[74]
- *Commercial Centers* are large, regional centers, with 400,000 square feet or more of leasable space, with limited access to the Oregon state highway system. For such centers, walking, bicycling, and transit are accommodated. Through traffic mobility is maintained, but lower standards may be agreed to through a management plan.[75]

For each of the categories above, land use planning guidance is adopted through the Oregon Highway Plan, and become enforceable through the process for designating the areas and through associated management plans.[76]

Just as importantly and central to this discussion, Oregon's access management policies[77] and standards[78] are established based on the speed limit, highway designation, and land use area. Minimum access spacing is set out in Table 3.

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[71] Oregon Transportation Commission. *1999 Oregon Highway Plan: Policy Element.* As updated through 2006. Pp. 44-64. Posted at http://www.oregon.gov/ODOT/TD/TP/docs/orhwyplan/hwyplan/PolicyElement.pdf Accessed October, 2008.
[72] Ibid., p. 49.
[73] Ibid.
[74] Ibid., pp. 51, 57
[75] Ibid., pp. 53-54
[76] Ibid., pp. 50-54
[77] Ibid., pp. 118-135
[78] Oregon Transportation Commission. *1999 Oregon Highway Plan: Appendices.* As updated through 2006. Pp. 207-213. Posted at http://www.oregon.gov/ODOT/TD/TP/docs/orhwyplan/hwyplan/appendices.pdf Accessed October, 2008.

Table 3. Oregon Highway Plan Minimum Access Spacing Standards for Urban Areas, in Feet

Highway Designation:		Posted Speed (mph):				
		≤ 25	30 and 35	40 and 45	50	≥ 55
Urban Expressway (Controlled Access Arterial) At-Grade Intersections and Commercial Centers		-	-	2640	2640	2640
Urban (See Note 1)	Statewide Highways	520	720	990	1100	1320
	Regional Highways	350	425	750	830	990
	District Highways	350	350	500	550	700
Special Transportation Area		See Note 2	See Note 2	-	-	-

Source: Oregon Transportation Commission. *1999 Oregon Highway Plan: Policy Element.* Pp. 44-64. http://www.oregon.gov/ODOT/TD/TP/docs/orhwyplan/hwyplan/PolicyElement.pdf. Accessed October, 2008.

Note 1: "The Urban standard applies in UBAs unless a management plan agreed to by ODOT and the local government(s) establishes a different standard. Spacing standards on access controlled facilities are also guided by those controls."

Note 2: "Minimum access management spacing for public road approaches is the existing city block spacing or the city block spacing as identified in the local comprehensive plan. Public road connections are preferred over private driveways and in STAs driveways are discouraged. However, where driveways are allowed and where land use patterns permit, the minimum access management spacing for driveways is 175 feet (55 meters) or mid-block if the current city block is less than 350 feet (110 meters)."

A highway access classification system such as Oregon's, based not only on transportation but land use, facilitates the achievement of land use goals while simultaneously providing a more consistent, enforceable, and effective access management standard.

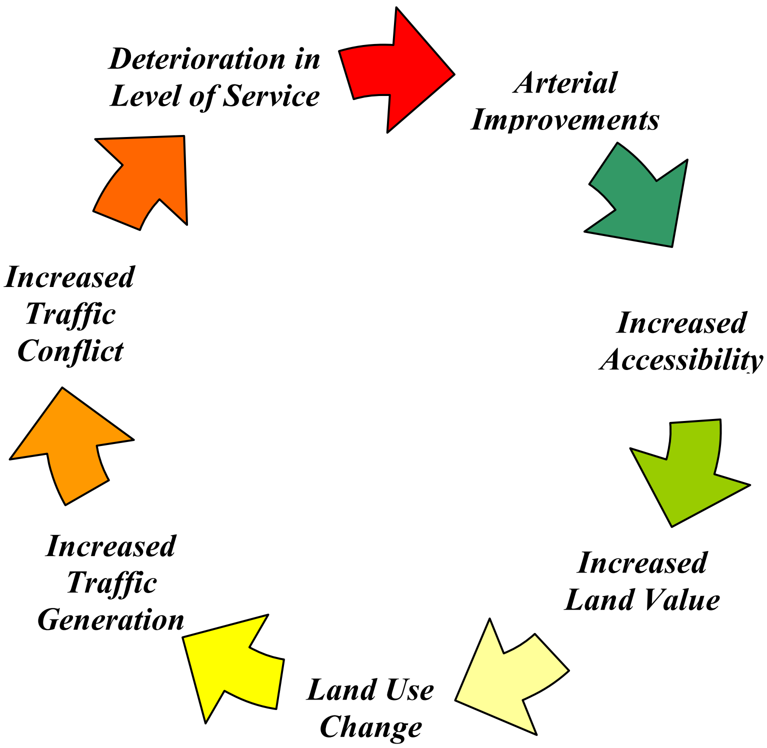
Modern Functional Classification and Land Development Challenges. Unfortunately, the traditional functional classification system presents a quandary for arterial access management and land use planning. Gluck, Levinson and Stover note that "property acquires value because of its location, accessibility, and exposure."[79] Property exposure is maximized along arterial highways, where traffic volume is highest. Properties along these roads become valuable and are increasingly developed, so demand for arterial access along these highways becomes a challenge to highway managers. Additional development and access brings more trips and increasing traffic conflicts, which may inspire new highway improvements. In turn, these highway improvements may increase property exposure and land values, bringing a new cycle of redevelopment and traffic conflict. This cycle, first conceptualized by Vergil Stover at Texas A&M University, is illustrated in Figure 8.

While it is true that access has become increasingly managed to improve arterial highway operations, major challenges exist. Access is necessary to complement a parcel's arterial

[79] Gluck, Levinson and Stover, op. cit., p. 79.

traffic exposure, and access to a parcel is still often uniquely from an arterial highway. In addition, local officials sometimes intervene on the behalf of developers to overrule established access permit regulations, further sacrificing safety and increasing traffic delay.[80]

Figure 8. The Unmanaged Transportation and Land Development Cycle



Source: Adapted from Stover and Koepke, *Transportation and Land Development.* Institute of Transportation Engineers. First Edition. 1988. p. 2.

Current arterial access management practices have not been sufficient to assure good arterial level of service because of the over-reliance on the arterial system for such access. That is, land is too often platted so that even local trips require arterial highway travel to access local businesses and other institutions. Thus, management of the arterial alone is not sufficient to improve safety and mobility – interconnected land development is critical to making arterial access management work.

Principle 2: Limit Direct Access to Major Roadways

Access control preserves the mobility functions for higher-classified roads. Reducing access points also improves safety substantially.[81] There are many techniques to limit access and several benefits of doing so.

[80] Author's discussions with highway operations and planning staffs.
[81] Committee on Access Management. *Access Management Manual.* Op. cit. pp. 16-17.

Driveway Access Management Techniques: *Subdivision Control.* The character of access control is a function of how land has been subdivided. Highway agency involvement in subdivision processes would facilitate improved access management. Coordinated review should not wait for a site plan and development proposal, but should take place at the time of subdivision to assure adequate access management. For example, both Wisconsin[82] and Michigan[83] require state review of subdivision activity on state highways and, in Michigan's case, roads connecting to state highways.

Subdivision and land development strategies to reduce the number of driveways include the following:

- Increase minimum lot frontage and setback requirements along major roadways.
- Regulate access to outparcels for large land developments.
- Provide an incentive for combining access points or relax parking and dimensional requirements where necessary to achieve shared access.[84]
- Optimize driveway location and access design in the development review process.
- Prohibit flag lots.
- Develop access overlay ordinances for high-priority corridors.[85]
- Develop a connected local road network of side streets and parallel roads to accommodate desired land development along major thoroughfares.[86]

Reverse Frontage. In suburban sites, reverse frontage is a widespread strategy to provide access for residential lots abutting arterial roads not from the arterial road, but from interior local streets. Increasingly, this is also applying to commercial and industrial developments.

For reverse frontage development, driveways are eliminated on arterial streets, reducing crashes and delay. To accomplish this, through lots or corner lots are platted with direct driveway access on the arterial highway denied in the land record process, a deed restriction carried with the property from owner to owner.[87]

While in the past reverse frontage developments have been suburban in character, such developments can also be high-density, urban developments. The notes to Table 3, above, show that in Oregon, driveways are avoided in urban "special transportation areas." For such developments, the buildings front directly on arterial streets, but parking and freight loading is in the rear. An illustration of how such development would differ from the current arterial-oriented driveway practice is shown in Figure 9.

