Access management in
Safer Transportation Network Planning

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D-2001-10

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Safety principles, planning framework, and library information

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Leidschendam, 2001
SWOV Institute for Road Safety Research, The Netherlands

Report documentation

Number:	D-2001-10
Title:	Access management in Safer Transportation Network Planning
Subtitle:	Safety principles, planning framework, and library information
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Research theme:	Road design and road safety
Theme leader:	Atze Dijkstra
Project number SWOV:	33.310
Keywords:	Entrance, land use, access road, accessibility, safety, road network, classification, planning, design (overall design), traffic control, traffic flow, textbook, program (computer).
Contents of the project:	The design tool - Safer Transportation Network Planning - is intended to guide network planners in designing safe transportation networks. This report is one in a series of reports which will be used in the development of the tool. The information in this report is intended to guide the structure and programming of Safer Transportation Network Planning with respect to access management.
Number of pages:	35 pp.
Price:	Dfl. 20,-
Published by:	SWOV, Leidschendam, 2001

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Summary

This report is one in a series of publications, used in the development of the network planning tool ‘Safer Transportation Network Planning’ (Safer-TNP). The publications were used to guide the development of planning structures, diagnostic tools, planning recommendations, and research information in the computer tool Safer-TNP.
Safer-TNP is a design tool that guides network planners in designing safe transportation networks (or improving safety of existing transportation networks). It provides the practitioner with diagnostic tools, and guiding information. At the moment of publication of this report, Safer-TNP is still being developed.
Besides this ‘Access management report’, the following reports have been published in this series:

- Route management in Safer Transportation Network Planning (Hummel, 2001a)
- Land use planning in Safer Transportation Network Planning (Hummel, 2001b)
- Intersection planning in Safer Transportation Network Planning (Hummel, 2001c).

The information in this report will be used to guide the structure and the programming of different parts of the Safer-TNP tool with respect to access management. Described is, in a step-by-step procedure, what information is needed, and in what way the information should be processed. In the last chapter of the report, background information is provided to give users of the tool guiding information. Because of the specific purpose of this report, its structure and style deviate somewhat from regular research reports. Because the different chapters are used in different stages of the development of Safer-TNP, there is some repetition of information. Furthermore, the information is written in telegraphic style, to simplify the electronic packaging of information in Safer-TNP.

In this publication, several access management techniques and their effects on safety and traffic operations are described. The purpose of the techniques is to provide appropriate access to land use, while preserving the capacity and safety of the road network. Access management is proved to be an effective technique for improving traffic safety, because of the exclusion of hazardous manoeuvres and stabilization of traffic flow.
The following techniques are discussed:

- Access spacing
- Corner clearance criteria
- Median alternatives
- Left-turn lanes
- U-turns
- Access separation at interchanges
- Frontage roads.

Contents

1. Background

1.1. Definition

At the general level, access management is the practice of:

- Providing appropriate access to different land uses, while preserving the capacity and safety of the surrounding road network
- Random entrance and exit volumes interrupt through-traffic, causing:
  - unstable traffic flow (drop of operating speeds and capacity)
  - hazardous manoeuvres.

Access management and land use management are inextricably bound. Access management goals cannot be achieved without parallel land use goals (Government of Alberta, 1996).

1.2. Scope

- Access management techniques:
  - Retrofit (corrective)
  - Policy actions (pro-active).
- Basic policy issues:
  - A. Classify roads
  - B. Establish access standards and geometric standards
  - C. Concentrate developments and concentrate access
  - D. Limit direct access on arterials
  - E. Developments (or access to developments) should not be planned in the vicinity of major intersections
  - F. New developments should be directed to access local roads
  - G. Consider restricting left-turns on arterials.

1.3. Potential benefits

- Access management is a very effective method to improve traffic safety. Safety improvements are caused by:
  - Preclusion of hazardous manoeuvres (e.g. left-turns)
  - Diverting access to low-speed, low-volume roads (road categorization)
  - Improvement of traffic flow on arterials (less disturbance)
  - Improved anticipation and operation of intersections.
- The benefits of access management depend on the access management techniques applied. Effects are described in chapter 6 ‘Library information’.

2. Planning activities

2.1. Activities

<u>I</u> <u>Planning framework</u>

At the commencement of an access management exercise, it is important to develop an understanding of the study area. At least the following elements need to be surveyed to obtain an understanding of the study area:
- Land uses/ Access requirements
- Road classes (road classification plan)
- Policies/ Legislation on access management
- Proposed land use plans and expected/ foreseen developments.

<u>II</u> <u>Diagnostics</u>

The effects of different access management strategies should be studied and evaluated beforehand. For those simulations, transportation models and accident models (see ‘Accident Modelling’) may be used. At least the following effects should be studied:
- Traffic operation on segments and intersections
- Accessibility
- Safety.

<u>III</u> <u>Option generation and evaluation</u>

A number of possible options for the new situation should be designed, evaluated and -if necessary- refined. Refinement or improvement of the access management strategy may include:

a. Deal with causes of poor safety:
   - change land use
   - change location of land use
   - change density of land use
   - change road type
   - combine accesses
   - relocate access
   - remove access
   - divert access to frontage road.

b. Deal with symptoms of poor safety:
   - traffic management (turn-lanes, signalization)
   - speed management
   - route management.

- Possible access management techniques are:
  - Access spacing
  - Corner clearance criteria
  - Median alternatives
  - Left-turn lanes
  - U-turns
  - Access separation at interchanges
  - Frontage roads.

2.2. Planning process

Scale	Phase			
	Strategic policies	**Shaping/ conceptual**	**Definition**	**Feasibility**
Regional				
Municipal		- Access spacing - Frontage roads	- Corner clearance criteria - Median alternatives	
Local area		- Access spacing - Frontage roads	- Corner clearance criteria - Median alternatives	
Element		- Frontage roads	- Corner clearance criteria - Median alternatives - Left-turn lanes - U-turns - Access separation at interchanges	- Left-turn lanes - U-turns - Access separation at interchanges

Table 1. *Phases and scales of the planning process.*

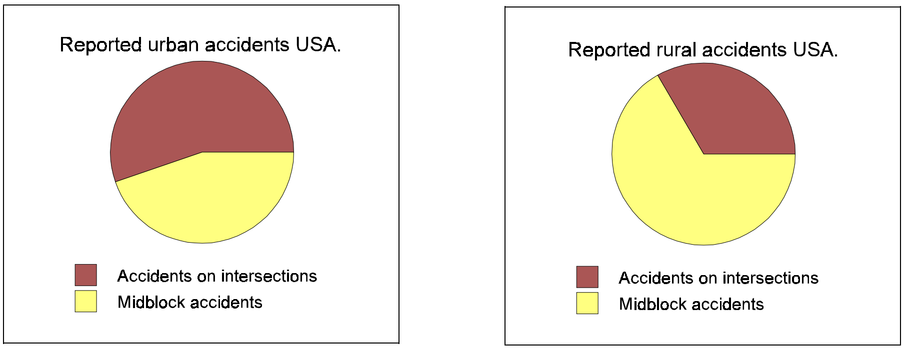
3. Safety principles

3.1. Safety characteristics

- Accident rates rise with greater frequency of driveways and intersections

Total access points per mile (both directions)	Accident rate index
10	1.0
20	1.4
30	1.8
40	2.1
50	2.5
60	3.0
70	3.5

Table 2. *Accident rate index, with rate at 10 access points per mile=1.0 (Gluck, Levinson & Stover, 1999).*



Figures 1a and 1b. *Accident rates in the USA (Kuciemba & Cirillo, 1992).*

- 6 - 10 percent of collisions and fatalities on rural primary highways (Alberta, Canada) are the result of intersecting approaches. Most of these accidents happen at farm/ field/ residential accesses, rather than at major road intersections.
- Accident records show that accident rates on controlled access roads are up to 40 - 60 percent lower than on roads without access control (Government of Alberta, 1996).

