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16. Abstract

This research report documents an applications manual for evaluating various diamond interchange design alternatives and their traffic operations using TRANSYT-7F. TRANSYT-7F is a macroscopic simulation model developed primarily for optimizing network-wide signal systems to reduce delays, stops, and fuel consumption. The manual could assist the traffic engineer in coding the needed data into TRANSYT -7F for evaluating the performance and the feasibility of future diamond interchange design alternatives in accommodating future traffic growth. Ever increasing traffic demands along urban freeway corridors may entail upgrading an older interchange to a higher capacity interchange. In such a case, the analyst may be interested in determining the preferred design based on an assessment of how various design alternatives would perform with the future traffic. this manual can be effective in evaluating various diamond interchange design alternatives from a traffic operations point of view.

It was found that the optimum signal timings produced by TRANSYT-7F performed consistently. The model is especially useful in situations where large queues are expected on the freeway exit ramps. A conclusion can be drawn that TRANSYT-7F can be used as a desirable evaluation strategy under conditions of substantial queues on the exit ramps of two-level diamond interchanges.

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Form DOT F 1700.7 (8-69)

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

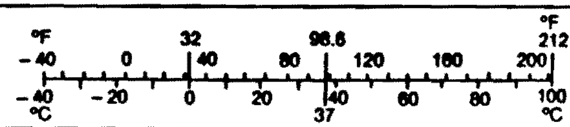
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

AN APPLICATIONS MANUAL FOR EVALUATING TWO AND THREE-LEVEL DIAMOND INTERCHANGE OPERATIONS USING TRANSYT-7F

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Research Report 1148-3
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The Texas A&M University System
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ABSTRACT

This research report documents an applications manual for evaluating various diamond interchange design alternatives and their traffic operations using TRANSYT-7F. TRANSYT-7F is a macroscopic simulation model developed primarily for optimizing network-wide signal systems to reduce delays, stops, and fuel consumption. The manual could assist the traffic engineer in coding the needed data into TRANSYT-7F for evaluating the performance and the feasibility of future diamond interchange design alternatives in accommodating future traffic growth. Ever increasing traffic demands along urban freeway corridors may entail upgrading an older interchange to a higher capacity interchange. In such a case, the analyst may be interested in determining the preferred design based on an assessment of how various design alternatives would perform with the future traffic. This manual can be effective in evaluating various diamond interchange design alternatives from a traffic operations point of view.

It was found that the optimum signal timings produced by TRANSYT-7F performed consistently. The model is especially useful in situations where large queues are expected on the freeway exit ramps. A conclusion can be drawn that TRANSYT-7F can be used as a desirable evaluating strategy under conditions of substantial queues on the exit ramps of two-level diamond interchanges.

KEY WORDS: TRANSYT-7F, signalized interchanges, diamond interchange, single-point urban interchange.

IMPLEMENTATION

The applications manual described in this study can be useful to the traffic engineer in evaluating two and three-level diamond interchange design and/or operations. The manual can be used to code the required data input in TRANSYT-7F. Optimum signal timing plans can be developed under large queue conditions on the exit ramps at diamond interchanges using this manual. Further, it can be used to assess the performance of various interchange design alternatives in serving future traffic demand.

ACKNOWLEDGEMENTS

The research reported herein was performed as a part of a study entitled "Guidelines for Operational Control of Diamond Interchanges." This study was conducted by the Texas Transportation Institute for the Texas Department of Transportation in cooperation with the U.S. Department of Transportation and Federal Highway Administration. Dr. Carroll J. Messer of the Texas Transportation Institute served as research supervisor, and Ms. Karen Glynn of the Texas Department of Transportation served as the technical coordinator for this study.

DISCLAIMER

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1. INTRODUCTION

PROBLEM DEFINITION

Traffic demand in the urban centers of Texas is growing about 3% per year, compounded annually. Traffic congestion caused by demand exceeding capacity is growing similarly on existing urban freeways and the conventional tight urban diamond interchanges serving them along the freeway corridor. As congestion continues to grow at the diamond interchanges, innovative design alternatives that provide more capacity will be needed to ameliorate the operational problems experienced at the interchanges.

Several design options might be considered to increase the capacity of the junction. Traditional improvements such as adding a through lane or turnaround lane to the existing tight urban diamond interchange, or TUDI for short, are well known. Analysis methods for studying these designs are likewise well established in Texas using the microcomputer program PASSER III-90 (*1*). Other new design options usually providing significantly more capacity may not be as well known to the analyst and are the subject of this manual.

The range of signalized interchange design options that might be considered for capacity enhancement at an existing congested tight urban diamond interchange (TUDI) are depicted in Figure 1. They range from larger two-level diamonds to three-level designs. This manual will describe each of these interchanges forms, provide typical signal timing strategies commonly used to operate them, and provide a recommended methodology to analyze them using the microcomputer program TRANSYT-7F.

BACKGROUND

TRANSYT-7F (TRAffic Network StudY Tool) is a macroscopic simulation model developed primarily for optimizing network-wide signal systems to reduce delays, stops, and fuel consumption. The program can also be used to evaluate existing or proposed interchange designs given their respective signalization strategies, determine what strategies produce minimum delays and stops, and produce a set of signal timing plans based on these

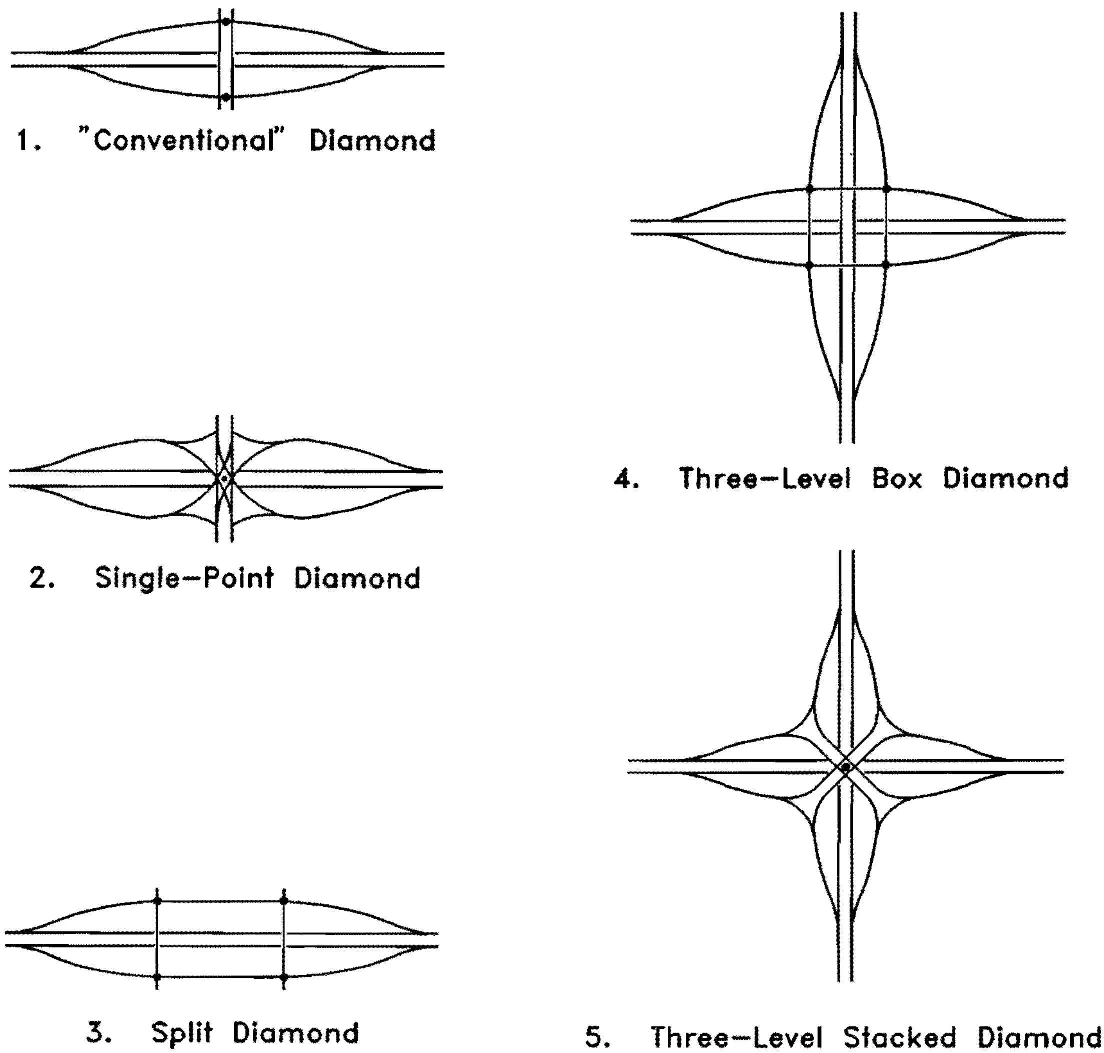


Figure 1. Signalized Diamond Interchange Design Alternatives.

results. The TRANSYT model was originally developed by Robertson (*2*) at Transportation Road Research Laboratory (TRRL), United Kingdom. The model was subsequently modified by McTrans, University of Florida (*3*) in order to apply it for U.S. conditions. The main program is written in FORTRAN 77 language and can be used on microcomputers. The microcomputer model, TRANSYT-7F- Release 6, Version 3.0, is the subject of this manual.

SCOPE OF MANUAL

The purpose of this manual is to provide application procedures using TRANSYT-7F to assist the traffic engineer in evaluating traffic operations of two-level and three-level diamond interchanges. With these optimal solutions, the analyst can then assess the performance of the proposed interchange design. Comparisons then can be made among design alternatives to determine the preferred design. The TRANSYT-7F coding system can be a laborious and complex process. Hence, the coding instructions for the two-level diamond interchange has been dealt with in detail, and the coding process for the three-level diamond interchange has been only briefly described. Developing optimum signal timing plans for an at-grade intersection and a single-point diamond interchange are also briefly described. Also included is the type of input needed in TRANSYT-7F to optimize signal timing plans produced by PASSER III-90. It is assumed that the user has some experience with TRANSYT-7F and PASSER III-90.

OVERVIEW OF TRANSYT-7F

The overall system design features of TRANSYT-7F are shown in Figure 2. The figure shows that the program is organized into a batch file and three basic system programs. These consist of the MCT7F batch file, the Data Input Manager (T7FDIM), the Main program (T7F), and the List program. The MCT7F is a batch file which interconnects and interacts with all of the system programs so that any program can be accessed at any time by the user. The MCT7F basically acts as a shell that connects the functional programs together. The major advantage of the batch file is that, with the use of a single letter, a selected program can be accessed. There is no need to type the name of the program in

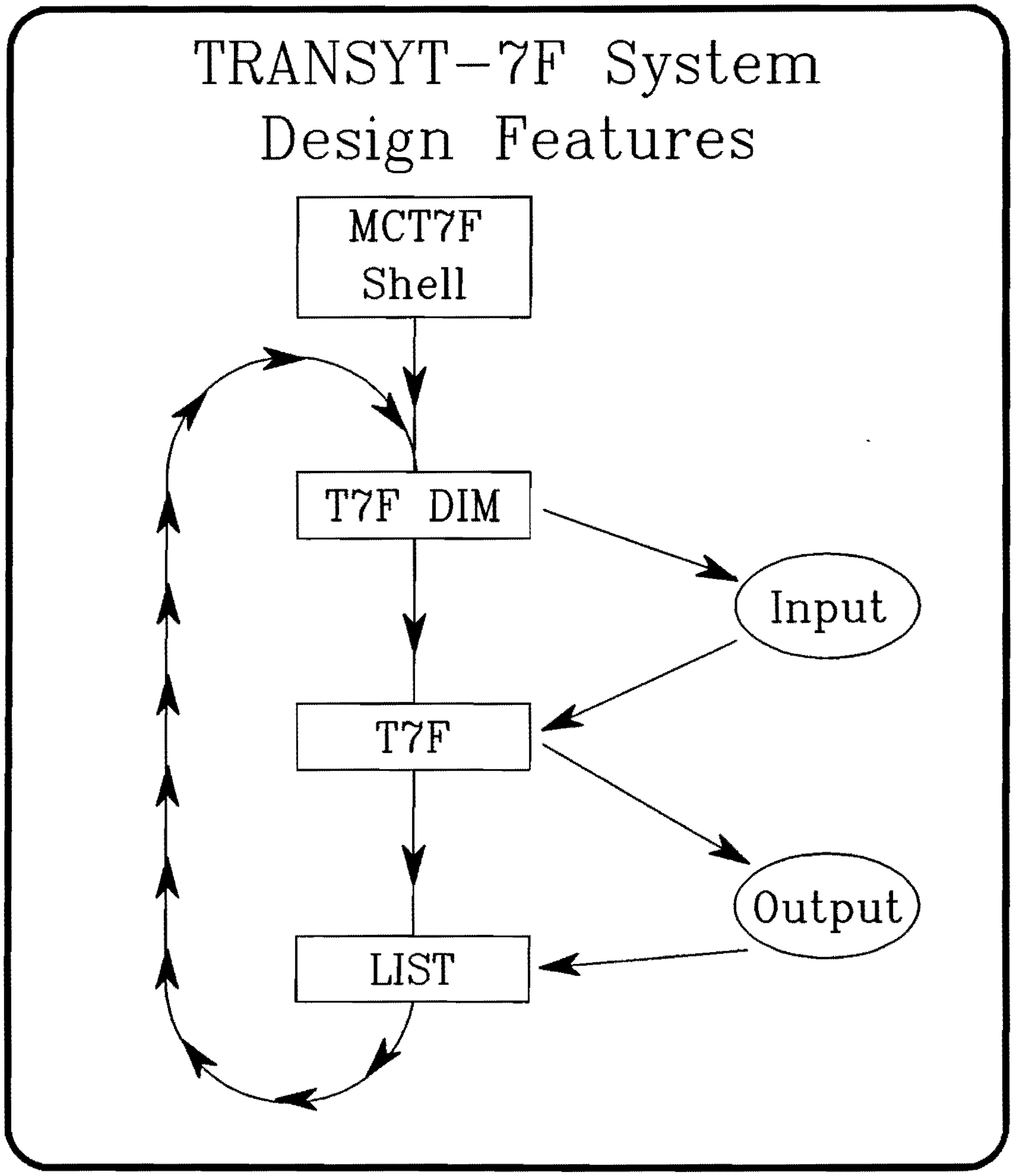


Figure 2. Basic System Design Features of TRANSYT-7F.

order to get to that program. Thus, the input, the main, and the output programs can be accessed through the MCT7F batch file.

The input program is called the T7FDIM. The T7FDIM is a vital component of the system in the sense that it serves the function of providing convenient data input to the program essential for defining the problem to be studied. T7FDIM is used in conjunction with the main program to make the TRANSYT-7F input coding process easier. It has window features available for each type of data input card. All parameters in a card are listed in a window. Any value for a particular parameter can be input using the window feature. Though no explanation is given for any parameter in the window, the listing in the window gives a view of the input data needed for the specific card. Thus, the T7FDIM program is basically used for the data input process.

Upon the completion of the input coding, the main TRANSYT program T7F is executed to obtain output for the given input conditions. This output can be viewed, but not edited, using the List feature. If there are any errors in the output of the program, the input will need to be modified accordingly by using T7FDIM. This editing process is thus repeated for any subsequent analysis using TRANSYT-7F.

BASIC FEATURES OF TRANSYT-7F

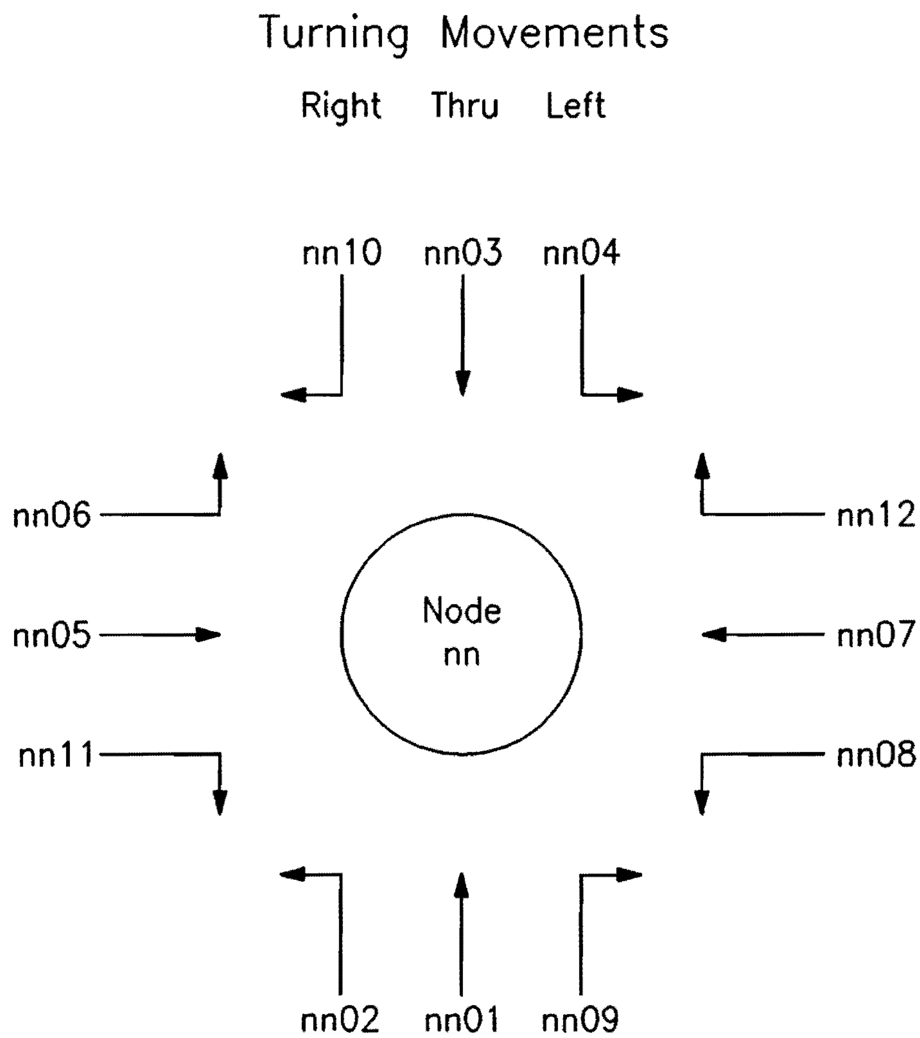
As mentioned in the Background section, TRANSYT-7F can be used to analyze existing or proposed designs for an isolated intersection, an interchange, or a network as a whole. The program can also be used for developing optimum signal timing plans and for determining what strategies produce minimum delays and stops. Signal timing plans can be fine-tuned (minutely refined) and appropriately modified to meet the prevailing traffic conditions so as to obtain the best possible operational results. This is a very attractive feature of the program probably not available in any other existing optimization models. The principal features of TRANSYT-7F follow:

Network Representation

1. The network of signalized intersections and streets is represented by a node/link identification scheme. A node is a signalized (normally) intersection, and a link is a traffic movement such as through, left, or right turn movements. Link numbers as defined by the model for an isolated intersection are shown in Figure 3. Due to the program structure of the model, link numbers (xx in Figure 3) may often need to be numbered more than 12. Such links are termed special links in TRANSYT.
2. Traffic flow is simulated in small time increments within the cycle called steps. The signal cycle length can be divided into a number of such small steps, up to a maximum of 60 steps per cycle through which variations in traffic flow occur.
3. TRANSYT uses a platoon dispersion model to estimate the arrivals of vehicles at downstream intersections based on the departures from upstream intersections. For detailed discussions on the model and the equation, refer to the latest TRANSYT-7F user's manual (*3*).

Signal Timing Parameters

1. The cycle length selected by the model is the one that results in a minimum Performance Index (PI) which is a linear combination of traffic flow measures of delay, stops, and maximum back of queue or operating cost as defined by the user. A range of cycle lengths will be evaluated and a PI will be calculated for each optimized timing plan for each cycle. The minimum PI gives the optimum cycle.
2. Phase lengths also can be optimized by the model. When an initial timing plan is not supplied to the program, initial phase lengths are first calculated by equalizing the degrees of saturation on the critical traffic movements. Phase sequences are input to TRANSYT-7F. Multiple phase sequences cannot be automatically analyzed by the model. Also, note that TRANSYT-7F is not an effective tool for evaluating traffic operations at intersections having traffic actuated signals.
3. Offset optimization in TRANSYT-7F is done through a procedure called "hill-climb" search process. Figure 4 shows this procedure. When an initial timing plan is not supplied to the program, offsets are all set to zero at the beginning of the



Notes: 1. 'nn' is the node number for an intersection.

2. Other special links will be numbered nnxx, where xx > 12, and must be user-assigned. This applies to bus links, shared stopline links or diagonal links.

Figure 3. Recommended Node - Link Identification Scheme in TRANSYT-7F.

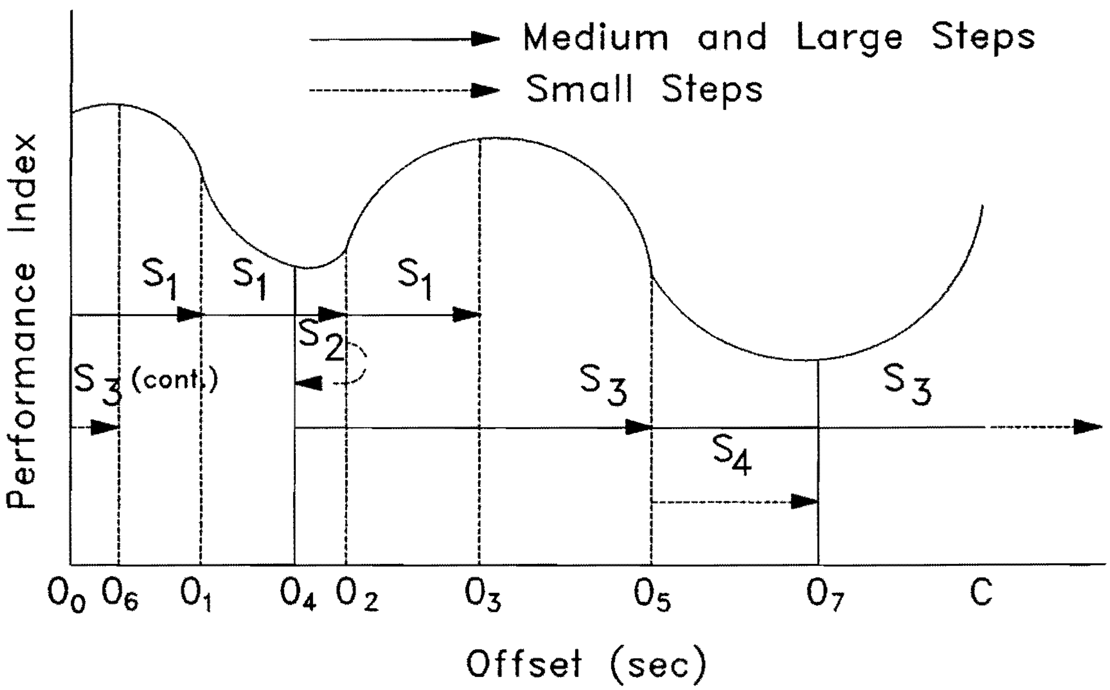


Figure 4. Illustration of the Hill-Climb Process.

optimization process. They are then increased in small steps (S_1 and S_2, about 15% of the cycle), and the resulting PI is calculated. If this PI is smaller than the previous PI, the offset (or split) is increased, and the process is repeated. If the PI at any point becomes greater than the previous PI, the offset is reduced to find a lower PI. Next, the procedure processes big steps (S_3 and S_4). If any of these big steps result in a lower PI than before, offsets are again increased in small steps to find a still lower PI. Thus, the process is repeated. The best offset is the one that results in the smallest PI. Phase split optimization is done in a similar manner. Offsets can also be determined that provide good progression by giving more weight to delays or by using the bandwidth constraint option for those movements which need to be progressed. This is more clearly explained in the input format section.

Measures of Effectiveness

1. Delay is calculated as the sum of two components: uniform delay and overflow (over-saturation) delay. Uniform delay is calculated by averaging the queue length over the cycle. Overflow delay is a function of the random arrivals of the vehicles and the degree of saturation. This delay is calculated in a similar manner as that of the Highway Capacity Manual (HCM) (*4*) equation except that the delay predicted by TRANSYT-7F is smaller than that of the HCM. The model simulates only one cycle of time. Hence, conditions which occur in one cycle are assumed to reoccur in subsequent cycles without blocking any upstream intersection.
2. Stops are not explicitly modelled by TRANSYT-7F. The model assumes that vehicles which are delayed are also partially stopped in most cases. The model uses a delay-stops relationship empirically developed by TRRL to estimate the stops. While this method is an approximation, this calculation was found to be consistent with NETSIM results. So, the calculation appears to generate reasonable results.
3. Fuel consumption is calculated as a function of delays and stops.
4. The model can also calculate the maximum back of queue and queue capacity based on the length of the link and the storage length of vehicles. Storage lengths of 25 feet per vehicle appear reasonable where low volumes of large trucks are present.

For more special features such as permitted turning movement modelling, shared stop line features, etc., refer to the TRANSYT-7F user's manual (*3*).

Performance Index

1. When optimizing, TRANSYT minimizes an objective function called the Performance Index (PI). The PI is either a linear combination of delay, stop, and (optionally) excessive maximum back of queue penalty or excess operating cost (also optionally weighted by excessive maximum back of queue penalty). The delay-stops PI is defined as follows:

$$PI = \Sigma \{[w_{di}d_i + Kw_{si}s_i] + u_i [w_{di-1}d_{i-1} + Kw_{si-1}s_{i-1}] + B_i [W_q(q_i-c_i)^2]\}$$

summed up over 1 to n links in the network and where:

i = 1 to n links in the network (interchange);

d_i = delay on link i (of n links) [and on an optional user-specified upstream input link (designated here as link i-1)] in veh-hr;

K = a user input coefficient to express the importance of stops relative to delay;

s_i = stops on link i (and i-1) in stops/sec of delay;

w_{si} = link specific weighting factor for stops (s) for link i (and i-1);

w_{di} = link specific weighting factor for delay (d) for link i (and i-1);

u_i = a binary variable which is '1' if link-to-link weighting has been established for link i, or zero otherwise;

B_i = a binary variable which is '1' if the maximum back of queue (q_i) exceeds the user-specified storage capacity, or zero otherwise;

W_q = a network-wide penalty applied to the excess queue spillover;

q_i = computed maximum back of queue on link i; and

c_i = maximum back of queue capacity for link i.

Regarding the maximum back of queue capacity (c_i), this is one of two values:

1. The value explicitly coded by the user, or

2. A default calculated value based on the number of lanes and link length, multiplied by the percentage coded by the user on a modification card (card type 34).

2. INTERCHANGE DESCRIPTION

INTRODUCTION

There are several types of signalized interchanges used with urban freeways as shown in Figure 1. The most popular grade separated structure often adopted in urban areas where the right of way is restricted is the tight urban diamond interchange (TUDI). Recently, however, the design concept of the single-point urban interchange (SPUI) is being preferred by some states over the TUDI, especially on freeways without frontage roads. This decision is due in part to the premise that the SPUI may operate more efficiently than the TUDI, thereby providing lower user costs but at a slightly higher construction cost. Analysis would determine the more cost-effective design for a given situation.