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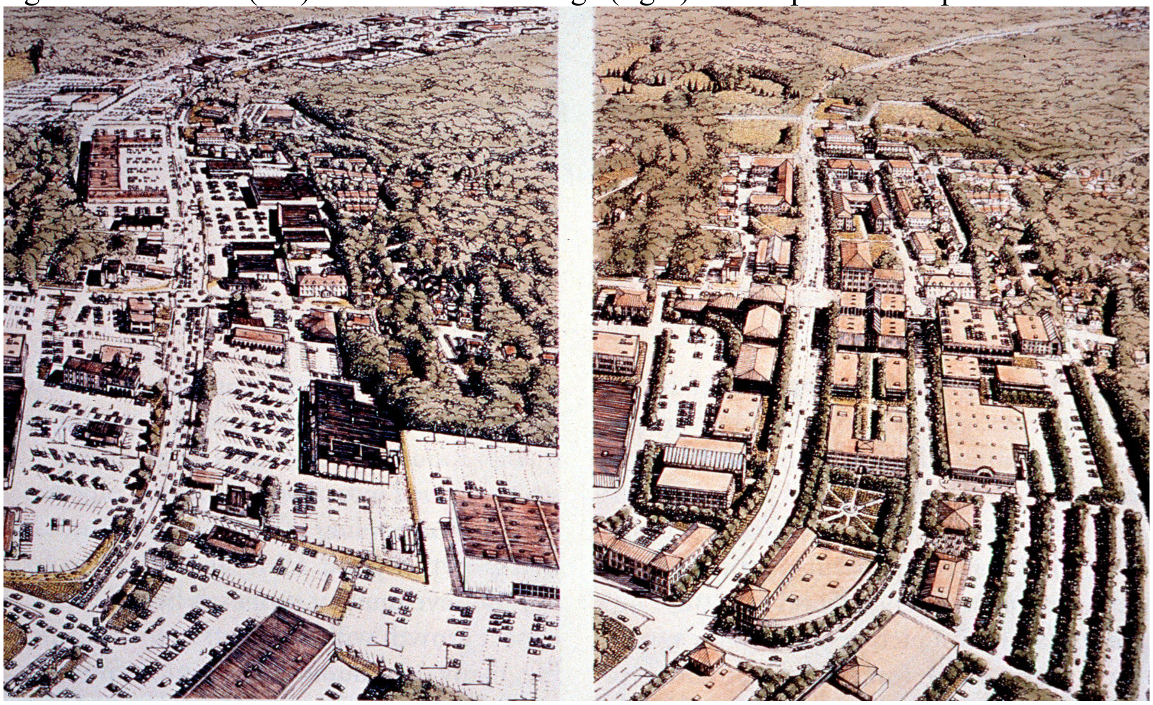
[82] Wis. Stat. § 236.12(2)(a) and Wis. Stat. § 236.13(1)(e)
[83] Mich. Comp. Laws § 560.115
[84] An example covenant is shown in NIPC's *Access Management Handbook.* Prepared for the Eastern Will County Regional Council. 1998. Part V.
[85] An example is shown in NIPC's *Access Management Handbook.* Op. cit. Part III.
[86] Committee on Access Management. *Access Management Manual.* p. 118.
[87] Ibid., pp 101-102.

Figure 9. Arterial- (left) and Reverse-Frontage (right) Development Comparison



Source: Dan Burden, Glatting Jackson/Walkable Communities.

Limiting Lower-Order Roadway Access to Major Roads. While an interconnected grid of streets is beneficial and is a key principle of access management, some access control from this grid to major arterial streets is often beneficial for safety and traffic flow, particularly on higher-speed suburban arterial roads. Examples of such restrictions include the following:

- Right-in/right out roadway access, which eliminate left-turn and through conflicts with arterial traffic.[88]
- Simple turn or entry restrictions, sometimes by time-of-day, using signs approved in the MUTCD.[89]
- Non-traversible medians, as explained in the "pavements" section of this report, with directional openings and u-turn provisions to provide access.[90]
- An extensive collector road system.
- Replacing excessive local roadway access with cul-de-sacs, assuring continued bicycle and pedestrian access with continued sidewalks and, where appropriate, bikeways.

[88] An example is illustrated at http://www.willcountyillinois.com/Portals/0/highway/pdfs/rightinout010307.pdf

[89] Examples are illustrated at http://mutcd.fhwa.dot.gov/htm/2003r1/part6/fig6f-03-1_longdesc.htm. Source: Federal Highway Administration. Manual on Uniform Traffic Control Devices. 2003. Figure 6F-3.

[90] The *Access Management Manual* (p. 18) notes that "U-turns are generally safer than direct left turns," with a 17% lower crash rate and 27.3% lower injury-fatality rate than direct left turns" on six-lane roads. Further, for driveways, "U-turning drivers experience less delay than those making a direct left turn under high-volume conditions."

Even in dense urban and suburban areas, roadway access restrictions like those above may be beneficial and should be evaluated when excessive crashes or congestion is present. Such an evaluation was conducted along Washington Street in Oak Park by Budrick and Koperniak in the *Traffic Study for the Village of Oak Park.*[91] The village-wide traffic study identified high-crash locations from among all of the intersections in Oak Park. Countermeasures were developed for intersections with high crash rates, including intersections along Washington Avenue. An example of such a change included the installation of a right-turn-only diverter for the local street at the Washington-Wisconsin intersection, and the installation of a traffic signal at the adjacent Washington-Home intersection. This action resulted in a reduction in the 3-year counts of dangerous, right-angle "t-bone" crashes from 32 before the improvement to 5 after the improvement.[92] Total crashes at the intersection fell from 49 before the improvement to 16 crashes after the improvement; see Figure 10.

Principle 3: Promote Intersection Hierarchy

In its 2004 *Green Book,* [93] the American Association of State Highway and Transportation Officials (AASHTO) identifies hierarchies of travel movements:

- main movement,
- transition,
- distribution,
- collection, and
- terminal access.

Typically, for trips that involve high-speed, regional travel, each of these movements should match a roadway classification. While these movements between freeways and major activity centers can sometimes be accommodated with direct access (e.g., I-190 access to O'Hare International Airport), such access is the exception and is accommodated with design transitions on the access road. The *Green Book* notes that "the deletion of intermediate facilities does not eliminate the functional need for the remaining parts of the flow hierarchy or the functional design components, although it may change their physical characteristics."[94]

Thus, the *Access Management Manual* sets out the principle of avoiding intersections between "a roadway of a lower classification directly to a roadway of much higher classification."[95] Desired intersections are shown by intersecting circles on the Venn diagram in Figure 11.

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[91] Jim Budrick and Michael Koperniak. *Traffic Study for the Village of Oak Park.* 1998-2001. Prepared for the Village of Oak Park.

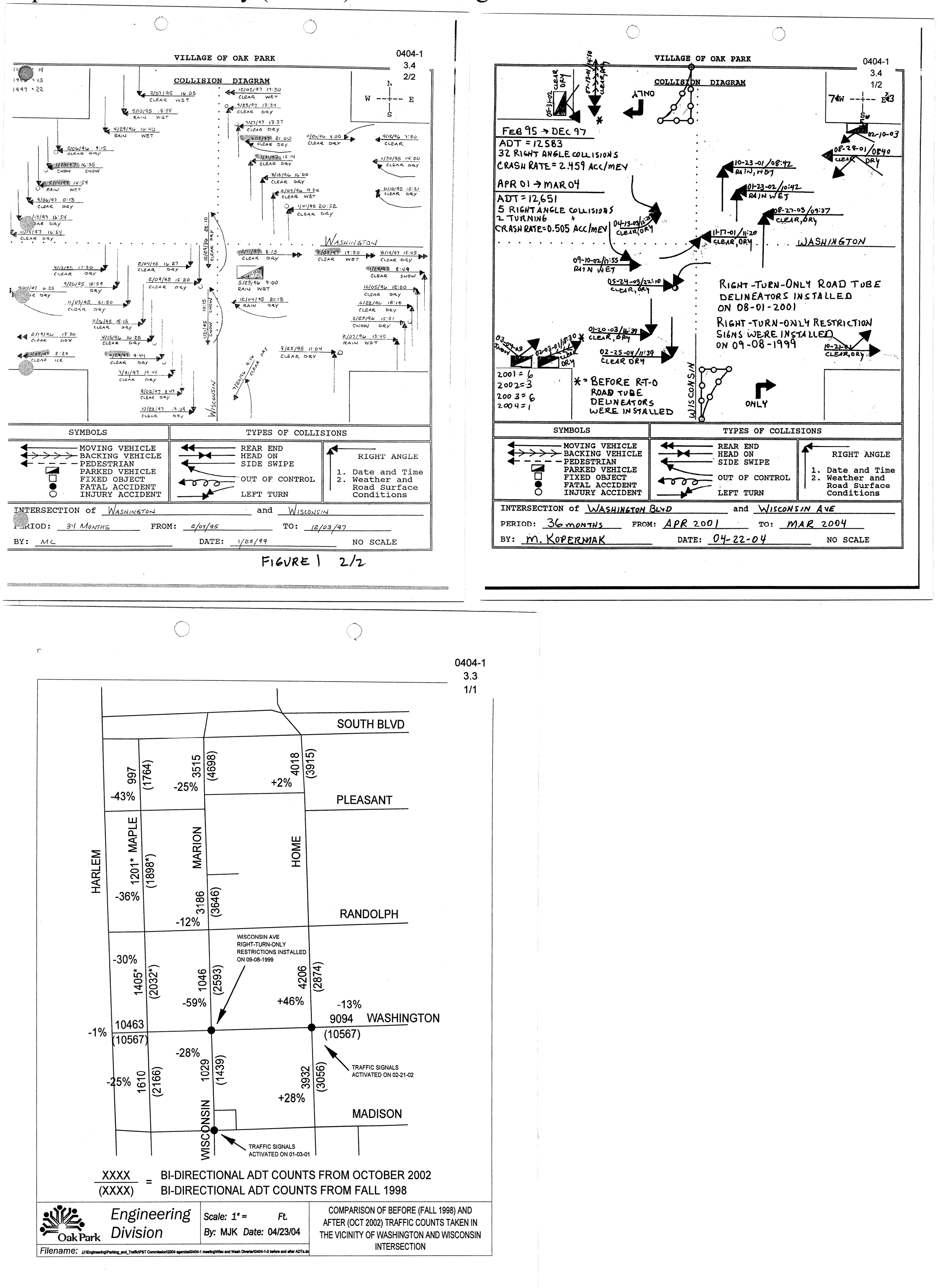
[92] Michael Koperniak. "Staff Recommendation and Background Information Regarding the Right-Turn Only Traffic Diverters on Wisconsin Avenue at Washington Boulevard." Memo to Parking and Traffic Commission, April 23, 2004. Note: despite the reduction in crashes, the memo suggested some relaxation in the restrictions. There were access concerns for a nearby business district. The Parking and Traffic Commission voted to retain the access management restrictions, a decision based on the safety record, a recommendation later upheld by the Village's Board of Trustees.

[93] AASHTO. *A Policy on Geometric Design of Highways and Streets.* 2004. p. 1

[94] Ibid., p. 2.

[95] Committee on Access Management. *Access Management Manual,* op. cit., p. 125.

Figure 10. "Before" (left) and "After" (right) 3—Year Crash Diagrams and Improvement Summary (bottom) for Washington and Wisconsin Avenues



Source: Budrick and Koperniak, Village of Oak Park. Prepared for Parking and Traffic Commission. April 27, 2004.