3.2. Planning principles

Introduction

- The overall Transportation Network Planning Approach is based on a framework of safety planning principles (i.e. as discussed in more detail in the 'Learn' Module).

  - **Minimize exposure**
    - Provide compact urban form
    - Provide efficient networks
    - *Promote alternative modes.*
  - **Minimize risk**
    - Promote functionality, by preventing unintended use of each road
    - Provide homogeneity, by preventing large differences in vehicle speed, mass, and direction of movement
    - Provide predictability, thus preventing uncertainty amongst road users by enhancing the predictability of the course of the road, and enabling the behaviour of other road users to be anticipated.
  - **Minimize consequences**
    - Reduce speeds
    - *Provide a forgiving roadside*
    - *Protect vulnerable road users.*

- This chapter discusses the interaction between these principles and access management. The principles printed in italic are not considered to be relevant to access management and will not be addressed in this chapter.

3.3. Minimize exposure

3.3.1. *Provide compact urban form*

Discussion

- The chosen urban form influences the density of land use and thereby the density of access requirements.
- A dense distribution of land uses creates the possibility to combine accesses and creates the possibility of diverting access to frontage roads, thus decreasing the total number of accesses.
- A dense net of access points may cause insufficient access spacing, causing unsafe operation of the individual accesses.

Guiding principles

- A compact urban form creates the possibility to combine accesses and to divert accesses to frontage roads, thus reducing the total number of accesses, and diverting accesses to more suitable places. Sufficient spacing between individual access points should be carefully controlled.

3.3.2. *Provide efficient networks*

Discussion

- Access management may improve the efficiency of the network considerably, by:
  - Reducing the total number of access points
  - Improved intersection and access spacing, causing an improvement in operations and safety
  - Diverting access to roads/ locations where the disturbance of traffic on arterials is less.

Guiding principles

- Accesses should not automatically connect to the closest road, but to a road where traffic operations and safety are not interfered with.
- Accesses should be combined wherever possible.

3.4. **Minimize risk**

3.4.1. *Promote functionality*

Discussion

- Local access interferes with the traffic (flow) function of roads:
  - Introduction of additional intersections
  - Additional disturbance of access traffic.
- All traffic to and from accesses is to be regarded as local traffic.

Guiding principles

- Local access should only be permitted on roads with a minor traffic function (residential roads), where the mix of moving directions and speeds have limited consequences for traffic operations and safety.
- Properties alongside traffic function roads should be made accessible via frontage roads and never via the traffic function road itself.

3.4.2. *Provide homogeneity*

Discussion

- Accesses introduce disturbance in the traffic flow.
  - Differences in directions of moving traffic
  - Differences in speeds.
- Disturbance of the traffic flow should only be permitted on roads where the traffic function is minor and mixed traffic (mix of modes, directions of moving, speeds) is accepted in the design.

Guiding principles

- Access should only be accepted on local/ residential roads (or on frontage roads).

3.4.3. *Provide predictability*

Discussion

- On roads where the traffic function prevails, disturbances in the traffic flow are not expected and anticipated. Local access should therefore not be introduced on those traffic function roads.

Guiding Principles

- Direct access should not be permitted on traffic function roads.
- Distances between individual accesses should be large enough to allow motorists to anticipate each individual access.

3.5. **Minimize consequences**

3.5.1. *Reduce speeds*

Discussion

- Accesses introduce disturbances on the target road. These disturbances are only acceptable if driving speeds are low.

Guiding principles

- Access should only be permitted if driving speeds on the target road are low.

4. Planning framework

- In order to obtain good and consistent access management in a study area, it is essential to develop an understanding of the study area.
- At least the following items need to be surveyed to get an understanding of the study area:
  - Land uses/ access requirements
  - Road classes
  - Policies/ Legislation
  - Proposed land use plans.

4.1. Land use/ Access requirements

- The present and planned land use is the main determining factor in the access requirements in the study area. For determining the access requirements, land use can be described in terms of:
  - Land use type
  - Density (concentrated versus dispersed)
  - Volumes.

4.1.1. *Land use types*

Based on differences in land use, the following access types can be distinguished:

- Public road access: intersection of an arterial with a (secondary) public road
- Residential access: access to a (single, private) home
- Multi-residential access: access to a residential subdivision consisting of more than one lot
- Highway commercial access: access to a parcel of land serving a highway commercial development such as a service station, truck stop etc.
- Industrial access: access to an industrial site
- Office access: access to a site with office buildings
- Shopping site access: access to shopping centres, or individual shops
- Recreational access: access to a recreational facility such as a golf course or a camp site
- Farmstead access: access to a farm residence and adjoining buildings
- Field access: access to a parcel of land with agricultural use
- Utility access: access to a utility installation such as a pumping-station, power company substation etc.
- Resources access: access to a well site, gravel pit, log haul etc.
- Schools.

- The abovementioned factors determine the following access requirements:
  - Number of accesses
  - Required directness of access (are detours or the use of frontage roads acceptable?)
  - Traffic volumes on access
  - Required dimensions of access and intersection (presence of trucks and agricultural vehicles).
- The access requirements for all the land use types in the study area have to be determined.
- Special attention has to be paid to the desired or required directness of access. It has to be determined whether access through secondary or frontage roads (detours) is acceptable.

4.1.2. *Density*

- The density of land uses identifies:
  - The number of accesses along a road
  - Access spacing.
- High densities create opportunities of combined accesses, leading to a reduction of both the total number of accesses and the access spacing.
- In order to be able to combine as many accesses as possible (for instance on frontage roads), land use development with high density should be preferred.

4.1.3. *Volumes*

- The types of land use and the possible combinations of accesses determine the traffic volumes on accesses.
- Large volumes to and from land uses create more disturbance of traffic flow on the main road, and cause a reduction of traffic safety.
- If the traffic volumes on an access are too large (HOW LARGE??), the access has to be redirected to a frontage road, where local access traffic causes less disturbance of through-traffic.

4.2. **Road classes**

- The road network classification is an essential element to be used in access management strategy.
  It has to be determined which accesses (in terms of type, density, volumes) are to be allowed on the different road categories in the network.
  This topic is elaborated in detail in the section ‘Network planning’ within Safer-TNP.

Policies/ Legislation
- The existing policies and legislation on access management strategies have to be surveyed.
- Possible existing policies and strategies may be:
  - Access rights
  - Preclusion of access on specified road classes
  - Policies on the use of frontage roads
  - Policies on the preclusion of left-turns on specified road classes
  - Etc.

- Policies do not always have to be written plans or laws, but may also include less formal standards that are applied in the study area.

4.3. Proposed land use plans

- For developments in the study area it is important to survey possible new developments in the study area. An inventory has to be made of proposed or foreseen land use plans in the future.

5. Option generation/ Option evaluation

- If in an existing or proposed network, incompatibilities are determined, the following solutions may be considered:
  - I Solve causes:
    - change land use
    - change location of land use
    - change density of land use
    - change road type
    - combine accesses
    - relocate access (on same road)
    - divert access to other road or (new) frontage road.
  - II Change symptoms:
    - traffic management (turn lanes, signalization)
    - speed management
    - route management.

