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16. Abstract

This report summarizes results of a study of detector placement on the diamond interchange frontage road (ramp) using the Texas Intersection Simulation Model. The criterion used for the optimization is the minimization of delay. A secondary criterion is to reduce the dilemma zone to a minimum.

The results indicate that the first detector located along the frontage road (ramp) should be placed about 30 meters (100 feet) back from the stop bar. The remainder of the layout should provide a vehicle interval between 1.1 and 1.3 seconds and not trap a vehicle at the design speed in a dilemma situation. The recommended layout of detectors achieves these two goals.

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EFFECTIVE PLACEMENT OF DETECTORS AT DIAMOND INTERCHANGES

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Research Report 1392-4
Research Study Number 0-1392
Research Study Title: Effective Detector Placement for Computerized Traffic Management

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IMPLEMENTATION STATEMENT

This research used the Texas Intersection Simulation Model to investigate the interrelationships of traffic demand and detector placement on the frontage road (ramp) approaches to the intersections of a diamond interchange. Based on the findings of the simulation studies and the need to minimize the dilemma zone for the driver, specific recommendations for detector placement on diamond interchange frontage road (ramp) approaches to minimize total delay and maximize dilemma zone coverage are provided. With the increasing development of freeway management systems, this research provides the designer with practical information as to the most effective pattern for detectors at diamond interchanges. The recommendations are directly applicable to diamond interchange signalization design and redesign.

The results of this study differ from common practice today in two ways: 1) the criterion for optimization was minimization of delay; and, 2) the incorporation of dilemma zone protection into the detector layout. The reader is urged to fully consider the advantages of optimizing on the basis of minimizing delay as opposed to maximizing capacity and of providing dilemma zone coverage in the detector layout before discarding the results of this study as being impractical.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Dr. Donald L. Woods (P.E. # 21315) was the Principal Investigator for the project.

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SUMMARY

Reducing congestion in our nation's urban areas has become a top priority of government agencies and transportation professionals and organizations nationwide. The development and implementation of freeway management systems have recently begun to help reduce these problems. A major component of freeway management systems is the traffic monitoring system, which must provide effective data for the dynamic management processes. Monitoring systems depend on detectors and the predominant type of detector is the inductive loop detector. This research effort evaluated the use of inductance loop detectors to determine the most effective placement of detectors at diamond interchange intersections.

Researchers used the Texas Diamond Intersection Simulation Model to test the placement of detectors on the frontage road (ramp) approach roadways. In particular, the research sought the location that resulted in the least total interchange delay. The findings suggest that the first detector should be about 30 meters (100 feet) back from the stop bar. The length of the detector coverage zone is determined by the distance required to stop at a reasonable deceleration rate (i.e., 8 fps^2) and 1 second perception reaction time. Intermediate detectors were place as required to obtain a 1.1 to 1.3 second passage interval between detectors. The resulting detector layouts minimize total interchange delay while reducing the dilemma zone along the frontage road (ramp) to a minimum.

1.0 INTRODUCTION

The two types of signalized intersection controls that are most commonly used are pretimed and vehicle actuated control systems. In pretimed control, the cycle length, phase sequences, green times, and change intervals are fixed to serve the average traffic demand occurring over an extended period of time. In the event of significant variations in demand and random fluctuations in traffic volumes, pretimed operation will not serve traffic efficiently (1). Actuated control, in contrast, assigns the right of way on the basis of actual traffic conditions within specific limitations. A critical element which provides input to actuated control is the traffic sensor or detector component of the system. Traffic detectors sense vehicular and pedestrian arrivals demand and convey these actuations to the controller so that appropriate signal indications may be displayed (2). However, a detector design not tuned to the geometry of the intersection and its traffic demands can result in higher traffic delays, and longer queues than those observed with pretimed control (1). As such, the success of an actuated control system depends largely on proper design, installation and maintenance of the detection system (3).

The three principal types of vehicle detectors that are currently used are inductive loop detectors, magnetic detectors, and magnetometers. Among all the vehicle detection systems, the inductive loop detector system is the most widely used and standard form of detection. The loop detector consists of a loop embedded in the pavement which is made of one or more turns of wire. The ends of this loop are connected by a lead-in cable to a detector oscillator (amplifier) usually located in the controller cabinet. A vehicle passing over or stopping in the loop will unbalance the tuned circuit resulting in a detection. Thus the inductive loop detector is able to detect either the presence or passage of a vehicle in the detection area (3), depending on the operational characteristic selected by the user.

Detector system design includes the detector layout and controller timing, which depend on the geometry of the intersection, approach speeds and arrival traffic demands. Improper detector design can make the traffic operation inefficient, resulting in high motorist delays, excess fuel consumption, air pollution, and accidents. Therefore, the various design elements of a detection system, such as number, size, and location of the detectors, passage time settings, and call-extension settings, play an important role in the design of an efficient traffic actuated control system.

1.1 PROBLEM STATEMENT

Diamond interchanges are grade-separated interchanges used to transfer traffic from a freeway to the local street system and vice versa via direct connecting ramps in all four quadrants. These interchanges are often signalized with pretimed signals, or they may be signalized with traffic actuated signals. Significant variations in traffic demand may exist at these locations, necessitating the type of signal control to be traffic actuated rather than pretimed. However, poorly operating traffic signals at diamond interchanges can cause these interchanges to act as bottlenecks to efficient traffic flow (4).

In Texas, most of the signalized interchanges are tight urban diamond interchanges of freeways, having closely spaced intersections and one-way frontage roads. At these interchanges, traffic actuated control having improper detector design may result in inefficient traffic operation, causing long queues to form on the exit ramps or frontage roads. These delayed vehicles may grow so large in number that queues may back up the freeway exit onto the freeway main lanes, interrupting large volumes of freeway traffic travelling at high speeds (5). This kind of situation results in unreasonable delays, excessive energy consumption and highly unsafe traffic conditions.

The signal designer of diamond interchanges usually does not have design guidelines readily available that are based on providing efficient operations. These guidelines might cover the number, size and location of detectors, passage time settings, and call-extension settings for the optimal functioning of actuated signals.

1.2 OBJECTIVE

The primary objective of this research is to determine the optimal placement of detectors on the frontage roads (and similar ramps) of a tight urban diamond interchange based on the traffic delay criterion. The analysis tool will be a microscopic traffic simulation model.

1.3 SCOPE

The Texas Transportation Institute (TTI) is performing this research as a part of project 1392 entitled "Effective Placement of Detectors for Computerized Traffic Systems", and is sponsored by the Texas Department of Transportation. This research will determine optimal detector designs at diamond interchanges for different interchange geometries, traffic volume conditions, and signal phasing sequences. This study is expected to provide application guidelines on the design of detectors for efficient traffic operation of traffic actuated control at a diamond interchange.

2.0 BACKGROUND AND LITERATURE REVIEW

2.1 DETECTOR TECHNOLOGY EVOLUTION

The need for some means of collecting traffic data at an intersection in order to assign the right-of-way based on real-time traffic volumes led Charles Adler, Jr. and Henry A. Haugh to develop a detector in 1927. It was activated when a driver sounded his car horn at a specified location. Henry A. Haugh developed a pressure sensitive pavement detector which proved to be more popular than the horn-activated detector for obvious environmental reasons. This detector consisted of two metal plates acting as electrical contacts brought together by the pressure of passing vehicles. Various problems associated with these types of detectors led to the development of different forms of vehicle detection systems based on properties of sound, opacity, geomagnetism, reflection of radiation, electromagnetic induction, and vibration (3).

2.2 DETECTORS IN USE TODAY

Inductive loop detectors, magnetic detectors, and magnetometers are the three main types of detectors widely used in traffic engineering today. While inductive loop detectors are based on the principles of electromagnetic induction, magnetometers and magnetic detectors are applications of the property of geomagnetism. Among all the detector systems, the most commonly used and standard form of detection is the inductive loop detector system (3).

2.3 INDUCTIVE LOOP DETECTOR

The inductive loop detector system consists of three parts: detector oscillator, a lead-in cable, and a loop embedded in the pavement consisting of one or more turns of wire. Figure 1 illustrates a typical inductive loop detector system. Energy is driven through the loop system by the detector electronics unit at frequencies in the range of 10 kHz to 200 kHz which causes the loop system to form a tuned electric resonant circuit. The loop possesses an electrical property called inductance which is an effect of the magnetic flux produced by the current being carried by the loop. The inductance of the loop is slightly decreased when a vehicle passes over the loop or is stopped within the loop. This decrease in inductance causes an increase in the amplifier frequency which activates a relay or circuit which in turn sends an electrical output to the controller notifying the detection of a vehicle (3).

Loop detectors can be either passage detectors or presence detectors. The passage detector, also known as a point detector, places a call on the controller when a vehicle passes over the detector loop. Passage detectors are short single loops which are less than 6 meters (20 ft) in length. The most commonly used point detectors are 1.8 x 1.8-meter (6 x 6-ft) loops. In contrast, the presence detector (area detector) holds the call on the controller as long as the detection area is occupied. The controller settings related to point and area detectors are often considered locking and non-locking memory settings, respectively. These settings are more clearly explained in the following sections.

Loop detector design is essentially a function of controller operation, detector unit configuration, and headway distribution of the arriving vehicles. As such, loop detector design includes controller settings and detector unit settings together with number, size and location of detectors. All these design parameters are interrelated and the operational relationships among them are very complex.

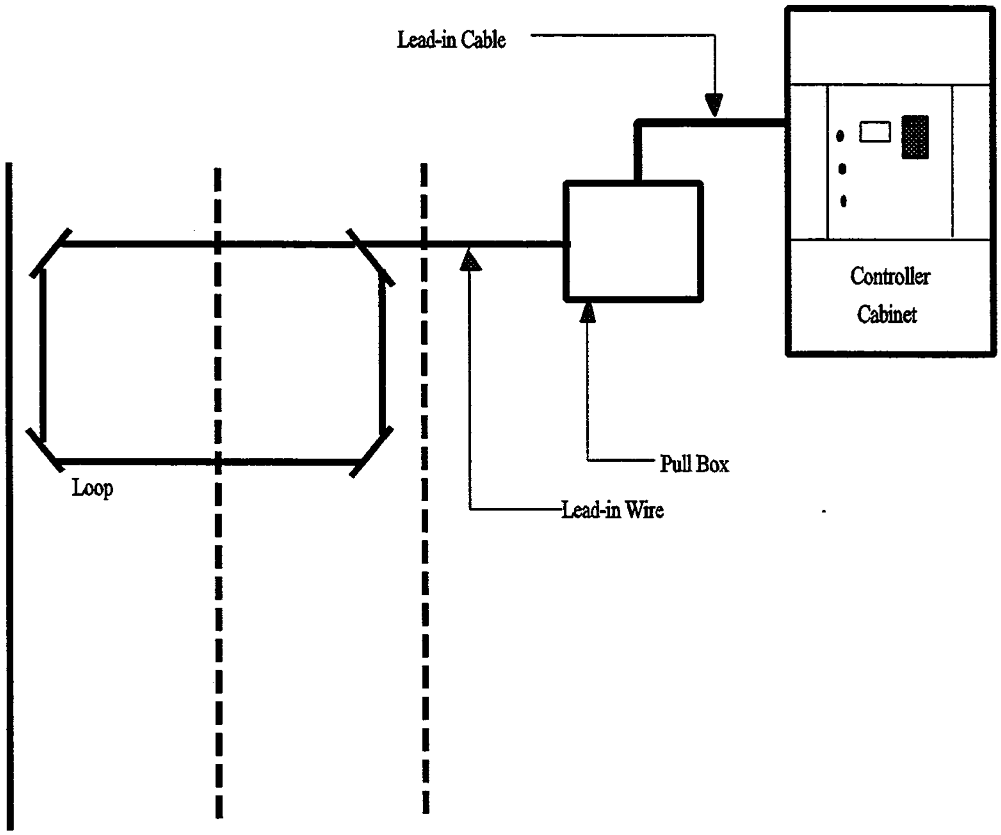


Figure 1. Inductive Loop Detector

2.4 CONTROLLER SETTINGS

The various features of controller operation include detection memory and signal timing parameters. Signal timing parameter features encompass: minimum green, passage, and maximum green times. These control features are discussed below in greater detail.

2.4.1 Detection Memory

The controller's ability to retain a call for service if the vehicle leaves the detection area before green display is referred to as detection memory. While the call retaining ability is called locking memory detection, call forgetting is known as non-locking memory detection. This feature is termed as phase specific-setting because the call retaining and call forgetting options can be chosen for each signal phase (6).

With locking memory, the controller retains all calls even when the calling vehicle leaves the detection area. This inefficiency is more pronounced where permissive movements (RTOR or permissive left turns on green) are present. Therefore, locking memory is best suited to phases serving primarily "main street" through traffic (6).

Non-locking memory operation causes the controller to drop all the calls as soon as the vehicles leave the detection area. As a result, phase service is not provided to an empty approach, but might not serve a waiting through vehicle. This type of memory operation is usually associated with phases serving permissive turning movements.

2.4.2 Minimum Green

The minimum green interval is also known as the initial interval. When only point detectors are used, minimum green time interval is time provided (required) to allow vehicles stopped between the first detector and the stop line to clear the intersection without further calls. The initial interval can be calculated using the following equation:

$$initial\ \ interval = 4 + 2\left(\frac{distance}{6}\right) \quad (meters) \qquad \textbf{Equation 1}$$

$$initial\ \ interval = 4 + 2\left(\frac{distance}{20}\right) \quad (feet) \qquad \textbf{Equation 1-A}$$

When a stop line detector with presence detection is used, the initial interval for left-turn phases could be set as low as zero seconds for snappy operation. However, a short minimum green period is needed for signal change interval operations for through movements to satisfy driver expectancy requirements for through traffic (4).

2.4.3 Passage Time

Passage time interval (also known as vehicle interval, extension interval, or gap time) is the time the green is extended for each vehicle arrival at the detector. The duration of vehicle interval is equal to the greatest of the travel times between any two consecutive detectors or from the first detector and the stop line, whichever is greater (7).

2.4.4 Maximum Green

Maximum green interval or maximum extension interval is the length of the time a phase can hold the green from the time a call is placed on a conflicting phase, or start of displayed green, whichever is greater. Maximum green times for through movements usually ranges between 30 and 60 seconds (2).

2.4.5 Volume Density Mode

In addition to the timing features discussed above, volume density operation includes variable initial timings and gap reduction timings. The initial interval can be increased based on the number of actuations stored on the phase while the signal display is yellow or red. The allowable gap between successive vehicle actuations can be reduced by decreasing the extension interval based on the time waiting of vehicles on an opposing red phase (3). However, volume density mode was not used in this study, as it is not within the scope of this research. Furthermore, the TEXAS Model does not have the capability to simulate volume density operation.

2.5 DETECTOR UNIT SETTINGS

2.5.1 Mode of Operation

The mode of operation of a detector unit is related to detection memory, which is a standard controller function. There are two modes of operation for each channel of the detector amplifier. These two modes are pulse and presence modes.

In the pulse mode operation, the detector output is a short "on" pulse of duration ranging from 0.08 to 0.12 seconds, every time a vehicle enters the loop area. The duration of the pulse is independent of the loop or vehicle length. Pulse mode is typically used where the detectors are located well upstream of the intersection with the controller in the locking detection mode. Call-delay and call-extension features are not applicable to this mode of operation (8).

In the case of presence mode, the detector output remains "on" as long as a part of the detector loop is occupied by a vehicle. As such, the duration of the call is a function of the loop length, vehicle speed, and vehicle length. This mode is typically used with long loop (or multiple loops with overlapping detection areas) installations with the controller set to operate in the non-locking memory detection mode. The start and stop times of the "on" output can be modified using call-delay and call-extension features (6). Gap timing does not start until loop presence detection ends. Gap timing may be set to zero for some long loop applications.

2.5.2 Timing Features

Presence mode detector units have two timing features that can be used to modify the time and duration of a call placed on the controller. They are the call-delay and call-extension features.

The call-delay feature delays the call from the detector unit to the controller by a preset period of time. The delay time starts timing when a vehicle enters the loop area. A call is placed to the controller only when a vehicle is present in the detection zone for a period of time greater than the specified delay time. This feature is typically used for detectors serving permissive turning movements.

The call-extension feature extends the duration of a call placed on the controller for a specified period of time after the activated loop occupancy has ended. This feature is used with two or more loop detectors to allow a vehicle to safely clear the intersection. The maximum travel time interval between two consecutive loop detectors is defined by the sum of the duration of loop occupancy and the passage time set on the controller.

Calling feature and extended-call/delay-call feature (EC-DC) are the two special timing features of a presence mode detector unit. The calling feature allows the detector to place calls to the controller only when the phase is either yellow or red. The EC-DC feature employs both call-extension and call-delay features. This feature is used exclusively with detectors at the stop line and is operated in the presence mode with non-locking memory (6).

2.6 DETECTOR LOCATION

The location of detectors at a fully actuated intersection in conjunction with controller and detector unit settings, to a large extent, determines the operational efficiency as well as the safety at the intersection. A good design would seek to maximize operational efficiency and safety.

Efficient operation at a fully actuated intersection would be one where there is no time when the signal is green for a given signal phase and no vehicles are either clearing the intersection signal or closely approaching the intersection on that phase (9). However, this may not be applicable to a situation where the green may rest in the most heavily travelled through route phases when there is no demand on any other conflicting phase. As such, the location of detectors would be such that they should enable the control to serve all the phases efficiently.

A dilemma zone is defined as that portion of the roadway on an intersection approach within which drivers become indecisive of their desire or ability to stop before reaching the stop line with the onset of a yellow indication.

Although the location of detectors for snappy operation may reduce delays, it may not provide maximum safety or dilemma zone protection for drivers. If detectors are located to provide dilemma zone protection, motorist delays may increase. Consequently, the optimal location of detectors may result in trade offs between traffic flow efficiency and safety. In addition to these considerations, the volume and speed distribution of the arriving vehicles has considerable impact on optimal detector location.

2.7 DIAMOND INTERCHANGES

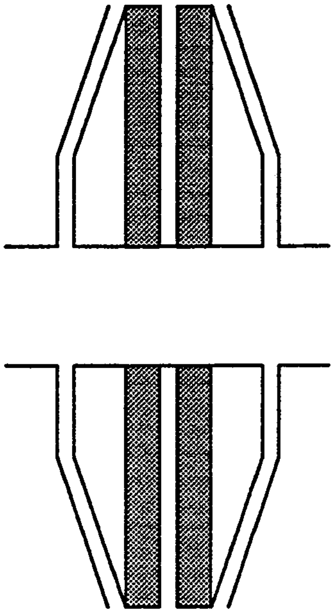
2.7.1 General Characteristics

An interchange is a system of interconnecting roadways that provides for the movement of traffic between roadways on different levels with the help of a grade separation (10). The most commonly found interchange is the two-level diamond interchange.