Figure 11. Access Relationship between Functional Classes.

The Venn Diagram at right shows the appropriate connections between roadways of given functional classifications applicable in rural, suburban and less dense urban settings.

For example, freeways should only intersect with major arterials. Major arterials should intersect only with freeways, minor arterials, and major collectors.

Notes and Caveats:
(1) Direct access between termination/parking and minor collectors is recommended only for residential development.

(2) Direct access between local streets and major collectors is also recommended only for residential development.

Site Circulation Equivalents
Appropriate equivalent site circulation needs to be included in site plan development. The *Access Management Manual* sets forth the following equivalencies:

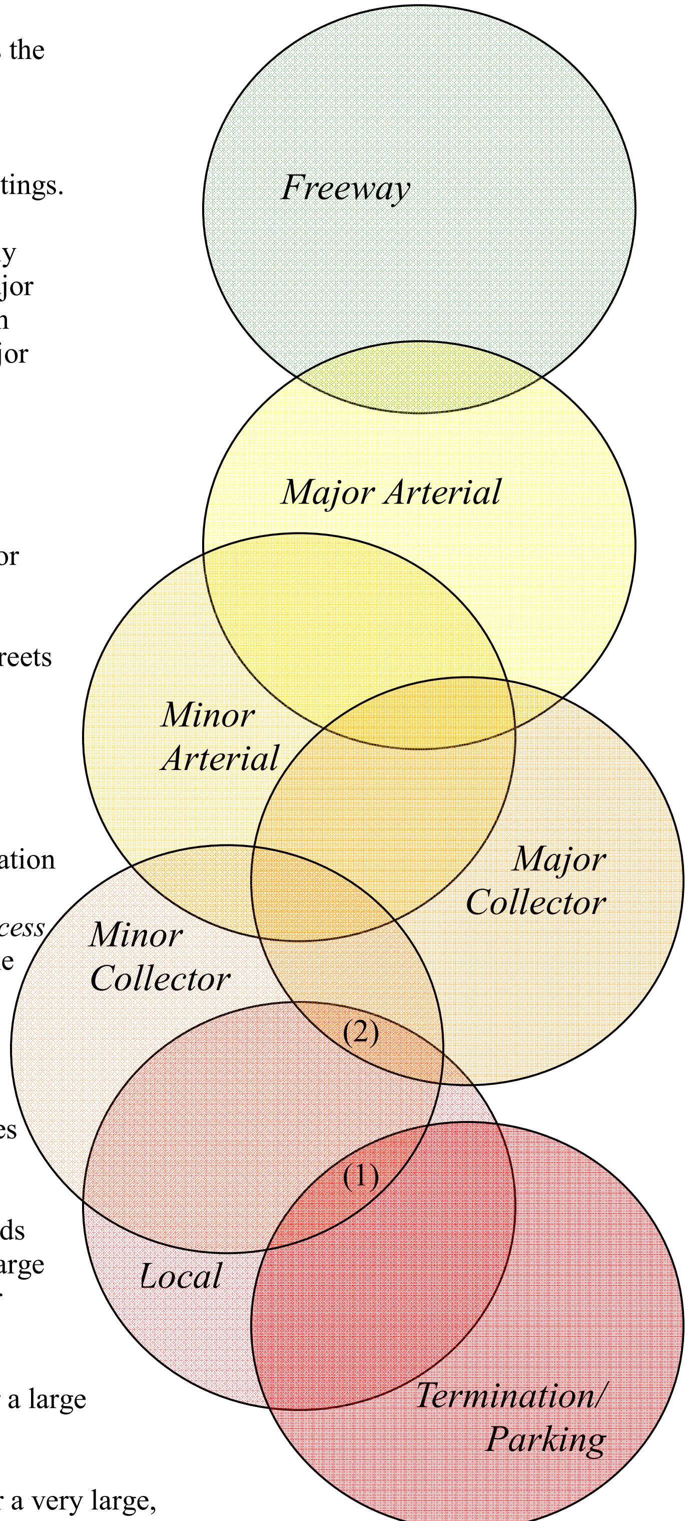
Local = aisle within parking lot.

Minor collector = circulation aisles at the end of parking rows.

Major Collector = circulation roads connecting parking areas within large developments *or* access drives for moderate-sized developments.

Minor Arterial = Access drive for a large development.

Major Arterial = Access drive for a very large, mixed use development or a regional shopping center.



Source: Based on Figure 8-3, *Access Management Manual*

Principle 4: Locate Signals to Favor Through Movements

Traffic signals account for most motorist delay.[96] Gluck, Levinson, and Stover note that signals constrain capacity, cause queues and spillback to upstream intersections. These performance problems are magnified when signals are "randomly located, ineffectively coordinated, or improperly timed. Closely and/or irregularly spaced signals can reduce arterial travel speeds thereby resulting in an excessive number of stops even under moderate traffic volume conditions."[97] A key access management technique is to space signals to reduce intersection delay, to improve platoon progression.[98]

For central business districts, closely-spaced signals are appropriate. For closely spaced intersections with balanced flows, the optimal signal timing plan is simultaneous coordination (signal cycle offsets = 0). With simultaneous coordination, the issue becomes cycle length and signal splits.[99] However, for most suburban and rural arterial segments, this is not the case and the emphasis is on platoon progression with access conflicts controlled to facilitate the progression.

Gluck, Levinson and Stover note that the following formulas, based on the dynamics of vehicle motion, show the long-established relationships between speed (V, in miles per hour), signal cycle length (C, in seconds), and signal spacing (S, in feet):[100]

$V = \frac{0.681S}{C}$ for simultaneous signals (e.g., the Chicago CBD signal system).

$V = \frac{1.362S}{C}$ for alternating signals (where cycles are offset for progressive flow).

They then invert the formula to derive a table showing optimum signal spacing as a function of desired speed and cycle length. This is shown below as Table 4. The authors then provide the following summaries of the impacts:

- *Spacings that are less than 1/4 mi (about 400 m)—i.e., more than four signals per mile—result in progressive speeds that are too low for urban conditions (except perhaps for central business districts).*

- *Signals spaced at about 1/4 mi (about 400 m) can provide progressive speeds from 26 to 30 mph at cycle lengths from 60 to 70 sec. These speeds and cycle lengths are acceptable in cities where traffic volumes are spread over several streets, where two-phase signal operations dominate, and posted speeds are 35 mph or less.*

- *Longer signal spacings are necessary along many suburban highways where both traffic volumes and speeds increase. Longer cycle lengths are commonly used to increase capacity and provide*

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96 Gluck, Levinson, and Stover. Op. cit., p. 22.
97 Ibid.
98 Improper signal spacing may also be a factor in traffic crashes. There are strategies to improve the safety of highway traffic signals, discussed separately in the intersection operations section of this strategy paper.
99 Gordon Newell, *Theory of Highway Traffic Signals* University of California at Berkeley Institute of Transportation Studies. Course Notes UCB-ITS-CN-89-1. June, 1989, p. 370
100 Gluck, Levinson and Stover, Op. cit., p. 24.

protected phases for left turns. Cycle lengths of 80 to 120 sec are common, especially during peak periods and require 1/2-mile signal spacings (about 800 m)—i.e., two signals per mile—to maintain progressive speeds of up to 45 mph.

- *Cycle lengths that exceed 120 sec result in progressive speeds less than 25 mph even with 1/2-mi spacings between signals and, therefore, should be avoided. Moreover, when green times exceed 50 sec, there is about a 10 percent decline in saturation flows because some drivers become less attentive and do not start moving immediately after the preceding vehicle.*[101]

Table 4. Optimum Signal Spacing as a Function of Speed and Cycle Length, for Alternating Signals/Progressive Flow

Cycle Length (seconds)	Speed (mph)						
	25	30	35	40	45	50	55
	Signal Spacing (feet)						
60	1,100	1,320	1,540	1,760	1,980	2,200	2,420
70	1,280	1,540	1,800	2,060	2,310	2,590	2,830
80	1,470	1,760	2,060	2,350	2,640	2,940	3,230
90	1,650	1,980	2,310	2,640	2,970	3,300	3,630
100	1,840	2,200	2,570	2,940	3,300	3,670	4,040
110	2,020	2,420	2,830	3,230	3,630	4,040	4,440
120	2,200	2,640	3,080	3,520	3,960	4,400	4,840

Source: Gluck, Levinson, and Stover. *Impacts of Access Management Techniques.* National Cooperative Highway Research Program Report 420. National Academy Press. 1999. Table 20, p. 24

Primary among the planning implications of these findings include the importance of long, uniform traffic signal spacing to facilitate bi-directional progression on arterial roads outside central business districts. In addition, the authors call for arterial through-movement green time to be maximized, either through prohibiting/redirecting left turns or by providing left-turn lanes and signal phases (with adjustments in cycle length to assure sufficient through-movement green time).[102,103]

Gluck, Levinson and Stover also note that intersection capacity is important in addressing travel demand.[104] Indeed, in metropolitan Chicago, many intersections are oversaturated in the peak period, making progression a moot issue during rush hour, so highway agencies often add intersection capacity to reduce oversaturated conditions and facilitate progression. However, because of the high level of pedestrian activity in metropolitan Chicago, such a solution may backfire. Since pedestrians are typically allocated 4 feet per second to cross the street (soon expected to be 3.5 seconds), providing more intersection capacity will require additional green time per pedestrian signal (sometimes on minor movements), and will thus require increased cycle lengths; these increased cycle lengths will result in lower progressive speeds. Engineers and planners will need to carefully weigh the tradeoff between potential peak-period oversaturated compact

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[101] Gluck, Levinson, and Stover, op. cit., pp 24-25.
[102] Ibid., p. 26
[103] Specific strategies to increase through movement green time are being addressed in the intersection operations strategy paper.
[104] Gluck, Levinson, and Stover, op. cit., p. 26

intersections and lower overall progressive travel speeds that may come from adding intersection capacity.[105]

Planning issues arising from signal location also include, lastly, tradeoffs in delay from one approach to another and one intersection to another. A signal established at the wrong location in a progressive signal system will typically require a trade-off between minor street green time and major street, through-movement green time to facilitate adequate progression bandwidth.[106] The result can be the inadequate green time seen on suburban streets in our metropolitan area at major arterial intersections. Alternatively, progression bandwidth may be adjusted by making changes upstream and downstream. Again, the result may be inadequate green time and travel delay.