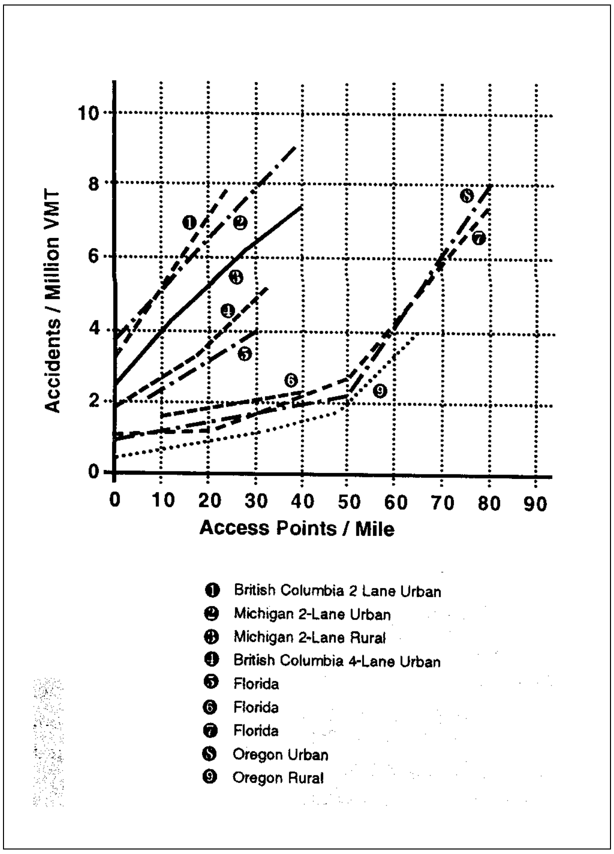


Figure 2. *Effect of access spacing on accident rates (composite; Gluck, Levinson & Stover, 1999).*

- The performance of different access scenarios may be simulated within Safer-TNP, with the accident prediction tool.

6. Library information

Information in this chapter is mainly based on the report *Impact of access management techniques* by Gluck, Levinson & Stover (1999).

6.1. Understanding

- A large number of access management techniques can be identified. The most significant techniques are:
  - Access spacing
  - Corner clearance criteria
  - Median alternatives
  - Left-turn lanes
  - U-turns
  - Access separation at interchanges
  - Frontage roads.

  The effects, benefits and planning and design considerations are described in the following sections.

6.2. Access spacing

- “Driveways are, in effect, at grade intersections; thus their design and location merit special consideration.” (American Association of State Highway and Transportation Officials -AASHTO, 2001).
- Driveway spacing has one of the most important effects on traffic safety. Increased spacing improves safety by:
  - Reduced number of conflict points per kilometre
  - Longer anticipation distances
  - Longer distances to recover from turning movements.

  The following procedure may be used to estimate the cumulative impacts of changing unsignalized access spacing along a section of road:

Given:	actual accident rate = A existing driveways per mile = D_1 existing signals/mile = S_1 proposed driveways per mile = d_2
Obtain:	estimated existing and future rates (R_1 and R_2) from *Figure 4*
Apply:	The ratio of R_2/R_1 to the actual rate A

  The following example will help to illustrate the application of this procedure.
  The actual accident rate on a roadway with three signals per mile and 18 driveways per mile is 7.0 accidents per million vehicle miles travelled (VMT). An additional 12 driveways are planned, resulting in a total of 30 driveways per mile.
  The projected accident rate is calculated as followed, using *Figure 4* to estimate R_1 and R_2: Projected rate = Actual rate x R_2/R_1 = 7.0 x 5.6/4.5 = 8.7 accidents per million VMT.

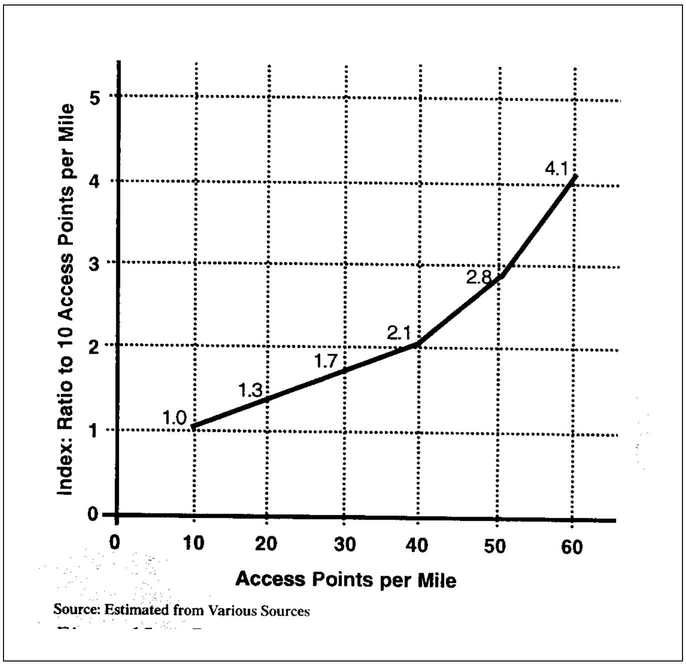


Figure 3. *Composite accident rate indices (Gluck, Levinson & Stover, 1999).*

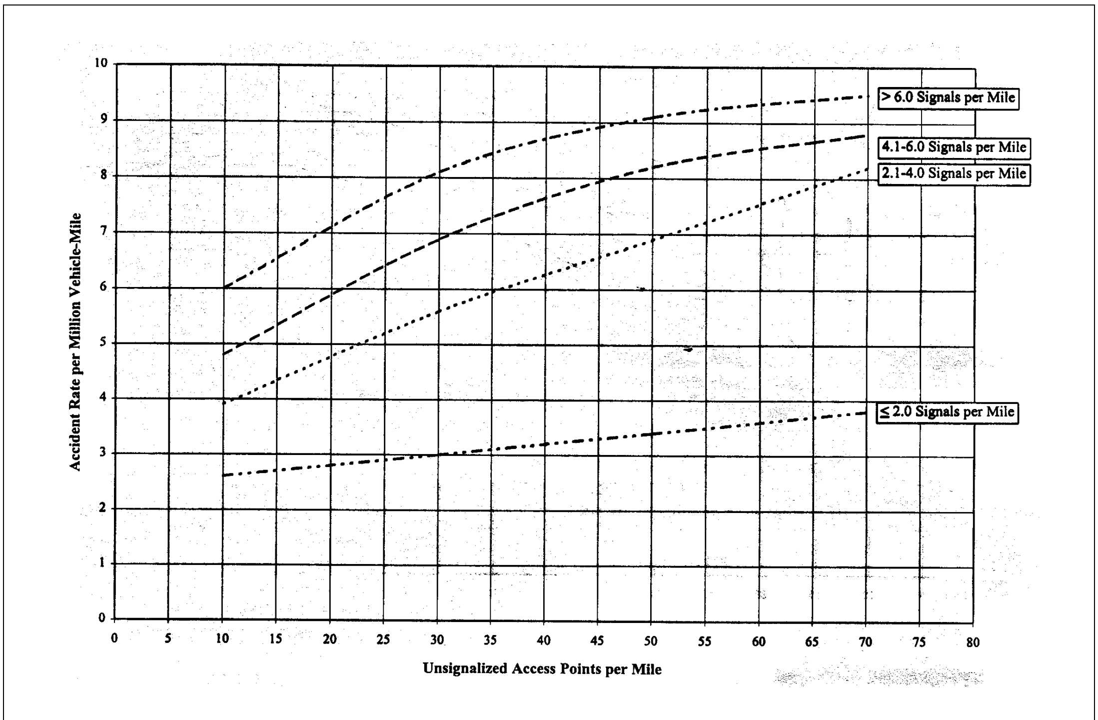


Figure 4. *Estimated accident rates by access density - urban and suburban areas (Gluck, Levinson & Stover, 1999).*

Table 3 shows the access separation distances at different ‘spill-back rates’. Spill-back occurs when vehicles entering or leaving an exit impede a right-lane through-vehicle up to (or beyond) the next exit upstream of the analysis exit. The spill-back rate represents the percentage of right-lane through-vehicles, experiencing this occurrence. *Table 3* is based on an average of 30 to 60 right turns per driveway.

