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Final Report

METHODOLOGY FOR ASSESSING THE EFFECTIVENESS OF ACCESS MANAGEMENT TECHNIQUES

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Prepared for

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16. Abstract

A methodology for assessing the effectiveness of access management techniques on suburban arterial highways is developed. The methodology is described as a seven-step process as follows: (1) establish the purpose of the analysis (2) establish the measures of effectiveness (3) divide the arterial corridor into one or more subareas (4) examine candidate access management techniques for each subarea (5) perform analysis and determine MOEs for each subarea (6) select the best access management technique(s) for each subarea and (7) estimate MOEs for the whole corridor. The candidate access management techniques are divided into six groups: (1) signalized intersections (2) unsignalized intersections and driveways (3) medians (4) left-turns (5) right-turns and (6) service road. Each group further consists of several access management techniques. A case study of subareas 1,4, and 8 of US 27 Colerain Avenue in Cincinnati, Ohio was performed. The results showed that travel speed in some segments of the subareas had decreased and accident rates in some subareas had increased after the installation of traffic signals. It is recommended that the methodology developed in this study be used for planning and/or evaluation of access management techniques on suburban arterial highways. The adoption of the methodology would assist the Ohio Department of Transportation to maintain uniformity and consistency in the conduct of access management studies in the state. Additional recommendations concerning subareas 1,4, and 8 of US 27 Colerain Avenue are made.

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DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specifications, or regulations.

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EXECUTIVE SUMMARY

Methodology for Assessing the Effectiveness of Access Management Techniques

1. Methodology

A thorough literature review of current access management techniques for suburban arterial highways was performed. Based on the findings of the literature review and current practices, a methodology for assessing the effectiveness of access management techniques on suburban arterial highways was developed. The methodology is described as a seven-step process as follows:

Step 1: Establish the Purpose of the Analysis

The methodology can be used either as a planning or as an evaluation tool.

Step 2: Establish the Measures of Effectiveness

The methodology suggests two primary measures of effectiveness (MOEs):

(1) Travel speed, and
(2) Accident rate

Step 3: Divide the Arterial Corridor into One or More Subareas

The arterial corridor is divided into one or more subareas based on their geometric, traffic, and land-use characteristics.

Step 4: Examine Candidate Access Management Techniques for Each Subarea

The candidate access management techniques for design and implementation are examined. The techniques are divided into six groups as follows:

(1) Signalized intersections
(2) Unsignalized intersections and driveways
(3) Medians
(4) Left-turns
(5) Right-turns
(6) Service road

The techniques under each group are listed below:

Step 4A: Examine the Subareas for Signalized Intersections

a) Establish traffic signal spacing
b) Establish corner clearance
c) Establish access separation distances at interchanges

Step 4B: Examine the Subareas for Unsignalized Intersections and Driveways

a) Establish spacing for unsignalized intersections
b) Consolidate driveways
c) Channelize driveways to discourage or prohibit left-turns on undivided highways
d) Install barrier to prevent uncontrolled access along property frontage
e) Coordinate driveways on opposite sides of the street

Step 4C: Examine the Subareas for Medians

a) Install physical continuous median on undivided highways
b) Replace continuous TWLTL with restrictive median
c) Provide continuous TWLTL
d) Provide median openings
e) Close existing median openings
f) Replace full median openings with median designed for left-turn from major roadway

Step 4D: Examine the Subareas for Left-turns

a) Provide left-turn deceleration lane
b) Provide U-turn as an alternative to direct left-turns
c) Provide jug-handle and eliminate left-turns along highways

Step 4E: Examine the Subareas for Right-turn

a) Install right-turn acceleration lane
b) Install right-turn deceleration lane
c) Install continuous right-turn lane

Step 4F: Examine the Subareas for Service Road

a) Install service road to provide access to individual parcels
b) Locate/relocate the intersection of parallel service road and cross road

Step 5: Perform Analysis and Determine the MOEs for Each Subarea

The next step is to perform an analysis of each subarea and determine the outcomes of the analysis. The outcome should indicate how the previously-defined MOEs are effected if the selected access management techniques are implemented. Many analytical and simulation techniques are currently available for performing the analysis.

Step 6: Select the Best Access Management Technique(s) for Each Subarea

After completing the analysis in step 5 above, the user selects the best access management technique(s) for each subarea. An outcome of this process is an estimation of future travel speed and accident rate in each subarea.

Step 7: Estimate MOEs for the Whole Arterial Corridor

The final step of this process is to estimate the future travel speed and accident rate for the whole arterial corridor.

2. Case Study : US 27 Colerain Avenue in Hamilton County

The methodology described above was used to evaluate the effects of newly installed traffic signals and of existing driveways in subareas 1,4, and 8 of US 27 Colerain Avenue in Hamilton County, Ohio as follows:

a) Subarea #1 – A traffic signal was installed at the intersection of Colerain Avenue and Colerain Crossings on May 18,1995.
b) Subarea #4 – A traffic signal was installed at the intersection of Colerain Avenue and Commons Circle on January 16, 1993, which was converted from a T intersection to a four-legged intersection.
c) Subarea #8 – Since 1991, the subarea has experienced several developments including a large shopping center. A traffic signal was installed at the intersection of Colerain Avenue and Dry Ridge Road.

A simulated study of traffic flow and an analysis of accident data revealed that:

a) Subarea #1

- The travel speeds on some segments of Subarea #1 have decreased; and
- Both accident rate and frequency in the subarea have increased.

b) Subarea #4

- The travel speeds on some segments of subarea #4 have decreased; and
- The frequency of accidents at the intersection of Colerain Avenue and Commons Circle has significantly increased, although there has been a small decrease in accident rate for subarea #4 as a whole.

c) Subarea #8

- Travel speed in Subarea #8 has significantly decreased; and
- Accident frequency in the subarea has increased, although accident rate seems to remain unchanged.

3. Recommendations

Based on the results of this study, we recommend that:

1. The methodology developed in this study be used for planning and/or evaluation of access management techniques on suburban arterial highways in the state of Ohio. The adoption of the methodology would assist ODOT to maintain uniformity and consistency among all districts in the State. It would provide a guideline for departmental personnel and consultants in the performance of access management analysis.

Additionally, based on our examination of traffic flow and safety in Subareas #1, 4, and 8 of Colerain Corridor, we recommend that:

1. The removal of the existing traffic signal at Colerain Crossings be considered.

2. Consolidation of driveways be considered for increasing travel speed in Colerain Corridor.

3. The installation of additional traffic signals in Colerain Avenue be strongly discouraged since more traffic signals would further reduce travel speed. Additionally, we recommend that the removal or consolidation of traffic signals in other subareas be given due consideration.

4. The methodology developed in this study be used in all future planning and evaluation of access management techniques in Colerain Corridor since the traffic volume in the corridor seems to have significantly changed due to the opening of Reagan Highway in Fall, 1997.

METHODOLOGY FOR ASSESSING THE EFFECTIVENESS OF ACCESS MANAGEMENT TECHNIQUES

1 INTRODUCTION

Access management involves providing (or managing) access to land development while simultaneously preserving the flow of traffic on the surrounding road system in terms of safety, capacity and speed (1). The whole roadway, according to access management principles, acts as a system whereby the activity centers, access to and from the centers, and the roads serving them constitute parts of the system. The efficient interaction among these individual parts of the system results in a successful roadway. The degree of access control and management is determined by statute, deeds, zoning and by operational and geometric standards (1). Besides providing easy access to the land, access management principles are also employed while designing a roadway to optimize travel capacity, speed and safety associated with the roadway.

Access and mobility are the main criteria in determining the functions of a street or highway. For example, freeways are designed and operated with limited access but they provide the highest degree of mobility. On the other hand, local streets provide full access to the adjoining properties but they are quite limited in providing mobility.

Safety and efficiency are of paramount interest in the design and operation of streets and highways. However, suburban arterial highways in many cities and counties have experienced deterioration of traffic flow conditions in recent decades. The growth in activity centers and the increase in trip frequency along the arterials have caused congestion and associated unsafe conditions. States, counties, and municipalities have implemented access management techniques to improve traffic flow conditions in the arterials while providing necessary access to the adjoining land.

Several investigations on access management have been performed in the past or are currently underway to provide better knowledge to designers and operators of streets and highways. However, with the growing investments of scarce resources on suburban arterial highways, it is necessary to develop a methodology that can assist planners and engineers to quantify and evaluate the effectiveness of access management techniques. Usually, claims are made that specific access management techniques increase capacity, increase operating speed, and decrease accidents. Only a well-performed evaluation based on a sound methodology can determine if the claims are true. Hence, a methodology that allows such evaluation needs to be developed by ODOT to expedite and bring uniformity to access management techniques in the State.

2 OBJECTIVES

The objective of the study was to develop a methodology for assessing the effectiveness of access management techniques on suburban arterial highways. The scope was limited to the effectiveness of engineering treatments on safety and efficiency. Safety included accident frequency and rate and efficiency included travel speed. Three subareas of the Colerain Corridor (US 27) in Hamilton County, Ohio, where several access management techniques had been implemented in recent years were used as a case study.

3 METHODOLOGY

The research staff performed a thorough literature review of current access management techniques. Important findings from the literature review are excerpted and presented in Appendix A. Based on the findings of the literature review (particularly from Reference 6) and current practices, a methodology for assessing the effectiveness of access management techniques on suburban arterial highways was developed. A flow chart showing the different steps of the methodology is given in Figure 3.1. This methodology allows a user to divide an arterial corridor into one or more subareas as necessary and assess the effectiveness of selected access management technique(s) in each subarea. The outcome of the analysis generally consists of two measures of effectiveness – travel speed and accident rate – which finally determine the impacts of the access management technique(s) employed in the arterial corridor. The methodology is described as a seven-step process in the following sections.

3.1 Steps for Assessing the Effectiveness of Access Management Techniques

Step 1: Establish the Purpose of the Analysis

The methodology can be used either as a planning or as an evaluation tool. During a planning stage, the user can use the methodology to (a) establish the measures of effectiveness, (b) select appropriate access management techniques, (c) perform analysis, and (d) estimate the outcomes. During the evaluation stage, which is normally done after the selected access management techniques are implemented in the field and a driver familiarity period of four to six months is allowed, the methodology can be used to compare the actual outcomes with the estimated outcomes.

Step 2: Establish the Measures of Effectiveness

This methodology suggests two primary measures of effectiveness (MOE's):

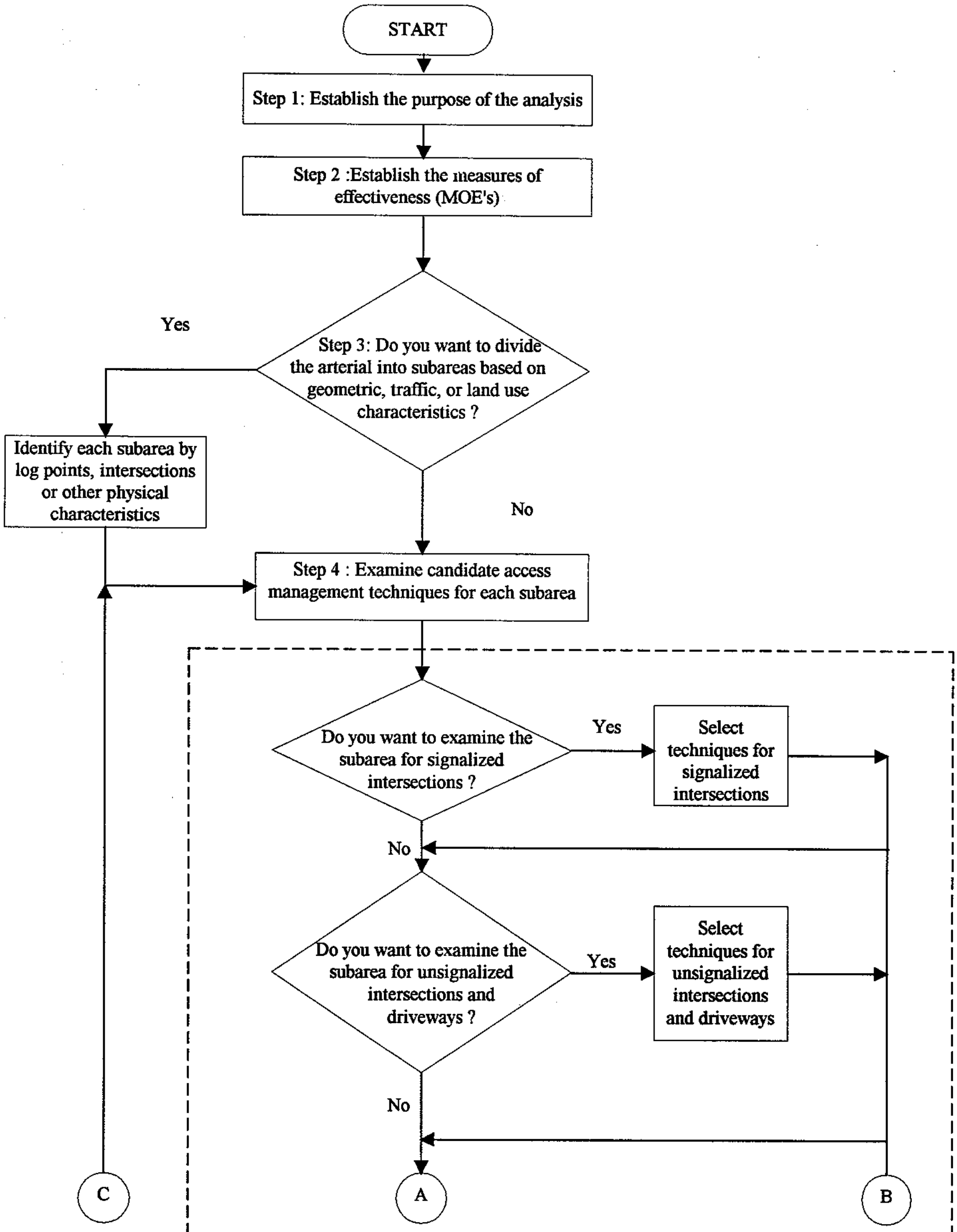
(1) Travel speed
(2) Accident rate

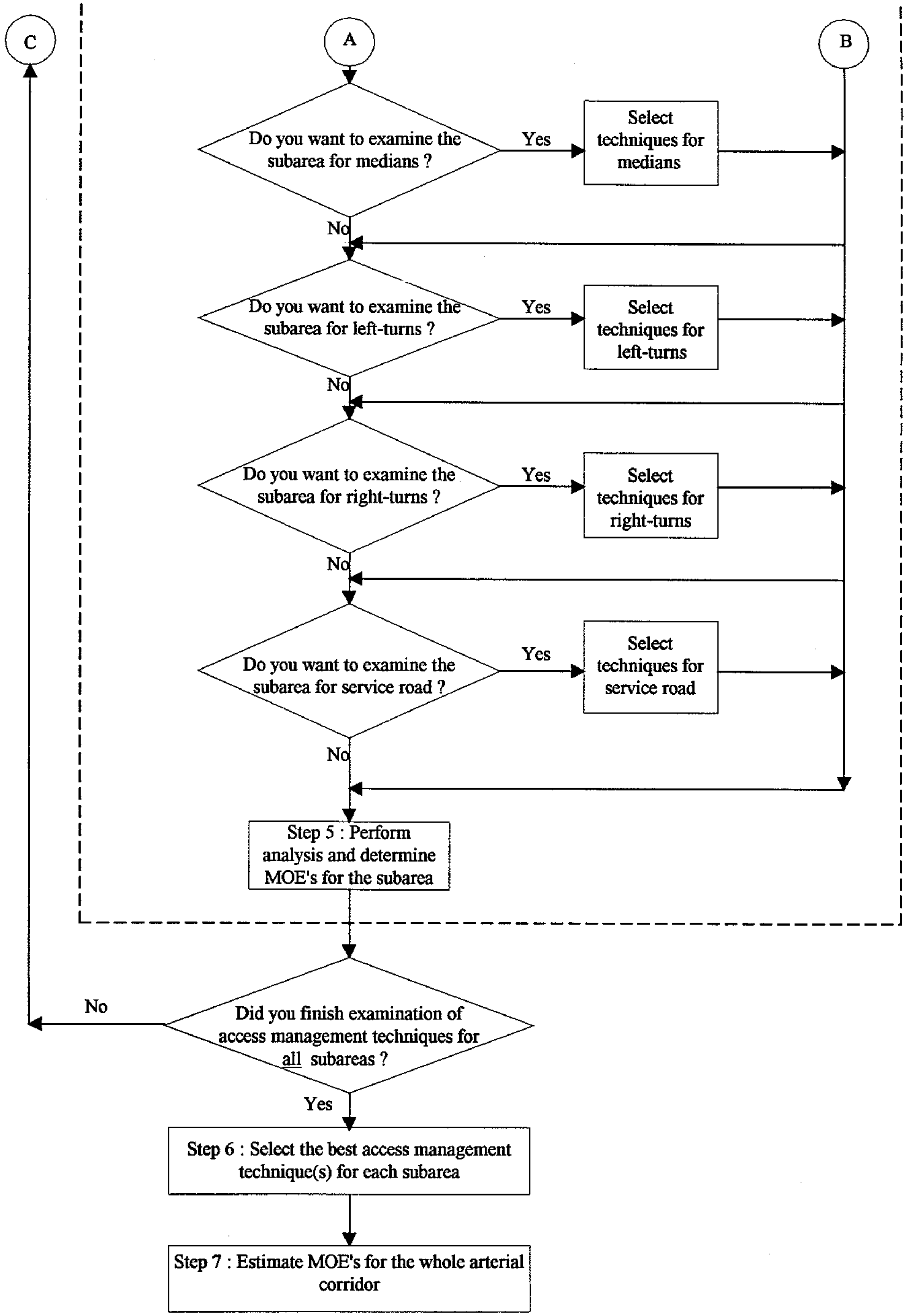
The first MOE represents the efficiency of traffic flow in the arterial corridor and the second MOE represents the safety of motorists and public/private property. Normally, access management for existing arterial highways is undertaken necessary because travel speed and/or safety in the corridor become unacceptable to the agency or the public. It is important to establish the measures of effectiveness during the planning or evaluation stage since neither appropriate access management techniques can be selected nor a rational evaluation of the outcomes of the project can be performed without the MOE's. Other measures of effectiveness such as economic benefits to business or community may be valid reasons for implementation of specific access management techniques; however, an explicit consideration of these and other MOE's are outside the scope of this study.

Step 3 : Divide the Arterial Corridor into One or More Subareas

The arterial corridor is divided into one or more subareas in order to facilitate the selection of appropriate access management techniques. In general, the arterial can be divided into subareas based on its (a) geometric, (b) traffic, or (c) land use characteristics. The geometric characteristics include the number of lanes, type of median (if any), number of intersections, number of driveways etc. The traffic characteristics include traffic volume, conflicting movements, type of control, etc. The land use characteristics include residential, commercial or industrial properties abutting the corridor. Each subarea is identified based on log points, intersections or other physical characteristics.

Figure 3.1 Flow Chart for Assessing the Effectiveness of Access Management Techniques




C
A
B
Do you want to examine the subarea for medians ?
Yes
Select techniques for medians
No
Do you want to examine the subarea for left-turns ?
Yes
Select techniques for left-turns
No
Do you want to examine the subarea for right-turns ?
Yes
Select techniques for right-turns
No
Do you want to examine the subarea for service road ?
Yes
Select techniques for service road
No
Step 5 : Perform analysis and determine MOE's for the subarea
No
Did you finish examination of access management techniques for all subareas ?
Yes
Step 6 : Select the best access management technique(s) for each subarea
Step 7 : Estimate MOE's for the whole arterial corridor

Step 4 : Examine Candidate Access Management Techniques for Each Subarea

After dividing the arterial corridor into one or more subareas, the user should examine candidate access management technique(s) for design and implementation. (See Reference 6 for additional information). In general, the techniques are divided into six groups as follows:

(1) Signalized intersections
(2) Unsignalized Intersections and Driveways
(3) Medians
(4) Left-turns
(5) Right-turns
(6) Service road

Each group consists of several access management techniques. These techniques should be examined to determine if one or more techniques could be identified as potential candidate(s) for access management in a subarea. As mentioned before, an excerpt of information collected during literature review of these techniques is attached in Appendix A. All existing state, county or municipal policies or guidelines should be examined. The techniques under each group are listed below:

Step 4A: Examine the Subareas for Signalized Intersections

a) Establish Traffic Signal Spacing

Traffic signals create delays along roadways due to slowdowns and stops. Signal spacing may have a greater influence on travel speed than traffic volume or volume to capacity ratio. While reviewing signal spacing, removal of existing traffic signals, if necessary, should not be ruled out.

b) Establish Corner Clearance

Adequate distance upstream and downstream of an arterial at an intersection should be allowed. Driveways should not be situated within the functional area of an intersection.

c) Establish Access Separation Distances at Interchanges

Heavy weaving traffic volumes at freeway interchanges are likely to create recurrent traffic congestion and accidents; access separations at these points can alleviate these problems.

Step 4B: Examine the Subareas for Unsignalized Intersections and Driveways

a) Establish Spacing for Unsignalized Intersections

Speed, sight distance, and several other factors, which must be carefully examined, affect the spacing of unsignalized intersections and driveways.

b) Consolidate Driveways

Driveway consolidation requires adjacent property owners to construct joint use driveways, thereby reducing the number of conflict areas on the arterial highway.

c) Channelize Driveways to Discourage or Prohibit Left-turn on Undivided Highways

Channelization of a driveway provides control of the left-turn ingress and egress maneuvers. Providing an island in the driveway can restrict the left-turn maneuvers.

d) Install Barrier to Prevent Uncontrolled Access along Property Frontage

A physical barrier such as guard rail or curb at the property frontage can reduce the conflict area by controlling and defining driveway openings.

e) Coordinate Driveways on Opposite Sides of the Street

Longitudinal separation of driveways on opposite sides of the street can be accomplished by realigning driveways.

Step 4C: Examine the Subareas for Medians

a) Install Physical Continuous Median on Undivided Highway

Left-turns and U-turns across the median except at a few designated locations can be prevented by installing continuous physical median.

b) Replace Continuous TWLTL with Restrictive Median

Continuous TWLTL can be replaced with restrictive medians since two-way left-turn lanes (TWLTL's) may increase rather than control access opportunities.

c) Provide Continuous TWLTL

A two-way left-turn lane can be provided to remove left-turning vehicles from through lanes, especially if there are closely-spaced, low-volume commercial driveways along the arterial highway.

d) Provide Median Openings

Unsignalized median openings at driveways on divided highways can be provided to allow storage for left-turning vehicles, or at locations where signalization is not appropriate due to spacing or other reasons.

e) Close Existing Median Openings

An existing median opening can be closed if left-turning vehicles cause spill back into through lanes or median openings are too closely spaced.

f) Replace Full Median Openings with Median Designed for Left-turn from Major Roadway.

A full median opening can be replaced with a restrictive median that allows only left-turn from the major roadway, thereby reducing the number of conflicting points.

Step 4D: Examine the Subareas for Left-turns

a) Provide Left-turn Deceleration Lane

The treatment of left-turning vehicles at an intersection may be the single most critical activity due to its potential influence on the efficiency and safety of the intersection.

b) Provide U-turn as an Alternative to Direct Left-turns

A U-turn in the median of a divided highway can be used to prohibit left-turns at an intersection and move them to another location from where they can be safely completed.

c) Provide Jug Handles and Eliminate Left-turns along Highways

Providing jug-handle type ramp or diagonal roadway that intersects a secondary crossing roadway can eliminate left-turns along highways.

Step 4E: Examine the Subareas for Right-turns

a) Install Right-turn Acceleration Lane

A right-turn acceleration lane can be installed to facilitate driveway merge maneuvers, especially on high-speed arterial highways.

b) Install Right-turn Deceleration Lane

A right-turn deceleration lane can be installed to remove turning vehicles from the through lanes, thereby reducing the delay for through traffic.

c) Install Continuous Right-turn Lane

A continuous right-turn lane can be installed for use by several nearby driveways.

Step 4F: Examine the Subareas for Service Road

a) Install Service Road to Provide Access to Individual Parcels

A service road facilitates the preservation of the through character of the highway by separating local traffic from the higher-speed through traffic.

b) Locate/Relocate the Intersection of Parallel Service Road and Cross Road

The intersection of parallel service road and cross road can be relocated if the distances between the service road and arterial are short and storage distance on the crossroad is inadequate.

Step 5: Perform Analysis and Determine the MOE's for Each Subarea

From the preceding steps, the user can select one or more possible access management techniques for each subarea. The next step is to perform an analysis of each subarea and determine the outcomes of the analysis. The outcomes should indicate how the previously-defined measures of effectiveness – travel speed and accident rate – are effected if the selected access management techniques are implemented. Many analytical and simulation methods are currently available for performing the analysis. It is not possible to generalize these methods for access management since each subarea is generally unique in its geometric, traffic, and land use characteristics. A potential tool for performing a traffic simulation study is the TRAF software system developed by the Federal Highway Administration.

Step 6: Select the Best Access Management Technique(s) for Each Subarea

After completing the analysis as described above, the user selects the best access management technique(s) for each subarea. An outcome of this process is an estimation of future travel speed and accident rate in each subarea.

Step 7: Estimate MOEs for the Whole Arterial Corridor

The final step of this process is to estimate the future travel speed and accident rate for the whole arterial corridor.

4 CASE STUDY: US 27 COLERAIN CORRIDOR

The methodology described in the previous section was used to evaluate the effects of newly installed signals and of existing driveways in some sections of US 27 Colerain Avenue in Hamilton County in the Cincinnati metropolitan area. The results of the analysis are described below.

Step 1: Establish the Purpose of the Analysis

Colerain Avenue, a part of U.S. 27, is a north/south suburban arterial in the Cincinnati metropolitan area. During the past 30 years, the 4.6 miles long section of Colerain Avenue from Kipling Road to Struble Road within Colerain Township has seen a proliferation of commercial developments, thereby creating numerous driveways on both sides of the highway. Traffic congestion and motorists' safety became serious issues that led to the beginning of a comprehensive study in the early 1990's. Some traffic improvements have been implemented in recent years as part of an access management project and others are in the process of implementation.

The purpose of the analysis is to determine the effects of the newly installed traffic signals and of the existing driveways in a few segments of Colerain Corridor.

Step 2: Establish the Measures of Effectiveness

The measures of effectiveness to be employed in the analysis were:

(a) Travel speed

(b) Accident rate

Thus, the evaluation of the effects of the newly installed traffic signals and the existing driveways were based on these two MOE's.

Step 3 : Divide the Arterial Corridor into One or More Subareas

Earlier, the consultant for the corridor planning study (Pflum, Klausmeier and Gehrum Consultants) had divided the Colerain Corridor into eight Subareas. Subareas 1, 4, and 8 were selected for evaluation. Subareas 1 and 4 were selected because of the installation of new traffic signals at Colerain Crossings and Commons Circle respectively. Subarea #8 was selected in anticipation of some improvements, which have not materialized to date.

Subarea #1 covers the section of Colerain Avenue from the intersection of Galbraith Road to Cross County (now Reagan) Highway Westbound Exit Ramp. The length of the section is about 2368 ft. There are three signalized intersections in this Subarea. The intersections are Galbraith, Colerain Crossings, and Cross County Highway Eastbound Exit Ramp. Along Subarea #1, there are densely-spaced, small-sized commercial properties such as fast food restaurants and specialty stores, as well as a large shopping plaza with K-Mart and other stores. The traffic signal at Colerain Crossings was installed in May 18, 1995, which provided an opportunity to compare travel speeds in the subarea before and after the installation of the traffic signal.

Subarea #4 includes the section of Colerain Avenue between Poole Road and Commons Circle. Like Subarea #1, there are numerous commercial developments with driveways on both sides of Colerain. The length of the section is about 2900 ft. There were three signalized intersections in this Subarea during the period of study. The intersections are Poole Road, Compton Road, and Commons Circle, among which Commons Circle was installed in January 16, 1993. (More recently, a new signal has been installed at Round Top Road; however the effects of this signal are outside the scope of this study.)

Subarea #8 covers the section of Colerain Avenue between I-275 WB Ramps and Struble Road. The length of the section is about 2494 ft. There are three signalized intersections in this subarea namely, the intersections at I-275 WB Ramp, Dry Ridge, and Struble. Unlike Subarea #1 and #4 there are not many driveways in this subarea. However, there exists a large shopping complex with Wal-Mart and many other stores.

Step 4 : Examine Candidate Access Management Techniques for Each Subarea

Since this analysis is performed for evaluation purposes, the analysis was performed as a "before and after" study for each subarea. The access management techniques evaluated for each subarea are as follows:

Subarea #1 – A traffic signal was installed at the intersection of Colerain Avenue and Colerain Crossings on May 18, 1995. The effects of the newly installed traffic signal were evaluated in this study. Additionally, the effects of driveways on both sides of Colerain Avenue were also evaluated.

Subarea #4 - A traffic signal was installed at the intersection of Colerain Avenue and Commons Circle on January 16, 1993, which was converted from a T intersection to a four-legged intersection. The effects of the newly installed traffic signal as well as the driveways on both sides of Colerain Avenue were evaluated.

Subarea #8 - Around 1991 (exact date unknown), a large shopping center opened in this subarea and a traffic signal was installed at the intersection of Colerain Avenue and Dry Ridge Road. The shopping center and the residential developments along Dry ridge Road and in the area north of Subarea #8 have contributed to a large growth in traffic volume on Colerain Avenue. A before/after study was performed to evaluate the effects of these developments on traffic flow and motorists' safety in Subarea #8.

Step 5: Perform Analysis and Determine the MOE's for Each Subarea

The analysis was performed separately for evaluation of traffic flow and safety in each subarea. The evaluation of traffic flow was performed by computer simulation since actual field data before the implementation of the access management techniques were not available. The evaluation of safety was performed by a before/after analysis of accident data in each subarea.

4.1 Traffic Simulation

The information regarding the roadway geometry was based on drawings obtained from the consultant. The research staff in the field collected the data on driveway widths, distance between driveways, and roadside stores. The ODOT (Ohio Department of Transportation) provided the traffic count records for signalized intersections. Signal timing sheets of the signalized intersections in each subarea were obtained from ODOT. The data for driveway traffic volumes during the AM, Noon, and PM peak periods were collected by ODOT using video cameras mounted on mobile vans. The research staff reviewed the videotapes and counted the number of vehicles exiting and entering each driveway during the three periods. Figures 4.1, 4.2, and 4.3 show the high number of driveways on both sides of Colerain Avenue.

Computer simulation was used to examine the travel speeds before and after the installation of the traffic signal. The effects of the driveways on traffic flow were examined under different conditions. In each case, the number of driveways as well as the entering and exiting traffic volumes remained unchanged. In another case, all driveways in the subareas were assumed to be non-existent. The latter assumption was made to provide a "what if" example of the effects of driveways on travel speed in the subareas. Past studies have used TRAF-NETSIM, a program developed by the Federal Highway Administration, for simulation of traffic flow on surface streets. In this study, CORSIM Version 1.03, which contains NETSIM, was used.

As mentioned before, the objective of simulation was to evaluate the effects of traffic signals and driveways in the subareas. For Subarea #1, four cases were simulated for each of three peak periods – AM, Noon, and PM. The traffic volume data for 1996 were used. The analysis was performed for the following four cases:

Case 1 : Traffic signal installed at Colerain Crossings; and all current driveways exist in the subarea

Case 2 : Traffic signal installed at Colerain Crossings; and no driveways exist in the subarea

Case 3 : No traffic signal installed at Colerain Crossings; and current driveways exist in the subarea.

Case 4 : No traffic signal installed at Colerain Crossings, and no driveways exist in the subarea.

Case 1 represents the effects of the installation of the new traffic signal at Colerain Crossings and the existing driveways in the subarea. However, Case 2 assumes a hypothetical situation where no driveways exist in the subarea (that is, all driveways on both sides of Colerain Avenue were removed from the network). The vehicles that were exiting from the driveways and entering into the driveways were deducted from the through traffic volume in the arterial. Case 3 assumes non-existence of the traffic signal at Colerain Crossing. Driveways in Cases 3 and 4 are treated in the same way as in Cases 1 and 2 respectively.

Figure 4.1 Colerain Avenue (Subarea #1)

(Distances are approximate values in feet.)

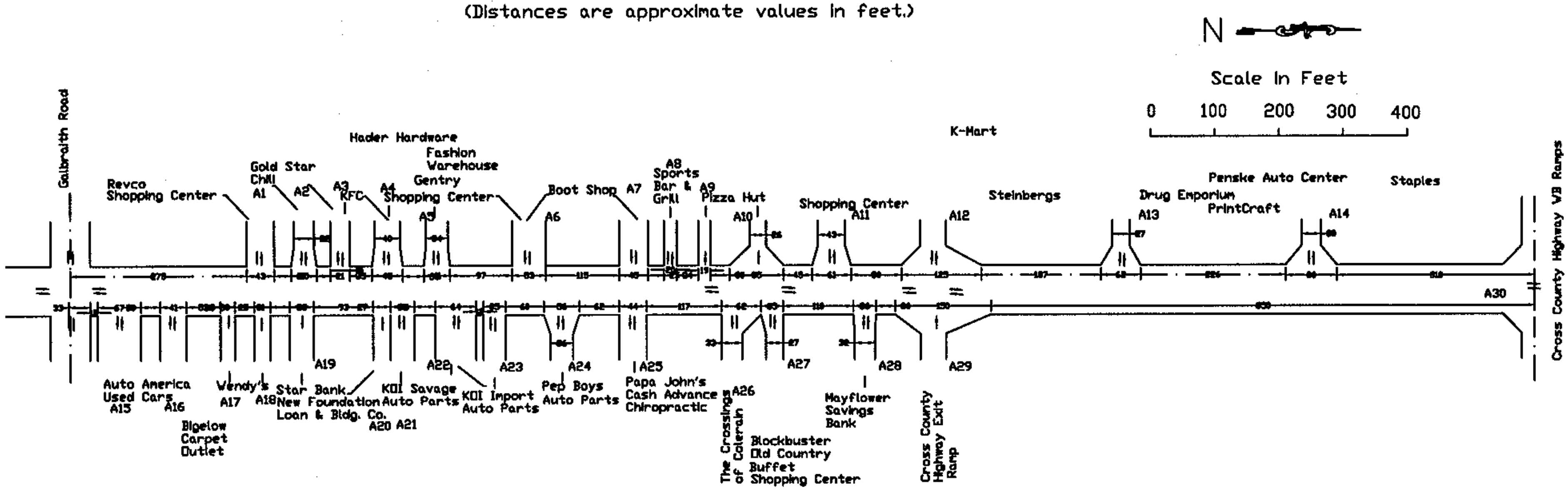
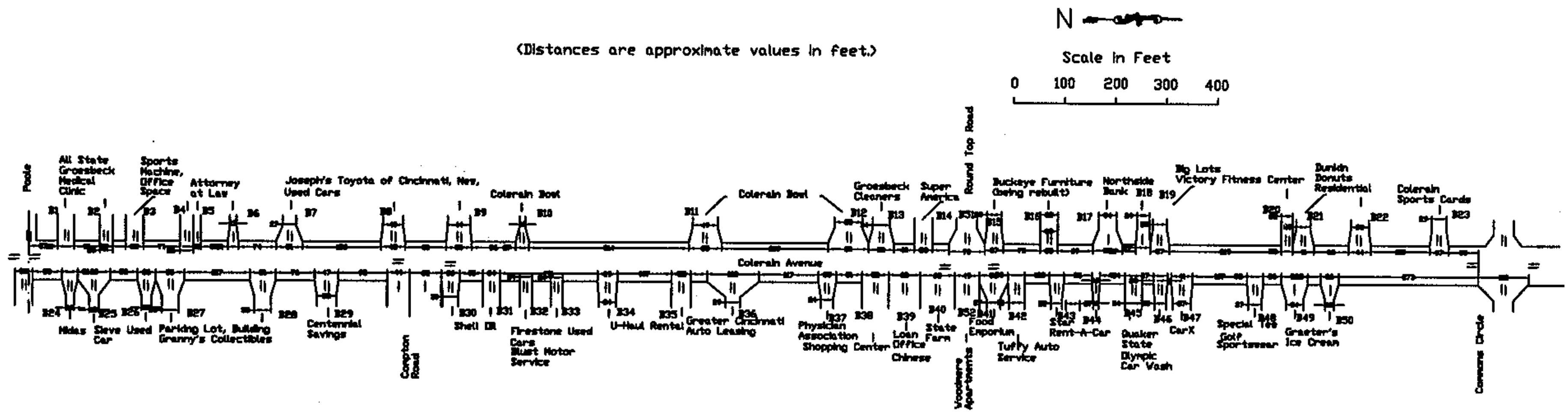


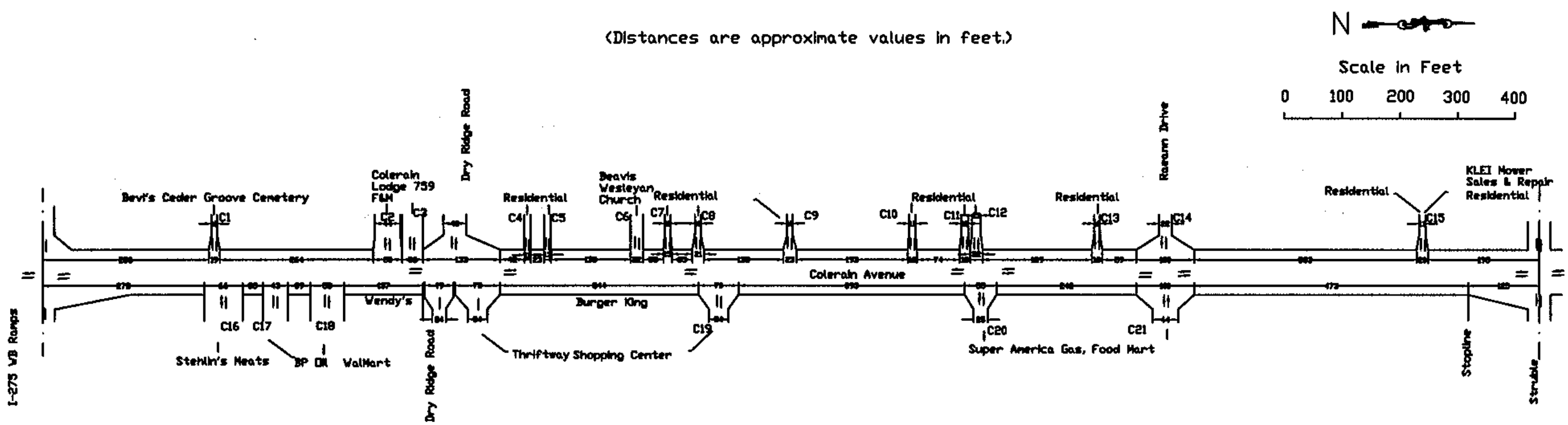
Figure 4.2 Colerain Avenue (Subarea #4)



(Distances are approximate values in feet.)