TWO-LEVEL DIAMOND INTERCHANGE

A two-level TUDI has 2 entrance and 2 exit ramps through which traffic can enter the freeway or exit from the freeway, respectively. The ramps are diagonal and intersect with the cross street or the frontage roads. Hence, a vehicle exiting the freeway to turn left would travel through two intersections in order to continue its movement. The spacing between the right-angled (in most cases) intersections is generally about 300 ft. Both intersections are usually signalized in such a way that perfect progression is provided to all traffic once it enters the intersection area. The usual geometric configuration of a two-level TUDI along with its four-phase, two-overlap phasing sequence is shown in Figures 5 and 6, respectively. Other phasing schemes can be used.

SINGLE-POINT URBAN INTERCHANGE

A SPUI, is a two-level grade separated structure with all the left turn movements from the freeway and all the movements from the cross street meeting at a single intersection. This intersection has a large area and large radii for the left turns. The central intersection is controlled by one traffic signal. Frontage roads are not often present but may be provided depending on the geometric design. When they are present, the SPUI is termed a four-phase SPUI. Otherwise, it is called a three-phase SPUI. Due to the large area and

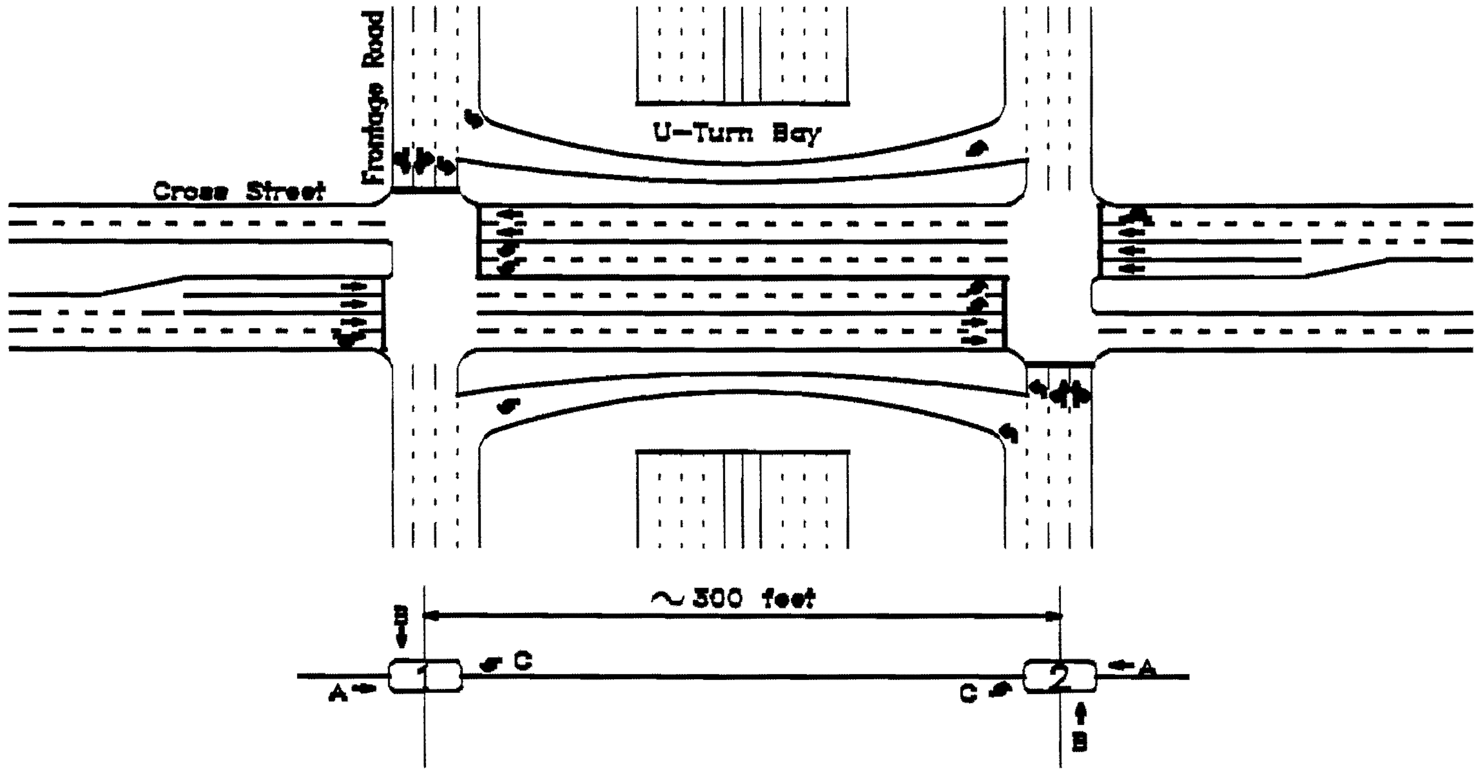


Figure 5. Conventional Tight Urban Diamond Interchange.

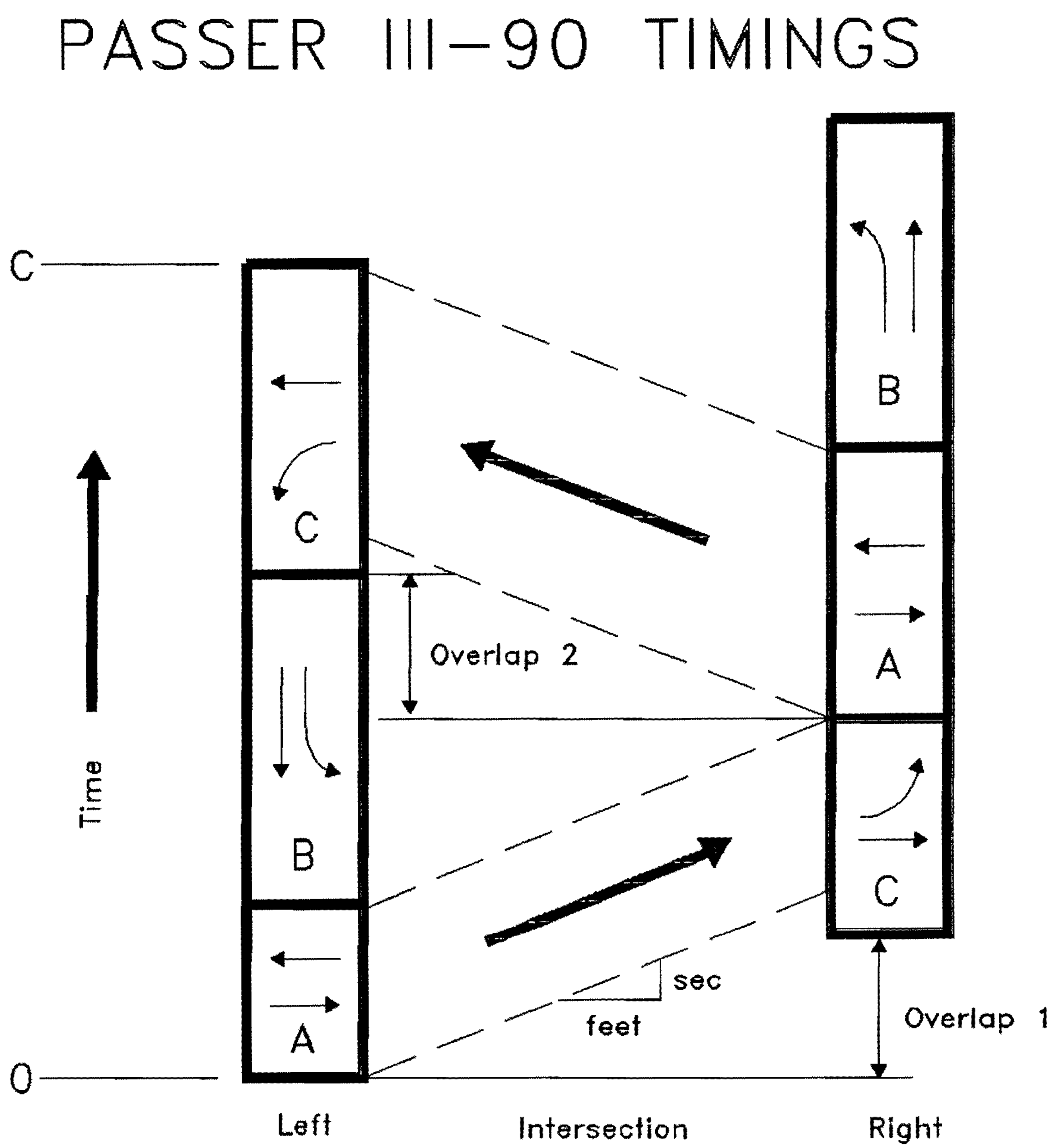


Figure 6. Four-Phase with Two Overlap Signalization at TUDI.

the large radii, left turns at the SPUI require longer signal clearance times than are required at an at-grade intersection. This is the main reason the SPUI operates more efficiently at higher cycle lengths. The SPUI without frontage roads is shown in Figure 7 and with frontage roads in Figure 8.

Three-Level Diamond Interchange

In case of a three-level diamond interchange (TLDI), there are 4 intersections within the interchange area, and vehicles turning left from the freeway have to travel through at least 3 intersections. Additionally, there are often frontage roads paralleling both arterials. The distance between each intersection varies but is usually 200-400 ft. A number of phasing sequences are possible in the TLDI. The TLDI is shown in Figure 9. Two types of phasing sequences, four-phase with four overlap and two-phase with two clearances, are shown in Figures 10 and 11, respectively. The phasing sequence shown in Figure 12 (a), where all the externals start at the same time, is also possible.

Three-Level Stacked Diamond

A three-level stacked diamond interchange is similar to a SPUI with respect to the number of intersections that vehicles have to travel after exiting from the freeway. Right-turns are usually not present. Figure 12 (b) shows the phasing sequence usually adopted at such interchanges.

Evaluation Model

An analyst desires to know the operational benefits of a proposed improvement to any facility, for example, to an existing AGI. The improvement or upgrade of the AGI should be fully justified. Possible improvements could be a SPUI, TUDI, or a TLDI. It is also useful to know how the proposed alternatives will perform in the future. The evaluation of performances can be done by a number of available traffic simulation tools. Examples of such tools are PASSER III, PASSER II, NETSIM, and TRANSYT-7F. PASSER III is a software tool developed solely for the purpose of optimizing signal timing plans at two-level diamond interchanges. The timing plans are generated to achieve perfect

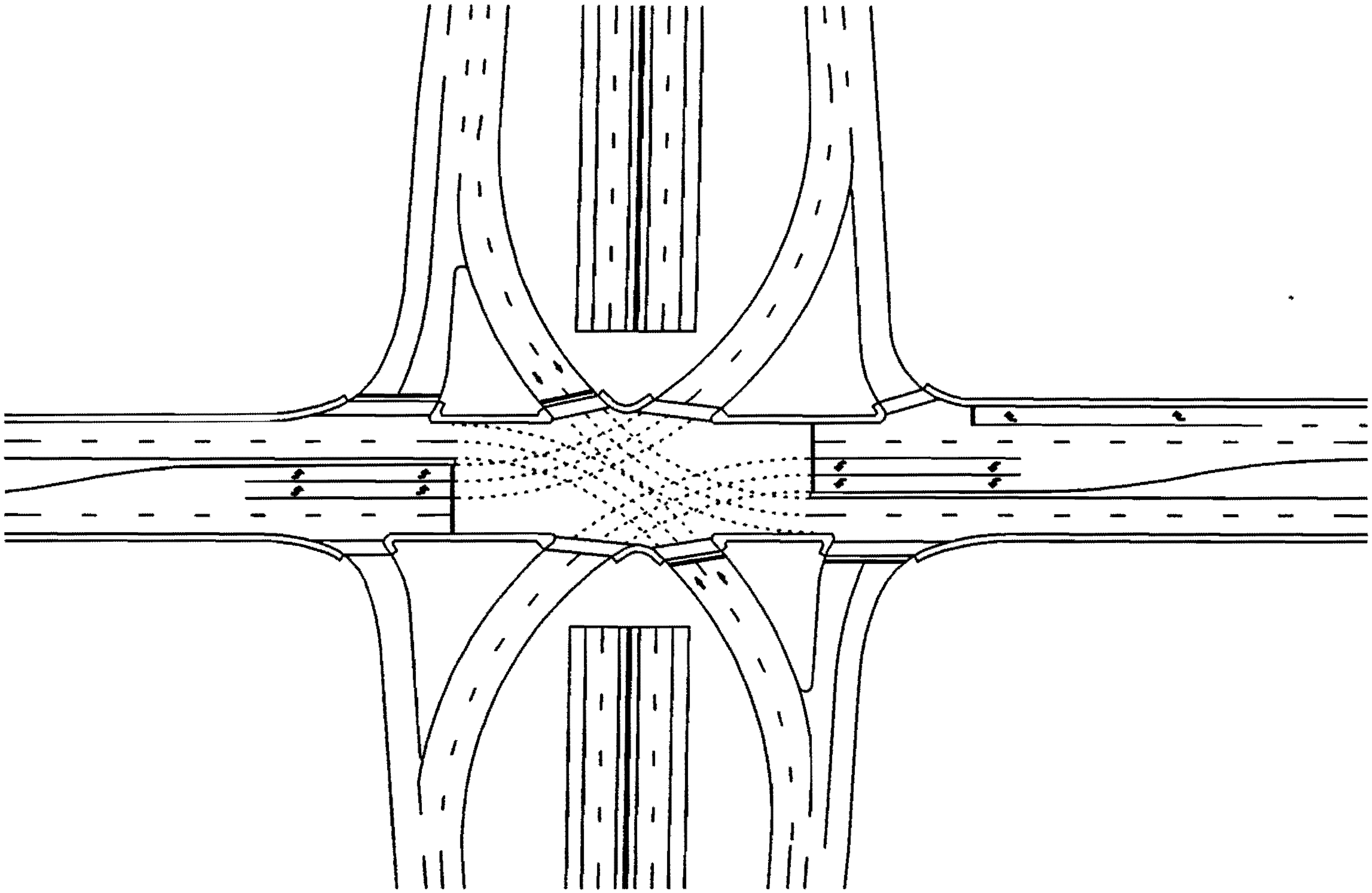


Figure 7. Single-Point Urban Interchange without Frontage Roads.

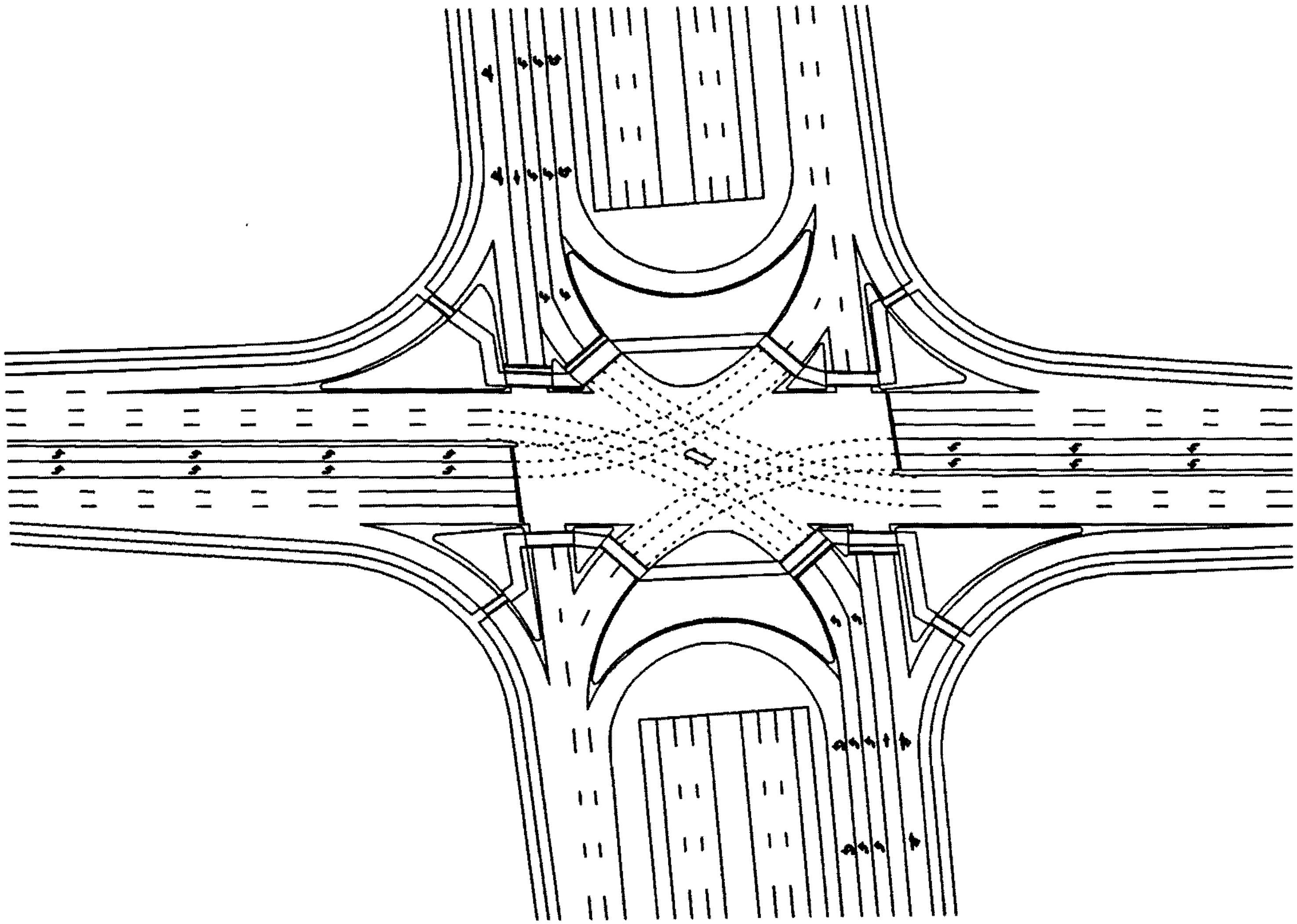


Figure 8. Single-Point Urban Interchange with Frontage Roads.

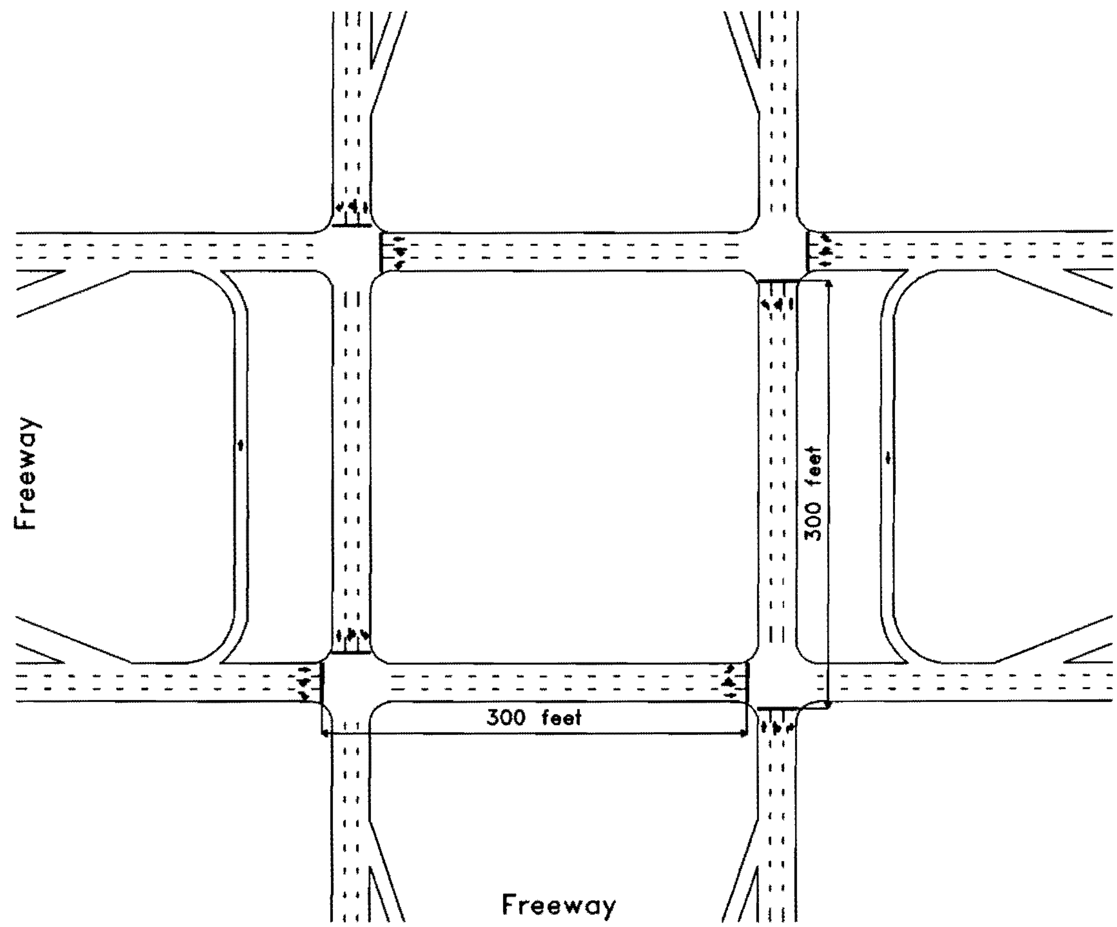


Figure 9. Typical Three-Level Diamond Interchange.

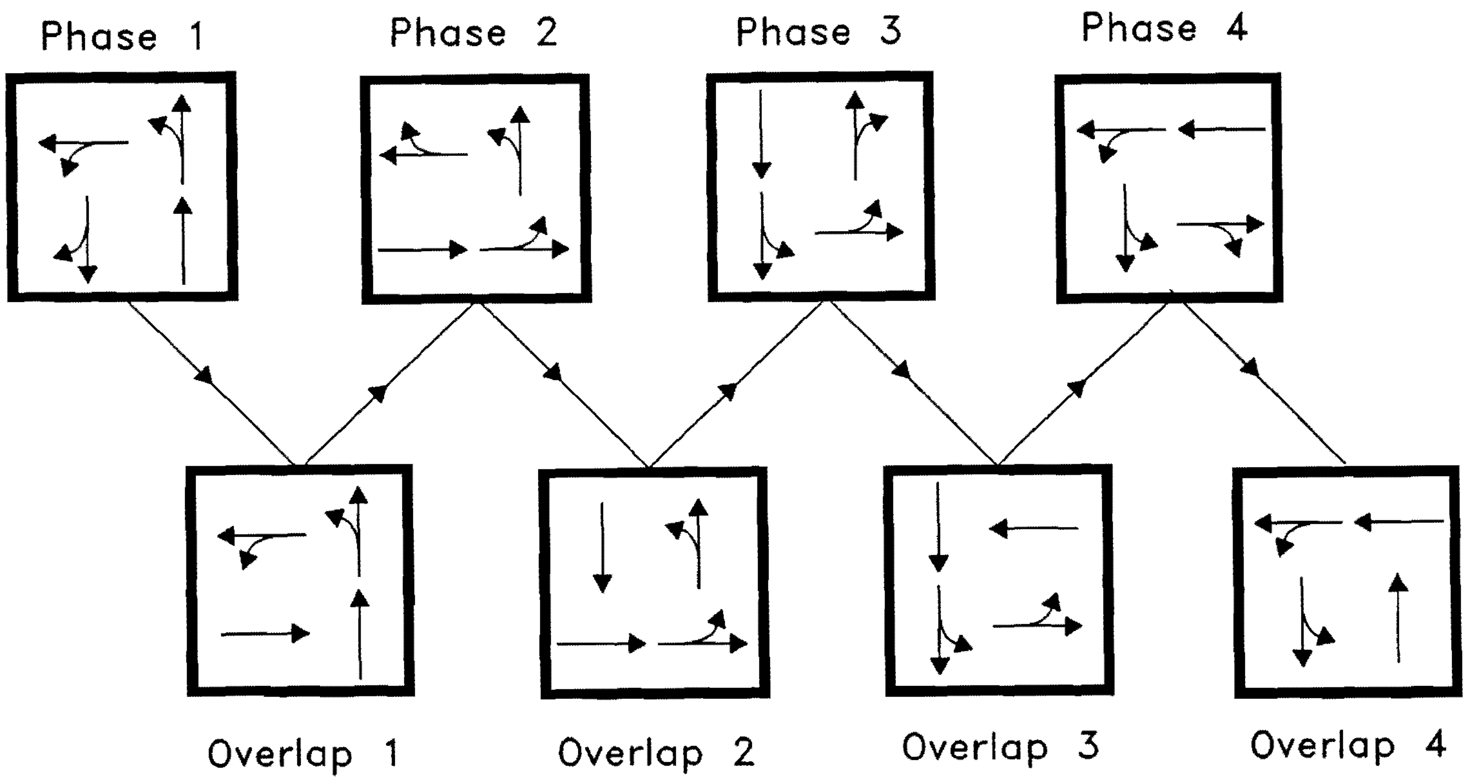


Figure 10. Four-Phase with Four Overlaps at Three-Level Diamond Interchange.

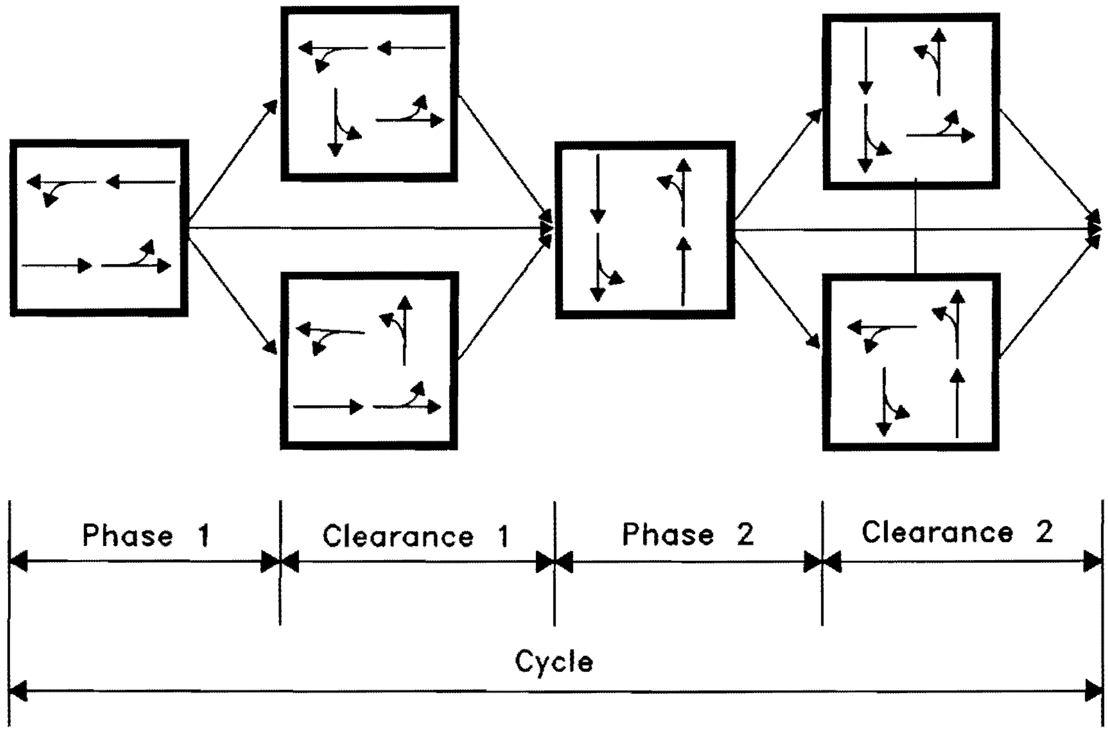


Figure 11. Two-Phase with Two Clearances at Three-Level Diamond Interchange.