Posted speed (km/h)	**Access separation distances at spill-back rate**			
	5%	**10%**	**15%**	**20%**
48	335	265 (a)	210 (b)	175 (c)
56	355	265 (a)	210 (b)	175 (c)
64	400	340	305	285
72	450	380	340	315
81	520	425	380	345
89	590	480	420	380

(a) Based on 12 driveways per km.
(b) Based on 16 driveways per km
(c) Based on 19 driveways per km.

Table 3. *Access separation distances based on 10-percent and 20-percent spill-back (Gluck, Levinson & Stover, 1999).*

6.3. Corner clearance criteria

Stopping sight distance (AASHTO, 2001)

- Stopping sight distance is the distance traversed by a vehicle from the instant an object in its path is detected to a complete standstill in front of the object (see *Table 5*).
- Stopping sight distance has to be provided at all intersections.

Intersection sight distance (AASHTO, 2001)

- This is the distance that stopped or slowed vehicles on the minor road have to be able to see in order to detect oncoming, conflicting traffic on the major road and to cross the intersection area safely.
- Intersection sight distance (ISD) is the length of the leg of the sight triangle along the major road (m). See *Table 5*.

ISD = $0.278 \, V_{major} \, t_g$
V_{major} = design speed of major road (km/h).
t_g = time gap for minor road vehicle to enter the major road (see *Table 4*).

Design vehicle	**Time gap for minor road vehicle (sec)**
Passenger car	7.5
Single-unit truck	9.5
Combination truck	11.5

Table 4. *Time gaps for minor road vehicles to enter the major road (t_g) in seconds.*

Note that the time gaps are given for a stopped vehicle to turn right or left onto a two-lane highway without median and with grades of 3 percent or less. The values of *Table 4* require adjustment as follows, for:
- Multilane highways: For left turns onto two-way highways with more than two lanes, add 0.5 seconds for passenger cars, or 0.7 seconds for trucks for each additional lane to be crossed by the turning vehicle.
- Minor road approach grades: If the approach grade is an upgrade that exceeds 3 percent; add 0.2 seconds for each percent grade for left turns.

Design speed (km/h)	**Stopping sight distance (m)**	**Intersection sight distance for passenger cars**	
		Calculated (m)	**Design (m)**
20	20	41.7	45
30	35	62.6	65
40	50	83.4	85
50	65	104.3	105
60	85	125.1	130
70	105	146.0	150
80	130	166.8	170
90	160	187.7	190
100	185	208.5	210
110	220	229.4	230
120	250	250.2	255
130	285	271.1	275

Table 5. *Stopping sight distance and intersection sight distance in metres (AASHTO, 2001).*

Note: Intersection sight distances in *Table 5* are for a stopped passenger car to turn left onto a two-lane highway without median and with grades of 3 percent or less.

Length of turn lanes (AASHTO, 2001)

- Intersections with turn lanes require longer stopping sight distances, because moving laterally to the turn lanes, while decelerating is a more demanding task. The turn lane should thus be longer than the stopping sight distance.

Speed (km/h)	**Length of turn lane (m)**
50	70
60	100
70	130
80	165
90	205

Table 6. *Length of turn lanes in metres; turning traffic leaving the through-lane with a speed difference of 15 km/h.*

6.4. Median alternatives

- Two types of median alternatives are discussed:
  - Two-way-left-turn lanes (TWLTL) (see *Figure 5*).
  - Non-traversable (physical) median (see *Figure 6*).

- Two-way-left-turn lane removes left turns from through-travel lane
- Raised median separates opposing traffic
- Raised median precludes (or controls) left turns
- Both TWLTL's and raised medians improve safety and traffic operations (see *Tables 7, 8 and 9*).
- Installation of a TWLTL or a non-traversable median reduces accident rates by 30 to 40 percent, compared with undivided cross-sections.
- TWLTL's remove left turns from through-travel lanes; but they increase rather than control access opportunities.
- As shown in *Figure 7*, safety improvements of raised medians are larger than those of TWLTL's.