Illustration of Impact of Signal Location on Platoon Progression. Some of these issues are displayed graphically in Figure 12. Figure 12 shows an arterial corridor with two existing signal locations (❶ and ❷ in Figure 12). Ideal, bi-directional progression is shown as gray bands following black vectors proceeding through the corridor over time. The placement of signals ❶ and ❷ allow for their signal timing plans to facilitate platooned vehicle progression with green phases, while allowing minor street traffic movements during gaps in the platoons (major street signal indications are illustrated with alternating red and green bands).

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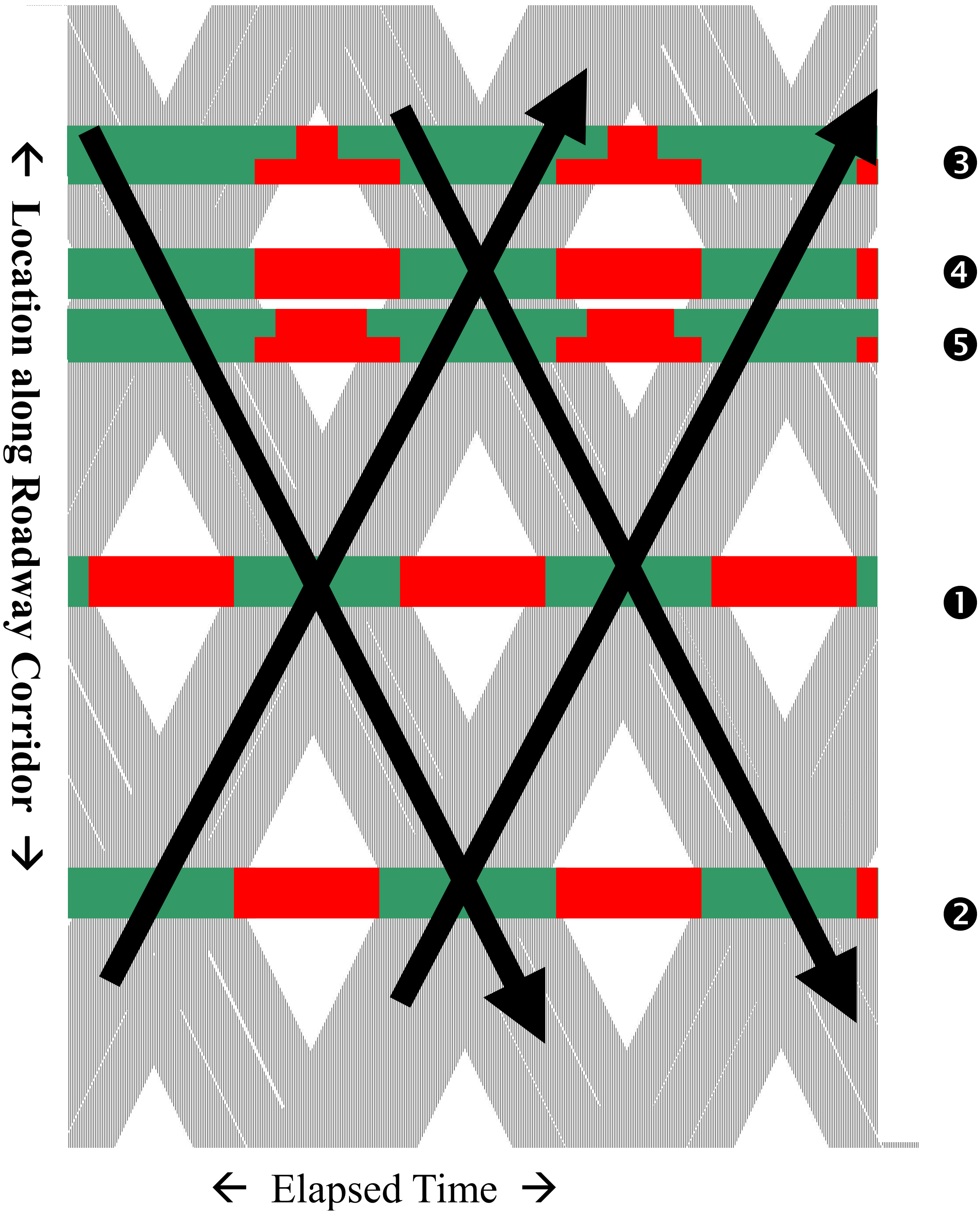
[105] For a discussion of pedestrian walking speeds, see LaPlante and Kaeser, *A History of Pedestrian Signal Walking Speed Assumptions.* Paper presented at 3rd Urban Street Symposium, June 24-27, Seattle. Posted at http://www.urbanstreet.info/3rd_symp_proceedings/A%20History%20of%20Pedestrian.pdf accessed November, 2008.
The current approved *Manual on Uniform Traffic Control Devices* (Federal Highway Administration, 2003, p. 4E-9, http://mutcd.fhwa.dot.gov/pdfs/2003r1r2/mutcd2003r1r2complet.pdf) governs the cycle times to be set aside for pedestrian crossings. The current manual provides guidance that "pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait." The proposed revision to the manual reduces the walking speed and makes the cross-section more challenging, that is, "the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.1 m (3.5 ft) per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.… The total of the walk interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 1.8 m (6 ft) from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 0.9 m (3 ft) per second to the far side of the traveled way being crossed." (FHWA, *2007 Notice of Proposed Amendments for the Manual on Uniform Traffic Control Devices,* p. 322. Posted at http://mutcd.fhwa.dot.gov/resources/proposed_amend/npa_text.pdf, accessed November, 2008).
The effects of adding intersection capacity on pedestrians is widely discussed, and is noted frequently in IDOT's Bureau of Design and Environment Manual (see, for example, Chapter 36, *Intersections,* http://www.dot.il.gov/desenv/BDE%20Manual/BDE/pdf/chap36.pdf). However, the negative feedback to signal operations is less frequently addressed in the available policy guidance.
One operational strategy sometimes implemented in the field for locations that do no have a large number of pedestrians is to "pre-empt" the signal timing plan and associated platoon progression to accommodate the pedestrian crossing, as many signalized intersections do for emergency vehicles. Of course, this has substantial disadvantages from an efficiency perspective.
[106] Gluck, Levinson, and Stover, op. cit., p. 26.

Figure 12. Idealized Time-Space Diagram of Arterial Corridor Illustrating Effects of Signal Placement on Platooned Traffic Progression



Source: Adapted from Stover and Koepke, *Transportation and Land Development.* ITE, 1988. Figure 4-23

An additional signal is being considered at locations ❸ ❹, ***or*** ❺. The diagram shows that a signal at location ❸ or ❺ will result in one of two undesirable signal timing options. At locations ❸ and ❺, in the case of a signal without a pedestrian crossing, accommodating the bidirectional platoons will require that an unnecessarily long portion of the green-time will need to be allocated to the major arterial (this is shown by the top alternating red and green bands showing signal indications at these locations). In this case at these locations, the green time for the minor street will be very short (and the red time for the major street, illustrated by the very short red bands for ❸ and ❺, will be correspondingly short).

If a pedestrian signal is required at proposed signal locations ❸ and ❺, the red signal phases for the major street will need to be lengthened to accommodate the pedestrian crossing (the bottom alternating red and green bands at these locations). In this case, the minor street receives sufficient green time, but the major street's platooned progression is significantly disrupted by the new signals – red signal indications straddle the gray progression bands, blocking flow and causing unnecessary delay. ***Thus, placing a signal at either location ❸ or ❺ in Figure 12 will result in suboptimal timing plans.*** Repeated cries that "we need better signal timing at this location!," as so often heard in our region, cannot be fully realized with such signal placement as ❸ or ❺. If signals are placed at these locations, travelers will be stuck with unnecessary delay.

If, instead, the proposed location new signal is placed at location ❹, both of the bidirectional platoon flows are accommodated, the minor street receives sufficient green time, and the red signal indication on the major street is sufficient to allow pedestrian crossings. ***Thus, placing a signal at location❹ in Figure 12 will result in an optimal signal timing plan.***

Figure 12, admittedly idealized, illustrates that a new signal location (or the location of a new arterial access point that may later require signalization) requires substantial study to assure minimum delay and maximum efficiency. Also note that, in some circumstances, such study will find that any new signal, no matter where it is placed, will result in new unacceptable delay, requiring the investigation of alternatives to signalization.

Summary. Traffic signals cause traffic delay. Travel times for corridors with three signals per mile will be, on average, nine percent greater than two signals per mile. For five signals per mile, travel times are 23% higher than two signals per mile; for 8 signals per mile, travel times are 39% higher than two signals per mile.

Significant variation is possible in these factors. If additional signals are required, delay can be minimized by careful placement of the signals to optimize through traffic movements.

Principle 5: Preserve the functional areas of intersections & interchanges.

Freeway access along an arterial can be expected to attract highway-oriented uses (gas stations, fast-food restaurants, motels), or even higher density residential, office, and commercial development.[107] These developments will require careful access

[107] Committee on Access Management. *Access Management Manual,* op. cit., p. 113.

management in order to maintain traffic flow not only on the arterial, but the freeway as well. As noted in the *Access Management Manual,*

> Research has shown that signalized intersections too close to interchange ramps can cause heavy volumes of weaving traffic, complex traffic signal operations, and traffic backing up the ramps onto the main line. Curb cuts and median openings near the interchange ramps further compound these problems.[108]

Guidelines have recently been developed for access spacing at interchanges. A summary of Oregon guidelines, as fully developed and clarified in the *Access Management Manual,* is below. The engineering work used to develop these guidelines is available in a paper by Layton.[109] The guidelines consider many factors in determining the minimum access spacing, including merging distances, weaving distances, transition distances, perception/reaction distances, and left-turn storage/queue distances. Application of these guidelines to land development, with minor modifications and detailed case studies, is also available in a Florida guide prepared by Land and Williams.[110] The guidelines are summarized in Table 5.