Figure 4.3 Colerain Avenue (Subarea #8)

(Distances are approximate values in feet.)



A comparison between Cases 1 and 3 or between Cases 2 and 4 revealed the effects of the new traffic signal at Colerain Crossings with or without the existing driveways in the subarea. Similarly, a comparison between Cases 1 and 2 or between Cases 3 and 4 represented the effects of the driveways in the subarea with or without the traffic signal at Colerain Crossings.

For Subarea #4, four cases were simulated for each of three peak periods – AM, Noon, and PM. The analysis were performed for the following four cases:

Case 1 : Traffic signal installed at Commons Circle; and all current driveways exist in the subarea

Case 2 : Traffic signal installed at Commons Circle; and no driveways exist in the subarea

Case 3 : No traffic signal installed at Commons Circle; and current driveways exist in the subarea.

Case 4 : No traffic signal installed at Commons Circle, and no driveways exist in the subarea.

Thus, it can be seen that the four cases in Subarea #4 are similar to those in Subarea #1 except that the simulation for Subarea #4 considered the effects of the new traffic signal at Commons Circle. In these cases, Round Top Road was considered as an unsignalized intersection since the traffic data were collected before the installation of a traffic signal at Round Top Road in Summer 1997. In Cases 3 and 4, Commons Circle was considered as an unsignalized Tee intersection with no roadway approach on the west side of Colerain Avenue.

For Subarea #8, the number of driveways between the signalized intersections is low. Hence, the following two cases were simulated for each of the three peak periods to evaluate the effects of the traffic signal installed at Dry Ridge Road and the opening of the shopping center with Wal-Mart and other stores.

Case 1 : Study year 1996. All existing driveways and traffic signals at I-275 WB Ramp, Dry Ridge Road, and Struble Road.

Case 2 : Study year 1990. All existing driveways and traffic signals at I-275 WB Ramp and Struble Road (that is, no traffic signal at Dry Ridge Road).

Note that Case 1 uses 1996 traffic volume data whereas Case 2 uses 1990 traffic volume data.

Finally, although it is the goal of the NETSIM software to simulate the real world conditions, it should be remembered that the results don't necessarily represent the absolute values of travel speeds in the subareas. Hence, the results of simulations should only be used to examine the relative differences in travel speeds between different cases.

4.1.1 Simulation Results

Subarea #1

A comparison between Cases 1 and 2 and between Cases 3 and 4 for Subarea #1 revealed the following:

- During the AM peak period, the driveway traffic volumes were 7% and 10% of the arterial traffic volumes in the northbound and southbound directions respectively. Since the driveway volume was low, it did not have any significant impact on the arterial travel speed.
- During the Noon peak period, the driveway traffic volumes were 30% and 34% of the arterial traffic volumes in the northbound and southbound directions respectively. During this period a complete elimination of driveways on both sides of Colerain Avenue showed an increase of 15% (3 mph) in travel speed between Colerain Crossings and Cross County Highway Exit Ramp and an increase of 11% (2 mph) in travel speed between Colerain Crossings and Galbraith Road.
- During the PM peak period, the driveway traffic volumes were 22% and 25% of the arterial traffic volumes in the northbound and southbound directions respectively. The elimination of driveways showed an increase of 21% (4 mph) in travel speed between Colerain Crossings and Cross County Highway Exit Ramp and an increase of 23% (4 mph) between Colerain Crossings and Galbraith Road.

A comparison between Cases 1 and 3 and between Cases 2 and 4 revealed the following:

- The installation of the new traffic signal at Colerain Crossing has some impact especially on the southbound traffic. A decrease of 11% (3 mph) in travel speed was observed between Cross County Highway Exit Ramp and Colerain Crossing during the PM Peak period.

Table 4.1 Comparison Between Different Cases During AM Peak Period in Subarea #1

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Galbraith To Colerain Crossings	29.2	29.5	30.2	30.4
Colerain Crossings To CCH Exit Ramp	19.9	21.5	20.2	19.9
CCH Exit Ramp To End of Sub Area#1	30.0	31.0	30.0	31.0
End of Sub Area#1 To CCH Exit Ramp	30.1	29.5	30.2	29.5
CCH Exit Ramp To Colerain Crossings	28.5	28.5	29.7	29.7
Colerain Crossings To Galbraith	19.1	20.6	19.0	20.9

Table 4.2 Comparison Between Different Cases During Noon Peak Period in Subarea #1

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Galbraith To Colerain Crossings	29.2	30.2	29.9	30.4
Colerain Crossings To CCH Exit Ramp	**18.7**	**21.9**	**19.0**	**21.9**
CCH Exit Ramp To End of Sub Area#1	30.5	31.7	30.5	31.4
End of Sub Area#1 To CCH Exit Ramp	27.9	29.7	28.0	29.7
CCH Exit Ramp To Colerain Crossings	28.2	28.2	29.3	29.5
Colerain Crossings To Galbraith	**17.4**	**19.7**	**16.6**	**19.7**

Table 4.3 Comparison Between Different Cases During PM Peak Period in Subarea #1

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Galbraith To Colerain Crossings	26.9	28.2	27.7	29.6
Colerain Crossings To CCH Exit Ramp	**15.4**	**19.5**	**14.6**	**18.1**
CCH Exit Ramp To End of Sub Area#1	29.8	31.1	29.8	31.1
End of Sub Area#1 To CCH Exit Ramp	25.0	26.4	24.7	26.2
CCH Exit Ramp To Colerain Crossings	**23.8**	**24.6**	**26.8**	**28.5**
Colerain Crossings To Galbraith	**13.8**	**17.9**	**13.6**	**17.2**

Subarea #4

A comparison between Cases 1 and 2 and between Cases 3 and 4 revealed the following:

- During the AM peak period, the driveway traffic volume was 15% of the arterial traffic volume in both northbound and southbound directions. The elimination of driveways showed some impact on the arterial travel speed especially for the segment between Poole Road and Compton Road. An increase of 8% (2 mph) in travel speed was observed for both southbound and northbound directions between these two intersections.
- During the Noon peak period, the driveway traffic volume was 24% and 22% in the northbound and southbound directions respectively. The elimination of driveways showed some significant impact on the arterial speed. An increase of 29% (6 mph) in arterial travel speed was observed between Poole and Compton Road and an increase of 10% (3 mph) was observed between Compton Road and Commons Circle. Also an increase of 6% (2 mph) in travel speed was observed between Commons Circle and Compton Road and an increase of 10% (2 mph) between Compton Road and Poole Road.
- During the PM peak period, the driveway traffic volume is 20% of the arterial volume in both northbound and southbound directions. The elimination of driveways showed some significant impact on the arterial travel speed. An increase of 64% (10 mph) in travel speed was observed between Poole and Compton Road and an increase of 22% (6 mph) was observed between Compton Road and Commons Circle. Also an increase of 18% (4 mph) in arterial travel speed was observed between Compton and Poole Road.

A comparison between Cases 1 and 3 and between Cases 2 and 4 revealed the following:

- The installation of the new traffic signal at Commons Circle showed some impact in travel speed especially on the northbound traffic. A decrease of 24% (7 mph) in travel speed was observed between Compton Road and Commons Circle during the PM peak period. During the Noon and AM peak periods, the decrease in travel speed for the same link was 10% (3 mph) and 6% (2 mph) respectively. Since Commons Circle is at the northern end of Subarea #4, the impact of this signal on the southbound traffic in advance of the intersection was not evaluated.

Table 4.4 Comparison Between Different Cases During AM Peak Period in Subarea #4

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Poole To Compton	**22.0**	**23.8**	**21.8**	**23.8**
Compton To Commons Circle	28.0	28.7	29.9	31.0
Commons Circle To Compton	28.0	29.0	28.7	29.9
Compton To Poole	**21.0**	**22.9**	**21.8**	**23.8**

Table 4.5 Comparison Between Different Cases During Noon Peak Period in Subarea #4

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Poole To Compton	**15.1**	**21.1**	**17.3**	**21.3**
Compton To Commons Circle	**25.9**	**28.6**	**28.7**	**30.1**
Commons Circle To Compton	**25.9**	**27.6**	**27.6**	**28.9**
Compton To Poole	**16.9**	**18.8**	**16.4**	**18.3**

Table 4.6 Comparison Between Different Cases During PM Peak Period in Subarea #4

LINK	SPEED (mph)			
	Case1	Case2	Case3	Case4
Poole To Compton	**5.9**	**16.2**	**5.4**	**15.4**
Compton To Commons Circle	**21.3**	**27.3**	**28.0**	**29.7**
Commons Circle To Compton	24.2	25.6	25.1	25.7
Compton To Poole	**17.9**	**21.7**	**16.0**	**21.5**

Subarea #8

A comparison between the two cases for Subarea #8 is given below.

- During AM peak in 1990, the average travel speed between I-275 and Dry Ridge Road was 28.2 mph which reduced to 15 mph in 1996, indicating a decrease of 47% (13 mph) in travel speed. Also a decrease of 27% (8 mph) in travel speed was observed for the section between Struble Road and Dry Ridge Road.

- During the Noon peak period in 1990, the average travel speed was 29 mph between I-275 and Dry Ridge Road which decreased to 13 mph in 1996, indicating a decrease of 57% (16 mph) in travel speed for this section. Also, a decrease of 29% (9 mph) in travel speed was observed for the section between Struble and Dry Ridge Road.

- During the PM peak period in 1990, the average travel speed was 28 mph between I-275 and Dry Ridge Road. In 1996 the average speed was reduced to 8 mph, indicating a decrease of 71% (20 mph) in travel speed for this section. Also a decrease of 30% (9 mph) in travel speed was observed for the section between Struble Road and Dry Ridge Road.

Table 4.7 Comparison Between Different Cases During AM, Noon, and PM Peak Period in Subarea #8

LINK	SPEED (mph)					
	AM		NOON		PM	
	Case1	Case2	Case1	Case2	Case1	Case2
I-275 To Dry Ridge	**15.0**	**28.2**	**12.5**	**28.9**	**8.0**	**27.9**
Dry Ridge To Struble	20.3	26.3	25.5	25.9	15.8	21.6
Struble To Dry Ridge	**22.3**	**30.6**	**21.9**	**31.1**	**21.5**	**30.8**
Dry Ridge To I-275	13.0	13.8	15.3	19.0	10.4	15.8

4.2 Accident Analysis

The following sections describe the analysis of historical accident data for Subareas #1, 4 and 8.The analysis is based on computer printouts of individual accident records for six years (1990-1996) obtained from the Ohio Department of Transportation.

Subarea#1

A traffic signal was installed at the intersection of Colerain Crossing and US 27 on May 18, 1995. The analysis was performed for nineteen and a half months before the installation of the traffic signal (10/01/93-05/17/95, which covers 594 days) and nineteen and a half months after the installation of the traffic signal (05/18/95-12/31/96, which also covers 594 days).

Table 4.8 summarizes the frequency of accidents based on severity. It shows that the total number of accidents increased from 62 to 78 (that is, an increase of 25.8 percent) and the number of property damage only (PDO) accidents increased from 39 to 53 (that is, an increase of 35.9%), indicating that motorists' safety in subarea #1 has deteriorated in recent years. Accident rates during the before and after periods were calculated as follows:

$$R = (A\ 1{,}000{,}000)/(365\ TVL)$$

where,

R = Accident rate for the subarea per million vehicle-miles
A = Number of accidents during the analysis period
T = Time of analysis in years
V = Average annual daily traffic during the analysis period
L = Length of the section in miles

Based on the Traffic Count Books (1991 and 1994) obtained from the Ohio-Kentucky-Indiana Regional Council of Governments, the ADTs were assumed as follows:

10/01/93 - 05/17/95 --- 40,000
05/18/95 – 12/31/96 --- 41,867

The calculations showed that the accidents rates were as follows:

Before - 5.79 accidents per million veh-mi
After - 6.96 accidents per million veh-mi

The results indicated that accident rate in subarea #1 increased during the after period. The accidents at the intersection of US 27 and Colerain crossings did not seem to increase (Table 4.9). However, the comparison may not be valid due to the small number of accidents at this intersection.

Figure 4.4 depicts the spatial distribution of accidents; the same data are illustrated in Figure 4.5. A significantly large number of accidents occurred at or near the intersection of Galbraith Rd and US 27. The data for this intersection were separately tabulated (Table 4.10). An interesting observation is that fewer accidents happened in 1995 than any other year. The collision diagrams for the before and after periods for the intersections of US 27 & Galbraith Road and for US 27 & Eastbound Cross County Highway Ramp are presented in Appendix B (Figure B.2.1 to Figure B.4.1).

In Table 4.11, accidents are classified according to weather conditions. Most of the accidents occurred under normal weather conditions. During the before period, 12 out 62 accidents (that is, 19 percent) occurred under rainy conditions, while only 6 out of 78 (that is, 8 percent) accidents occurred under rainy conditions during the after period.

In Figure 4.6, the accidents are classified based on the day-of-week. Fridays and Saturdays were the days with highest number of accidents before the signal was installed, while Tuesdays and Fridays were the days with highest number of accidents after the installation.

Figure 4.7 illustrates the hourly distribution of accidents. About 82% accidents occurred between 10:00 AM and 9:00 PM (store opening hours), both during the before and after periods. The highest hourly frequency of accidents occurred during the afternoon peak traffic period.

Subarea #4

A traffic signal was installed at the intersection of Commons Circle and US 27 on January 16, 1993. An accident analysis for subarea #4 was performed for three years before the installation of the traffic signal (01/16/90-01/15/93) and three years after the installation (01/16/93-01/15/96).

Table 4.12 summarizes the frequency of accidents based on severity. The total number of accidents increased from 200 to 205 (that is, an increase of 2.5 percent) indicating only a minor change during these periods.

Accident rates were calculated as for Subarea#1 before. The ADTs during the before and after periods were assumed as follows:

Before (01/16/90 – 01/15/93) --- 36,000
After (01/16/93 – 01/15/96) --- 39,800

The calculations revealed that the accident rates were as follows:

Before --- 7.93 accidents per million veh-mi
After --- 7.35 accidents per million veh-mi

The results confirm that there was a small decrease in accident rate during the after period.

Figure 4.8 depicts the spatial distribution of accidents; the same data are illustrated in Figure 4.9. The data shows that the accidents occurred along the entire length of Subarea #4, with high concentrations at or near the intersections of Poole Road, Compton Road, Round Top Road, and Commons Circle. Figures B.5.1 to B.8.2 in Appendix B show the collision diagrams for these locations. At Commons Circle (Table 4.13), where the new traffic signal was installed, both the number and the severity of accidents increased during the after period. Twenty three accidents occurred at his intersection before the signal was installed, which increased to 30 accidents (that is, an increase of 30 percent) after the installation of the traffic signal. The number of rear-end accidents increased from 8 to 14 (that is, an increase of 75 percent).

In Table 4.14, accidents are classified according to weather conditions. Most of the accidents occurred under normal weather conditions. During the before period, 43 out 200 accidents (that is, 22 percent) occurred under rainy conditions, while only 28 out of 205 (that is, 14 percent) accidents occurred under rainy conditions during the after period

In Figure 4.10 the accidents are classified based on the day-of-week. Fridays and Saturdays were the days with highest number of accidents before the signal was installed, while Thursdays and Fridays were the days with the highest number of accidents after the installation.

Figure 4.11 illustrates the hourly distribution of accidents. About 84% to 89% accidents occurred between 10:00 AM and 9:00 PM (store opening hours), with heavy concentrations in the afternoon.

Subarea #8

In Subarea #8, accident data for three "before" years (01/16/90-01/15/93) were compared with accident data for three "after" years (01/16/93-01/15/96). Table 4.15 summarizes the accidents based on severity. The total number of accidents increased from 97 to 107 (that is, an increase of 10 percent).

Accident rates for the before and after periods were calculated. The ADTs assumed for subarea#4 were used since they covered the same periods. The calculations showed that the accident rates were as follows:

Before -- 4.03 accidents per million veh-mi
After -- 4.02 accidents per million veh-mi

The results indicated no change in accident rate during the two periods.

Figure 4.12 depicts the spatial distribution of accidents; the same data are illustrated in Figure 4.13. Figures B.9.1 to B.10.2 in Appendix B are the before-after collision diagrams for these locations.

In Table 4.16, accidents are classified according to weather conditions. Most of the accidents occurred under normal weather conditions. During before period, 20 out of 97 accidents (that is, 21 percent) took place under rainy weather conditions, while only 17 out of 87 (that is, 16 percent) accidents did during after period.

In Table 4.17 the temporal dimension of accident is illustrated. The accidents are classified based on the year they occurred.

In Figure 4.14 the accidents are classified based on the day-of-week. Mondays and Fridays were always the two days with the highest number of accidents.

Table 4.8 Subarea #1 Accident Frequency by Severity

No. of Accidents	Total	Fatal	Injury	Property Damage Only
Before	62	0	23	39
After	78	0	25	53
Change (%) + = Increase - = Decrease	+25.8%	-	+8.7%	+35.9%

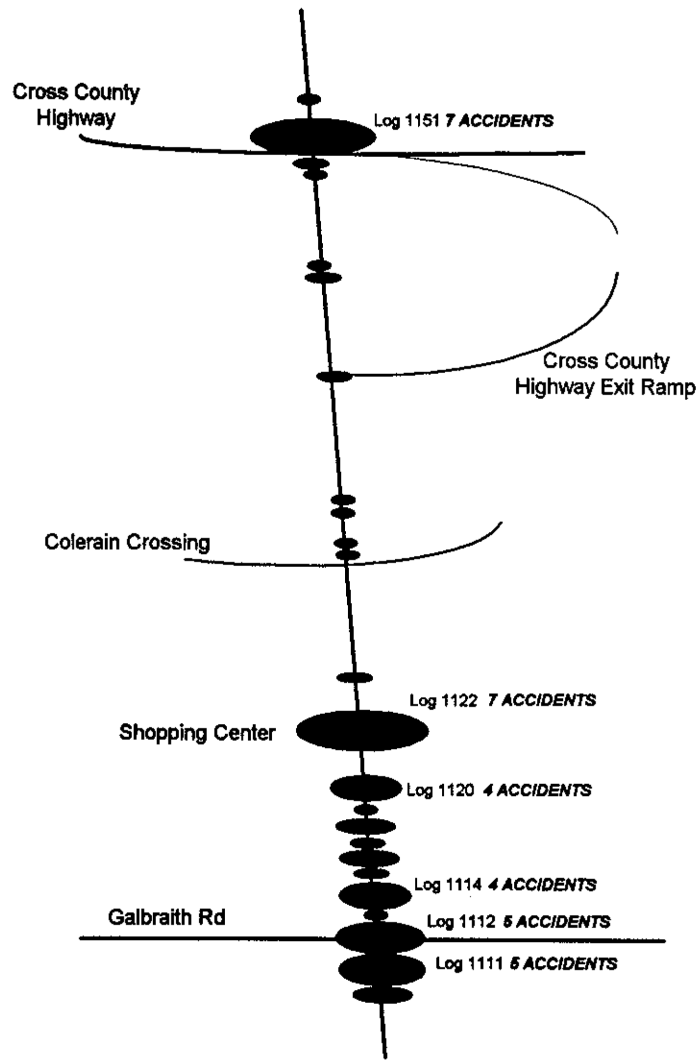
Change (%) = [(before - after)/before]*100

Table 4.9 Accident Frequency by Severity at the Intersection of US 27 and Colerain Crossing

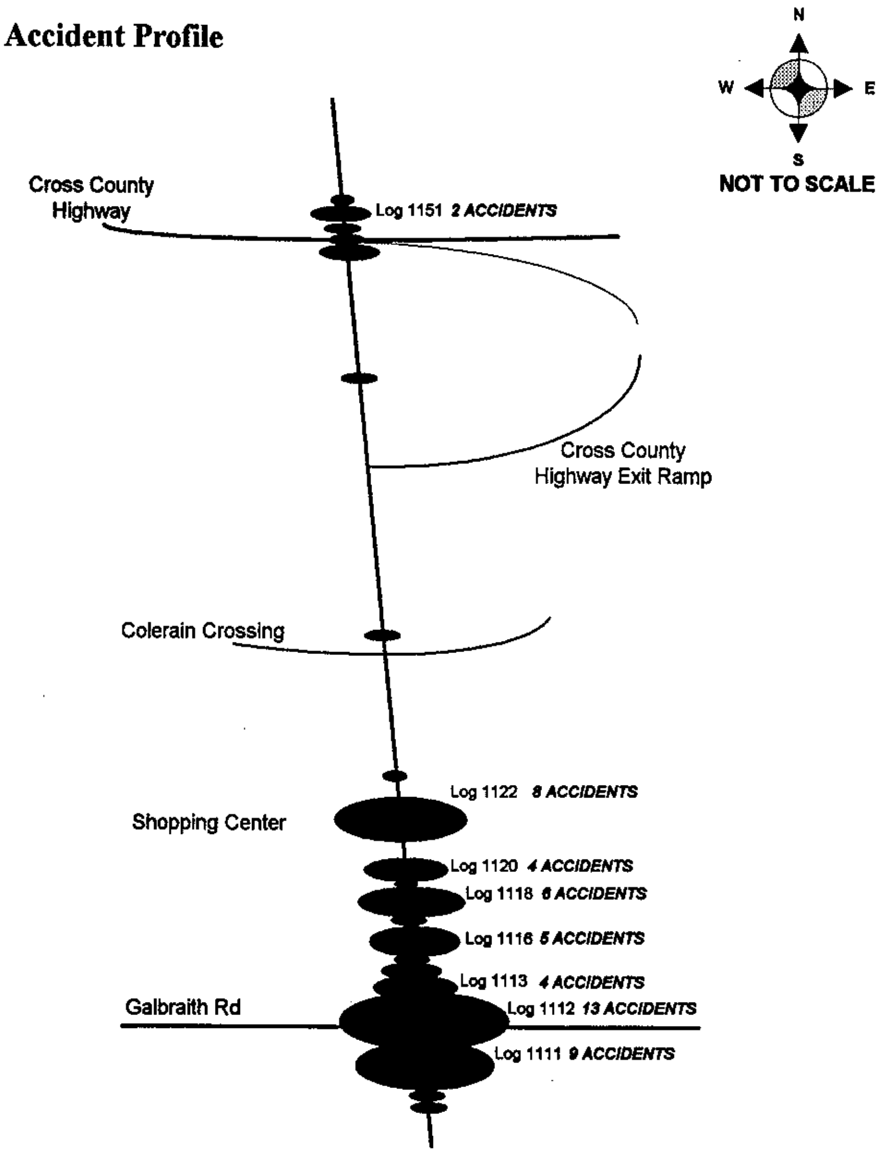
No. of Accidents	Total	Fatal	Injury	Property Damage Only
Before	4	0	2	2
After	2	0	0	2
Change(%) +=Increase -=Decrease	-50%	-	-100%	0

Change(%)=[(before-after)/before]*100

Figure 4.4 Subarea #1 Accident Profile

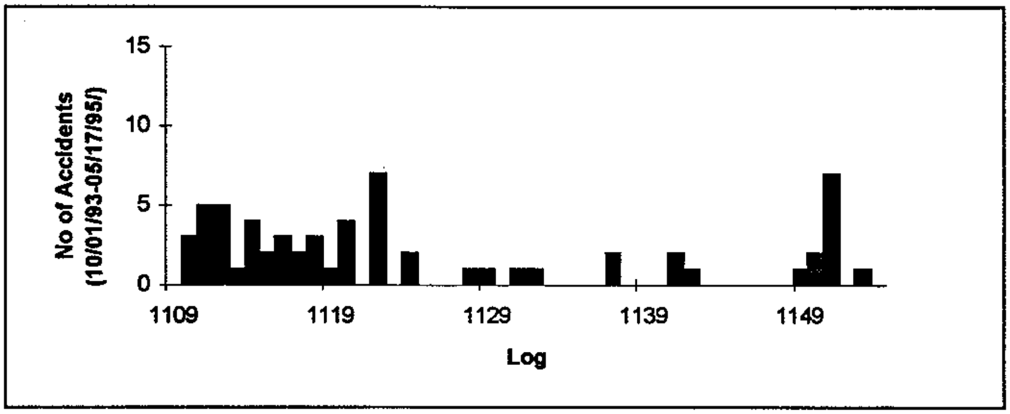


(a) 10/01/93 - 05/17/95



(b) 05/18/95 - 12/31/96

Figure 4.5 Subarea #1 Spatial Distribution of Accidents



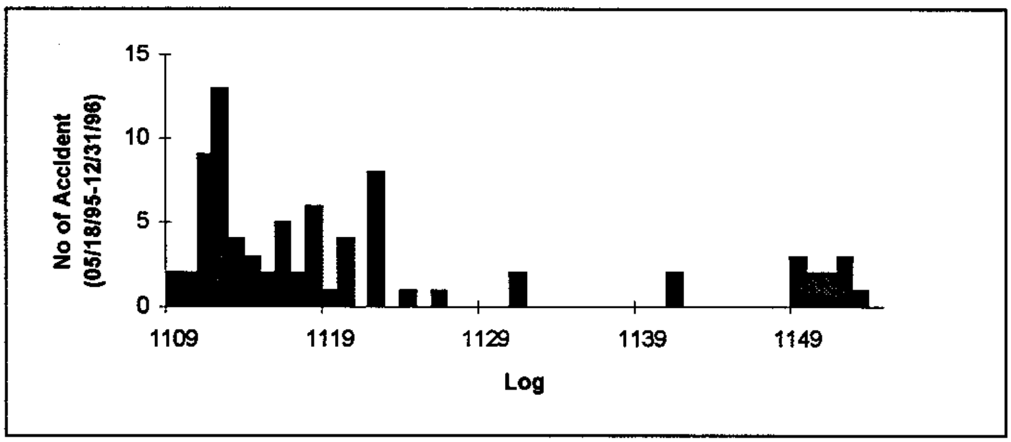


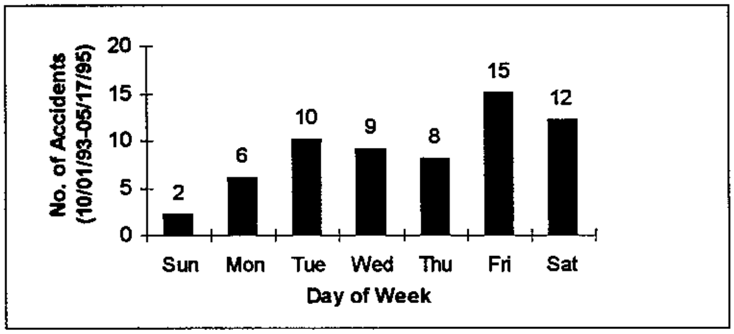
Table 4.10 Subarea #1 Accident Distribution by Year

<table>
<tr><th colspan="2">Year</th><th colspan="2">Total No. of Accidents in Subarea #1</th><th colspan="2">Total No. of Accidents at the Intersection of Galbraith Rd</th></tr>
<tr><td colspan="2">'93(10/01-12/31)</td><td colspan="2">11</td><td colspan="2">4</td></tr>
<tr><td colspan="2">94</td><td colspan="2">46</td><td colspan="2">14</td></tr>
<tr><td rowspan="2">'95</td><td>01/01-05/17</td><td rowspan="2">25</td><td>5</td><td rowspan="2">9</td><td>2</td></tr>
<tr><td>05/18-12/31</td><td>20</td><td>7</td></tr>
<tr><td colspan="2">'96</td><td colspan="2">58</td><td colspan="2">28</td></tr>
</table>

Table 4.11 Subarea #1 Accident Frequency by Weather Conditions

Weather Condition	Total Number of Accidents in Subarea #1		Total Number of Accidents at Galbraith Rd	
	Before	After	Before	After
No Adverse Weather Condition	50	68	18	33
Rain	12	6	2	2
Snow	0	4	0	0
Fog	0	0	0	0

Figure 4.6 Subarea #1 Accident Frequency by Day-of-Week



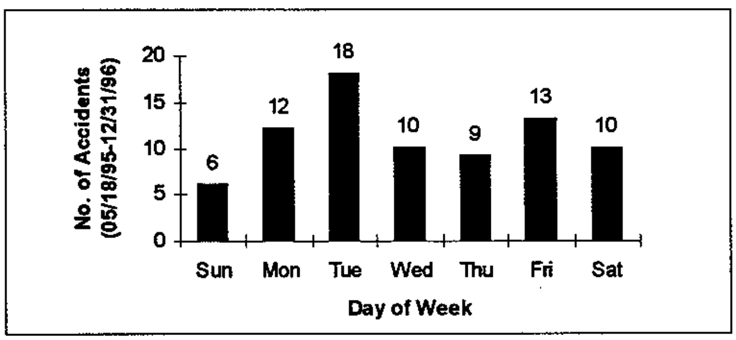
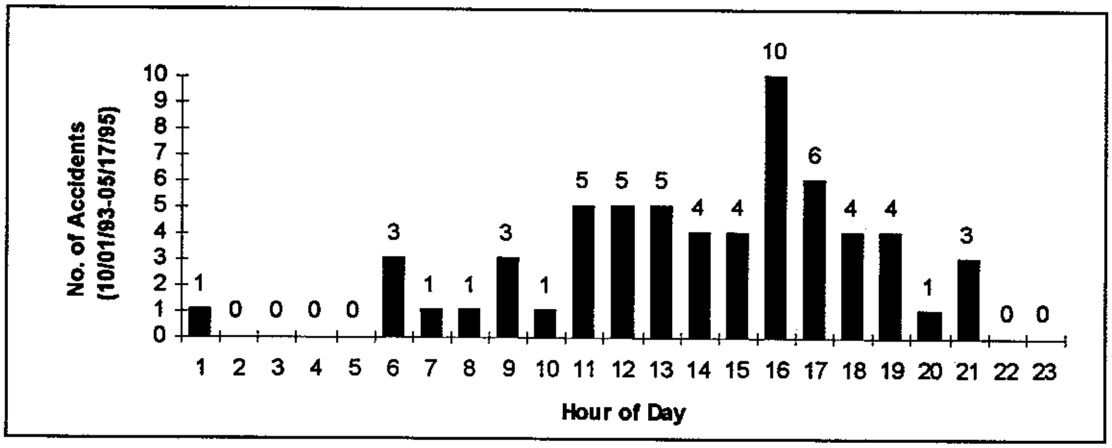


Figure 4.7 Subarea #1 Hourly Distribution of Accidents



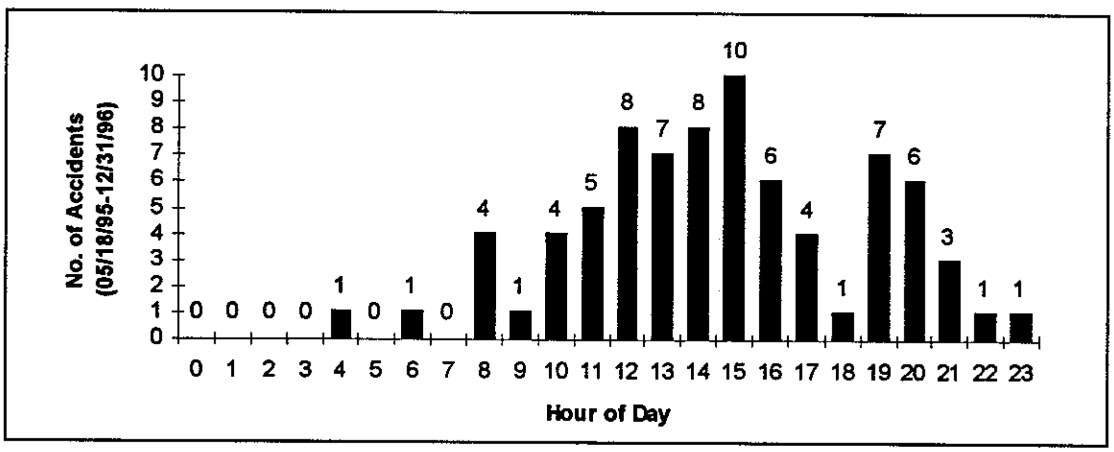


Table 4.12 Subarea #4 Accident Frequency by Severity

No. of Accidents	Total	Fatal	Injury	Property Damage Only
Before	200	0	82	118
After	205	0	77	128
Change (%) + = Increase - = Decrease	+2.5	-	-6.1	+8.5

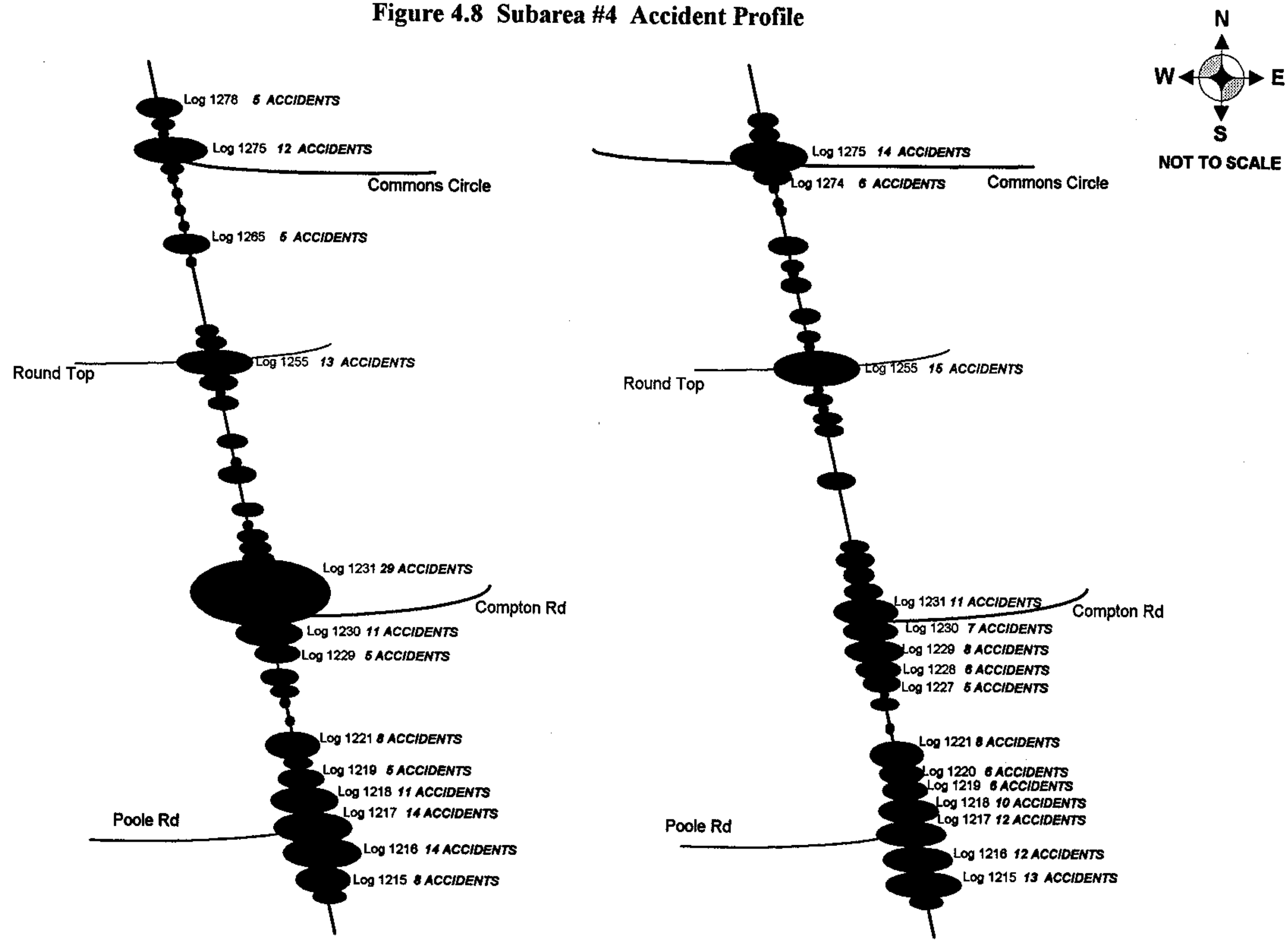
Change (%) = [(before - after)/before]*100

Table 4.13 Accident Frequency by Severity at the Intersection of US 27 and Commons Circle

No. of Accident	Total	Fatal	Injury	Property Damage Only
Before	23	0	4	19
After	30	0	14	16
Change(%) +=Increase -=Decrease	+30.4%	-	+250%	-15.8%