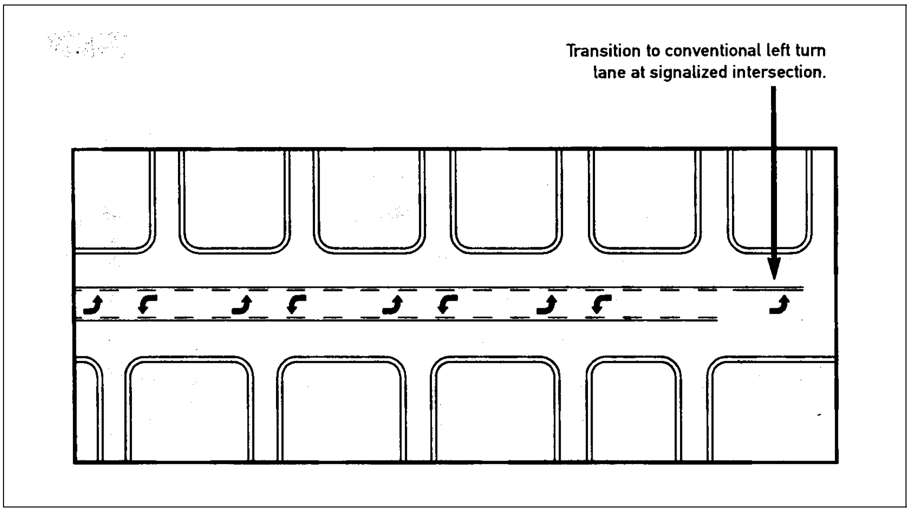


Figure 5. *Continuous two-way left-turn lane (Gluck, Levinson & Stover, 1999).*

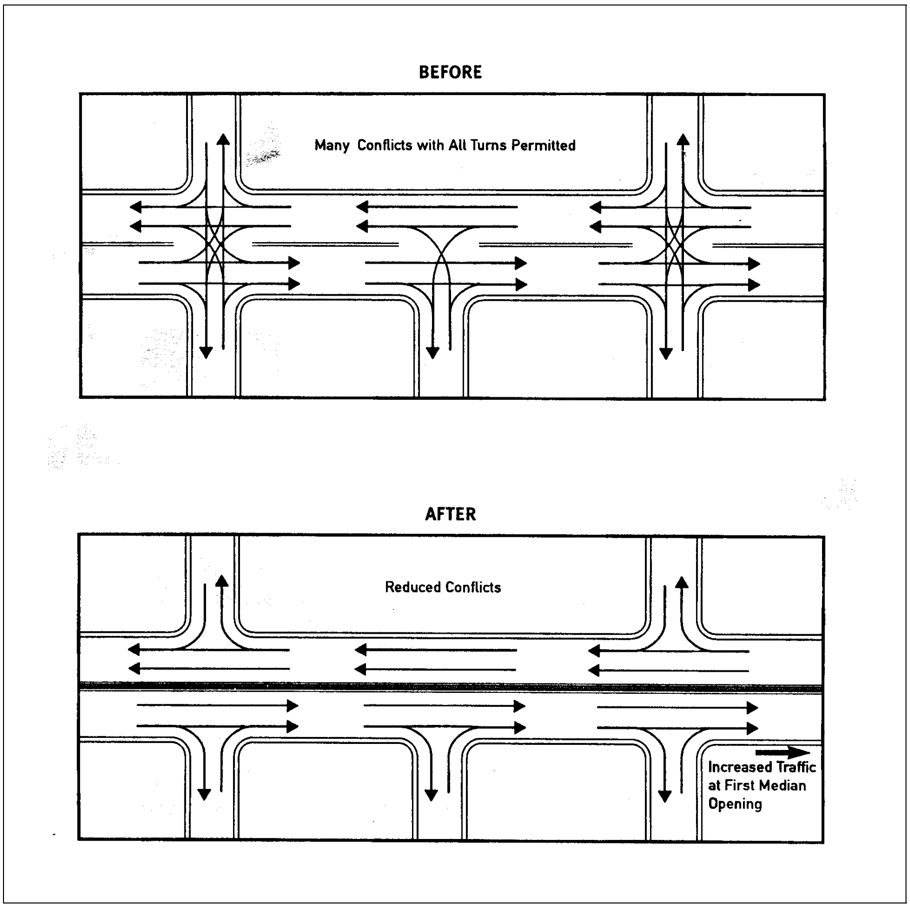


Figure 6. *Reduction in conflicts by installation of continuous non-traversable median on a previously undivided highway (Gluck, Levinson & Stover, 1999).*

Study & Location	Year	Accidents			Accident rates (per million VMT)			Remarks
		Undivided	TWLTL	% diff.	Undivided	TWLTL	% diff.	
1. Busbee	1974	-	-	-38	-	-	-	Before and after study
2. Southern section ITE	1975	-	-	-31	-	-	-	Before and after study
3. Burrit and Coppula (Arizona)	1978	-	-	-36	-	-	-	Seven locations. Before and after study
4. Walton, Horne, Fung (Texas)	1978	-	-	-33	-	-	-	Before and after study
5. Parker (Virginia) (1)	1983	-	-	-	6.79	6.11	-9	14 four-lane undivided sections 17 sections with traversable medians
6. Thakkar (Illinois)	1984	824 222	558 130	-32 -41	90.8 53.3	54.3 28.6	-40 -46	15 five-lane sections. Before and after study. 16 three-lane sections. Before and after study
7. Harwood and St. John (1)	1985	-	-	-	3.14 1.79	0.86 0.26	-73 -85	2-lane highways; 7 sites with TWLTL compared to 4 without. 4 sites Before and after study
8. Harwood (California) (1) Harwood (Michigan) (1)	1986	-	-	-	2.06 1.79	1.28 1.89	-38 6	Non-intersection accidents/commercial land use
9. ITE	1986	2,479	1,788	-28	-	-	-36	30-road stretches. Before and after study
10. Kuhlmann (Metro Toronto)	1987	-	-	-	-	-	-21	11-road sections. Before and after study
11. Box (Illinois)	1989	174	104	-40	-	-	-	4-lane urban arterials. Before and after study
12. Long (Florida) (1)	1993	-	-	-	4.44	3.2	-28	4-lane urban arterials
13. Bowmann-Vecellio (Arizona, California, Georgia)	1994	2,751 4,487	2,181 15,110	-21 236.7	9.92 4.23	5.56 6.89	-44 63	15-road sections. (CBD arterials and suburban arterials, respectively)

(1) These represent rates for different sections of roadway.

Table 7. *Accident experience with TWLTL's (Gluck. Levinson & Stover, 1999).*

Study & Location	Year	Data compared	Rear-end	Sideswipe	Right-angle	Left-turn	Head-on	Fixed object/ Parked vehicle	Other	Remarks
1. Busbee	1974	Frequency		-90						
2. Burrit and Coppula (Arizona)	1978	Frequency	-45	-100 -52	same direction opposite direction	-20	-67	-65	-30 (1)	
3. Walton, Horne, Fung (Texas)	1978	Frequency	-45	-	-	-	-42			
4. Thakkar (Illinois)	1984	Rates	-34 (2) -40 (2)	-26 -45	- -		- -			5 lanes 3 lanes
5. Long, Gan and Morris (Florida) (*)	1993	Midblock rates	-24	-47	-16	-27	-46		37 (3)	4 lanes

(1) Pedestrians
(2) Includes left turns
(3) Right turns
(*) This study compares different sections or groups of roadways

Table 8. *Accident experience by type of accident with TWLTL's percent difference (Gluck, Levinson & Stover, 1999).*

Study & Location	Year	Accidents			Accident rates (per million VMT)			Remarks
		Undivided	Median	% diff.	Undivided	Median	% diff.	
1. Parker (Virginia)	1983	-	-	-	6.79	4.42	-35	19 median sections; 14 four-lane sections
2. Arlington (Texas)	1983	-	-	-66	-	-	-	4-lane roads
3. New York state	1984	-	-	-	11.28	7.43	-34	six-lane road; Statewide study
4. Murthy (Rhode Island)	1992	31	29	-7	1.11	0.94	-15	2-lane road - controlled access
5. Long, Gan Morrison (Florida)	1993	-	-	-	4.44	2.09	-53	
6. Bowman-Vecellio (Arizona, California, Georgia)	1994	2,751 4,487	1,714 7,663	-38 71	9.92 4.23	6.42 3.79	-35 -10	15 sections; CBD, Suburban
7. Harwood et al.	1995							
California-urban		-	-	-	3.59	2.58	-28	Statewide study, includes uncontrolled access hwy only
California-rural		-	-	-	2.13	1.15	-46	
Minesota-rural		-	-	-	7.14	2.37	-67	Statewide study, incl. hwys with partial access control or
Utah-rural		-	-	-	2.27	2.22	-2	with no control

Table 9. *Synthesis of median safety experience (Gluck, Levinson & Stover, 1999)*

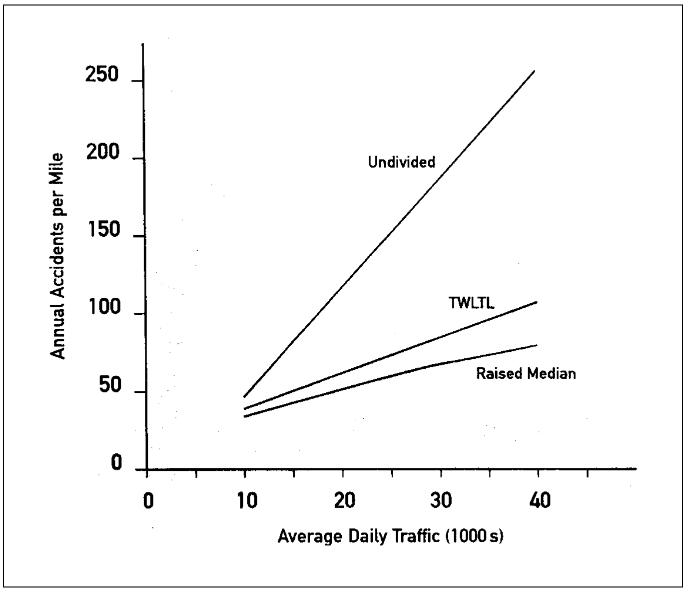


Figure 7. *Safety improvements of raised medians and TWLTL's, compared to undivided traffic (Gluck, Levinson & Stover, 1999).*

Average daily traffic	Undivided	TWLTL	Raised median
10000	48	39	32
20000	126	60	55
30000	190	92	78
40000	253	112	85

Table 10. *Estimated total accidents/mile/year average of various safety models (see Figure 7 above; Gluck, Levinson & Stover, 1999).*