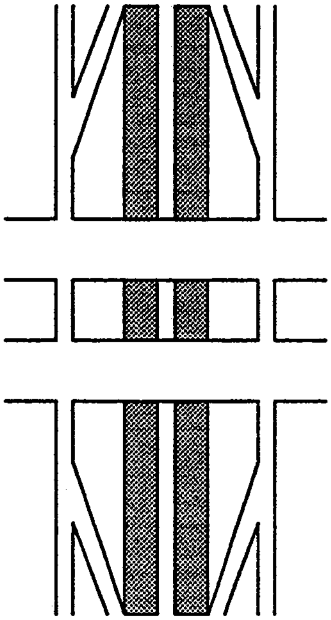
There are several design variations of the diamond interchange. The different types of diamond interchanges are shown in Figure 2. In Texas, most of the diamond interchanges are conventional full diamonds having parallel one-way frontage roads in urban areas. Some diamond interchanges have U-turn lanes, or turnarounds, that accommodate heavy left-then-left vehicular traffic from the one-way frontage roads. Diamond interchanges are characterized by a common feature: two closely spaced intersections that connect the entrance and exit ramps (and frontage roads if they exist) with the cross-street (11).

There exists a major operational difference between conventional two-level diamond interchanges and regular intersections. The path of the opposing left turns interlock within diamond interchanges, so that the opposing left turns cannot be served simultaneously. This difference between diamonds and at-grade intersections is illustrated in Figure 3 (12).

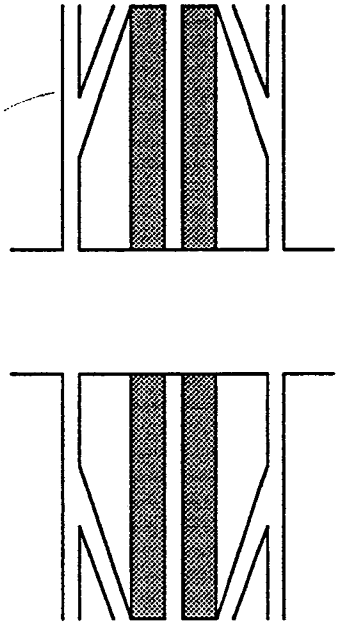
Some of the operational problems occurring at a diamond interchange include queue spill back from one of the intersections resulting in the blockage of the upstream intersection and overflow of the interior left-turn lane into the lane serving through traffic. Other problems include off-ramp queue spill back as a result of the formation of long queues backing up into the freeway and weaving problems on the frontage road between the ramp termini and the cross-street (11).



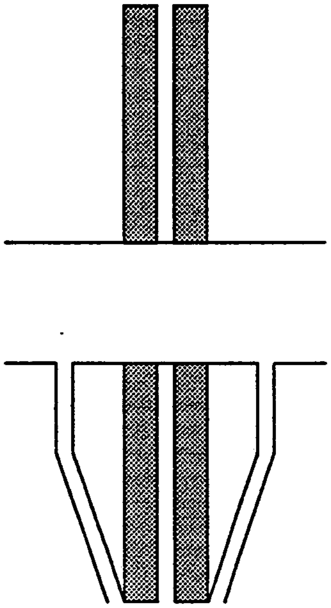
Full Diamond Interchange



Split Diamond Interchange

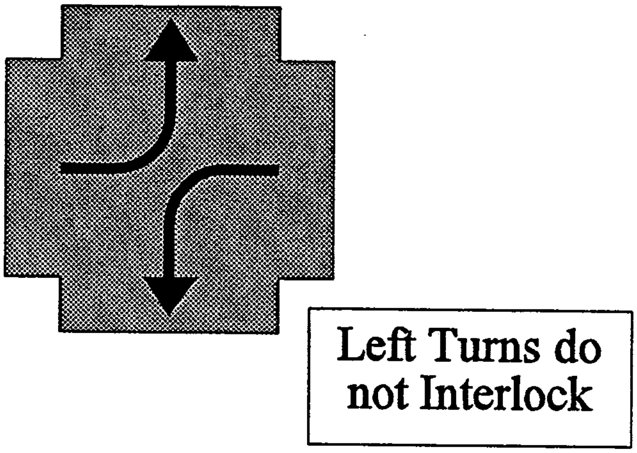


Full Diamond Interchange
with Frontage Roads

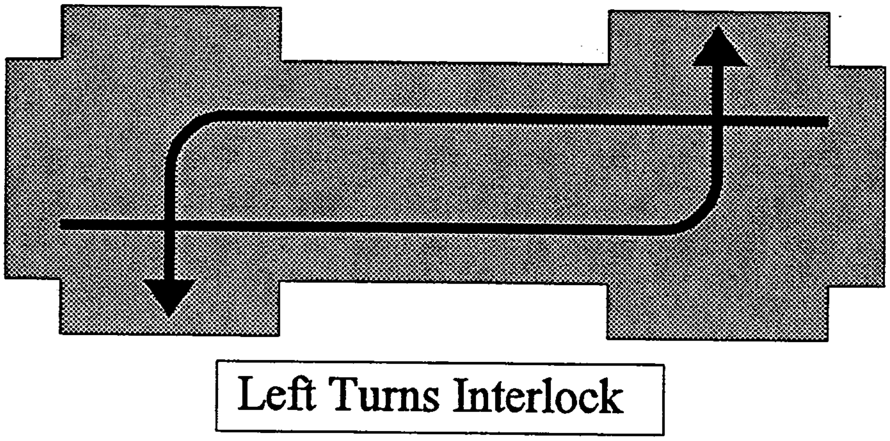


Half Diamond Interchange

Figure 2. Types of Two-Level Diamond Interchanges (11)


Left Turns do not Interlock

Standard Intersection


Left Turns Interlock

Interaction requiring Diamond Interchange rules

Figure 3. Operational Difference Between a Diamond and an Intersection (12)

2.7.2 Phasing Strategies

The phasing strategies used at diamond interchanges may be classified through a number of basic phases and the sequence of movements. Two-phase, three-phase, and four-phase controls are the primary phase configurations when the signal classification is based on the number of phases involved. Traffic volume levels and the spacing between the two intersections of a diamond interchange determines the type of phasing strategy to be used at that interchange.

In both the two-phase and three-phase control, left-turning vehicles are stored in the middle of the interchange. An intersection with two-phase control has a cross-street phase and a frontage road phase. In three-phase control, each intersection has the following: the cross-street phase, the frontage road phase, and the interior left-turn phase. The primary difference between two-phase and three-phase control is that the interior left-turn movements are not protected in two-phase control, while they are protected in three-phase control.

The diamond interchange is treated as a single intersection having four-phase control. The four phases are the two external movements on the cross-street and two external movements on the ramp or frontage road. The interior left-turns are protected (may be permitted plus protected). The phase duration for the left-turn phase is obtained by subtracting the sum of the two exterior phases from the cycle length. The four-phase with two overlaps, or TTI Lead-Lead phasing, is an important subset of four-phase control.

When the classification is based on the sequence of movements at the diamond interchange, the following four basic phasing patterns are possible:

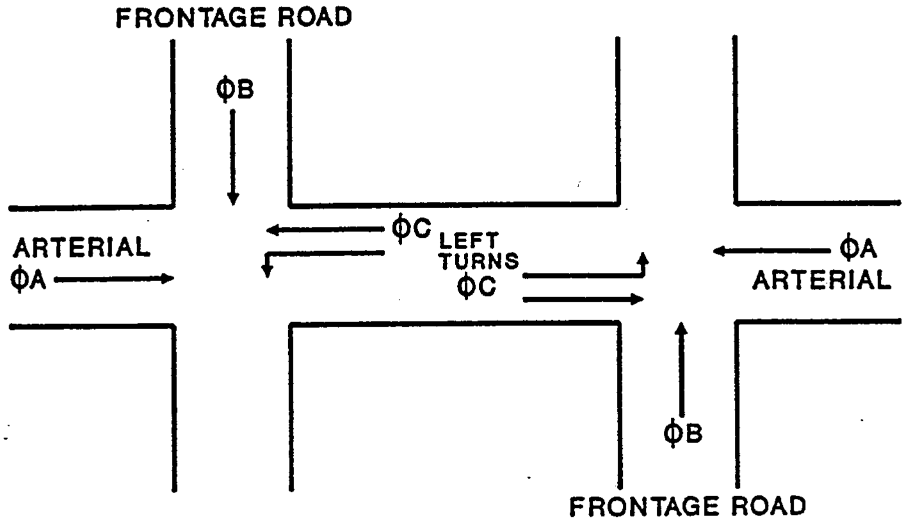
(a) **Lead-Lead**: protected interior left-turn movements lead the opposing cross street entry phase at both intersections;

(b) **Lead-Lag**: protected interior left-turn movements lead the opposing cross street entry phase at the left intersection and lag the opposing cross street phase at the right intersection;

(c) **Lag-Lead**: protected interior left-turn movements lag the opposing cross street entry phase at the left intersection and lead the opposing cross street phase at the right intersection; and

(d) **Lag-Lag**: protected interior left-turn movements lag the opposing cross street entry phase at both intersections.

These phasing patterns are illustrated in Figure 4.


FRONTAGE ROAD
ϕB
ϕC
LEFT TURNS
ϕC
ARTERIAL
ϕA
ϕA
ARTERIAL
ϕB
FRONTAGE ROAD

LEFT SIDE PHASE SEQUENCE			LEFT TURN SEQUENCE	RIGHT SIDE PHASE SEQUENCE		
→ ← A	↓ B	← ⬐ C	LEAD-LEAD	→ ← A	↑ B	⬏ → C
→ ← A	← ⬐ C	↓ B	LAG-LEAD	→ ← A	↑ B	⬏ → C
→ ← A	↓ B	← ⬐ C	LEAD-LAG	→ ← A	⬏ → C	↑ B
→ ← A	← ⬐ C	↓ B	LAG-LAG	→ ← A	⬏ → C	↑ B
→ ← A	↓ B	← ⬐ C	TTI-LEAD	→ ← A	↑ B	⬏ → C

Figure 4. Phasing Patterns at Diamond Interchanges (11)

2.7.3 Phasing Terminology used in Texas

A special terminology is used in Texas for denoting the phasing strategies at a diamond interchange. According to this special terminology, the phase patterns are denoted by the term "Figure XX". The number "XX" could be 3, 4, 6, or 7. "Figure 3" refers to all lag-lag phasing patterns whereas "Figure 4" refers to all lead-lead phasing sequences. The lead-lag and lag-lead phasing patterns are referred as "Figure 6" and "Figure 7", respectively. While the most common implementation of "Figure 3" operation is the "Texas Three-Phase" pattern, the most popular implementation of "Figure 4" operation is the "TTI Four-Phase" with overlap phasing sequence. The names "Figure 6" and "Figure 7" are arbitrary and do not refer to 6-phase or 7-phase patterns. "Figure 3" and "Figure 4" phasing sequences are illustrated in Figure 5 and Figure 6, respectively.

2.8 CURRENT RESEARCH IN DETECTOR PLACEMENT FOR DIAMOND INTERCHANGES

Early research in the area of detector placement at diamond interchanges was conducted in 1985. Messer, et al. (4) conducted field studies to evaluate small loop detection patterns, single and multiple point detection for "Figure 3" and "Figure 4" operations. Messer found that "Figure 3" operation frequently produced less delay than "Figure 4" operation. However, he observed that "Figure 4" phasing sequence provides better progression and fewer stops within the interior of the interchange. Messer also found that single point detection provided the same traffic performance as multipoint detection for "Figure 3" phasing sequence; whereas, multipoint detection was more delay effective in the case of "Figure 4" operation. Lum (13) studied the effects of various actuated traffic signal controller settings under two symmetrical and one lop-sided traffic demand for "Figure 3 and Figure 4" operations using TEXAS Model, Version 3.0. He found that in the case of three-phase, lag-lag phase sequence, the clearance green, green split, and end-of-maximum intervals were sensitive to both interchange geometry and traffic demand. His findings for four-phase-with-two-overlaps, lead-lead phase sequence indicated that the advance green timer and internal detector logic were the only controller settings that had significant effect on traffic performance.

The above studies make recommendations on the type of detection system and optimal controller settings to be used for "Figure 3 and Figure 4" operations, but they do not provide recommendations on optimal location of detectors at diamond interchanges. The present study attempts to provide guidelines on optimal location of detectors on frontage roads to minimize total interchange delay.

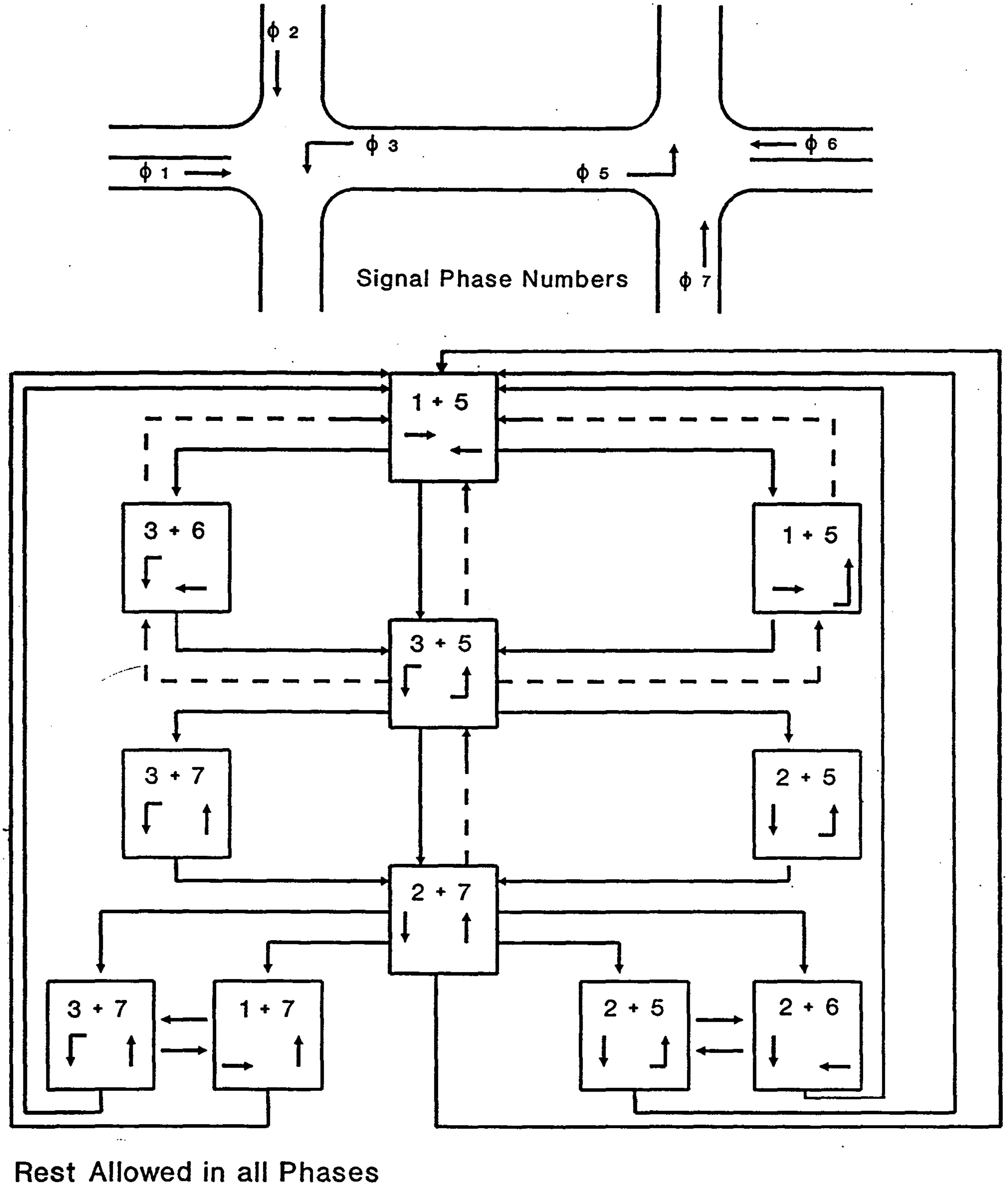

φ 2
φ 3
φ 1
φ 5
φ 6
φ 7
Signal Phase Numbers
1 + 5
3 + 6
1 + 5
3 + 5
3 + 7
2 + 5
2 + 7
3 + 7
1 + 7
2 + 5
2 + 6
Rest Allowed in all Phases

Figure 5. "Figure 3" Phasing Sequence (13)

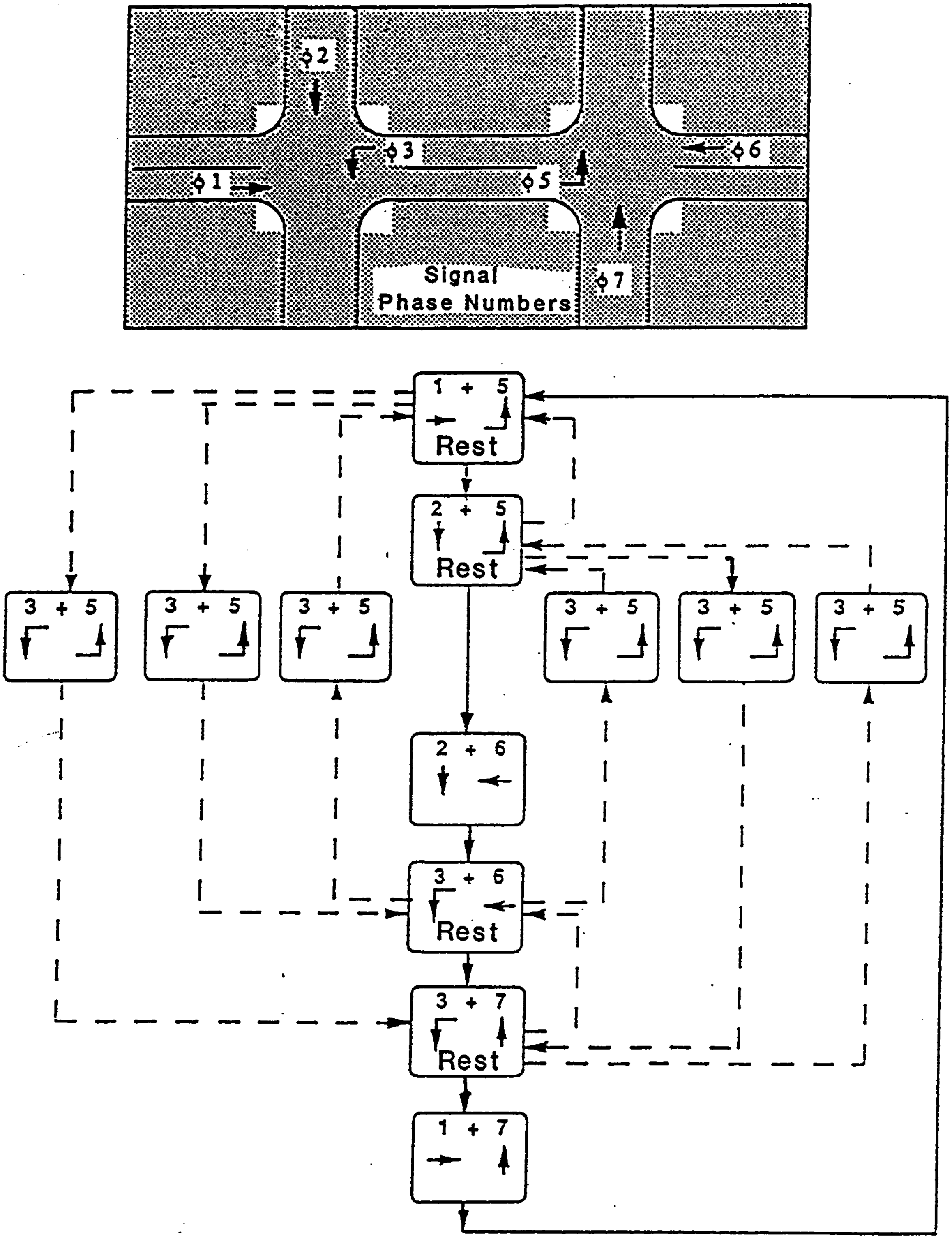

ϕ2
ϕ3
ϕ6
ϕ1
ϕ5
ϕ7
Signal
Phase Numbers
1 + 5
Rest
2 + 5
Rest
3 + 5
3 + 5
3 + 5
3 + 5
3 + 5
3 + 5
2 + 6
3 + 6
Rest
3 + 7
Rest
1 + 7

Figure 6. "Figure 4" Phasing Sequence (13)

3.0 STUDY DESIGN

3.1 OVERVIEW

This research focused on determining the effective placement of detectors on one-way frontage roads at diamond interchanges in order to minimize total interchange delay. Spacing between the two intersections of a diamond interchange is also a critical factor. It largely determines the phasing strategy, location of detectors, controller settings, and detector unit settings. Hence, the researchers deemed it important to study the relationship between intersection spacing and detector setback on frontage roads at diamond interchanges. To achieve this objective, it was necessary to compare the influence of different detector setback distances on total interchange delay for different intersection spacings. The research team proposed that this task be accomplished using an existing simulation model to evaluate the performance of a typical diamond interchange for the proposed detector layouts, controller settings, and detector unit settings. TEXAS Model and TRAF-NETSIM are two microscopic simulation models that were considered for use in evaluating the performance of loop detectors at diamond interchanges.