Change(%)=[(before-after)/before]*100

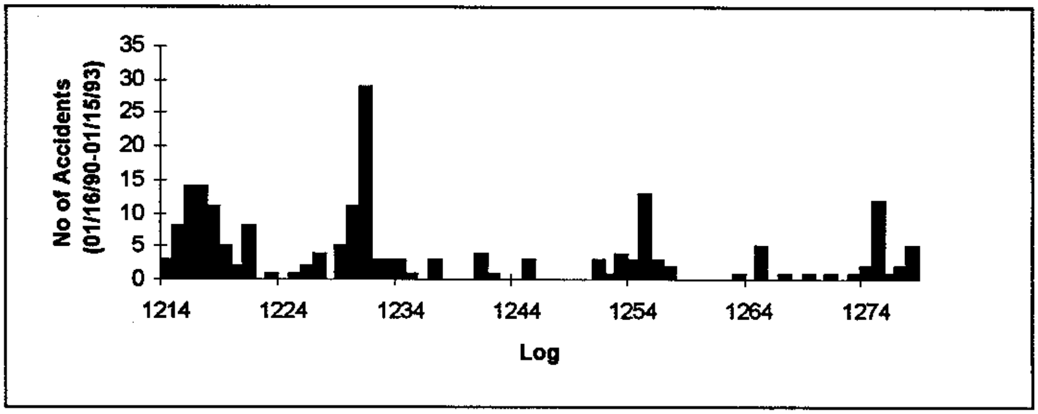
Figure 4.8 Subarea #4 Accident Profile



(a) 01/16/90 - 01/15/93

(b) 01/16/93 - 01/15/96

Figure 4.9 Subarea #4 Spatial Distribution of Accidents



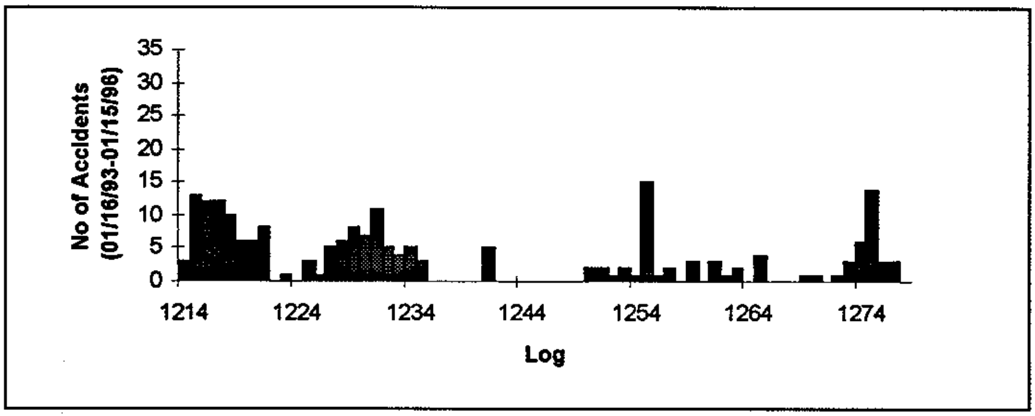
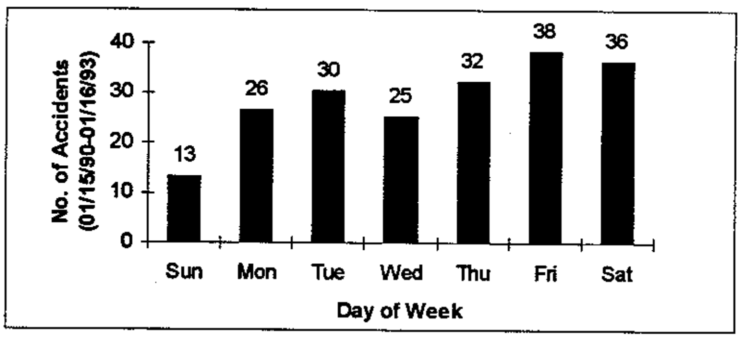


Table 4.14 Subarea #4 Accident Frequency by Weather Conditions

Weather Condition	Total Number of Accidents	
	Before	After
No Adverse Weather Condition	152	171
Rain	43	28
Snow	5	4
Fog	0	1

Figure 4.10 Subarea #4 Accident Frequency by Day-of-Week



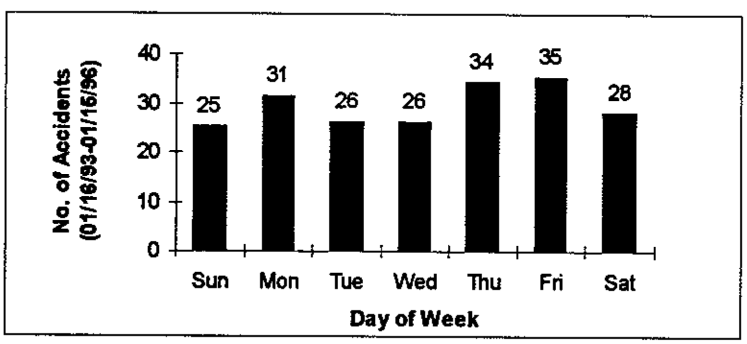
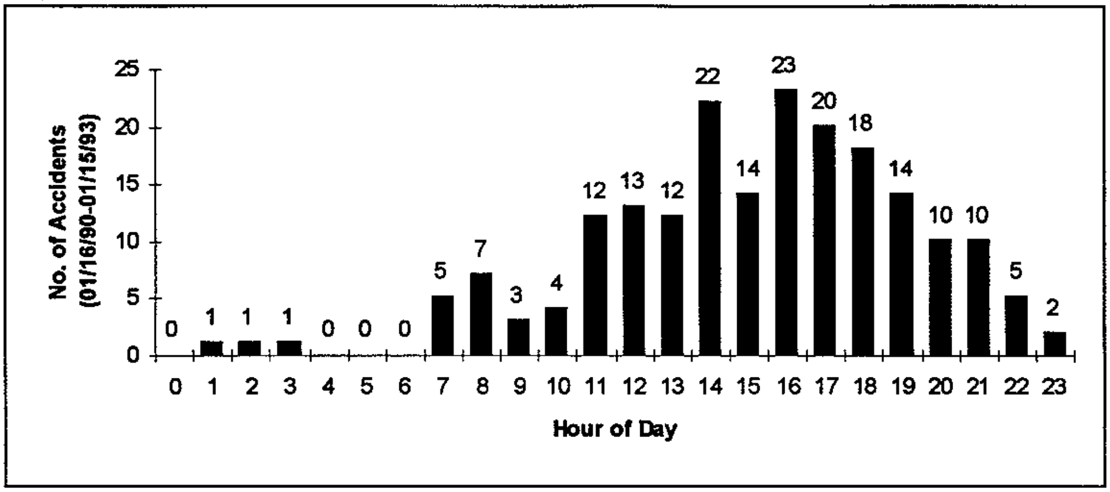


Figure 4.11 Subarea #4 Accident Frequency by Hour-of-Day



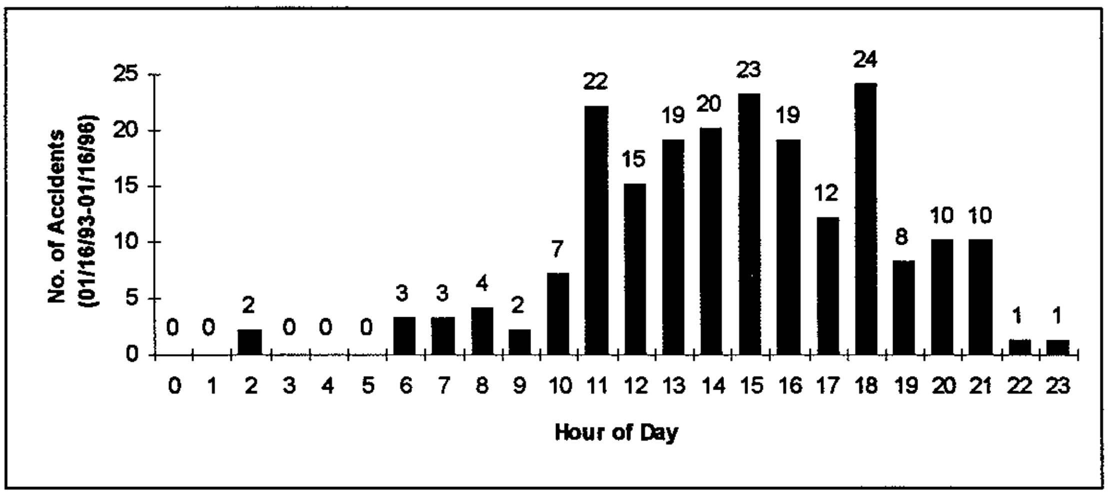
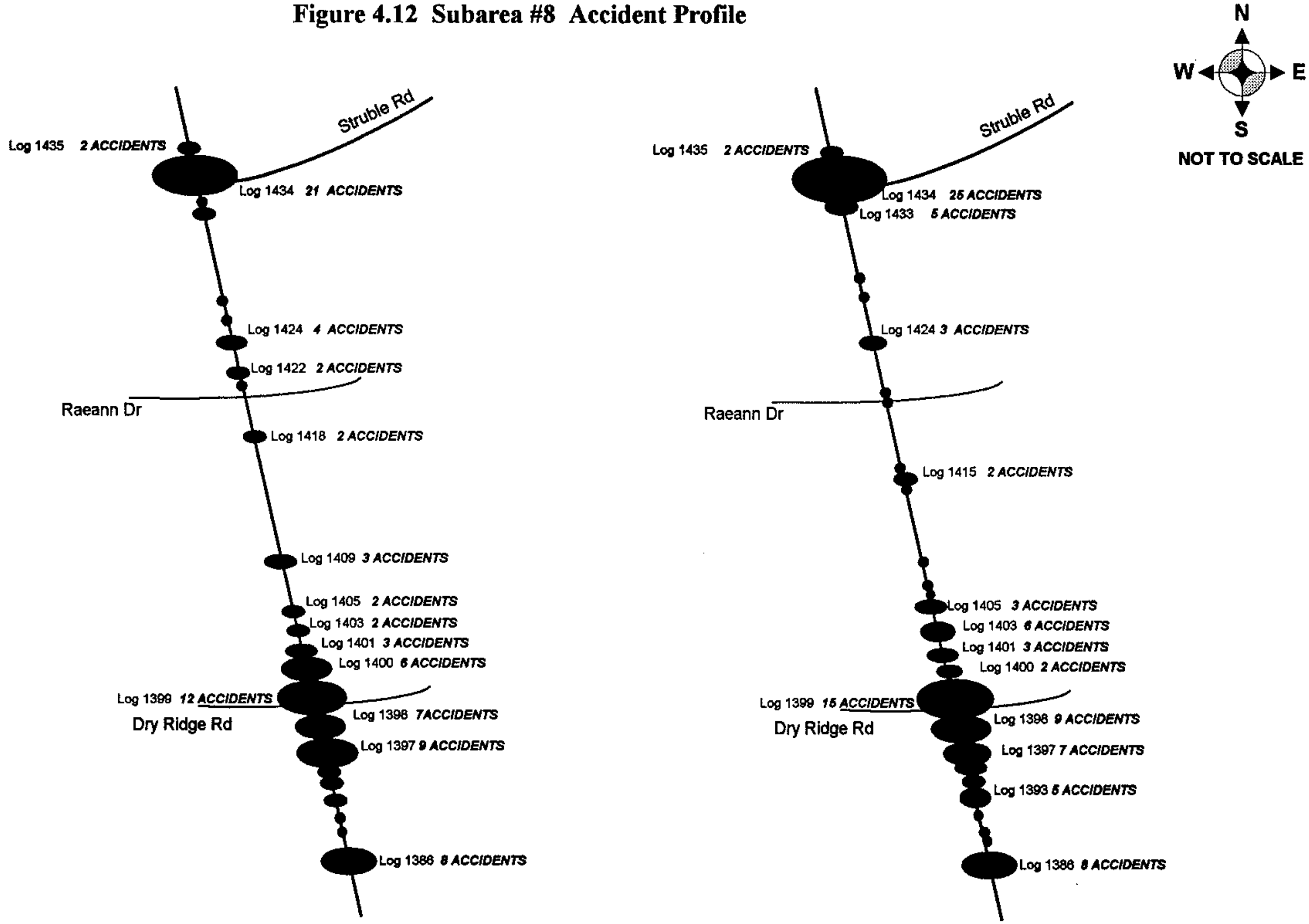


Table 4.15 Subarea #8 Accident Frequency by Severity

No. of Accidents	Total	Fatal	Injury	Property Damage Only
Before	97	0	36	61
After	107	1	36	70
Change (%) + = Increase - = Decrease	+10.3	+100	-	+14.8

Change (%) = [(before - after)/before]*100

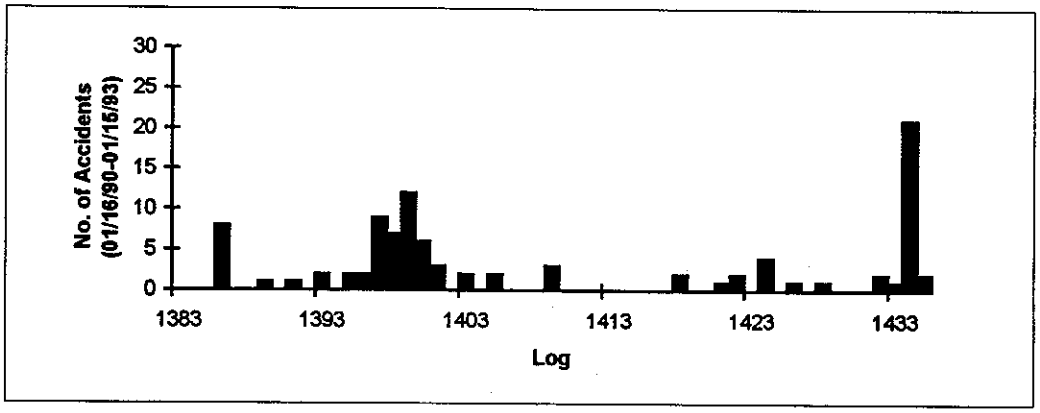
Figure 4.12 Subarea #8 Accident Profile



(a) 01/16/90 - 01/15/93

(b) 01/16/93 - 01/15/96

Figure 4.13 Subarea #8 Spatial Distribution of Accidents



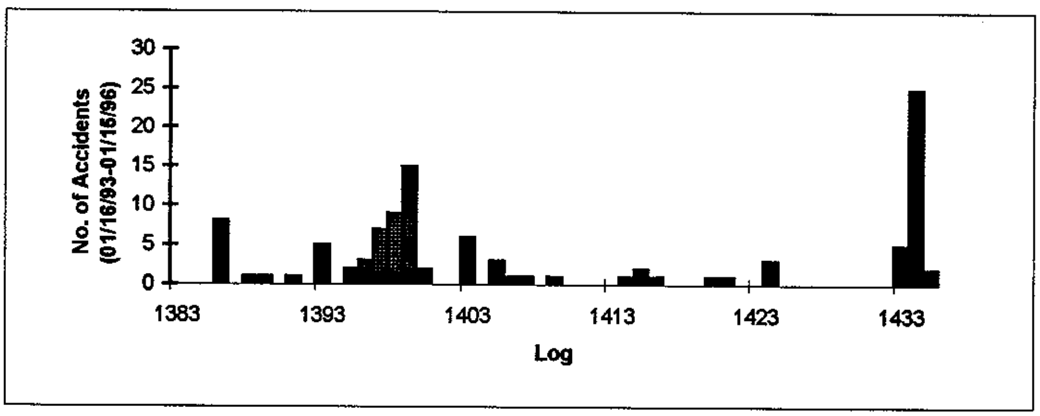


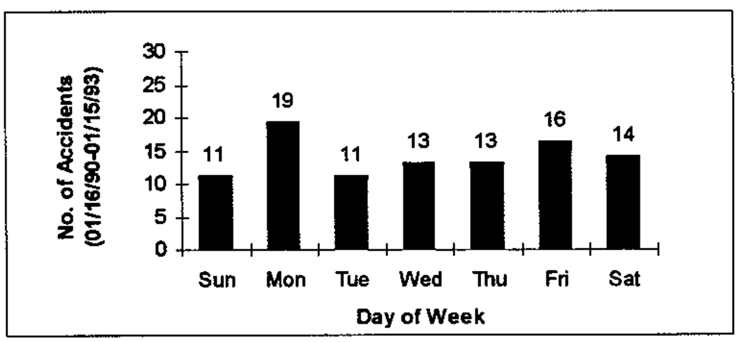
Table 4.16 Subarea #8 Accident Frequency by Weather Conditions

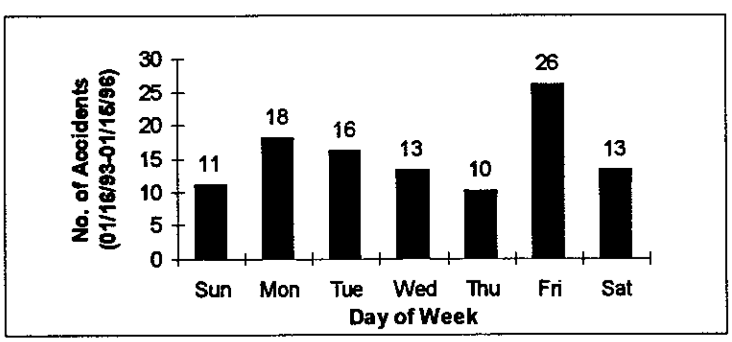
Weather Condition	Total Number of Accidents	
	Before	After
No Adverse Weather Condition	75	88
Rain	20	17
Snow	1	2
Fog	1	1

Table 4.17 Subarea #8 Accident Distribution by Year

Year	Total No. of Accidents	No. of Accidents at Dry Ridge Rd	No. of Accidents at Struble Rd
90(01/16-12/31)	36	19	9
91	28	11	6
92	32	9	11
93(01/01-01/15)	1	0	0
93(01/16-12/31)	38	12	12
94	34	13	10
95	35	11	10
96(01/01-01/15)	0	0	0

Figure 4.14 Subarea #8 Classification of Accidents by Day-of-Week





4.3 Conclusions on the Evaluation of Subareas #1, #4, and #8

Based on the analysis of traffic flow and accident data as described in the previous sections, the following conclusions are made:

a) Subarea #1

- The travel speeds on some segments of Subarea #1 have decreased; and
- Both accident rate and frequency in the subarea have increased.

b) Subarea #4

- The travel speeds on some segments of subarea #4 have decreased; and
- The frequency of accidents at the intersection of Colerain Avenue and Commons Circle has significantly increased, although there has been a small decrease in accident rate for subarea #4 as a whole.

c) Subarea #8

- Travel speed in Subarea #8 has significantly decreased; and
- Accident frequency in the subarea has increased, although accident rate seems to remain unchanged.

5 ACCESS MANAGEMENT TECHNIQUES SOFTWARE (AMTS)

This chapter provides a detailed description of Access Management Techniques Software (AMTS) version 1.0, which was specially developed for guiding an user through the various steps of the methodology for assessing the effectiveness of access management techniques described earlier in Chapter 2.

5.1 What is AMTS?

AMTS, Access Management Techniques Software (Version 1.0) offers transportation engineers and planners a uniform and consistent way of reviewing all possible access management techniques and performing access management analysis by following the methodology developed in this study.

5.2 Function Design

The functions implemented by the software can be grouped into six classes: system control, view, information input and retrieve, transcript writing, and printing. Each class is briefly described in the following sections.

5.2.1 System Control

1. Start
   Start running the program.

2. Exit
   Exit from the program.

5.2.2 View

The user can choose to view the software introduction, study framework, or the excerpts from literature review. The excerpts from literature review can be accessed either during an analysis or directly from the study framework window.

5.2.3 Information Input and Retrieval

AMTS provides dialog windows for the user to input arterial corridor information. The information can be saved to a file and retrieved at a later time.

5.2.4 Print

The program can save all the input and prepare a transcript. The user can print the transcript and the literature review excerpts.

5.3 Software Implementation

The software is built on Windows 95 and Windows NT Workstation Version 4.0. It is written in Microsoft Visual Basic Version 5.0.

5.4 Software Installation

The software package includes the Access Management Techniques Software, AMTS 1.0 and a free product from Microsoft, Word Viewer 7.1. We recommend using AMTS 1.0 on a computer equipped with Pentium processor with at least 16 MB of RAM memory and Windows 95 or Windows NT 4.0 operating system.

Installation

To install or uninstall AMTS (Version 1.0), start Windows and follow the instructions as listed below.

1. Insert disk #1 into floppy disk drive.
2. Open the "Add/Remove Programs" item in the control panel.
3. Select the "Install" panel and then choose "setup.exe" on floppy disk as command line for installation program.
4. Follow the instructions on screen.

If the user doesn't have Word for Windows (version 6.0 or later) in the computer, it becomes necessary to install Word Viewer 7.1 in order to read the excerpts from literature review. To install Word Viewer 7.1, copy all the files (totally three files) from WordViewer disk 1 and disk 2 to your temporary directory, then double click the file "wdvw95.bat" from this directory. This will unpack a utility that extracts the Word Viewer 7.1 distribution files and launches the Word Viewer 7.1 Setup program.

If neither Word for Windows (version 6.0 or later) nor Word Viewer 7.1 (or later version) can be found in the system, the literature review excerpts will only be displayed as icons.

Uninstall

To remove AMTS 1.0 and/or Word Viewer 7.1 from the system, do the followings:

1. Open the "Add/Remove Programs" item in the control panel.
2. Select the "Install/Uninstall" panel and choose "AMTS 1.0" and/or "Microsoft Word Viewer 7.1" from the list of installed programs.
3. Click the "Add/Remove..." button.
4. Follow the instructions on screen.

Figure 5.1 Splash Screen

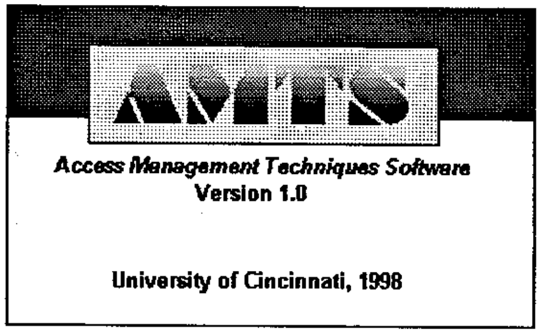
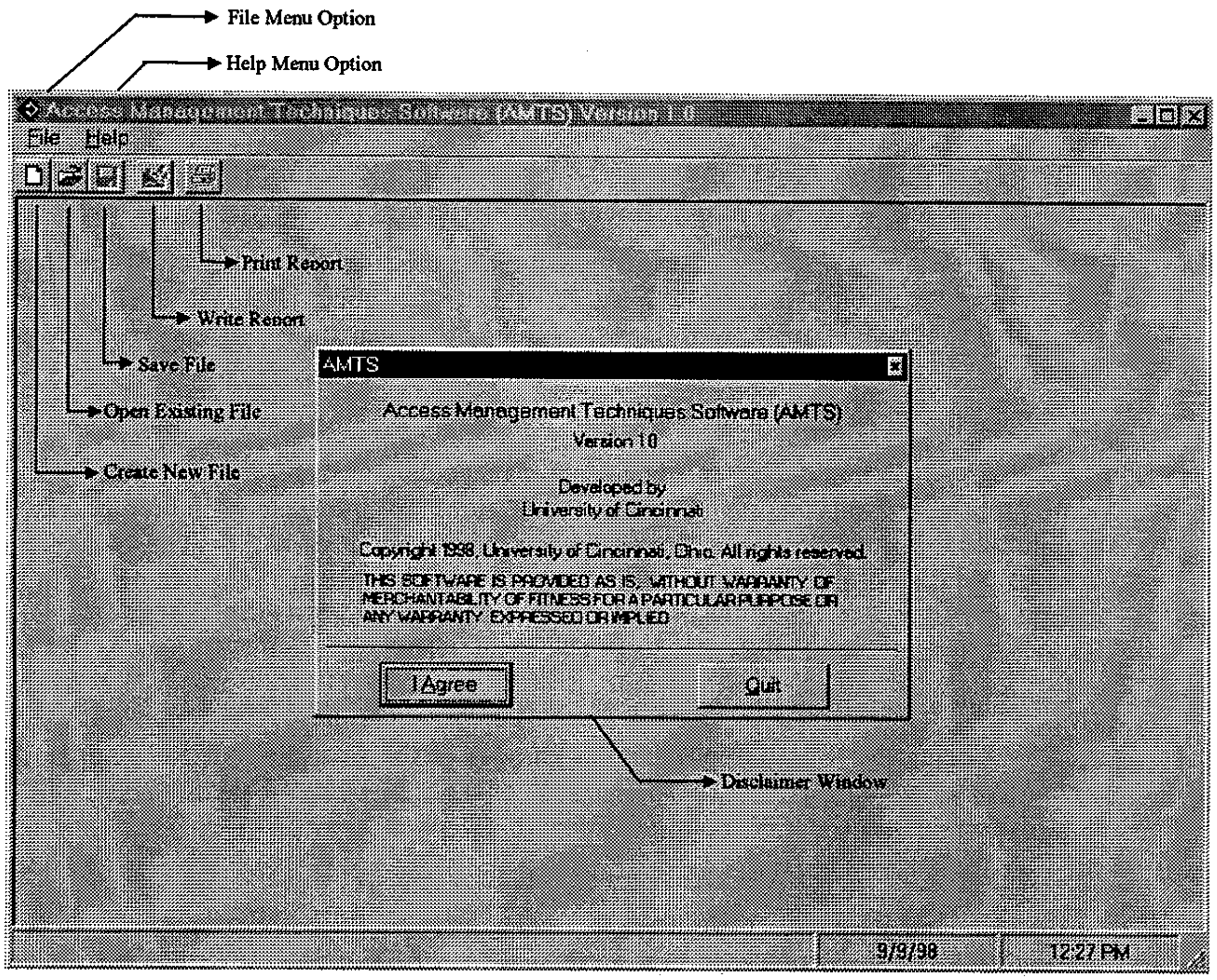


Figure 5.2 Start-up Screen of AMTS



5.5 Operating AMTS 1.0

5.5.1 Starting AMTS

The easiest way of starting an AMTS 1.0 session is to double click the AMTS icon if the user has created a shortcut to AMTS on the desktop. The user can also choose AMTS from the Start up Menu programs. Once started, the program begins loading and a splash screen, as shown in Figure 5.1, will appear. The splash screen disappears after the program is successfully loaded. AMTS pops up the start-up screen along with the disclaimer window, as shown in Figure 5.2. Click the 'I Agree' button of the disclaimer window to continue the program. Quit the program at this point by clicking the 'Quit' button.

5.5.2 Program Introduction and Study Framework

To give the user a brief description of the software, an introduction screen will be shown automatically after the 'I Agree' button of the disclaimer window is clicked. Figure 5.3 shows the introduction screen from AMTS. Users that are new to the software can read the introduction and then click the 'OK' button to go to the study framework screen, as shown in Figure 5.4. Experienced users can directly begin a new analysis or edit an existing analysis. The procedures are described in the next section.

5.5.3 Start a New Access Management Project

To start a new access management project, the user can either click the 'New' button from the Toolbar or choose 'New' from the 'File' menu. This will open an empty file for data input. The study framework will be enabled on the screen, as shown in Figure 5.5.

5.5.3.1 Preliminary Information

Before starting the seven-step access management analysis, the user should fill in some preliminary information. Clicking the 'Preliminary Information' button brings the preliminary information dialog to screen, as shown in Figure 5.6. The preliminary information dialog has six text boxes, which prompt the user for information about the arterial corridor, including 'Name of the Arterial Corridor', 'From', 'To', 'Length', 'District No.'and 'Name of the Analyst'. Click the 'OK' button to finish this step.

5.5.3.2 Step 1. Establish the Purpose of the Analysis

Clicking the 'Step 1. Establish the Purpose of the Analysis' button brings up the dialog box shown in Figure 5.7. The purpose of the analysis can be either 'Planning' or 'Evaluation'. Click the 'OK' button to finish this step.

5.5.3.3 Step 2. Establish the Measures of Effectiveness

Clicking the 'Step 2. Establish the Measures of Effectiveness' button brings up the dialog box shown in Figure 5.8. The user must select one or both from the two available MOEs. Click the 'OK' button to finish this step.