6.5. Left-turn lanes

- More than 65 percent of all driveway-related accidents involve left-turning vehicles.
- The installation of left-turn lanes improves both traffic safety and capacity.
- Left-turns can be:
  - Provided
  - Prohibited
  - Diverted
  - Separated

Option	Condition	Application considerations
Provide	Shared lane Left-turn lane Dual left-turn lane	Limit to minor roads or places where R/W is not available for left-turn lane Protected or permissive phasing Protected phasing only
Prohibit	Full time Peak periods only	Requires alternative routes Requires alternative routes
Divert	Jug-handle Modified jug handle Michigan 'U'	Divided highways at minor roads (signalized junctions only) 6-lane divided highways Divided highways with wide median - Allows two-phase signals
Separate	Directional design Left-turn flyover Through-lane flyover	Large number of turns in one direction Large number of turns in one direction Major congestion points

Table 11. *Treatment of left turns at intersections and driveways (Gluck, Levinson & Stover, 1999).*

- Benefits of left-turn lanes:
  - Remove left-turns from through-lanes (reduction of rear-end collisions; increased capacity)
  - Improve visibility of oncoming traffic for left-turning vehicles (reduction of right-angle collisions; see *Figure 8*).

- Left-turn lanes may reduce the number of accidents from 20 up to 65 percent. (See *Table 12, 13 and 14*).

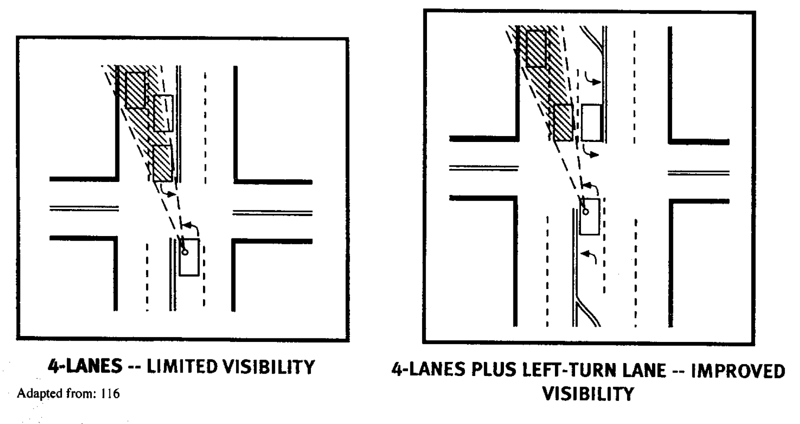


Figure 8. Improved visibility from providing turn lanes (Gluck, Levinson & Stover (1999).

Study Location	Year	Type	Accidents			Accident rates			Remarks
			Without	With	% diff.	Without	With	% diff.	
1. *California*	1967	Before/After							
Unsignalized						1.16	0.58	-50	53 locations
Signalized						1.00	0.82	-18	
All locations						1.08	0.70	-35	
Painted			157	106	-32				40 locations
Curbed			61	25	-59				
Raised Bars			95	31	-67				
All			313	162	-48				
2. *Indiana*	1968	Compares locations				1.65	0.59	-65	8 intersections without lanes; 3 with lanes
3. *Ohio*	1973	Compares locations							
Unsignalized						4.35 (1)	1.04 (1)	-76	239 legs without;
Signalized						2.47 (1)	1.54 (1)	-38	93 legs with left-turn lanes
4. *Israel*	1980	Before/After				1.65 (2)	1.03 (2)	-38	25 intersections
5. *Kentucky*	1983	Before/After							
Unsignalized						5.7 (3)	1.3 (3)	-77	
Signalized						7.9 (3)	3.6 (3)	-54	
6. *Indianapolis*	1986	Before/After	102 (4)	44 (4)	-57				8 intersections
7. *Nebraska*	1989	Compares locations							3 year comparison
Unsignalized			95	62	-35	1.00	0.49	-51	14 sites with; 14 sites without
Signalized			145	67	-54	1.28	0.56	-56	15 sites with; 20 sites without
8. *New Jersey, Route 47*	1992	Before/After	109	67	-39				1.8 miles; 4-lane road converted to 3-lane
9. *New Jersey, Route 130*	1993	Before/After				3.36	2.16	-35	8 miles (south)
						3.88	1.99	-51	28 miles (north)

(1) Per million vehicles per leg per year
(2) Accidents per intersection per year
(3) Per million left-turning vehicles
(4) Mean accidents/intersections/year

Table 12. *Synthesis of safety experience with left-turn lanes (Gluck, Levinson & Stover, 1999).*

Study location	Year	Conditions Compared	Percent change in Accidents				Remarks
			Rear-end	Right-Angle	Left-turn	Other	
A. Unsignalized							
California	1967	acc./million entering veh.	-87 (1)	+50	-37	-45	
Indiana	1968	acc./million entering veh.	-62	-65			
Ohio	1973	acc./million veh. per leg			-90		
Kentucky	1983	acc./million left turning veh.			-77 (1)		
Nebraska	1989	acc./million entering veh.	-88 (3)	+68 (3)	-86 (3)	-53	4-lane arterials
B. Signalized (4)							
California	1967	acc./million entering veh.	+16 (5)	-9	-56	-29	
Ohio	1973	acc./million veh. per leg			-43		
Kentucky	1983	acc./million left turning veh.			-54 (2)		
Nebraska	1989	acc./million entering veh.	-59 (3)	-38	-66 (3)	-74 (3)	4-lane arterials

(1) Statistically significant at .10 level
(2) Includes left-turn related, rear-end, and sideswipe accidents
(3) Statistically significant at .05 level
(4) Without protected left-turn phases
(5) Appears inconsistent with other findings

Table 13. *Synthesis of accident experience by type of accident (Gluck, Levinson & Stover, 1999).*

Treatment	Accident reduction percentage
UNSIGNALIZED	
1. Add left-turn lane (physical separation)	65 24 (fatal + injury)
2. Add left-turn lane (painted separation)	27
SIGNALIZED	
3. Add left-turn lane (physical separation)	40
4. Add left-tun lane (painted separation)	15

Table 14. *Reported accident reduction factors for left-turn lanes (for all accidents, except where noted). (Gluck, Levinson & Stover, 1999).*

6.6. **U-turns**

- U-turns can be used to replace left-turns from and onto arterials and highways (see *Figure 9*).
- The left-turn movements are redirected to the U-turn, after which a right-turn in the desired direction can be made.
- The intersection that accommodates the U-turn is signalized (phase for U-turning vehicles).
- Closing full-median openings (bi-directional) and replacing them with directional U-turns, generally improves safety (see *Figure 10*). Research in Michigan showed the results as in *Table 15.*