3.2 SELECTION OF SIMULATION MODEL

TEXAS Model and TRAF-NETSIM are both calibrated/validated simulation models. While the TEXAS model was developed by University of Texas at Austin, TRAF-NETSIM was developed by the Federal Highway Administration. Based on previous research (14) the performances of these two models was judged to be quite adequate for application as traffic engineering analysis tools.

The researchers proposed that the diamond-interchange simulation version of the TEXAS Model be used to perform the experimental simulation, as it has the capability to explicitly simulate the TxDOT "Texas Diamond Controller". However, on reviewing the literature on TEXAS Model, it was found that the model poses certain disadvantages that were not initially apparent.

TEXAS Model simulates a diamond controller (Model 828A Microprocessor Controller) which operates according to 1982 specifications. The model simulates ten detectors which are numbered as shown in Figure 7. The analyst can neither increase nor decrease the number of these detectors. This becomes a severe limitation if the user wants to simulate multiple loop detectors to improve operations at an interchange.

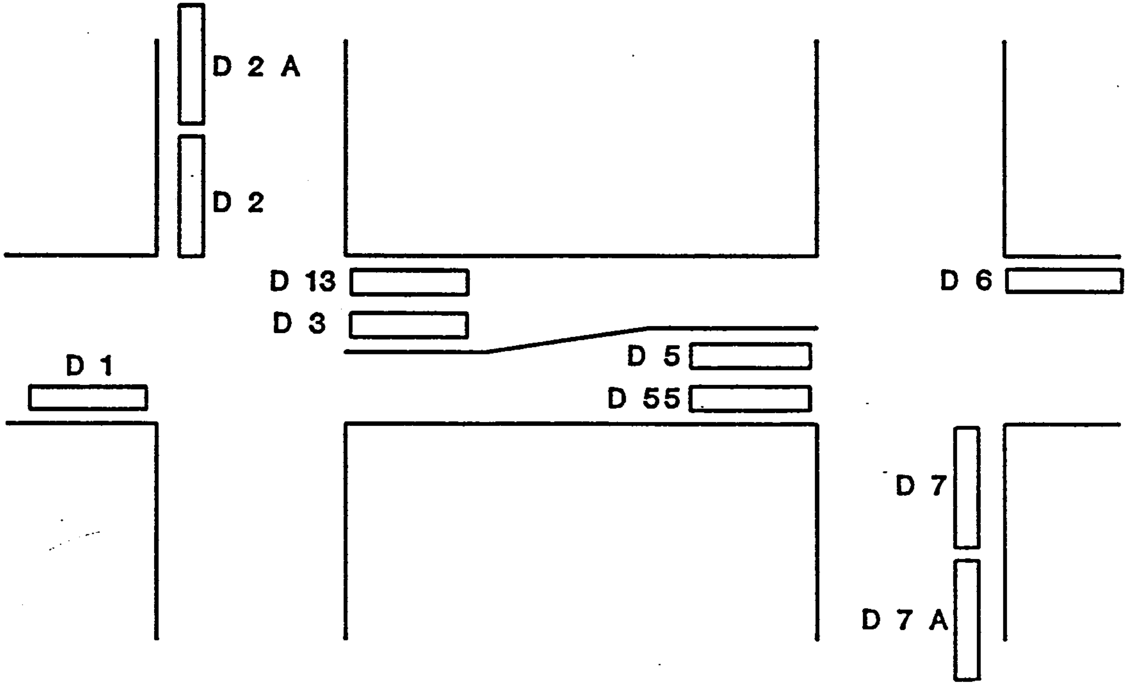


Figure 7. Typical Detector Placement and Numbering Scheme of TEXAS Model (14)

TRAF-NETSIM has an advantage over the TEXAS Model in that it allows the user to have virtually an unlimited number of detectors at a diamond interchange. However, the major disadvantage of TRAF-NETSIM is that it cannot simulate a "Texas Diamond Controller." Though the NEMA controller in TRAF-NETSIM can be modified to function somewhat like a diamond controller, it is not possible to have single control for two nodes, according to the TRAF-NETSIM logic. Hence, TEXAS Model was chosen to perform the simulation even with its noted limitations.

3.3 TEXAS MODEL FOR DIAMOND INTERCHANGES

The TEXAS Model for Diamond Interchanges is a computer simulation software package that can be used to study in great detail the interaction among individually-characterized driver-vehicle units as they approach and pass through the two closely spaced at-grade intersections of a conventional diamond interchange having one-way traffic on diagonal ramps that form the two opposite legs of each intersection (14).

3.3.1 Terminology of TEXAS Model

In the TEXAS Model, the diamond interchange is configured as two adjacent, three-leg, at-grade intersections connected by a set of internal lanes. These left and right intersections are designated as L and R, respectively. Legs, lanes, approaches, curb returns, and the signal phases are numbered as shown in Figure 8.

3.3.2 Data Entry and Processing in Texas Model

Input data for the TEXAS Model are entered through two data-entry programs called GDVDATA and SIMDATA. GDVDATA is the Geometry, Driver, and Vehicle data file which contains the details of the interchange geometry, driver characteristics, and vehicles comprising the traffic stream. This file is processed by the data processor GDVPRO. SIMDATA is the Simulation data file which contains the details required for performing simulation. This data-entry program pairs the entered data with data previously defined through GDVDATA to be processed by the data-entry processor called SIMPRO. All the data are entered into appropriate "fields" which define specific features.

Critical data relating to interchange geometry, entered through GDVDATA, include spacing between the two intersections, number of inbound and outbound lanes, lane widths together with lengths of inbound and outbound lanes. Details of vehicles include number of vehicle classes, speed limits, mean and 85th percentile speeds on inbound and outbound lanes, type of inbound traffic headway frequency distribution, and total hourly volumes together with outbound traffic destination data for all legs.

Data required by the SIMDATA file include type of intersection control, phasing sequence, controller options, signal timing features, special intervals, and detector information. The type of intersection control can be specified to be one of the following options:

(1) Uncontrolled (U)
(2) Yield (Y)
(3) Stop, Less than All Way (ST)
(4) All Way Stop (A)
(5) Texas Diamond Controller, Actuated (T)
(6) Pretimed Signal (P)
(7) NEMA Actuated Signal (N)

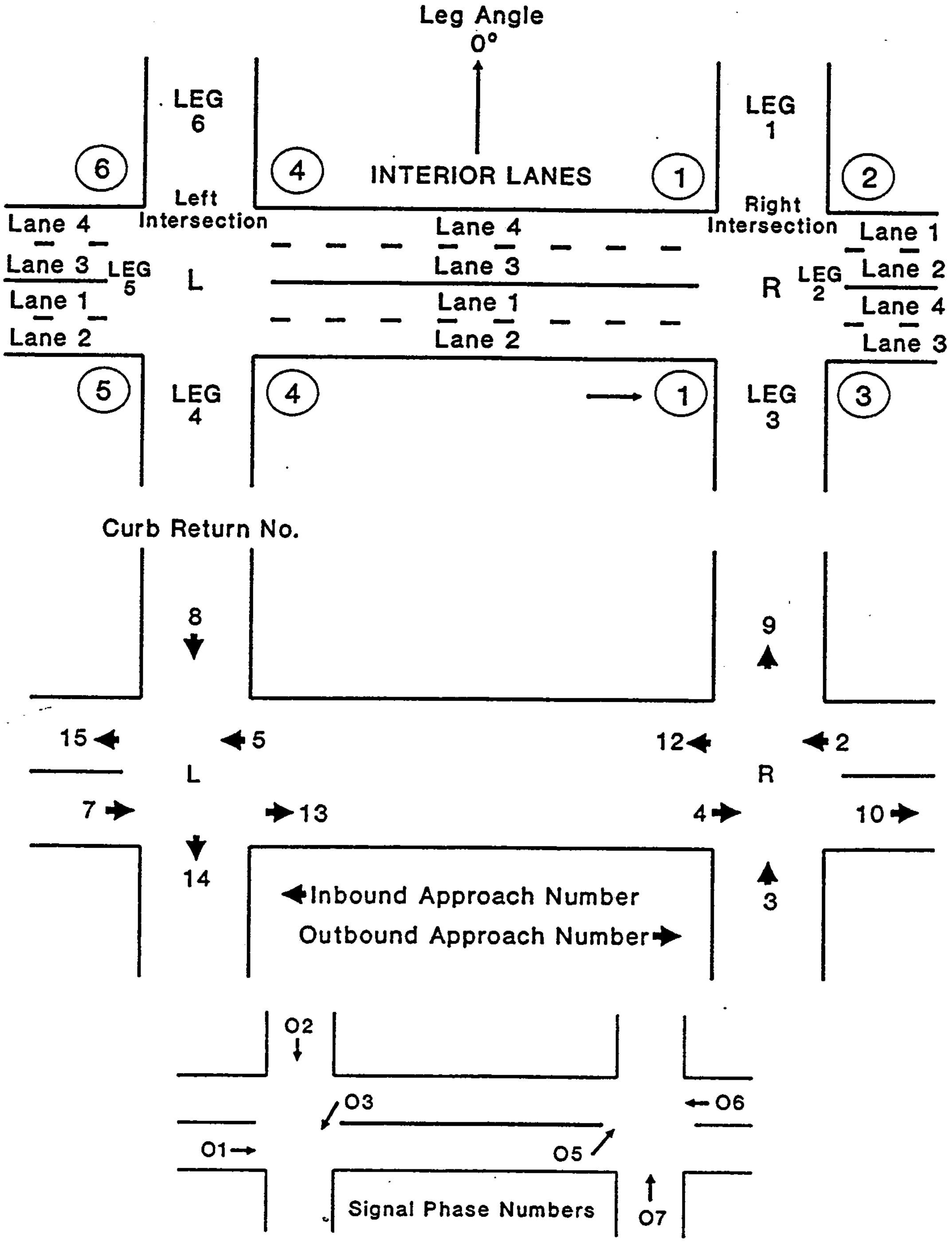

Leg Angle
0°
LEG 6
LEG 1
⑥
④
INTERIOR LANES
①
②
Left Intersection
Right Intersection
Lane 4
Lane 3
Lane 1
Lane 2
LEG 5
L
R
LEG 2
Lane 1
Lane 2
Lane 4
Lane 3
⑤
LEG 4
④
①
LEG 3
③
Curb Return No.
8
9
15
5
12
2
L
R
7
13
4
10
14
3
Inbound Approach Number
Outbound Approach Number
O2
O3
O6
O1
O5
Signal Phase Numbers
O7

Figure 8. TEXAS Model Terminology and Nomenclature for Diamond Interchanges (14)

The signal timing features include initial interval, vehicle interval, yellow-change interval, all-red clearance interval, and maximum extension for each of the signal phases. There are twelve special intervals in the TEXAS Model, only a few of which are applicable, depending on the type of phasing sequence chosen. This study focuses on those special intervals associated with "Figure 3" and "Figure 4" operations (14).

For the "Figure 3" operation given in Figure 5, the three special intervals that need to be defined are phase 1-7 advance green, phase 2-6 advance green, and phase 3-5 clearance green. The first two intervals are set equal to the travel time between the two intersections of the diamond interchange. The phase 3-5 clearance green is usually the travel time from the frontage road of one intersection to the other intersection. Estimated travel times based on the width of the diamond interchange were used in calculating these special intervals (15). These are also common for the "Figure 4" operation given in Figure 6. In addition to these special intervals, "Figure 4" operation involves two more special intervals called the phase 2 transfer gap and phase 7 transfer gap.

Transfer gap times are used during phase combinations 2-5 and 3-7. Their purpose is to delay the transfer of extension logic from the front set of detectors to the back set of detectors until queued traffic on the frontage road has reached normal speed. When a gap size greater than the transfer gap is detected, the extension logic is switched from the front detector to the advance detector.

For "Figure 3" operation, the controller has two options for termination logic of phase combination 2-7. In "Figure 3" operation, the phase combination 2-7 can be followed by any other phase combination. The decision logic has been designed so that the user can select the most efficient combination to follow 2-7. In the data entry program, field 5 and field 6 of the Texas Diamond controller options determine the phase combination that is favored after 2-7. When field 5 is ON, phase combination 1-7 is selected, and when field 6 is ON, phase combination 2-6 is selected. Though both the fields can be OFF, they cannot both be ON at the same time. In "Figure 4" operation the controller options are different. The four fields are used to enable or disable the detectors D3 and D13 during phases 3-7, and D5 and D55 during phases 2-5.

The data for the detectors include: specifying the phases to which the detectors are connected; the first inbound lane covered by the detector; the number of inbound lanes covered by the detector; spacing between the leading edge of the detector and nominal lane terminal; and length and type of the detector. Examples of the interactive data entry programs GDVDATA and SIMDATA are included in Appendix A.

There are two replicate run processors in the TEXAS Model. They are REPRUN and REPTOL. The user may specify the number of runs when REPRUN is used. The runs are made using different random seed numbers and output files are created for each run. When REPTOL is used, runs are performed by the program until a tolerance value specified by the user is reached. The tolerance value is considered to be reached when the mean of the overall average total delay for the replicate runs is within the specified percentage of the overall average total delay for the population. However, REPTOL performs a minimum of 3 runs and a maximum of 10 runs. In addition to the output files created for each run, an additional file containing the mean, minimum, maximum, variance, and standard deviation for all the MOEs is also created.

TEXAS Model output includes various MOEs such as total delay, queue delay, stopped delay, delay below 16 km/h (10 mph), travel time, vehicle-miles travelled, time mean speed, space mean speed, average maximum acceleration, and average maximum deceleration. These MOEs are summarized as either per approach or per movement, or both as specified in the simulation data file. Delay statistics are measured based on actual simulated delay. Information on number of max-outs, gap-outs per signal phase, and signal combination are included in the output. All statistics are collected after the startup time.

Output can also be displayed graphically in real time using a processor called DISPRO. Intersection geometry is extracted from the data file created by GDVDATA and displayed on the screen. The position of each simulated vehicle is represented on the screen. The vehicles are color-coded according to the performance capability with respect to time (14).

3.4 ESTABLISHMENT OF STUDY SCENARIO

Researchers thought a typical interchange geometry having six lanes on the arterial with left-turn lanes on the interior, and three lanes on the frontage road, as shown in Figure 9, adequate for study. They considered no U-turn lanes at the interchange. The type of inbound traffic headway frequency distribution was assumed to follow a "Shifted Negative Exponential" distribution. The total hourly volumes on all the approaches were assumed to be 800 vph over three lanes.

The study assumed the turning percentages for the traffic on the arterial to be 20% turning right, 60% going straight, and 20% turning left. Researchers also assumed that on the frontage roads, 33% of the traffic turned right, 33% turned left, and the rest was through traffic. The speeds on all the external approaches were assumed to be 73 km/h (45 mph) whereas the speeds on the internal approaches were assumed to be 48 km/h (30 mph). The spacing between the two intersections of the diamond interchange was varied from 61 meters (200 feet) to 152 meters (500 feet) which covers a range from narrow to wide urban diamond interchanges. The total simulation time including the startup time for a single run was specified to be 20 minutes.

A startup time of 5 minutes and a simulation time increment of 0.5 seconds were specified. Texas Diamond Controller (Actuated) was chosen as the type of intersection control. "Figure 3" and "Figure 4" operations were the two signal phasing strategies considered for the study. The size and location of the detectors on the external and internal approaches of the arterial were fixed as shown in Figure 10.