Figure 5.3 Introduction Screen

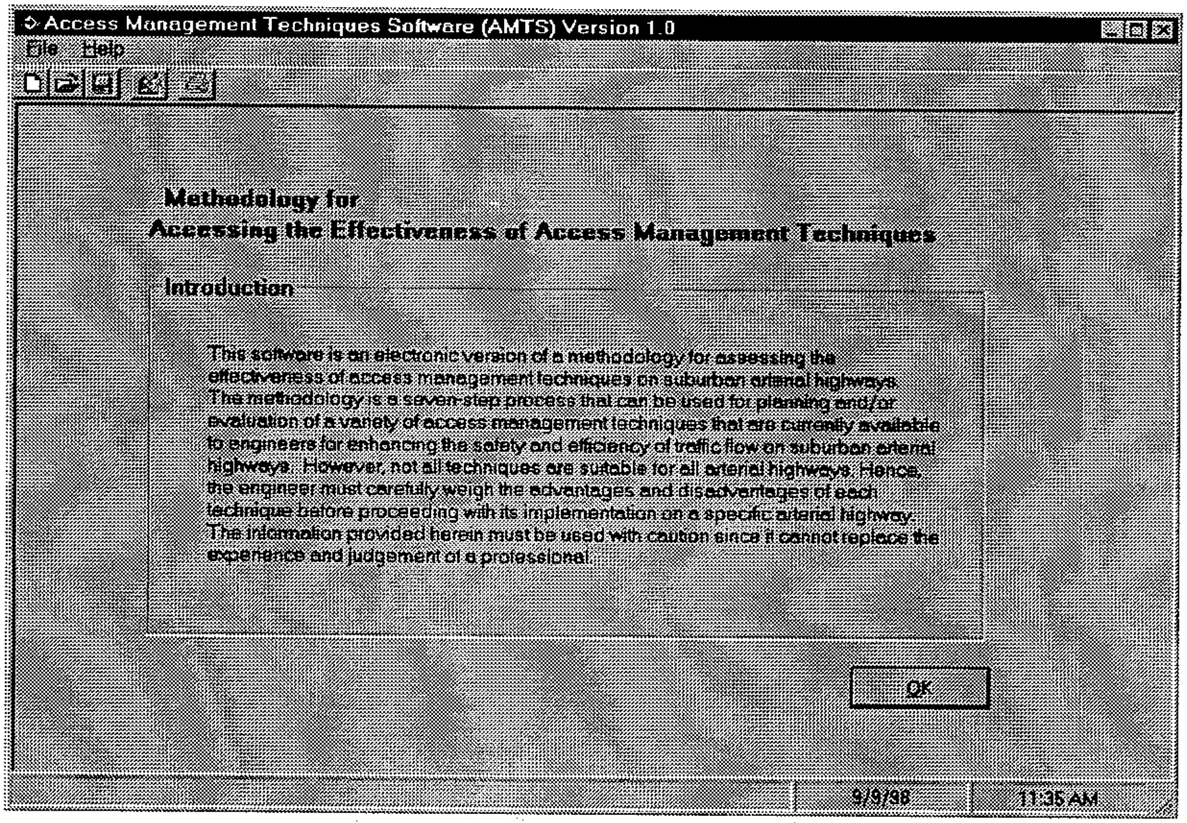


Figure 5.4 Study Framework Screen

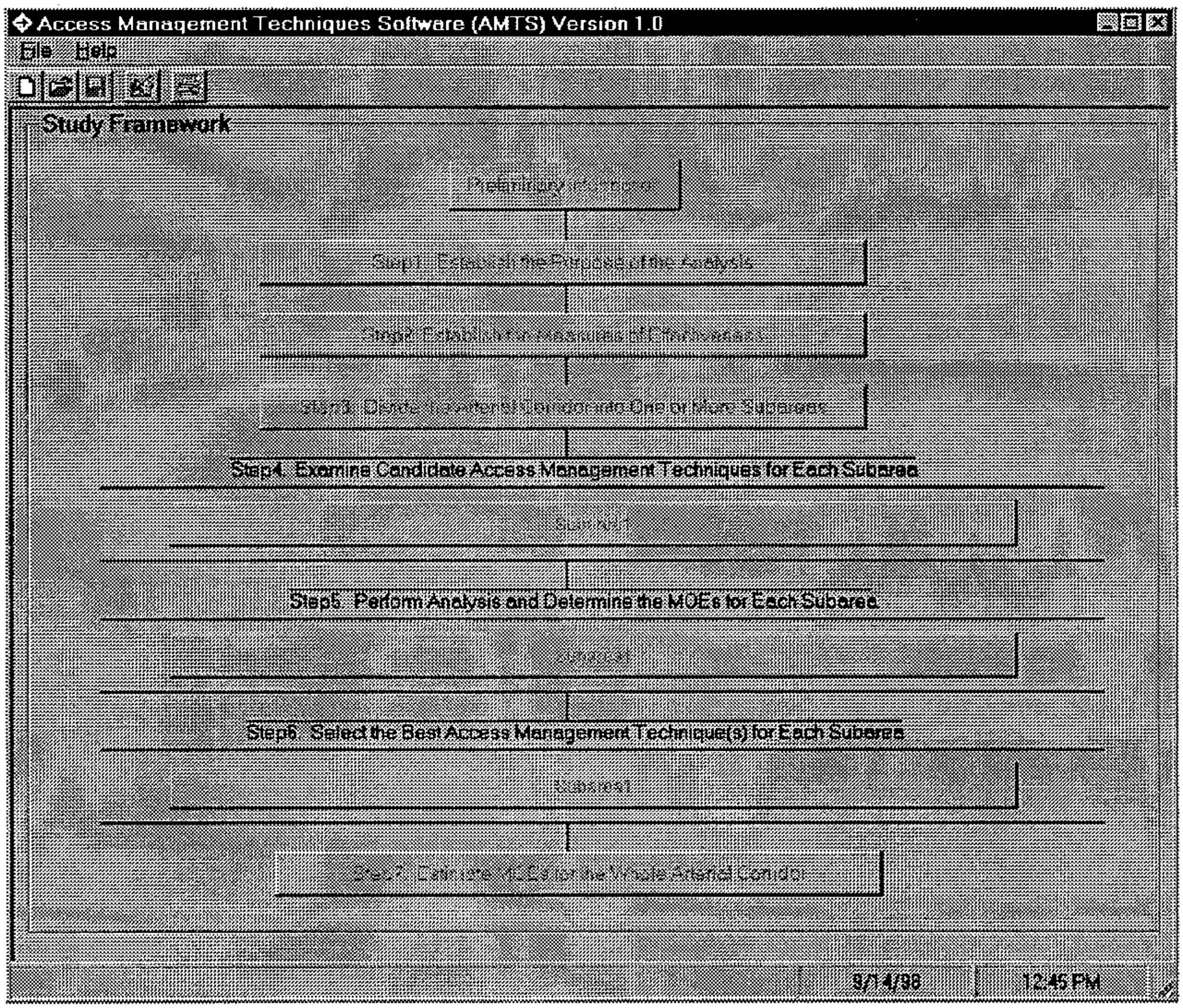


Figure 5.5 Enabled Study Framework Screen

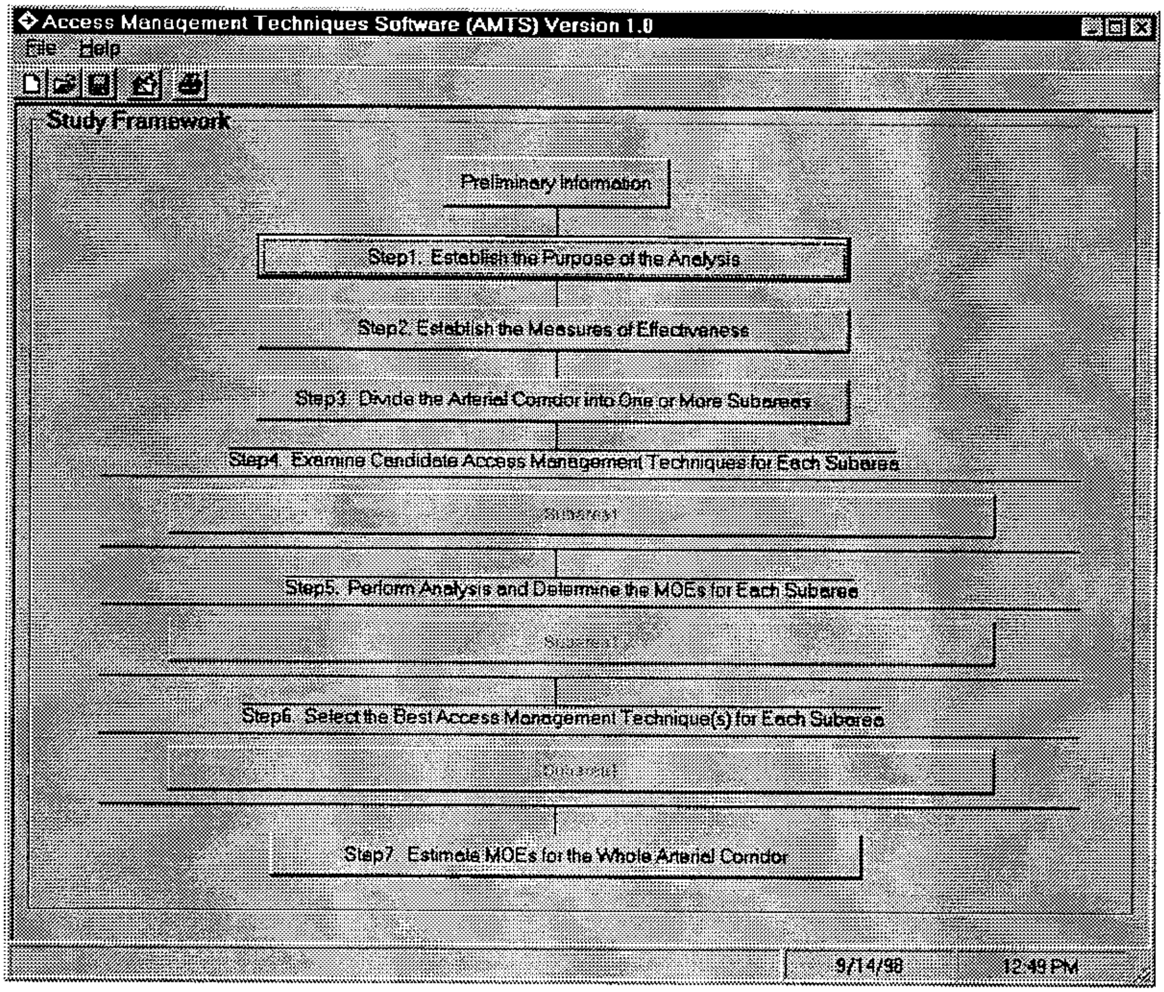


Figure 5.6 Preliminary Information Dialog

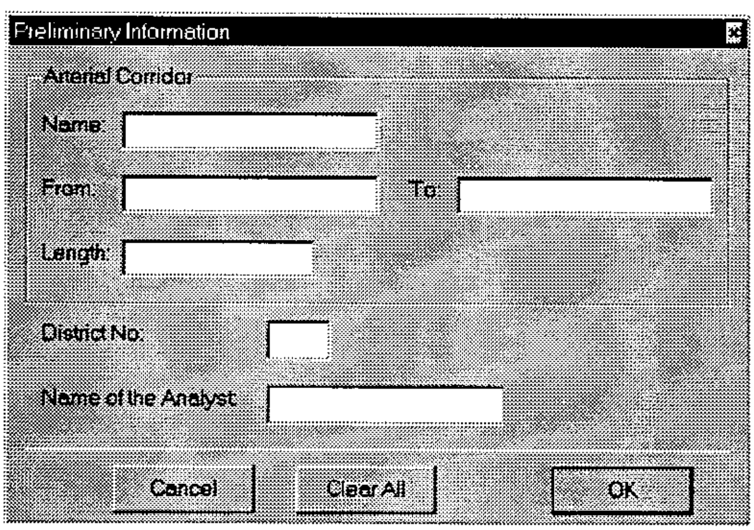


Figure 5.7 Step 1 Dialog

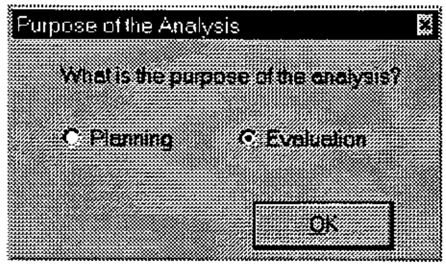


Figure 5.8 Step 2 Dialog

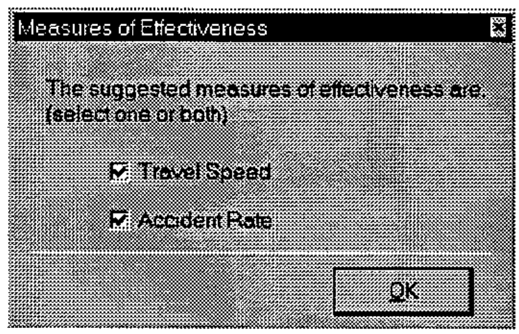


Figure 5.9 Step 3 Dialog

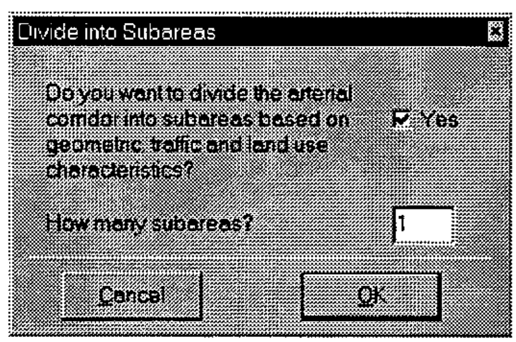
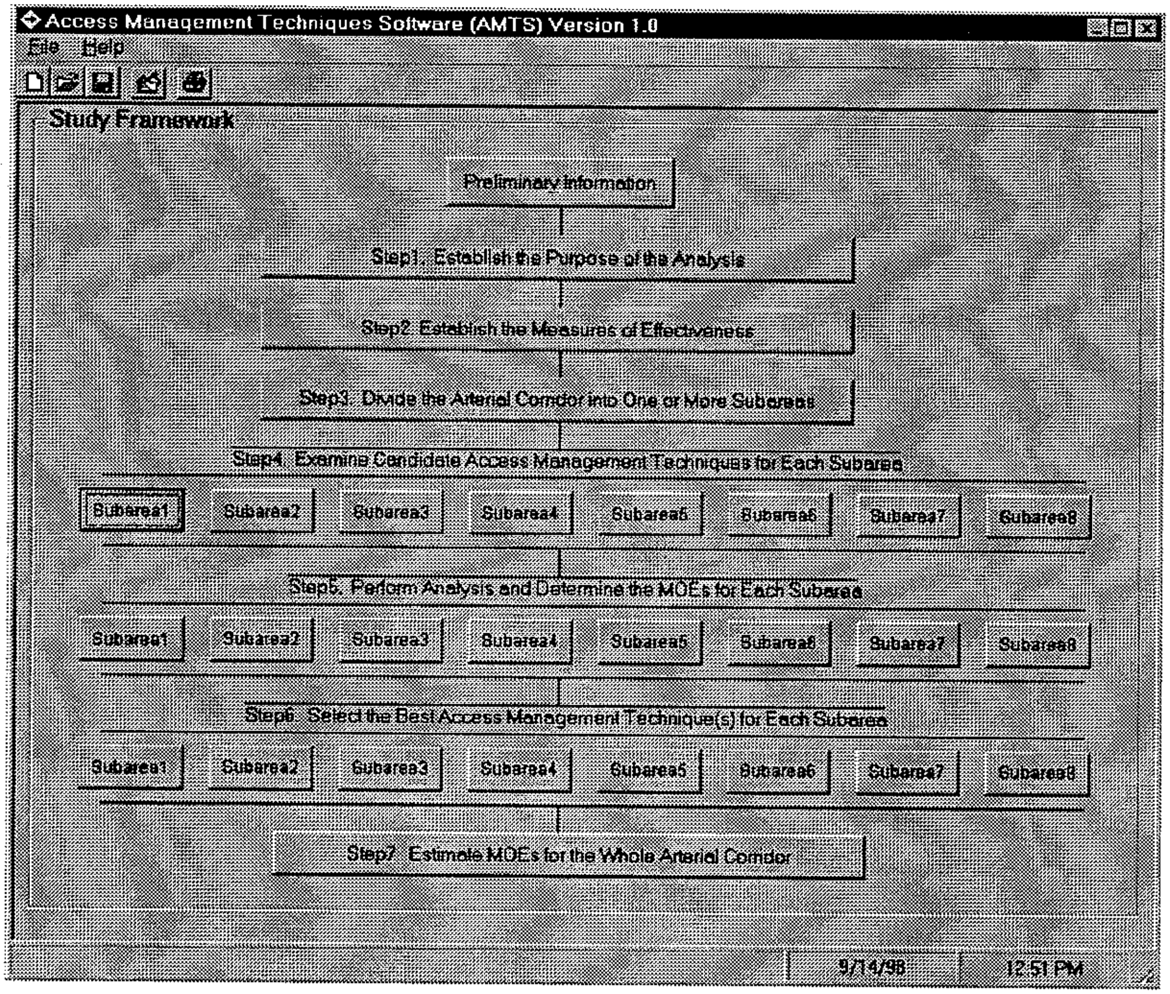


Figure 5.10 Study Framework with Enabled Subarea Buttons



5.5.3.4 Step 3. Divide the Arterial Corridor into One or More Subareas

Clicking the 'Step 3. Divide the Arterial Corridor into One or More Subareas' button brings up the dialog box shown in Figure 5.9.

There is a check box that prompts the user 'Do you want to divide the arterial corridor into subareas based on geometric, traffic and land use characteristics?'. The default option of this box is 'Yes'. The user can divide the arterial corridor into no more than 15 subareas; thus the valid range for 'How many subareas?' is 1-15. The text box for 'How many subareas?' will be disabled once the option for dividing the arterial corridor into subareas is not set to 'Yes'.

By clicking the 'Cancel' button the dialog will be closed and no input will be saved.

Click the 'OK' button to finish this step and the program will reload the study framework with the specified number of enabled subarea buttons. An example of eight subareas is shown in Figure 5.10.

5.5.3.5 Step 4. Examine Candidate Access Management Techniques for Each Subarea

Clicking the subarea button under Step 4 brings up the subarea dialog for that subarea. Figure 5.11 shows the subarea dialog for subarea 1.

The subarea dialog prompts the user to define the start and end points of the subarea. It prompts the user to examine all possible access management techniques that are classified into the following six groups:

(1) Signalized intersection
(2) Unsignalized intersections and driveways
(3) Medians
(4) Left-turns
(5) Right-turns
(6) Service roads

Once the user clicks a particular group, the access management techniques applicable to the group will appear on the screen.

All access management techniques are not applicable to all subareas. Hence, the user must perform appropriate analysis that could be quite extensive and determine which technique(s) is applicable to the subarea. Once this determination has been made, the user can check the box for the technique in subarea dialog.

The user can go to next or previous subarea by click the 'Next' or 'Back' buttons at the bottom of the dialog box.

The user can choose to jump between different access management groups by clicking the tabs for these groups. There are different numbers of techniques in each group. The question mark button for each technique is designed to provide an easy access to the excerpts of literature review on the technique. Clicking the question mark

Figure 5.11 Step 4 Subarea Dialog

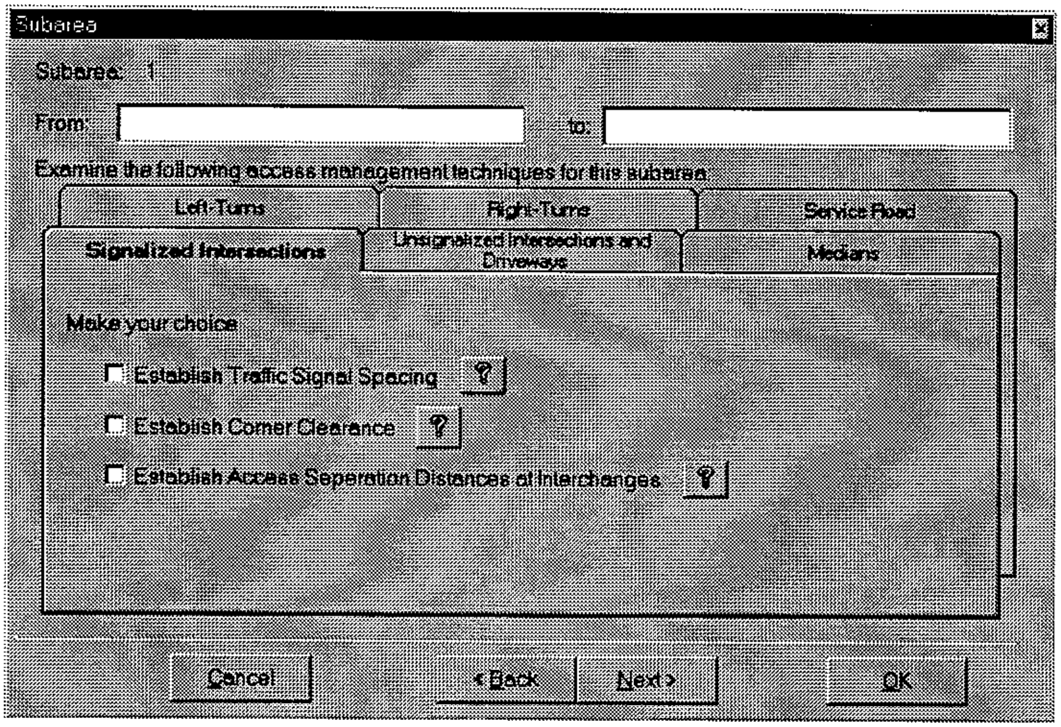
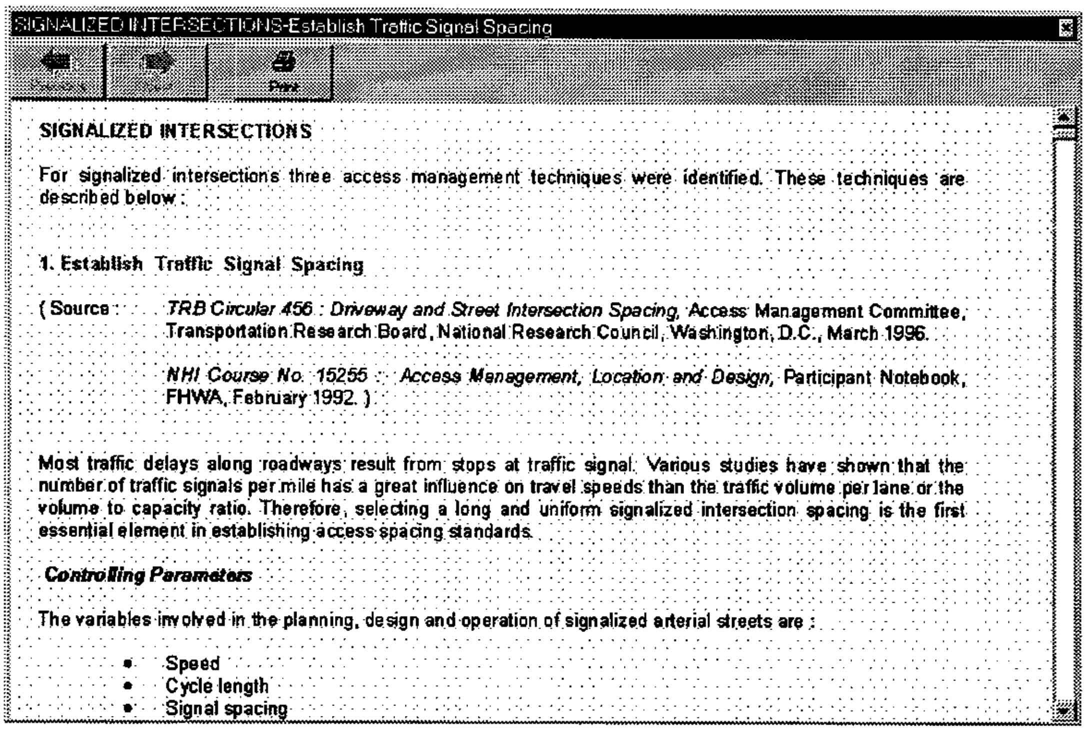


Figure 5.12 Literature Review Dialog



SIGNALIZED INTERSECTIONS

For signalized intersections three access management techniques were identified. These techniques are described below :

1. Establish Traffic Signal Spacing

(Source : *TRB Circular 456 : Driveway and Street Intersection Spacing*, Access Management Committee, Transportation Research Board, National Research Council, Washington, D.C., March 1996.

NHI Course No. 15255 : Access Management, Location and Design, Participant Notebook, FHWA, February 1992.)

Most traffic delays along roadways result from stops at traffic signal. Various studies have shown that the number of traffic signals per mile has a great influence on travel speeds than the traffic volume per lane or the volume to capacity ratio. Therefore, selecting a long and uniform signalized intersection spacing is the first essential element in establishing access spacing standards.

Controlling Parameters

The variables involved in the planning, design and operation of signalized arterial streets are :

- Speed
- Cycle length
- Signal spacing

Figure 5.13 Literature Review Print Dialog

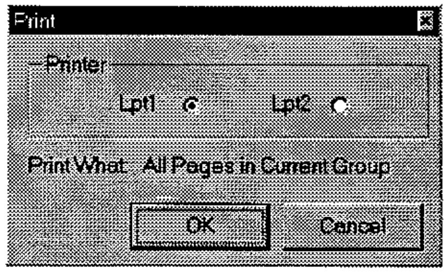
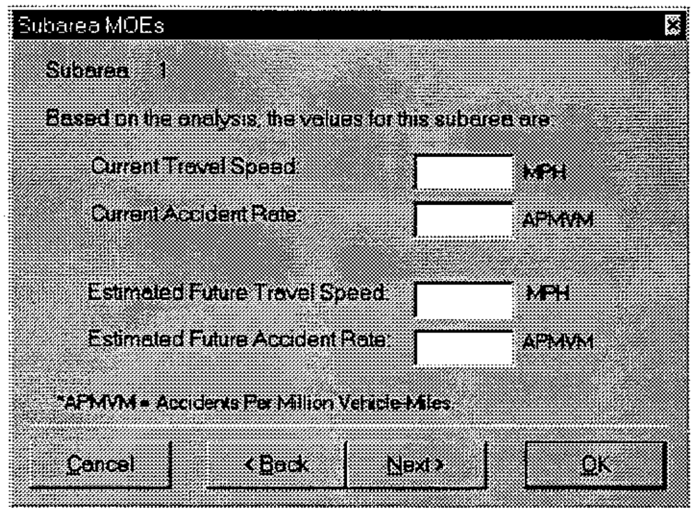


Figure 5.14 Step 5 Dialog



button brings up the literature review window for the technique. Figure 5.12 is an example of a window brought up by clicking the button for 'Establish Traffic Signal Spacing' in the 'Signalized Intersection' group. Some literature review excerpts have multi-pages. Clicking the 'Next' and 'Previous' buttons at the upper left corner of the window can turn the pages.

To print the current section of the literature review excerpts, click the 'Print' button. A print dialog box, as shown in Figure 5.13, will come up. Choose the LPT that the target printer is connected to, and then press 'OK'. Usually a printer is connected to LPT1.

5.5.3.6 Step 5. Perform Analysis and Determine the MOEs for Each Subarea

Clicking the subarea button under Step 5 brings up the subarea MOEs dialog for that subarea. Figure 5.14 shows the dialog for subarea 1 with both 'Travel Speed' and 'Accident Rate' selected as MOEs.

Only the selected MOEs will be enabled. The values for selected MOES can be entered to the text boxes. The user can go to next or previous subarea by click the 'Next' or 'Back' buttons at the bottom of the dialog box.

Clicking the 'Cancel' button will close the dialog without saving any input made this time.

Click the 'OK' button to finish this step.

5.5.3.7 Step 6. Select the Best Access Management Technique(s) for Each Subarea

Clicking the subarea button under Step 6 brings up the subarea dialog with selected candidate techniques and subarea information for that subarea. Figure 5.15 shows the dialog for subarea 1.

The user can make a final determination on the best access management technique(s) for each subarea.

5.5.3.8 Step 7. Estimate MOEs for the Whole Arterial Corridor

Clicking the 'Step 7. Estimate MOEs for the Whole Arterial Corridor' button brings the arterial corridor MOEs dialog to screen, as shown in Figure 5.16.

Only the selected MOEs will be enabled. The values for selected MOES can be entered to the text boxes.

Clicking the 'Cancel' button will close the dialog without saving any input made this time.

Click the 'OK' button to finish this step.

Figure 5.15 Step 6 Subarea Dialog

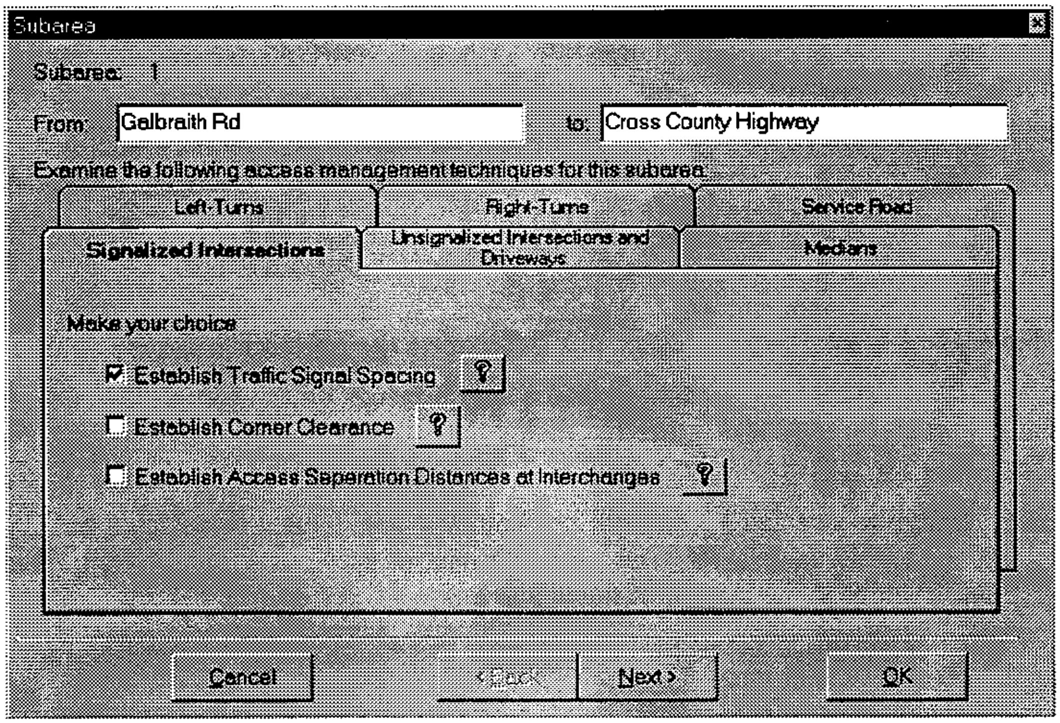


Figure 5.16 Step 7 Dialog

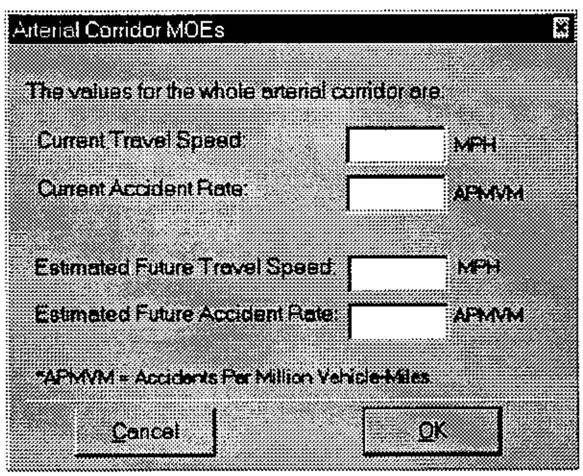
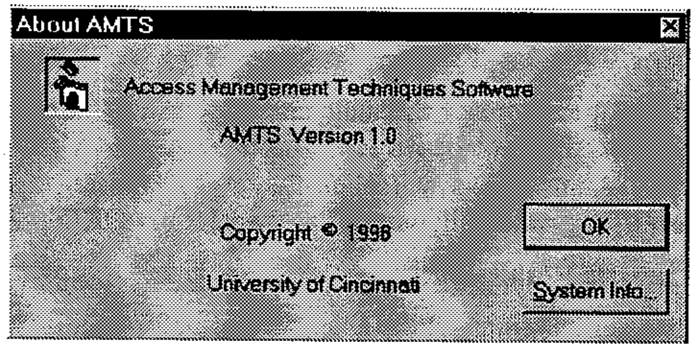


Figure 5.17 'About Program' Dialog



5.5.4 Write and Print Transcript

AMTS saves the data input for a transcript. To have the transcript written, click the 'Write Transcript' button on the toolbar or choose 'Write Transcript' from the 'File' menu.

To print the transcript of the analysis, click the 'Print Transcript' button on the toolbar to print it on the default printer. Another way is to go to the 'File' menu and choose 'Print Transcript'. This will open the 'Print Transcript' dialog box, which is a standard window dialog box. Choose a printer and click 'OK'.

5.5.5 Save Analysis Result

Once the user has finished the analysis and before exiting from the program, it is recommended to save the work to a file for future review or editing. To do so, go to the 'File' menu and choose 'Save As' if this is the first time to save or 'Save' if it has been saved before. The standard window dialog box will lead the user through the steps of saving a file.

There is also a 'Save' button on the toolbar. Clicking this button will also bring the window dialog box.

5.5.6 Close the Current Analysis File

To close the current analysis file, go to 'File' menu and choose 'Close'. Be sure to save the file before closing it. If the file is closed without being saved, all the data will be lost.

5.5.7 Open an Existing Analysis File

An analysis file saved on a disk can be opened at later time. To open a file, click the 'Open' button on the toolbar or choose 'Open' from the 'File' menu. The window dialog box 'Open' will be shown. Choose the file name from the file list and then click the 'Open' button.

5.5.8 About the Program

Choosing 'About AMTS' from the 'Help' menu of AMTS window pops up the 'About AMTS' dialog box, as is shown in Figure 5.17. The dialog displays the name and version of the software, the copyright notice and the agency that developed it. The user can also get the system information by clicking the 'System Info' button.

5.5.9 Exit

The option of exiting from the program run is located at the end of 'File' menu. Clicking the 'Exit' menu option will close all the open windows of the software and stop the program.

6 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of this study are presented in the following sections.

6.1 Conclusions

This study performed a thorough literature review of the existing access management techniques for arterial highways. Based on the findings from the literature review and current practices, a methodology for assessing the effects of access management techniques on suburban arterial corridors was developed. The methodology includes several specific steps that must be followed in the performance of an access management study. The methodology can be used as a planning or an evaluation tool.

The methodology classifies access management techniques into the following six groups:

1. Signalized intersections
2. Unsignalized intersections and driveways
3. Medians
4. Left turns
5. Right turns
6. Services

Each group consists of several access management techniques that may be suitable for applications in specific corridors. Since all techniques are not suitable for all corridors, it is incumbent upon the user of the methodology to determine the "best" technique(s) applicable to the specific corridor under analysis.

The methodology uses the following two measures of effectiveness (a) travel speed, and (b) accident rate. At the planning stage, these MOEs allow the user to determine the "best" technique(s) that has the highest potential of either increasing travel speed, or decreasing accident rate, or both. At the evaluation stage, the MOEs allow a valid comparison of the situations before and after the implementation of one or more access management techniques.

A computer program called Access Management Techniques Software (AMTS) was developed to duplicate the methodology for assessing the effectiveness of access management techniques. The software guides the user through each step of the methodology and provides a medium for maintaining uniformity and consistency in the analysis.

Due to the large number of existing techniques and the generally unique characteristics of arterial corridors, it is not possible to suggest a "universal" tool that can be used for determining the most effective access management technique for enhancing traffic flow or safety in a particular corridor. That is not to say that the current practice of transportation engineering or planning lacks some powerful, and some not so powerful, tools for performing an analysis. At the planning stage, computer simulation should be seriously considered, especially due to the fact that the Windows interface and traffic flow animation in the currently available software such as CORSIM make it a powerful tool. At the evaluation stage, a direct comparison of field-collected travel speeds would provide a good basis for comparison. It also highlights the importance of collecting field data before implementing an access management technique in a corridor so an evaluation can be performed after the implementation of the access management technique(s).

Traditionally, estimation of accident frequency or rate is generally available for some widely used, but not all, access management techniques. Any conclusion about the impact of a technique on reducing accident rate can be valid only if the sample size is adequate and multiple (preferably three) years of accident data before and after the implementation of the techniques are used in the analysis. The provision of a control site is an important consideration that will render the comparison valid and meaningful.

Three subareas of Colerain Avenue in Colerain Township in the Cincinnati metropolitan area were used as a case study for application of the methodology developed in this study. The analysis used computer simulation since speed data before the installation of traffic signals at Colerain Crossings, Commons Circle, and Dry Ridge Road were not available. The result showed that each of these traffic signals had the effect of reducing travel speed in each subarea. The driveways at Colerain Crossings carried low traffic volume and, hence, safety did not seem to be a problem. It was not clear why a signal is required at this intersection, which is separated by only 320 ft from the next traffic signal. The result showed that accident frequency and rate in Subarea #1 increased during the 19-½ months after the installation of the traffic signal at Colerain Crossings. Accidents also increased at Commons Circle after the installation of the traffic signal. Analysis was also done for examining the effects of driveways in Subareas#1 and 4. As expected, the results showed that the elimination of driveways would significantly contribute toward increasing the travel speeds in the subareas, indicating that consolidation of driveways is a potential candidate for access management.

The traffic volume in Colerain Avenue seems to have significantly changed due to the opening of Reagan Highway in Fall, 1997. The data collected before the opening may no longer be valid for future analysis.

6.2 Recommendations

Based on the results of this study, we recommend that:

1. The methodology developed in this study be used for planning and/or evaluation of access management techniques on suburban arterial highways in Ohio. The adoption of the methodology would assist ODOT to maintain uniformity and consistency among all districts in the State. It would provide a guideline for departmental personnel and consultants in the performance of access management analysis.

Additionally, based on our examination of traffic flow and safety in Subareas #1, 4, and 8 of Colerain Corridor, we recommend that:

1. The removal of the existing traffic signal at Colerain Crossings be considered.

2. Consolidation of driveways be considered for increasing travel speed in Colerain Corridor.

3. The installation of additional traffic signals in Colerain Avenue be strongly discouraged since more traffic signals would further reduce travel speed. Additionally, we recommend that the removal or consolidation of traffic signals in other subareas be given due consideration. For example, although outside the scope of this study, a potential candidate for removal may be the traffic signal located south of Springdale Road (at the northeast corner of Northgate Mall) in Subarea #2. Also, potential candidates for consolidation may be the traffic signals at the two ends of Sun shopping plaza in Subarea #5 which, of course, is possible only if the driveways are consolidated.

4. The methodology developed in this study be used in all future planning and evaluation of access management techniques in Colerain Corridor since traffic volume in the corridor seems to have significantly changed due to the opening of Reagan Highway in Fall, 1997.

7 REFERENCES

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6. Gluck, J., Levinson, H., Stover, V., Koepke, F., and Demosthenes, P., *Impacts of AccessManagement Techniques*, Interim Report, NCHRP, Transportation Research Board, National Research Council, January 1996.

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10. Pflum, Klausmeier & Gehrum Consultants, Revised Final Report, Corridor Planning Study, Colerain Avenue (U.S. 27), Subareas 3-8, Hamilton County, Ohio, April 1995.

APPENDIX A

SUGGESTED GUIDELINES FROM LITERATURE REVIEW

A-1 SIGNALIZED INTERSECTIONS

For signalized intersections three access management techniques were identified. These techniques are described below :

A-1.1 Establish Traffic Signal Spacing

(Source : *TRB Circular 456 : Driveway and Street Intersection Spacing,* Access Management Committee, Transportation Research Board, National Research Council, Washington, D.C., March 1996.

NHI Course No. 15255 : Access Management, Location and Design, Participant Notebook, FHWA, February 1992.)

Most traffic delays along roadways result from stops at traffic signal. Various studies have shown that the number of traffic signals per mile has a great influence on travel speeds than the traffic volume per lane or the volume to capacity ratio. Therefore, selecting a long and uniform signalized intersection spacing is the first essential element in establishing access spacing standards.

Controlling Parameters

The variables involved in the planning, design and operation of signalized arterial streets are :

- Speed
- Cycle length
- Signal spacing
- Progression band width

An example of this relationship obtained from a simulated study for intersections with uniform spacing is shown below in Table A-1.1.

Table A-1.1 Optimum Signalized Intersection Spacing (in Feet) Needed to Achieve Efficient Traffic Progression at Various Speeds and Cycle Lengths

Cycle Length (sec)	Speed (mph)						
	25	30	35	40	45	50	55
	Distance in Feet						
60	1,100	1,320	1,540	1,760	1,980	2,200	2,430
70	1,280	1,540	1,800	2,050	2,310	2,500	2,820
80	1,470	1,760	2,050	2,350	2,640	2,930	3,220
90	1,630	1,980	2,310	2,640	2,970	3,300	3,630
120	2,200	2,640	3,080	3,520	3,960	4,400	4,840
150	2,750	3,300	3,850	4,400	4,960	5,500	6,050

Major urban arterials will experience high traffic demand during peak periods. Thus, it is suggested that a uniform signalized intersection interval be selected to provide maximum potential capacity when the area is fully developed. This involves selecting a signal spacing which will accommodate traffic speeds of at least 30 to 35 mph using the longest cycle length which may be anticipated. When a shorter cycle length will produce an unacceptably high progression speed given the selected long, uniform signal spacing, progression may be achieved by increasing the percentage of the cycle devoted to the major roadway's green time. The corresponding reduction in green for the intersection minor street will increase the delay to left turning and crossing traffic; right turning traffic will not be materially affected with right-turn-on-red.

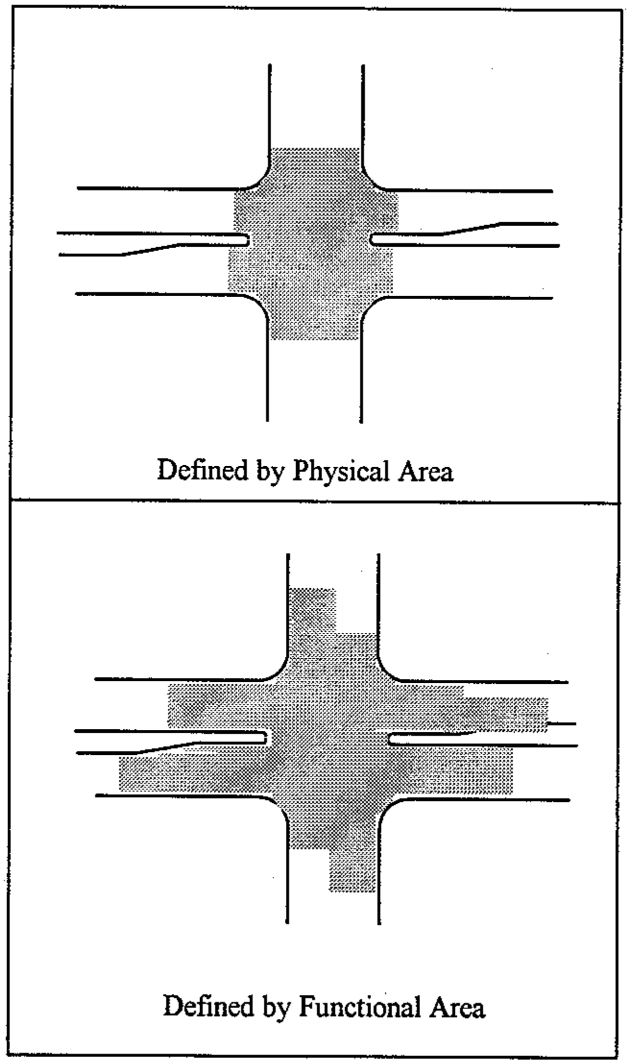
In many developed areas, signal spacing has already been established by the locations of intersecting streets. Existing operating speed may be preserved by introducing signals for land development only where they fit into the time-space pattern and do not reduce significantly the through band width.

A-1.2 Establish Corner Clearance

(Source : *TRB Circular 456 : Driveway and Street Intersection Spacing,* Access Management Committee, Transportation Research Board, National Research Council, Washington, D.C., March 1996.)

Corner clearances upstream and downstream of an intersection should be governed by the functional area of an intersection. AASHTO ("Green Book", page 793) specifically states that : "Driveways should not be situated within the functional boundary of at-grade intersections. This boundary would include the longitudinal limits of auxiliary lanes". While AASHTO does not present guidelines as to the size of this functional area, logic indicates that it must be larger than the physical area as shown in Figure A-1.1. It extends both upstream and downstream of the intersection and increases as the percentage of trucks increases.

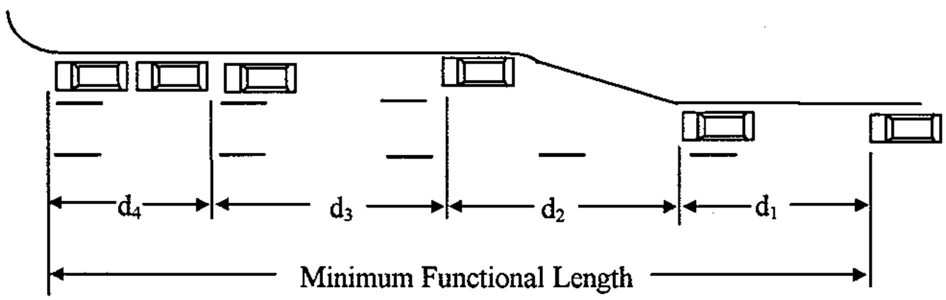
Figure A-1.1 Boundary of Intersection



Upstream Dimensions :

The elements that define the upstream functional area of an intersection are shown in Figure A-1.2. They include the following :

Figure A-1.2 Determinants of the Intersection Maneuver Distance



d_1 = distance traveled during perception -reaction time

d_2 = distance traveled while driver decelerates and maneuvers laterally

d_3 = distance traveled during full deceleration and coming to a stop or to a speed at which the turn can be comfortably executed

d_4 = storage length

d_1 : The perception-reaction time required by the driver. For motorists who frequently use the street, this may be as little as one second or less. However, strangers may not be in the proper lane to execute the desired maneuver and may require several seconds .

d_2 : Braking while moving laterally is a more complex maneuver than braking alone - perhaps one half the deceleration rate used in d_3. Lateral movement is commonly assumed to be 4 feet per second under urban condition and 3 feet per second for rural conditions. At low deceleration rates, the driver will have shifted laterally so that a following vehicle can pass without encroaching on the adjacent lane before a 10 mph speed differential occurs. At deceleration rates greater than about 4 fps^2, the speed differential will exceed 10 mph before the turning vehicles clears the through traffic lane. Clearance is considered to have occurred when a following vehicle can pass without physically encroaching on the adjacent lane.

d_3 : Deceleration after moving laterally into the turn bay should be at a rate that will be used by most drivers. Studies have found that most drivers (85%) will utilize a deceleration rate of 6 fps^2 or more; only about 50% can be expected to accept a rate of 9 fps^2 or greater (M.S. Chang, C.J. Messer, and J. Santiago, " Timing Traffic Signal Change Intervals Based on Driver Behavior ", TRB, 1985), the rate used by AASHTO in establishing safe stopping sight distances.

d_4 : Length required to store all turning vehicles.

Functional upstream intersection areas for different speeds, excluding queue storage, are given in Table 2. In calculating deceleration distances, full deceleration rates of 6 fps^2 and 9 fps^2 were used. The 6 fps^2 deceleration is accepted by 85% of drivers. This value is used for a "desirable condition" since it will be used, or accepted, by most drivers. Since only 50% of drivers accept an acceleration of 9 fps^2, this value is used as a limiting condition or upper limit for design. Maneuvering from the through lane into a right-lane or left-lane while decelerating is a more demanding driving task than decelerating only. Therefore, a lower deceleration rate was used in calculating distances d_2 than d_3.

The difference in the maneuver distance required for the peak and off-peak speeds will provide some storage. This difference will generally be sufficient to provide the necessary right-turn storage on arterial approaches at intersections with collector streets. At high volume intersections, the functional limits are commonly controlled by peak-period conditions since peak period maneuver distance plus storage for queuing is longer than the maneuver and storage distances needed in the off-peak. Thus, the functional area is comprised of the distance shown in the "Total" column in Table A-1.2 plus the queue storage distance.

Table A-1.2 Functional Intersection Area, Excluding Storage

	Desirable Condition		Limiting Condition	
Speed (mph)	Deceleration (feet)	Total (feet)	Deceleration (feet)	Total (feet)
30	225	325	170	215
35	295	425	220	270
40	375	525	275	335
45	465	630	340	405
50	565	750	410	480
55	675	875	495	565
60	785	1005	565	655

(The calculated distances given in Table A-1.2 are the sum of d_2 and d_3 as defined in Figure A-1.2)

Downstream Dimensions :

The downstream functional area of an intersection extends some distance downstream from the crosswalk location. It recognizes the need for guidance and tracking after a vehicle passes through an intersection. Although guidelines are needed for both upstream and downstream of an intersection, they are not as well as developed for the downstream distances.