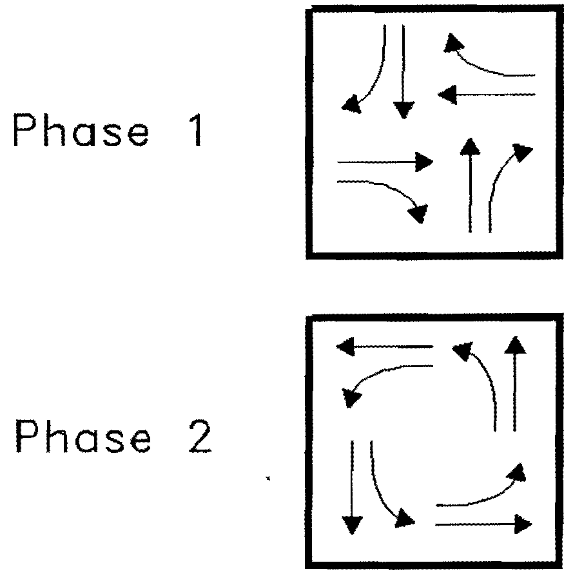


Figure 12A. Three-Level Diamond Interchange with All the External Movements Starting Simulataneously.

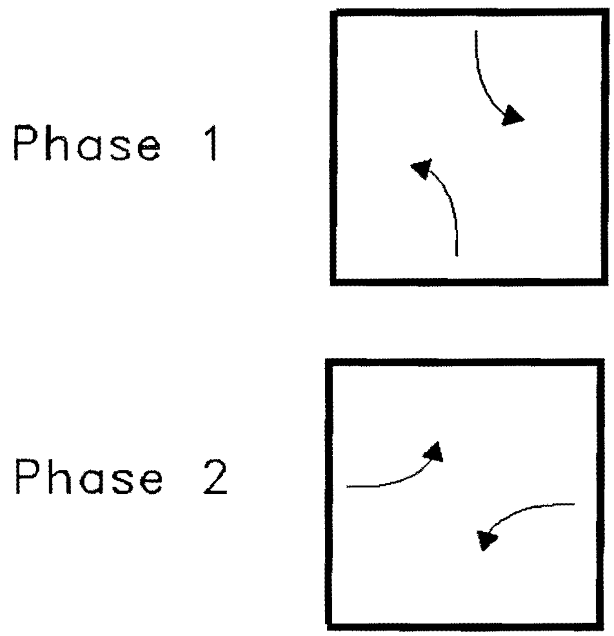


Figure 12B. Three-Level Stacked Diamond Phasing Pattern.

progression. Currently, however, PASSER III can only be applied for two-level diamond interchanges and is not suitable to evaluate various interchanges such as mentioned previously. PASSER II (*5*) was designed to be used only for arterial progression. Although it can be used for AGIs, SPUIs, or TUDIs, wherever a closed network is involved, this tool is not appropriate. Since a TLDI on the whole is a small network, PASSER II cannot be used. NETSIM (*6*) is a microscopic simulation tool and requires detailed signal timing plans to be provided as input. TRANSYT-7F is a widely accepted macroscopic traffic model for optimizing and evaluating signal timing plans for networks, arterials, and isolated intersections. Thus, it can be used to model AGIs, SPUIs, TUDIs, and TLDIs unlike other models. Further, TRANSYT's capability of modeling shared links is apparently better than any other existing models. Hence, TRANSYT-7F was chosen as the tool to evaluate all the interchanges described in this manual because of its broad range of features.

INTERCHANGE DESIGNS EVALUATED

The following interchange designs were evaluated on the basis of delays and stops as possible upgrades to an assumed existing high-type at-grade intersection (AGI):

1. SPUI with three-phase and four-phase operations,
2. TUDI with frontage roads using four-phase, two-overlap timing plan, and
3. TLDI with frontage roads.

The base case turning movement hourly volumes are shown in Figure 13. These are the existing volumes at the signalized AGI for the year 1990. TRANSYT-7F can be used to evaluate the efficiency of the intersection under optimal signal timing settings at this AGI. Then, the AGI can be upgraded to a SPUI, a TUDI, or a TLDI to analyze the same volumes using TRANSYT-7F for these interchanges. Additionally, all of the above were evaluated for the years 1990 and 2010. The geometric configurations for these strategies are shown in Figures 13-22 (see pp. 23-32). These configurations do not represent ideal configurations from a traffic engineering point of view. They have been defined to demonstrate modeling in TRANSYT-7F. Since the same software is used to analyze all the types of interchanges, the evaluation in terms of delays, stops, etc., can be made on a common basis without any analysis bias. In other words, a comparison of all the

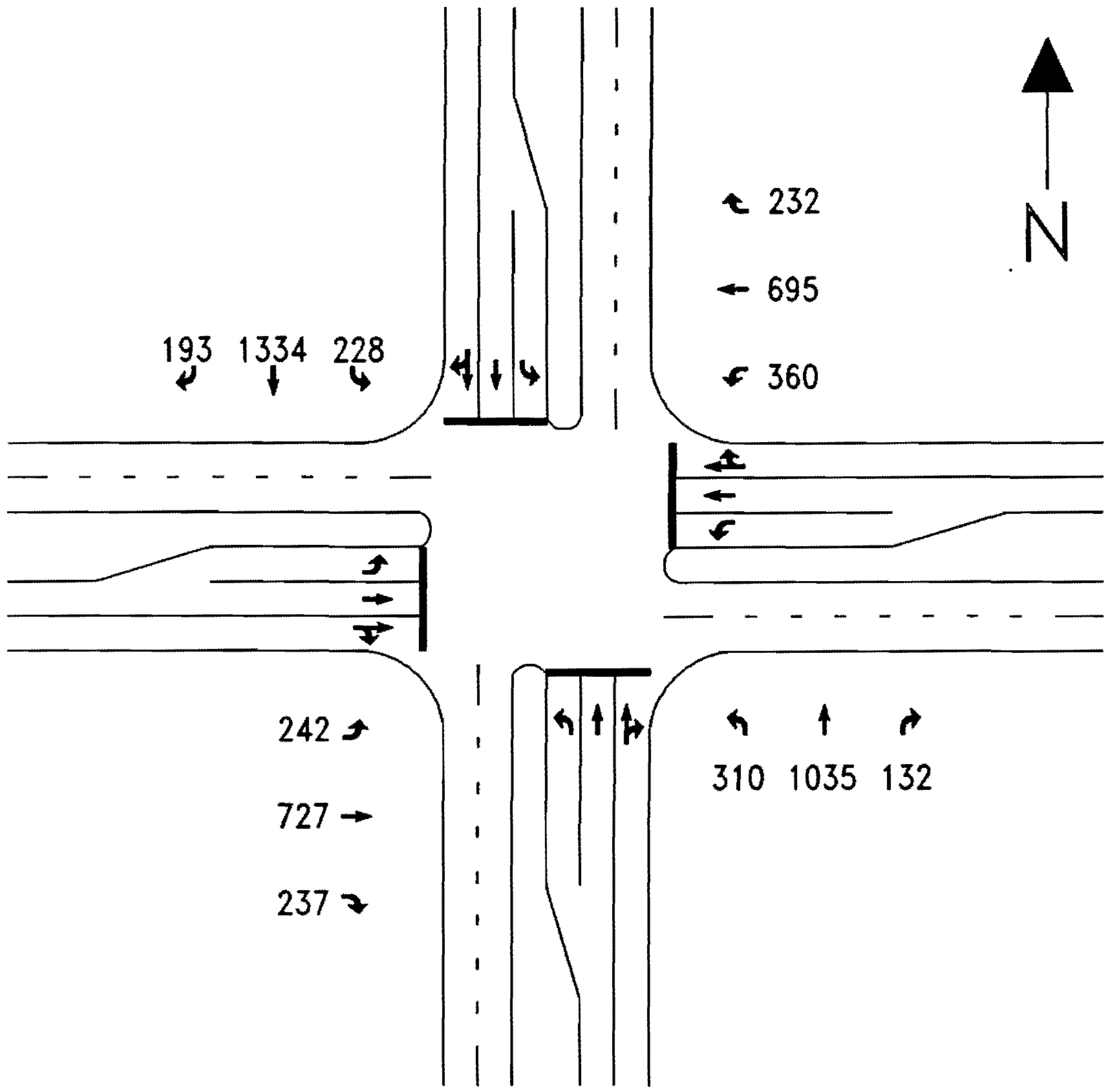


Figure 13. AGI Configuration for 1990 Traffic Volumes.

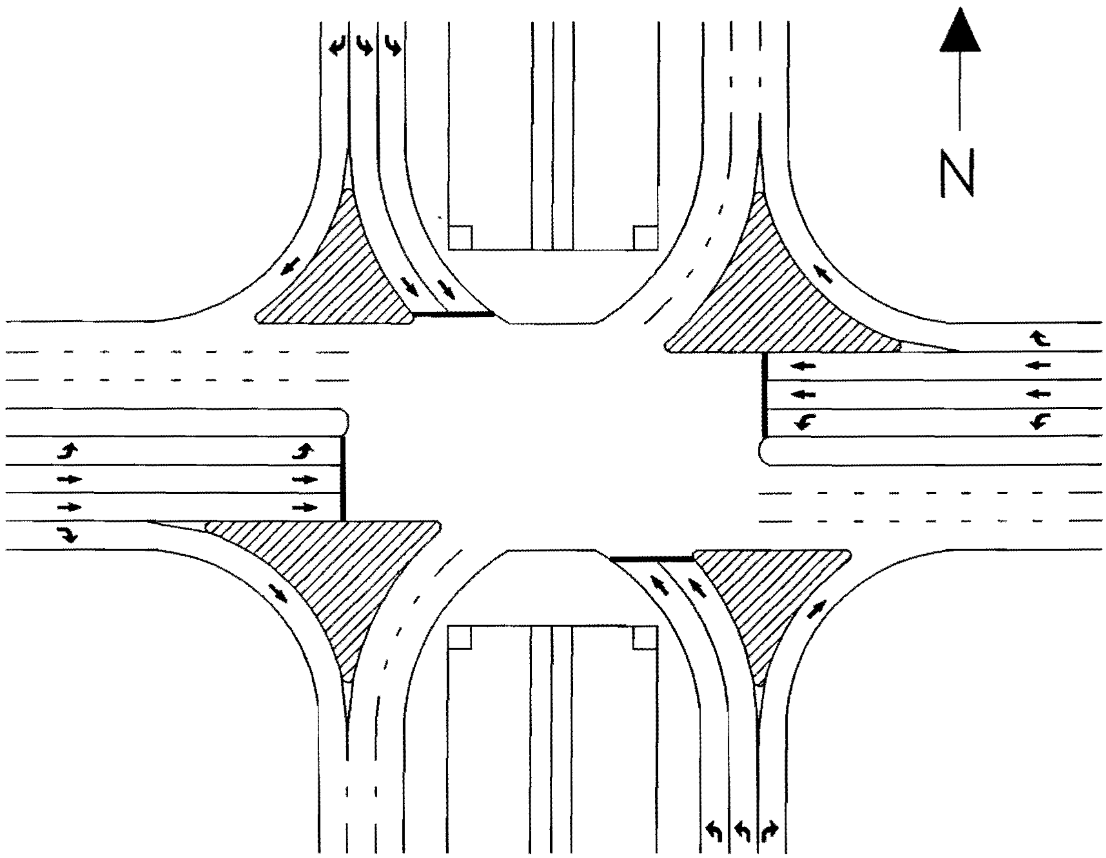


Figure 14. SPUI Configuration without Frontage Roads for 1990.

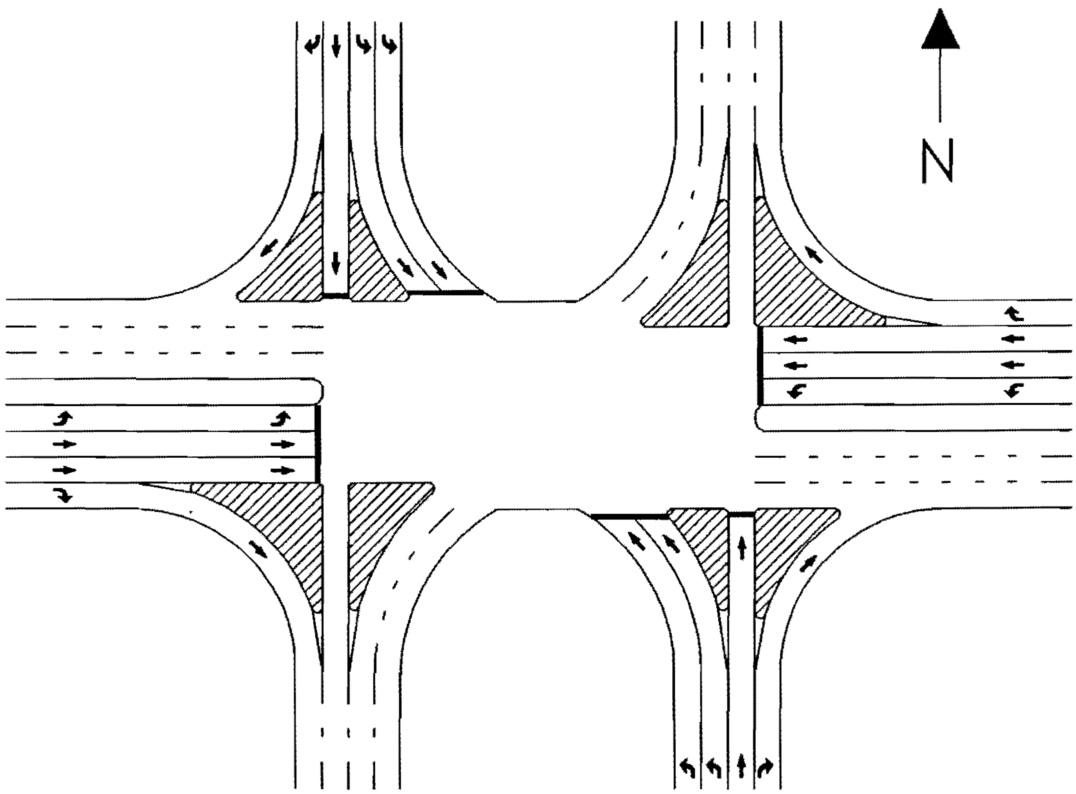


Figure 15. SPUI with Frontage Road Configuration for 1990.

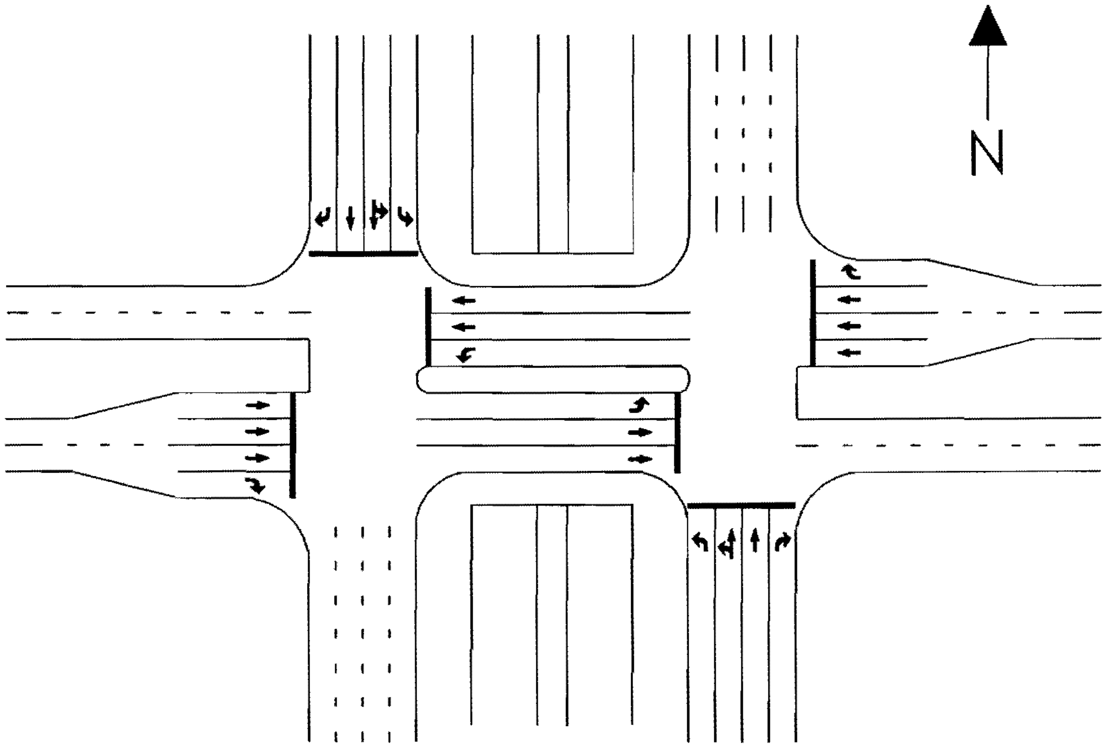


Figure 16. TUDI Configuration for 1990.

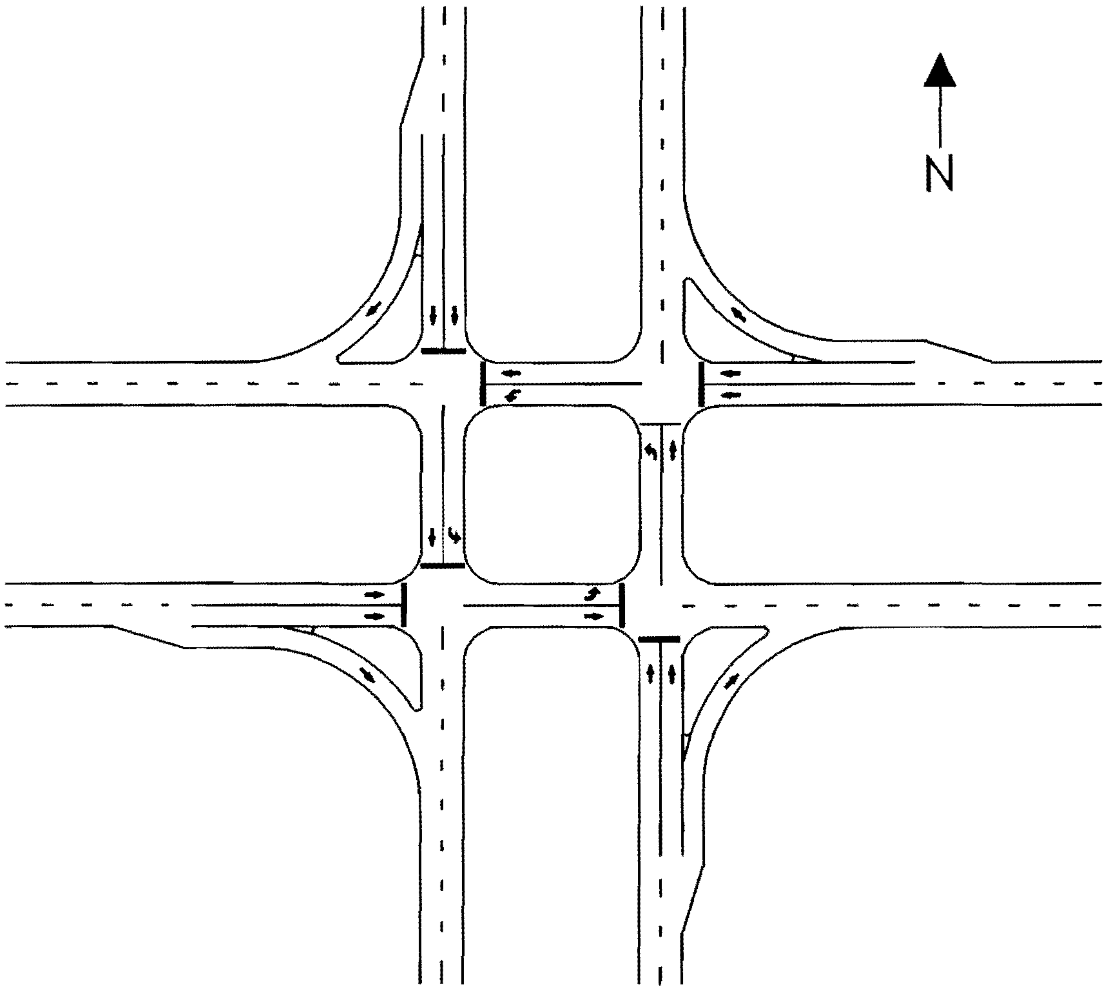


Figure 17. Three-Level Diamond Interchange Configuration for 1990.

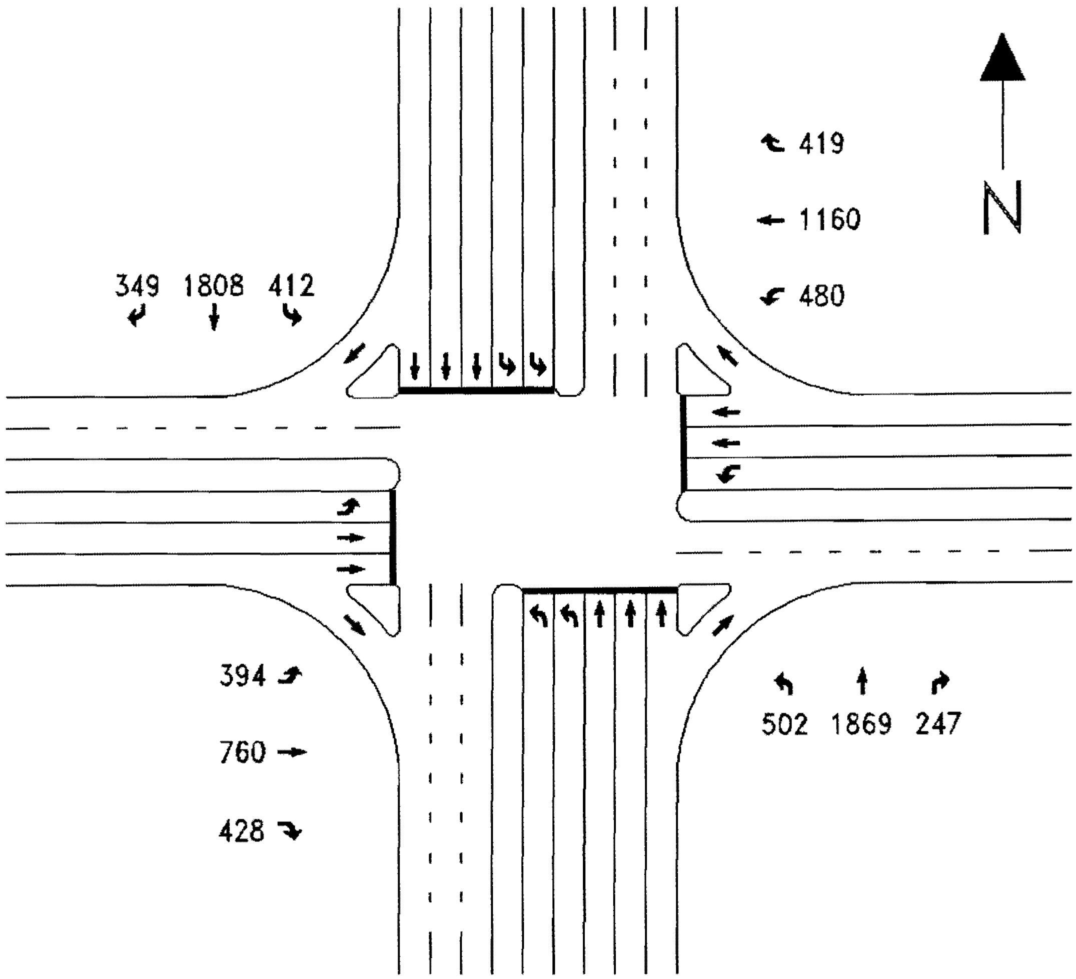


Figure 18. Proposed AGI Configuration to Satisfy 2010 Traffic Volumes.

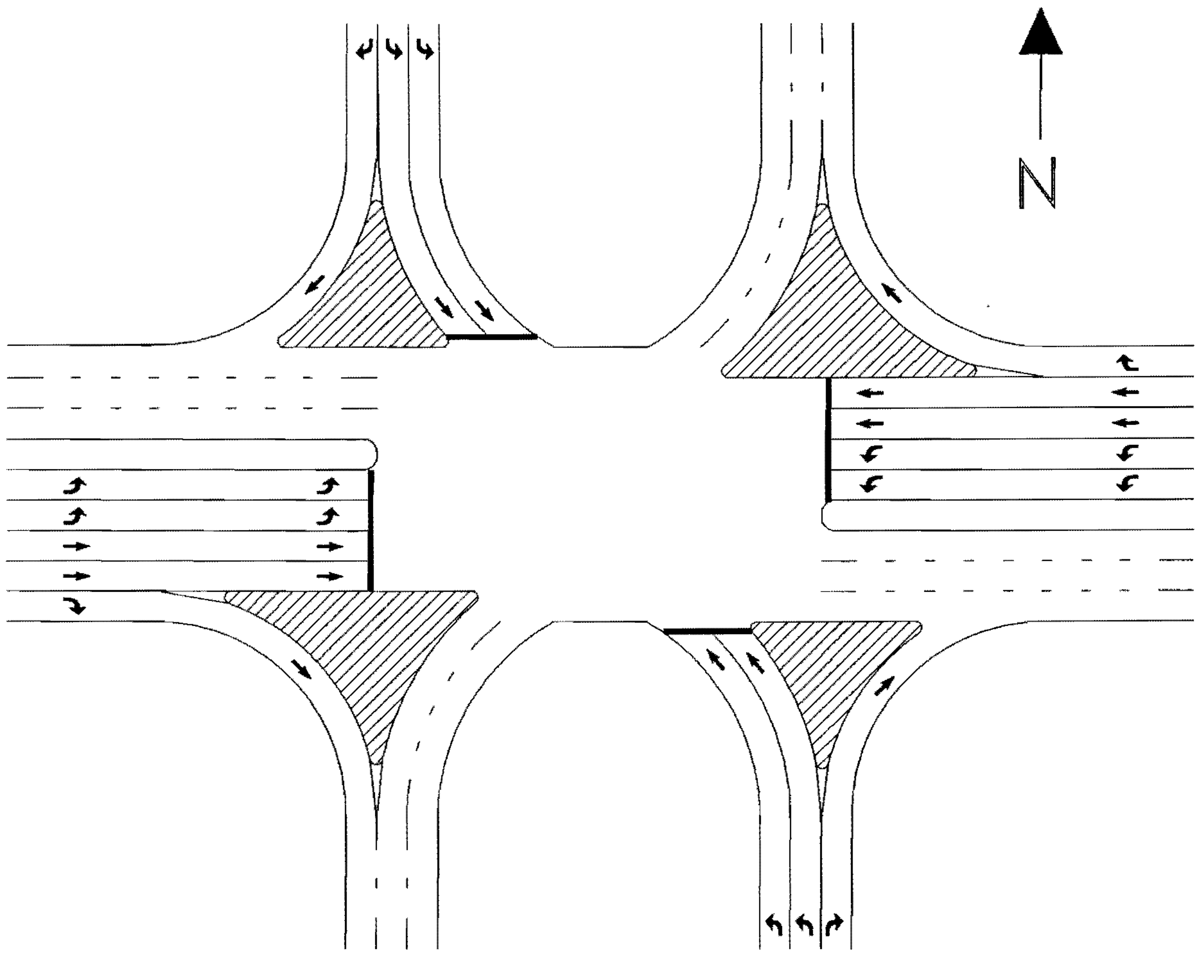


Figure 19. Proposed SPUI Configuration without Frontage Roads to Satisfy 2010 Traffic Volumes.