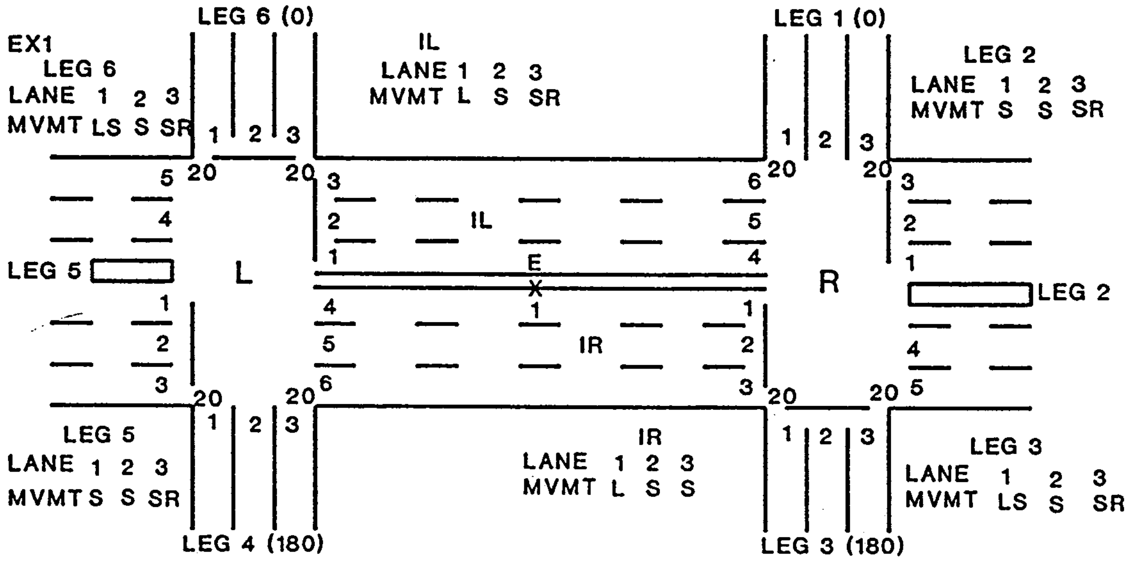

EX1
LEG 6
LANE 1 2 3
MVMT LS S SR
LEG 6 (0)
1 2 3
IL
LANE 1 2 3
MVMT L S SR
LEG 1 (0)
1 2 3
LEG 2
LANE 1 2 3
MVMT S S SR
20
20
20
20
5
4
3
2
1
IL
6
5
4
3
2
1
LEG 5
L
E
X
1
R
LEG 2
1
2
3
4
5
6
IR
1
2
3
4
5
20
20
20
20
1 2 3
LEG 5
LANE 1 2 3
MVMT S S SR
LEG 4 (180)
IR
LANE 1 2 3
MVMT L S S
1 2 3
LEG 3 (180)
LEG 3
LANE 1 2 3
MVMT LS S SR

Figure 9. Typical Interchange Geometry Used for Study

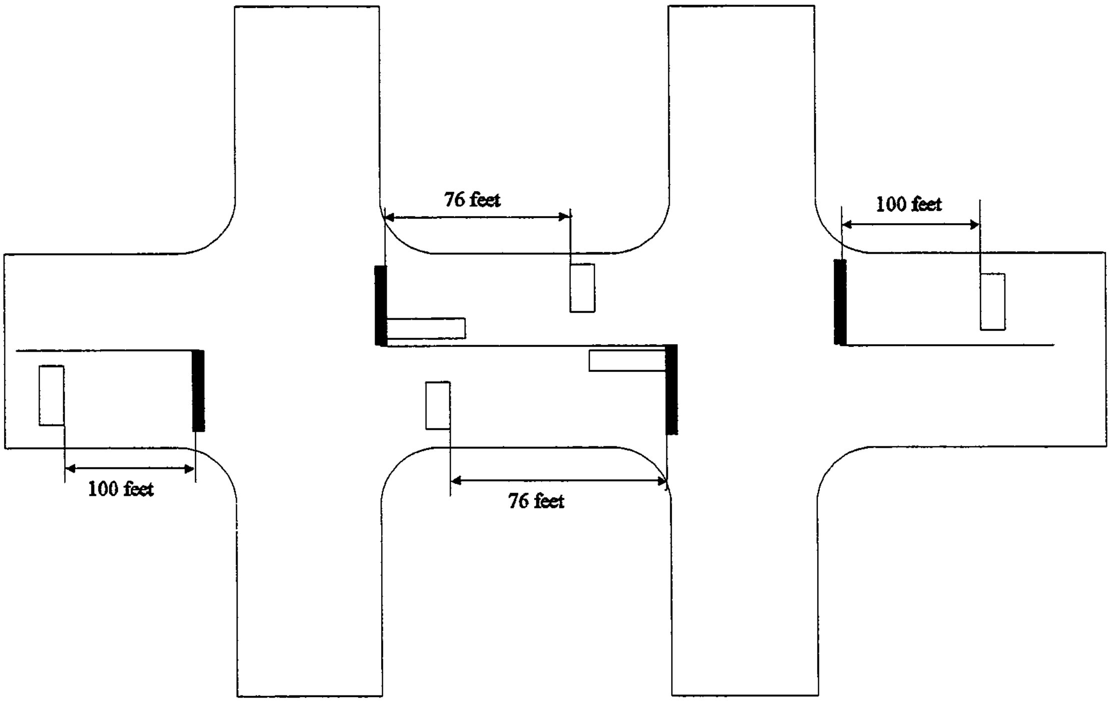

76 feet
100 feet
100 feet
76 feet

Figure 10. Detector Layouts on the Arterial at a Diamond Interchange

On each of the external approaches of the arterial, 1.8 meter (6 feet) long loop detectors were placed at a distance of 30 meters (100 feet) from the stop line. Loop detectors 12 meters (40 feet) in length were placed at the stop line in each of the interior left-turn lanes. The interior lanes serving the through traffic had loops 1.8 meters (6 feet) in length placed at a distance of 23 meters (76 feet) from the stop line. These typical detector layouts were based on the earlier studies done by Messer, et al. (4). While a 12 meter (40 foot) long loop placed at the stop line acted as the front detector, a 1.8 meter (6 feet) loop was used as an advance detector on each of the frontage roads. Setback distance of the advanced detector on the frontage roads was varied from 30 meters (100 feet) to 121 meters (400 feet) in increments of 30 meters (100 feet). All loop detectors were of presence type. A detector setback distance of 15 meters (50 feet) was also included in the study.

The study calculated signal timing features, such as initial intervals and vehicle intervals, according to the specified detector layouts. Initial interval was calculated using equation 1, and the vehicle interval was computed based on the passage time from the advanced detector to the stop bar. The researchers specified initial intervals as 0.5 seconds for phases having stop line detectors. Yellow-change intervals of 4 seconds, all-red clearance of 0 seconds, and maximum extensions of 40 seconds were used for all the signal phases. The transfer gap time was set equal to 2.5 seconds, a value on the upper side of the saturation headway. For the "Figure 4" operation, while detectors D3 and D13 were enabled during phases 3-7, detectors D5 and D55 were enabled during phases 2-5. In the "Figure 3" operation, the termination logic was turned OFF so that no particular phase combination is selected after 2-7.

3.5 DEFICIENCIES IN DATA-ENTRY PROGRAM IN TEXAS MODEL

The study identified certain problems when using TEXAS Model while carrying out data entry. It was observed that the data entry program SIMDATA does not allow the user to code data for detector D7A, which is the advance detector on the frontage road approaching the right intersection. Therefore, the user must edit the data file using some kind of editor such as MS-DOS editor and then go through the data entry program again. Another problem noted; was that whenever a value greater than zero is entered for all-red clearance interval, the simulation processor indicates an error. Therefore, a 4-second yellow clearance was used instead of a 3-second interval to compensate for the 1-second red clearance interval desired.

4.0 RESULTS

This chapter documents the results of the simulation studies performed using TEXAS Model. Also documented are the comparison and analysis of results obtained using various detector layouts and different interchange geometries.

4.1 SIMULATION USING TEXAS MODEL

Simulation studies were conducted using TEXAS model to study the performance of detectors for two signal phasing strategies: "Figure 3 and Figure 4" operations. The studies sought to examine the relationship between intersection spacing and advanced detector setback on the frontage road for each of the above signal operations. Therefore, the simulation process was carried out in two parts.

4.1.1 "Figure 3" Operation ("Texas Three-Phase")

The set of geometric data files with varying intersection spacing were run in combination with simulation data files with varying detector layouts on the frontage roads. This was accomplished by specifying these data files as a geometric-driver-vehicle reference data file in the simulation data files. GDVPRO and SIMPRO programs were used to process geometric-driver-vehicle and simulation data files, respectively. REPTOL was then used to make replicate runs with a tolerance value of 5 percent.

Graphs of average total delay against intersection spacing were plotted for all the approaches for different detector layouts in order to compare the performance of these detector layouts. Figures B-1, B-2, and B-3 of Appendix B illustrate plots of average total delay against intersection spacing for the frontage roads, and external and internal approaches of the arterial, respectively. A plot of total interchange delay versus intersection spacing for different detector layouts is shown in Figure 11. Total interchange delay was also plotted against detector setback distance for different intersection spacing as shown in Figure 12.

The results from the simulation runs confirm that, for a "Figure 3" operation, delays on the interior approaches of the arterial are significantly high in contrast to "Figure 4" operation. Figure B-1 indicates that delays on frontage road approaches in general are increasing with increasing detector setback distance. It can be observed from Figure B-2 and B-3 that delays on external as well as internal approaches of the arterial are increasing with an increase in detector setback distance. There is a higher probability of gapouts when the detector setback distances are shorter, resulting in shorter cycles, which in turn results in lower delays. When the detector setback distances are longer, there is a higher probability of extension of the phase causing the number of maxouts to be higher, which in turn usually results in longer cycle lengths. Further,

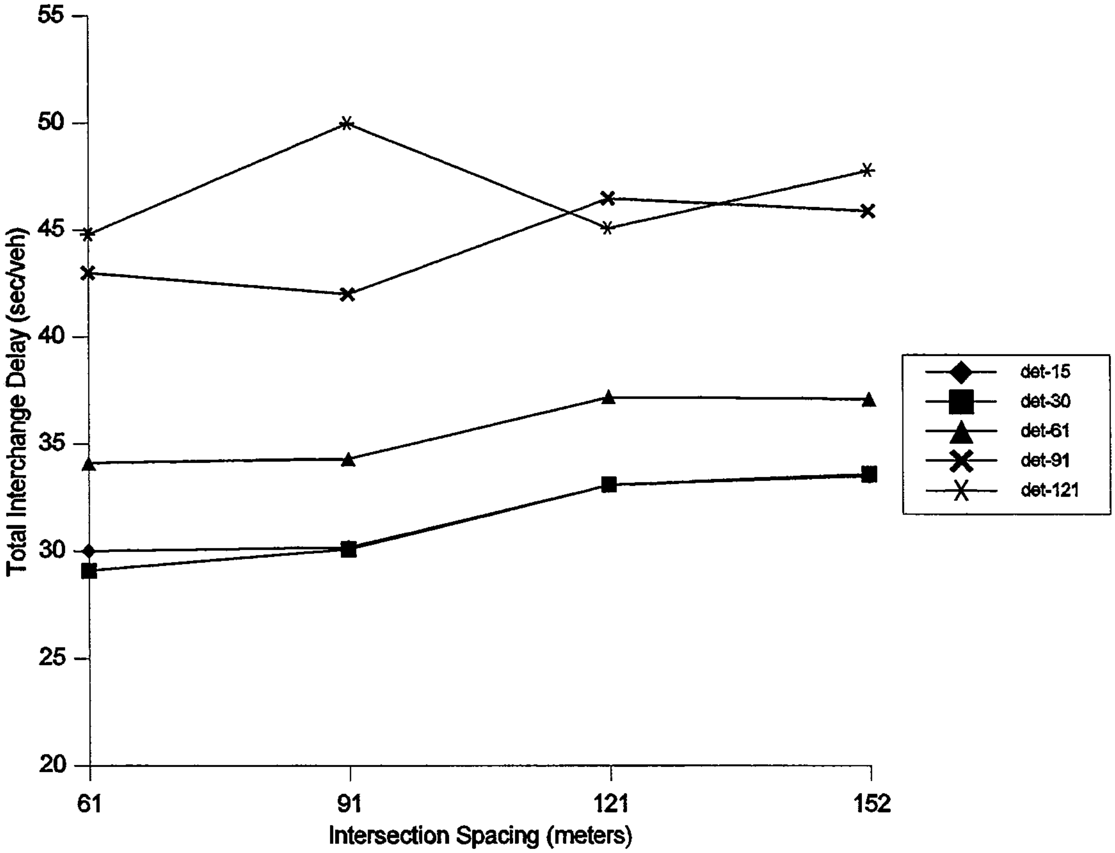


Figure 11. Total Interchange Delay Versus Intersection Spacing ("Figure 3" Operation)

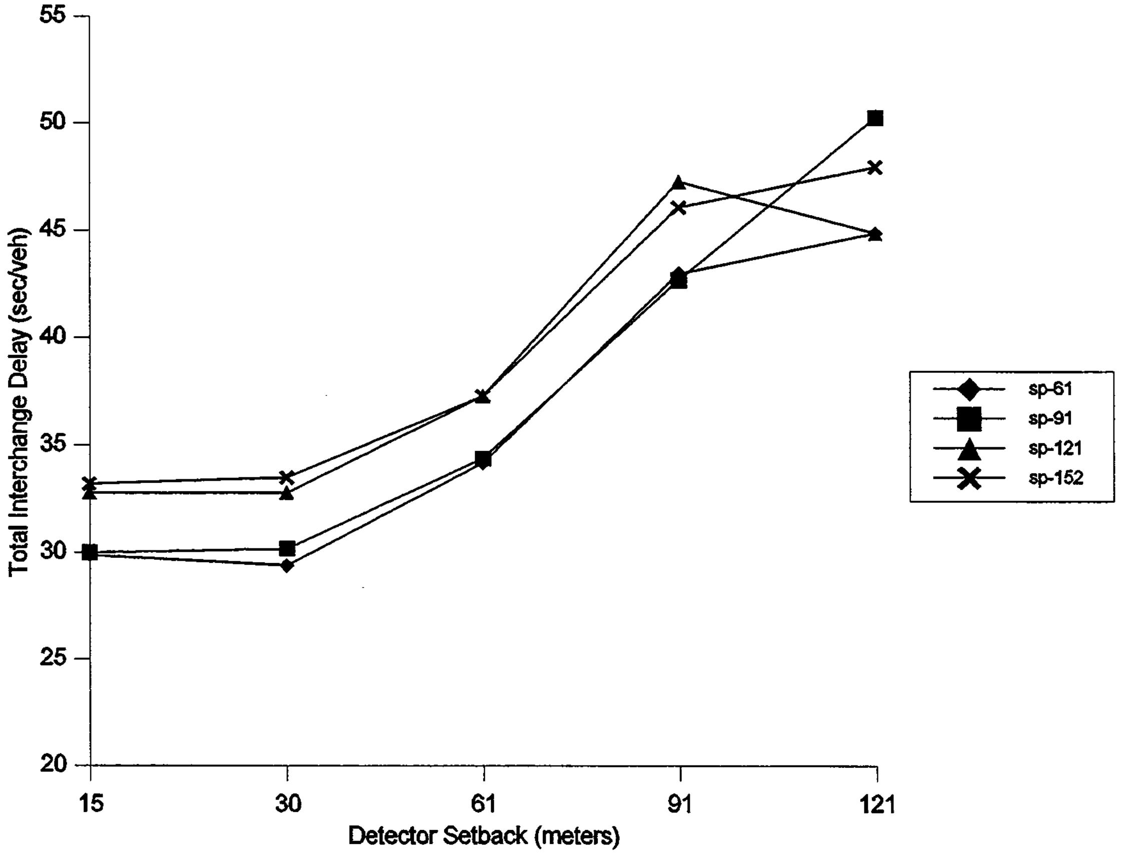


Figure 12. Total Interchange Delay Versus Frontage Road Detector Setback Distance ("Figure 3" Operation)

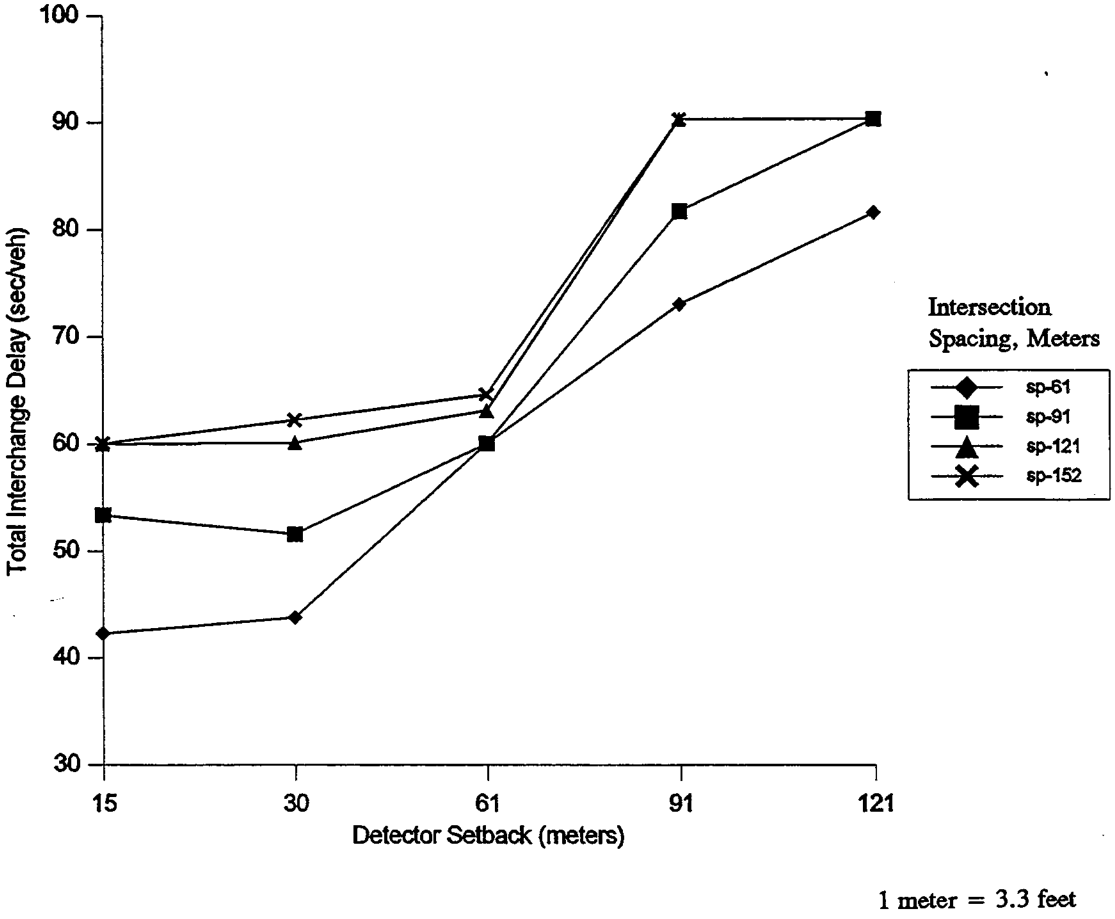


Figure 13. Cycle Length Versus Frontage Road Detector Setback Distance ("Figure 3" Operation without U-turns)

the increase in passage interval with an increase in detector setback is also a causal factor for longer cycles. This phenomenon is substantiated by Figure 13, where an increase in detector setback distance results in an increase in cycle length. Further, it can also be observed from

Figure 13 that cycle lengths are longer for interchanges with wider intersection spacing. This may be due to an increase in travel time between the intersections of the interchange. It can be observed from Figure 11 and Figure 12 that the 15 meters (50 feet) and 30 meters (100 feet) detector setback distances result in lower total interchange delays.