Layton also recommended several related transportation and access management strategies in interchange areas. These include:

- ***Traffic controls,*** including signal phasing modifications, intersection channelization, and turn restrictions, all to reduce the likelihood of ramp queue or congestion spillback onto the mainline freeway. Ramp queue detection with traffic signal feedback and traffic signal interconnection will also help prevent backups onto the freeway mainline. Likewise, ramp meters for the freeway entrance ramps are an access management technique whose function is to prevent ramp terminal signal platoons from causing a breakdown in freeway traffic flow as the ramp traffic merges onto the mainline.[111]
- ***Circulation/Distribution and Local Roads System,*** to provide access to land uses in the interchange area with a minimal impact on the freeway or arterial. Access between and among these land uses, and to adjacent land uses, should be provided without needing to travel on the arterial roadway. This system should provide arterial access subject to the spacing controls in Table 5, as already discussed.[112] Furthermore, at arterial intersections, signal phasing priority should be given to the arterial roadway within one-half mile of the freeway interchange.

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[108] Ibid.

[109] Robert Layton. *Background Paper #2: Interchange Access Management.* Oregon State University Department of Civil, Construction, and Environmental Engineering. Prepared for Oregon Department of Transportation. August 1996. Available at http://www.oregon.gov/ODOT/HWY/ACCESSMGT/docs/IntAccMgmt.pdf Accessed November, 2008.

[110] Laurel Land and Kristine Williams. *Land Development and Access Management Strategies for Florida Interchange Areas.* Center for Urban Transportation Research, University of South Florida. Prepared in Cooperation with the State of Florida Department of Transportation. March, 2000. Available at http://www.accessmanagement.info/pdf/interchange.pdf. Accessed November, 2008.

[111] Layton, op. cit., pp. 2-3.

[112] Layton, op. cit., pp. 3-4.

Table 5. Oregon Minimum Arterial Highway Spacing Standards for Freeway Interchange Areas

Spacing Dimension	Fully Developed Urban (35 mph – See Note)		Suburban (45 mph)		Rural (55 mph)	
	2-Lane	4-Lane with Median	2-Lane	4-Lane with Median	2-Lane	4-Lane with Median
Spacing from Ramp Terminal to First Drive/Access on the Right (Right-in/Right-out Only) (Minimum)	750 feet	750 feet	990 feet	990 feet	1,320 feet	1,320 feet
Spacing between Ramp Terminal and Nearest Major Intersection (First 4-Legged Intersection) (Minimum)	1,320 feet	2,640 feet	1,320 feet	2,640 feet	1320 feet	2,640 feet
Spacing to First Median Opening from Off-Ramp Terminal – Access to First Drive on Left (Minimum)	N.A.	990 feet	N.A.	1,320 feet	N.A.	1,320 feet
Spacing between Last Access Drive and the Start of Taper for On-Ramp Terminal (Minimum)	750 feet	990 feet	990 feet	1,320 feet	1,320 feet	1,320 feet

Note: "Free-flow ramps are generally discouraged in fully developed urban areas and are questionable in suburban/urban areas because pedestrian and bicycle movements are difficult and potentially dangerous." Table Source: Committee on Access Management, *Access Management Manual.* Op cit., p. 161. See also Layton, op cit.

- Where appropriate, consider additional ***grade-separated roadway crossings*** of the freeway or the intersecting arterials. Such crossings will improve the likelihood of an acceptable level of service at the freeway interchange and adjacent intersections by diverting traffic away from the arterial interchange and adjacent intersections. According to Layton, grade-separated crossings help to "provide crossing corridors that relieve traffic demand on crossings at interchanges."[113] Such crossings can also facilitate walking and cycling trips where they otherwise may not be feasible.
- ***Land Use Controls*** consistent with the interchange access management strategy.[114]
- ***Balance interchange design with ultimate mainline facility.***[115]
- ***Protective buying and sale of excess property.***[116]

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[113] Layton, op. cit., p. 4.
[114] Ibid.
[115] Ibid.
[116] Ibid.

- ***Closure of Interchange or Ramps.*** Substandard interchanges cause substantial delay and may cause excessive numbers of traffic crashes. These interchanges may have substandard on ramp merges, improper arterial intersection spacing, improper freeway interchange spacing, or arterial delay resulting in ramp spillback onto the freeway mainline. Such interchanges or ramps may be closed.[117]
- ***Frontage Road Relocation or Closure.*** Where existing frontage roads do not meet spacing criteria, and where this is causing excessive delay or crashes, closing or relocating frontage roads, and providing alternative access, should be considered.[118]

Taken together, these actions will assure that freeway-arterial interchanges do not remain the focus of highway travel delay and crashes.

Interchange area access management plans are one suggested implementation method for interchange access management.[119] According to Land and Williams, such plans

> "…target a specialized area and take a comprehensive approach. Like a corridor plan, an interchange area plan is linked to the roadways and should concentrate on the interrelationship of land use and access. Because an interchange area shapes the perception of a community, an interchange area access management plan gives clear direction for development, provides organizational structure, and is the basis for achieving a positive, welcome perception of the community. A good plan will also prevent situations from occurring that will limit economic benefits to the community.
>
> … Elements that need to be evaluated to assure future access management include, but are not limited to:
>
> - Site plans (encourage unified development such as shared signage, driveways, and parking);
> - Signage (control of billboards and advertisements);
> - Highway and traffic (road function, access to adjacent land, evaluation of traffic generation versus benefits such as employment generation);
> - Access control (minimizes conflict);
> - Street system (internal, frontage, backage, local, and crossroads);
> - Setbacks (safety, future construction, aesthetics);
> - Corner clearance;
> - Loading on premises (for pickup, delivery, service, and emergency vehicles);
> - Consolidated signage;
> - Pedestrian circulation.
>
> It will also be necessary to assess existing conditions, such as:

[117] Ibid., p. 6.
[118] Ibid., pp. 5-6
[119] Land and Williams, op. cit., pp. 6- 7.

- Property ownership and land divisions;
- Lot frontage;
- Access points;
- Transportation characteristics.[120]

Subdivision and zoning regulations can be employed to implement interchange area access management plans. Specific zoning applications may include an overlay district ("interchange overlay district"); specialized districts, as "interchange zoning districts;" planned unit developments; and special or conditional use permits.[121] Land and Williams also suggest that "developments of regional impact" (DRI) processes can also provide an "opportunity to require a thorough assessment of site impacts and developer mitigation;" which, in Florida's case, such mitigation may be established as a condition of approval.[122]

Principle 6: Limit the Number of Conflict Points; And Principle 7: Separate Conflict Areas.

The *Access Management Manual* says "traffic conflicts occur when the paths of vehicles intersect and may involve merging, diverging, stopping, weaving, or crossing movements."[123] Limiting the number of conflict points reduces driving complexity, reduces driver error, and reduces the number of crashes.[124] Separating conflict areas allows drivers to have "sufficient time to address one set of potential conflicts before facing another."[125]

High-volume, high-speed roadways should be a focus of efforts to reduce and separate conflict points, since the effects of driver error on such facilities are much greater than would be the case on lower-speed, lower-volume facilities. The *Access Management Manual* states that "the necessary spacing between conflict areas increases as travel speed increases, to provide drivers adequate perception and reaction time."[126]

Specific strategies to control conflict points include **medians** and **driveway controls**, both discussed earlier, and **intersection design**, discussed in detail later in a separate section. Note here, however, that a typical four-way intersection has 32 vehicle-vehicle conflicts, plus 24 vehicle-pedestrian conflicts, as shown in Figure 13. Many innovative intersections discussed later are designed primarily to reduce the number of conflict points. Here, we concentrate on the relationships among various highway access elements to reduce conflicts and control their spacing.

An "intersection functional area" is an important concept in defining conflict points and conflict areas for arterial highways. Access should be managed to limit conflicts in intersection functional areas.

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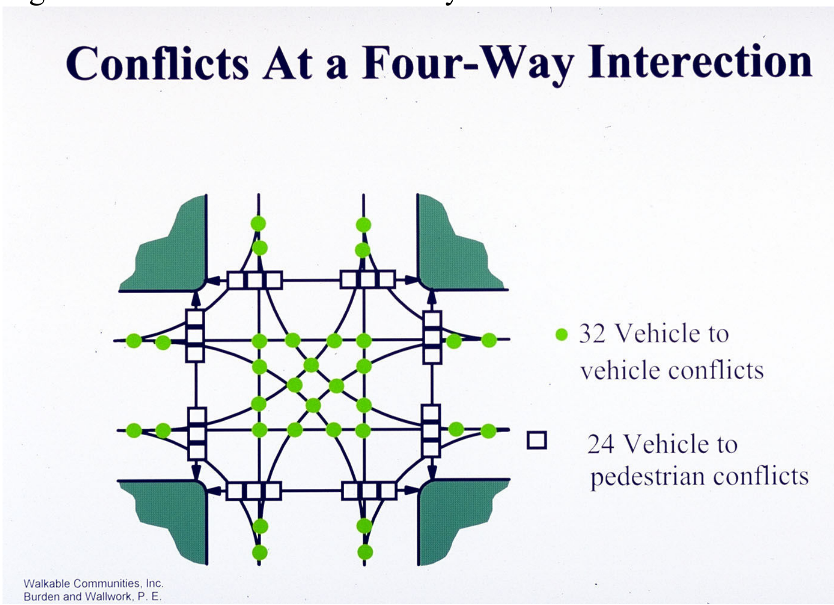
[120] Ibid.
[121] Ibid., p. 8
[122] Ibid.
[123] Committee of Access Management. *Access Management Manual.* Op. cit., p. 8.
[124] Ibid.
[125] Ibid.
[126] Ibid.