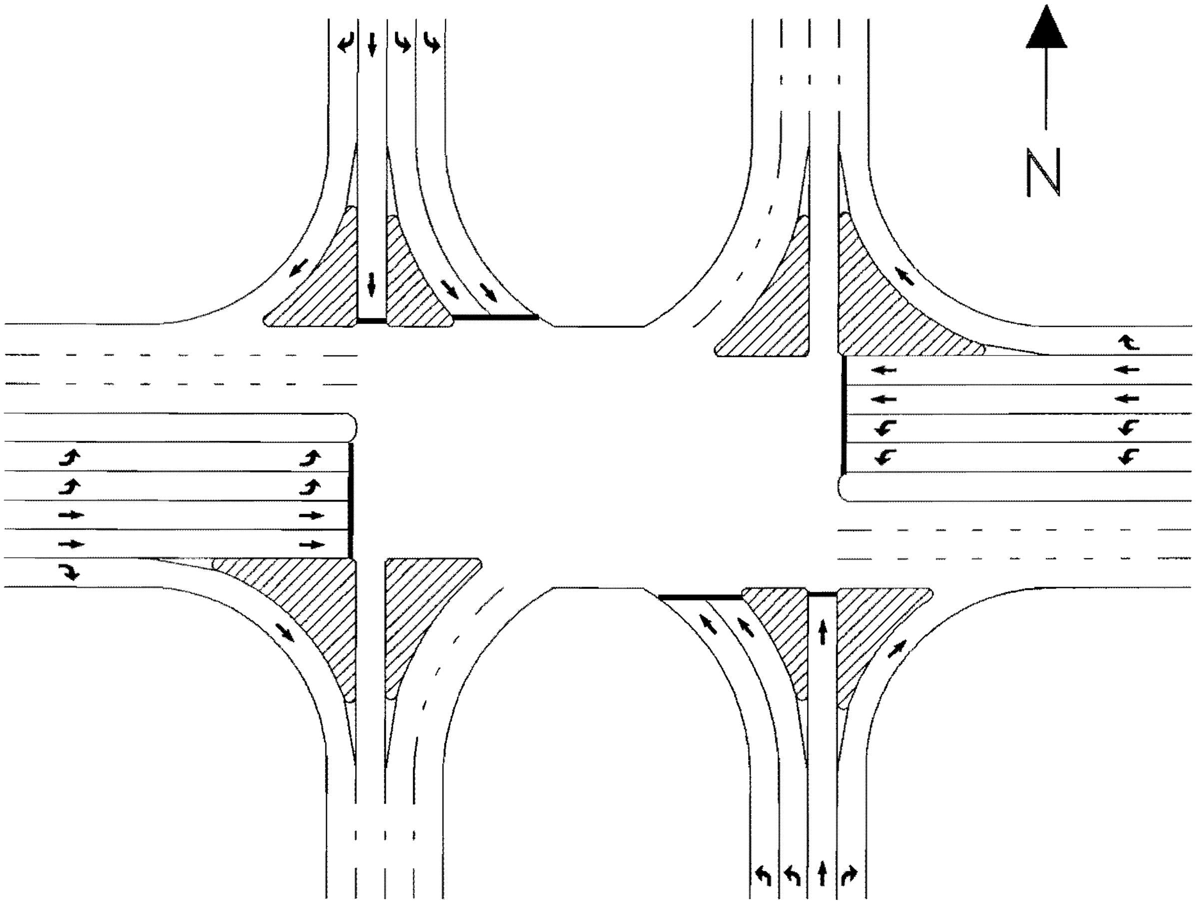


Figure 20. Proposed SPUI Configuration with Frontage Roads to Satisfy 2010 Traffic Volumes.

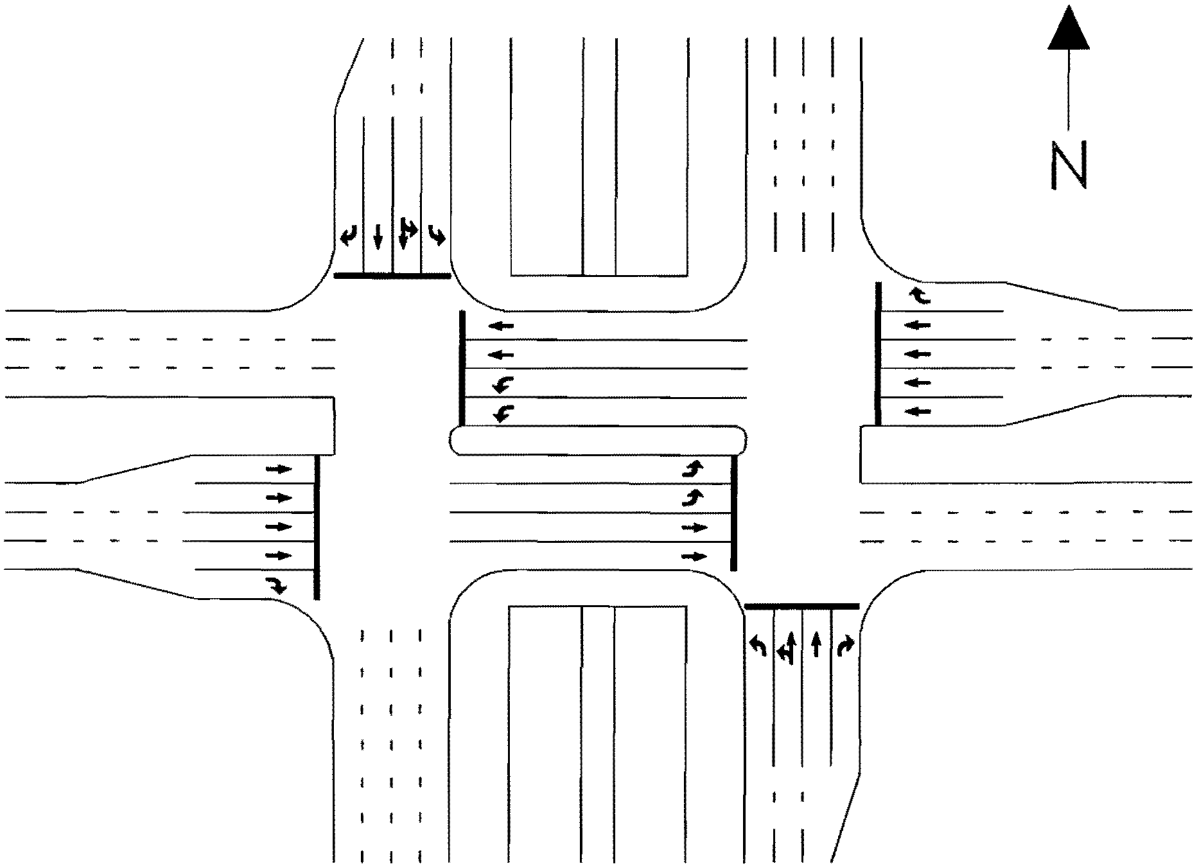


Figure 21. Proposed TUDI Configuration to Satisfy 2010 Traffic Volumes.

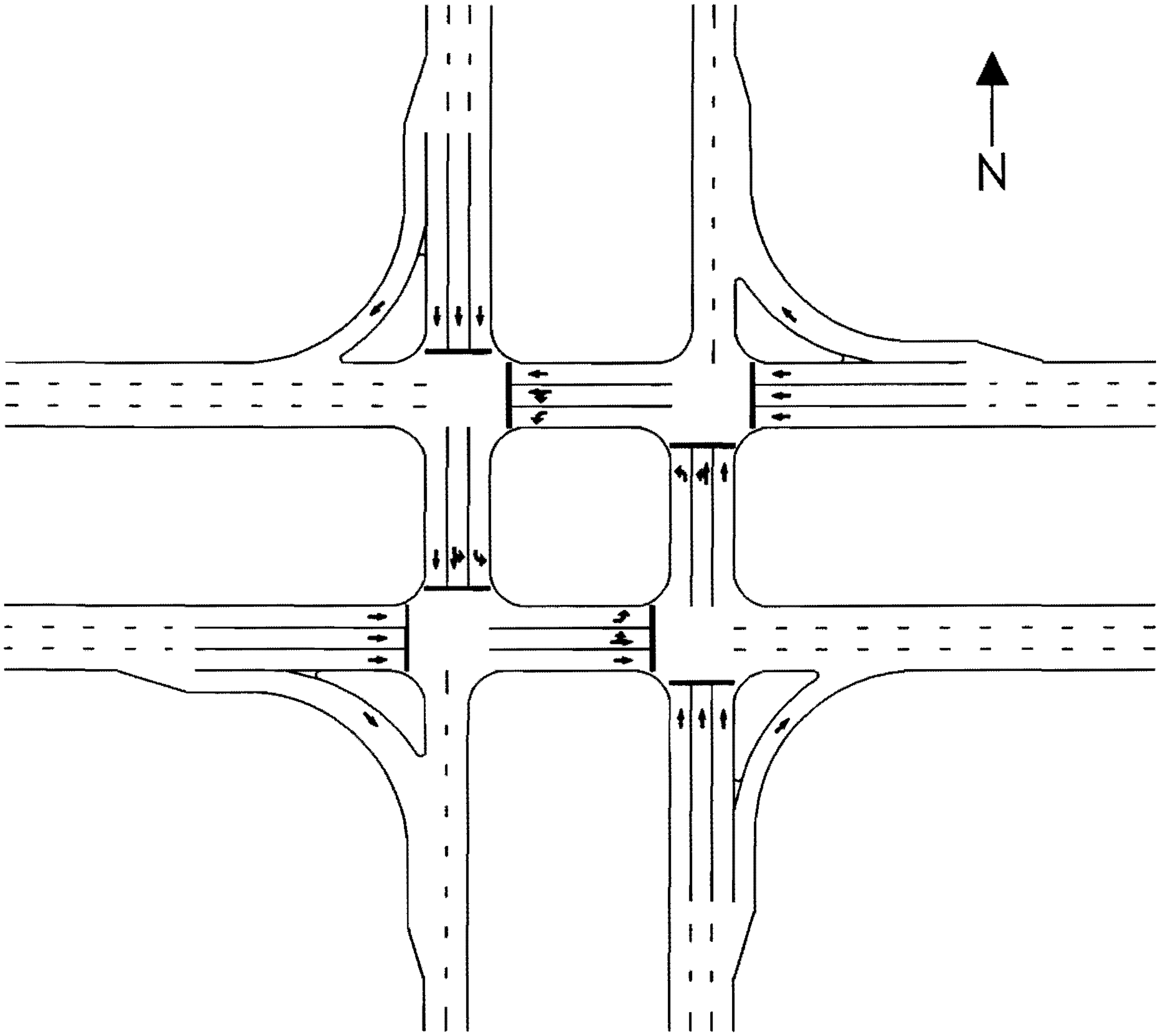


Figure 22. Proposed TLDI Configuration to Satisfy 2010 Traffic Volumes.

interchanges can be made using the same principles of delays, stops, etc. This would be expected to yield reliable conclusions regarding the operational efficiency of the various interchanges studied.

Figure 18 shows an improved configuration of the AGI for the year 2010. The turning movement volumes at the AGI in the figure were developed using a 2% growth rate in order to project the traffic to 2010. Available data were utilized for defining the traffic volumes and hence, the 3% growth rate in traffic mentioned in Chapter 1 was not used. The upgraded configurations of various types of interchanges as mentioned above are shown in Figures 19-22. The same turning movement volumes for 2010 are used for all the interchanges in 2010. The operational analyses of the AGI, SPUI, TUDI, and TLDI for the years 1990 and 2010 are provided in Chapter 7 of this manual.

Several assumptions were made regarding the various interchange geometric configurations. It should be noted that the configurations described above do not represent ideal designs from a traffic engineering viewpoint. They have only been proposed as improved configurations and have not been optimized. The input coding for all the designs is given in the Appendix. Some of the assumptions made for all of the designs are given below:

1. An ideal saturation flow of 1800 vphgpl was used. This is the most generally applied value as it represents an average headway of 2 sec. between vehicles in platoon.
2. Approximate ranges of cycle lengths were evaluated. For example, a SPUI operates at higher cycle lengths under high volume conditions. Hence, cycle lengths in the range of 80 to 100 sec. have been used. Similarly, a TLDI operates at lower cycle lengths. Thus, a range from 60 to 80 sec. would seem to be reasonable.
3. A platoon start-up lost time of 2 sec. and a clearance lost time of 2 sec. were used. The clearance lost time is actually less than 2 sec. but more than 1 sec. Since TRANSYT-7F does not accept fractional values, an integer value of 2 sec. for both lost times was deemed appropriate. For a SPUI, the total lost time was assumed to

be 6 sec. This is because, at SPUIs, a higher clearance lost time is needed due to the larger open area at the interchange.

4. A network-wide yellow change interval duration of 4 sec. has been used as this represents a nominal value used in practice.
5. An entry speed of 30 mph was used on external links feeding the facility. This speed is the default in TRANSYT-7F.
6. All left turn movements at all interchanges are assumed to be protected movements. Right-turn-on-red is permitted, however.
7. Traffic conditions are assumed to exist for a time period of 15 minutes. This is the time period used by the HCM in calculating the overflow delay term. Traffic volumes, however, are input in vehicles-per-hour flow.
8. No pedestrian traffic is assumed to be present. This is because pedestrian traffic is seldom present along urban freeways. If pedestrian traffic is present, minimum green time computation should include pedestrian crossing times. Also, right turn traffic must yield to the crossing pedestrian traffic. These two factors should be kept in mind when evaluating diamond interchanges using TRANSYT-7F.
9. Delays and stops are the only operational measures considered in the optimization process of PI.

The traffic volumes mentioned earlier are given in the Appendix in the form of data input coding in TRANSYT-7F for the interchanges. A 1990 base volume for the AGI has been used for all the designs. Frontage road traffic volumes were input wherever frontage roads were present in case of interchanges. The same frontage road volume was retained for all the interchange designs. The number of lanes on each approach is shown in the design configurations in Figures 13-22.

3. INPUT CODING USING TRANSYT-7F

This section describes the input coding procedure for a TUDI having the previously shown configuration in Figure 16 for 1990 traffic. The input coding structure of TRANSYT-7F is a card-type format. Numerous card types have to be input to define all volumes, geometrics, and operational parameters of the problem. A card is designated for a particular data set. The data set might include network parameters, geometrics, signal timing, etc.

MAIN PROGRAM

First, to enter into the shell mentioned previously in the Overview of TRANSYT-7F section, type "mct7f" at the prompt. This is a batch file which executes commands in a sequential order. The TRANSYT-7F main menu shown in Figure 23 appears on the screen. The main menu contains several options. The first option "T" is used for executing the analysis program after the data input coding has been completed, and a TRANSYT-7F run is desired. The second option "R" is for reading the input or output files. Generally, this option is only used for viewing the output produced for a given input. Input files are viewed/edited employing the "A" option (third option), which is also called the TRANSYT-7F's Data Input Manager (T7FDIM). When a new file is being created, it is better to first generate a skeleton input file rather than using the data input manager (DIM) since it is a time-consuming process to input all the basic card types and titles using the DIM. Hence, skeleton input files are first generated by selecting "N" from the menu, which means that a new file is to be generated (T7FGEN). The next two options are self explanatory. The choice "7" from the main menu is used only if a platoon progression diagram (PPD) is desired. This option is not used in this study. Files can be copied, moved, or deleted using the file management feature in the menu by selecting "F".

Once "N" is selected to code a new problem, a prompt for a title is made. Enter the title for the run. The title can be up to 80 characters long. Remember that this is not the name of the input file. This is only an identification of the run. Also, keep in mind that

McT7F - TRANSYT-7F MAIN MENU

T	------->	TRANSYT-7F Program
R	------->	Read Input/Output Files
A	------->	Alter Data Files (T7FDIM)
N	------->	New File (T7FGEN)
S	------->	Send Output File to Printer
Y	------->	Your Special Program
T	------->	TRANSYT-7F Program
+	------->	EZ-TRANSYT PLUS
7	------->	7F PPD Program
F	------->	File Management

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Enter Your Choice [Quit, eXit or Esc]

Figure 23. TRANSYT-7F Main Menu.

the skeleton input file should always be edited later using the DIM. Next, the number of intersections in the system is input. For a TUDI, this entry is two (2); for a TLDI this entry, is four (4). Since we are coding a TUDI, enter 2 here and press "Enter". The third prompt can be left blank for a TUDI or TLDI because a time space diagram is not normally coded. Hence, leave blank and press "Enter". The fourth input is the number of phases per intersection. For a TUDI, this is 3 phases. So, enter 3 and go to the next question which is about the card type identifiers. These identifiers put the appropriate title before a set of card types. For example, "signal timing" title is inserted before a set of cards which specify the signal phase sequences, etc. The default is "Yes". So, enter "Y" and press "Enter". Next, give the input file name with an extension (preferably ".dat"). This is the name needed to retrieve the file while editing using the DIM. An input file extension in the form of either ".dat" or any other name is a must in the program. The filename along with the extension has to be given when using the DIM. An example for starting to code a new TUDI problem (having a four-phase, two-overlap signal phasing) is given below. For our example, the name of the file is Evatudi.19 (the answers are bold faced).

TRANSYT-7F DATA FILE GENERATOR

K. G. Courage & C. E. Wallace

Version 1.1 March, 1988

==========================

ENTER TITLE OR <CR> TO QUIT?

Evaluating TUDI -- Case I

NO. OF INTERSECTIONS? **2**

NO. OF TSD ROUTES?

NO. OF PHASES PER INTERSECTIONS? **3**

CARD TYPE IDENTIFIERS (Y/N) ? **Y**

FILENAME ? **Evatudi.19**

OK (Y/N) ? **y**

GENERATING EVATUDI.DAT

DONE ... HIT ANY KEY TO CONTINUE

The skeleton file for the two-intersection TUDI has been prepared, stored, and ready for editing. Now, hit any key and then press "Enter" to get back into the main menu.

USING THE DIM

Select "A" from the main menu to edit (alter) the skeleton file. The file "Evatudi.19" can now be edited using the DIM. There are three modes in the DIM. One is the Command mode, second is the Browse mode, and third is the Window mode.

The Command mode is a mode which can be used to load, save, or print the files. It can also be used to insert cards not generated by TRANSYT-7F in the skeleton file or to delete cards that are found unnecessary in the input file.

The Browse mode is used to view and edit all the values in each card type simultaneously. This mode is basically used to modify the value of any parameter in any card. Note that in this mode, the values of the parameters can only be modified by direct entry and that the parameters themselves cannot be viewed on the screen.

The Window mode is often used for viewing the parameters in a particular card. Names of the elements and their respective coded values are displayed in the window on the right side of the monitor screen. This mode is designed to assist in identifying the appropriate parameters for which modifications are really needed.

When "A" is selected from the menu, the DIM is loaded. As a default, the Browse mode of the DIM appears. The Browse mode cannot be used until a file is loaded into the DIM. To load the skeleton file "Evatudi.19", the Command mode first must be used. Hence, to enter the Command mode, press the function key F1 from the Browse mode. Several function key commands appear at the bottom of the screen in the Command mode. These are explained below:

F2 - finds the number of the intersection.

F3 - loads a file you want to edit.

F4 - saves the file while editing and without quitting.

F5 - prints the file.

F6 - inserts a title wherever you want the title to be.

F7 - inserts a card immediately before the card where the cursor is.

F8 - deletes the card on which the cursor is placed.

F9 - inputs a new file letting you to either save or quit without saving the current file.

F10 - exits the DIM.

The function key number or first letter of the command will start the related activity. Use F3 to load the skeleton file generated earlier by TRANSYT-7F. The filename as explained earlier must have an extension. If ".dat" is given while generating the new file, the DIM adds this as a default. Any other extension must be specified. In this example of TUDI, "Evatudi.19" would suffice. The skeleton file as generated by T7FGEN and now being edited by DIM is shown in Figure 24. Editing can be done either in the Browse mode or in the Window mode as preferred by the user.

To go back from the Command mode to the Browse mode to edit the skeleton file, press the function key F1. To change a parameter value in a particular card type in the Browse mode, the cursor is first directed to the card type for which editing is needed by using the up or down arrows. Appropriate changes are then made to any element in the card type by moving the cursor to the respective element. To edit in the Browse mode, the user must memorize the position (column) of each element in the card. Unlike the Browse mode where the user must know the position of each element, the Window mode does not require the positions to be remembered. The window that appears on the right side of the screen contains all parameters and their associated values that have been input. The Window mode can be activated by pressing the "Esc" function key while in the Browse mode. Window mode cannot be activated in the Command mode even after pressing the "Esc" key. It is only through the Browse mode that the window can be viewed. The Window mode for the skeleton file "Evatudi.19" is shown in Figure 25.

```
----Evaluating TUDI for 1990 Traffic -----------------
1    *   0  5     3   1    0    0    -1   0   0     60      0      0      0      0
--------- OPTIMIZATION NODE LIST -----------------------
2    1    2
--------- NETWORK MASTER -----------------------
10   0    4   1     1700   30     35   100  25   0
******** INTERSECTION 1 ****************
--------- SIGNAL TIMING -----------------------
13   1
21   1
22   1
23   1
--------- LINK DATA ---------------------------
28   101
28   102
29   102
28   103
28   104
29   104
28   105
28   106
29   106
28   107
28   108
29   108
******** INTERSECTION 2 ****************
--------- SIGNAL TIMING -----------------------
13   2
21   2
22   2
23   2
--------- LINK DATA ---------------------------
28   201
28   202
29   202
28   203
28   204
29   204
28   205
28   206
29   206
28   207
28   208
29   208
--------- RUN SPECIFICATIONS ------------------
51
--------- TERMINATION -------------------------
90
```

Figure 24. Skeleton File Generated by T7FDIM for the TUDI Example Problem.

```
TRANSYT-7F DATA INPUT MANAGER                                      Version 6.3
 1   2   3   4   5   6   7   8   9   10   11   12   13   14   15   16
```

```
-----Evaluating TUDI for 1990 Traffic. ----      CARD TYPE        1      SYSTEM CONTROLS
[ 1    *    0    5    3    1    0
-------OPTIMIZATION NODE LIST ------             MINIMUM CYCLE          ..................  [*    ]
[ 2    1    2                                    MAXIMUM CYCLE          ..................  [0    ]
-------NETWORK MASTER -------                    CYCLE INCREMENT        ..................  [5    ]
[10    0    4    1    1700 30    35    10        SEC/STEP (CYC)         ..................  [3    ]
-********* INTERSECTION 1 ******                 SEC/STEP (OPT)         ..................  [1    ]
------- SIGNAL TIMING -------                    START LOST TIME        ..................  [0    ]
[13    1                                         EXT. EFF. GREEN        ..................  [0    ]
[21    1                                         STOP PENALTY           ..................  [-1   ]
[22    1                                         OUTPUT LEVEL           ..................  [0    ]
[23    1                                         INITIAL TIMING (Y=1)   ..................  [0    ]
------- LINK DATA ------------                   PERIOD LENGTH          ..................  [60   ]
[28    101                                       SEC(0)/PERCENT (1)     ..................  [0    ]
[28    102                                       SPEED(0)/TIME(1)       ..................  [0    ]
[29    102                                       U.S.(0)/METRIC(1)      ..................  [0    ]
[28    103                                       PUNCH (Y=1)            ..................  [0    ]
[28    104
[29    104
[28    105
[28    105
[28    106
[29    106
```

```
[Pg Up] [Pg Dn] to change cards   ...        [Esc] to return to Browse Mode
File Name : A:EVATUDI.19        WINDOW MODE          Card No. 2 OF 38.
```

Figure 25. TRANSYT-7F Skeleton Input File as Viewed in the Window Mode.

All of the card types listed in the skeleton file need to be modified as all of them do not contain any data and have no default values. Further, some cards generated in the skeleton file are redundant and are not required. Those cards not required must be deleted. The file should be modified in the Browse (or Window or "Esc") mode. Observe the following steps to modify the skeleton file:

1. Enter the Browse mode (if presently in the Command mode) by pressing the "F1" key.
2. Next, press the "Esc" key to add the Window mode. The Window mode shown on the right side of the screen identifies all of the parameters used for any card type. The parameters are displayed for the card on which the cursor is placed.
3. Modification of input values for a card type can be made in the Window mode by moving the cursor down to the appropriate parameter and entering the value.
4. To get back to edit another card, use the Pg Up or Pg Dn controls in the Window mode to move to other card types. In this way, the Window mode will always be present on the screen, but the cards will keep changing.
5. Another way to switch to other cards is to press "Esc" again so that the window disappears and to place the cursor on the card which is to be edited. Now, follow steps 2 through 5 until all the card types are appropriately coded.
6. If a card is not required, delete the card by placing the cursor on the card and press the key F8.
7. If a new card not generated by T7FGEN for the skeleton file is to be input, position the cursor where the new card is to be added and press F7. A blank space appears. Press "Esc" to go to the Window mode and then give the card type you want to input in the right window of the screen. Then, follow steps 3-5 above.

Steps To Be Followed After Input Completion

1. After all the input coding has been completed, press F10 to save the data and exit the DIM. As discussed previously, F4 can also be used to save the file without exiting.

2. The filename can be retained or can be changed. Press "Enter" at the "Filename?" prompt if the filename is retained.
3. To change a filename, save the file after the new filename has been given. The old file will not be replaced, but a new file with this new name will be formed.
4. To run TRANSYT-7F, press "T" from the main menu. Give the input and output filenames. Ignore GDF prompt as this is used only for PPD which is not usually required. Ignore the next "Punch Data?" prompt unless a fine-tuning of the signal timing is desired. When a fine-tuning of the signal timing is desired, give a new file name at this prompt. TRANSYT-7F will develop a new data input file which does not need modifications at all and which can be used to "fine-tune" initial timing plans developed by TRANSYT-7F during the run. Note that, to enable TRANSYT-7F to punch a new data file, a parameter in card type (card type) 1 must be input which will be discussed in the subsequent sections.
5. Select "R" to read the output. Output cannot be edited unless modifications to the "mct7f" batch file are made. Editing of the output is not required.
6. To print a file, select "S". When this option is selected, a prompt for compressed print is made. A compressed print allows the output file to be printed in a 132-column format. A normal print command allows an 80-column output format. Since the TRANSYT-7F output file cannot be completely printed on the normal print, a compressed print for the output is needed. Answer "y" to the compress prompt so that the entire output is printed on the paper.

4. EXAMPLE PROBLEM FOR TUDI

This section describes various card types that are most essential for developing signal timing plans for a two-level TUDI using TRANSYT-7F. The example problem in terms of the geometric configuration and volumes for the TUDI are shown in Figure 26. Volumes are also shown in Table 1. The link numbering scheme and the phasing sequences for the TUDI for developing optimum signal timing plans are shown in Figure 27. TRANSYT-7F will be used to determine phase splits and offsets using the phase sequence shown in Figure 27. The input coding process in TRANSYT-7F for PASSER III output will later be discussed in Chapter 5.