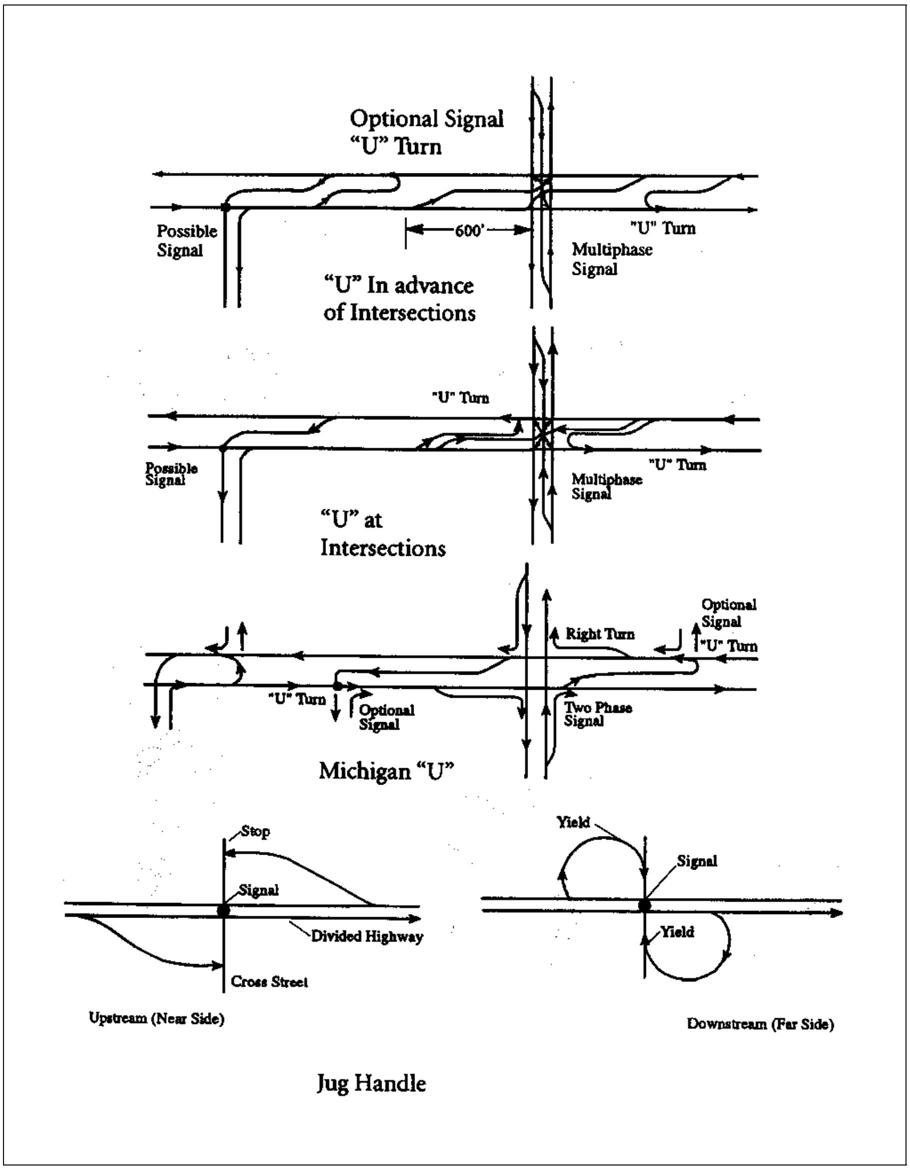


Figure 9. *U-turns as an alternative to direct left turns (Gluck, Levinson & Stover, 1999*).

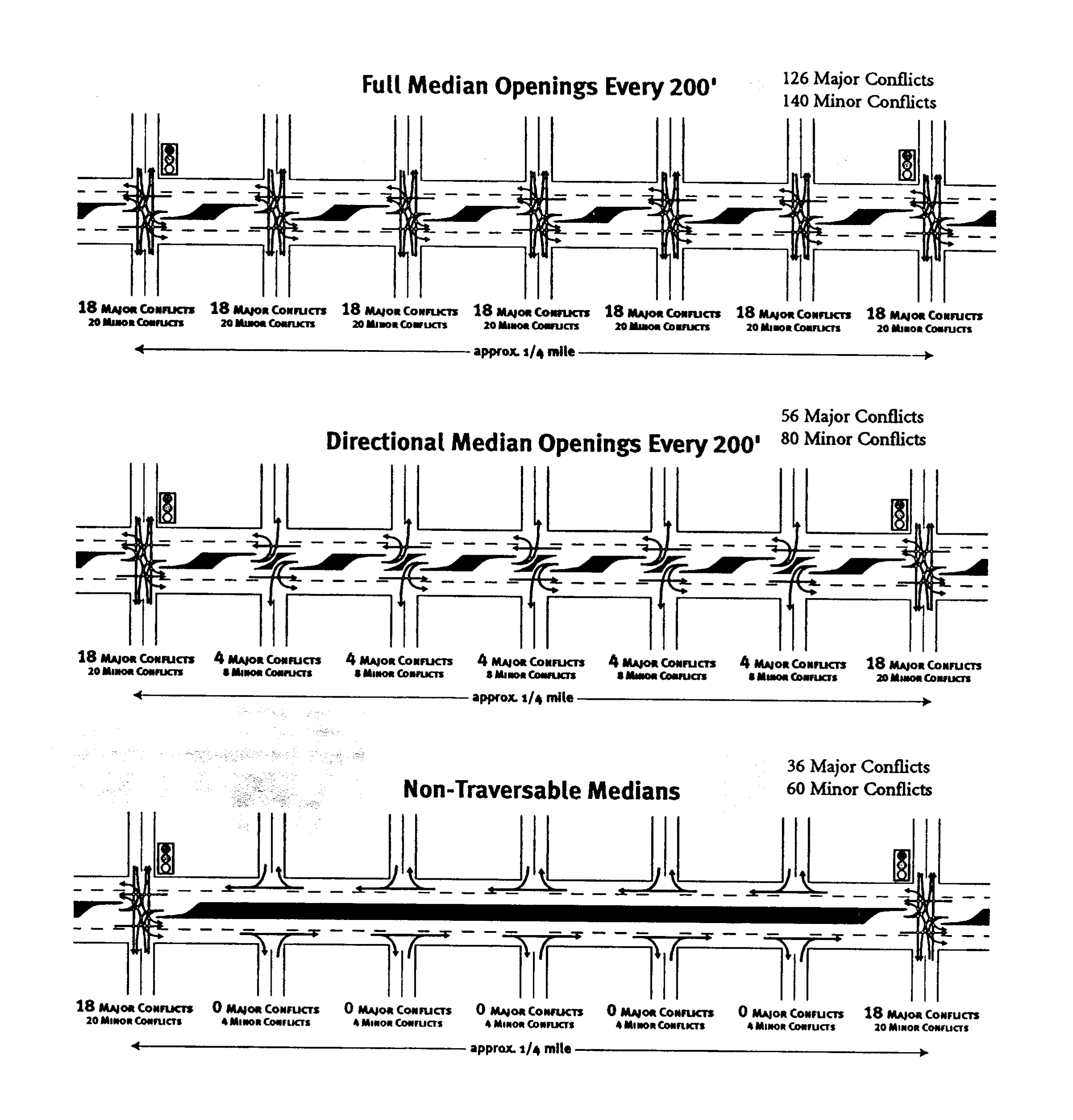


Figure 10. *Conflicts at median openings (Gluck, Levinson & Stover, 1999).*

Signals per mile	Bi-directional	Directional (U-turn)	Difference (percent)
0	420	480	+ 14
0 - 1	533	339	- 36
1 - 3	1.685	856	- 49
> 3	2.658	1.288	- 59

Table 15. *Accidents per 100 million vehicle miles (Gluck, Levinson & Stover, 1999).*

- On stretches without traffic signals, the replacement of multiple left-turns by one U-turn, caused an increase in accidents.
- In situations where the U-turn could be accommodated at signalized intersections, the replacement of multiple left-turns by U-turns caused a decrease in accidents.
- U-turns should therefore only be used if they can be accommodated at signalized intersections.
- When U-turns are introduced to replace multiple left-turns, median width at the signalized 'U-turn-intersection' should be adequate to store vehicles making the U-turn. The required width for making a U-turn is larger than the width required to make a left-turn. Generally, a median width of at least 12 m (preferably 18 m) should be available.