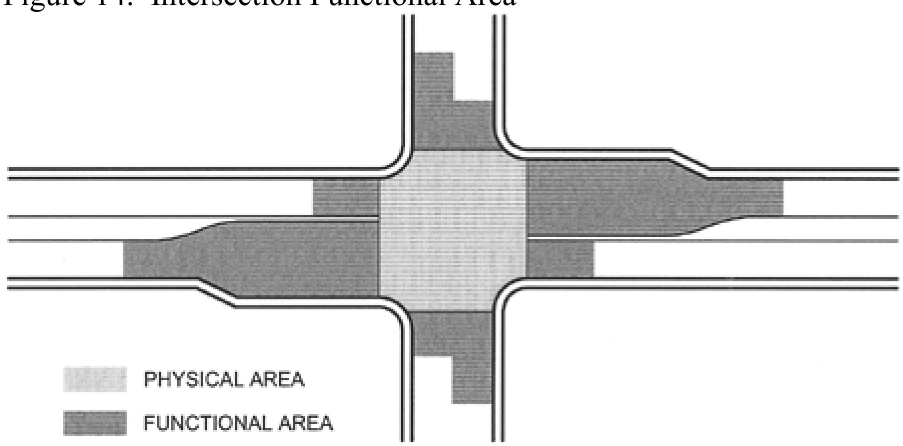
Figure 13. Conflicts at a Four-Way Intersection.



Source: Dan Burden, Glatting Jackson/Walkable Communities.

Managing Access in Intersection Functional Areas. Intersection functional areas are defined to include areas upstream and downstream of the physical area of an intersection. Moving upstream from an intersection, the functional area includes the queue storage for the intersection, the deceleration distance for stop maneuvers, and the distance required for the perception/reaction time for the intersection approach. The functional area downstream of an intersection is the distance sufficient so a driver may clear the intersection before needing to react to downstream traffic events.[127] See Figure 14.

Figure 14. Intersection Functional Area



Source: Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.*

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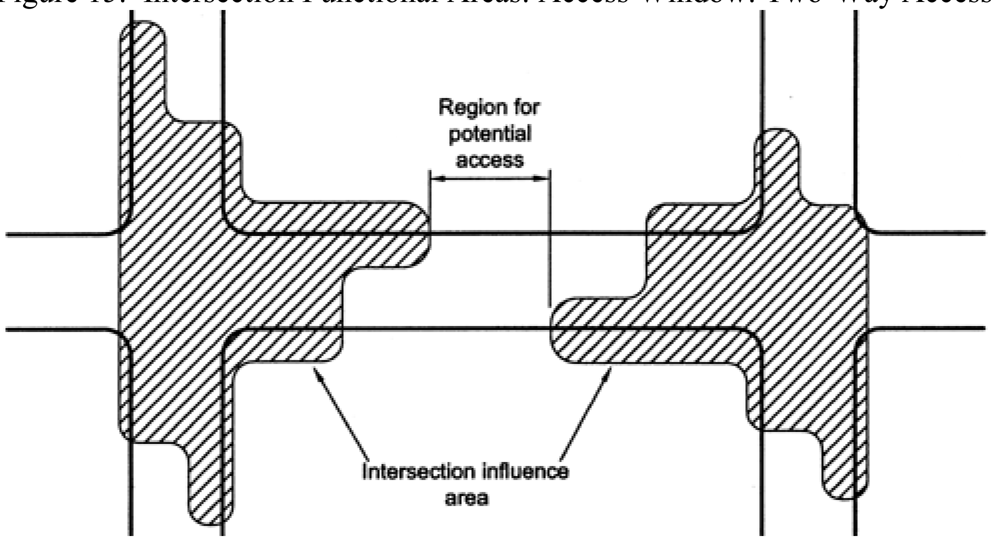
[127] Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.* Federal Highway Administration. Prepared for the Federal Highway Administration. 2004. Based on earlier versions in the *Access Management Manual* and Florida Department of Transportation Procedures. Posted at http://www.tfhrc.gov/safety/pubs/04091/04091.pdf. Accessed November, 2008.

A key strategy for access management is to separate conflict points and conflict areas from intersection functional areas, where appropriate. For example, AASHTO's *Policy on Geometric Design of Highways and Streets* states "driveways should not be located witin the functional area of an intersection or in the influence area of another driveway."[128] *Signalized Intersections: Informational Guide* and the *Access Management Manual* both graphically demonstrate the windows of opportunity for access between intersection functional areas.[129] Figure 15 shows an access window between intersections with sufficient separation to allow two-way access.

Figure 15. Intersection Functional Areas: Access Window: Two-Way Access.



Source: Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.*

Figure 16 shows the two intersections with overlapping functional areas. A much more limited access window is available. To separate traffic conflict areas in such a situation, consider limiting access to right-in/right-out access in the area indicated. Any traffic crossing the highway centerline from a new access point will encroach on one of the two intersection functional areas.

Figure 17 shows the two intersections with further overlapping functional areas. In Figure 17, there is no access window between the two intersections. Determining appropriate access in the cases of Figures 16 and 17 requires careful analysis. Often, alternative access from adjacent collector or local streets is possible. Frontage, backage, and service roads are also alternatives, with sufficient planning, and due care to separate conflict areas for such access roads.[130] Another alternative is land assembly and redevelopment, to include merging contiguous parcels and off-street loading and parking (perhaps *off-site* parking). However, short street spacings or small parcels may require that driveway access be permitted, despite the negative safety and congestion impacts.[131]

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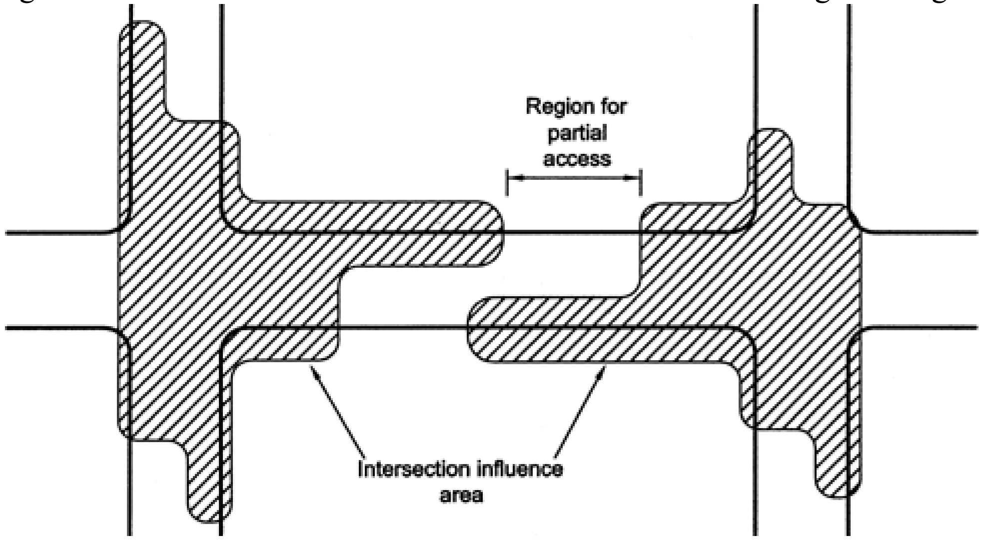
[128] AASHTO, op. cit., p. 729.

[129] Committee on Access Management, *Access Management Manual,* op. cit., pp. 133-135. Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide,* op. cit., p. 175.

[130] Committee on Access Management, *Access Management Manual,* op. cit., pp. 189-191.

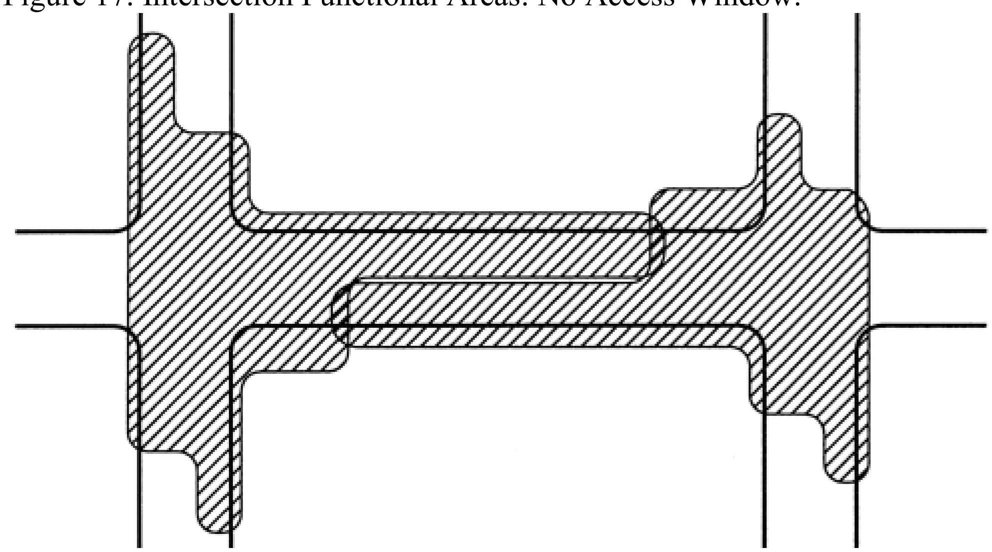
[131] Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide,* op. cit., p. 173.

Figure 16. Intersectional Functional Areas: Access Window: Right-In/Right-Out Access.



Source: Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.*

Figure 17. Intersection Functional Areas: No Access Window.