Several assumptions are made regarding lost times, saturation flows, etc., in the current evaluation. All the assumptions were mentioned in the earlier sections of Chapter 2. However, major assumptions are reiterated again.

As mentioned, the example problem for coding the TUDI is shown in Figure 26. The traffic volumes and the geometric configuration are also shown in the figure. A saturation flow rate of 1800 vphgpl is assumed for all approaches. As explained earlier, a thorough analysis of the appropriate range of cycle lengths is not made and hence, a cycle length range of 60 to 90 sec. is assumed. The phasing sequence adopted is the PASSER III phasing sequence as shown in Figure 27. A 4 sec. yellow change interval duration, a start-up lost time and a clearance lost time of 2 sec. each are assumed. A distance of 300 ft. between the two intersections at the TUDI is assumed. Left turns are protected, and right-turn on red is permitted. Traffic conditions are assumed to exist for 15 minutes.

Titles for various cards available in TRANSYT-7F are given in Figure 28. Remember that the values of parameters in any card must be changed (edited) by going into the Window mode after pressing the "Esc" key. Once all the input has been completed, the file should look same as in Figure 29 for the given example.

Table 1. Traffic Volumes at the TUDI for the AM Peak - Year 1990.

Movement	Volume	Movement	Volume
101	125	201	46
102	180	202	110
103	75	203	200
104	48	204	200
105	969	205	955
107	1005	206	242
108	360	207	1055
110	193	209	137
111	237	212	232

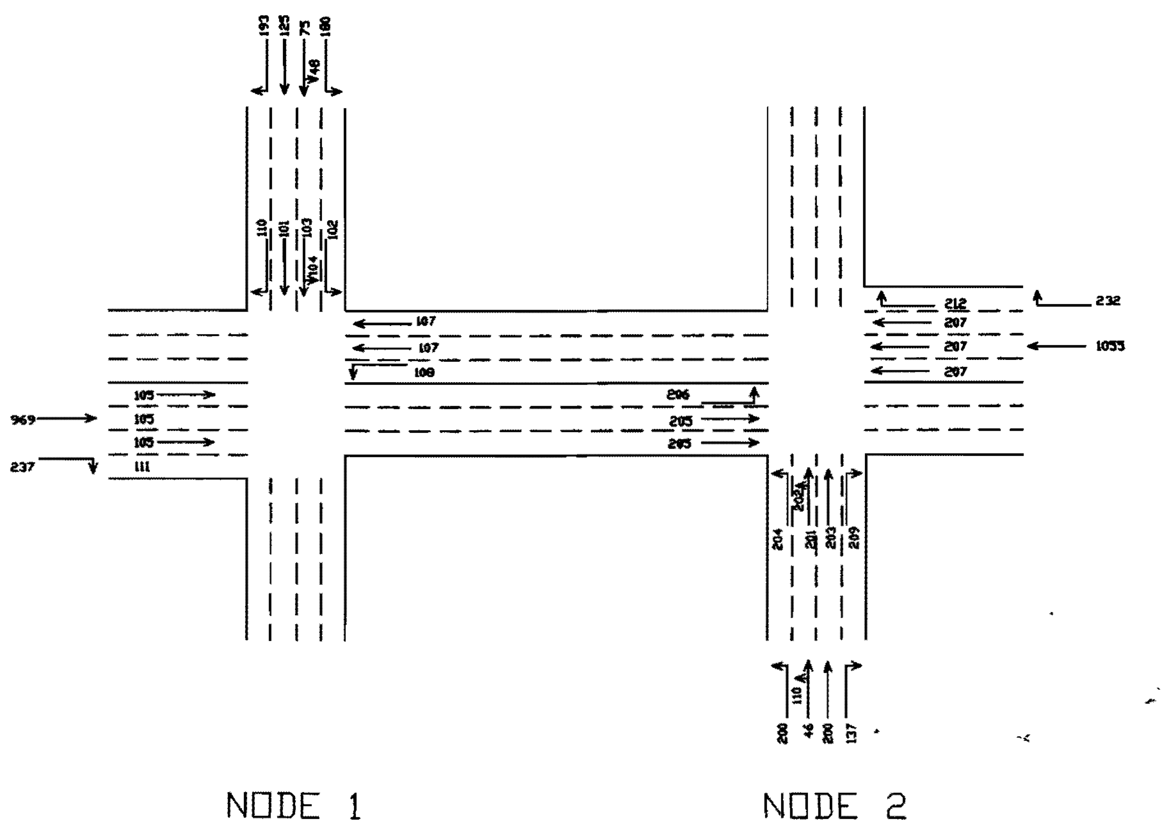


Figure 26. TUDI Configuration and A.M. Volumes for the Example Problem.

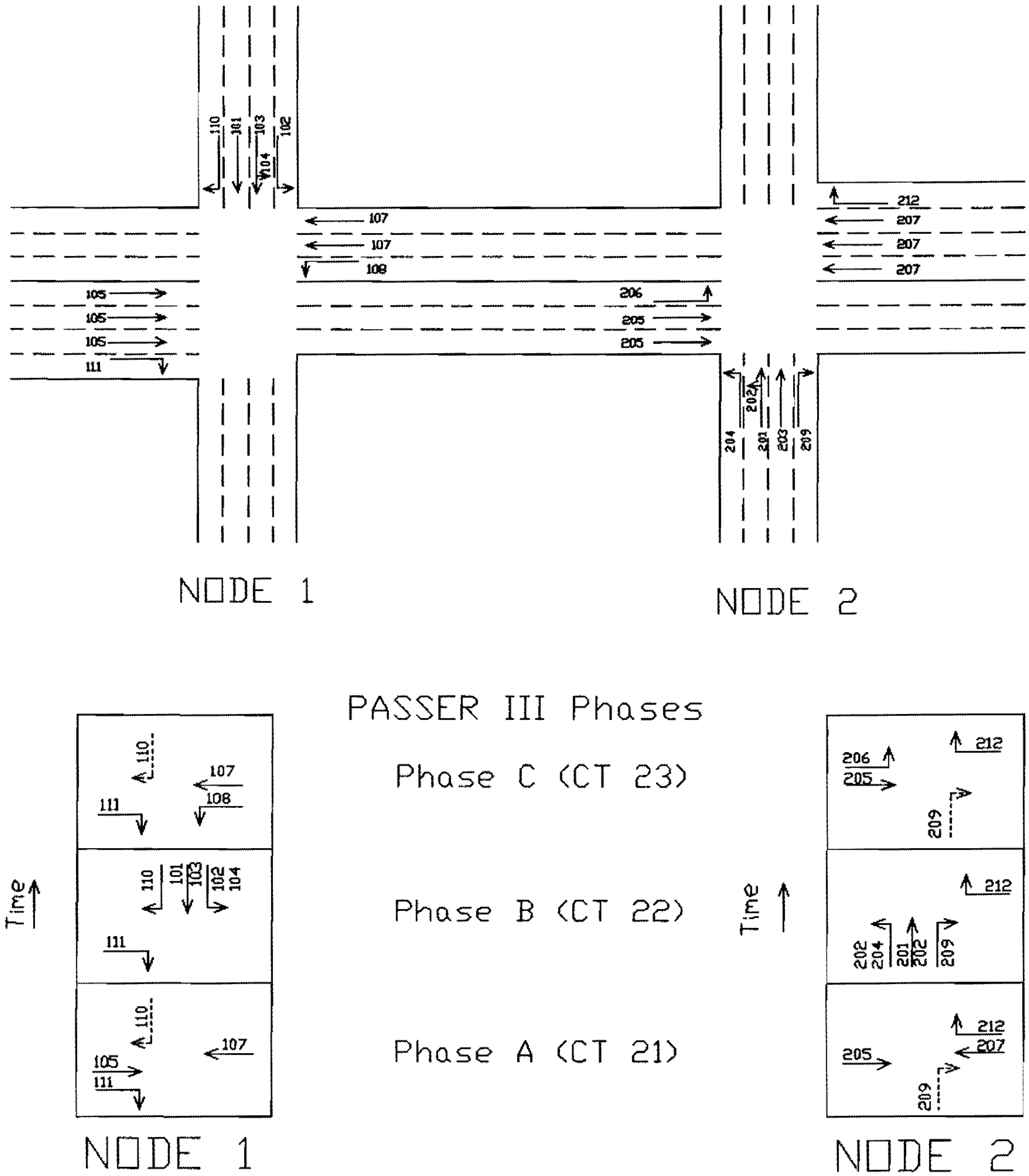


Figure 27. Node-Link and Phase Diagram for the TUDI Example.

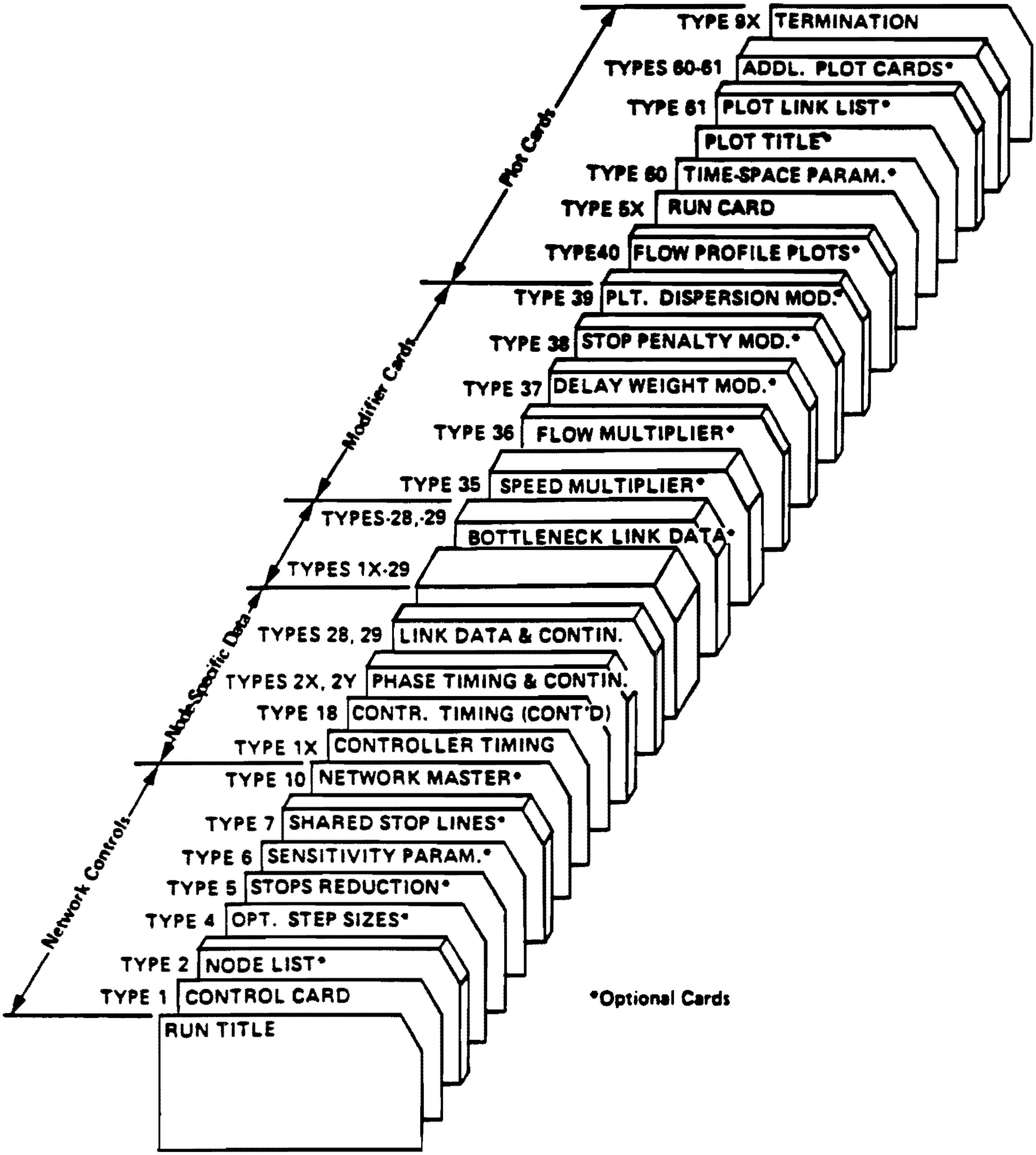


Figure 28. TRANSYT-7F Card Titles.

---------------------Evaluating TUDI FOR 1990 Traffic-----------

1	60	90	5	3	1	2	2	-1	1	1	15	0	0	0	0
2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	103	104	0	0	0	201	202	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	1	85	25	40	100	125	120
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	6	105	107	-110	111	0	0	0	0	0
22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0
28	101	0	1800	125	0	0	0	0	0	0	0	0	0	0	0
28	102	0	1800	180	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1700	75	0	0	0	0	0	0	0	0	0	0	0
28	104	0	0	48	0	0	0	0	0	0	0	0	0	0	0
28	105	0	5400	969	0	0	0	0	0	0	0	0	0	0	0
28	107	300	3600	1005	0	202	110	21	204	200	21	207	695	21	0
28	108	300	1800	360	0	207	360	21	0	0	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
13	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	2	1	1	2	0	6	205	207	-209	212	0	0	0	0	0
22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0
28	201	0	1800	46	0	0	0	0	0	0	0	0	0	0	0
28	202	0	0	110	0	0	0	0	0	0	0	0	0	0	0
28	203	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	204	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	205	300	3600	955	0	102	180	21	104	48	21	105	727	21	0
28	206	300	1800	242	0	105	242	21	0	0	0	0	0	0	0
28	207	0	5400	1055	0	0	0	0	0	0	0	0	0	0	0
28	209	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	50	0	0	0	0	0
28	212	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
52	0														
90															

Figure 29. Completed TRANSYT-7F Input for TUDI Example.

CARD TYPE 1 : RUN CONTROL CARD

Field Description

1 The number of the card type and should always be 1.

2 The lower range of cycle lengths to be evaluated. For our case (TUDI with four-phase, two-overlap), this is set at 60 sec. A large range results in a higher execution time. Hence, 60 sec. for a TUDI is appropriate. Also, it is unlikely that a TUDI would operate efficiently (good progression and lower delays) at lower cycle lengths. Hence, this value should always be properly selected. Pedestrian requirements also should be kept in mind when selecting the lower range of cycle length.

3 The upper range of cycle lengths to be evaluated. An appropriate value can be given based on volumes, and engineering judgement. Generally, for higher volumes, the cycle length will not be more than 100. Hence, 90 sec. has been chosen for this value. The range of cycle lengths to be evaluated should be based on judgement or prior calculations using other software. The cycle length will be kept constant for the interchange over the 15 minute time period of study.

4 The increment by which the above range of cycle lengths should be evaluated. The range should be evenly divisible by this value. In our example, 5 sec. has been used. This is also the default value.

5 The seconds per step resolution to be used for cycle length evaluation. As mentioned previously, TRANSYT-7F divides the cycle length into short time increments called steps. The sec./step value is entered here. Though a lesser value would yield more accurate results, it would take a lot of execution time. Hence, TRANSYT-7F limits the number of sec./step to 60 per cycle. In our example, this field is 3 sec. which is also the default value.

6 The seconds per step resolution for optimization. This is similar to field 5 except that a smaller value should be given because this value will be used for final optimization runs. The default value is 1 which is usually recommended.

7 The network-wide start-up lost time. This time is usually 2 sec. Note that TRANSYT-7F defines this time as the time it takes the first vehicle to clear the stop line. This value can be changed for individual links on card type 29.

8 The network-wide extension of effective green which is defined as the change interval (yellow) minus the end lost time. This value can be changed for individual links on cards to be described later. It is usually 2 sec.

9 The network-wide stop penalty. A non-zero value must be given in this field. A value of 0 indicates that delays only are to be minimized and stops are not to be considered in calculating the PI. If a 1 is coded, then delays and stops are to be considered in calculating the PI. Thus, in minimizing the PI, delays and stops are minimized. A higher value should be given if stops are deemed more critical. Weights for stops and delays can also be modified by other card types to be described later. A value of -1 would result in minimizing the excess fuel consumption due to delays and stops. The default is 0. In our example, a -1 is coded to minimize excess fuel consumption due to stops and delays.

10 The output level flag. A range from 0-3 can be coded. A "0" is used for cycle length evaluation, "1" for final optimization run, "2" for analysis of existing conditions (simulation), and "3" for evaluation of different cycle lengths. Since optimum timing plans are to be developed for the TUDI in this case, code "1".

11 The initial signal timings flag. Input "0" if all the offsets and signal phase timings are known and an evaluation or optimization is to be made. Input "1" if offsets and phase timings are to be determined by TRANSYT-7F. A "1" has been coded since the aim is to determine optimum offsets and splits for the TUDI using the program. If offsets or splits are input, they will be ignored.

12 Study length in minutes. Period of time for which traffic conditions exist. This is generally 15 minutes. For undersaturated conditions, this could be 30 minutes also. Though traffic counts may have been taken only for 15 minutes, the volume should be coded in veh/hr. All MOEs given by the program will similarly be on a per hour basis.

13 Signal timing units flag. User must provide all offsets and splits (if any), in sec. if a "0" is coded. If a "1" is input, all offsets and phase durations should be given in units of percent of cycle.

14 Speed/travel time flag. A "0" for coding speed in mph, and "1" for using travel time instead of speed.

15 English/metric units flag. Use "0" for link lengths in ft, and "1" for meters.

All values in fields 13, 14, and 15 should be coded "0" as most of the time speed is in mph, length in ft, and so on.

16 Punch flag. A "1" input here will punch a new data deck to fine tune the signal timings. The meaning of punching a new data deck has been explained at the end of Chapter 3 in step 4. A "0" will not develop new data deck. Card type 1 is shown below for the present case of TUDI for the 1990 data. A new field starts after each column space between the numbers below:

1 60 90 5 3 1 2 2 -1 1 1 15 0 0 0 0

To get back to edit another card, follow steps 4 or 5 in Chapter 3 on page 42.

CARD TYPE 2 : OPTIMIZATION NODE LIST CARD

Field Description

1 The number of the card type and should always be 2.

2-16 Node numbers of nodes (intersections) to be optimized. For a TUDI, these are 1 and 2. Nodes not mentioned here will not have their phase and offset durations optimized, and their phase timings should be provided even if field 11 on card type 1 is coded "1". If offsets between the two intersections are to be held fixed, code the first intersection 1 with a negative sign (-1) and the next one with a positive sign (2). TRANSYT-7F will not change the offset for grouped nodes. However, when a range of cycle lengths is given, the offsets and splits will be optimized even for grouped nodes. In the present case, all offsets and splits will be determined by the program. Since a range of cycle lengths is being given in the present case, fixed offsets will be ignored by the program. Also, when the initial timing flag in field 11 of card type 1 is coded as 1, TRANSYT-7F ignores any coded offset. Thus, fixed offsets are not coded. Node and link numbers that should be adopted for the TUDI are shown in Figure 27. The coded card looks as shown below:

2 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0

CARD TYPE 4 : OPTIMIZATION STEP SIZES CARD

This is a card which is not used in our current example. But, if this card is needed, it has to be inserted because TRANSYT-7F does not generate this card in the skeleton file. To insert a new card, follow step 7 in Chapter 3 on page 42. Refer to User's manual for a description of this card.

CARD TYPE 7 : SHARED STOP LINE CARD

This important card was not generated by the skeleton file. So, this card has to be inserted in the file because it is clear in the configuration of the TUDI (Figure 27) that the frontage road through and left turn movements share a lane. This card is required for all shared link movements. The card is used for link movements which share lanes such as through and left sharing one lane. As many card type 7s as necessary can be coded. A link can be a through, a left, or a right turn movement. Link numbers for TUDI are shown in Figure 27. This card must be used for any movement that shares a lane with any other movement.

Field	Description
1	The number of the card type and should always be 7.
2	The first link in the set of links that share the stop line. This link is usually the through link.
3-6	The second link that shares a lane with the link listed in field 2. This link could be either a left or right turn movement. The second link could also be the through movement when the first link in field 2 is either a left or right turn movement. But, such is rarely the case. Usually, the through movement is coded as the first link.
7-16	Same as 2-6 for a 2nd and 3rd set of shared links. Remember: 1. Any left or right turning bay is a separate link and not a shared link. 2. All shared links must use the same signal timing. That is, they must move in the same signal phase and time.

3. No saturation flow (s) must be coded for any secondary shared links such as left turn links, or right turn links which share a lane with the through link. Saturation flows will be coded on card type 28 to be described later.

For our example TUDI, the through and left turns on frontage roads share lanes as shown in the configuration in Figure 27. The major problem here is that the left turn has an exclusive lane and a shared lane. So, a saturation flow must be coded for this link to identify it as an exclusive lane. At the same time, it should also be identified as a shared link for which the saturation flow must not be coded. To avoid this problem, two link numbers have been given to the same left turn link. Thus, 102, 104 are the same frontage road left turns, 102 being exclusive and 104 being a shared link with through movement 103. Same is the case with the through movement. Links 101 and 103 are the same frontage road through movements; 101 is an exclusive through, whereas 103 shares a lane with 104. Note that it is not necessary to give 2 link numbers to the through movement here. This is because a saturation flow can be coded for the primary shared link. Hence, a combined saturation flow for both exclusive and shared lanes would have been sufficient. However, in order to have accurate results, this procedure was not adopted. Card type 28 discusses how volumes have been divided between the two links for the same movement. The case is similar at the second intersection. In essence, card type 7 for the present case, looks as given below:

7 103 104 0 0 0 201 202 0 0 0 0 0 0 0 0

CARD TYPE 10 : NETWORK MASTER CARD

Field	Description
1	The number of the card type which should be 10.
2	The master node of the network. All offsets will be referenced to the start of the first interval at this node. This node could generally be the first intersection. In our case, this is 1, the first (left side) intersection. A '0' coded in this field means that the master node is an arbitrary time base which is applicable to SPUIs and AGIs.

3 The network yellow change interval duration. When an initial timing flag is given as '1' in field 11 on card type 1, this duration will be the default value used by the program for the change interval. Change intervals are always an input in TRANSYT-7F. A default value of 4 will be used if this field is left blank. A value of 4 sec. has been used for the current example. Lost time as defined by TRANSYT-7F is as follows:

Total Lost Time = Start up lost time + Change interval - Extension of Green.

4 A network red clearance interval, if any. No red clearance has been used for our case.

5 A network saturation flow rate. This rate is only used to calculate the number of lanes. For all other purposes (MOEs, etc), link wise s as given on card type 28 (to follow) will be employed. Default is 1700 vphgpl. A value of 1800 vphgpl recommended by HCM has been used here. TRANSYT still uses card type 28 for the input of saturation flow rates for individual links including shared lanes. See card type 28 for details.

6 Network approach speed for external (entry) links. This speed is used to calculate fuel consumption on external links. For internal links, speeds will be given on card type 28. The default value of 30 mph has been retained.

7 The network platoon dispersion factor (PDF). The factor ranges from a low of 0 to a high of 0.5. The default value is .35 which is applicable to light turning traffic, and light pedestrian traffic based on the empirical studies made by TRRL (*2*). For higher volumes and moderate to heavy pedestrian traffic, a value of 0.5 may be appropriate. For low friction (12-foot lanes, no parking, etc.), a value of 0.25 is suggested. All the values were provided by the University of Florida (*3*). The default has been retained in the present case and is of little consequence for interchanges.

8 An adjustment factor for the fuel consumption estimates. No guidelines are available. Hence, retain default of 100 (i.e. 1). The fuel consumption estimates can still be used for analysis, since the same factor will be used for all types of interchanges.

9 An average vehicle spacing which is used to calculate queue capacity. A default spacing of 25 ft is appropriate and has been used.

10 The orientation flag. A value greater than or equal to '1' indicates that the link numbering scheme is consistent with Figure 3. Code '0' to indicate that the link numbering scheme is different from the scheme shown in Figure 3.

11 Desired degree of saturation for actuated controllers. Leave blank or retain default. This is applicable to actuated controllers. Even if a value is given, it will be ignored unless it is specified that this is an actuated controller on card type 2X later.

12 Degree of saturation for double cycle. This is the field to identify nodes which can be double cycled. A double cycled node is that node which completes two cycles within one cycle of the network. If any node has a maximum degree of saturation (v/c) less than the value coded here, that node will be double cycled. Adopt a default value of 25%. This value, however, is not of any particular use in case of interchanges. It is useful for network optimization but not for interchanges.

13 Queue penalty value. If queue is included in the calculation of PI, the value coded here will be applied in the calculation. Since queue is not included in PI in the current case, leave blank. If any value is coded, it is ignored.

14 Inflation rate. This is more useful to currencies other than dollar. Leave blank (default 100).

15 Fuel cost (cents/gallon). Default is 125.

16 Vehicle occupancy times hundred. Use a default of 120 (1.2).

The coded card type 10 looks as shown below:

10 1 4 0 1800 30 35 100 25 0 85 25 40 100 125 120

CARD TYPE 1X : CONTROLLER TIMING CARD

Field Description

1 The number of the card type, 1X. The value of 'X' is the number of phases at the node coded in the next field. This is 13 (3 phases, 'A', 'B', and 'C') for the TUDI at each intersection and the three-phase SPUI, 14 for the AGI and the four-phase SPUI, and 12 for the TLDI at all intersections. Each phase consists of at least 2

intervals. For the TUDI (shown in Figure 27), phase 1 is 'A' which is the external and internal through movements at the left side intersection (i.e., 105 and 107), phase 2 is 'B' which is the frontage road movement (101, 102, 103, and 104), and phase 3 is 'C' which is the internal through and left at the left side intersection (107 and 108). Link numbers which move during phase 'A' at the right side intersection are 205, 207, and two other right turns (209 and 212). In phase 'B', the frontage road movement and a cross street right turn move. Lastly, in phase 'C', 205, 206, and two right turns, one each from frontage road and cross street move.

2 The node number for this intersection.

3 The input offset for this node referenced to the master node. When field 11 in card type 1 is coded as '1', leave blank because offsets are to be determined by TRANSYT-7F and not input. Even if the offset is specified, it will be ignored if initial timing is coded as '1'. In our case, leave blank.

4 The interval to which the offset is referenced to at this node. It will be referenced to the start of the specified interval. The interval used in our case is the first interval. For the master node, this field can be left blank as there will not be any offset. But, for other intersections, there would be some offset and, hence, this field would have to be specified.

5-15 The duration of intervals 1 through 11. Interval 1 will be green, 2 yellow, and 3 all red, if any. If there is no all red interval, interval 3 will be green. If initial timing is given as '1' on card type 1, leave all the fields blank since timings will be optimized and determined by TRANSYT-7F. Remember that for a three-phase signal, there should be at least 6 intervals, and for a four-phase, 8 intervals, and so on. For additional intervals that could not appear on this card, input card type 18 which is a continuation card. All parameters in card type 18 are similar to those in this card.