4.1.2 "Figure 4" Operation Without U-turns ("TTI Four-Phase")

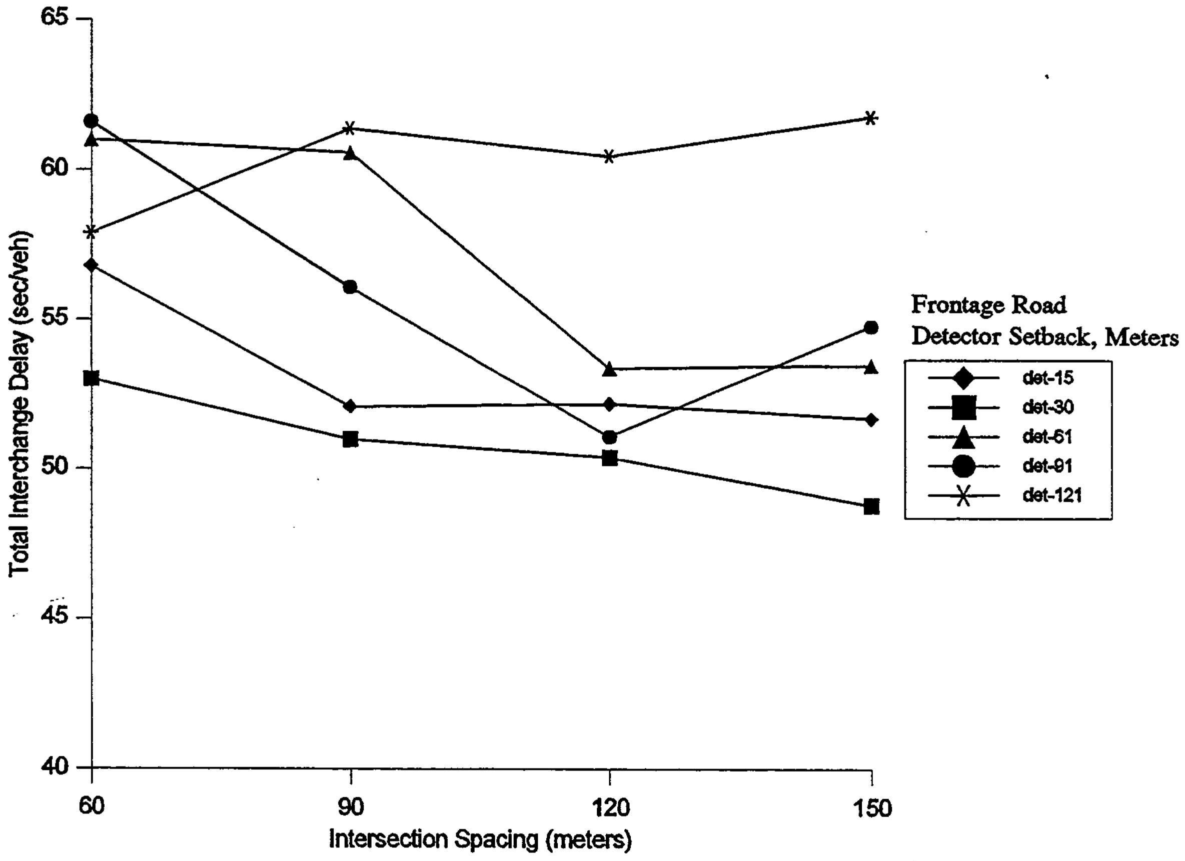
For "Figure 4" operation, simulation runs were performed using geometric-driver-vehicle data files with varying intersection spacing and simulation data files with varying detector layouts. Graphs of average total delay versus intersection spacing were plotted for all approaches for different detector layouts. Figures B-4, B-5, and B-6 illustrate plots of average total delay versus intersection spacing for the frontage roads, the external approaches and internal approaches of the arterial, respectively.

Results from the simulation runs are consistent for "Figure 4" operation, for the case where no U-turns are present. Delays on external approaches were observed to be significantly higher than delays on interior approaches. Delays on external approaches of the arterial can be observed to increase with increase in detector setback distance. The greater the setback distances, the more the green is extended for the frontage road, resulting in higher cycle lengths. This may be one of the reasons for the increase in delays on the external approaches of the arterial. The variability in the delay trends on the internal approaches for different detector layouts as observed from Figure B-6 may be due to randomness.

Total interchange delay was plotted against intersection spacing for different detector layouts as shown in Figure 14. Figure 15 illustrates a plot of total interchange delay versus detector setback distance for different intersection spacing.

Figure 14 illustrates that "Figure 4" operation is a fairly robust phasing strategy for a wide range of geometric conditions without any significant deterioration in operation. It is also observed that total interchange delays are lower for a detector setback of 30 meters (100 feet) for advanced detectors on the frontage roads. Further, for an intersection spacing of 121 meters (400 feet), there is a cluster of data points which indicates that an intersection spacing of 121 meters (400 feet) is marginally optimal with any detector setback distances not greater than 91 meters (300 feet). Figure 15 indicates that the detector layout with advance detector setback distance of 30 meters (100 feet) on frontage roads for any interchange spacing results in the least total interchange delay.

In order to study the influence of approach volumes on total interchange delay for two detector layouts with detector setback distances of 30 meters (100 feet) and 121 meters (400 feet), the volumes were varied from 200 vphpl to 400 vphpl. The plot of total interchange delay against approach volume is shown in Figure 16. It appears from Figure 16 that at lower volume conditions, the detector layout with advance detector setback of 30 meters (100 feet) on frontage is marginally optimal to the detector layout with a detector setback of 121 meters (400 feet).



1 meter = 3.3 feet

Figure 14. Total Interchange Delay Versus Intersection Spacing.
("Figure 4" Operation without U-turns)

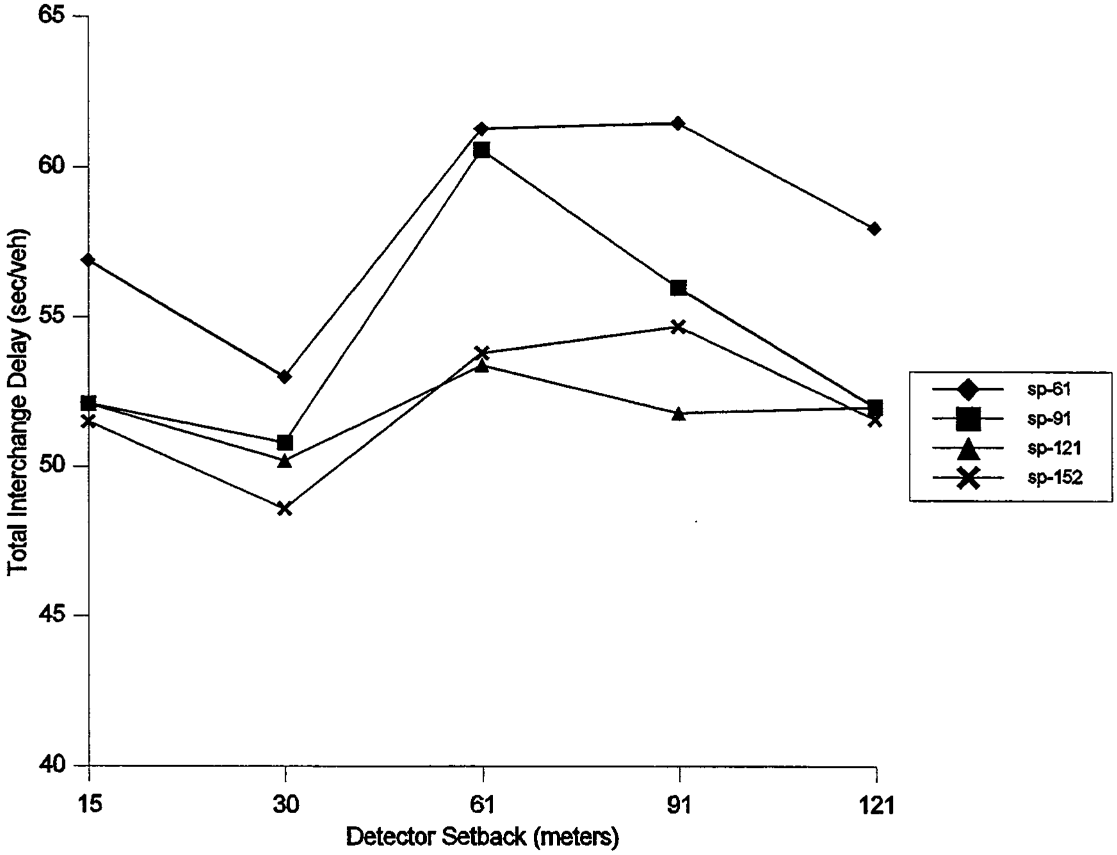


Figure 15. Total Interchange Delay Versus Frontage Road Detector Setback Distance ("Figure 4" Operation without U-turns)

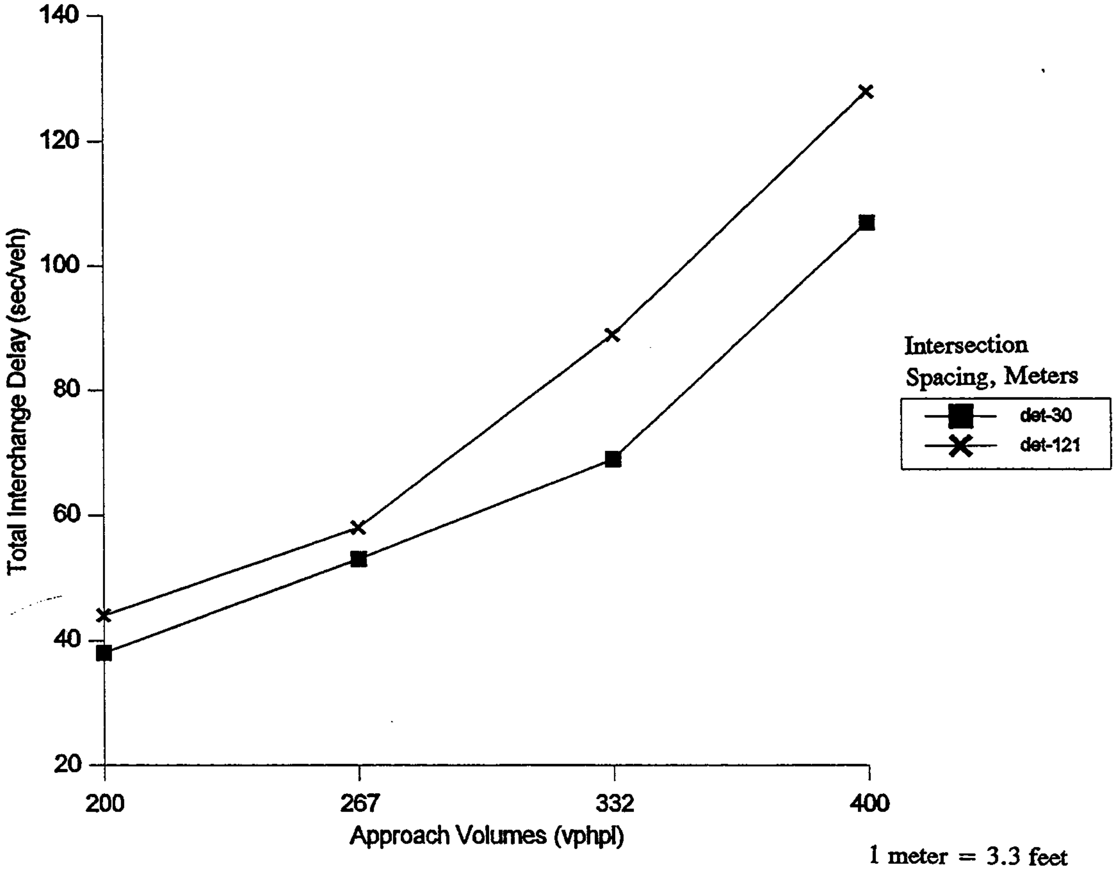


Figure 16. Total Interchange Delay Versus Approach Volume
("Figure 4" Operation without U-turns)

However, at higher volume conditions, the detector layout with 30 meters (100 feet) detector setback distance results in significantly lower delays than those resulting from the detector layout with 121 meters (400 feet) detector setback distance.

With the 12 meters (40 feet) long stop line detectors and a transfer gap of 2.5 seconds, the switching of extension logic to the advance detector is possible only when gap size greater than 3.5 seconds. A gap of such size is fairly large. Typical headway range is from 2 to 2.5 seconds, therefore, a transfer gap of size equal to 1.5 seconds was used for subsequent simulations runs. A repeat run of the simulation for "Figure 4" operation required a transfer gap of 1.5 seconds. The results indicate that delays decreased for a transfer gap of 1.5 seconds as compared to a transfer gap of 2.5 seconds. Graphs of total interchange delay versus intersection spacing and detector setback are illustrated in Figure B-7 and B-8 of Appendix B, respectively.

4.1.3 "Figure 4" Operation with U-turns ("TTI Four-Phase")

A study of the performance of the detector layouts for a case where a significant number of vehicles on frontage roads were turning left-then-left at the downstream signal was considered. This required another set of simulation runs including U-turns in the traffic from the frontage roads. On the frontage roads, 33% of the traffic turned right, 34% went straight, 20% turned left, 13% turned left and then left. Turning percentages on the arterial remained the same. Plotting of the total interchange delay against intersection spacing for different detector layouts as shown in Figure 17. Figure 18 illustrates a plot of total interchange delay versus detector setback distance for different intersection spacing.

The total interchange delay for the case where a significant percentage of traffic from frontage roads was turning left-then-left increased as compared to those resulting from an operation where U-turns were absent. One of the reasons for the high delays is due to the stopped delay experienced by the vehicles being trapped in the interchange while trying to make U-turns. The travel times for these vehicles were high because they were travelling at low speeds, having to negotiate two turns. Therefore, some of these vehicles would not be able to clear the interchange before the overlap ends. Figure 17 indicates that the delays are lower for an interchange spacing of 121 meters (400 feet). Figure 18 clearly shows that 30 meters (100 feet) detector setback on frontage roads produces lower delays.

The effect of U-turn volume on total interchange delay is quantifiable by plotting one against another for the detector layout with 30 meters (100 feet) advance detector setback distance. The range of U-turn volume in performing the simulation was 0 to 160 vph. Figure 19 illustrates a plot of total interchange delay versus U-turn volume for detector layout with 30 meters (100 feet) advance detector setback distance.

A comparison of Figure 16 and Figure 19 shows that the increase in delay is more sensitive to an increase in U-turn volume than an increase in the total approach volume. As such, shorter detector setback distances are more efficient when there exists significant U-turning volume on frontage roads. However, when the advance detector is very close to the stop line there is a possibility of the phase gapout without serving the traffic demand completely, resulting in premature gapouts.

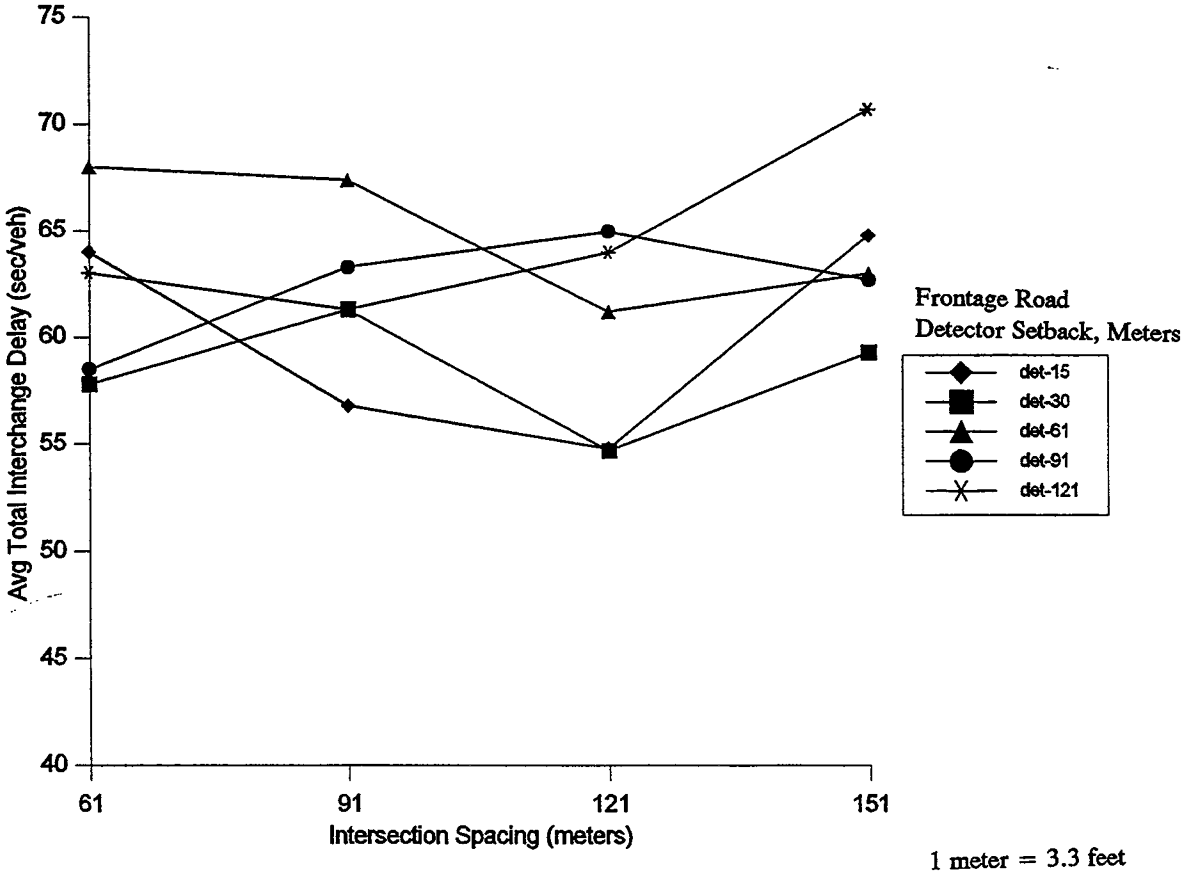


Figure 17. Total Interchange Delay Versus Intersection Spacing.
("Figure 4" Operation with U-turns)

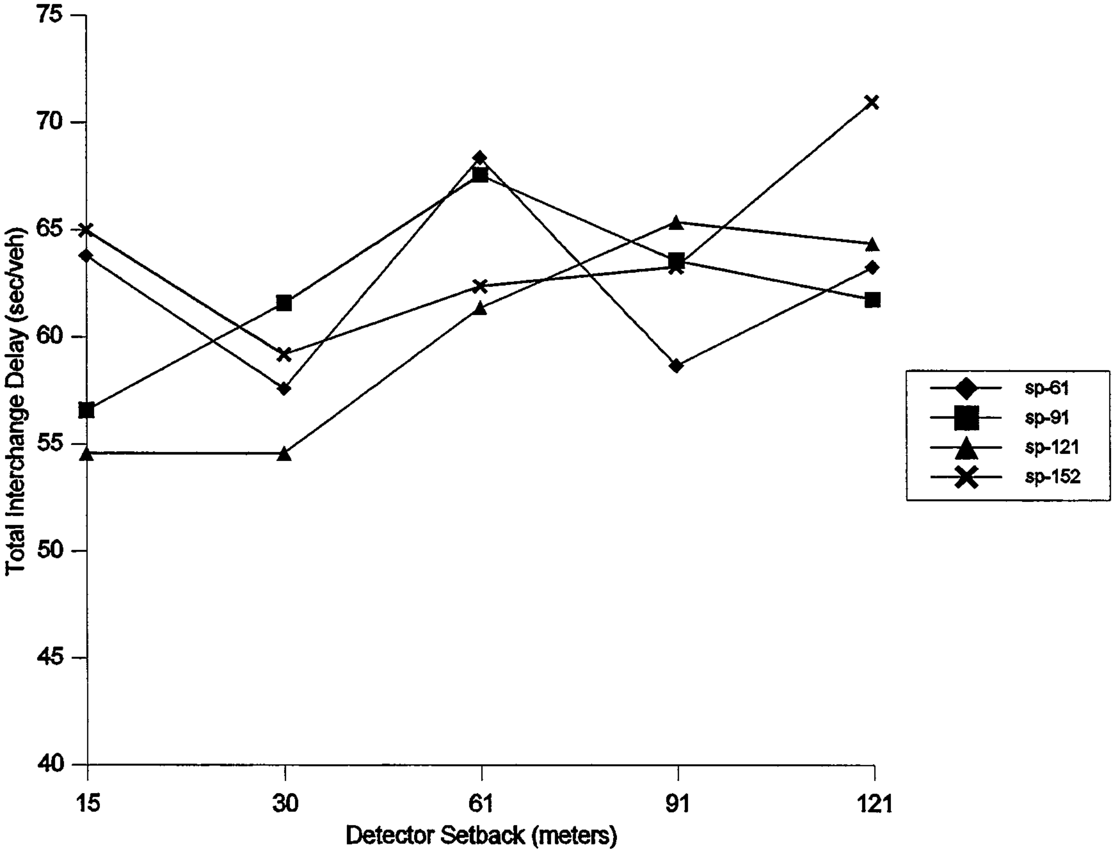


Figure 18. Total Interchange Delay Versus Detector Setback Distance ("Figure 4" Operation with U-turns)