Various approaches may be considered in deriving the downstream distance in which no driveways should be located. These approaches include the following :

- Length of an acceleration lane,
- Stopping sight distance,
- Right-turn conflict overlap, and
- The left-turn driving tusk.

Length of an Acceleration lane

A driveway or approach connection should not be placed within the length of an acceleration lane. In addition, there should be some separation distance between the end of the acceleration lane and the first downstream driveway. However, since acceleration lane are rarely used on at-grade arterials, this criterion will seldom apply.

Stopping Sight Distance

Ideally, a vehicle should clear a major intersection before the driver is required to response to vehicles entering, leaving or crossing the arterial. This simplifies the driving task and minimizes driver mistakes and collisions.

AASHTO stopping sight distances provide a possible criterion that enables the drivers to clear an intersection before having to decelerate in response to a downstream conflict. AASHTO uses a 2.5 second perception-reaction time and coefficients of friction of that are acceptable to about 50 percent of drivers. These distances which are based on a deceleration rate of about 9 fps^2 are shown in Table A-1.3. The table also shows stopping sight distances for a rate of 6 fps^2 that is acceptable to 85% of the drivers.

Table A-1.3 Minimum Stopping Sight Distances

Speed (mph)	AASHTO Stopping Distance (ft)	Calculated Stopping Distance(ft) 9 fps^2 Deceleration	6 fps^2 Deceleration
20	125	120	145
25	150	165	205
30	200	220	275
35	250	275	350
40	325	340	435
45	400	410	530
50	475	485	640
55	550	565	750
60	650	655	870

Right-Turn Conflict Overlap :

Minimizing the number of access points that a driver must monitor simultaneously simplifies the driving task. Drivers need to be alert for turning vehicles at one driveway at a time. This criterion referred to in the literature as the "Right-Turn Conflict Overlap"- calls for adequate separation of conflict points.

Two conflict points between a through vehicle and a driveway vehicle are created where the driver of the through vehicle must be alert for a right-turning vehicle entering the roadway, from one drive at a time, or for a vehicle making a right-turn into a driveway. In both cases, through vehicles must decelerate to avoid a collision. this will create a shock wave in the through traffic stream. Moreover , a driver executing a right-turn or left-turn from the traffic stream will seriously disrupt the platoon flow. This has a negative impact on capacity and traffic operation as well as jeopardizing the public safety.

The minimum distances that are required to avoid this conflict overlap for one-driveway at a time are given in Table A-1.4. These distances can be used to determine minimum spacings when drivers monitor multiple driveways at a time. This is accomplished by dividing the distances shown by the number of driveways to be monitored simultaneously. Thus, half of these distances are needed where drivers are required to monitor two access points at a time. For example, using 300 feet for 45 mph, a separation of 150 feet will require drivers in the through lane to monitor two driveways simultaneously.

Table A-1.4 Minimum Distances to Reduce Collision Potential due to Right-Turn Conflict Overlap

Speed (mph)	Separation (ft)
30	100
35	150
40	200
45	300

A comparison of stopping sight distances (Table A-1.3) and conflict overlap (Table A-1.4) shows that the latter are shorter than the stopping sight distances (i.e., 100 ft vs. 200 ft at 30 mph). This is because the through vehicles do not come to a complete stop. The resulting high speed differentials in the through traffic lanes poses a potential collision problem on high speed, high volume streets and roads.

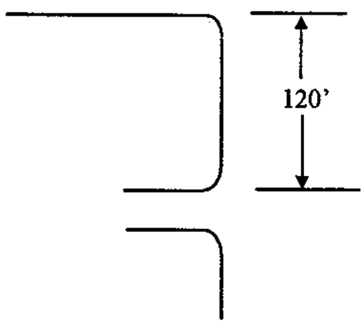
Left-Turn Driving Task :

The left turn maneuver at intersections is difficult and critical. Drivers making left turns should have at least 2.0 seconds before any encounter vehicles entering or leaving the roadway. This calls for a downstream distance of 45 to 60 feet.

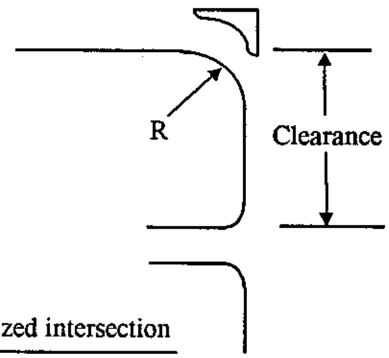
Right-Turn Downstream Clearance Distances :

Suggested corner clearances downstream from a major intersection are illustrated in Figure A-1.3. Where a right-turn deceleration lane of sufficient length is provided downstream from a major intersection, a distance of 35 to 40 ft between the end of the curb return and the beginning of the right-turn lane bay taper is desirable.

Figure A-1.3 Right-Turn Downstream Corner Clearance



Unchannelized intersection with or without right turn on RED



Channelized intersection

R (feet)	Clearance (feet)
50	200
75	230
100	275

A-1.3 Establish Access Separation Distances At Interchanges

NCHRP Project 3-47 -- Capacity Analysis of Interchange Ramp Terminals -- was initiated in 1994 to develop an appropriate methodology for determining capacity and level of service at signalized ramp terminals including closely spaced arterial intersections. The project has been completed but the report is not going to be published now. We have requested the authority to give us a copy of their report. When we get the report we will be able to the review the results of the project to develop access management standards regarding access separation distances at interchanges.

A-2 UNSIGNALIZED INTERSECTIONS AND DRIVEWAYS

For unsignalized intersections and driveways five access management techniques were identified. These techniques are described below :

A-2.1 Establish Spacing For Unsignalized Intersection

(Source : *TRB Circular 456 : Driveway and Street Intersection Spacing,* Access Management Committee, Transportation Research Board, National Research Council, Washington, D.C., March 1996.)

The following factors might be considered in selecting driveway spacing standards :

- Stopping sight distance
- Intersection sight distance
- Length of turn lanes
- Right turn conflict overlap, and
- Egress capacity

Table A-2.1 Summary of Minimum Unsignalized Access Spacing (in feet) by Speed for Various Criteria

Criteria	Posted Speed (mph)								
	20	25	30	35	40	45	50	55	60
1. Stopping Sight Distance	120	165	220	275	340	410	485	565	655
2. Length of Turn Lane: Turning Traffic to leave Through Lane with a speed Differential of:									
a) ≤ 10 mph					490	590	700	820	950
b) ≤ 15 mph				390	390	490	590	700	820
c) ≤ 20 mph			320	320	320	390	490	590	700
3. Minimize Right Turn Conflict Overlap			100	150	200	300			
4. Intersection Sight Distance Through Traffic Reduces Speed by 15%	230	300	375	460	575	700	850	1000	1150
5. Maximum Egress Capacity	120	190	320	450	620	860	1125	1500	1875

A more detailed description of the criteria is given below :

Stopping Sight Distance

Stopping sight distance must be provided at all intersections including driveways. AASHTO uses coefficients of friction that result in braking rates that are acceptable to about 50% of the drivers. The high deceleration rates suggested that minimum stopping sight distances suitable for access design may be longer than the recommended AASHTO values. Moreover, AASHTO does not address the problem of severe braking on the horizontal curve where locked wheel braking will cause a driver to lose control of the vehicle. Additionally, the higher height of eye in trucks does not offset the longer stopping distance required by trucks.

Intersection Sight Distance

Unobstructed sight distance must be provided on all approaches to an intersection. Any object within the sight triangle that is high enough above the elevation of the adjacent roadway to constitute a sight obstruction should be removed or lowered. Such object include buildings, signs, cut slopes, hedges, trees, bushes, and all tall crops. Curb parking within the sight triangle should be prohibited.

AASHTO assumes a perception-reaction time of 2.0 seconds as being adequate for left turns, right turns, and crossing maneuvers. However, logic and experience indicate that need drivers making a left turn or crossing maneuver require more time than drivers turning right and only looking left.

For divided highways where the median is wider than the length of the design vehicle plus front and rear clearance, the maneuver can be performed as two operations. The stopped vehicle must first have adequate sight distance to depart from a stooped position and cross traffic approaching from the left. The crossing vehicle may then stop in the median before performing the second operation. The second move requires the necessary sight distance for vehicles to depart from the median to turn left into the cross road and to then accelerate without being overtaken by vehicles approaching from the right.

The AASHTO intersection sight distances assume that the stopped vehicle makes the turn and accelerates to 85% of the speed of traffic on the major roadway. This requires that on-coming traffic on the major roadway decreases speed by about 15%. Such an assumption is probably suitable for rural conditions; however, it may be a questionable assumption for high volume urban situations with coordinated traffic signal timing where traffic flow occurs in platoons. This is because: (1) drivers in the through lanes will have limited opportunity to change lanes even under moderate volumes; and (2) forcing vehicles in the through traffic lanes to decelerate 15% will produce a speed differential "shock wave" in the traffic lane.

Table A-2.2 AASHTO Passenger Vehicle Sight Distances for Left and Right Turns

Design Speed (mph)	AASHTO Left and Right Turns (ft)
20	230
25	300
30	375
40	460
45	575
50	700
55	1,000
60	1,500

The sight distances shown in Table A-2.2 suggest that the AASHTO values may be low for major urban arterials, especially for left turn maneuver. However, the left-turn sight distance can be increased to account for a larger perception-reaction time by multiplying the through traffic speed in feet or meters per second by the number of seconds the perception-reaction time to be increased.

Table A-2.3 : Comparison of Sight Distances for a Passenger Vehicle Crossing a Two-Lane Roadway

	Crossing Sight Distance (Feet)			
		Calculated		
Speed (mph)	1990 AASHTO	2-lane	4-lane Undivided	6-lane Undivided
20	195	205	235	260
25	240	255	295	325
30	290	310	350	390
35	340	360	410	450
40	390	410	470	515
45	440	465	530	580
50	480	515	590	645
55	525	565	645	710
60	570	615	705	775
65	620	670	765	840
70	650	720	825	905

The sight distances given in Table A-2.3 suggest that the AASHTO intersection sight distance curves appear low for the crossing maneuver as compared to the calculated sight distances shown.

Length of turn Lanes

The AASHTO "Green Book"(page 793) makes the statement that " Driveway terminals are in effect at-grade intersections .... and ...... Driveways should not be situated within the functional boundary of at-grade intersections. This boundary would include the longitudinal limits of the auxiliary[left-turn and right-turn] lanes". Under this criteria, minimum driveway spacing would exceed the dimensions given in Table A-2.4.

Table A-2.4 Functional Intersection Area, Excluding Storage

	Desirable Condition		Limiting Condition	
Speed (mph)	Deceleration (feet)	Total (feet)	Deceleration (feet)	Total (feet)
30	225	325	170	215
35	295	425	220	270
40	375	525	275	335
45	465	630	340	405
50	565	750	410	480
55	675	875	495	565
60	785	1005	565	655

Right-Turn Conflict Overlap

Minimum distances required to avoid the right-turn conflict overlap is shown in Table A-2.5.

Table A-2.5 Minimum Distances to Reduce Collision Potential due to Right-Turn Conflict Overlap

Speed (mph)	Separation (ft)
30	100
35	150
40	200
45	300

These distances would result in a speed differential substantially in excess of 10 mph. Thus, the conflict overlap criteria results in considerably shorter distances than the criteria of a 10 mph speed differential between a turning vehicle and through traffic.

If the right-turn conflict is to be limited to one driveway at a time and vehicles in the through traffic lanes are not required to reduce speed more than some accepted amount (such as a speed reduction of 0 mph, or 15% below design speed), the minimum driveway spacing is the intersection sight distance. Thus it should be realized that the minimum spacings in Table A-2.5 represent conditions where the access spacing has a significant impact on the through traffic. The potential magnitude of this impact is suggested by the speed differential that may be precipitated in the traffic stream.

As previously indicated, the distances for driveway spacing and downstream corner clearance given in Table A-2.1 may be used to determine minimum spacings requiring the driver to monitor multiple driveways by simply dividing the distance by the number of drives to be monitored simultaneously.

Egress Capacity

Driveways spaced at distances greater than 1.5 times the distance required to accelerate from zero to the speed of the through traffic will reduce delay to vehicles entering the traffic stream (I.T. Major and D.J. Buckley, "Entry to a Traffic Stream, Proceedings of the Australian Road Research Board, 1962). Spacing based on acceleration distances for passenger cars on level grades are given in Table A-2.6 below :

Table A-2.6 Minimum Access Spacing to Provide Maximum Egress Capacity

Speed (mph)	Spacing (feet)
20	120
25	190
30	320
35	450
40	620
45	860
50	1,125
55	1,500
60	1,875

At desirable peak-period speeds (about 35 mph), the desirable spacing is 450 feet. This suggests that more than five right-turn in and right-turn out driveways between signals at 1/2 mile spacings will result in a reduction in the number of vehicles that can enter through the roadway from adjacent properties and will actually be detrimental to the business located on the arterial. At an off-peak period of say 50 mph, no more than one right-turn access drive can be provided without having a negative effect on capacity. The actual capacity effects will depend on the driveway volumes involved.

Summary

Table A-2.1 summarizes the unsignalized access spacing guidelines for various criteria that have been described. Spacing standards within the ranges shown should be selected whenever possible to ensure safe traffic operations. However, their application may require adjustments in developed areas, where land subdivision has often limited property frontage and the desired spacings may not always be achievable. To address these situations, procedures should be established to deal with exceptions to the adopted access standards.

A-2.2 Consolidate Driveways

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

This general operating practice encourages adjacent property owners to construct joint-use driveways in lieu of separate driveways. Strategies for implementing this technique include closing existing driveways or authorizing joint-use driveways or authorizing joint-use driveways.

A prime example of this technique is the neighborhood shopping center, where access to several properties is provided by a few access points. The feasibility of this technique is viewed primarily at the permit-authorization stage. The joint driveway will cause a reduction in the concentration of driveways along an arterial. The reduction in driveway concentrations is expected to be accompanied by a reduction in the frequency and severity of conflicts.

Design

The physical means by which access can be consolidated between two adjacent properties involves construction of a joint use driveway between the two properties. It is recommended that the joint-use driveway be owned by both property owners. That is, the driveway should be located precisely straddling the property line dividing the two establishments. This practice will not enable either owner the opportunity to deny or restrict access to his neighbor's property. The resulting joint-use parking area should be accompanied by an efficient internal circulation plan.

A-2.3 Channelize Driveways To Discourage Or Prohibit Left-Turn On Undivided Highways

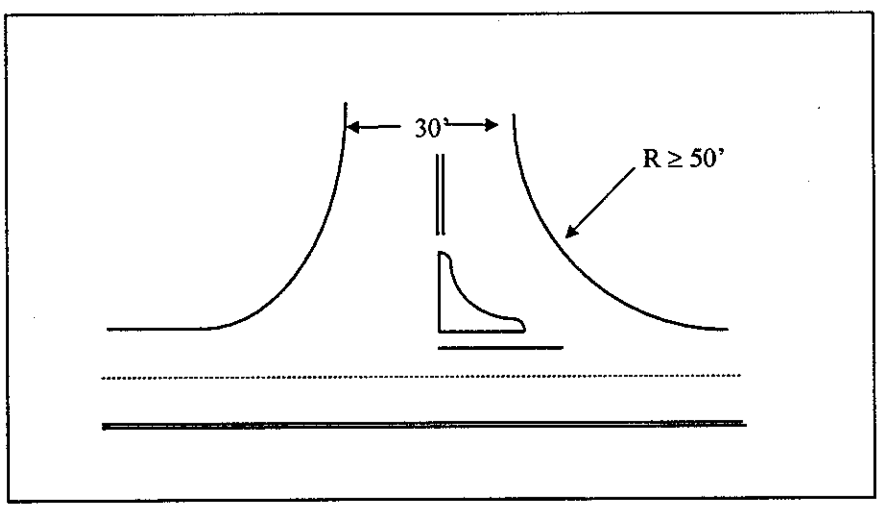
(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.

Glennon, J.C., Valenta, J.J., Thomson, B.A., and Azzeh, J.A., *Technical Guidelines for the Control of Direct Access to Arterial Highways : Volume II, Detailed Description of Access Control Techniques,* Report FHWA-RD-76-87, Federal Highway Administration, August 1975.)

This driveway design technique directly controls access by preventing left-turn ingress and egress maneuvers. The left-turn maneuvers are restricted by a channelizing island in the driveway throat. The main objective of this technique is to reduce the number of conflicts points by limiting the basic crossing conflicts.

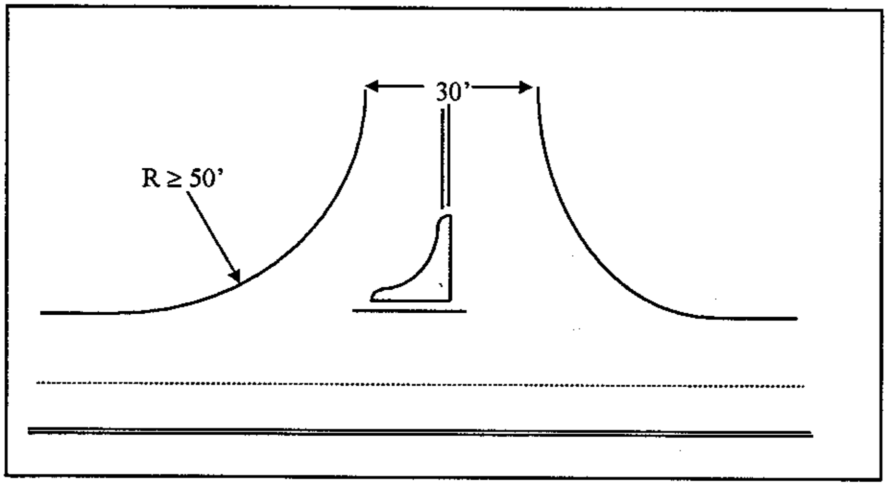
The technique reduces the frequency and severity of conflicts by reducing the basic conflict points from nine to two at a driveway. This measure completely eliminates the crossing conflicts that accompany left-turn ingress and egress maneuver.

Figure A-2.1 Driveway Channelizing Island to Prevent Left-Turn Ingress Maneuvers



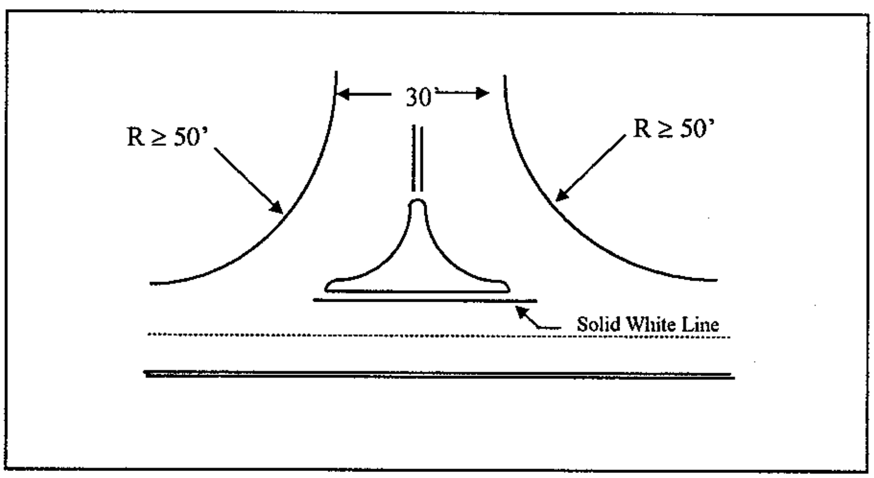
The first case eliminates left-turn ingress maneuvers. Widening of the driveway will be required to accommodate the large turning radius for right turn ingress maneuvers. At least 50-ft curb return radius is recommended for the optimum operation of this design.

Figure A-2.2 Driveway Channelizing Island to Prevent Left-Turn EgressManeuvers



The second case eliminates left-turn egress maneuver. Again a driveway channelizing island is located in the driveway throat to prevent left-turn egress maneuvers. Widening of the driveway is required to accommodate the island. A 50 ft curb return radius is recommended for the optimum operation of this design.

Figure A-2.3 Driveway Channelizing Island to Prevent Left-Turn Ingress and Egress Maneuvers



The third case eliminates both left-turn egress and ingress maneuvers. A triangular shaped island is located in the driveway throat to prevent both maneuvers. Widening of the driveway on both sides is required to accommodate the turning radii for right-turn egress and ingress vehicles. A minimum of 50 ft curb return radius is recommended for the efficient operation of this design.

A-2.4 Install Barrier To Prevent Uncontrolled Access Along Property Frontage

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

The installation of a physical barrier along a single property or many adjacent frontages is a design technique for controlling access on all kinds of highways. The controlled of access can be accomplished by erecting fences, barriers, plantings, or curbs adjacent to the roadway or shoulder. Possibilities exist for the construction of rock walls, rail fences, or other structures that are compatible with the aesthetics of the area. Curbing, however, is the most common method.

The design technique reduces the total area of conflict by controlling and defining driveway openings. The frequency of conflicts is reduced because the number of possible conflict points limited to the defined driveway openings.

Design

Regulation of uncontrolled access along property frontages can be accomplished by several methods. Included in this list are :

- Barrier
- Curbing
- Shrubbery
- Railing

Of the above, curbing is widely used due to :

- Ease of installation
- Low maintenance and
- Effectiveness

Care however must be exercised when placing curb to review not only the impact on control of access, but also its affect on the site and roadway drainage.

A-2.5 Coordinate Driveways On Opposite Sides Of The Street

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.

Glennon, J.C., Valenta, J.J., Thomson, B.A., and Azzeh, J.A., *Technical Guidelines for the Control of Direct Access to Arterial Highways : Volume II, Detailed Description of Access Control Techniques,* Report FHWA-RD-76-87, Federal Highway Administration, August 1975.)

This technique involves the longitudinal separation of driveways on opposite sides of the highways, and it can be implemented either at existing locations or as an optimization practice when authorization driveway permits.

The functional objective of coordinating driveways is to limit the number of conflict points. Conflicting points are reduced from 32 for directly opposing driveways (4-leg intersections) to 18 for the two offsetting driveways (two 3-leg intersections). The more severe crossing conflict points decreases from 16 to 6.

Figure A-2.4 Preferred Design to Coordinate Driveways on Opposite Sides of the Street

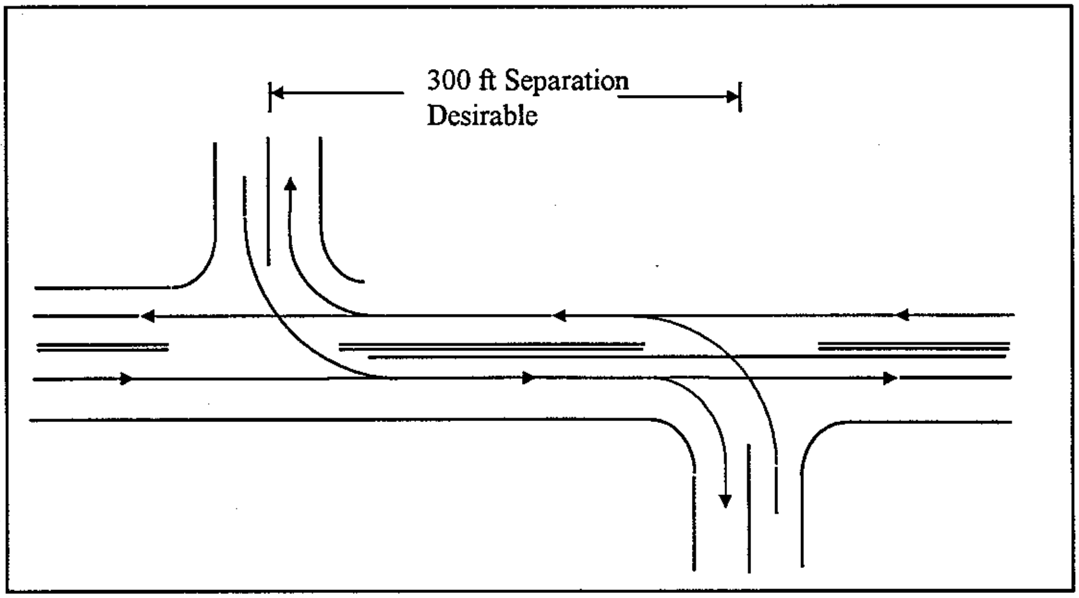
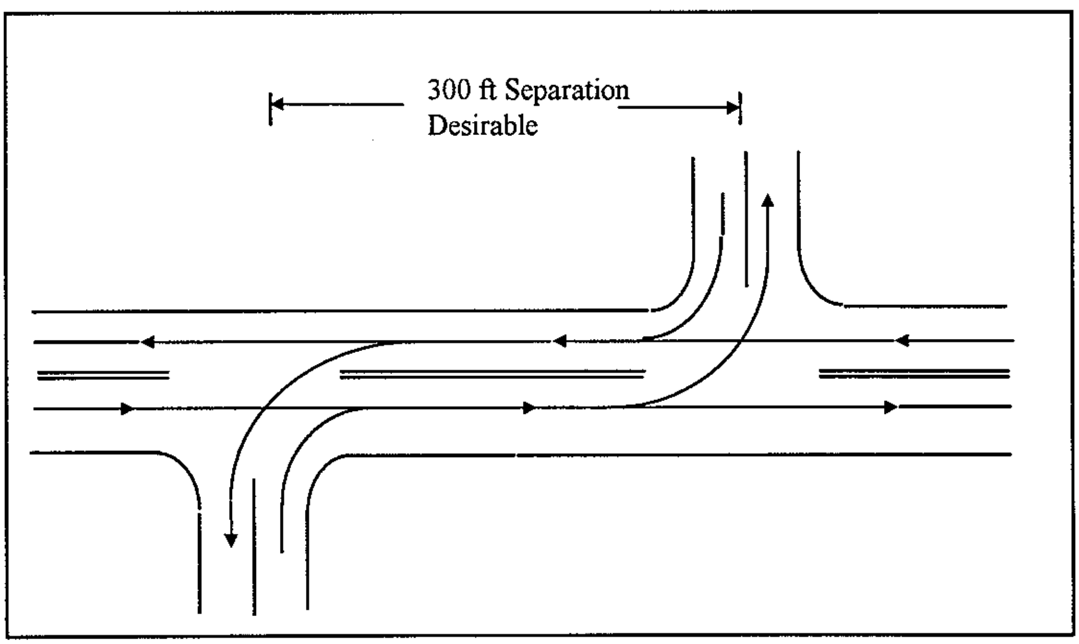


Figure A-2.5 Alternate Design to Coordinate Driveways on Opposite Sides of the Street



A-3 MEDIANS

For medians six access management techniques were identified. These techniques are described below :

A-3.1 Install Physical Continuous Median on Undivided Highway

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

This median treatment directly controls access on urban multilane highways by preventing left-turns and U-turns across the median except at a few designated locations. Access is provided with left-turn lanes at intersections and major driveways. In addition to preventing left turns at minor driveways, the raised median divider reduces stream friction by separating opposing traffic.

This technique reduces the frequency of total conflicts by reducing the basic conflict points from 9 to 2 at all minor driveways. More important, it completely eliminates the more hazardous crossing conflict points at these driveways. For intersections and major driveways, the frequency and severity of conflicts associated with left-turn vehicles are reduced by allowing deceleration and shadowing of these vehicles in left-turn lanes.

The median divider usually reduces the total number of driveway maneuvers. However, the maximum reduction in the frequency of conflicts is moderated by increases in right-turn volumes at minor driveways where desired left-turns are accomplished through indirect, circuitous paths.

A-3.2 Replace Continuous Two-Way Left-Turn Lane With Restrictive Median

(Source : Gluck, J., Levinson, H., Stover, V., Koepke, F., and Demosthenes, P., *Impacts of AccessManagement Techniques*, Interim Report, NCHRP, Transportation Research Board, National Research Council, January 1996.)

Two-way left-turn lanes (TWLTLs) remove left turns from the through traffic lanes. They have been widely used to provide access to closely-spaced, low-volume commercial driveways along arterial roads. But, from an access management perspective, they increase rather than control access opportunities. For this reason, a growing number of highway agencies have installed physical (restrictive) medians on four and six-lane highways to better manage highway access.

The medians reduce the number and location of conflicts. This results in improved safety, even though there may be some increase in rear-end accidents at median openings. However, rerouted left-turn volumes may increase congestion at downstream signalized intersections and the median may have an adverse economic impact o some business establishments.

A-3.3 Provide Continuous Two-Way Left-Turn Lane

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

A two-way left-turn lane is provided to remove left-turning vehicles from the through lanes and store these vehicles in a median area until an acceptable gap in opposing traffic appears. The two-way left-turn lane completely shadows turning vehicles from both through-lane traffic streams. Thus, accident severity and frequency reductions will result. Delay to through vehicles will also be reduced.

A-3.4 Provide Median Openings

(Source : Koepke F.J. and Levinson H.S., *NCHRP Report 348 : Access Management Guidelines for Activity Centers*, Transportation Research Board, National Research Council, Washington, D.C.,1992.)

Minimum desired spacings of unsignalized median openings at driveways as a function of speed are given in Table A-3.1. These spacings best apply to retrofit situations. Lower spacings will be appropriate for new driveways to avoid the accumulative impacts associated with repeated application of minimum standards. Suggested guidelines for spacing and design of median openings on divided highways are as follows:

1. The spacing of median openings for signalized driveways should reflect traffic signal coordination requirements and the storage space needed for left turns.

2. The spacing of median openings for unsignalized driveways should be based on the values suggested in Table A-3.2. Ideally, spacing of breaks should be conducive to signalization.

3. Median openings for left-turn entrances (where there is no left-turn exit from the activity center) should be spaced to allow sufficient storage for left-turning vehicles.

4. Median openings at driveways can be subject to closure where volumes warrant signals, but signal spacing would be inappropriate.

5. Median openings should be set far enough back from nearby signalized intersections to avoid possible interference with intersection queues.

6. **Note:** In all cases, storage for left turns must be adequate.

Table A-3.1 Spacing Criteria Between Unsignalized Median Openings on Divided Highways.

Speed (mph)	Spacing Recommendations (feet) Desirable Minimum
30	370
35	460
40	530
45	670
50	780
55	910

Table A-3.2 Guidelines for Spacing of Unsignalized Median Openings on Divided Roadways.

Access Category	Urban	Sub-urban	Rural
Freeway	NA	NA	NA
Expressway	NA	NA	NA
Strategic Arterial	NA	NA	NA
Principal Arterial	660 (a)	660 (a)	1320 (a)
Minor Arterial	660	(b)	(b)
Collector	330	660	1320
Local/Frontage Road	-	-	-

NOTES:

NA Not Applicable

(a) Left turn entrance only - must accommodate left turn storage requirements, but may not be closer than values shown.

(b) Function of traffic signal spacing requirements.

A-3.5 Close Existing Median Openings

(Source : Gluck, J., Levinson, H., Stover, V., Koepke, F., and Demosthenes, P., *Impacts of AccessManagement Techniques*, Interim Report, NCHRP, Transportation Research Board, National Research Council, January 1996.)

Closing existing median openings has merit where:

- Left-turn lanes cannot be provided.
- Left turning vehicles from nearby driveways spill back across the median opening.
- A left-turn lane has inadequate storage causing spill back onto through lanes.
- Median openings are too closely spaced along a high-speed roadway.
- Large number of accidents has occurred.

A-3.6 Replace Full Median Openings with Median Designed for Left-turns From Major Roadway

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

This median technique directly controls access on highways by preventing left-turn ingress and/or egress maneuvers. The left-turn maneuvers are restricted by channelizing the medians on divided highways to physically prevent vehicles from crossing. The technique reduces the frequency of total conflicts by reducing the basic conflict points from 9 to 5 when eliminating either left-turn ingress or egress maneuvers, and from 9 to 2 when eliminating both left-turn maneuvers at driveways. In particular, this measure eliminates the more severe crossing conflict points caused by left-turn ingress or egress movements. However, the maximum reduction in frequency of conflicts is moderated by increases in right-turn maneuvers and other indirect left turns which are accomplished through circuitous paths.

A-4 LEFT-TURNS

For left-turns three access management techniques were identified. These techniques are described below :

A-4.1 Provide Left-Turn Deceleration Lane

(Source : Neuman Timothy R., *NCHRP Report 279 : Intersection Channelization Design Guide*, Transportation Research Bord, National Research Council, Washington D.C., 1985.)

New Construction - Signalized Intersection

Left-turn lane should be considered at the planning and preliminary design stages of any new signalized intersection. Special efforts should be made to include separate left-turn lanes because of their many advantages.

Signalized capacity analysis procedures should be used to determine lane arrangements. Because of the many variables involved, it is not feasible to develop guidelines for all conditions. However, the following general "rules of thumbs" are useful in evaluating left-turn needs at specific locations.

Separate treatment of left turns will be required if

- Left-turn design volume exceeds 20 percent of total approach volumes; or
- Left-turn design volume exceeds 100 vehicles per hour in peak periods

This usually means either separate turning lanes, separate phases for left turns, or both.

Left-turn lanes may also be considered based on approach geometries. If more than minimum stopping sight distance is not available to the intersection, it may be appropriate to include left-turn lanes regardless of demand volume. This may help to reduce the rear-end accident potential.

At high speed, rural signalized intersections, separate left-turn lanes are considered necessary for safe operations. While capacity is not generally a problem, protection of queued left-turning vehicles from through traffic is critical. Because the availability and cost of right-of-way is not usually a problem, separate left-turn lanes can in most cases be easily implemented.

New Construction - Unsignalized Intersections

Streets and highways with unsignalized intersections also may require left-turn lanes to facilitate traffic flow. The following guidelines are suggested :

- Left-turn lanes should be considered at all median crossovers on divided, high-speed highways.
- Left-turn lanes should be provided at all unstopped (i.e. through) approaches of primary, high-speed rural highway intersections with other arterials or collectors.
- Left-turn lanes on stopped or secondary approaches should be provided based on analysis of capacity and operations of the unsignalized intersection. Considerations include minimizing delays to right turning or through vehicles, and total approach capacity.

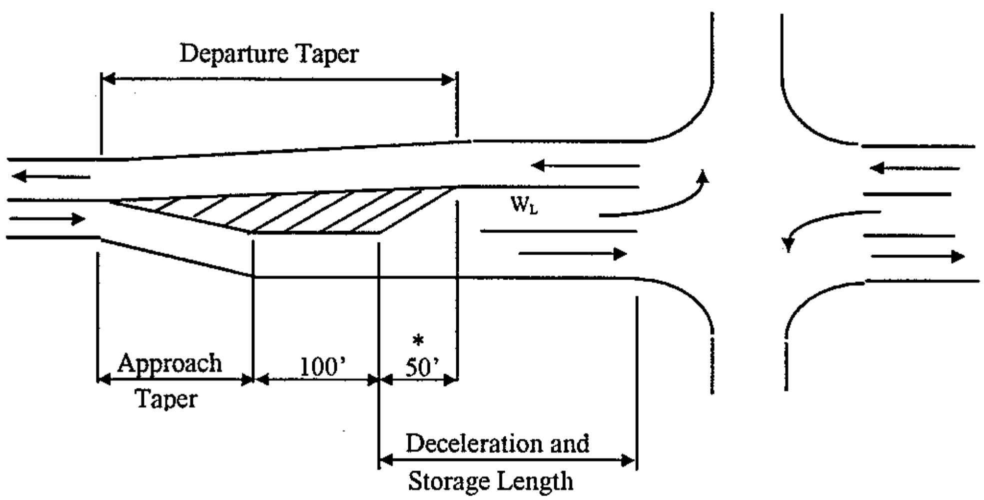
Reconstruction / Rehabilitation

Addition of left-turn lanes at existing intersections should be considered if safety or capacity problems occur, or if land-use changes are expected to produce significant shifts in local traffic patterns (such as increases in left-turn demand). Left-turn lanes can often be added within existing street widths by removing parking, narrowing of lanes or a combination of the two. In terms of safety, the following guidelines are suggested :

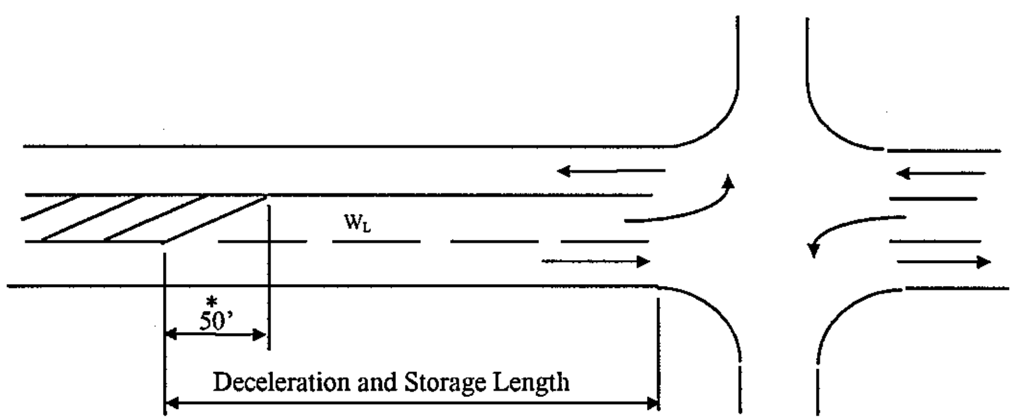
- Left-turn lanes should be considered at intersection approaches that experience a significant number of left-turn involved (rear-end, left-turn angle, same direction sideswipe) accidents. A total of 4 or more such accidents in 12 months, or 6 or more in 24 months, is considered appropriate.
- Where room for separate left-turn lanes is not available, traffic control alternatives should be investigated. Such alternatives to left-turn implementation include split phasing at signalized intersections (i.e. operating each approach individually) or prohibition of left turns.

(Source : *Location and Design Manual,* Volume One, Roadway Design, The Ohio Department of Transportation, December 1990.)

Figure A-4.1 Left-Turn Lane



Left-Turn Lane - No Median or Median Width < W_L



Left-Turn Lane - Median Width ≥ W_L

* Diverging Taper

A-4.2 Provide U-Turn As An Alternative To Direct Left-Turns

(Source : *A Policy on Geometric Design of Highways and Streets,* American Association of State Highway and Transportation Officials, Washington, D.C., 1990.)