16 An option to double cycle the node. Since there will not be any node in our case whose v/c will be less than 25%, input '0' here. For both the intersections, the card types would be:

First Inter. 13 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Second Int. 13 2 0 1 0 0 0 0 0 0 0 0 0 0 0 0

Note that these two cards will not be given in succession. Any data for the second intersection must appear after all the link data (on card type 28 and/or card type 29) has been completed for the first intersection. Also, for the second intersection, the offset is being referenced to the start of the first interval 'A'. That is, the offset that will be output by the program will be the time from start of 'A' at the 1st intersection to the start of 'A' (and NOT 'C') at the 2nd intersection. Note that the intervals 'A' and 'C' here refer to PASSER III phasing definitions.

CARD TYPE 2X - PHASE TIMING CARD

Field	Description
1	The number of the card type, 2X. 'X' here is the number of the signal phase, e.g., phase 1, phase 2, and so on. The number of card types 2X that should appear must be equal to the 'X' in card type 1X. For example, if there are 3 phases, 3 card types 2X (21, 22, and 23) must appear, one following the other in sequential order. 21 represents the first phase, 22 the second, and 23 the third phase. If there are 4 phases (e.g., AGI and SPUI), card type 24 will also exist.
2	Node number which must be same as the node number in card type 1X.
3	The number of the interval in card type 1X (fields 5-15), which is the start of green interval for this signal phase. If a red clearance interval is absent, this value will be '1', '3', '5', etc., depending on the signal phase (21, 22, or 23). This means that phase 1 (CT 21) consists of intervals 1 and 2, where interval 1 is the green interval and 2 is the yellow interval. The number of the yellow interval is coded in field 5. Phase 2 consists of intervals 3 and 4 (3 is green and 4 is yellow), and so on.
4	The number of the interval that can have variable time for this phase. This is most generally the green interval, i.e., either '1', '3', '5', etc., for card types 21, 22, and 23, respectively. These intervals can be varied by the program to obtain optimum timing values.
5	The number of the yellow change interval. Again, if a red clearance interval is not there, this field will have '2', '4', '6', etc., for phases 21, 22, and 23 respectively as explained above. These intervals are referred to as fixed intervals by TRANSYT-7F.

Hence, these values are not optimized. They have to be provided by the user as data inputs in this field. If left blank, TRANSYT-7F uses default values as coded on card type 10 in field 3. Table 2 shows the concept of fixed and variable intervals as defined by TRANSYT-7F.

6 The number of the red clearance interval. If this interval does not exist, leave this field blank.

7 The minimum phase duration of this phase. Always give a minimum of 6 sec. if this duration is not known. The 6 sec. duration is to ensure that the minimum phase duration is atleast equal to the sum of the start-up lost time (2 sec.) and the yellow change interval (4 sec.). Consider pedestrian requirements in giving this value.

8-15 Link numbers which receive green during this phase. Links which receive green during a particular phase are shown in Figure 27. The figure shows that in the first phase (Phase A or in other words card type 21) at node 1, links 105 and 107 move. So, code 105 and 107 for this phase. For the second phase (phase B), 101, 102, 103, and 104 move. Hence, code these movements on card type 22 as they move in the second phase. Similarly code the third phase. Links which are permitted should be coded as negative numbers. Since left turns are protected in our case, they will be positive. But, right turns are permissive in certain phases when they have to yield to the through traffic when right-turn-on-red is permitted. Each right turn becomes permissive when an opposing through movement is moving. These related movements are shown in Table 3. When any of the through movements shown in the table are moving in any phase, and an additional lane is not available for the right turn, code the corresponding right turn as negative to identify that the right turn movement yields. If the fields are not sufficient to code all the links that move in this phase, input a phase continuation card 2Y where 'Y' should be the same as 'X' on this card and should appear immediately after this card. All other parameters are the same.

Table 2. Fixed and Variable Intervals for the TUDI Problem*.

	CT 13			CT 13			CT 13		
Type	V	Y	R	V	Y	R	V	Y	R
Number	1	2	-	3	4	-	5	6	-
Length	-	4	0	-	4	0	-	4	0
Min. Phase		6			6			6	
	CT 21			CT 22			CT 23		

* V represents variable interval (green), Y and R are yellow and red clearance intervals respectively. They represent fixed intervals.

Table 3. Opposing Movements for Permissive Right Turns**.

Permissive Right Turn Movement	Movement That Makes Right Turn Permissive
110	107
111	101, 103,108
209	205
212	201, 203,206

** Relate this table to Figure 26 for ease of understanding.

16 Actuated phase flag. Actuated - '1', otherwise '0'. Input '0' since the modeling is for fixed time operations.

The completed data card is shown below.

Node 1

21	1	1	1	2	0	6	105	107	-110	111	0	0	0	0	0
22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0

For node 2 card types 21, 22, and 23 appear after card type 1X at the 2nd node.

Node 2

21	2	1	1	2	0	6	205	207	-209	212	0	0	0	0	0
22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0

CARD TYPE 28 - LINK DATA CARD

Field Description

1 The number of the card type which should be 28.

2 Link number of the subject link being described.

3 Link length of the subject link. This is particularly applicable to internal links. Internal link lengths for the TUDI problem are assumed as 300 ft in each direction. For external links, leave blank unless the approach speed differs from network-wide default.

4 The subject link's total saturation flow rate including all lanes. Leave blank if this link is a shared link or permitted-only link.

5 Total volume on the link (for all lanes) in vehicles per hour.

6 Mid block volume (if any) included in field 5. This volume is generally from parking areas. Since there are no mid blocks assumed, leave blank.

7 Upstream link number that feeds the subject link. For the TUDI, assume that the internal through at the right side intersection is the subject link. Off-ramp left turn (not U-turn) at the left intersection is a feeder for the internal through at the right

intersection. So, enter the off-ramp left turn link number of the left intersection as the link number which feeds the subject link. Similarly, give feeders for other subject links at the left and right side intersections.

8 Link volume for the link coded in field 7 that feeds the subject link. For the TUDI, the entire interior through volume may come from the off-ramp left turn flow. It is always possible that the entire off-ramp left turn volume may not be a source flow.

9 The average speed from the upstream stop line to the subject link's stop line. For external links, leave blank unless the speed differs from the network-wide default coded in field 6 of card type 10.

10-11 Same as fields 7-9 for second and third feeder links. For additional input links to the subject link, use card type 29.

16 The queue capacity value. TRANSYT-7F will calculate the queue capacity value if this field is left blank. For our example, leave blank.

The following cards give an example of how the TUDI links should be coded. One internal link and two external shared links at the left side intersection are given. If the link is not shared, it should be coded in a similar manner as that of link 107 below (if there are no input links, leave corresponding fields blank):

28 103 0 1700 75 0 0 0 0 0 0 0 0 0 0 0 }
28 104 0 0 48 0 0 0 0 0 0 0 0 0 0 0 } Shared Lanes
28 107 300 3600 1662 0 202 110 30 204 200 30 207 695 30 0

It can be seen that 202, 204, and 207 are feeder links to link 107. Similarly, a part of the flow (traffic which is turning left) of 207 is an input link to 108. Follow the same steps for the right side intersection (node 2). For the right side intersection, 102, 104, and some flow (left turn) of 105 will be feeder links to link 205. Similarly, 105 will be the input link for 206. All other links will be external links. These links should be coded without any input links as coded for link 103 above.

CARD TYPE 29 : LINK DATA CONTINUATION CARD

This card is used for adding or reducing lost times and/or for permitted movements. If neither of these exist for a particular link, do not use this card for that link even if the card is generated by TRANSYT-7F as a skeleton file. Delete using F8.

Field	Description
1	The number of the card type which should be 29.
2	Subject link number (must be same as field 2 of card type 28).
3	Addition or reduction to the start-up lost time on this link. If this link has a higher or lower lost time, add or subtract the value respectively from the lost time coded earlier on card type 1 in field 7.
4	Additional extension of green time. Time can only be added. This field is useful for SPUIs where the total lost time is higher for left turns. For TUDIs, this is not applicable. Leave blank.
5	Adjustment for the upper limit of the maximum flow rate for permitted movements. If the link is protected-permitted, code the adjusted saturation flow here for the protected-permitted link. This is usually obtained from other software such as PASSER III. Leave blank for our case since there are no permitted left turns.
6	Number of sneakers turning on permitted phase per cycle. Code decimal values as multiples of 10. A value of 2 is 20. Leave blank for TUDI example.
7-9	Same as fields 7-9 of card type 28 for a fourth upstream input link. None for our case of a TUDI.
10	Link number of the movement that opposes the subject link. For permitted movements, this is obviously the opposing through movement. But, for the right turns, as shown in Table 3, there could be two movements for which the right turn needs to yield, and hence, becomes permissive. When these opposing movements are moving in a phase, the permissive right turns should be coded as such on card type 1X, and in this field.
11	Percentage of traffic that opposes the subject link. This is self-explanatory. For the left turns, 100% of opposing through applies. For the right turns, if there is more

than 1 lane for the opposing through, 50% or less will apply. See example on the card below.

12-15 Same as fields 10 and 11 for two or more opposing links.

16 Permissive movement model override. See TRANSYT-7F manual for details. Leave blank, and TRANSYT-7F will apply the default. The coded card looks as shown below for a right turn which has to yield to the through traffic.

29 110 0 0 0 0 0 0 0 107 50 0 0 0 0 0

If the left turn is permissive, follow the same pattern. For the TUDI, right turns 110 and 209 only yield to the through movements. All other right turns are protected (see card type 2X).

At the right side intersection, link 209 should be coded similarly except for the opposing link. The opposing link for 209 will be 205.

CARD TYPE 37 : DELAY WEIGHT MODIFICATION CARD

Field Description

1 The number of the card type, 37.

2 Factor which when divided by 100, multiplies the delay calculation on this link. Code a higher factor (such as 5000) to achieve good progression. This is the recommended way to try to achieve good progression using TRANSYT-7F. Bandwidth constraint requires all signal timing parameters to be input. Hence, coding a higher penalty for delay on internal through and left links results in good progression, but probably higher overall delays.

3-16 List of link numbers for which the value in field 2 applies. Code all internal throughs and left turns for TUDI and also three-level diamond interchanges to result in good progression.

These fields have not been coded, but are recommended for good progression.

If coded for internal progression, the card looks as below.

37 5000 107 108 205 206 0 0 0 0 0 0 0 0 0 0

Since good progression can only be achieved by reducing delays and stops for internal links, only internal links have been shown above as an example. Do not give weight modification to external links as this will not result in progression on the internal links.

CARD TYPE 5X : RUN CARD

Field Description

1 The number of the card type, '5X'. 'X' could be as follows:

0 = Simulation or optimization controlled by card type 4 step sizes. If a range of cycles is given, the cycle length will be decided by the step size listed on card type 4, and optimization will be performed based on the step size generated internally by the program.

1 = Simulation run only.

2 = Normal optimization run. If card type 4 is coded, it will be ignored. The best cycle length will be selected based on quick optimization. Final optimization will be done using this best cycle length. For optimization, code card type 52 as in this problem.

3 = Quick optimization run using step sizes generated internally.

4 = Cycle length evaluation run only. No optimization will be done.

9 = Process input data for input errors only.

2 Definition of PI. Optimization criteria can be chosen as any of:

0 = Delay, stops, and fuel consumption.

1 = Same as 0 plus the maximum back of queue.

2 = Operating cost.

3 = Same as 2 plus the maximum back of queue element.

Normally use 0.

3-16 Not applicable or defined.

The coded card is as follows.

52 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

CARD TYPE 9X - INPUT TERMINATION CARD

Field Description

1 Card type, 9X.

X = 0 indicates that no other input data follows. Hence, code 90.

X = 1 indicates that another input case is to follow. This is generally used if a number of input files are to be processed simultaneously. This is not generally used.

2-16 Not used. Leave blank.

Once the input is complete, follow the procedures stated in steps 1-6 at the end of Chapter 3 for saving, executing, and using other commands.

5. INPUT CODING FOR PASSER III OUTPUT

This section discusses the input format for optimizing phase timings produced by PASSER III. The example problem given in Chapter 4 and shown in Figure 26 was coded in PASSER III, and the best cycle length output by the program was 60 sec. The internal travel time as input was 10 sec. For this travel time, the offset given by the program was 8 sec. The phase lengths for each of the phases 'A', 'B', and 'C' at the left side intersection were 23 sec., 16 sec., and 21 sec., respectively. At the right side intersection, the corresponding phase lengths were 23 sec., 14 sec., and 23 sec., respectively. These offsets and phase lengths should now be coded in TRANSYT-7F input in order to obtain optimized results. The coding process for PASSER III output in TRANSYT-7F largely remains the same as discussed in Chapter 4 except for a few cards. These cards are card type 1, card type 1X (CT 13), and card type 28. Minor modifications given below are needed in these card types for the optimization run.

CARD TYPE 1	**SYSTEM CONTROLS**
Minimum Cycle	[60]
Maximum Cycle	[60]
Cycle Length	[5]
Sec/Step (Cyc)	[3]
Sec/Step (Opt)	[1]
Start Lost Time	[2]
Ext. Eff. Green	[2]
Stop Penalty	[-1]
Output Level	[1]
Initial Timing	[0]
Period Length	[15]
Sec(0)/Percent (1)	[0]
Speed(0)/Time (1)	[0]
U.S.(0)/Metric (1)	[0]
Punch (Y = 1)	[0]

CARD TYPE 13		INTERVAL TIMING NODE 1	Node 2
Node Number		[1]	[2]
Offset or Yield Point......		[0]	[8]
Reference Interval.........		[1]	[5]
Interval Length	1.........	[19]	[19]
. (Note: If the	2.........	[4]	[4]
. '1X' is neg-	3.........	[12]	[10]
. ative (-1X)	4.........	[4]	[4]
. the splits	5.........	[17]	[19]
. will not be	6.........	[4]	[4]
. optimized.)	7.........	[0]	[0]
.	8.........	[0]	[0]
.	9.........	[0]	[0]
.	10.........	[0]	[0]
.	11.........	[0]	[0]
Double Cycle ? (Y=1)		[0]	[0]

Card Type 1

Two coding modifications are noted in this type of problem. Note that the range of cycle lengths given in the previous case (Chapter 4) was not given here. This is because PASSER III had provided the optimum cycle length, and hence there is no need to give a range of cycle lengths to be evaluated. Another major change is that of the initial timing parameter. When phase lengths and offsets are available, it is not necessary to have TRANSYT-7F develop phase lengths and offsets but rather optimize the given set of values. Hence, the initial timing parameter has been set to zero in this card as shown on the preceding page. These are the two modifications required in this particular card type.

Card Type 13

Primary changes necessary in this card are with respect to the interval timing parameters. In the earlier case (Chapter 4), the duration of intervals were each given a zero value so that TRANSYT-7F would develop the timings. In the current case, however, the duration of intervals output by PASSER III have to be coded in fields 5-15 of card type 13. Consider the left side intersection first. Interval 1 will be the green duration of phase 'A' in which the external through movement at the left side intersection moves. The total duration of phase 'A' in PASSER III output was 23 sec. Assuming a 4 sec. yellow interval, the green interval thus becomes 19 sec. Interval 2 will be the yellow interval (4 sec.) of phase 'A'. Similarly, interval 3 and 4 are green and yellow durations for phase 'B' which are 12 sec. and 4 sec. Likewise, code intervals 5 and 6 which are 17 and 4 sec., respectively.

At the right side intersection, the above discussion also applies, but the values change. The offset for this intersection with respect to the first intersection should be coded when interval timing for the second intersection is being coded. Remember that the offset given in PASSER III (8 sec.) is measured from the start of interval 1 (start of phase 'A') at the left side intersection to the start of interval 5 (phase 'C') at the right side intersection. Hence, code the input offset for this node as 8 sec. in field 3 of card type 13 and the reference interval in field 4 as 5. Note that the reference interval in this case is different from that mentioned in Chapter 4 which was 1. This reference interval was adopted to be consistent with PASSER III output. However, if the methodology described in Chapter 4 is to be adopted, that is if the reference interval at the second intersection is given as 1, then code 31 sec. offset (8 sec. offset + 23 sec. phase 'C' duration).

CARD TYPE 28

The internal travel time given as an input in PASSER III was 10 sec. It is essential to see that the same travel time is coded in TRANSYT-7F also. When the link length is coded as 300 ft (as in the earlier case), the travel time would be 10 sec. only if the speed is 21 mph. Hence, all internal speeds in card types 28 should be coded 21 mph.

The completed input in TRANSYT-7F for PASSER III output is shown in Figure 30.

---------------------Evaluating TUDI for 1990 Traffic ---------------------------

1	60	60	5	3	1	2	2	-1	1	0	15	0	0	0	0
2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	103	104	0	0	0	201	202	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	1	85	25	40	100	125	120
13	1	0	0	19	4	12	4	17	4	0	0	0	0	0	0
21	1	1	1	2	0	6	105	107	-110	111	0	0	0	0	0
22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0
28	101	0	1800	125	0	0	0	0	0	0	0	0	0	0	0
28	102	0	1800	180	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1700	75	0	0	0	0	0	0	0	0	0	0	0
28	104	0	0	48	0	0	0	0	0	0	0	0	0	0	0
28	105	0	5400	969	0	0	0	0	0	0	0	0	0	0	0
28	107	300	3600	1005	0	202	110	21	204	200	21	207	695	21	0
28	108	300	1800	360	0	207	360	21	0	0	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
13	2	8	5	19	4	10	4	19	4	0	0	0	0	0	0
21	2	1	1	2	0	6	205	207	-209	212	0	0	0	0	0
22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0
28	201	0	1800	46	0	0	0	0	0	0	0	0	0	0	0
28	202	0	0	110	0	0	0	0	0	0	0	0	0	0	0
28	203	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	204	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	205	300	3600	955	0	102	180	21	104	48	21	105	727	21	0
28	206	300	1800	242	0	105	242	21	0	0	0	0	0	0	0
28	207	0	5400	1055	0	0	0	0	0	0	0	0	0	0	0
28	209	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	50	0	0	0	0	0
28	212	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
52	0														
90															

Figure 30. TRANSYT-7F Input for PASSER III Output.

6. EXAMPLE PROBLEM FOR A THREE-LEVEL DIAMOND INTERCHANGE

This chapter briefly describes the input coding procedure to develop optimum signal timing plans for a three-level diamond interchange (TLDI) having 4 one-way frontage roads. The configuration of the three-level diamond and the volumes at the interchange for the AM peak in 1990 are shown in Figure 31. The volumes are shown in a tabular form in Table 4. The link numbers and the phasing diagram for the TLDI are shown in Figure 32. All external phases are assumed to start at the same time. This interchange and the adopted phase sequence do not represent an existing one, nor is it an exact representation of a three-level diamond interchange. For simplicity, no shared lanes are assumed. However, a more realistic TLDI was evaluated with shared lane operations. The input coding is shown in the Appendix. The input coding for the present case is described below. Note that there is no explanation given for many of the default parameters because most of them essentially share the same description with that of the TUDI explained in detail in Chapter 4. The input links are not explained as the user is assumed to know how a TLDI operates and how the turning movements take place at each intersection. Input modifications (or additions) needed for the TLDI in different cards described in Chapter 4 are discussed below. Fields not mentioned will have the same type of input as that of a TUDI.

CARD TYPE 1 : RUN CONTROL CARD

Field	Description
1	1 (card type).
2	Minimum cycle length of 30 sec. A 30 sec. cycle length is often too low for a TLDI. But, it has been chosen for this particular problem because the volumes do not seem to be high enough to justify higher cycle lengths. No analysis was made to determine the minimum or maximum limits of the cycle lengths since the aim was to model various interchanges.
3	Maximum cycle length of 60 sec.
4-16	These fields are the same as the example problem of TUDI described in Chapter 4.

Table 4. Traffic Volumes at the Three-Level Diamond Interchange for the Year 1990.

Movement	Vol.	Movement	Vol.	Movement	Vol.	Movement	Vol.
103	606	201	510	301	442	403	474
104	228	205	228	302	310	407	310
105	242	206	242	307	360	408	360
111	237	209	137	312	232	410	193

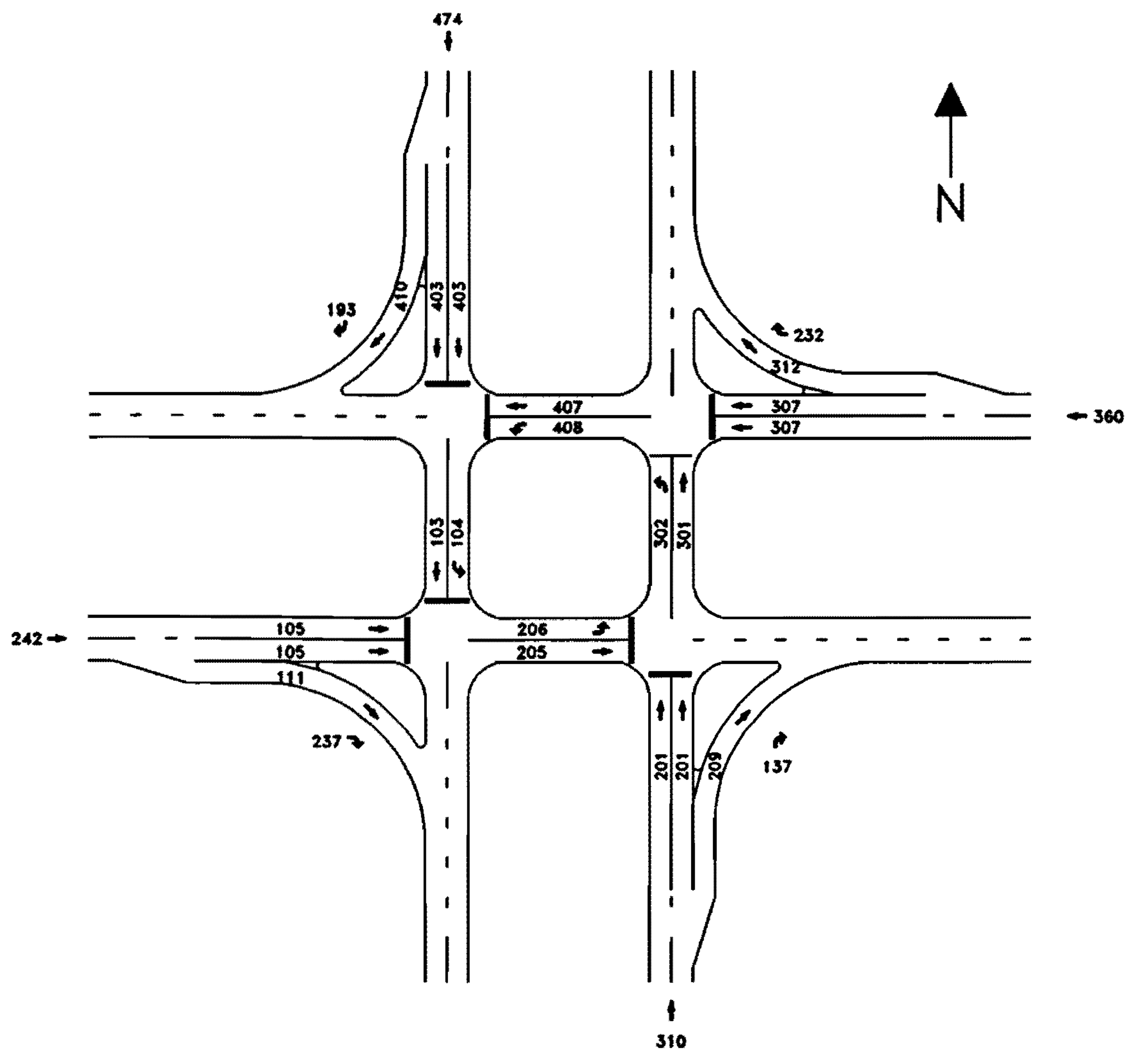
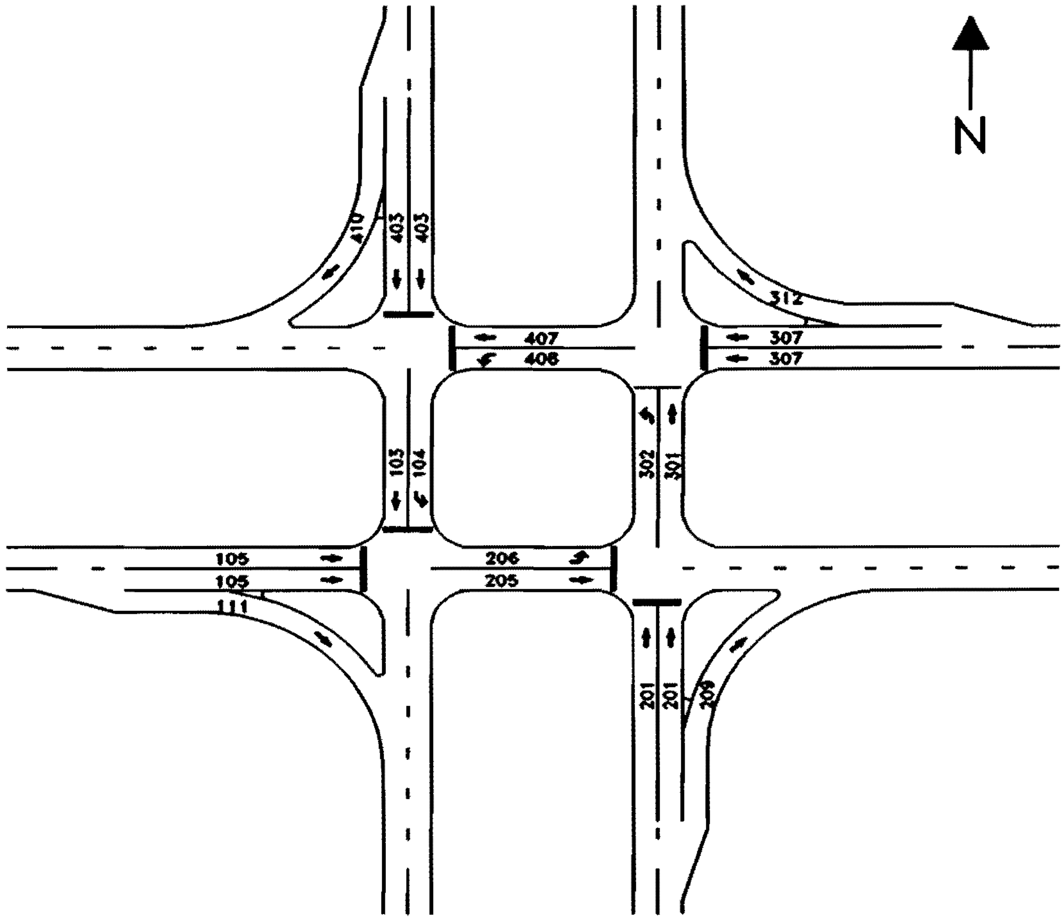


Figure 31. Configuration and Volumes for TLDI Example Problem.



PHASE DIAGRAM				
	NODE 1	NODE 2	NODE 3	NODE 4
PHASE 1	105 111	201 209	312 307	410 403
PHASE 2	103 104	206 205	302 301	407 408

Figure 32. Node-Link and Phase Diagram for TLDI Example Problem.

Fields 4-16 are identical and have the same values as that of the example problem for the TUDI. The lost times are assumed as 4 sec. at each intersection for the current example.

CARD TYPE 2 : OPTIMIZATION NODE LIST CARD

Field	Description
1	2 (card type).
2-16	There are 4 intersections for which signal timing have to be optimized in this case of the TLDI. Hence, code all 4 intersections here, that is, 1, 2, 3, and 4 where these numbers are the node numbers as shown in Figure 32.