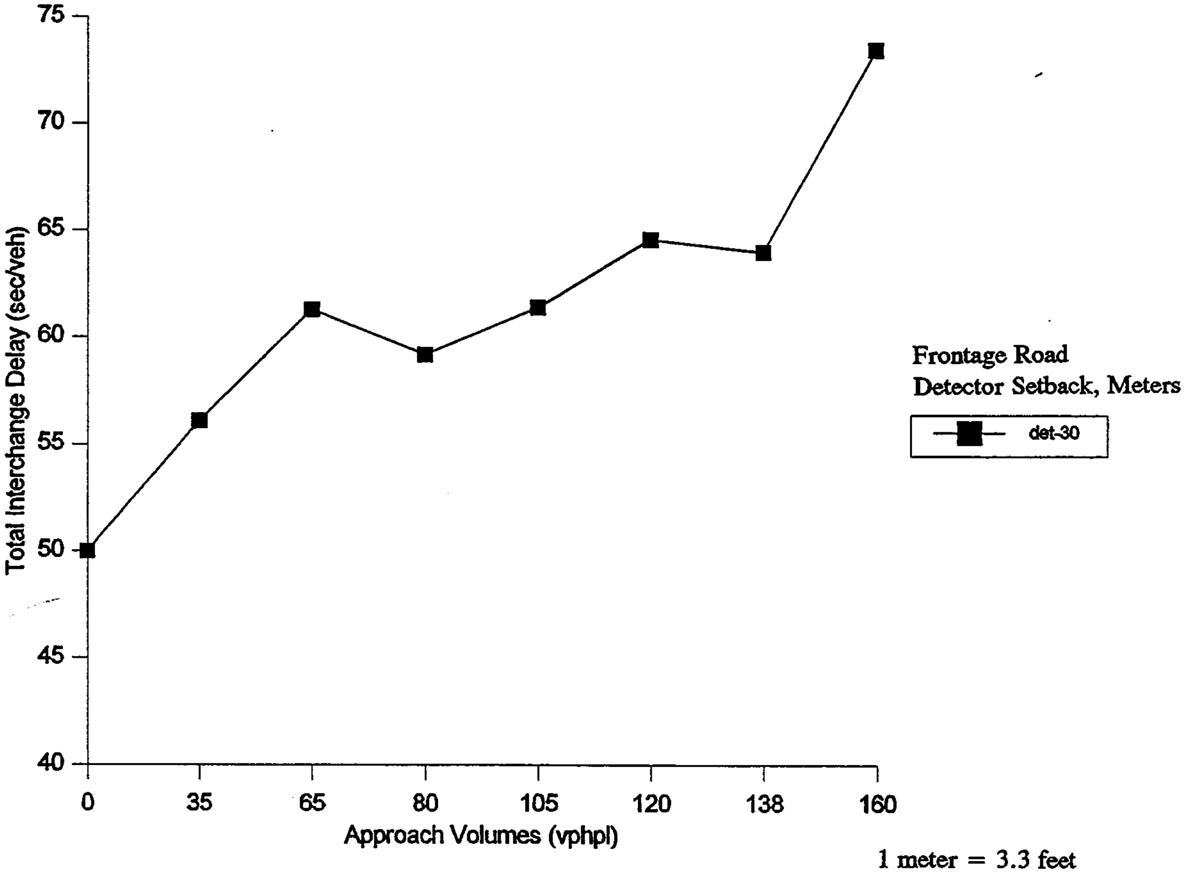


Figure 19. Total Interchange Delay Versus U-turn Volume ("Figure 4" Operation)

5.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations of this research performed to determine effective placement of detectors on frontage roads at a diamond interchange that would minimize the total interchange delay. The scope and context of the conclusions and recommendations of this study are based on various aspects of TEXAS Model. The diamond controller and detectors in TEXAS Model are according to 1982 specifications of the TxDOT diamond interchange controller unit. Further, these conclusions and recommendations are limited by the specific interchange geometry, traffic volume levels, and turning percentages on the arterial and frontage roads.

5.1 CONCLUSIONS

The following are the conclusions of this study:

1. For both "Figure 3" and "Figure 4" operations, short advance detector setback distances on frontage roads result in lower interchange delays. "Figure 3" and "Figure 4" operations refer to lag-lag and lead-lead phasing patterns, respectively.

2. The performances of the detector layouts with 15 meters (50 feet) and 30 meters (100 feet) advance detector setback along the frontage road appear to be the same in the case of "Figure 3" operation.

3. At moderate volume conditions (200 vphpl), the detector layout with 30 meters (100 feet) advance detector setback distance on frontage roads may be marginally better than the other detector layouts in terms of total interchange delay for "Figure 4" operation. However, at high volume conditions (400 vphpl) there is a significant improvement in the performance of that particular detector layout in comparison with other detector layouts.

4. A setback distance of 30 meters (100 feet) from the stop line may be the optimal location for the advance detector on frontage roads at a diamond interchange for "Figure 4" phasing sequence for both the cases where U-turns are absent as well as present.

5. Interchange delays are lower for "Figure 4" operation when a transfer gap of 1.5 seconds is used as compared to a situation where a 2.5 seconds transfer gap was used, primarily because lower cycles result.

6. The total interchange delay is more sensitive to U-turn volume than the total approach volume for the "Figure 4" phasing sequence.

5.2 RECOMMENDATIONS

Optimal detector layout on frontage roads at a diamond interchange includes a 12 meter (40 feet) long loop located at the stop line and a 1.8 meter (6 feet) long advance detector at a distance of 30 meters (100 feet), respectively (Figure 20). Both detectors should be operated under presence mode in order to minimize total interchange delay. It is recommended that the size of transfer gap for use in "Figure 4" operation should be based on the difference between the maximum saturation headway at the interchange and the loop presence time.

The limitation in TEXAS Model regarding the number of detectors that can be used at a diamond interchange has prevented a more detailed study of detector placement strategies at diamond interchanges. Current multiple loop detector placement strategies used by the Texas Department of Transportation apparently cannot be evaluated due to this limitation. Therefore, it is recommended that further study be conducted on detector placement at diamond interchanges with multiple loop detection. Improvements to the TEXAS Model are recommended, as it may enable a detailed study if the identified limitation is rectified. Further, the deficiencies in the data-entry program of TEXAS Model need to be addressed. Also, proper documentation on special intervals involved is needed in the user's manual for TEXAS Model.

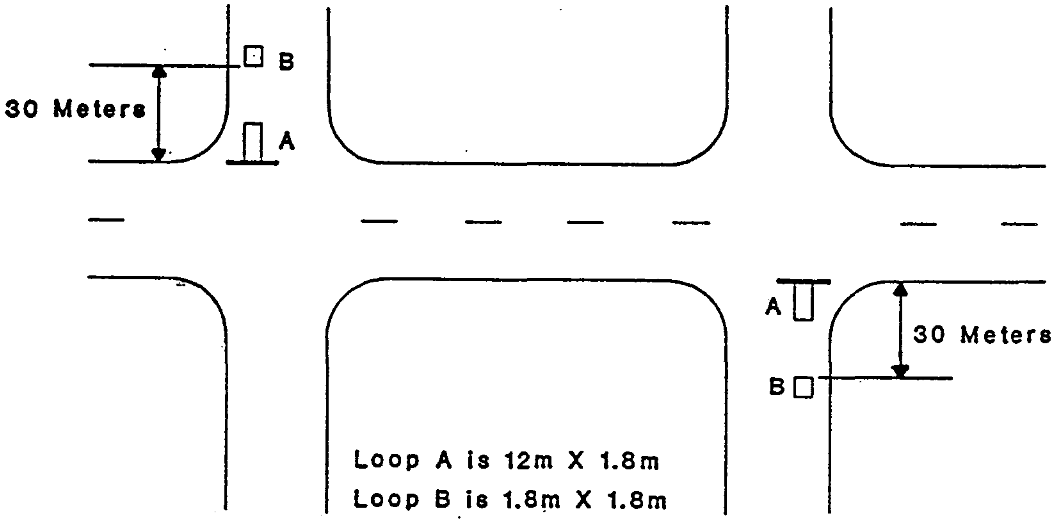


Figure 20. Recommended Detector Layouts for the Frontage Road Approach at a Diamond Interchange

6.0 REFERENCES

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APPENDIX A

DATA ENTRY EXAMPLES FOR GDVDATA AND SIMDATA

```
GDVDATA V3.21

GEOMETRY & DRIVER-VEHICLE DATA FOR THE TEXAS MODEL MUST BE DEFINED.

DO YOU WANT TO USE A FILE FROM THE PERMANENT LIBRARY ?
N
DO YOU WANT TO USE AN EXISTING DATA FILE ?
Y
KEYIN AN EXISTING DATA FILE NAME:

DI200IN8.S13
IS EXISTING DATA FILE NAME "C:\TEXAS\USER_DAT\DI200IN8.S13" OK ?
Y
DO YOU WANT TO REVISE THE EXISTING DATA ?
Y
DO YOU WANT TO SAVE THE REVISED DATA ?
Y
KEYIN FILE NAME FOR NEW/REVISED DATA:
Y
IS FILE NAME "C:\TEXAS\USER_DAT\Y.S13" OK ?
N
KEYIN FILE NAME FOR NEW/REVISED DATA:
DI200IN8.S13




         1         2         3         4         5
1234567890123456789012345678901234567890123456789012345
S13-EX1  STANDARD DIAMOND

IS TITLE TEXT OK ?
Y

PARAMETER-OPTION DATA FOR DIAMOND INTERCHANGE:
F(1) - TOTAL (STARTUP+SIMULATION) TIME IN MINUTES.  <1 TO 65> [20]
F(2) - MINIMUM HEADWAY IN SECONDS.  <1.0 TO 3.0> [1.0]
F(3) - NUMBER OF VEHICLE CLASSES.  <12> [12]
F(4) - NUMBER OF DRIVER CLASSES.  <3> [3]
F(5) - PERCENT OF LEFT TURNING VEHICLES TO ENTER IN MEDIAN LANE.<50 TO 100>[80]
F(6) - PERCENT OF RIGHT TURNING VEHICLES TO ENTER IN CURB LANE. <50 TO 100>[80]
F(7) - CREATE A GEOMETRY PLOT DATA FILE ? <"YES" OR "NO"> ["NO"]
F(8) - SIZE OF GEOMETRY PLOT (INCHES). <4.0 TO 34.0> [7.50]
EDIT EXAMPLE: "F(6)=75" CHANGES FIELD 6 TO "75", OTHER FIELDS REMAIN UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:     20  1.0   12    3   80   80 NO
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \7/ \.8./

IS PARAMETER-OPTION DATA FOR DIAMOND INTERCHANGE OK ?


  DATA FIELDS:     20  1.0   12    3   80   80 NO
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \7/ \.8./

IS PARAMETER-OPTION DATA FOR DIAMOND INTERCHANGE OK ?
Y

CURB RETURN RADII:
EACH FIELD - CURB RETURN RADIUS AS SHOWN BELOW.  <INTEGER, 0 TO 200>  [20]
           | LEG 6 |                     | LEG 1 |    >
           |   :   |                     |   :   |
           |   :   |                     |   :   |
--------CR6        CR4-----------------CR1       CR2--------
- - - - - -        - - - - - - - - - - - -       - - - - - -
LEG 5 ----         -----INTERNAL LANES----       ------LEG 2
- - - - - -        - - - - - - - - - - - -       - - - - - -
--------CR5        CR4-----------------CR1       CR3--------
           |   :   |   CR=CURB RETURN    |   :   |
           |   :   |      RADIUS         |   :   |
           | LEG 4 |                      | LEG 3 |
        LEFT INTERSECTION              RIGHT INTERSECTION
  DATA FIELDS:      20    20    20    20    20    20
FIELD NUMBERS:    \.1/  \.2/  \.3/  \.4/  \.5/  \.6/

ARE CURB RETURN RADII OK ?


IS INTERNAL LANES GEOMETRY DATA OK ?
Y

LANE DATA FOR INTERNAL LANES:
F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE AT END NEAR CENTER R. <"L" (LEFT) AND/OR "S" (STRAIGHT)
F(3) - MOVEMENT CODE AT END NEAR CENTER L. <"L" (LEFT) AND/OR "S" (STRAIGHT)
F(4) - LENGTH OF USABLE LANE FROM CENTER R.  [0, FOR OPEN LANE]
F(5) - LENGTH OF USABLE LANE FROM CENTER L.  [0, FOR OPEN LANE]
F(6) - OFFSET OF LN. TERM. NEAR CENTER R, + IS TOWARD CNTR. R.<-350 TO 100>[0]
F(7) - OFFSET OF LN. TERM. NEAR CENTER L, + IS TOWARD CNTR. L.<-350 TO 100>[0]
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE        DESCRIPTION
 NO.   RIGHT INT.   LEFT INT.     DATA:
  1    INBOUND 1    OUTBOUND 1     12 LS LS    0     0     0     0
  2    INBOUND 2    OUTBOUND 2     12 S  S     0     0     0     0
  3    INBOUND 3    OUTBOUND 3     12 S  S     0     0     0     0
  4    OUTBOUND 1   INBOUND 1      12 LS LS    0     0     0     0
  5    OUTBOUND 2   INBOUND 2      12 S  S     0     0     0     0
  6    OUTBOUND 3   INBOUND 3      12 S  S     0     0     0     0
                                 \.1/ \2 \3 \.4/ \.5/ \.6/ \.7/
IS LANE DATA FOR INTERNAL LANES OK ?
Y

KEYIN "YES", "NO" OR A LANE DATA FIELD EDIT REQUEST: L((i(,j)))=fj(,fj+1,...)
OR A FIELD COLUMN DATA EDIT REQUEST: FC(((i)(,j)))=fj(,fj+1,...)
Y

THERE IS NO FREE U-TURN DATA IN THIS FILE


LEG 1 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
       <0 TO 359,  +/- 40 FROM DEFAULT>  [0]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES. <0> [0] (THIS LEG IS ONE WAY OUTBOUND)
F(5) - NUMBER OF OUTBOUND LANES. <1 TO 6> [2]
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:      0  800  250    0    3   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 1 GEOMETRY DATA OK ?


  DATA FIELDS:      0  800  250    0    3   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 1 GEOMETRY DATA OK ?
Y
KEYIN "YES", "NO" OR A DATA FIELD EDIT REQUEST: F((i))=(n*)fi(,...)
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
```

```
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 1:
 1  (OUTBOUND 1)      12 LS      0    0    0    0
 2  (OUTBOUND 2)      12 S       0    0    0    0
 3  (OUTBOUND 3)      12 SR      0    0    0    0
                   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 1 OK ?


 1  (OUTBOUND 1)      12 LS      0    0    0    0
 2  (OUTBOUND 2)      12 S       0    0    0    0
 3  (OUTBOUND 3)      12 SR      0    0    0    0
                   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 1 OK ?
Y

LEG 2 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
       <0 TO 359,  +/- 40 FROM DEFAULT>  [90]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES.  <0 TO 6>  [2]
F(5) - NUMBER OF OUTBOUND LANES.  <0 TO 6>  [2]
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:        90  800  250    3    3   45   45    0    0
FIELD NUMBERS:    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 2 GEOMETRY DATA OK ?
Y

FIELD NUMBERS:    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 2 GEOMETRY DATA OK ?
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 2:
 1  (INBOUND 1)       12 S       0    0    0   32
 2  (INBOUND 2)       12 S       0    0    0   35
 3  (INBOUND 3)       12 SR      0    0    0   33
 4  (OUTBOUND 1)      12 S       0    0    0    0
 5  (OUTBOUND 2)      12 S       0    0    0    0
 6  (OUTBOUND 3)      12 SR      0    0    0    0
                   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 2 OK ?
Y


INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 2:
F(1) - NAME FOR INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION:
       "CONSTAN", "ERLANG", "GAMMA", "LOGNRML", "NEGEXP","SNEGEXP" OR "UNIFORM"
       MAY BE ABBREVIATED TO THE FIRST CHARACTER.
F(2) - TOTAL HOURLY VOLUME ON LEG, VPH. <0 TO 4000> [200 PER INBOUND LANE]
F(3) - PARAMETER FOR HEADWAY FREQUENCY DISTRIBUTION:
         CONSTANT - NONE.
         ERLANG - INTEGER VALUE (ROUNDED) FOR MEAN**2/VARIANCE.<GREATER THAN 1>
         GAMMA - MEAN**2/VARIANCE. <GREATER THAN 1>
         LOGNORMAL - STANDARD DEVIATION.
         NEGATIVE EXPONENTIAL - NONE.
         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 2 OK ?
Y

         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 2 OK ?
Y

OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 2:
EACH FIELD - PERCENT OF VEHICLES FROM LEG 2 TO LEAVE THE INTERSECTION VIA THE
             SPECIFIED (BY FIELD NUMBER) LEG.  <0 TO 100 AND SUM = 100>
EDIT EXAMPLE: "F(2)=3*20" CHANGES FIELDS 2 THRU 4 TO "20", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE

  DATA FIELDS:    20   0   0  20  60   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 2 OK ?
Y


  DATA FIELDS:    20   0   0  20  60   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 2 OK ?
Y

LEG 3 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
       <0 TO 359,  +/- 40 FROM DEFAULT>  [180]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES. <1 TO 6> [2]
F(5) - NUMBER OF OUTBOUND LANES. <0> [0] (THIS LEG IS ONE WAY INBOUND)
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:    180  800  250    3    0   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/
```