Location and Design of U-Turn Median Openings

Median openings designed to accommodate vehicles making U-turns only are needed on some divided highways in addition to openings provided for cross and left-turning movements. Separate U-turn median openings may fit at the following locations :

1. Locations beyond intersections to accommodate minor turning movements not otherwise provided in the intersection or interchange area. The major intersection area is kept free for the important turning movements, in some cases obviating expensive ramps or additional structures.

2. Locations just ahead of an intersection to accommodate U-turn movements that would interfere with through and other turning movements the intersection. Where a fairly wide median on the approach highway has few openings, U-turning is necessary to reach roadside areas. Advance separate openings to accommodate them outside the intersection proper will reduce interference.

3. Locations occurring in conjunction with minor crossroads where traffic in not permitted to cross the major highway but instead is required to turn right, enter the through traffic stream, weave to the left, U-turn, then return. On high-speed or high-volume highways the difficulty and long lengths required for weaving with safety usually make this design pattern undesirable unless the volume intercepted are light and the median is of adequate width. This condition may occur where a cross road with high volume traffic, a shopping area, or other traffic generators that requires a median opening nearby and additional median openings would not be practical.

4. Locations occurring where regularly spaced openings facilitate maintenance operations, policing, repair service of stalled vehicles, or other highway related activities. Openings for this purpose may be needed on controlled-access highways and on divided highways through undeveloped areas.

5. Locations occurring on highways without control of access where median openings at optimum spacing are provided to serve existing frontage developments and at the same time minimize pressure for future median openings. A preferred spacing at 0.25 to 0.50 mi is suitable for most instances. Fixed spacing is not necessary, nor is it fitting in all cases because of variations in terrain and local service requirements.

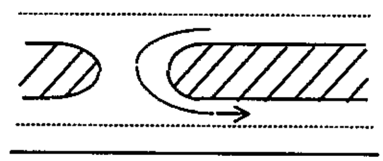
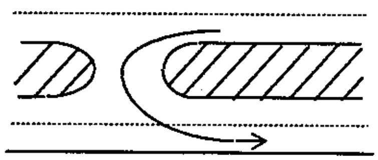
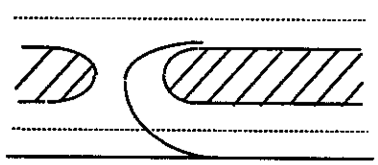
One requirement of satisfactory design for a U-turn is that the width of the highway, including the median, be sufficient to permit the turn to be made without encroachment beyond the outer edges of the pavements. Desirably the median should be wide enough to permit the turn to be accomplished from the lane next to the median onto the lane nearest the shoulder the shoulder on the roadway of opposing traffic.

Medians of 20 ft and wider are needed for passenger and truck traffic, to permit vehicles to turn from the inner lane (next to the median) on one pavement to the outer lane of a two-lane opposing pavement. A median left-turn lane is highly desirable in advance of the U-turn opening to eliminate stopping on the through lanes. This scheme would increase the required median width by approximately 12 ft.

Wide medians are uncommon in highly developed areas. Consequently, it is necessary to consider U-turn designs of a lower standard. Where right-of-way is restricted, speeds are low, and signal control is used to provide sufficient gaps in the traffic stream, medians 10 to 15 ft wide may be used for U-turn openings. This design permits passenger vehicles to turn from the inner lane to the shoulder on a four lane divided highway and from the inner to the outer lane on a six-lane facility. Preferably, openings for U-turn should be located in advance of an intersecting road or street, at least 100 ft from the median end, to keep entrance onto the U-turn free of vehicles stopped by traffic signals.

Normally, U-turns should not be permitted from the through lanes. However, where medians have adequate width to shield a vehicle standing in the median opening, it may be permissible. Minimum widths of median required for U-turns by different design vehicles turning from the lane adjacent to the median are given in Figure A-4.2. These dimensions are for a four-lane divided facility.

Figure A-4.2 Minimum designs for U-turns

Type of Maneuver		M- Min. width of median -feet for design vehicle						
		P	WB-40	SU	BUS	WB-50	WB-60	TDT
		Length of design vehicle						
		19'	50'	30'	40'	55'	65'	118'
Inner Lane to Inner Lane		30	61	63	63	71	71	101
Inner Lane to Outer Lane		18	49	51	51	59	59	89
Inner Lane to Shoulder		8	39	41	41	49	49	79

Indirect Left Turn or Indirect U-Turn-Wide Medians

Figure A-4.3 illustrates an indirect left turn for two arterials where left turns are heavy on both roads. The north-south roadway is undivided and the east-west roadway is divided with a wide median. Because left turns from the north-south road would cause congestion because of the lack of storage, left turns from the north-south roads are prohibited at the main intersection. Left turning traffic turns right onto the divided roadway and then makes a U-turn at a one-way crossover located in the median of the divided road. Auxiliary lanes are highly desirable on each sides of the median between the crossovers for storage of turning vehicles.

The crossover should be 400 to 600 ft away from the intersection to allow the left-turn traffic to approach the intersection on a green signal. This schemes provides a slight increase in capacity at very little cost with no additional acquisition of right-of-way. The main disadvantage is that the left-turn traffic has to pass through the same intersection twice. This maneuver also may be confusing to motorists unfamiliar with the design and thus requires special signing.

Figure A-4.3 Indirect Left- Turn Through Crossover

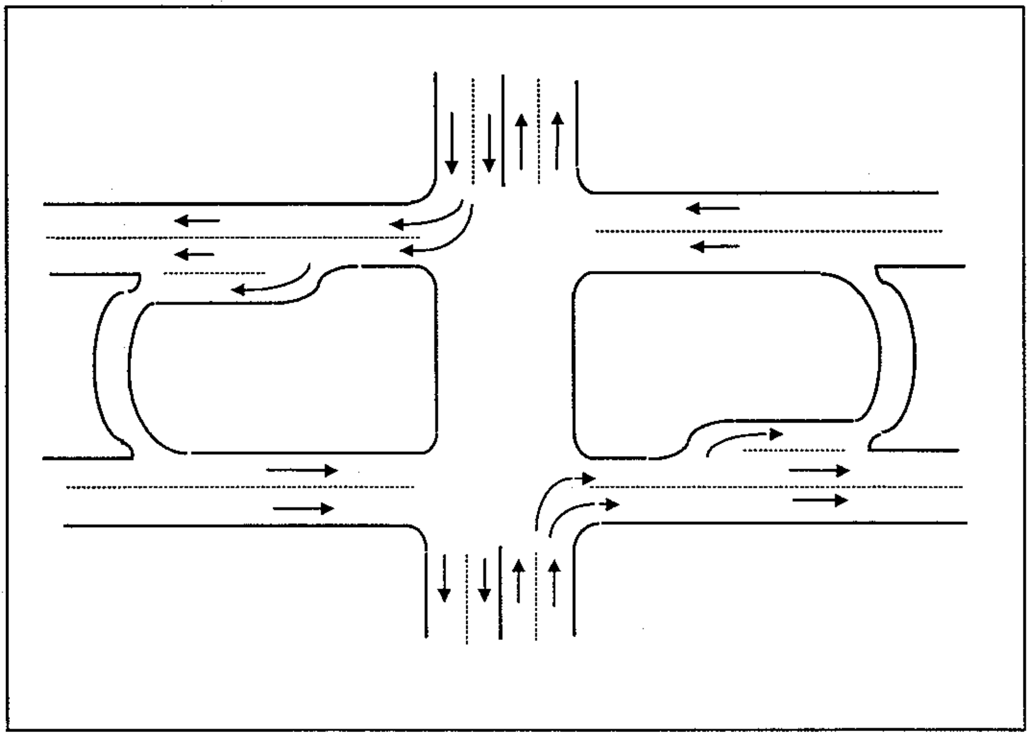
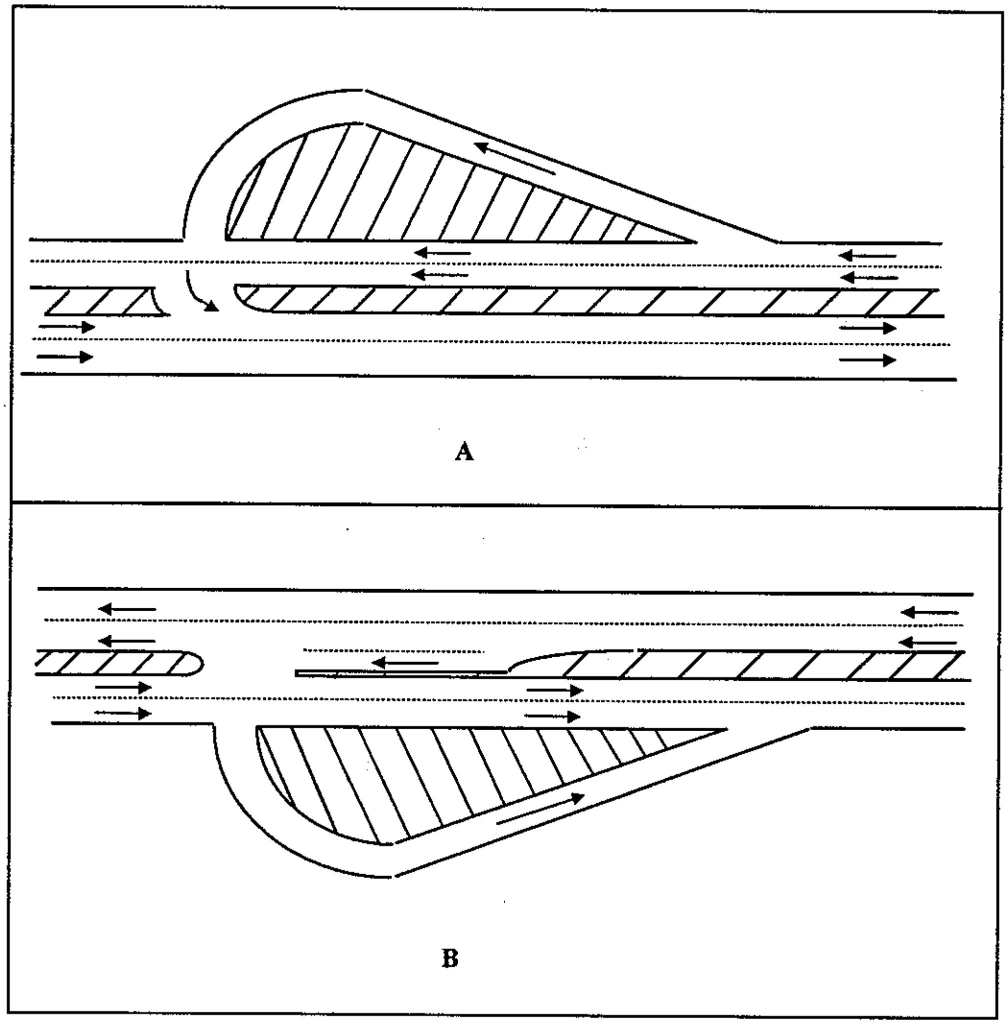


Figure A-4.4 illustrates special U-turn designs with narrow medians. In Figure A-4.4A the U-turning vehicle swings right from the outer lane, loops around to the left, stops clear of the divided highway until a suitable gap in the traffic stream develops, and then makes a normal left turn onto the divided highway. In Figure A-4.4B the U-turning vehicle begins on the inner lane of the divided highway, crosses the through-traffic lanes, loops around to the left, and then merges with the traffic. To deter vehicles from stopping on through lanes, a left-turn lane with proper storage capacity should be provided to accommodate turning vehicles.

Figure A-4.4 Special Indirect U-Turns with Narrow Medians



A-4.3 Provide Jug Handles And Eliminate Left-Turns Along Highways

(Source : *A Policy on Geometric Design of Highways and Streets,* American Association of State Highway and Transportation Officials, Washington, D.C., 1990.)

Divided highways require median openings to provide access for crossing traffic in addition to left-turning and U-turning movements. At intersections where the median is too narrow to provide a left turning vehicles and the traffic volumes or speeds, or both, are relatively high, safe, efficient operation is particularly troublesome. Vehicles that slow down or stop in a lane primarily used by through traffic to turn left greatly increase the potential for rear-end collision.

Other factors that require special design considerations for left and U-turning movements are the required turning paths of the various design vehicles in conjunction with narrow medians. The necessity to turn left or U-turn in the urban or heavily developed residential or commercial sectors also presents serious problems with respect to safety and efficient operation.

The design plans shown in Figure A-4.5 and A-4.6 offer several options with respect to indirect left turns and also provide for indirect U-turning movements. Figure A-4.5 involves a jug-handle-type ramp or diagonal roadway that intersects a secondary crossing roadway. The motorist exits via the jug-handle-type ramp, makes a left turn onto the crossroad, and then makes a left turn onto the divided highway to complete the left-turn or U-turning maneuver.

Figure A-4.6 shows an at-grade loop that can serve as an alternate to the jug-handle-type ramp. The loop design might be considered when the jug-handle-type ramps necessitate costly right of way, the opposite quadrant being less costly. There might be other justifications in selecting the loop instead of the ramp, such as improved vertical alignment and comparative grading costs.

An additional advantage of the loop occurs where the intersecting road is on one side of the divided highway. The accommodation for an indirect left-turn or indirect U-turn could be accomplished in placing the loop on the side opposite the intersecting roadway.

Figure A-4.7 illustrates a design that provides for indirect left-turns to be made from the right, via separate turning roadways connected to a crossroad. Such arrangements have the advantage of eliminating the left turns from the through lanes and providing storage for the left-turning vehicles not available on the highway itself. The left-turning vehicles with little extra travel distance are able to cross the main highway safely with appropriate traffic control devices. Figure A-4.7 illustrates three design options that might be adaptable to various roadway patterns. The turn from bottom to left is accomplished via the added left-turn slip ramp at the lower right (similar to previous discussions). This arrangement permits safe left-turns onto the minor road under traffic signal protection and prevents cars making left-turns from blocking the lane adjacent to the medians. Where there is a parallel roadway nearby, the added ramp may connect to it, as shown in the upper left or alternately as shown by the dashed-line connection. However, this design is less desirable because the vehicles must pass through the crossroad intersection and create delays by reducing speed in turning right. This problem might be overcome by the introduction of auxiliary lanes if space is available.

Figure A-4.5 Jug-Handle Type Ramp with Crossroad

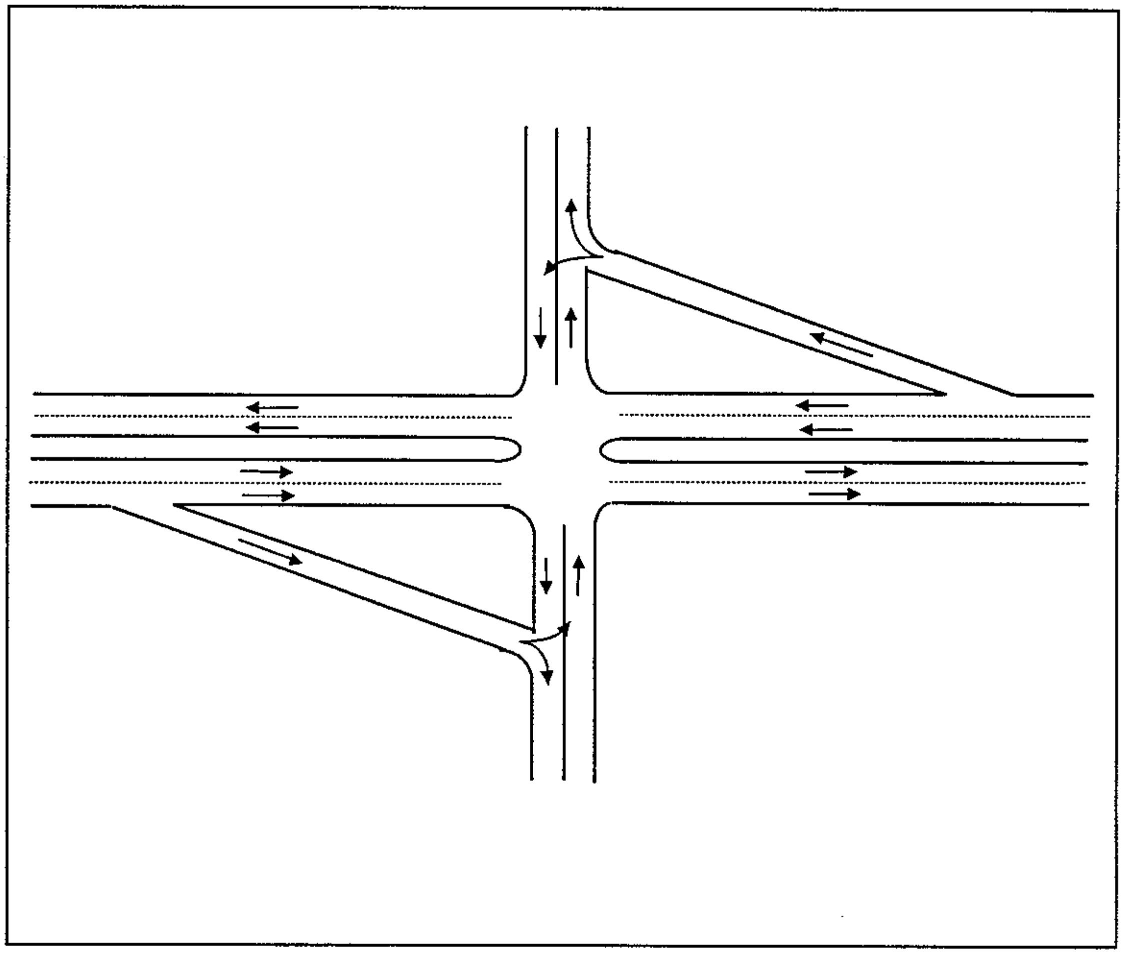


Figure A-4.6 At-Grade Loop (Surface Loop) with Crossroad

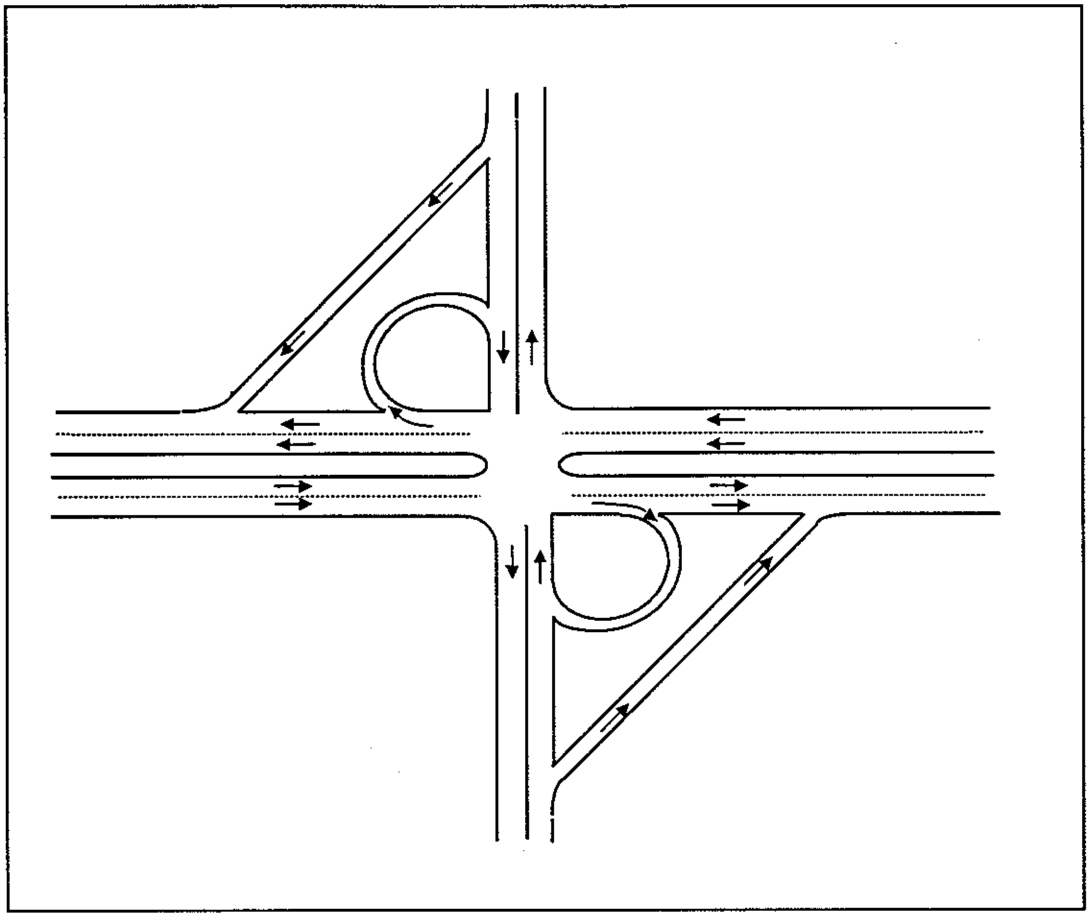
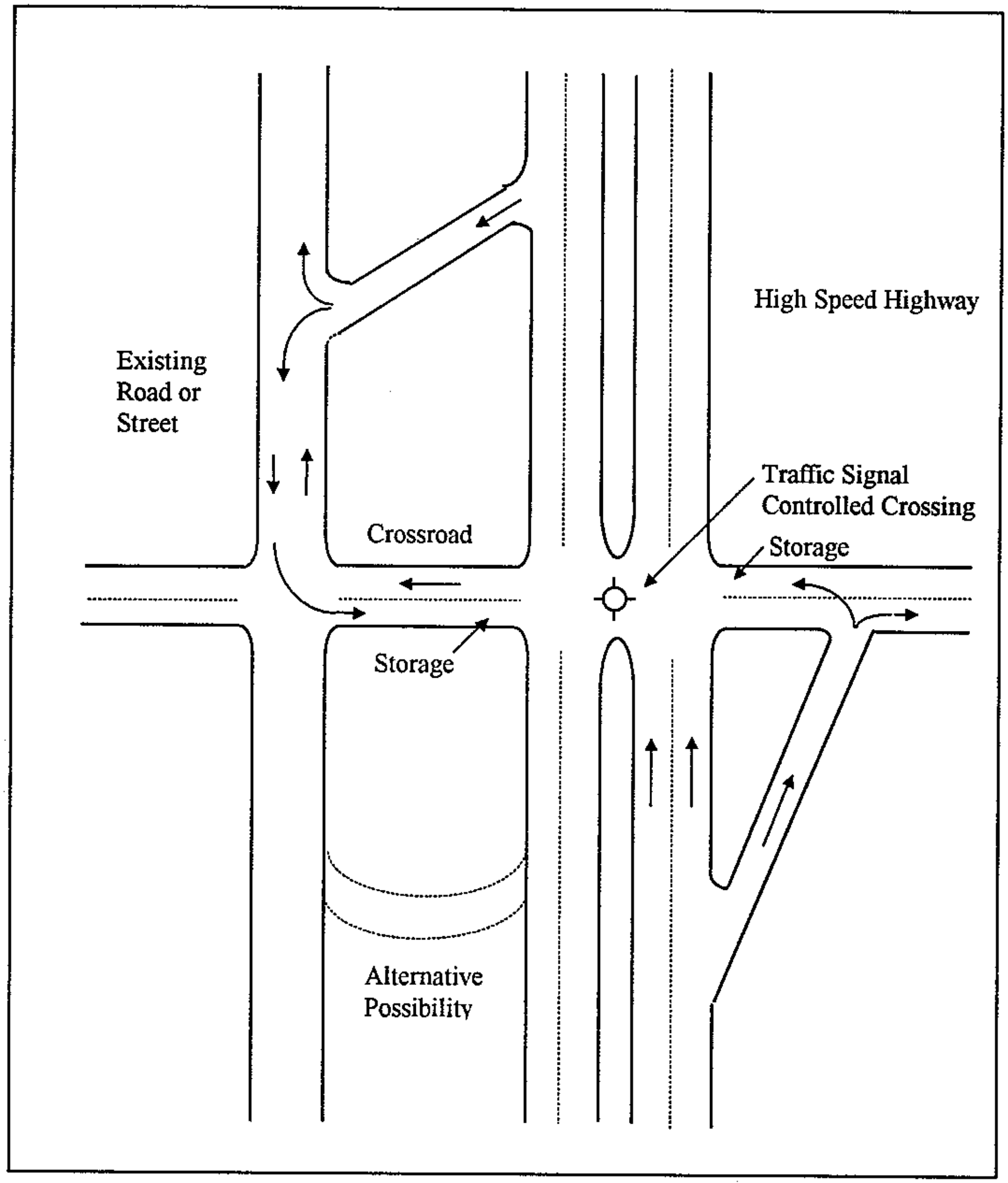


Figure A-4.7 Special Indirect Left-Turn Designs for Traffic Leaving Highway with Narrow Median



A-5 RIGHT-TURNS

For right-turns three access management techniques were idenified. These techniques are described below :

A-5.1 Install Right-Turn Acceleration Lane

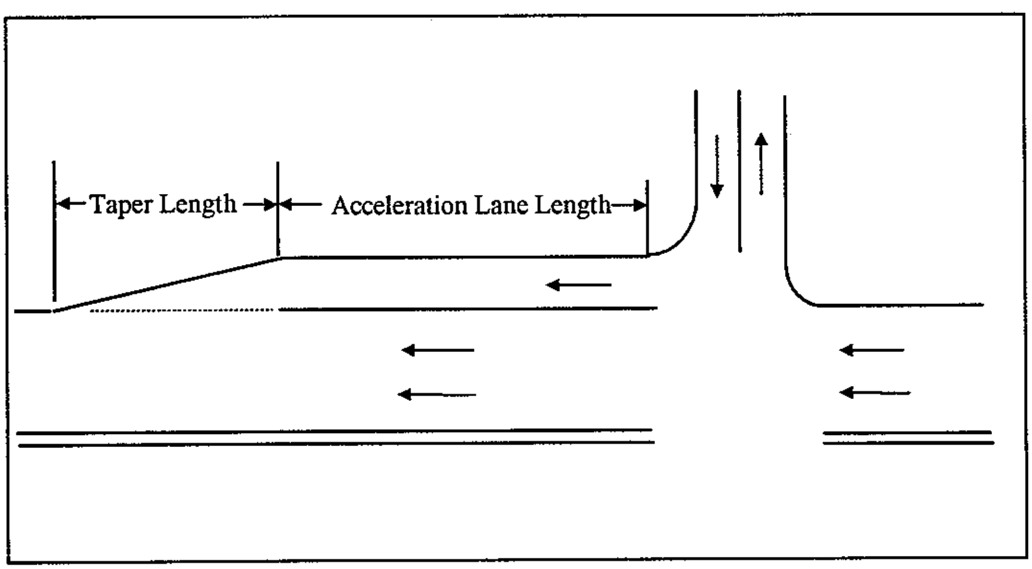
(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

This design technique reduces through lane deceleration requirements by facilitating higher speed driveway merge maneuvers. The merge maneuver is facilitated by a right-turn acceleration lane for use by right-turn egress driveway vehicles. This technique can be applied both during the permit-authorization stage or at existing facilities.

The speed of driveway to highway merges is increased by allowing driveway vehicles the necessary length to accelerate. The merge maneuver can be accomplished more safely when the speed is more compatible with highway running speeds.

Merge and rear-end conflicts are expected to decrease because of a reduction in the deceleration requirement of through vehicles. Increased perception time will also result.

Figure A-5.1 Right-Turn Acceleration Lane

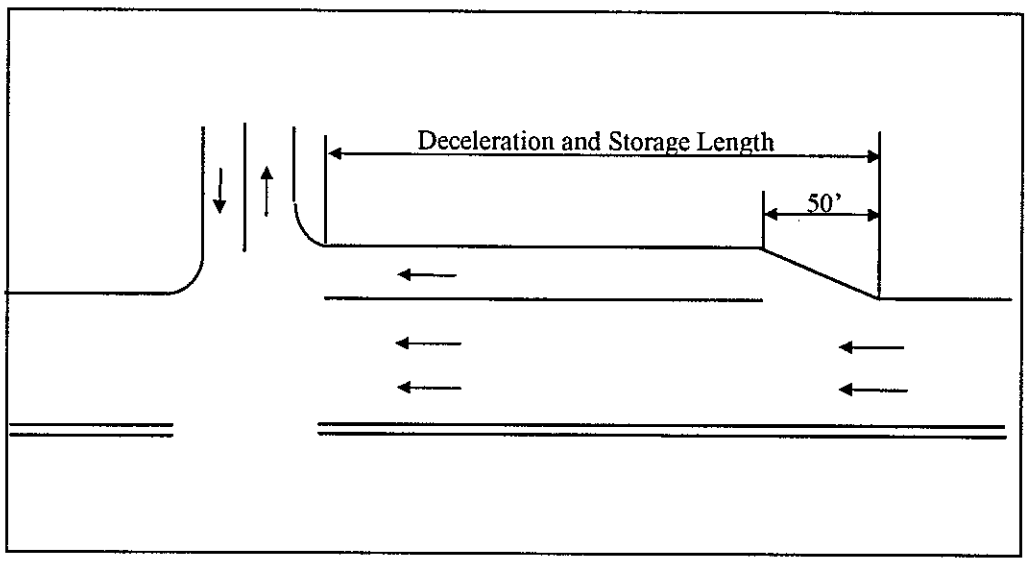


A-5.2 Install Right-Turn Deceleration Lane

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

This driveway design technique is aimed at removing turning vehicles or queues from sections of the through lanes. The deceleration lane will reduce the severity of rear-end conflicts on the highway by allowing right-turn vehicles to leave the through lanes at a high speed.

Figure A-5.2 Right-Turn Deceleration Lane

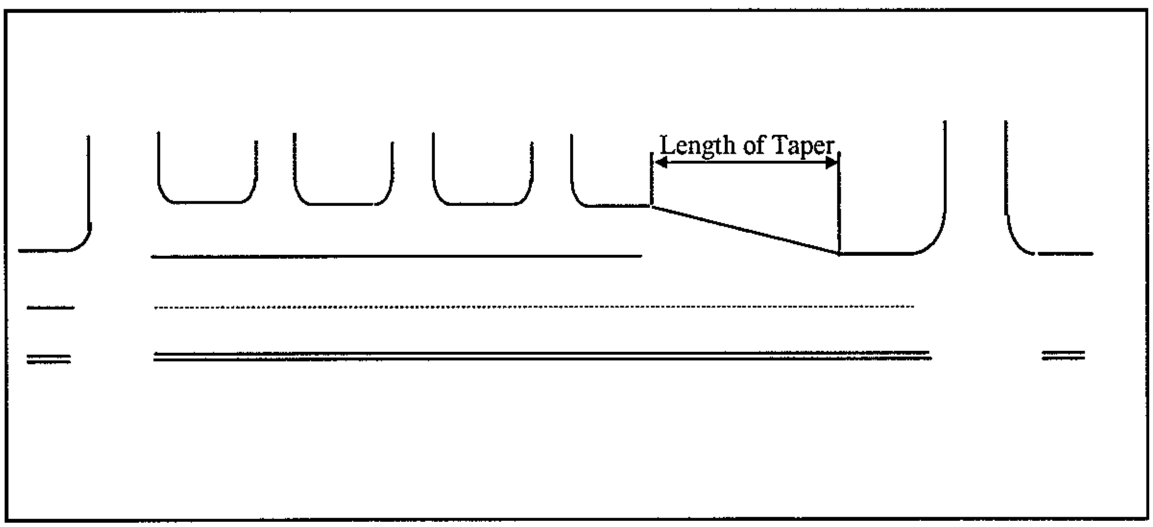


A-5.3 Install Continuous Right-Turn Lane

(Source : Flora John W., Keitt Kenneth M., *Access Management for Streets and Highways*, Report FHWA- IP- 82-3, U.S. Department of Transportation, Federal Highway Administration, June 1982.)

A continuous right-turn lane is essentially a combination of a right-turn acceleration and deceleration lane that is extended to accommodate several nearby driveways. It is used along a section of highway where driveways cannot otherwise accommodate right-turning queues and/or high enough right-turn speeds. This technique reduces the frequency and severity of rear-end conflicts by removing turning vehicles at higher speeds and by shadowing right-turn queues.

Figure A-5.3 Continuous Right-Turn Lane



A-6 SERVICE ROAD

For service road two access management techniques were identified. These techniques are described below :

A-6.1 Install Service Road to Provide Access to Individual Parcels

(Source : *A Policy on Geometric Design of Highways and Streets,* American Association of State Highway and Transportation Officials, Washington, D.C., 1990.)

Service roads may be used to control access to the arterial, to function as a street facility serving adjoining property, and to maintain circulation of traffic on each side of the arterial.

- Despite the advantages, the use of continuous service roads on relatively high-speed arterial streets with intersections at grade may be undesirable. At the cross streets, the various through and turning movements at several closely spaced intersections greatly increase the accident potential. The multiple intersections are also vulnerable to wrong-way entrances. Traffic operations are improved if the service roads are located at a considerable distance from the mainline at the intersecting cross roads in order to lengthen the spacing between successive intersections along the cross roads. In urban areas a minimum spacing of about 150 ft between the arterial and the service roads is desirable, and 300 ft is desirable in rural areas.

- Service roads generally are, but need not be, parallel to the roadway for through traffic, they may or may not be continuous, and they may be provided on one or both sides of an arterial.

- From an operational and safety standpoint, one-way service roads are much preferred to two-way.

- Two-way service roads may be considered for partially developed urban areas where the adjoining street system is so irregular or so disconnected that one-way operation would introduce considerable added travel distance and cause undue inconvenience. Two-way service roads may also be necessary for suburban or rural areas where points of access to the through facility are infrequent, where only one service road is provided, where roads or streets connecting the service roads are widely spaced, or where there is no parallel street within reasonable distance of the urban areas that are developed or likely to be developed.

(Source : Koepke F.J. and Levinson H.S., *NCHRP Report 348 : Access Management Guidelines for Activity Centers*, Transportation Research Board, National Research Council, Washington, D.C.,1992.)

The following design guidelines should be considered in installing arterial service roads in both new developments and retrofit situations.

- Service roads for "retrofit" situations should operate one-way and should enter pr leave the main level lanes as merging or diverging movements. There should be no signalized junctions along the artery or the service road in this area.

- One way service road are desirable.

- The separation of service roads and cross streets should be maximized to ensure, sufficient storage for cross road traffic between service roads and artery. The absolute minimum separation should be 300 ft. This dimension is about the shortest acceptable length needed for placing signs and other traffic control devices. Spacings of 600 to 1,320 ft are desirable especially where the cross road is a major arterial. This dimension usually provides acceptable storage space on the cross road in advance of the main intersection to avoid blocking the service road. The spacings of at least 300 ft (preferably more) enable turning movements to be made from the main lanes onto the service roads without seriously disrupting arterial traffic and, thereby minimize the potential of wrong-way entry onto the through lanes of the predominant highway.

- "Reverse" service roads, with developments along each side, are desirable to "close-in" service roads. A desirable set-back distance is 600 ft with a minimum distance of 300 ft. They my operate either one-way or two-way. Where two major arteries with service roads intersect, the mainline roads should be grade separated, or the service roads should be diverted. Direct crossings of two major highways and their service roads must be avoided.

- Service roads that can be terminated at each block operate well with respect to the arterial roadway and the cross street. This type of design should be considered where continuity of the service road is not needed.

- Where major activity centers front along an arterial roadway, service roads should be incorporated into the ring road or otherwise eliminated.

- A minimum outer separation of 20 ft should be used to provide space for pedestrian refuge and safe placement of traffic control devices and landscaping.

- Pedestrian and bicycle movements should utilize the service roads. Parking may be permitted where the service roads traverse residential areas.

A-6.2 Locate/Relocate the Intersection of Parallel Service Road and Cross Road

(Source : *A Policy on Geometric Design of Highways and Streets,* American Association of State Highway and Transportation Officials, Washington, D.C., 1990.)

Service roads are generally required contiguous to arterials or freeways where adjacent property owners are not permitted direct access to the major facility. Short lengths of service roads are desirable along urban arterials to preserve the capacity and safety of the arterial through control of access. Much of the improvement in capacity and safety may be offset by the added hazard introduced where the service road and arterial intersect the at-grade cross road. The added hazard results in part from the increase in the number of conflicting movements and from the confusing pattern of the roadways and separations, which lead to wrong way entry. Inevitably, where an arterial is flanked by service roads, the problem of design and traffic control at intersections are far more complex than where the arterial consists of a single roadway. Three intersections (two, if there is only one service road) actually exist at each cross street.

The preferred alternative to restricting turns is to design the intersection with expanded dimensions, particularly the width of the outer separation. This design permits the intersections between the crossroad and the service roads to be well removed from the cross road intersection with the main lanes.

For satisfactory operation with moderate to heavy traffic volumes on the service roads, the outer separation should preferably be 150 ft or more in width at the intersection. The 150-ft dimension is derived on the basis of the following considerations:

- This dimension is about the shortest acceptable length needed for placing signs and other traffic control devices to give proper direction to traffic on the crossroad.
- It usually affords acceptable storage space on the crossroad in advance of the main intersection to avoid blocking the service road.
- It enables turning movements to be made from the main lanes onto the service roads without seriously disrupting the orderly movement of traffic.
- It facilitates U-turns between the main lanes and two-way service road.
- It alleviates the potential of wrong-way entry onto the through lanes of the predominant highway.

Accordingly, outer separations at intersections should be 150 ft or more in width wherever practical and feasible. Narrower separations are acceptable where service road traffic is very light, where service road operates one way only, or where some movements can be prohibited.