Card type 7 will not be used as there are no shared links in this case.

CARD TYPE 10 : NETWORK MASTER CARD

Field	Description
1-16	Same as the TUDI example problem. All the values can be retained as these are the values being adopted in the TLDI case also. The master node is node 1. Ideal saturation flow of 1800 vphgpl and the 30 mph default speed are retained. The speeds between intersections within the TLDI are assumed to be 30 mph.

CARD TYPE '1X' : CONTROLLER TIMING CARD

This card is required for each of the four intersections at the TLDI. Each intersection will have two phases: one, for moving the external movements, and the second, for moving the internal movements. See Figure 32 for a clear comprehension of the phases and the corresponding link movements which move during a particular phase at each of the four intersections.

Hence, the card type '1X' in this case is 12 where X is the number of phases as explained earlier in Chapter 4. For our case, X is 2 at each intersection. The card type as it looks in the window mode is shown below. Note that this card type is given below for all the intersections at the interchange. Also, note that the card does not differ significantly from the TUDI example card, except that there are 2 phases and that there are 4 nodes while the previous example had 3 phases at each of the two nodes. All the reference intervals (offset measurements) will be made to the start of the first interval of the first phase at each intersection.

Card Type 12 Interval Timing		**Node 1**	**Node 2**	**Node 3**	**Node 4**
Node Number		[1]	[2]	[3]	[4]
Offset or Yield Point		[0]	[0]	[0]	[0]
Reference Interval		[1]	[1]	[1]	[1]
Interval Length	1....................	[0]	[0]	[0]	[0]
. (Note: If the	2....................	[0]	[0]	[0]	[0]
. '1X' is neg-	3....................	[0]	[0]	[0]	[0]
. ative (-1X)	4....................	[0]	[0]	[0]	[0]
. the splits	5....................	[0]	[0]	[0]	[0]
. will not be	6....................	[0]	[0]	[0]	[0]
. optimized.)	7....................	[0]	[0]	[0]	[0]
.	8....................	[0]	[0]	[0]	[0]
.	9....................	[0]	[0]	[0]	[0]
.	10..................	[0]	[0]	[0]	[0]
.	11..................	[0]	[0]	[0]	[0]
Double Cycle ? (Y=1)		[0]	[0]	[0]	[0]

CARD TYPE 2X : PHASE TIMING CARD

Card type 2X at any of the four intersections will consist of card types 21 and 22 since 2 phases were given in the previous card 12. Card type 21 (phase one) will move the external link movements, and card type 22 (phase 2) will move the internal through and left turn movements. For a clear understanding of how the link movements occur in each phase, refer to Figure 32. For example, in phase 1 (i.e., on card type 21) at the first intersection, external movement 105 would move. Since the right turn (link number 111) becomes protected when the contiguous through is moving, the right turn would move protected in this phase. In the second phase (on card type 22), the internal through and left turn link movements move. These links are numbered in our example as 103 and 104. It should be recognized that, in this phase when the through and the left turns move, the right turn cannot maneuver in a protected phase since it has to yield for the opposing through traffic as an additional lane is not available. The case is similar with all movements at all the other intersections except that the link numbers obviously change. The following cards 21 and 22 show the phases at all four intersections. Shown below is card type 21 for all the nodes.

Card Type 2X : Phase Timing Card

Card Type 21 Signal Phasing		**Node 1**	**Node 2**	**Node 3**	**Node 4**
Node Number	....	[1]	[2]	[3]	[4]
Start Interval	....	[1]	[1]	[1]	[1]
Variable Interval	....	[1]	[1]	[1]	[1]
Yellow Interval	....	[2]	[2]	[2]	[2]
All - Red Interval	....	[0]	[0]	[0]	[0]
Minimum Phase Length	....	[6]	[6]	[6]	[6]
Links Serviced	1....................	[105]	[201]	[307]	[403]
.	2....................	[111]	[209]	[312]	[410]
. (Negative	3....................	[0]	[0]	[0]	[0]
. Numbers	4....................	[0]	[0]	[0]	[0]
. Mean	5....................	[0]	[0]	[0]	[0]
. Permitted.)	6.................	[0]	[0]	[0]	[0]
.	7....................	[0]	[0]	[0]	[0]
.	8....................	[0]	[0]	[0]	[0]
Actuated Or Desired D/S	....	[0]	[0]	[0]	[0]

Remember that this is only the first phase at each intersection, and the second phase, card 22, is still to be coded. For simplicity, all card types 21 have been given in succession here. But when coding the program to run, card type 22 must appear immediately after card 21. It is only after the phasing and volume coding for one intersection has been completed that the corresponding coding for any other intersection would start. Generally, once the base cards (card types 1, 2, and 10) are given, the coding for any intersection starts with card type 1X. This sequence of cards has been previously explained in Chapter 4.

CARD TYPE 2X

Card Type 22	Signal Phasing Continuation	Node 1	Node 2	Node 3	Node 4
Node Number	....	[1]	[2]	[3]	[4]
Start Interval	....	[3]	[3]	[3]	[3]
Variable Interval	....	[3]	[3]	[3]	[3]
Yellow Interval	....	[4]	[4]	[4]	[4]
All - Red Interval	....	[0]	[0]	[0]	[0]
Minimum Phase Length	....	[6]	[6]	[6]	[6]
Links Serviced	1....................	[103]	[205]	[301]	[407]
.	2....................	[104]	[206]	[302]	[408]
. (Negative	3....................	[-111]	[-209]	[-312]	[-410]
. Numbers	4....................	[0]	[0]	[0]	[0]
. Mean	5....................	[0]	[0]	[0]	[0]
. Permitted.)	6....................	[0]	[0]	[0]	[0]
.	7....................	[0]	[0]	[0]	[0]
.	8....................	[0]	[0]	[0]	[0]
Actuated Or Desired D/S	....	[0]	[0]	[0]	[0]

CARD TYPE 28 : LINK DATA CARD

This card as identified in Chapter 4 deals primarily with volumes, saturation flows, and input link volumes. In the current problem, assume an ideal saturation flow of 1800 vphgpl, a distance of 300 ft between each of the successive intersections, and average speeds of 30 mph. The input link for a particular link can only be understood if the general operation of the TLDI is known. For example, any external through movement (say 105) except the frontage road movement would turn left at the intersection immediately succeeding it (becomes 206). The same left turn (206) at this succeeding intersection now becomes an internal through at the next intersection (becomes 301). Note that 301 also contains some of the frontage road traffic from intersection 2 (coming from 201). The case is similar with all other movements at all the other intersections. The card type shown below is for all the links at intersection 1 and intersection 2.

Card Type 28 Link Data	Node 1				Node 2			
Link Number	[103]	[104]	[105]	[111]	[201]	[205]	[206]	[209]
Link Length	[300]	[300]	[0]	[0]	[0]	[300]	[300]	[0]
Saturation Flow	[1800]	[1800]	[3600]	[1800]	[3600]	[1800]	[1800]	[1800]
Total Volume	[606]	[228]	[242]	[237]	[510]	[228]	[242]	[137]
Midblock Entry	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
1st Input Link No	[408]	[403]	[0]	[0]	[0]	[104]	[105]	[0]
Volume	[360]	[228]	[0]	[0]	[0]	[228]	[242]	[0]
Speed	[30]	[30]	[0]	[0]	[0]	[30]	[30]	[0]
2nd Input Link No	[403]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Volume	[246]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Speed	[30]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
3rd Input Link No	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Volume	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Speed	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Queuing Capacity	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]

The '0's indicate that they do not exist. Card type 29 should follow these cards at the first node. As explained earlier, card 29 is used to give details about permitted links. Hence, it should be used for coding the opposing through traffic for which the right turn 111 should yield. Remember that once all the card types 28 have been completed for all the links at any intersection, card type 29 (if any) should immediately follow. After card types 29, data for the next intersection can be coded. If this is not followed, an error will be printed by the program and the run will be terminated. To ease understanding, all card types 28 have been given in succession in this section. Card type 29 will be presented after card types 28 are completed for all the links at all the nodes.

Card Type 28 Link Data	**Node 3**				**Node 4**			
Link Number	[301]	[302]	[307]	[312]	[403]	[407]	[408]	[410]
Link Length	[300]	[300]	[0]	[0]	[0]	[300]	[300]	[0]
Saturation Flow..................	[1800]	[1800]	[3600]	[1800]	[3600]	[1800]	[1800]	[1800]
Total Volume	[442]	[310]	[360]	[232]	[474]	[310]	[360]	[193]
Midblock Entry	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
1st Input Link No	[206]	[201]	[0]	[0]	[0]	[302]	[307]	[0]
Volume	[242]	[310]	[0]	[0]	[0]	[310]	[360]	[0]
Speed	[30]	[30]	[0]	[0]	[0]	[30]	[30]	[0]
2nd Input Link No.............	[201]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Volume	[200]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Speed	[30]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
3rd Input Link No	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Volume	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Speed	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Queuing Capacity	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]

CARD TYPE 29 LINK DATA CONTINUATION CARD

Link Data (Continued)	Node 1	Node 2	Node 3	Node 4
Link Number	[111]	[209]	[312]	[410]
Lost Time Adjustment	[0]	[0]	[0]	[0]
Green Extension Adj	[0]	[0]	[0]	[0]
Permitted Mfr	[0]	[0]	[0]	[0]
Sneakers	[0]	[0]	[0]	[0]
4th Input Link No	[0]	[0]	[0]	[0]
Volume	[0]	[0]	[0]	[0]
Speed	[0]	[0]	[0]	[0]
1st Opposing Link.............	[103]	[205]	[301]	[407]
% of Flow	[100]	[100]	[100]	[100]
2nd Opposing Link............	[0]	[0]	[0]	[0]
% of Flow	[0]	[0]	[0]	[0]
3rd Opposing Link.............	[0]	[0]	[0]	[0]
% of Flow	[0]	[0]	[0]	[0]
Permitted Model #	[0]	[0]	[0]	[0]

CARD TYPE 5X : RUN TYPE CARD

Code 2 for 'X' which means that an optimized solution is required to be determined. This is same as the TUDI example. Code '0' for the PI definition which means that stops and delays are to be minimized.

This constitutes the overall input process for optimizing signal timings for the three-level diamond interchange using TRANSYT-7F. Progression, as obtained through TRANSYT-7F, may not be satisfactory, but the calculated system delays would be less.

For a SPUI, all input cards remain the same, but the values change. The input is shown in the Appendix. Note that the SPUI is treated as a single intersection and, hence, all links are external links. Thus, no input (feeder) links are present for the SPUI or AGI.

7. OUTPUT INTERPRETATION AND EVALUATION

OUTPUT INTERPRETATION

The program output presented in the Appendix is an example of how the output looks when printing of the input data is not suppressed. If one wishes to suppress the input during subsequent runs, it is possible. It is advisable to keep an input echo with the output as it helps in checking if the output corresponds to the input. Along with the input echo, several warning messages are printed. All these warning messages and program notes are self-explanatory. The primary measures of effectiveness (MOEs) calculated by the model are delay, stops, queueing, and fuel consumption. The model has an output which typically contains the following elements and MOEs.

1. An echo of the input with the coded values associated with each parameter in a card.
2. Warning messages which vary with the type of input, but most commonly are not big errors. For example, a very small sec./step factor in field 6 of card 1.
3. The best cycle length in a range of cycle lengths based on the performance index.
4. The degree of saturation (v/c ratio) associated with each link in the network. This depends on the volume and capacity at the intersection. TRANSYT-7F outputs this ratio as a percentage of available capacity.
5. Total travel for each link in the system and for the system as a whole. Total travel is defined by the model as the aggregate of the product of link volumes and link length. Hence, for external links, this value will not be output because the link lengths traveled by the external movements are not exactly known. The equation for the total travel on a link is given below:

$$TT_i = q_i \times L_i$$

where TT_i = total travel on link i in veh-mi per hour;

q_i = traffic volume on link i, vph; and

L_i = length of link in miles.

This MOE will not change in any given optimization, since the basic values (flow rates and link lengths) do not change. The systemwide total travel is simply the sum of all the linkwise total travel values. The systemwide value is given immediately below the linkwise totals in the TRANSYT-7F output.

6. Total travel time (TTT) for each link in the network and the network as a whole. This MOE is the product of the link volumes and total time spent on the links, including delay. Similar to the total travel, the systemwide total travel time is the aggregate of total travel time for all the links in the system. TTT is given by

$$TTT_i = q_i(L_i/u_i + D_i)$$

where TTT_i = total travel time in veh-hr per hour on link i;

q_i = traffic volume on link i, vph;

L_i = length of link i in miles;

u_i = average cruise speed on link i in mph; and

D_i = total delay on link i in hours.

This measure should decrease as the network signal timing is improved to reduce delay.

7. Total approach delay (not stopped delay) in veh-hr per hour. As explained in Chapter 2, this is made up of two basic components: uniform and random delay. It is a function of the arrival volumes and the phase capacity. This delay is output as linkwise and systemwide totals. This is an effective measure as it is used for calculating the average delay in the system.

8. Average delay in sec/veh. It is output on a link-by-link basis, and the system as a whole. Average delay is obtained when the total delay is multiplied by 3600 and divided by the total flow in vph on the link. This is the average approach delay on the link. If the average system approach delay is needed, multiply the total system delay by 3600 and divide by the total flow in the system. If an average stopped delay is desired, divide the average approach delay by 1.3 on the link or in the system, whatever is the case. The *Highway Capacity Manual* (HCM) (*4*) uses the average stopped delay to determine the LOS at the intersection. The reason to adopt stopped delay instead of the approach delay is that stopped delay is easier to measure in the field. A LOS of D or C is desirable at isolated signalized urban intersections during peak hour conditions. Even though LOS B is highly desirable,

it is difficult to attain and may not be practical to achieve at isolated urban intersections. A LOS of E or less can be termed as poor operations. The following are the values given by the HCM to arrive at the LOS for a signalized intersection based on the average stopped delay:

Average Stopped Delay sec/vehicle	Level of Service
Less than or equal to 5	A
5.1 to 15.0	B
15.1 to 25.0	C
25.1 to 40.0	D
40.1 to 60.0	E
Greater than or equal to 60.0	F

9. Number of stops on each link and in the entire network (system). As mentioned in the features of the model, the stops estimated by the program are not totally explicitly modelled. The stops during green are computed by using an empirical relationship (in a S-curve form) between average delay and percent stops. That is, as the average delay increases, the percentage of stops during green increases sharply up to a certain point but remains relatively constant after this point. The number of stops are then estimated using this percentage of stops. As mentioned earlier, this method seems to work well and is used for calculating the outputs. The lower the percentage of stops on the internal links, the better the progression is. Once stops are minimized, it means that good progression and minimum delays probably have been achieved for that cycle.
10. Maximum back of queue (MBQ) in veh./link. The model reports the maximum back of queue in terms of the number of vehicles storing per cycle. This MOE is related to the number of stops. Maximum back of queue can be used to identify sections

where spillover may occur. This indication is made by comparing the maximum back of the queue value with the queue capacity value given by TRANSYT-7F based on the link length and vehicle spacing. If the back of queue exceeds the queue storage capacity value, queue spillover occurs at that specific point. The queue capacity value, as identified earlier, is calculated by the model or can also be input.

11. Fuel consumption in gallons per hour. This is given on a linkwise basis and for the whole system. The system fuel consumption is simply an aggregate of the linkwise fuel consumption estimates. Fuel consumption is predicted based on the MOE's produced by the TRANSYT model. The following empirical model is used in the program to estimate fuel consumption:

$$F = K_{i1}\,TT + K_{i2}\,D + K_{i3}\,S$$

where F = fuel consumed in gallons per hour;

TT = total travel in veh-miles per hour;

D = total delay in veh-hour per hour;

S = total stops in stops per hour; and

K_{ij} = model coefficients which are functions of speed on each link.

12. Optimized phase lengths for each link in seconds.

13. Total operating cost in $. The total cost is a function of total travel, total stops, total delay, total fuel consumption, average vehicle occupancy, total travel time, and cruise speed. Operating cost can be used to estimate the cost-benefits associated with a particular change in design or strategy. Though this is not the only cost considered, it would assist in estimating the total user cost.

14. Performance index. This is given for information and is not very useful. However, when analyzing different conditions such as cycle lengths, the performance index might be used as a check. The index always decreases as the conditions improve.

15. The average speed in the system in mph. The average speed is an indication of the quality of flow in the network. It is simply the ratio of total travel and total travel time. External links are excluded from the calculation of the average network speed.

The higher the speed, the better the operation. Safety issues should however, be taken into consideration while assessing the operational efficiency of interchanges. When the average speed is so great that a potential safety problem exists, possible ways of reducing the average speed should be examined.

EVALUATION OF THE CONFIGURATIONS

The following configurations were evaluated for the years 1990 and 2010:

1. AGI;
2. SPUI - three-phase and four-phase;
3. TUDI - four-phase, two-overlap; and
4. TLDI - two-phase.

The evaluation presented in this chapter for different interchanges should be carefully interpreted. The evaluations should not be treated as a basis for comparison between various types of interchanges such as a SPUI or a TUDI. The evaluation performed in this chapter is very limited and is highly problem-specific. It is valid only for the specific configurations and under specific geometric and operational conditions. Hence, extreme caution should be exercised not to draw any global conclusions about the traffic operations of a SPUI, a TUDI, or a TLDI using the results presented in this chapter. The discussion of results provided in this chapter is intended only to illustrate that TRANSYT-7F is an effective tool to analyze and evaluate different interchange operations.

Different interchange configurations were analyzed as discussed previously. It should be mentioned here that the geometric configurations may not ideally match the volumes because no analysis was done to optimize the lane configurations. The purpose was solely to model these types of interchanges. However, some engineering judgement was used to represent the number of lanes and phases to more closely match real-world operations. Though there were some inconsistencies with respect to some parameters such as cycle lengths, the analysis made here does provide a near equitable comparison.

Study MOEs

The program results are presented in Figures 33-35. The graphs were developed using the spreadsheet "Quattro pro". These graphs plot total delays, stops, and fuel consumption for the years 1990 and 2010 for the various interchanges. Various measures of effectiveness discussed below include delays, stops, fuel consumption, and queue lengths. The three-level diamond interchange without frontage roads was not evaluated for the year 1990 and hence the 1990 MOEs show zero values for the TLDI without frontage roads.

Delays

Total delays, stops and fuel consumption for the years 1990 and 2010 are plotted and shown. It can be seen that enormous savings in delays, stops and fuel consumption can be achieved by upgrading the intersection to any type of interchange, which should be obvious given the basic objective of constructing any interchange to eliminate one or more congested traffic movements from intersecting with other traffic.

The three-phase SPUI performed better than the TUDI with frontage roads in all respects. This is mainly because the frontage road through volumes are absent in the three-phase SPUI, and hence, the volumes are smaller in this case. But for the four-phase SPUI, the delays were higher than with the same TUDI. This justifies the previous argument that the presence of frontage road volumes contributes to higher delays for the SPUI than for the TUDI.

Stops

In case of total stops, the SPUI performance was better. This may be due to the fact that in the TUDI, the same through movements process two intersections and some get delayed slightly at the second intersection due to acceleration and deceleration. This slight delay in TRANSYT-7F is enough to produce substantial stops. This could be one of the reasons why the stops were higher for the TUDI than for the four-phase SPUI.

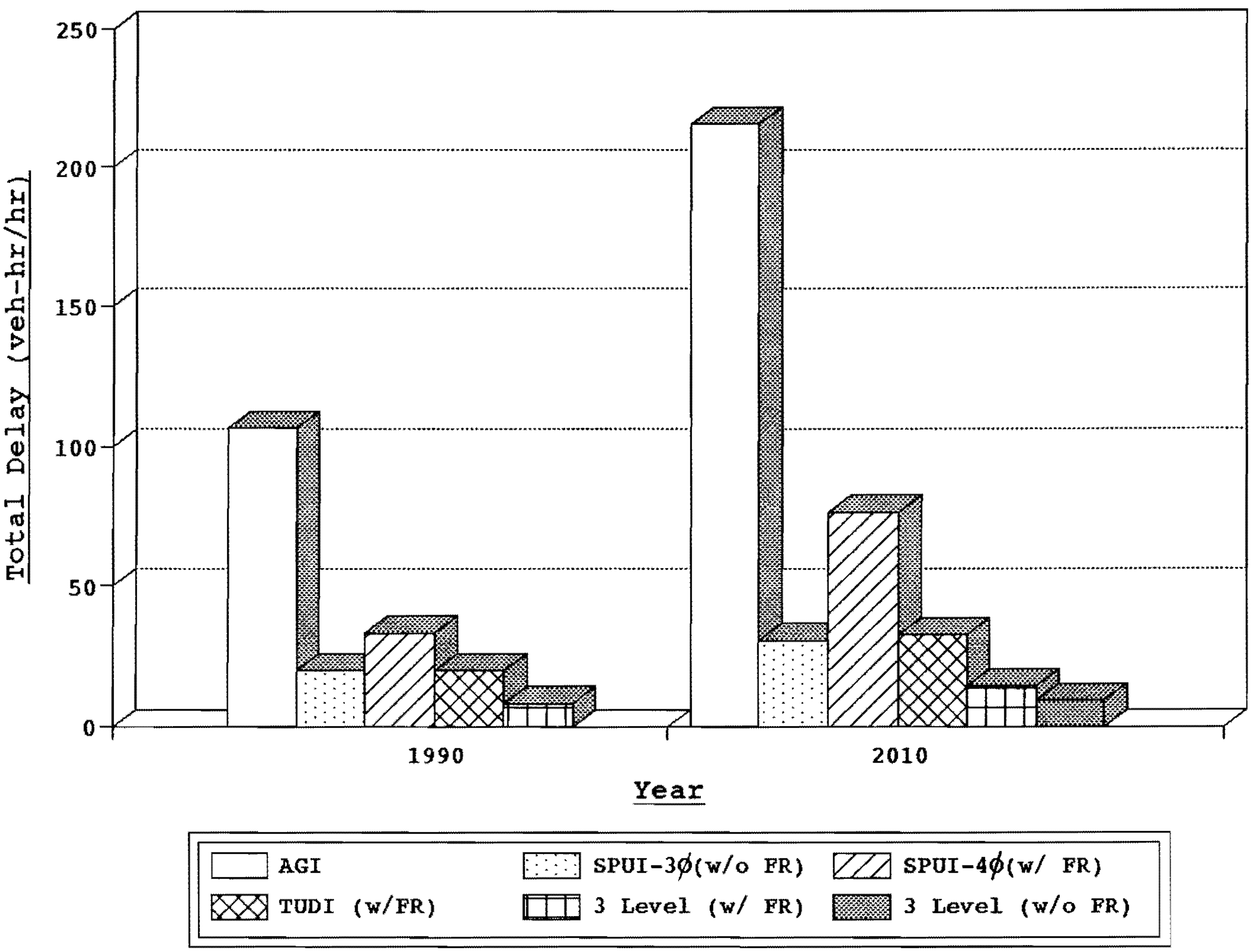


Figure 33. Total Delay for AGI, SPUI, TUDI and TLDI for 1990 and 2010 Peak Periods.

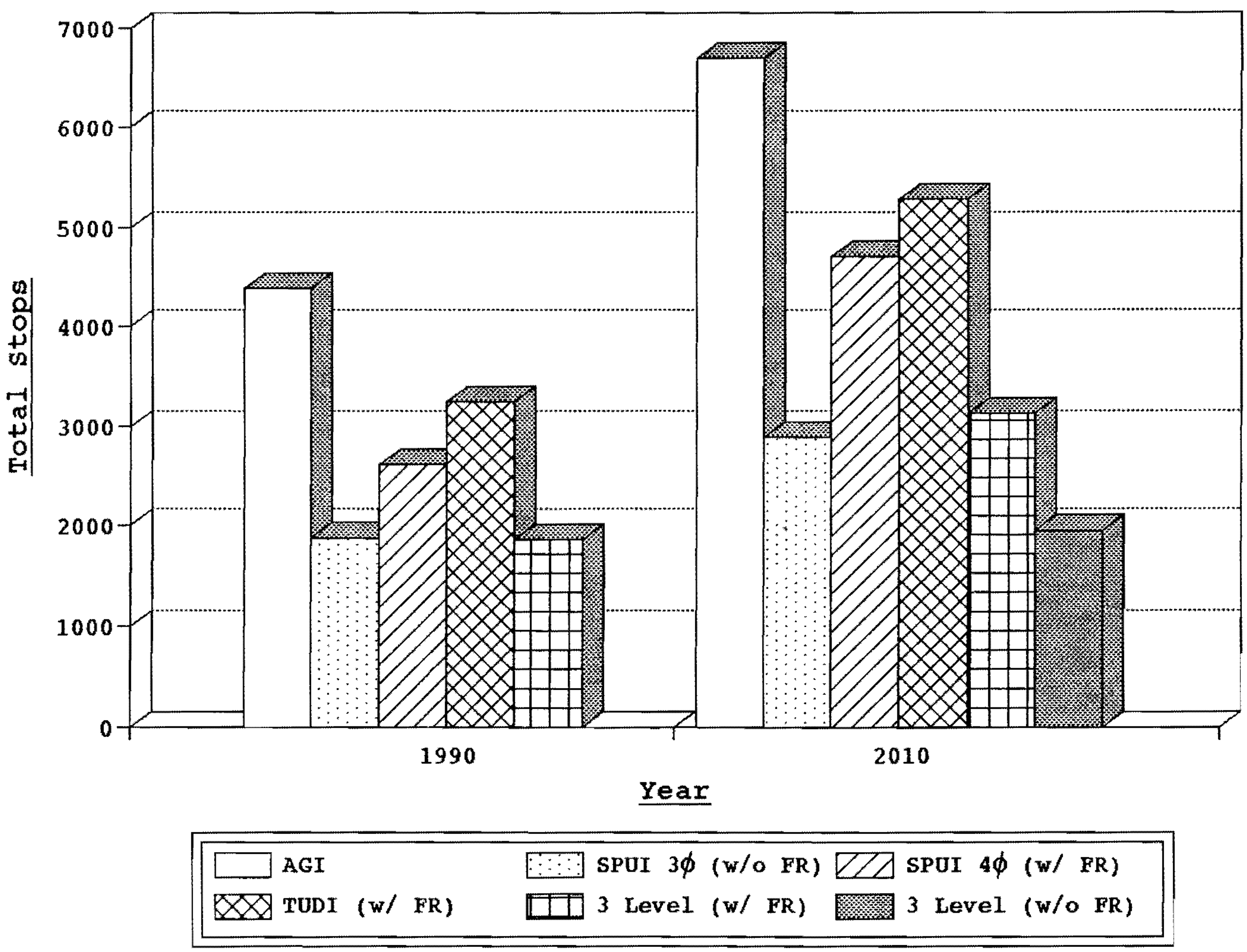


Figure 34. Total Stops for AGI, SPUI, TUDI and TLDI for 1990 and 2010 Peak Periods.