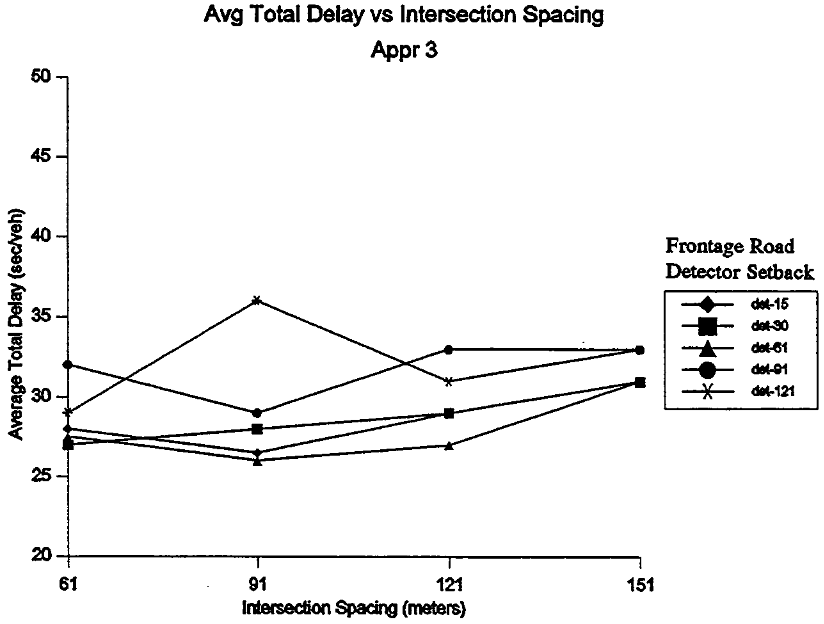
```
IS LEG 3 GEOMETRY DATA OK ?
Y

      WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:    180  800  250    3    0   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 3 GEOMETRY DATA OK ?
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 3:
 1  (INBOUND 1)      12 LS      0    0    0   32
 2  (INBOUND 2)      12 S       0    0    0   35
 3  (INBOUND 3)      12 SR      0    0    0   33
                   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 3 OK ?
Y


INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 3:
F(1) - NAME FOR INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION:
       "CONSTAN", "ERLANG", "GAMMA", "LOGNRML", "NEGEXP","SNEGEXP" OR "UNIFORM"
       MAY BE ABBREVIATED TO THE FIRST CHARACTER.
F(2) - TOTAL HOURLY VOLUME ON LEG, VPH. <0 TO 4000> [200 PER INBOUND LANE]
F(3) - PARAMETER FOR HEADWAY FREQUENCY DISTRIBUTION:
         CONSTANT - NONE.
         ERLANG - INTEGER VALUE (ROUNDED) FOR MEAN**2/VARIANCE.<GREATER THAN 1>
         GAMMA - MEAN**2/VARIANCE. <GREATER THAN 1>
         LOGNORMAL - STANDARD DEVIATION.
         NEGATIVE EXPONENTIAL - NONE.
         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 3 OK ?
Y

         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 3 OK ?
Y

OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 3:
EACH FIELD - PERCENT OF VEHICLES FROM LEG 3 TO LEAVE THE INTERSECTION VIA THE
```

```
          SPECIFIED (BY FIELD NUMBER) LEG.  <0 TO 100 AND SUM = 100>
EDIT EXAMPLE: "F(2)=3*20" CHANGES FIELDS 2 THRU 4 TO "20", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE

  DATA FIELDS:    34  33   0   0  33   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 3 OK ?
Y


  DATA FIELDS:    34  33   0   0  33   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 3 OK ?
Y

LEG 4 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
       <0 TO 359,  +/- 40 FROM DEFAULT>  [180]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES. <0> [0] (THIS LEG IS ONE WAY OUTBOUND)
F(5) - NUMBER OF OUTBOUND LANES. <1 TO 6> [2]
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:    180  800  250    0    3   45   45    0    0
FIELD NUMBERS:  \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 4 GEOMETRY DATA OK ?
Y

       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:    180  800  250    0    3   45   45    0    0
FIELD NUMBERS:  \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 4 GEOMETRY DATA OK ?
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 4:
 1  (OUTBOUND 1)      12 LS      0    0    0    0
 2  (OUTBOUND 2)      12 S       0    0    0    0
 3  (OUTBOUND 3)      12 SR      0    0    0    0
                    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 4 OK ?
Y

 1  (OUTBOUND 1)      12 LS      0    0    0    0
 2  (OUTBOUND 2)      12 S       0    0    0    0
 3  (OUTBOUND 3)      12 SR      0    0    0    0
                    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 4 OK ?
Y

LEG 5 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
```

```
        <0 TO 359, +/- 40 FROM DEFAULT>  [270]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES.  <0 TO 6>  [2]
F(5) - NUMBER OF OUTBOUND LANES.  <0 TO 6>  [2]
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:    270  800  250    3    3   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 5 GEOMETRY DATA OK ?
Y

FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 5 GEOMETRY DATA OK ?
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 5:
 1  (INBOUND 1)       12 S         0    0    0   32
 2  (INBOUND 2)       12 S         0    0    0   35
 3  (INBOUND 3)       12 SR        0    0    0   33
 4  (OUTBOUND 1)      12 S         0    0    0    0
 5  (OUTBOUND 2)      12 S         0    0    0    0
 6  (OUTBOUND 3)      12 SR        0    0    0    0
                    \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 5 OK ?
Y


INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 5:
F(1) - NAME FOR INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION:
       "CONSTAN", "ERLANG", "GAMMA", "LOGNRML", "NEGEXP","SNEGEXP" OR "UNIFORM"
       MAY BE ABBREVIATED TO THE FIRST CHARACTER.
F(2) - TOTAL HOURLY VOLUME ON LEG, VPH. <0 TO 4000> [200 PER INBOUND LANE]
F(3) - PARAMETER FOR HEADWAY FREQUENCY DISTRIBUTION:
         CONSTANT - NONE.
         ERLANG - INTEGER VALUE (ROUNDED) FOR MEAN**2/VARIANCE.<GREATER THAN 1>
         GAMMA - MEAN**2/VARIANCE. <GREATER THAN 1>
         LOGNORMAL - STANDARD DEVIATION.
         NEGATIVE EXPONENTIAL - NONE.
         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800    2.00  45.0  50.5 NO      0
FIELD NUMBERS:  \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 5 OK ?
Y

         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:    SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 5 OK ?
Y

OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 5:
EACH FIELD - PERCENT OF VEHICLES FROM LEG 5 TO LEAVE THE INTERSECTION VIA THE
             SPECIFIED (BY FIELD NUMBER) LEG.  <0 TO 100 AND SUM = 100>
EDIT EXAMPLE: "F(2)=3*20" CHANGES FIELDS 2 THRU 4 TO "20", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE

  DATA FIELDS:     20  60   0  20   0   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 5 OK ?
Y


  DATA FIELDS:     20  60   0  20   0   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 5 OK ?
Y

LEG 6 GEOMETRY DATA:
F(1) - LEG ANGLE.  POSITIVE IS CLOCKWISE FROM REFERENCE = 0 (ZERO) DEGREES.
       <0 TO 359,  +/- 40 FROM DEFAULT>  [0]
F(2) - LENGTH OF INBOUND LANES.  <400 TO 1000>  [800]
F(3) - LENGTH OF OUTBOUND LANES.  [250]  (SUGGEST 250 FOR LOW TRAFFIC VOLUME,
       400 FOR HIGH VOLUME. FOR EMISSIONS, MUST BE SAME AS INBOUND LANE LENGTH)
F(4) - NUMBER OF INBOUND LANES. <1 TO 6> [2]
F(5) - NUMBER OF OUTBOUND LANES. <0> [0] (THIS LEG IS ONE WAY INBOUND)
F(6) - SPEED LIMIT ON INBOUND LANES (MPH).  <10 TO 80>  [30]
F(7) - SPEED LIMIT ON OUTBOUND LANES (MPH).  <10 TO 80>  [30]
F(8) - LEG CENTERLINE OFFSET FROM INTERSECTION CENTER. POSITIVE IS TO THE RIGHT
       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:        0  800  250    3    0   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 6 GEOMETRY DATA OK ?
Y

       WHEN FACING IN DIRECTION OF INBOUND TRAFFIC.  <-200 TO 200>  [0]
F(9) - MEDIAN WIDTH. WILL BE CENTERED ON INTERSECTION CENTERLINE. <0 TO 100>[0]
  DATA FIELDS:        0  800  250    3    0   45   45    0    0
FIELD NUMBERS:   \.1/ \.2/ \.3/ \.4/ \.5/ \.6/ \.7/ \.8/ \.9/

IS LEG 6 GEOMETRY DATA OK ?
Y

F(1) - WIDTH OF LANE.  <8 TO 15>  [12]
F(2) - MOVEMENT CODE. ANY OF"U"(U-TURN),"L"(LEFT),"S"(STRAIGHT) AND "R"(RIGHT).
F(3) - LENGTH OF USABLE LANE FROM LANE TERMINAL.  [0, FOR OPEN LANE]
F(4) - LENGTH OF USABLE LANE FROM OUTER END.  [0, FOR OPEN LANE]
F(5) - OFFSET OF LANE TERMINAL.  POS. IS TOWARD INTERSECTION. <-350 TO 100> [0]
F(6) - PERCENT OF INBOUND TRAFFIC TO ENTER IN THIS LANE.
       <0 TO 100, SUM FOR LEG=100, 0 FOR OUTBOUND OR LANE WITH F(4) NOT= 0>
EDIT EXAMPLE: "LANE(3,1)=8" CHANGES FIELD 1 OF LANE 3 TO "8", OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL INFORMATION

LANE DATA FOR LEG 6:
 1  (INBOUND 1)       12 LS       0    0    0   32
 2  (INBOUND 2)       12 S        0    0    0   35
 3  (INBOUND 3)       12 SR      0    0    0   33
                     \.1/ \.2/ \.3/ \.4/ \.5/ \.6/
IS LANE DATA FOR LEG 6 OK ?
Y


INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 6:
F(1) - NAME FOR INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION:
       "CONSTAN", "ERLANG", "GAMMA", "LOGNRML", "NEGEXP","SNEGEXP" OR "UNIFORM"
       MAY BE ABBREVIATED TO THE FIRST CHARACTER.
F(2) - TOTAL HOURLY VOLUME ON LEG, VPH. <0 TO 4000> [200 PER INBOUND LANE]
F(3) - PARAMETER FOR HEADWAY FREQUENCY DISTRIBUTION:
         CONSTANT - NONE.
         ERLANG - INTEGER VALUE (ROUNDED) FOR MEAN**2/VARIANCE.<GREATER THAN 1>
         GAMMA - MEAN**2/VARIANCE. <GREATER THAN 1>
         LOGNORMAL - STANDARD DEVIATION.
         NEGATIVE EXPONENTIAL - NONE.
         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 6 OK ?
Y

         SHIFTED NEGATIVE EXPONENTIAL - MINIMUM HEADWAY IN SECONDS. <LESS THAN
                                        OR EQUAL MEAN HEADWAY>
         UNIFORM - STANDARD DEVIATION
F(4),F(5)- MEAN,85 PERCENTILE SPEED OF ENTERING VEHICLES, MPH.<10 TO 80>[29,31]
F(6) - TRAFFIC MIX DATA TO FOLLOW ? <"YES" OR "NO">  ["NO"]
F(7) - SEED FOR RANDOM NUMBERS (0 FOR AUTO. SELECTION).  <0 TO 99999> [0]
EDIT EXAMPLE: "F(4)=29,32" CHANGES FIELD 4 TO "29" AND FIELD 5 TO "32"
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE
  DATA FIELDS:   SNEGEXP   800   2.00  45.0  50.5 NO      0
FIELD NUMBERS:   \..1../ \.2./ \..3./ \.4./ \.5./ \6/ \.7./

IS INBOUND TRAFFIC HEADWAY FREQUENCY DISTRIBUTION DATA FOR LEG 6 OK ?
Y

OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 6:
EACH FIELD - PERCENT OF VEHICLES FROM LEG 6 TO LEAVE THE INTERSECTION VIA THE
             SPECIFIED (BY FIELD NUMBER) LEG.  <0 TO 100 AND SUM = 100>
EDIT EXAMPLE: "F(2)=3*20" CHANGES FIELDS 2 THRU 4 TO "20"; OTHERS UNCHANGED
KEYIN "HELP" FOR ADDITIONAL ASSISTANCE

  DATA FIELDS:     0  33   0  34  33   0
FIELD NUMBERS:   \1/ \2/ \3/ \4/ \5/ \6/

IS OUTBOUND TRAFFIC DESTINATION DATA FOR LEG 6 OK ?
Y

             TEXAS Model for Intersection Traffic - Version 3.20

 This is the Master Command Menu.  Select, and, at the DOS prompt, key-in
 the Command that corresponds to your current needs......

COMMAND   USAGE AND EFFECTS OF KEYING-IN THIS COMMAND AT THE DOS PROMPT

gdvdata   Enter or change specifications for intersection geometry or traffic.
          This must be the first command if you are beginning a new problem.
gdvpro    Process your specifications for geometry and traffic.
geoplot   Optionally display/plot the intersection geometry and vehicle paths.

simdata   Enter or change specifications for traffic control, duration of
          simulation process, or request creation of animated graphics file.
         This command can be used only after successful execution of gdvpro.
simpro   Executes the actual simulation using specifications from files
         created by the gdvpro and simdata commands.
dispre   Optionally prepare an animation graphics file for display.
dispro   Optionally view the animated graphics.

reptol   reptol <tolerance_value> <gdvdata_file> <simdata_file>
         Perform replicate runs until the specified tolerance is achieved and
         create SIMSTAT.REP statistics file.
C:\TEXAS>
```

APPENDIX B

AVERAGE TOTAL DELAY PLOTS



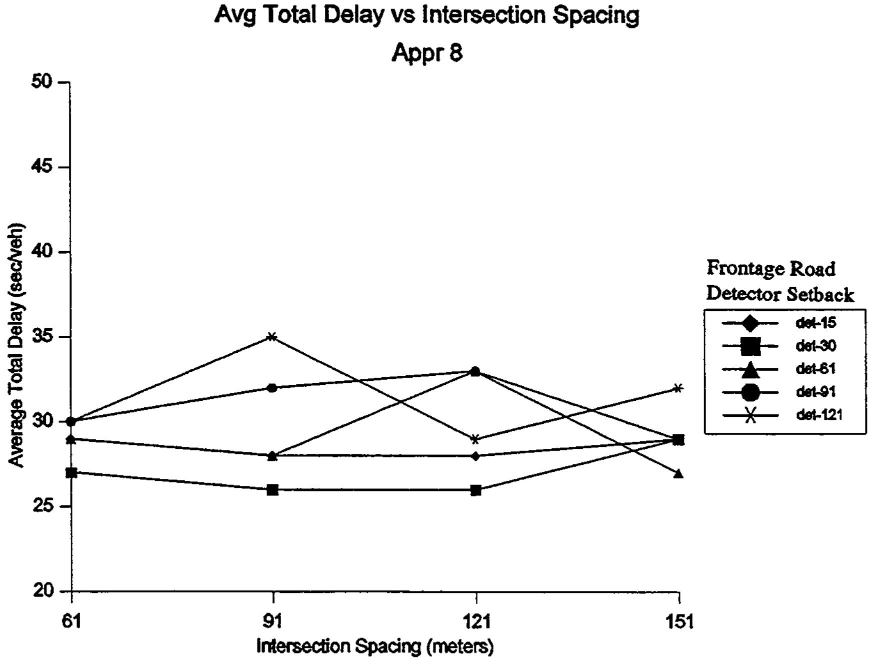
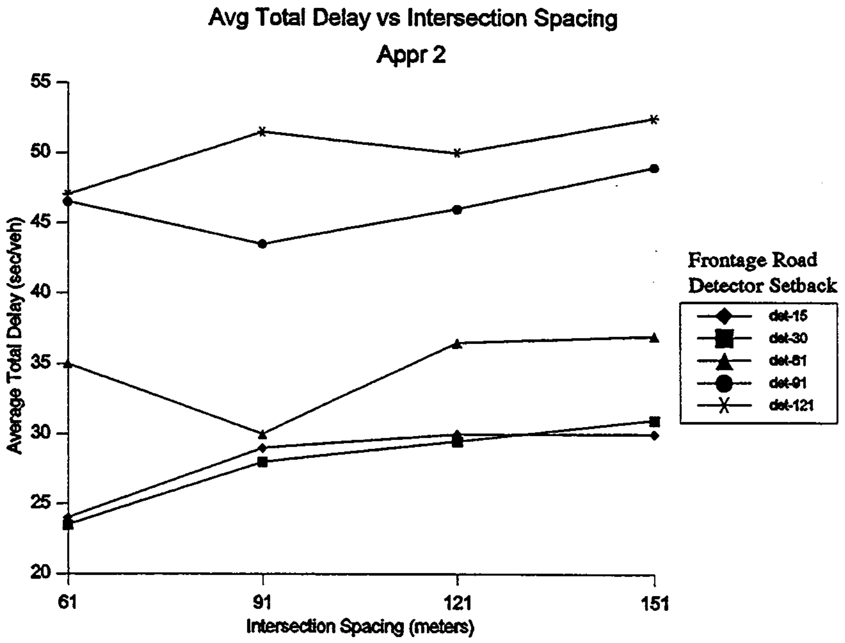


Figure B-1. Average Total Delay Versus Intersection Spacing for Frontage Road Approaches ("Figure 3" Operation)



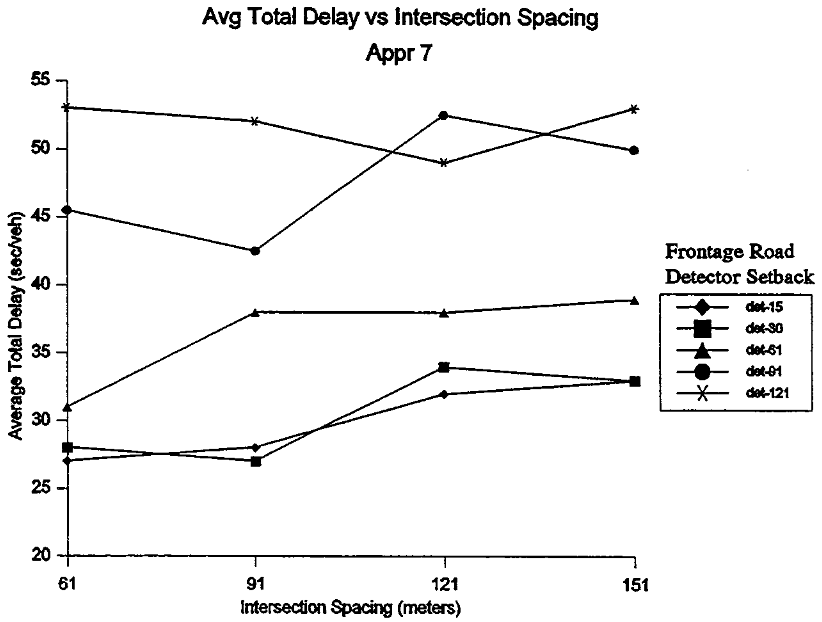


Figure B-2. Average Total Delay Versus Intersection Spacing for External Approaches on the Arterial ("Figure 3" Operation)