APPENDIX B

Figure B.1 Key to Collision Diagram Symbols

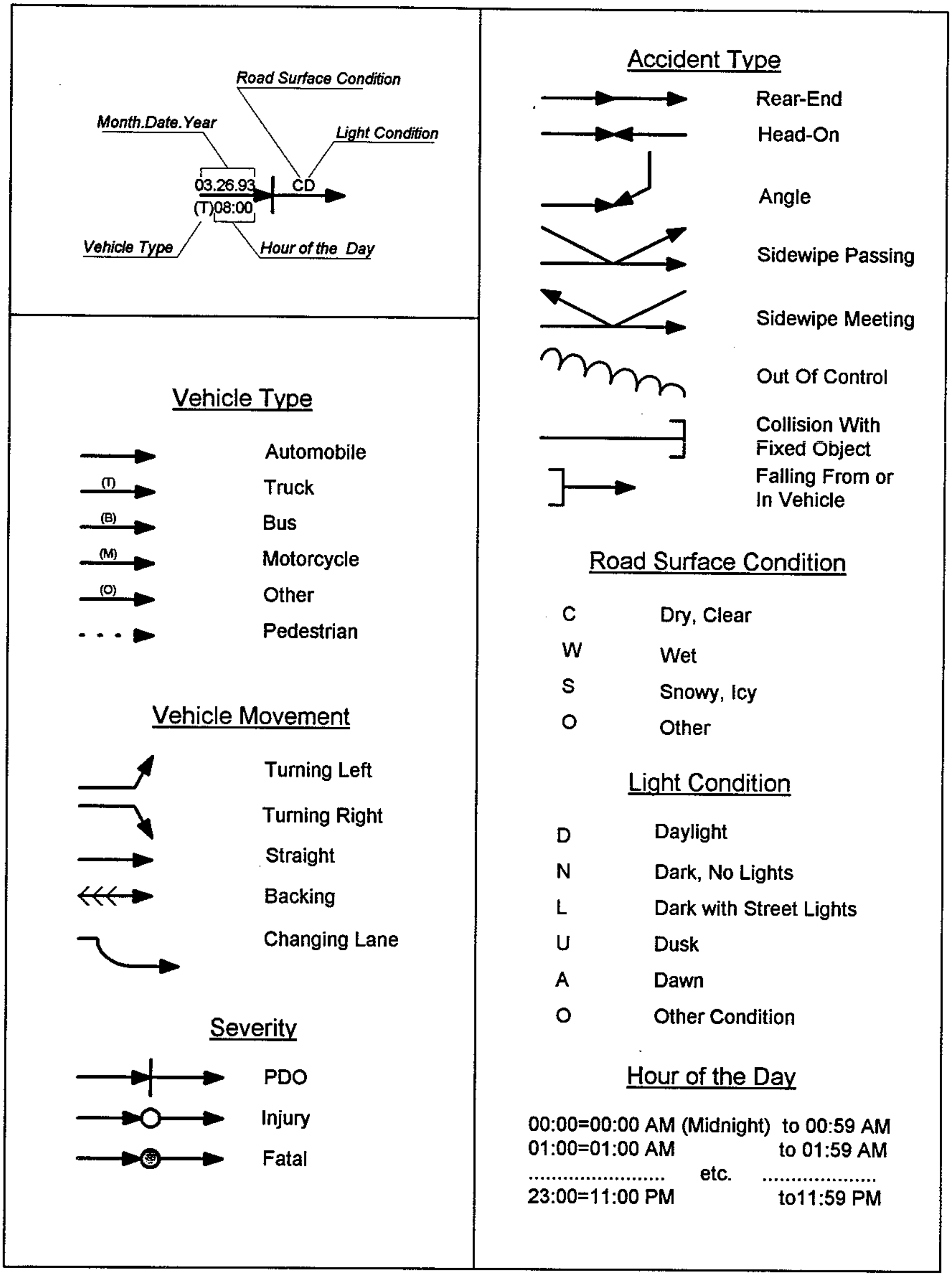
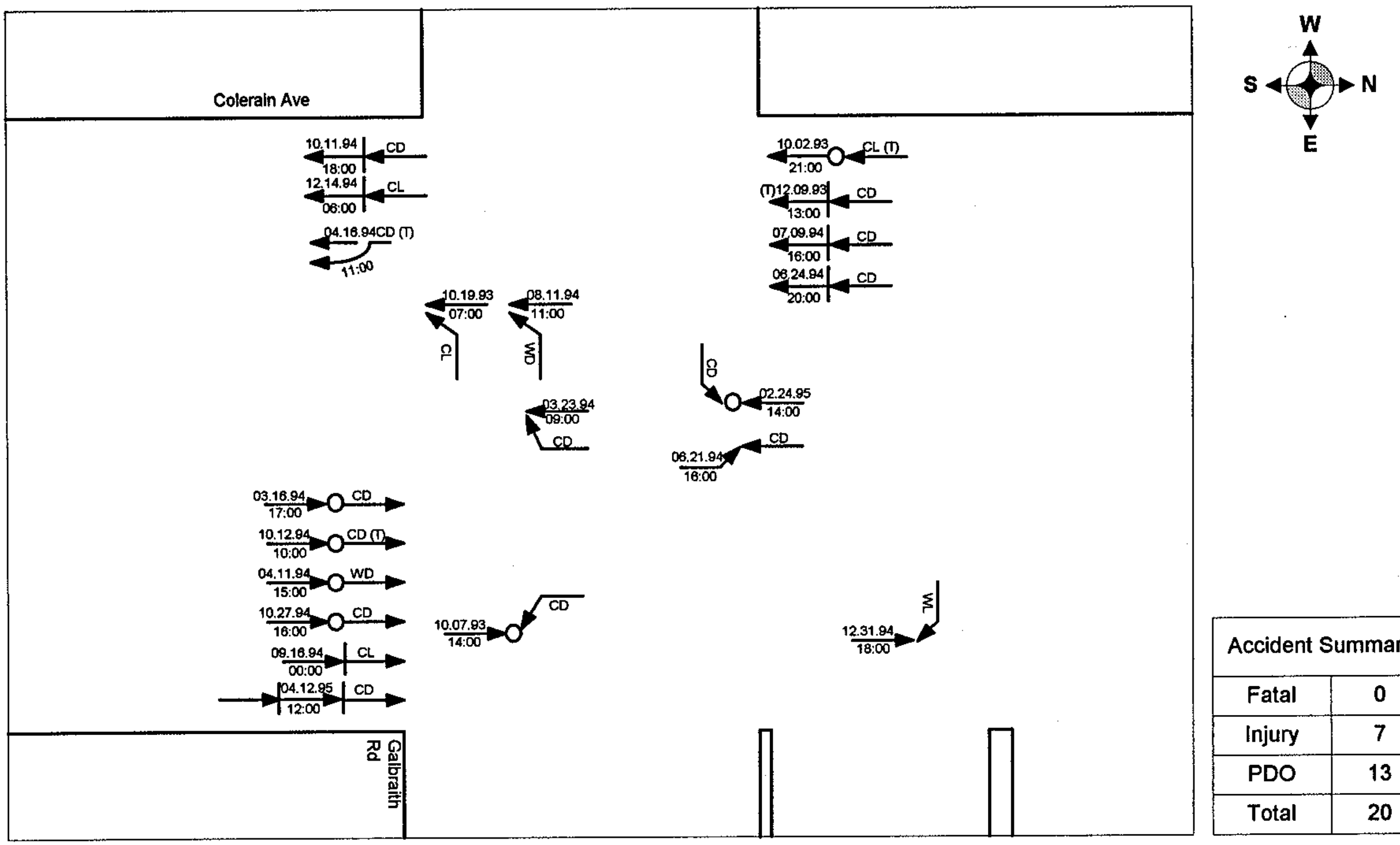


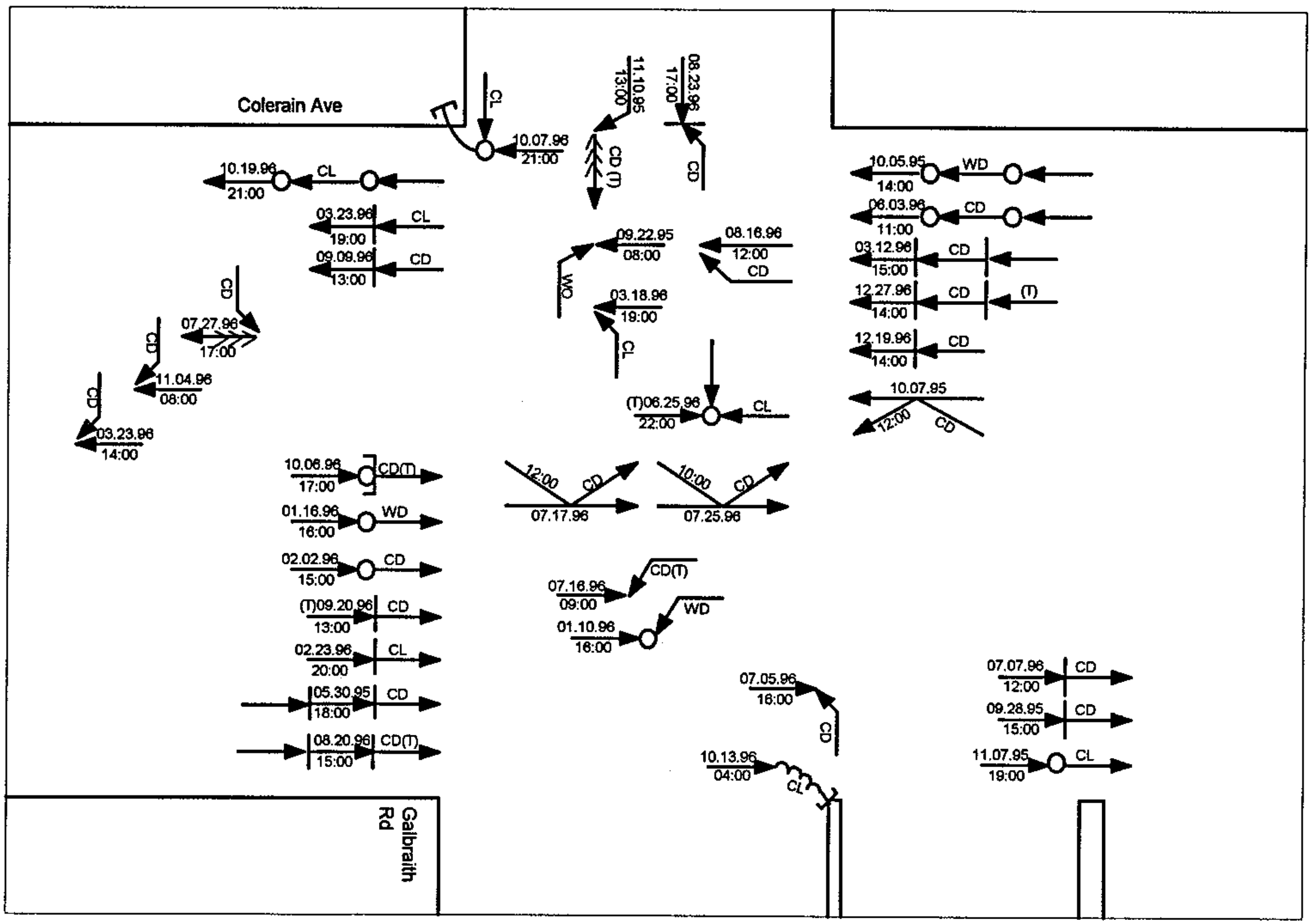
Figure B.2.1 Subarea #1 Colerain Ave & Galbraith RD
10/01/93 - 05/17/95

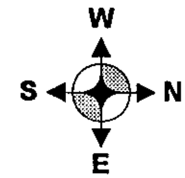


Accident Summary	
Fatal	0
Injury	7
PDO	13
Total	20

* For key to symbols, see Figure B.1.

Figure B.2.2 Subarea #1 Colerain Ave & Galbraith RD
05/18/95 - 10/31/96

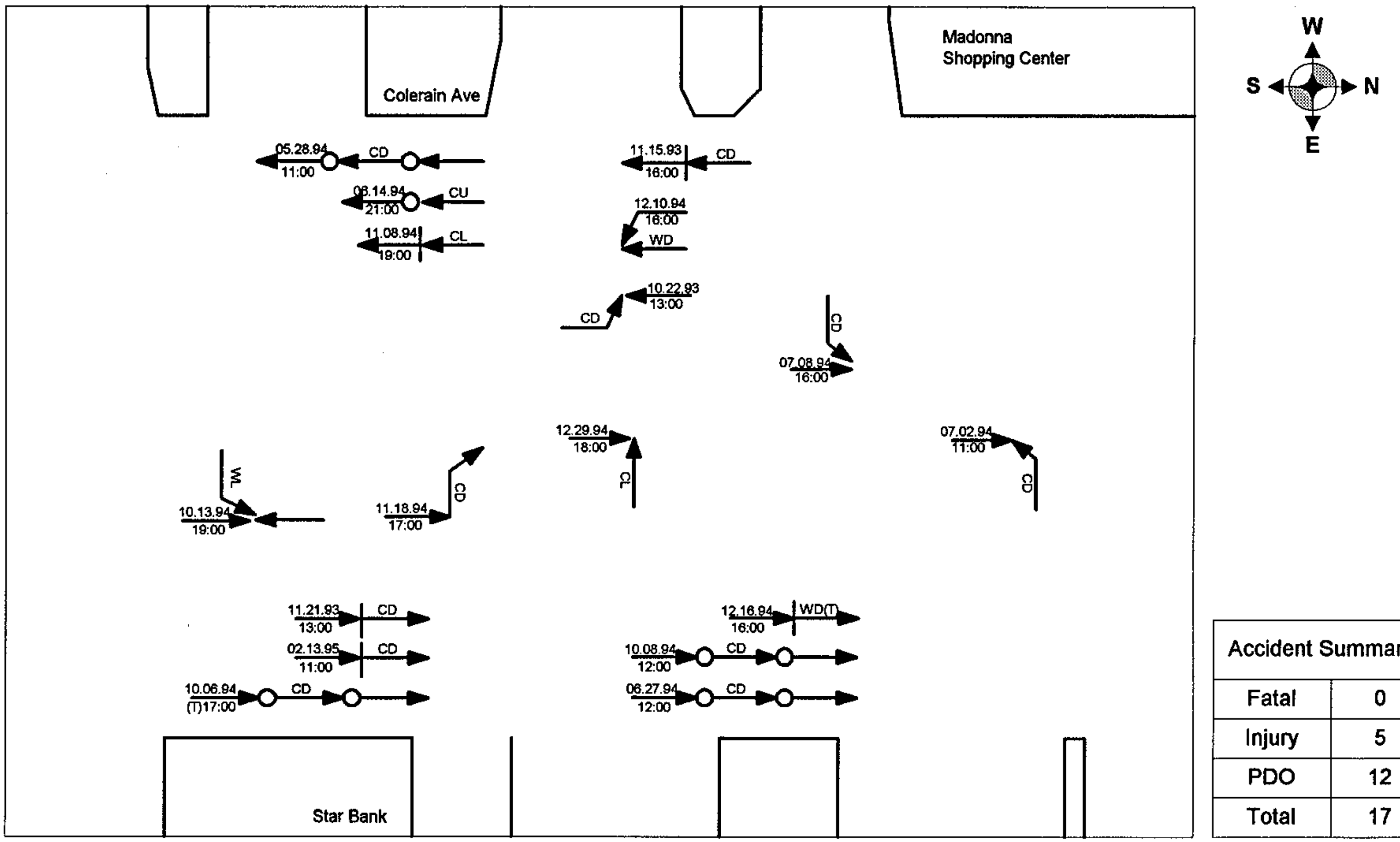




Accident Summary	
Fatal	0
Injury	10
PDO	25
Total	35

* For key to symbols, see Figure B.1.

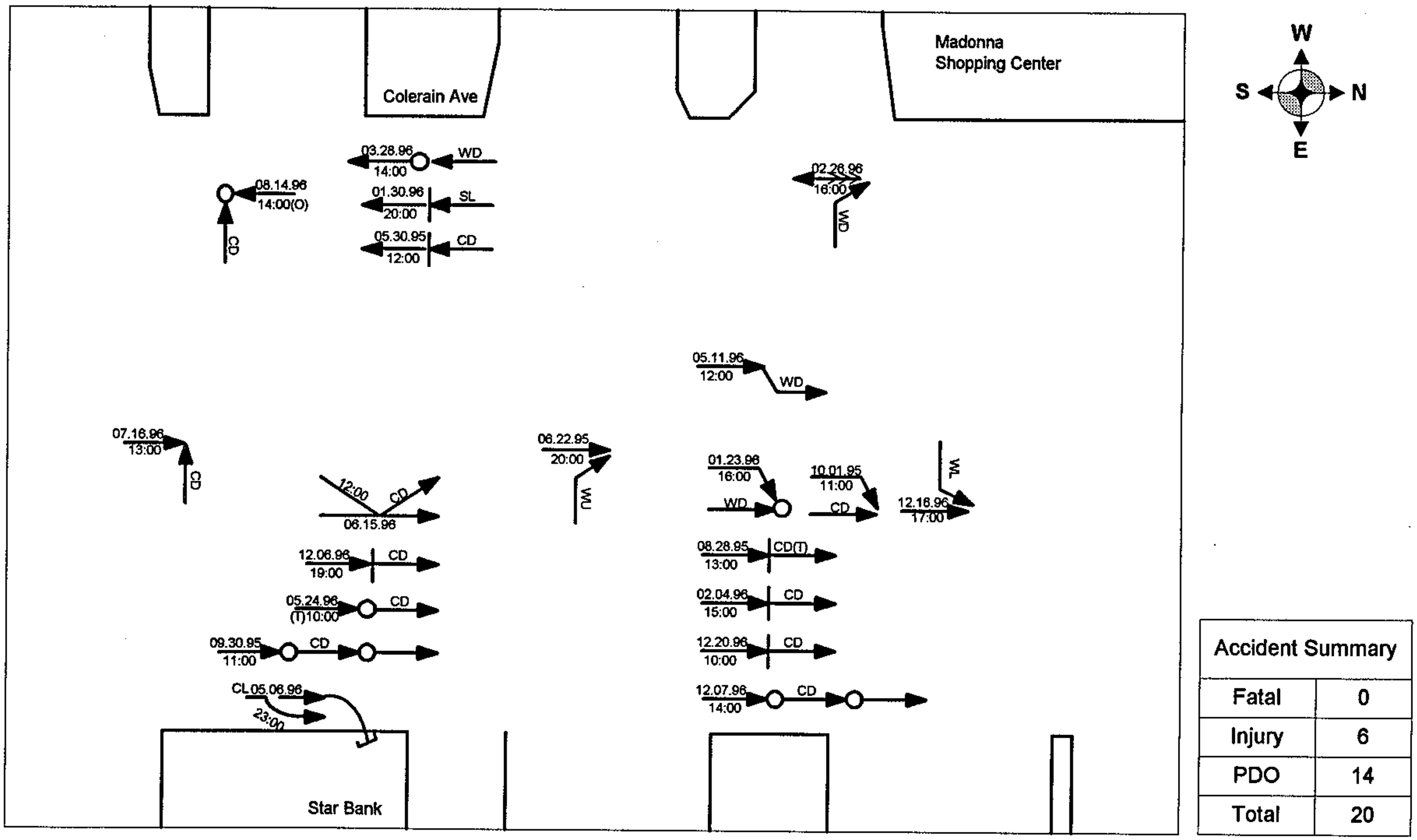
Figure B.3.1 Subarea #1 Colerain Ave & Madonna Shopping Center
10/01/93 - 05/17/95



Accident Summary	
Fatal	0
Injury	5
PDO	12
Total	17

* For key to symbols, see Figure B.1.

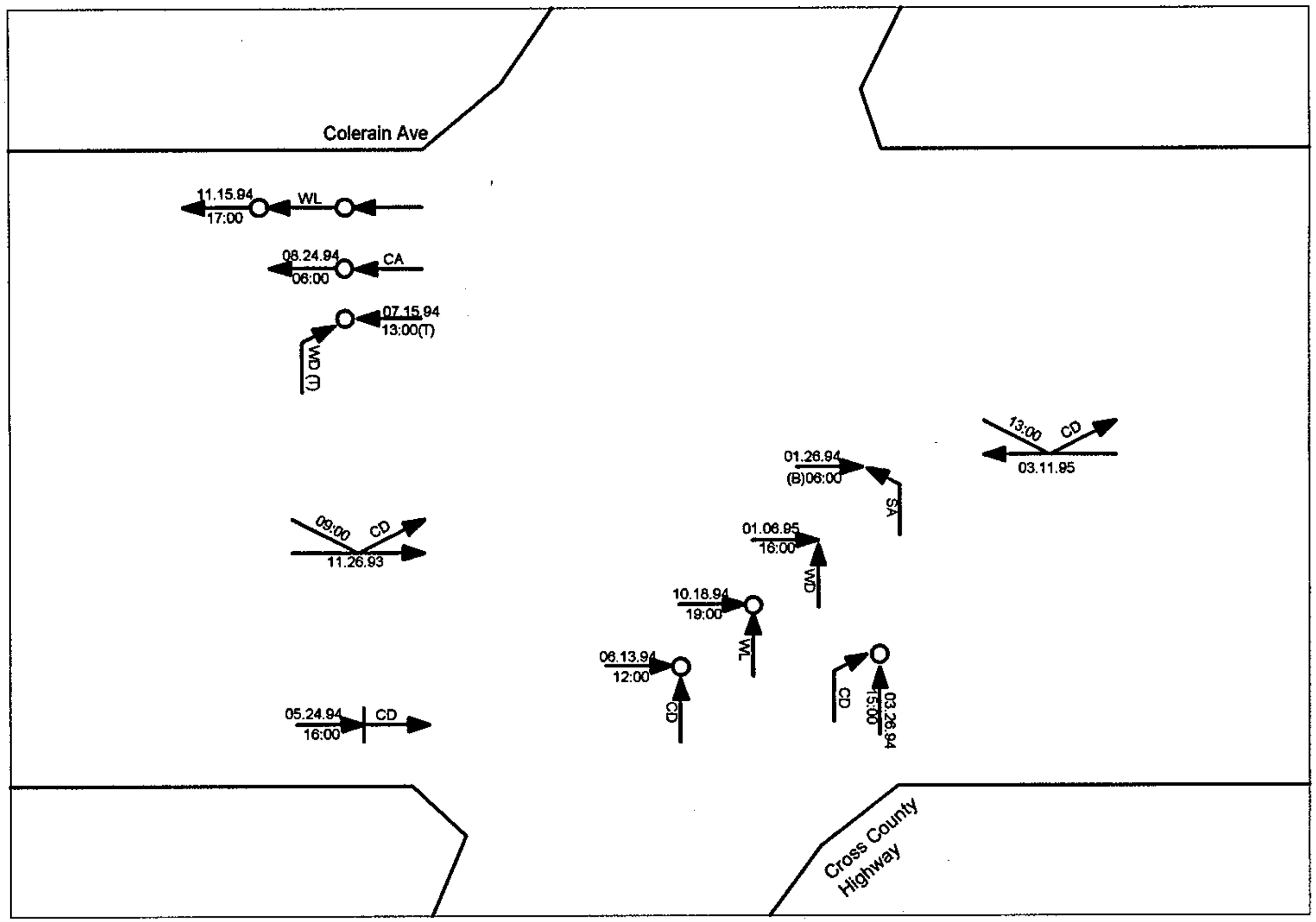
Figure B.3.2 Subarea #1 Colerain Ave & Madonna Shopping Center
05/18/95 - 10/31/96

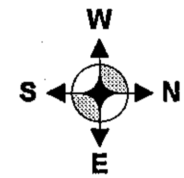


Accident Summary	
Fatal	0
Injury	6
PDO	14
Total	20

* For key to symbols, see Figure B.1.

Figure B.4.1 Subarea #1 Colerain Ave & Cross County Highway
10/01/93 - 05/17/95

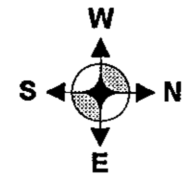


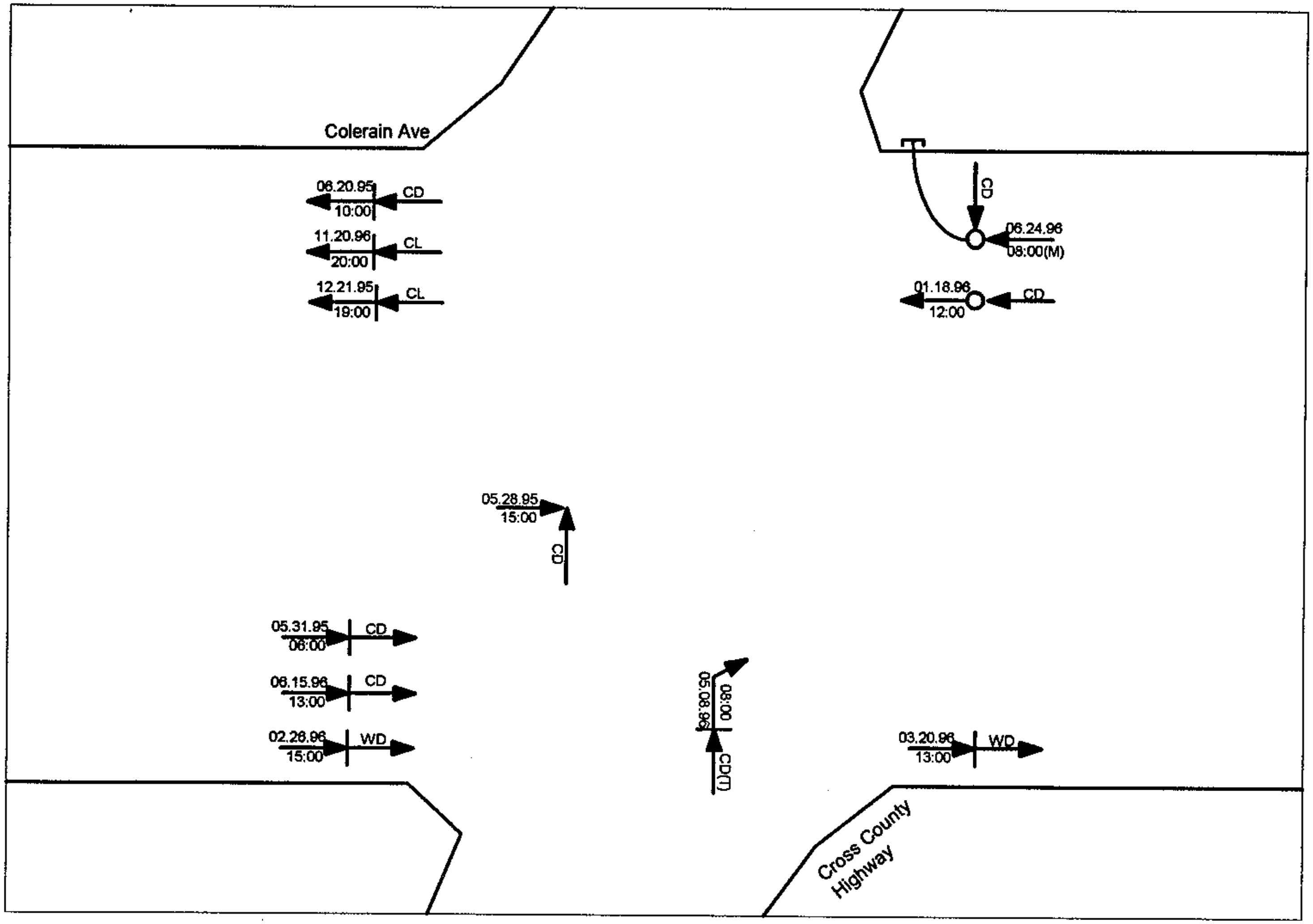


Accident Summary	
Fatal	0
Injury	6
PDO	5
Total	11

* For key to symbols, see Figure B.1.

Figure B.4.2 Subarea #1 Colerain Ave & Cross County Highway
05/18/95 - 10/31/96

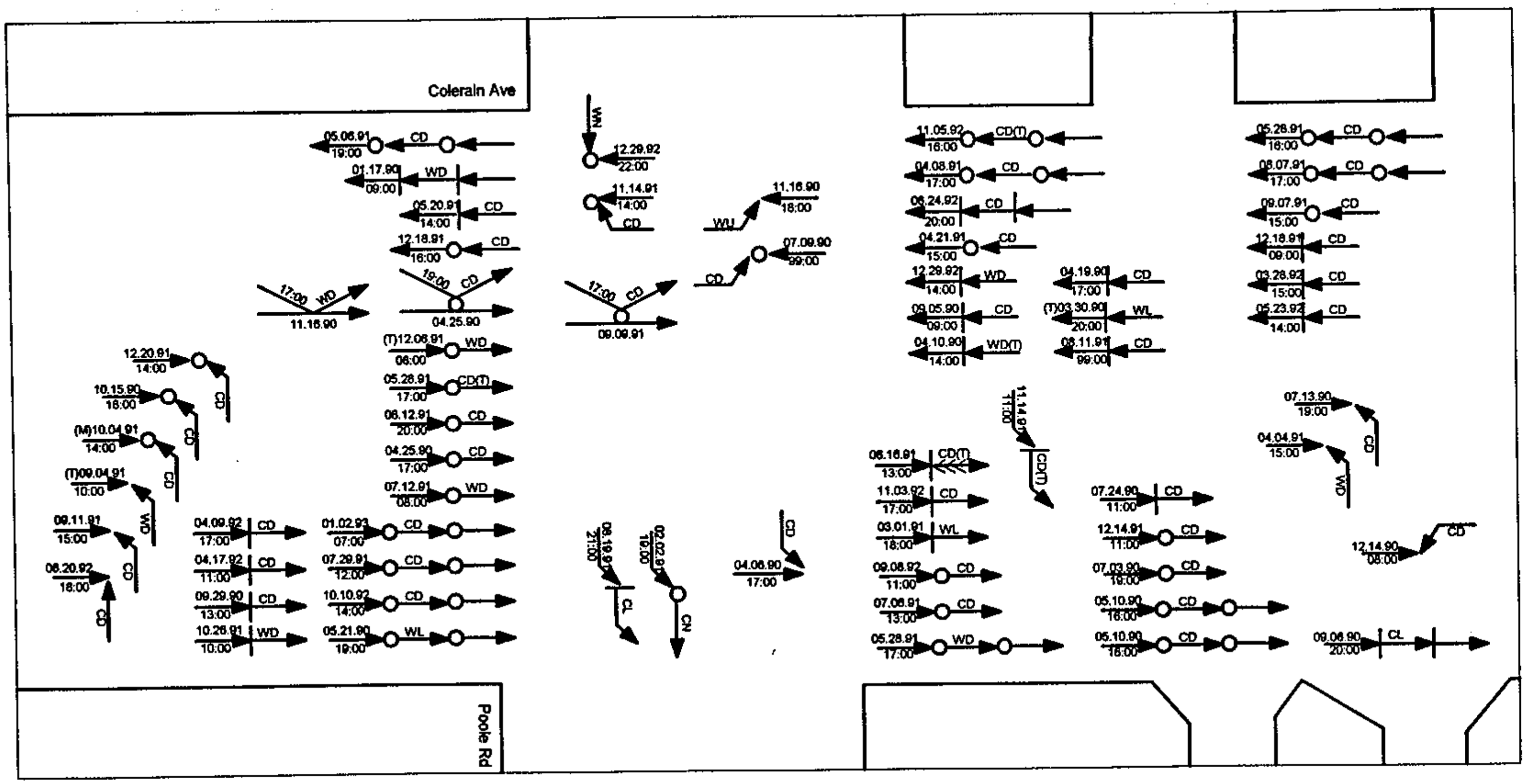


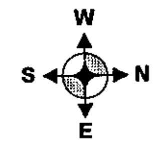


Accident Summary	
Fatal	0
Injury	2
PDO	9
Total	11

* For key to symbols, see Figure B.1.

Figure B.5.1 Subarea #4 Colerain Ave & Poole Rd
01/16/90 - 01/15/93

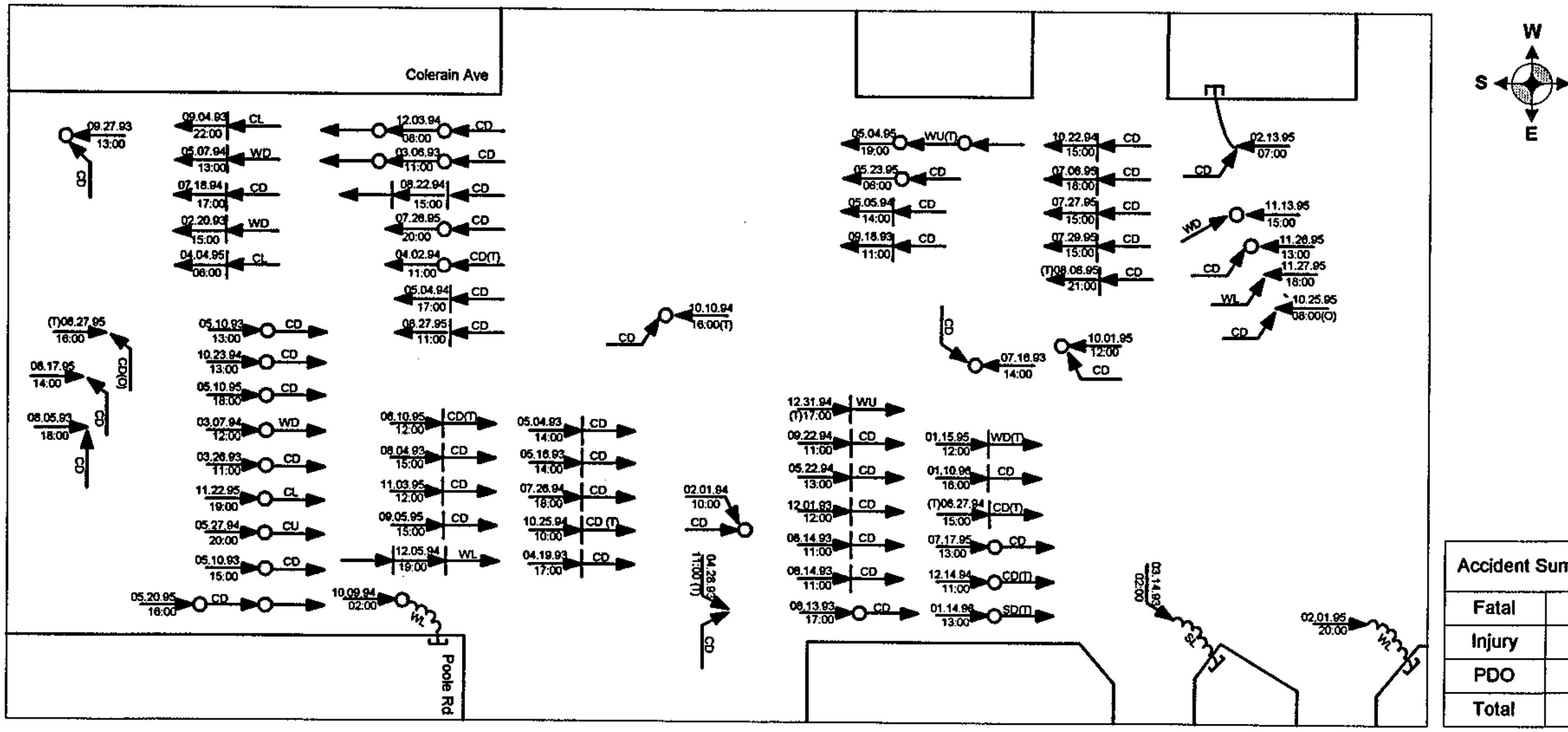




Accident Summary	
Fatal	0
Injury	33
PDO	32
Total	65

* For key to symbols, see Figure B.1.

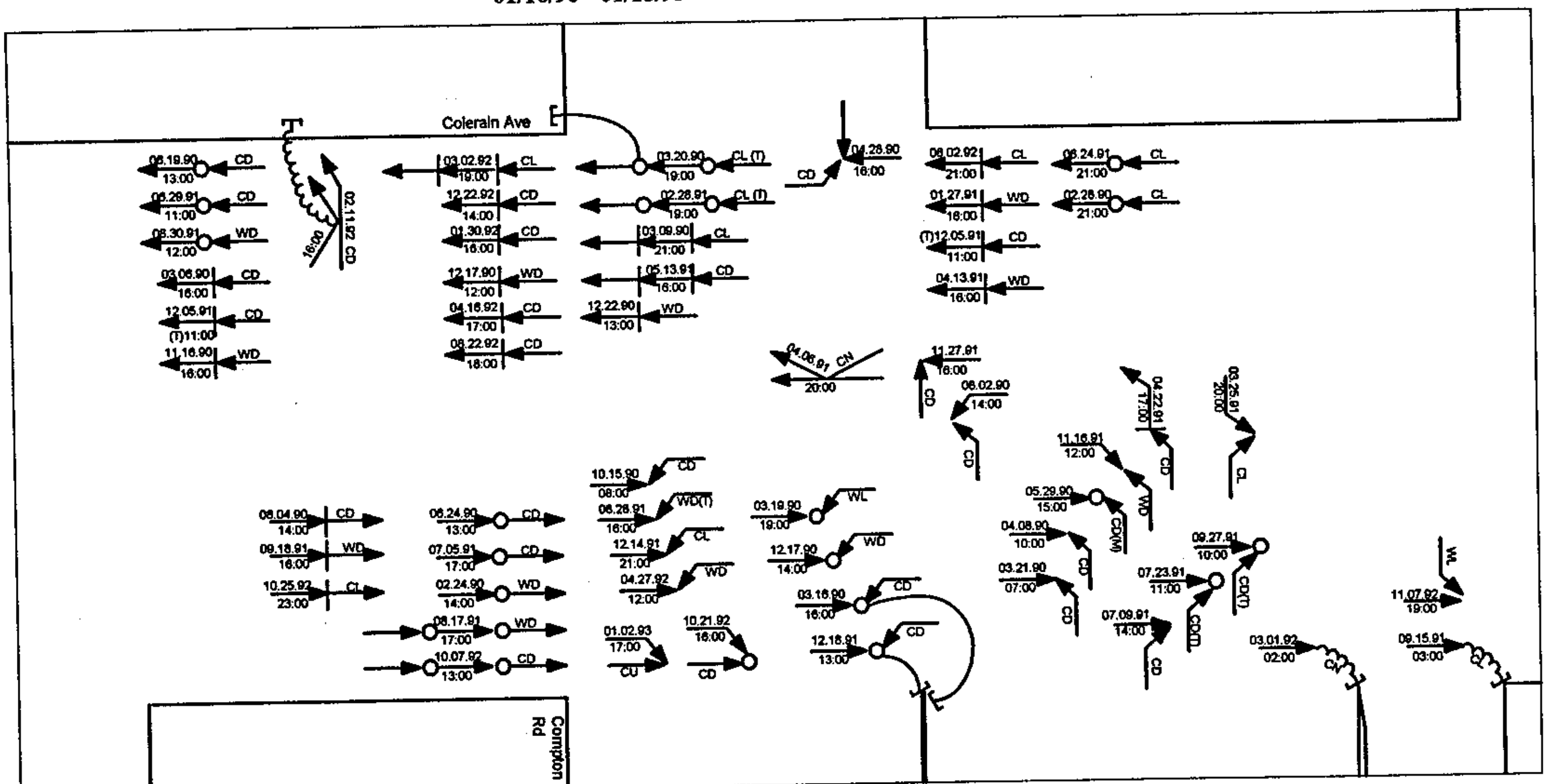
Figure B.5.2 Subarea #4 Colerain Ave & Poole Rd
01/16/93 - 01/15/96

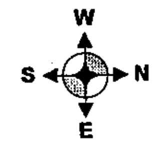


Accident Summary	
Fatal	0
Injury	27
PDO	43
Total	70

* For key to symbols, see Figure B.1.