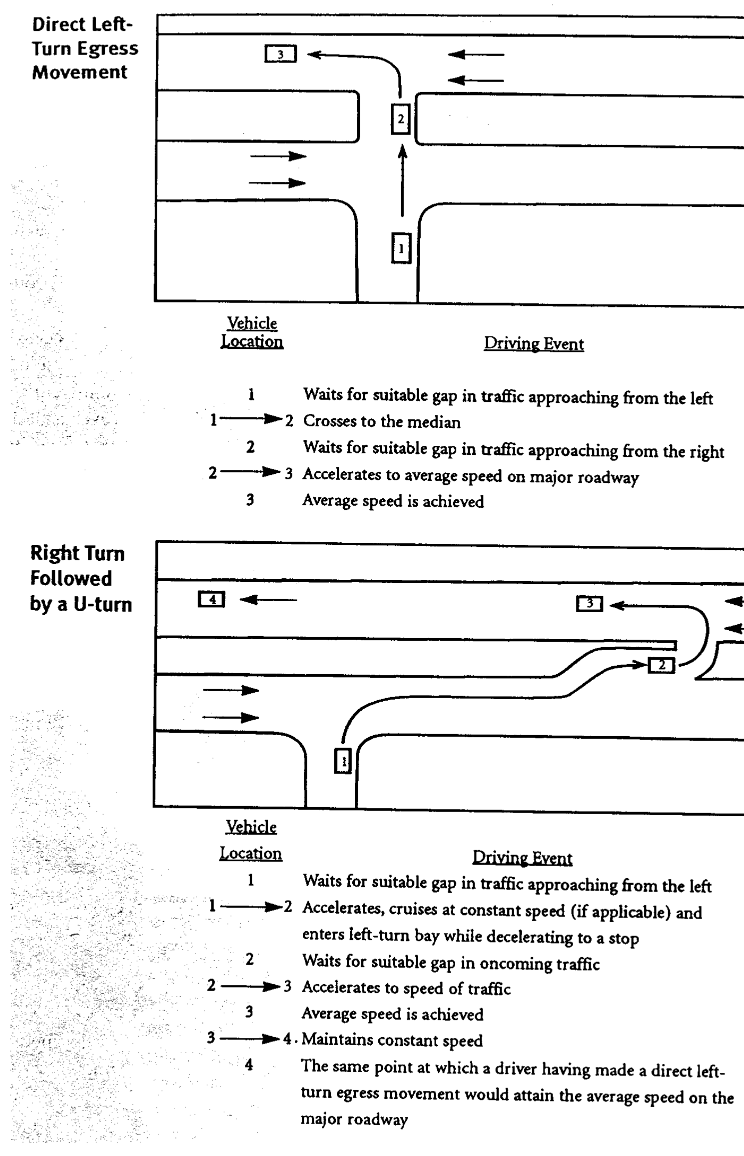


Figure 11. *Analytical framework for providing U-turns as an alternative to direct left turns (Gluck, Levinson & Stover, 1999).*

6.7. **Access separation at interchanges**

- Although access is controlled on freeways, there are often no access management strategies for interchanges and connecting arterials.
- Access on interchanges and connecting arterials (in vicinity of interchanges) may seriously impede traffic operations and, in a lesser degree, traffic safety.

- Problems that may be created by access to or in the vicinity of interchanges are:
  - Congestion with spill-back on ramps
  - Weaving problems due to inadequate weaving distances
  - Congestion caused by large number of left-turn movements
  - Double use of road (both access and arterial leading to interchange), leading to combination of local traffic and through-traffic.

- In order to maintain constant flow and safety conditions, the following distances in *Table 16* have to be provided between interchanges and other intersections (e.g. accesses).

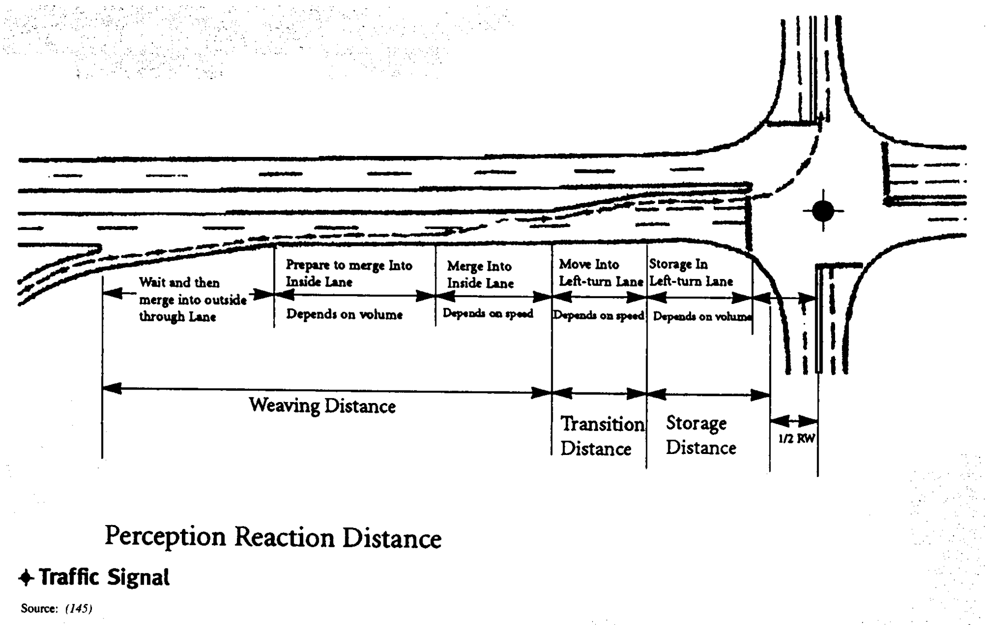


Figure 12. *Factors influencing access separation distance (Gluck, Levinson & Stover, 1999).*

Lefts/lane/cycle	Distance (m)
2	31
4	61
6	92
8	122
10	152

Table 16. *Estimated access separation distances in metres (Gluck, Levinson & Stover, 1999).*

6.8. **Frontage roads**

- Frontage roads are used to redirect access from the main road, thus separating through-traffic and local land-service traffic on the main road. (See *Figure 13*).

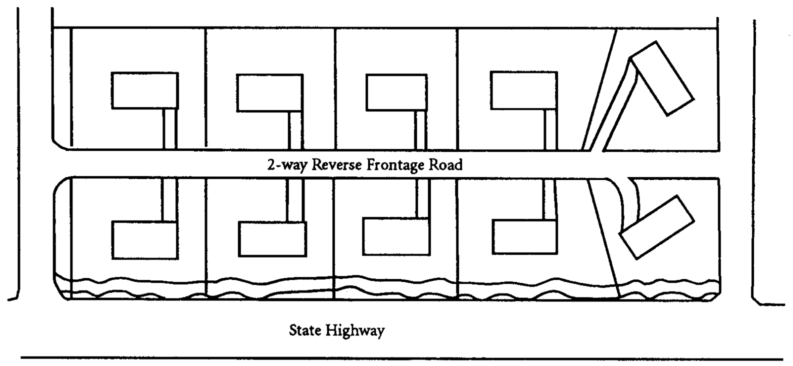


Figure 13. *Illustration of a reverse frontage road concept (Gluck, Levinson & Stover, 1999).*

- By eliminating accesses from the main road, the through-lanes are protected from encroachments, conflicts and delays.

- Frontage roads introduce more circuitous access to adjacent land developments.

- Frontage roads may allow closer access spacing than would be practical on main travel lanes. Frontage roads are not used by through-traffic and speeds are generally lower than on main travel lanes.

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