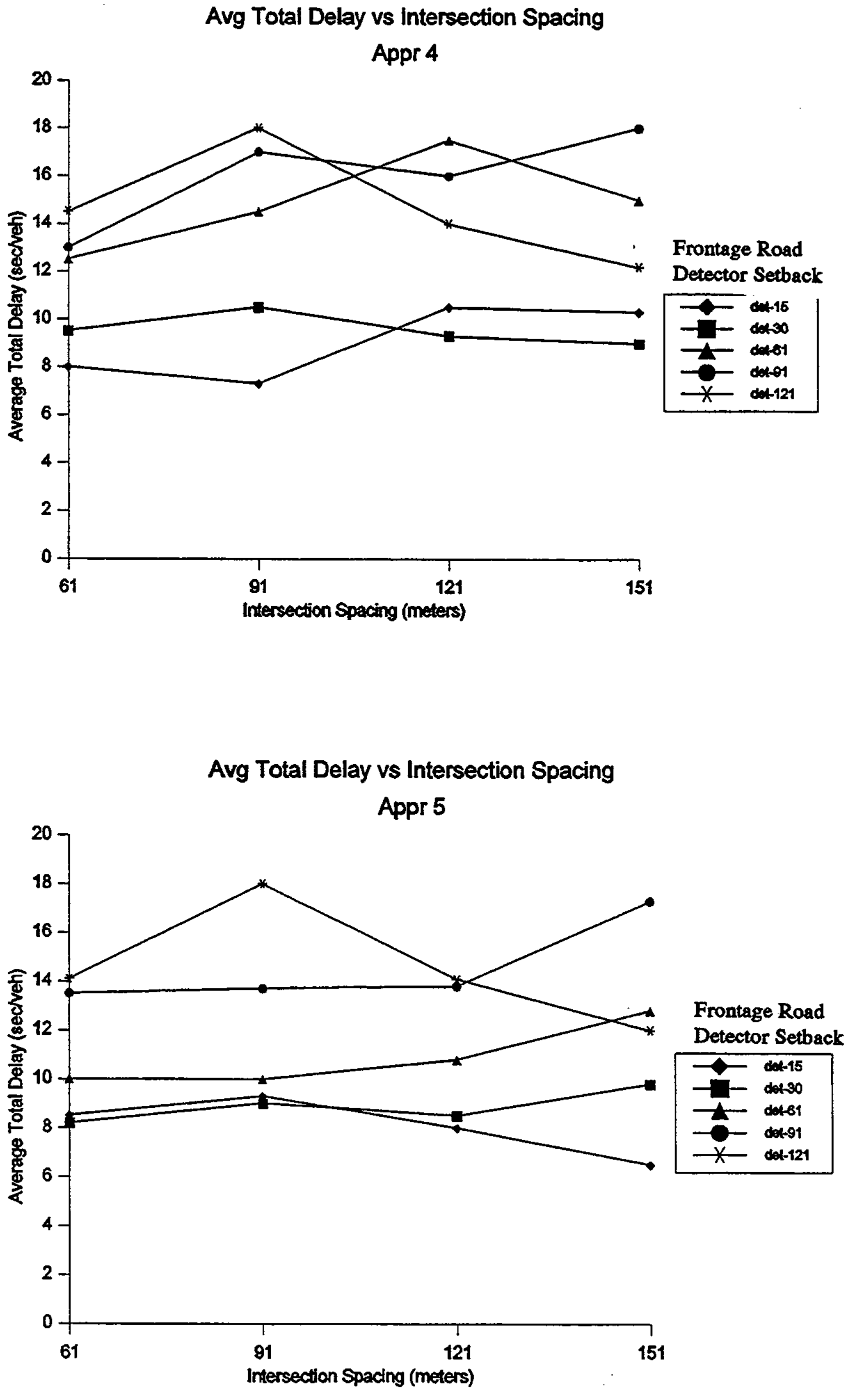
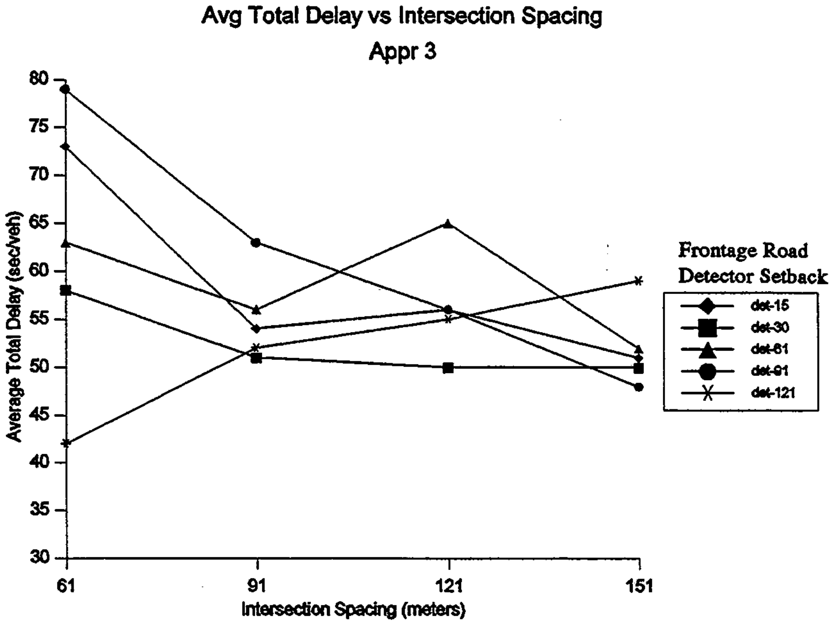


Figure B-3. Average Total Delay Versus Intersection Spacing for Internal Approaches on the Arterial ("Figure 3" Operation)



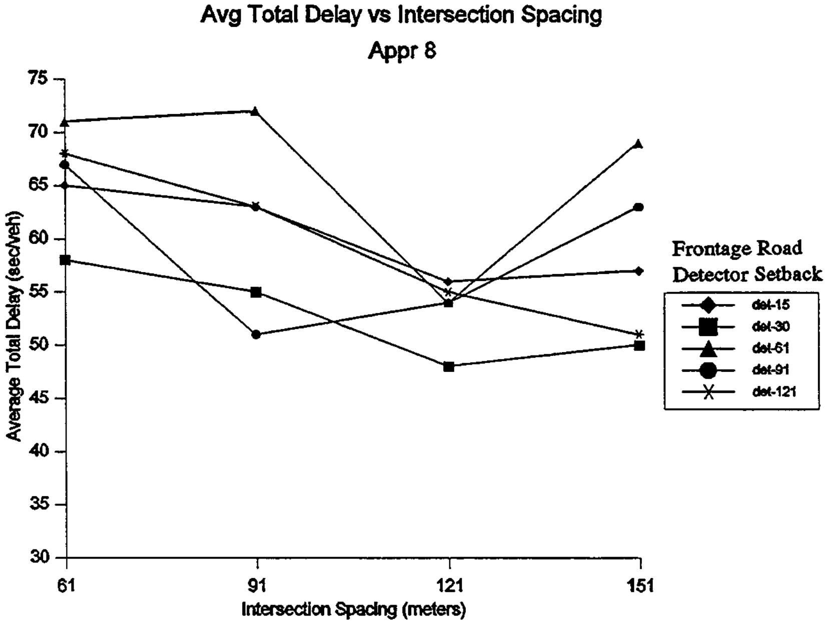


Figure B-4. Average Total Delay Versus Intersection Spacing for Frontage Road Approaches ("Figure 4" Operation)

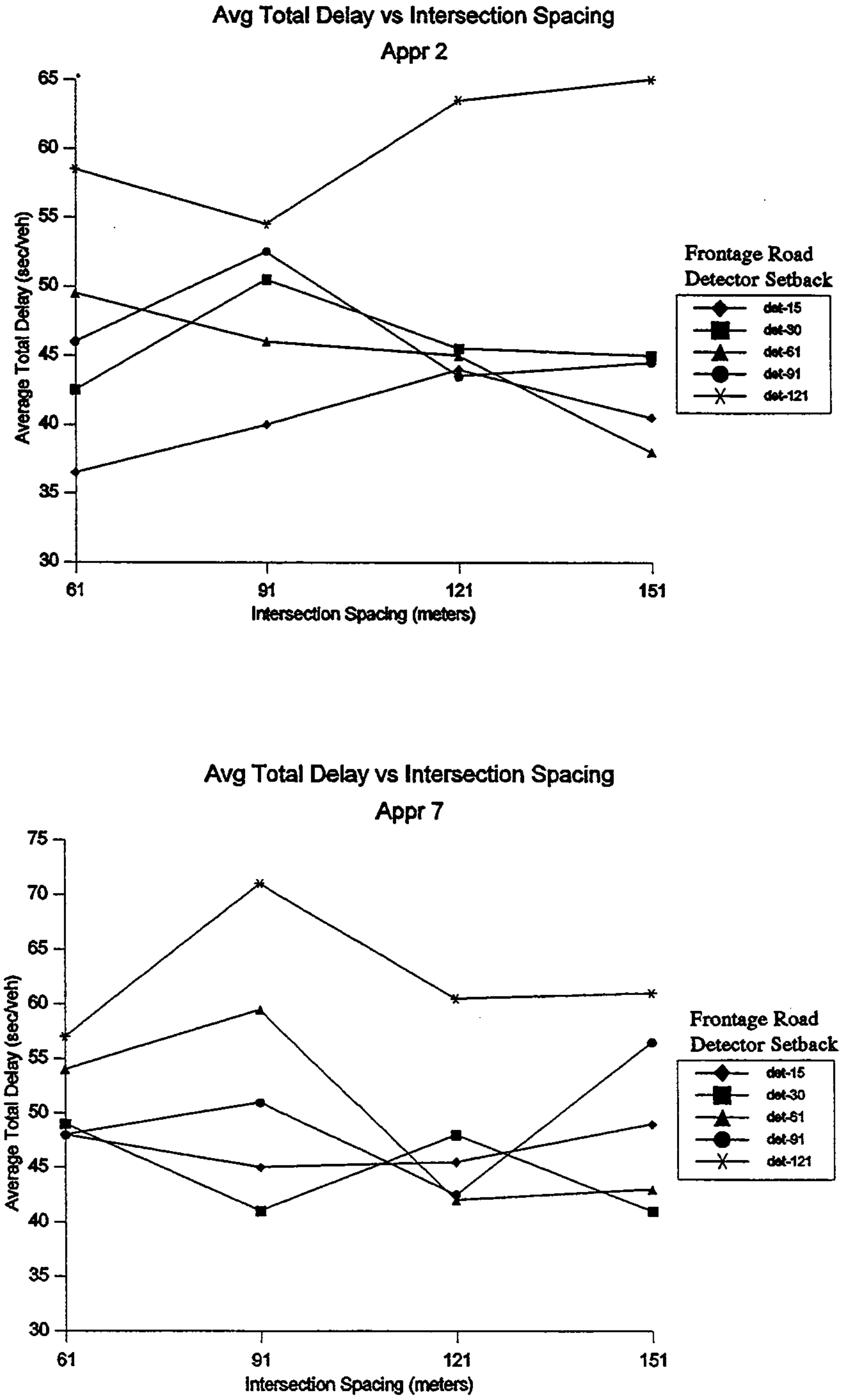
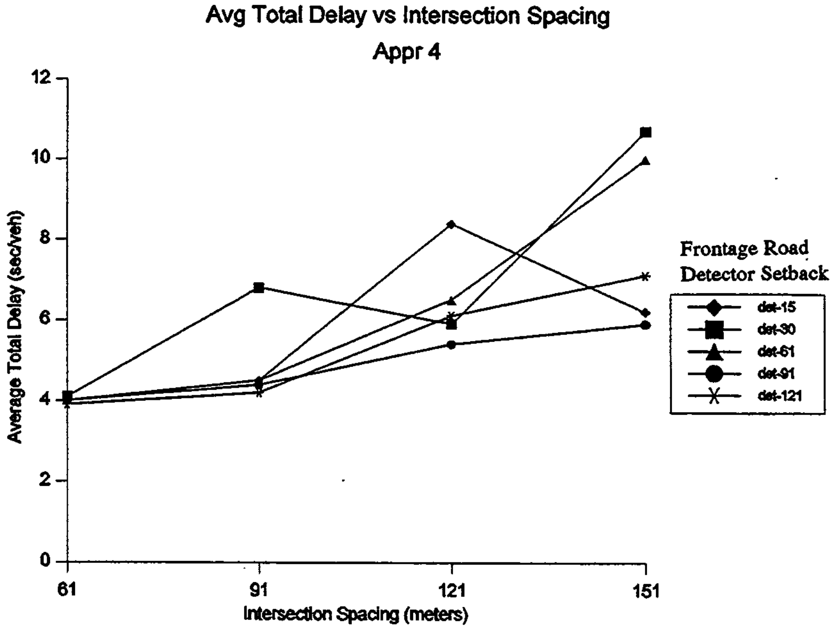


Figure B-5. Average Total Delay Versus Intersection Spacing for External Approaches on the Arterial ("Figure 4" Operation)



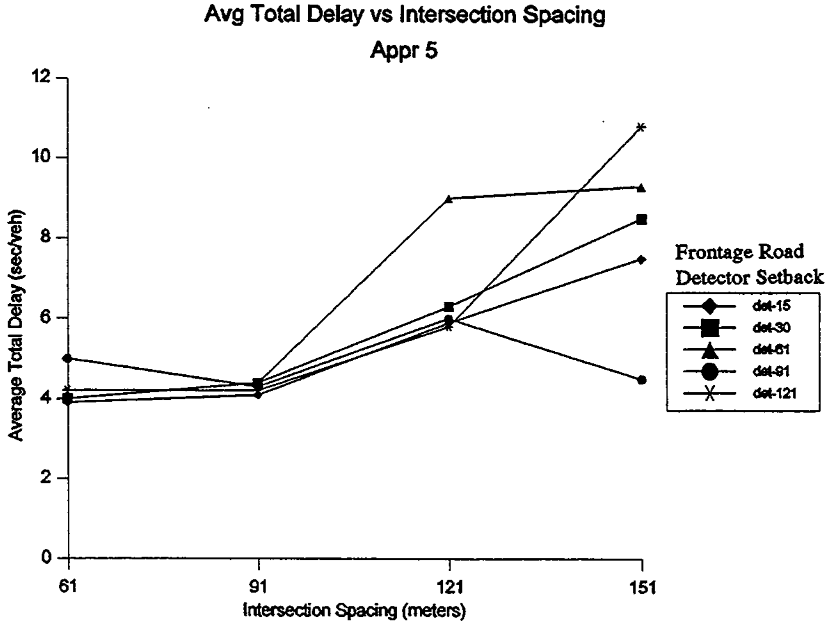


Figure B-6. Average Total Delay Versus Intersection Spacing for Internal Approaches on the Arterial ("Figure 4" Operation)

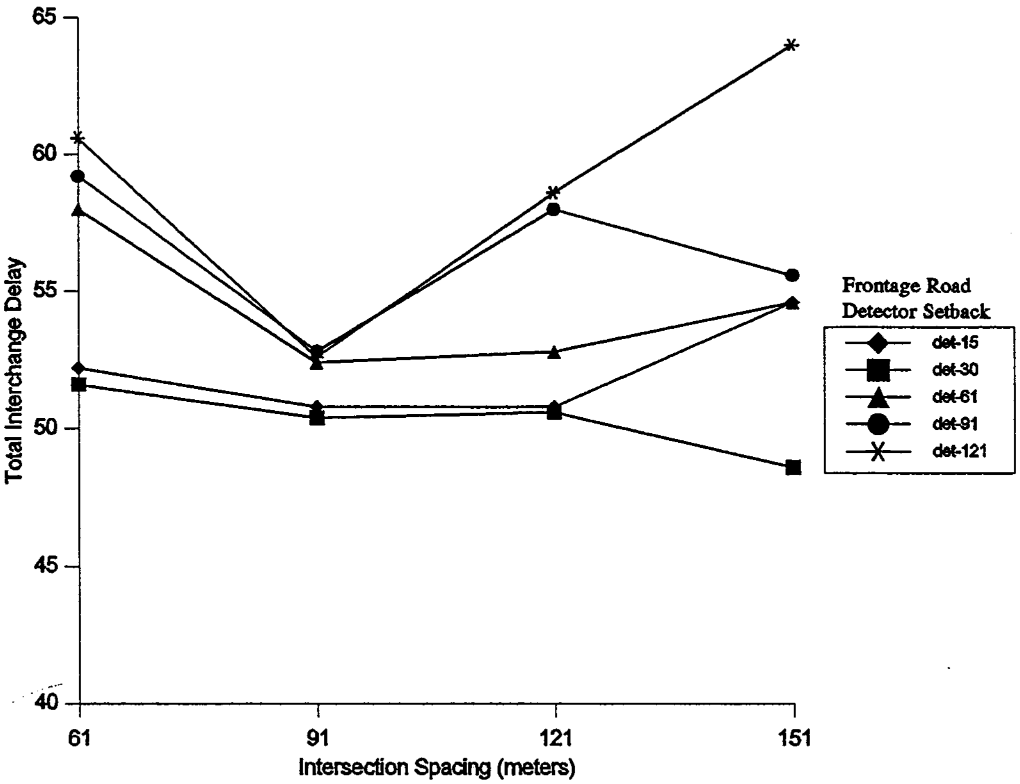


Figure B-7. Total Interchange Delay Versus Intersection Spacing ("Figure 4" Operation, no U-turns, transfer gap: 1.5 sec)

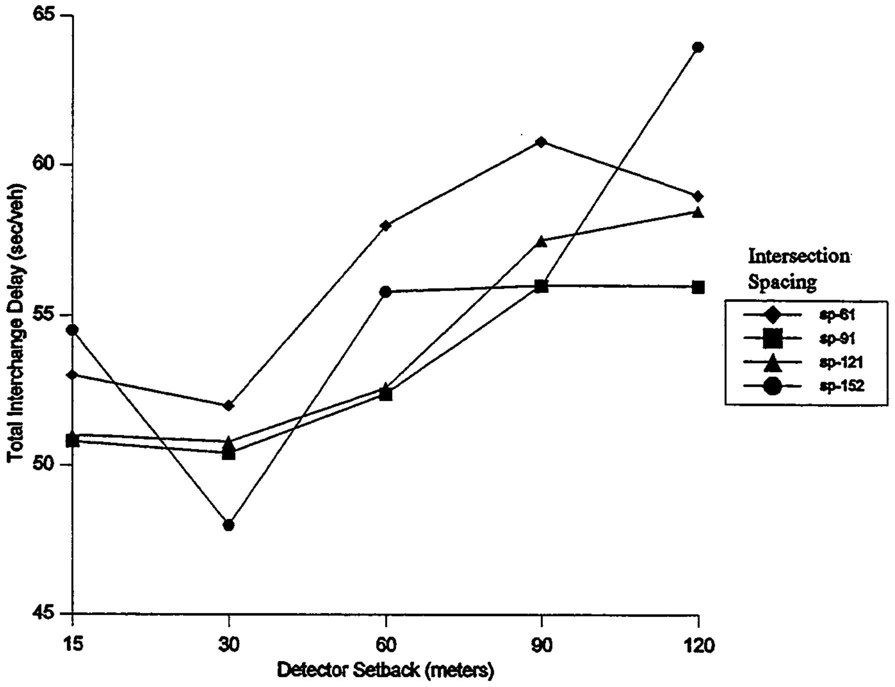


Figure B-8. Total Interchange Delay Versus Frontage Road Detector Setback ("Figure 4" Operation, no U-turns, transfer gap: 1.5 sec)