Source: Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.*

The *Signalized Intersections: Informational Guide* cautions about the importance of analysis of situations like those above. Downstream system effects need special consideration, since "solving" a problem in one location may create a much worse problem elsewhere. In addition, the *Guide* states that "as a general guideline, the functional area of an intersection is more critical along corridors with high speeds (45 mph or greater) and whose primary purpose is mobility.[132]

The *Access Management Manual* addresses further non-signalized access spacing guidelines based on safety, stopping sight distance, intersection sight distance, functional

[132] Ibid.

areas, right-turn conflict overlaps, driveway influence distance, and egress capacity.[133] The *Manual* also suggests the following strategies to retrofit existing deficiencies in access spacing:

- *Install a median barrier in high crash locations* [discussed previously].
- *Work with property owners to obtain permission for driveway closure, reconstruction of substandard driveways, or relocation during roadway resurfacing or improvement.*
- *Encourage property owners to allow reconstruction or consolidation of driveway access during sidewalk maintenance, reconstruction, or additions.*
- *Adopt an access management policy that addresses the need for improvement of access and inter-parcel connections during redevelopment or expansion of an existing use.*
- *Strategically purchase vacant or abandoned properties and resell them with access restrictions….*
- *Place planter boxes along unlimited access points to better define driveways.*
- *Require consolidation of access where adjacent parcels come under common ownership.*
- *Redesign internal road and parking systems.*
- *Eliminate closely spaced or jogged intersections.*[134]

Principle 8: Remove Turning Vehicles from Through-Traffic Lanes.

Removing turning vehicles from traffic lanes is important because people slow down to make such turns. In slowing down, a conflict is created with following vehicles. The greater the speed differential between turning vehicles and through movement, the greater the crash involvement for such turning movements. Turning movements tend to be made at low speeds, with very low speeds for turns into driveways. While geometric characteristics of driveways have some effect on the speed of the turning movement (important for pedestrian safety), this speed change is insignificant in relationship to the speed differential for most suburban arterial roads. Therefore, the *Access Management Manual* concludes that "auxiliary left-turn and right-turn lanes (bays) are the most effective means of reducing the speed differential between turning vehicles and other traffic on major roadways."[135]

The installation of bays for turning movements is widespread in metropolitan Chicago, and can still be increased. As a corollary for focusing conflict area improvements on higher-speed arterials, channelization is likewise most important on such roads.

Specific strategies for providing auxiliary turn lanes include two-way left turn lanes and medians with appropriate openings, as discussed on pages 10-14. Other strategies include right-turn bays and turning roadways. For right-turn lanes, the best study available showed that installation of a single right-turn lane on a major-road approach

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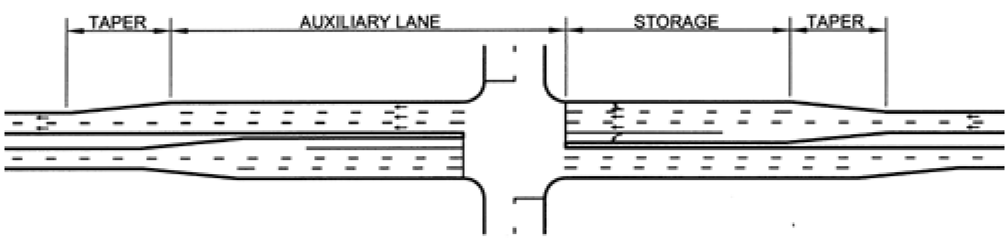
[133] Committee on Access Management. *Access Management Manual*. Op. cit., pp 149-155.
[134] Ibid., p. 92.
[135] Ibid. p. 170. The *Manual* reviews the impacts of the geometry of driveways, and concludes that increasing the driveway throat width from 20' to 35' raises the turning speed only 1.5 mph. Increasing the curb return radius from 0' to 30' increases turning speed 3mph. For pedestrian operations, this is significant, but not significant compared to a 45mph operating speed on a suburban arterial. Thus, the *Manual* makes a strong call for the use of auxiliary lanes.

reduced total crashes at urban signalized intersections by four percent and at rural unsignalized intersections by 14 percent.[136] Separating right turns from through-movements may also increase capacity, dependent on the inter-relationship of the curb return radius, pedestrian volumes, and pedestrian crossing distances.

Auxiliary Through Lanes. Often, in the urban parts of the metropolitan Chicago, "auxiliary through lanes" are implemented at signalized intersections, providing a short, shared lane for through and right-turn movements. See Figure 18. Downstream of the intersection, through movements must merge to the left. While these lanes allow through vehicles to merge effectively as they accelerate downstream from a stop condition at the signal, auxiliary through lanes may also be used by aggressive drivers to jump a queue in a saturated condition, which may increase intersection delay and crashes. Detailed operational and safety information for such lanes is not available, but a formal evaluation of these lanes is forthcoming.[137] However, in the interim, high-crash locations with such lanes may be evaluated, examining each crash record, to determine whether such lanes should be replaced with right-turn-only lanes.

Figure 18. Auxiliary Through Lanes (Not Recommended at this Time)



Source: Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide.*

Right-Turn Channelization/Turning Roadways. Another method to separate turning vehicles from through traffic is with turning roadways, channelizing right turns away from through-lanes with a "pork chop" island. A typical application is shown in Figure 19. The limited research is available on such turning roads raises questions; indeed, the research shows that right-turn channelization with turning roadways may, in fact, *increase crash rates* for urban and rural, signalized and unsignalized intersections.[138]

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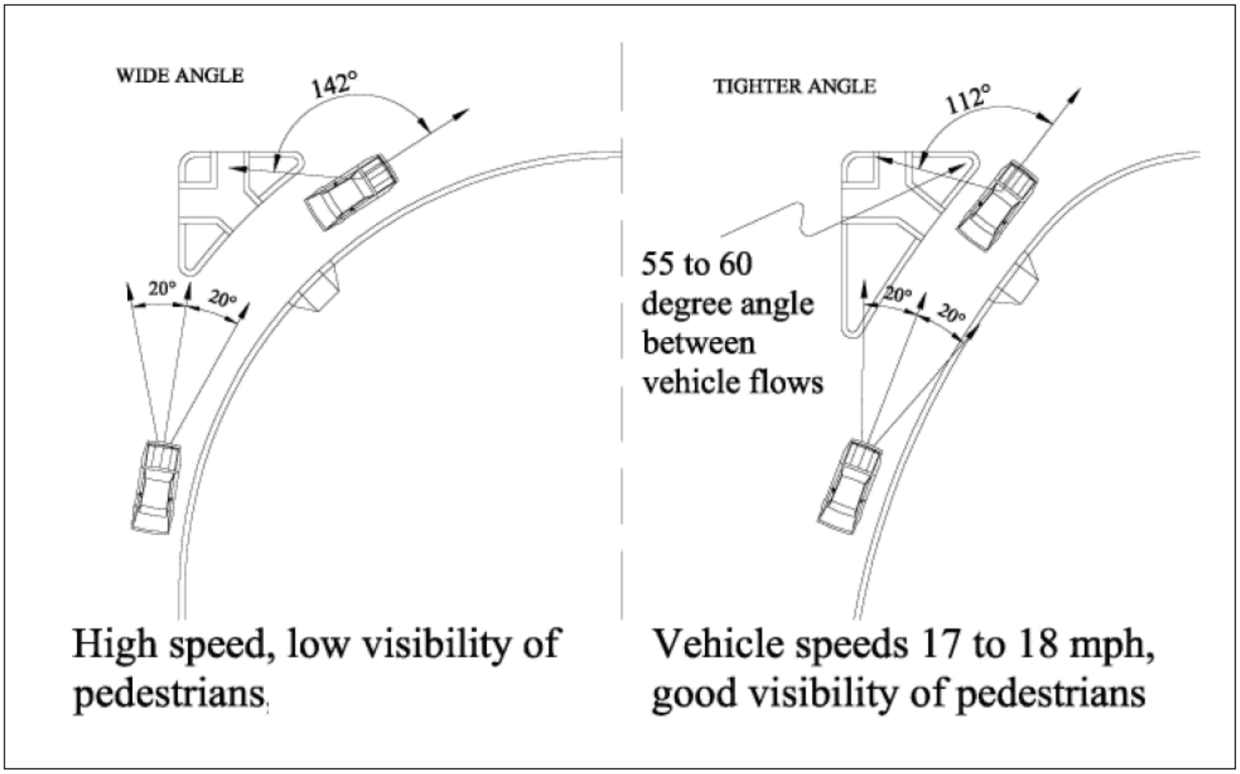
[136] Harwood and Bauer, et al. *Methodology to Predict the Safety Performance of Urban and Suburban Arterials.* Op. cit., p. 33. Referenced study is Harwood and Bauer et al. (2) *Safety Effectiveness of Intersection Left- and Right-Turn Lanes*, Federal Highway Administration, Report No. FHWA-RD-02-089, July 2002. Posted at http://www.tfhrc.gov/safety/pubs/02089/02089.pdf. Accessed November, 2008.

[137] NCHRP 03-98 [Pending] Guidelines on the Use of Auxiliary Through Lanes at Signalized Intersections http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=2492 Accessed November, 2008. Limited information about such lanes is available in section 12.2.1 of Lee A. Rodegerdts, et al. *Signalized Intersections: Informational Guide,* op. cit.

[138] Harwood and Bauer et al. (2) *Safety Effectiveness of Intersection Left- and Right-Turn Lanes*, Federal Highway Administration, Report No. FHWA-RD-02-089, July 2002. Page A-8. Posted at http://www.tfhrc.gov/safety/pubs/02089/02089.pdf. Accessed November, 2008. Referenced model (revised) is at Harwood and Bauer (3), *Statistical Models of At-Grade Intersection Accidents – Addendum*. Prepared under Auspices of Midwest Research Institute for Federal Highway Administration. See pp. 27,

Figure 19. Right-Turn Channelization: Old (*Left*) and New (*Right*) Designs



Source: Michael Ronkin and Fred Ranck. "Designing Streets for Pedestrian Safety." Presentation, June 2006. Chicago, Illinois, Chicago Metropolitan Agency for Planning. Sponsored by Federal Highway Administration.

Typical designs for turning roadways, shown on the left in Figure 19, have been criticized and may cause the unexpected higher crash rates. Like auxiliary through lanes, right-turn channelization is still being researched.[139] Newer designs, like those on the right above, and included in *Signalized Intersections: Informational Guide,*[140] generally address criticisms by putting pedestrian crossings in the normal range of vision of most approaching motorists, controlling the operating speed of turning vehicles, and providing a better angle for turning traffic to see cross-traffic (112 degrees instead of 142 degrees). These new designs are worth evaluating to safely separate conflicting traffic movements. In addition, well-designed "pork chop" islands are pedestrian refuges, reducing pedestrian crossing distances and crossing times, and reducing traffic delay.