Figure B.6.1 Subarea #4 Colerain Ave & Compton Rd
01/16/90 - 01/15/93

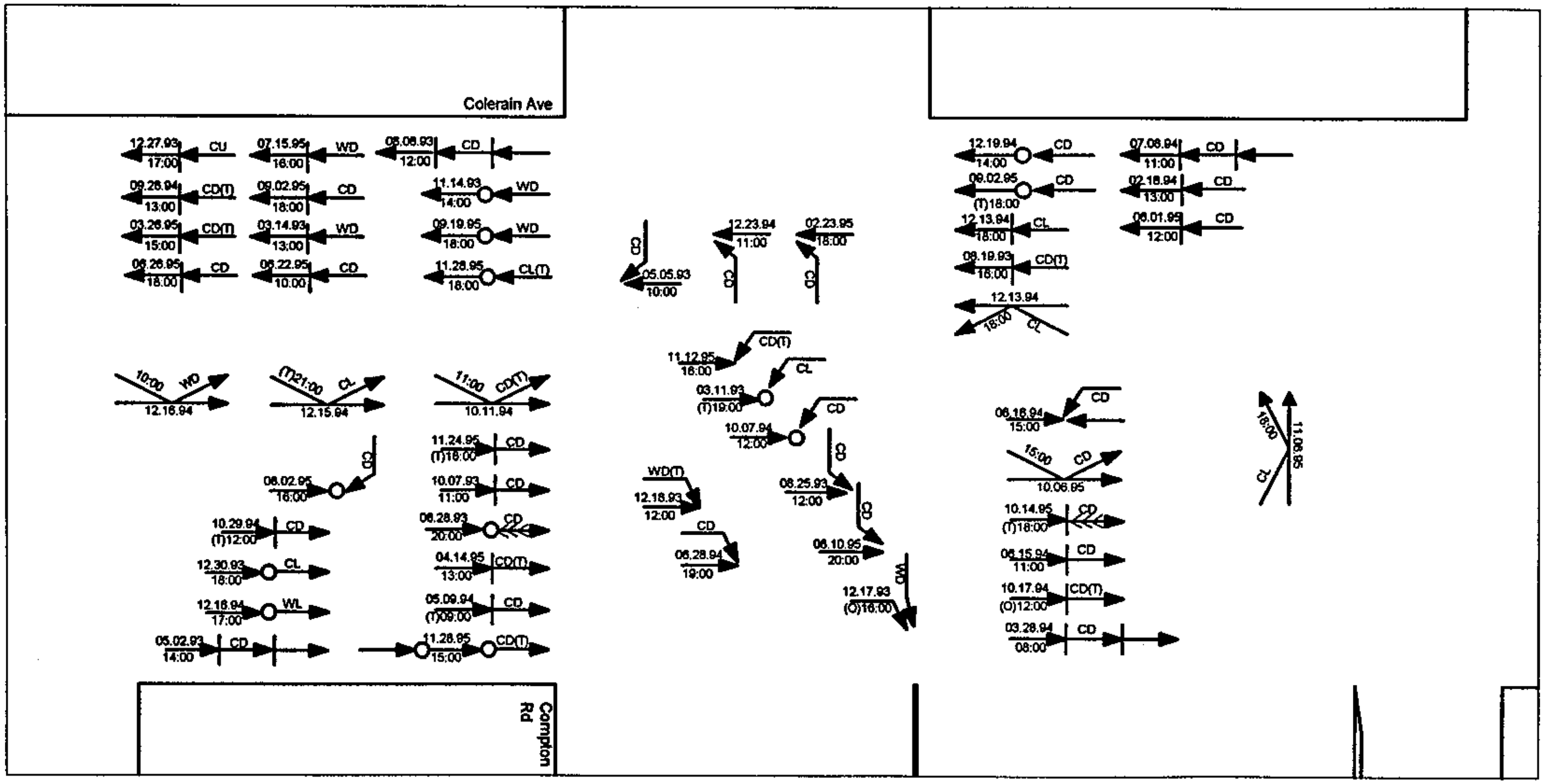


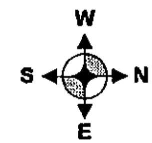


Accident Summary	
Fatal	0
Injury	20
PDO	38
Total	58

* For key to symbols, see Figure B.1.

Figure B.6.2 Subarea #4 Colerain Ave & Compton Rd
01/16/93 - 01/15/96

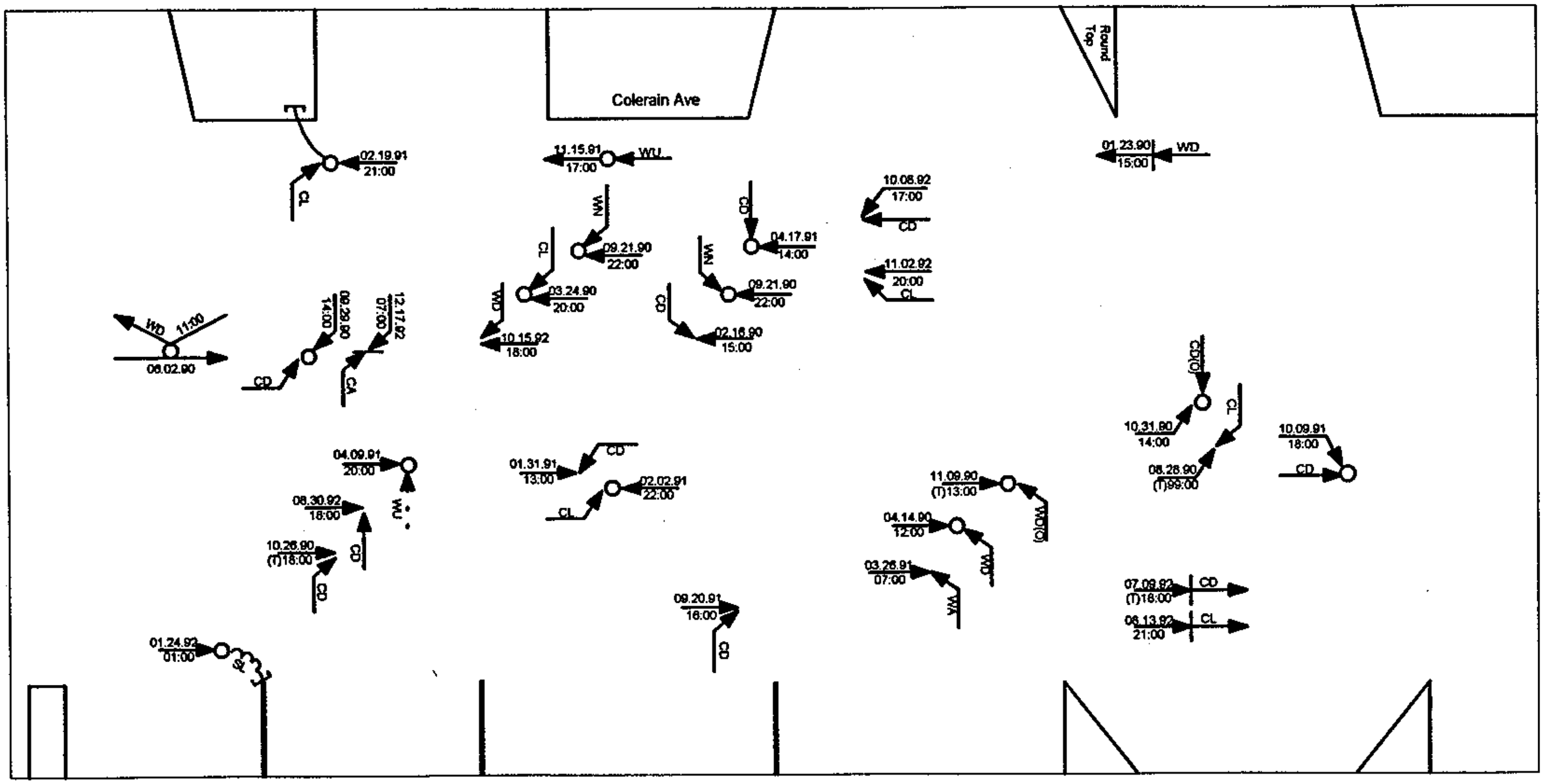


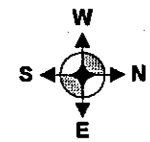


Accident Summary	
Fatal	0
Injury	11
PDO	40
Total	51

* For key to symbols, see Figure B.1.

Figure B.7.1 Subarea #4 Colerain Ave & Round Top
01/16/90 - 01/15/93

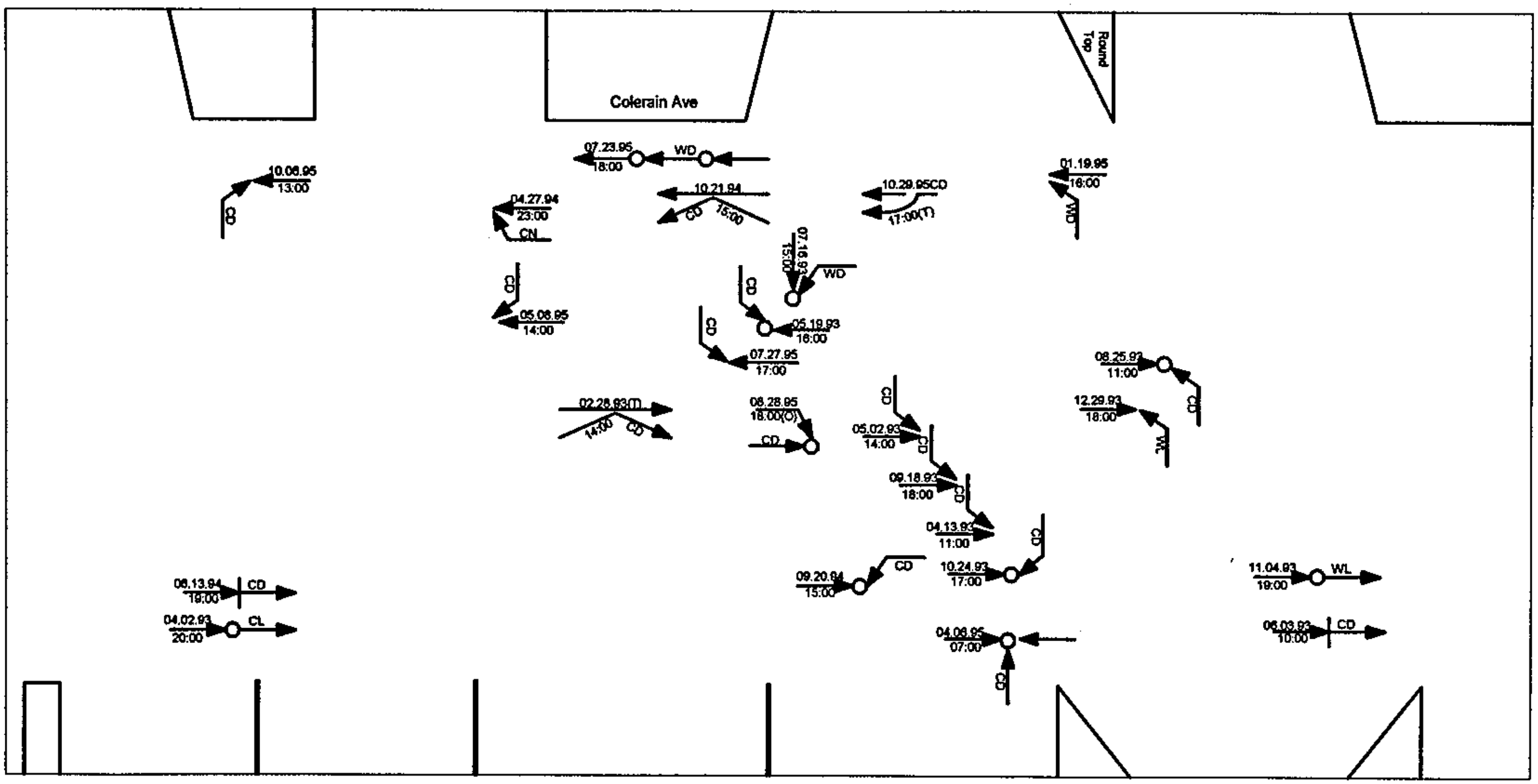


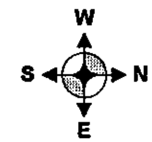


Accident Summary	
Fatal	0
Injury	15
PDO	14
Total	29

* For key to symbols, see Figure B.1.

Figure B.7.2 Subarea #4 Colerain Ave & Round Top
01/16/93 - 01/15/96

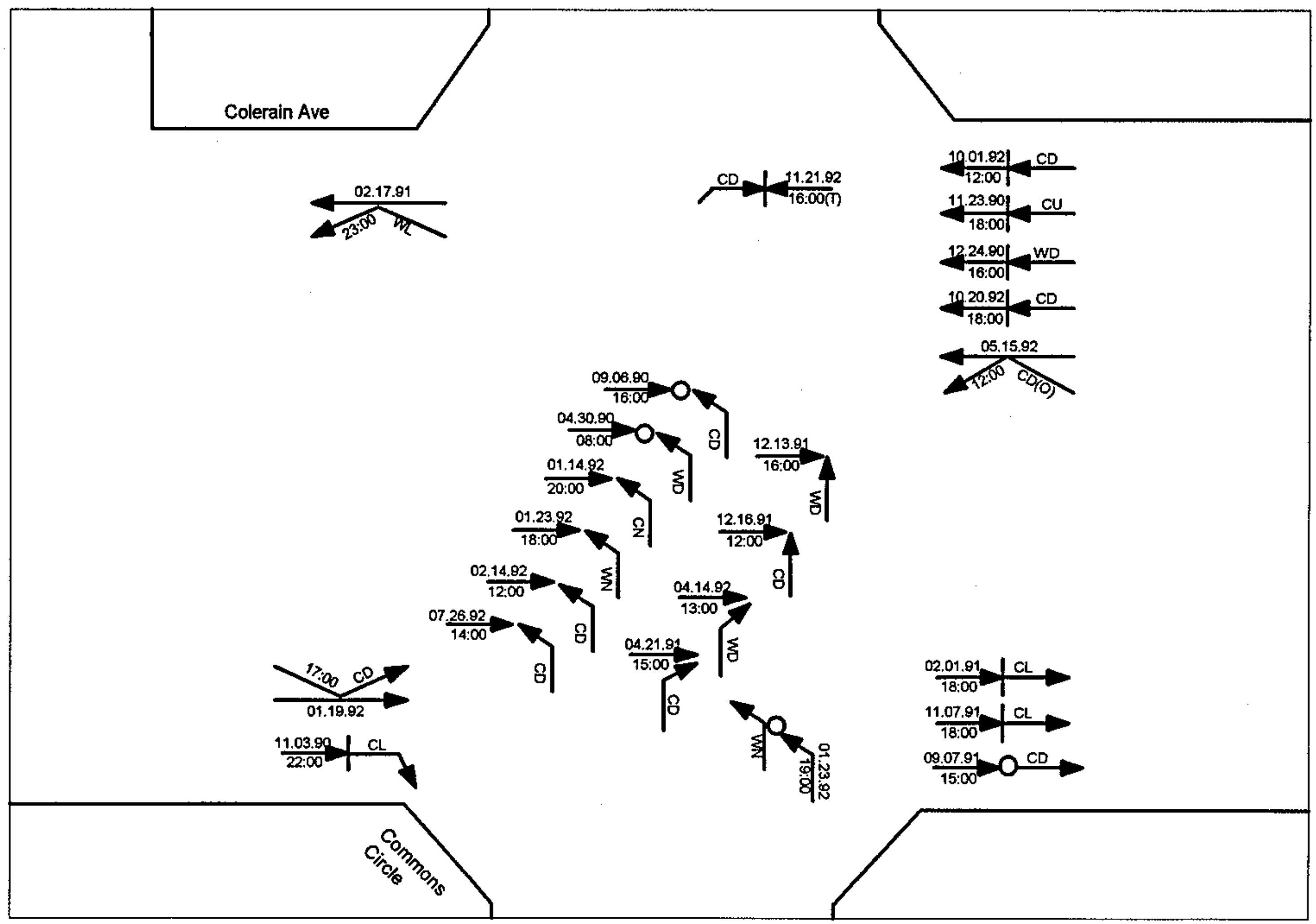


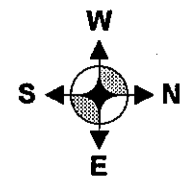


Accident Summary	
Fatal	0
Injury	10
PDO	14
Total	24

* For key to symbols, see Figure B.1.

Figure B.8.1 Subarea #4 Colerain Ave & Commons Circle
01/16/90 - 01/15/93

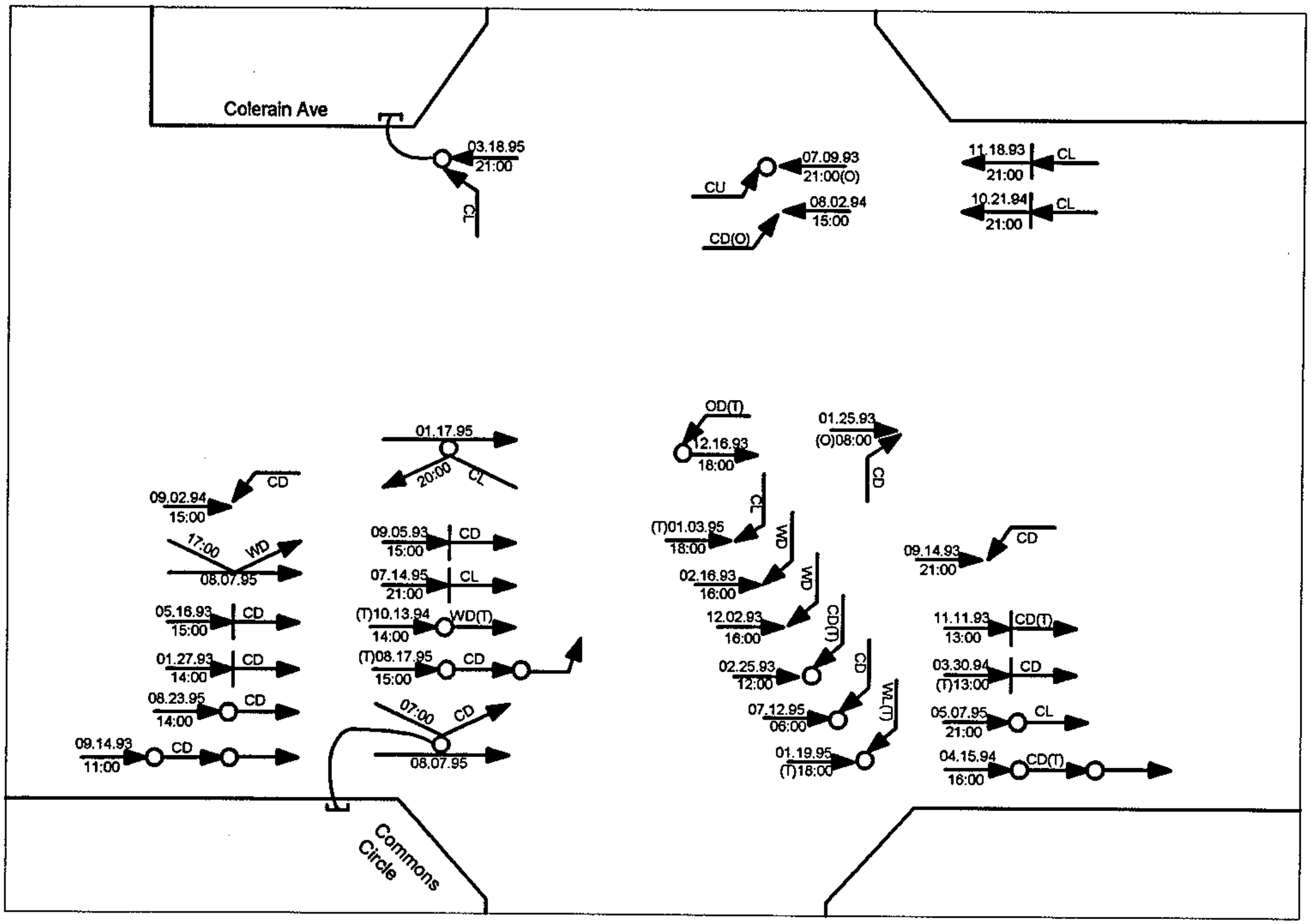


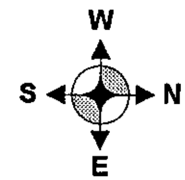


Accident Summary	
Fatal	0
Injury	4
PDO	19
Total	23

* For key to symbols, see Figure B.1.

Figure B.8.2 Subarea #4 Colerain Ave & Commons Circle
01/16/93 - 01/15/96

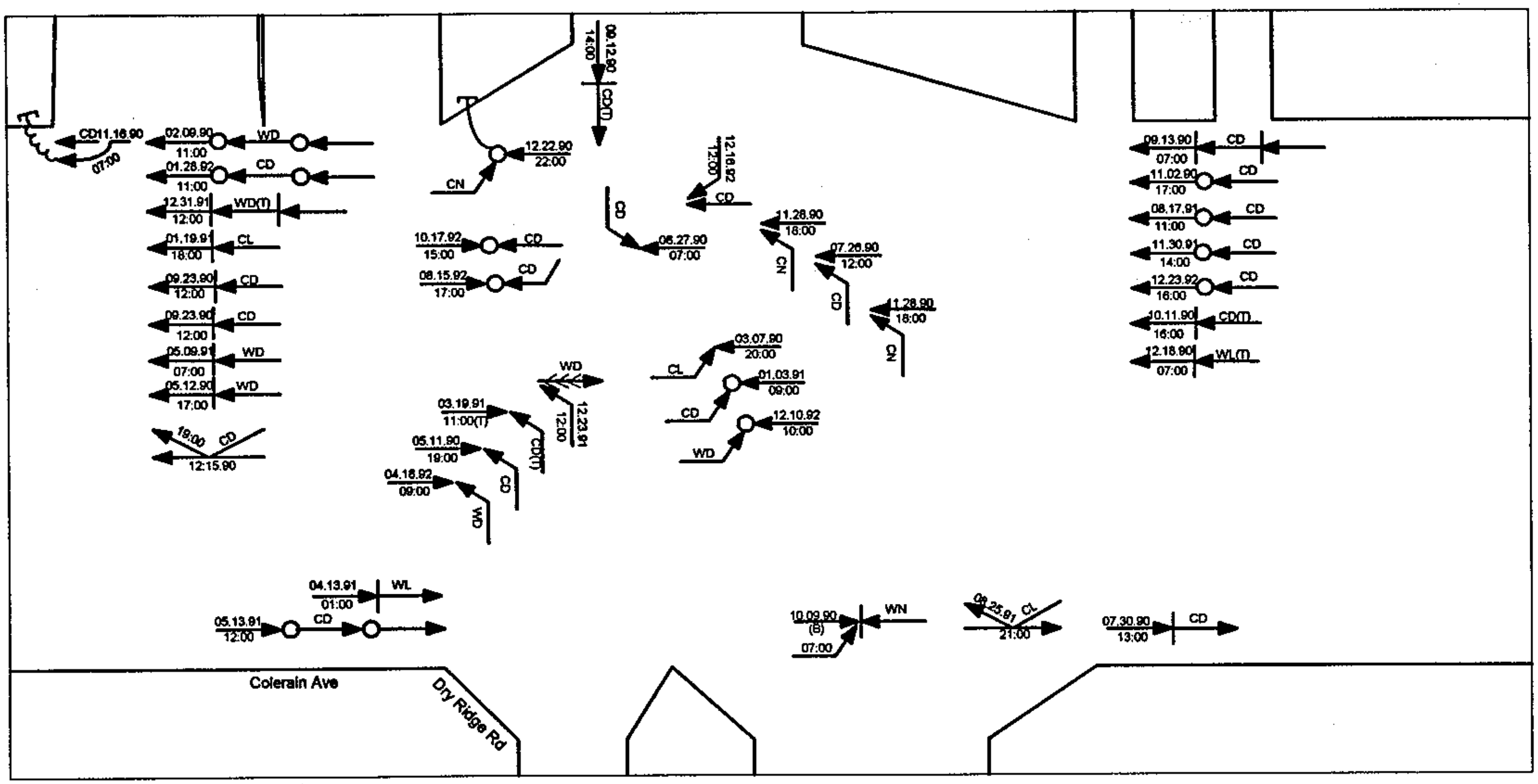


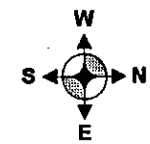


Accident Summary	
Fatal	0
Injury	14
PDO	16
Total	30

* For key to symbols, see Figure B.1.

Figure B.9.1 Subarea #8 Colerain Ave & Dry Ridge Rd
01/16/90-01/15/93

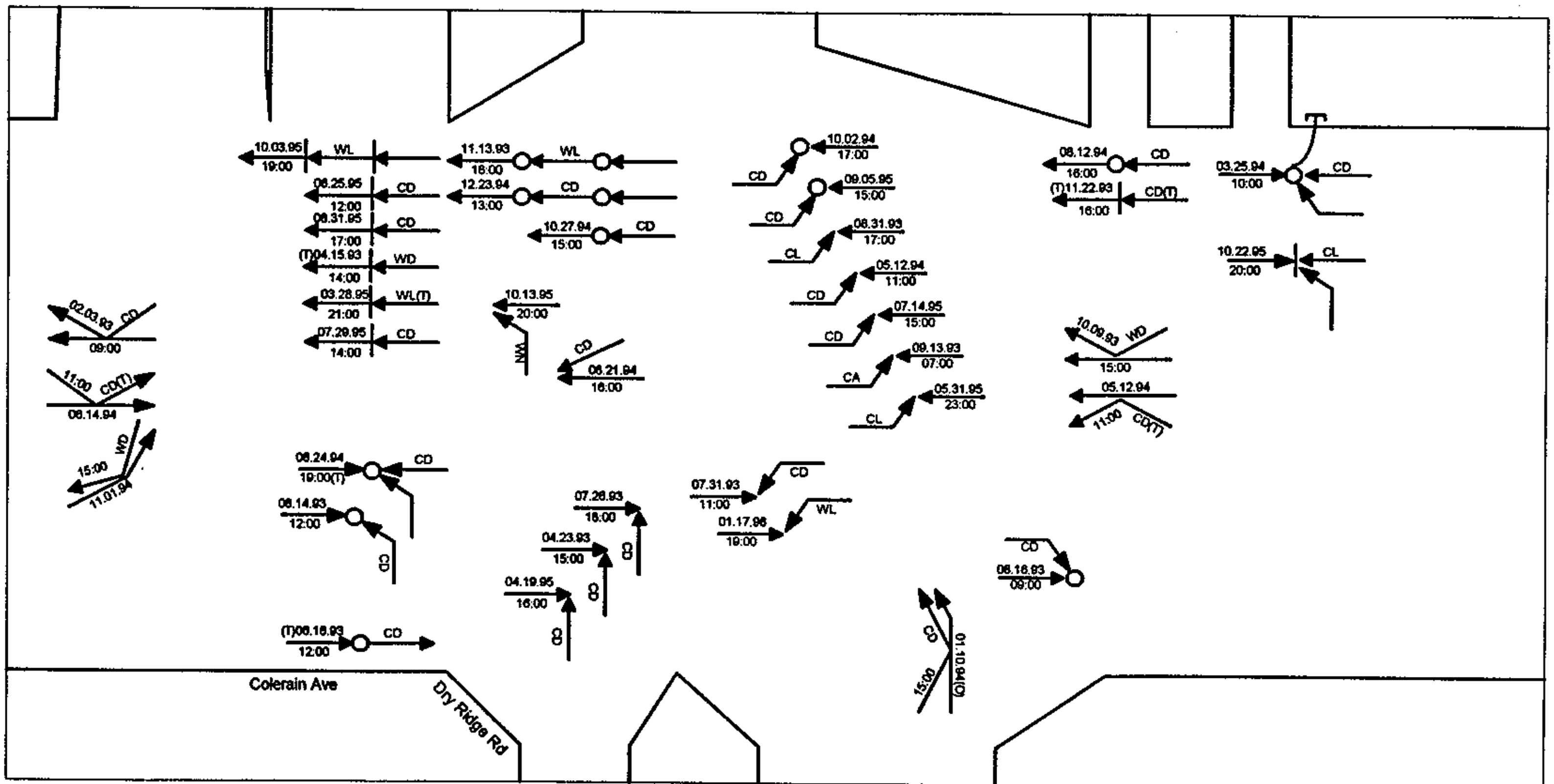


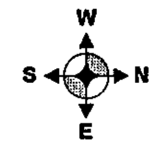


Accident Summary	
Fatal	0
Injury	12
PDO	25
Total	37

* For key to symbols, see Figure B.1.

Figure B.9.2 Subarea #8 Colerain Ave & Dry Ridge Rd
01/16/93-01/15/96

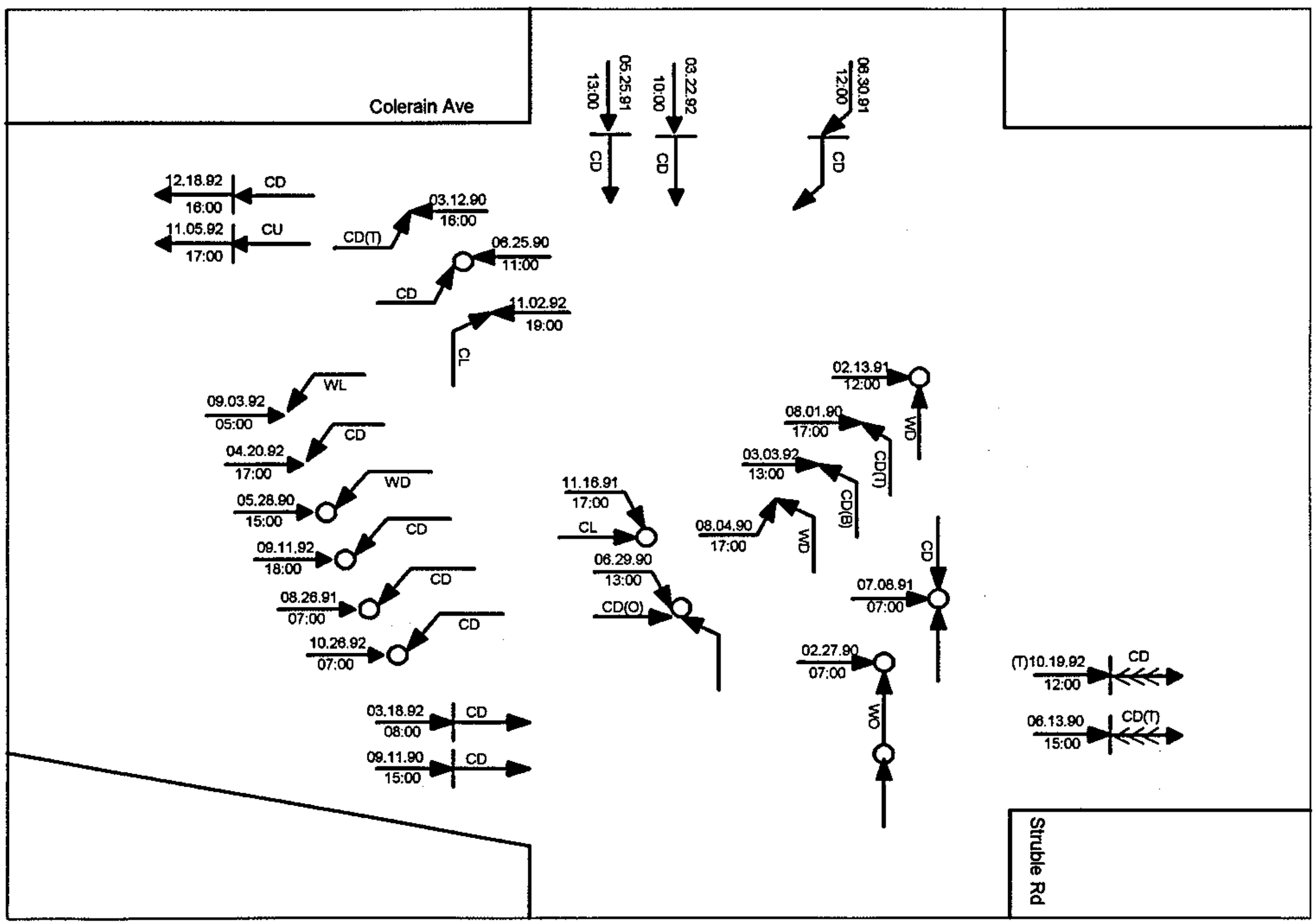


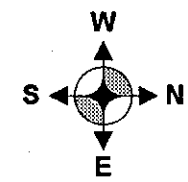


Accident Summary	
Fatal	0
Injury	12
PDO	25
Total	37

* For key to symbols, see Figure B.1.

Figure B.10.1 Subarea #8 Colerain Ave & Struble Rd
01/16/90 - 01/15/93

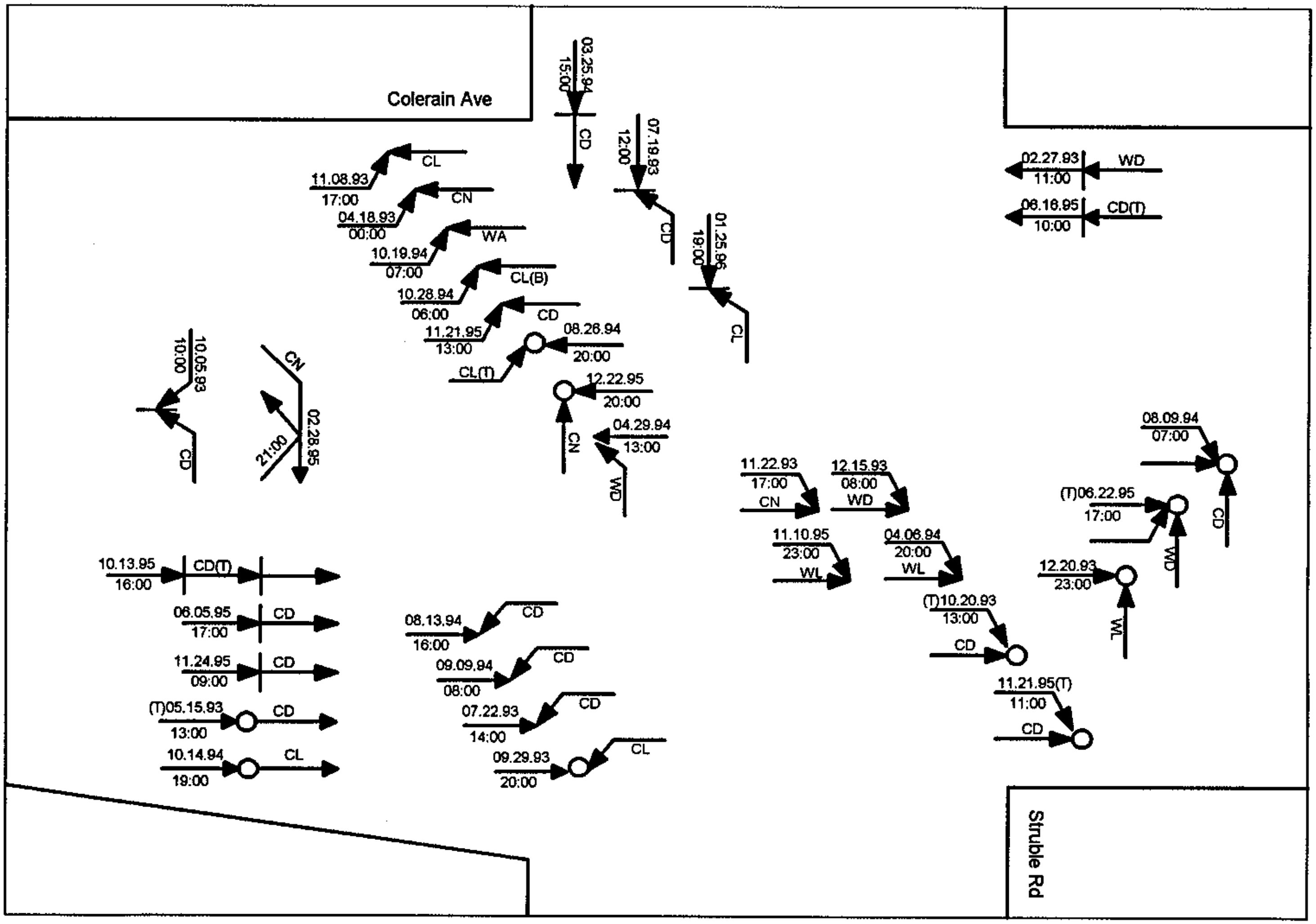


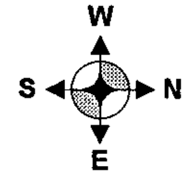


Accident Summary	
Fatal	0
Injury	10
PDO	16
Total	26

* For key to symbols, see Figure B.1.

Figure B.10.2 Subarea #8 Colerain Ave & Struble Rd
01/16/93 - 01/15/96





Accident Summary	
Fatal	0
Injury	10
PDO	23
Total	33

* For key to symbols, see Figure B.1.