Principle 9. Use Nontraversable Medians to Manage Left-Turn Movements

This topic was covered in detail on pp 10-14.

39, and 45, as well as the discussion of applicability on pp 51-52. Posted at http://www.tfhrc.gov/safety/99-094.pdf. Accessed November, 2008.

[139] NCHRP Project 03-89. "Design Guidance for Channelized Right-Turn Lanes. http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1609 Accessed November, 2008.

[140] Op. Cit., Figure 124.

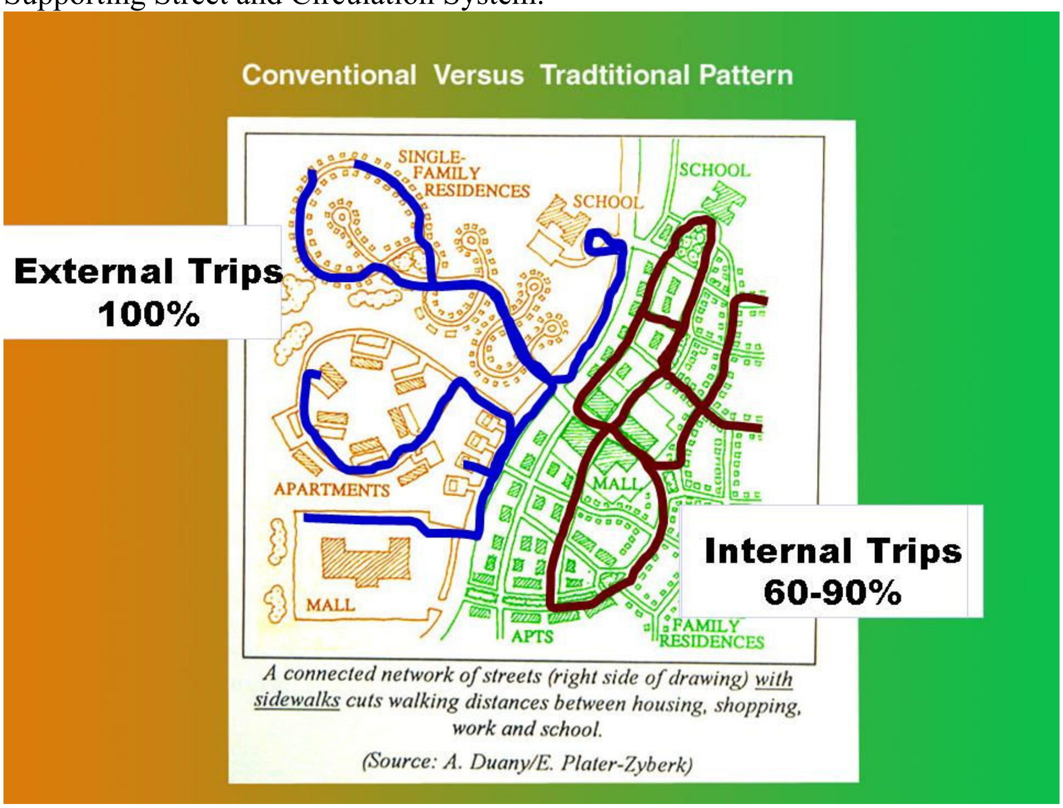
Principle 10. Provide a Supporting Street and Circulation System.

In the words of the *Access Management Manual,*

> *Well-planned communities provide a supporting network of local and collector streets to accommodate development, as well as unified property access and circulation systems. Interconnected street and circulation systems provide alternative routes for bicyclists, pedestrians, and drivers alike. Alternatively, commercial strip development with separate driveways for each business forces even short trips onto arterial roadways, thereby impeding safety and mobility. Connectivity can be maintained while advancing access management objectives for arterial roadways by ensuring that local street connections to the arterial conform with the connection spacing interval.*[141]

Developing such a supporting street system includes side streets, collector streets connecting to arterial roads at regular intervals, parallel roads, and interparcel circulation systems.[142] Benefits include improved accessibility for businesses to abutting neighborhoods, more compact development, and fewer driveways along arterial roads.[143] Fewer arterial trips are required. These benefits are shown graphically in Figure 20.

Figure 20. Illustration of a Neighborhood's Trips With (*Right*) and Without (*Left*) a Supporting Street and Circulation System.



Source: Dan Burden, Glatting Jackson/Walkable Communites, from Duany and Plater-Zyberk.

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[141] Committee for Access Management, *Access Management Manual, op. cit.,* p. 10.
[142] Ibid., p. 87-88
[143] Ibid.

To facilitate such a supportive roadway network, the *Access Management Manual* recommends that major arterials be spaced every mile in developed areas, with minor arterials preferred to intersect at every half-mile to coordinate median openings and signal coordination.[144]

Constructing such a street network requires financial support. Frequently, private developers can be required to provide such support as a condition for land development.[145] In other cases, particularly for retrofits, higher-level support is required. Examples of such support include Kansas, where funds are set aside for local road improvements included on corridor management plans that improve safety and operations on state highways.[146] The Colorado Department of Transportation also targets local street improvements during highway construction to implement its access management program.[147] Virginia provides another approach, whereby both local and regional roads are under the jurisdiction of the Virginia Department of Transportation. Thus, decisions about access management, a strong focus in Virginia, are facilitated by a unified highway jurisdiction that finances not only marked routes, but the coordinated and supportive street systems.[148]

In the subdivision and development process, the continuation and extension of the local street system is important. "Dead-end streets, gated communities, and cul-de-sacs force more traffic to use major roadways for even short local trips. Fragmented street systems also impede emergency access and increase the length of automobile trips."[149] Adjacent developments should be tied together by connecting streets. Neighborhood connectivity can be further enhanced in an access management environment by providing walk-and-bike connections between the arterial and local streets, rather than unrestricted vehicle connections between local and arterial streets.[150] Walking and biking access across natural and man-made barriers, providing alternatives to arterial travel, also provide alternative connectivity (see Figure 21).

Within large commercial developments, internal circulation and connections are critical. For example, at regional shopping centers, outparcel access should be from within the development, not from the arterial. To control disadvantageous arterial access, parking should be shared; inter-parcel walking and bicycling access should be maximized; the number of parcels minimized; a minimum lot frontage standard should be established; and massing regulations should be considered.[151]

[144] Committee for Access Management, *Access Management Manual, op. cit.,* p. 88.
[145] Ibid.
[146] Ibid.
[147] Ibid.
[148] Author Discussion with VDOT staffer, November, 2008.
[149] Committee for Access Management, *Access Management Manual, op. cit.,* p. 103.
[150] Ibid., pp. 104-105.
[151] Ibid., p. 110.

Figure 21. Northfield Walk-bike Alternative Access Across Chicago River from Residential Area to Business District

Photo by Dan Burden, Glatting Jackson/Walkable Communities.

Access Management Bottom Line: The Benefits

The *Access Management Manual* lists many benefits from a comprehensive access management strategy.[152] Key benefits of access management on the list include the following:

- extended functional life of roads and highways;
- increased motorist, bicyclist, and pedestrian safety;
- reduced traffic congestion;
- improved appearance and quality of the built environment;
- preserved long-term property values;
- greater fuel efficiency;
- reduced vehicle emissions;
- alternative travel routes for walking and cycling from a fully-developed local street system

Access management is often a concern for business owners. However, as noted for the discussion about medians (pp. 10-14), the negative business impacts are usually minimal. More importantly, access management can be an important part of a strategy to increase a business's market area. By reducing travel delay, access management increases market area. Delay that reduces average speeds by 20% reduces the market area by 35%; a 50% reduction in average speed reduces market area by 75%.[153]

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[152] Committee for Access Management, *Access Management Manual* Op. cit., pp. 4, 19, 20-25.
[153] Ibid., pp. 22-23.

Access Management Bottom Line (II): The Regional Role.

The *Access Management Manual* suggests the following roles for Metropolitan Planning Organizations (MPO's), such as CMAP, in furthering access management:[154]

- Long-range planning:
        - Example: (Albany-Troy-Schenectady): Screen projects to assure land use and access management consistency with long range plan before moving a project to the Transportation Improvement Program. In addition, "do not identify specific projects in long-range transportation plan until a local study focused on land use and transportation issues, which includes detailed consideration of access management strategies, is completed."
    - Establish goals, objectives, and policies promoting and requiring access management implementation.
    - Establish access management as a required project implementation strategy.
    - Facilitate and endorse the implementation of the strategies laid out below
- Congestion management and programming:
        - Example: Metroplan (Orlando) sets aside funds for non-capacity improvements identified in congestion management process. These often focus on access management.
    - Identify access management strategies in congestion management process corridor studies.
    - Consider corridor improvement strategies in programming process.
    - Use CMAQ funds to implement access management strategies.
- Visioning:
    - Envision land development, access, and transportation solutions together.
    - Address preferred growth patterns, alternative transportation modes, and quality of life.
    - Use visioning to address access management both to complement and to replace more expensive capacity additions.
- Special Studies:
        - Example: Louisville MPO identified access management, right-of-way preservation, and developer mitigation strategies that could be implemented at the local level, with subarea plans illustrating the strategies' application.
    - Corridor studies
    - Sub-area studies
    - Thoroughfare plans
- Technical Assistance:
        - Example: The Northeastern Illinois Planning Commission provided a guide to access management that included a model ordinance (now outdated).
    - Provide "about" and "how-to" information regarding access management techniques to local communities.

[154] Committee for Access Management, *Access Management Manual* Op. cit., pp. 62-64

- Provide information for higher-level bodies, including the legislature and departments of transportation, for policy consideration.
- Workshops and Conferences:
    - Examples: access management workshops have been held by the Little Rock and Kansas City MPO's.
  - Provide educational outreach and training
  - Form and inform a key group of regional stakeholders and champions.
- Project Review
  - During any conceptual design review in which the MPO participates, promote access management.