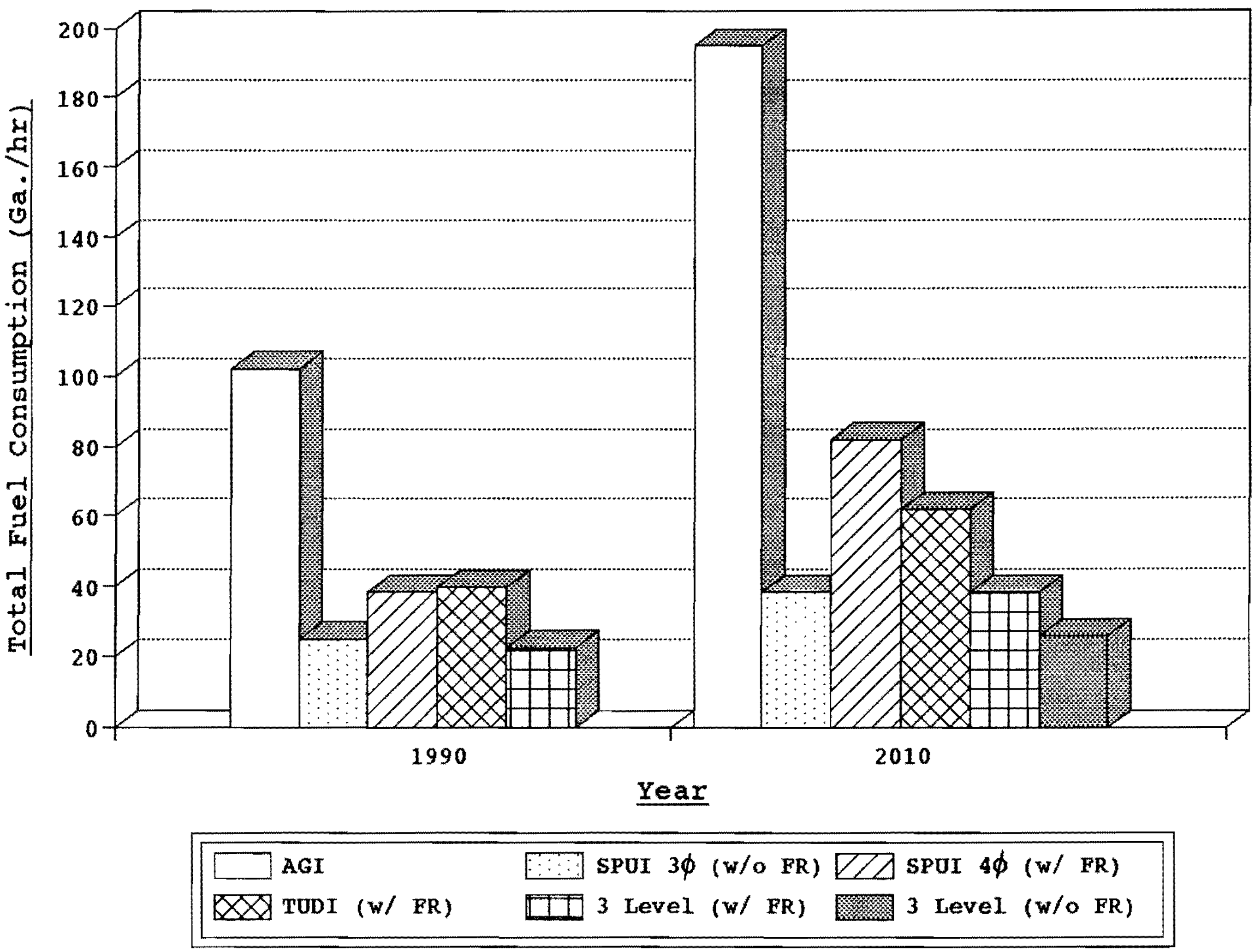


Figure 35. Total Fuel Consumption for AGI, SPUI, TUDI and TLDI for 1990 and 2010 Peak Periods.

Fuel Consumption

The fuel consumption estimate is a function of delays and stops. Since delays were much smaller in 2010 for the TUDI than for the SPUI, the fuel consumption estimate was lower for the TUDI.

From the above results, it could be inferred that the three-phase SPUI performed better than the TUDI. This is because of the fact that the delays experienced by the traffic in the example are less. These lower delays result in lower user costs. However, these savings tend to be in favor of the TUDI when frontage road traffic is present.

The three-level diamond interchange with frontage roads was better than all types for both years in all respects except in total stops for the year 2010. It can be seen that the TLDI had slightly higher stops than the three-phase SPUI. This could be again due to two reasons: 1. the SPUI does not have frontage roads; or 2. minor delays at the four intersections cause ample stops and, hence this trend.

Queue Length Evaluation for TUDI for the Years 1990, 2000 and 2010

An important factor affecting traffic operations along the freeway exit ramps is the queue length. If the queue length on the ramps exceeds the queue capacity of the ramp, traffic spills over onto the freeway potentially causing significant delays to the freeway traffic. In such cases, care should be taken to manage the queues on the ramps so that they do not extend from the traffic signals onto the freeway mainlanes. This control may not be achieved without sacrificing the usual progression on the diamond interchanges. This is because the signal timing may have to be adjusted to provide more green time to the exit ramp traffic in order to reduce the queues on the exit ramps. This implies that the green time for the interior movements decreases while the left turning traffic from the exit ramp that arrives at the internal intersections increases. Thus, some left turning traffic from the exit ramp get stopped at the internal intersections disrupting the usual progression. Notwithstanding this reduction in progression, significant reductions in average delays and total stops would be obtained when the external ramp queues are reduced. Thus, queue management on the ramps is also one of the important considerations in diamond interchange operations. Refer to the research effort made by Kim and Messer (7) on queue management for oversaturated conditions at diamond interchanges for a detailed discussion on how to manage queues and still maintain acceptable throughput along the interchange.

TRANSYT-7F was used to determine if queues on the ramps can be managed if they grow large in number. This analysis was done subject to the constraint that large queues do not form at the interior portion of the TUDI. Queue lengths were evaluated for the years 1990, 2000, and 2010 for the TUDI configurations as shown earlier in Figures 16 and 21. The configuration for the year 2000 was the same as that of 1990 due to a smaller increase in volumes. The storage distance to the exit ramps was assumed to be only 400 feet to determine its queue storage capacity. As mentioned earlier, TRANSYT-7F internally calculates the queue capacity value based on the length of the link, the number of lanes on the link, the length of the vehicle, and the inter-vehicular spacing, here assumed to be 25 feet per vehicle.

Three simulation models - PASSER II, PASSER III, and TRANSYT-7F were used to evaluate the queue lengths. First, PASSER III was used to develop signal timing for the four-phase, two-overlap TUDI for all the years. Since the model does not output queue length, the timings were simulated in TRANSYT-7F, and the maximum back of the queue values were determined on the ramps at both the intersections and on the cross streets at both the intersections for the years 1990, 2000, and 2010 peak period traffic volumes. TRANSYT-7F was then used to optimize the timings generated by PASSER III without affecting the progression. This was accomplished by using the bandwidth constraint feature built in the program. Finally, a queue penalty was applied, and TRANSYT-7F was used to generate signal timing based on this queue penalty without using the bandwidth constraint. All the maximum back of queue values were then compared with the queue length values output by PASSER II under the same volume and geometric conditions. The comparison was made to ascertain the validity of the queue values predicted by TRANSYT-7F.

Table 5 and Figures 36-39 show the summary of all the above queue length results. Figure 36 shows that when PASSER III timings were simulated in TRANSYT-7F, the queues were less than half of the queue capacity value (shown in Table 4) for all the design years for the left side ramp. Performing an optimization function in TRANSYT-7F using or not using bandwidth constraint did not effectively yield any better values. However, average delay and stops values can be slightly reduced if TRANSYT-7F is utilized to optimize the timings, which will not be discussed here. The figure also shows that for the year 2010, PASSER II yielded slightly higher queue values. These higher values may be because of problems associated with coding shared lanes in PASSER II. In essence, at the left side ramp, since the maximum back of queue values were negligible, TRANSYT-7F optimization with or without bandwidth constraint provides essentially the same results as that of PASSER III or PASSER II.

Figure 37 on the otherhand, shows that the maximum back of queue value on the right side ramp for the year 2010 was more than half of the queue capacity value (given in Table 4). For the years 1990 and 2000, the queue values were much lower. Thus, using the bandwidth constraint or no bandwidth constraint in TRANSYT-7F did not indicate notable reductions in the queue values. Nevertheless, for the year 2010 where the queue values amounted to more than half of the queue capacity value, optimization in TRANSYT-7F showed marked differences. The maximum back of queue values were reduced by more than 20%. This reduction was accomplished at the expense of providing good progression for the internal movements. Given that the queue backup onto the freeway is more critical, this trade-off is valid. Care should be exercised to see that no excessive queues develop on the interior lanes. If they do develop, a fine tuning of the signal timing parameters using the program should be made.

Figure 38 shows the queue values on the cross street at the left side intersection. Although cross street queues are not as critical as those of the ramps, they can pose serious problems where there are nearby intersections on the approaches to the interchange. Hence, queue values on the cross street at both intersections were also evaluated. A slight

Table 5. Maximum Back of Queue in Vehicles per Approach for TUDI for 1990,2000, and 2010.

	Simulation of PASSER III in TRANSYT-7F		Opzn of PASSER III in TRANSYT-7F using Bandwidth Constraint		TRANSYT Optimization w/o Bandwidth Constraint	Passer II Optimized Values	Total Queue Capacity Value
	Year	Total Max. Queue	Year	Total Max. Queue	Total Max. Queue	Total Queue Length	
Left Side Ramp	1990	9	1990	9	9	9.1	45
	2000	12	2000	12	12	12	45
	2010	20	2010	20	20	21.4	45
Right Side Ramp	1990	10	1990	10	10	10.4	51
	2000	17	2000	17	15	16.4	51
	2010	33	2010	33	26	46.8	51
Cross Street at Left Side	1990	14	1990	13	12	13.6	72
	2000	20	2000	19	19	20.4	72
	2010	22	2010	22	22	23.6	72
Cross Street at Right Side	1990	14	1990	14	14	14.8	72
	2000	21	2000	21	21	21.6	72
	2010	42	2010	42	33	41.6	72

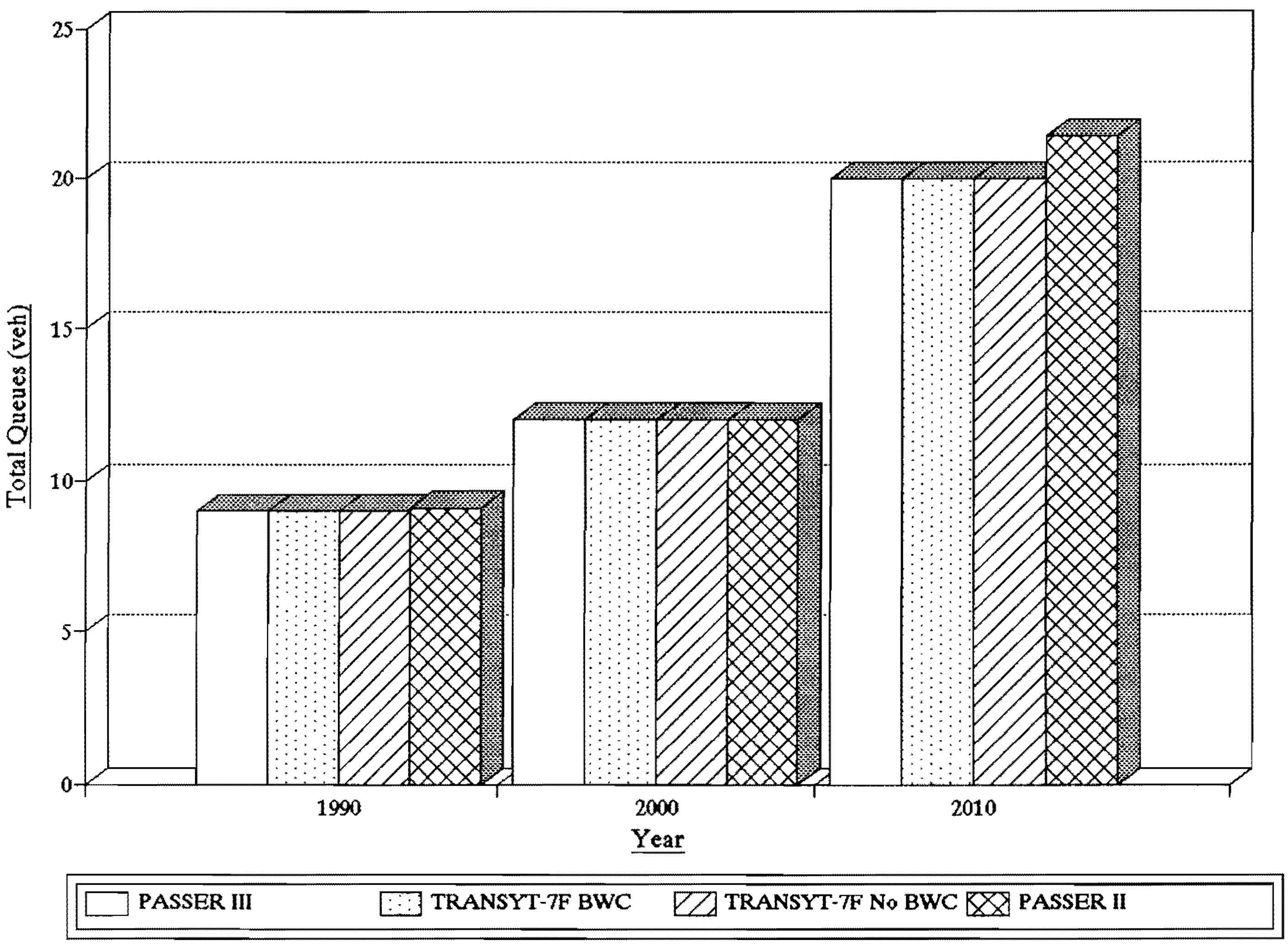


Figure 36. Queue Lengths on Left Side Ramp for TUDI Peak Periods.

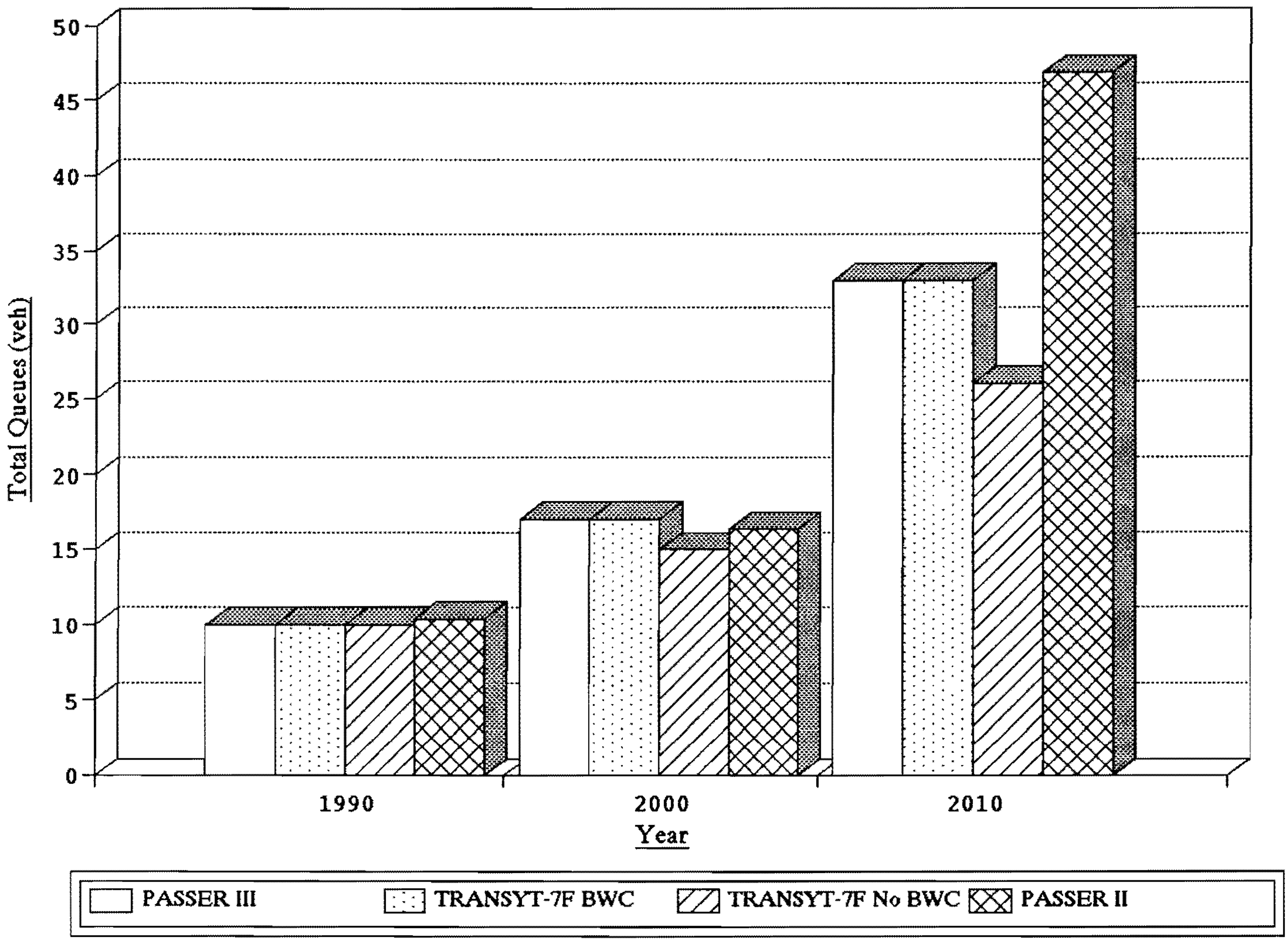


Figure 37. Queue Lengths on Right Side Ramp for TUDI Peak Periods.

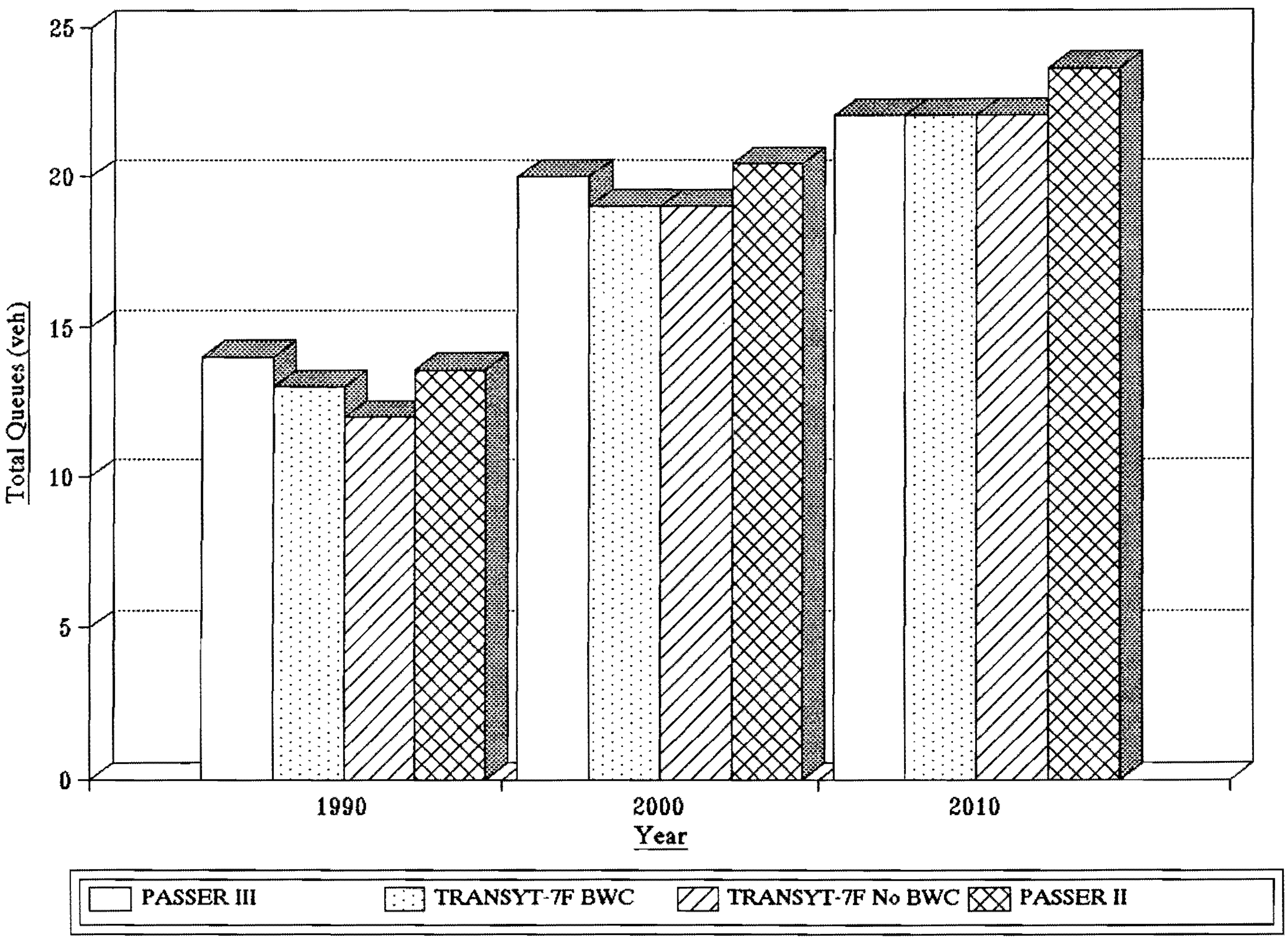


Figure 38. Queue Lengths on Left Side Cross Street for TUDI Peak Periods.

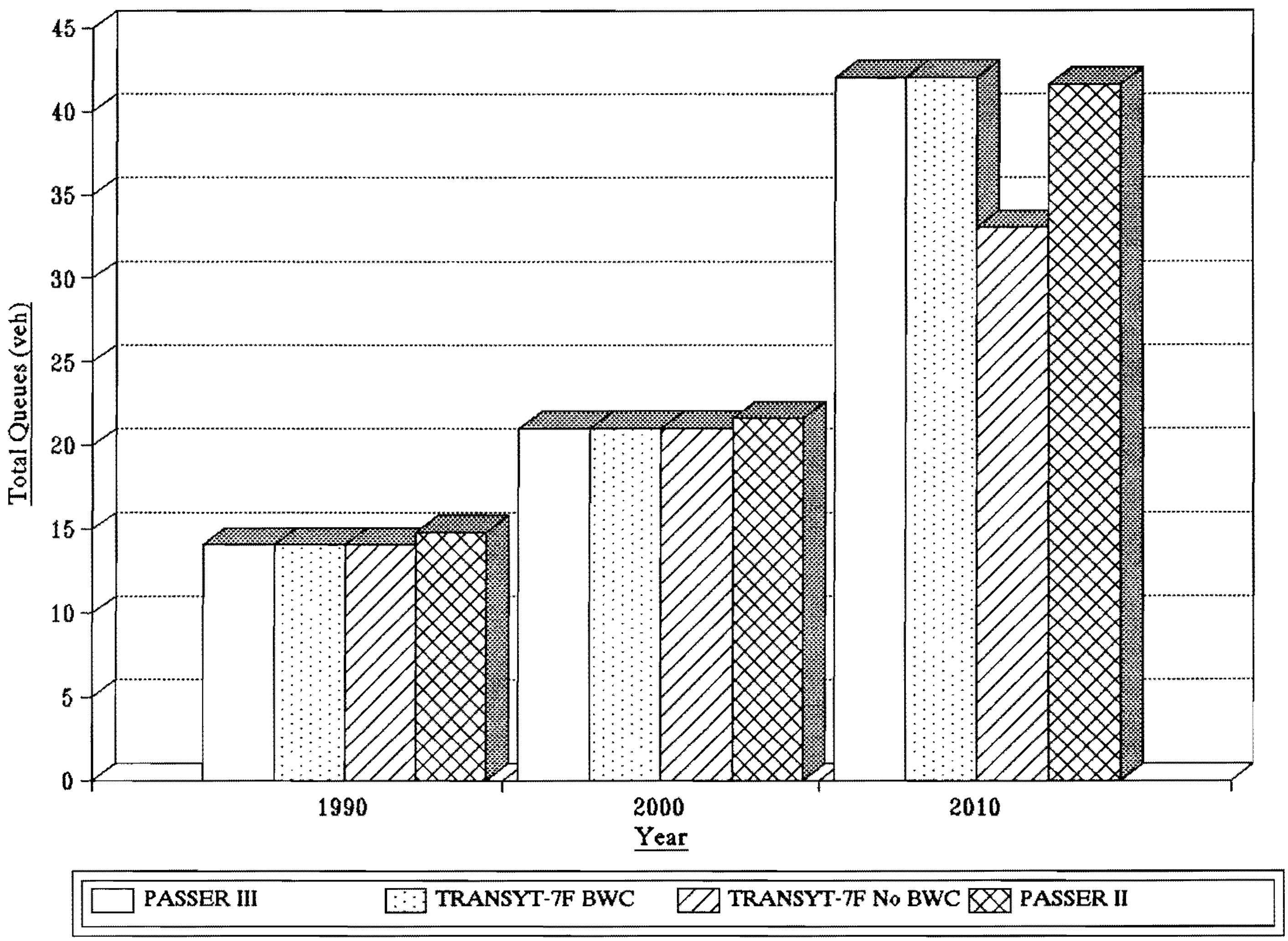


Figure 39. Queue Lengths on Right Side Cross Street for TUDI Peak Periods.

decrease in the range of 5 to 7 % was observed with and without the bandwidth constraint conditions for the years 1990 and 2000. Thus, in this case, queue values were reduced without sacrificing any progression for the interior movements. Signal timings were fine-tuned by TRANSYT-7F to result in more efficient operations.

Lastly, Figure 39 shows the queue lengths on the cross street at the right side intersection. For the years 1990 and 2000, queue length values remained the same under bandwidth and no bandwidth conditions. For the year 2010, a 20 % reduction in the queue values was obtained when optimization was performed without the bandwidth requirement. Again, consideration should be given to decide whether it is appropriate to sacrifice progression in order to manage the queues. It becomes imperative only when the queue is backing up on to the freeway or when it is so large that it extends into any existing upstream intersection causing traffic gridlock.

All the queue values predicted by TRANSYT-7F when simulating and under bandwidth constraint requirement closely agree with the queue length values produced by PASSER II. Thus, it can be inferred that the maximum back of queue values determined by TRANSYT-7F are not unrealistic and can be relied upon. From these results, it appears that TRANSYT-7F with no bandwidth constraint may be the desired optimization strategy during overflow conditions at two-level diamond interchanges.

The study results show that as traffic volumes grow over time, the exterior traffic queues can be expected to likewise grow with time. At some point, they may become a serious secondary problem unless increased interchange capacity or queue management techniques are provided. See references Kim (*7*) and Herrick (*8*) for further details on the features of interchange queue management strategies.

It is emphasized again that the purpose of this section was to illustrate modelling these interchanges using TRANSYT-7F and, hence, evaluation has not been discussed at great length. Also, improved geometric configurations based on a thorough analysis of existing conditions may result in different results regarding these interchanges. Nevertheless, these results should provide insight into how various interchanges may operate given the same volume conditions. The discussion on the maximum back of the queue values and the capability of TRANSYT-7F to reduce queues without and with losing progression for the interior flow reveals how diamond interchanges can not only be modeled appropriately but also be operated efficiently in an urban environment.

Summary and Conclusions

The applications manual documented in this research report can be very useful to model various diamond interchanges in TRANSYT-7F. This manual provided the methodology to code the needed data input into TRANSYT-7F for evaluating the performance and the feasibility of future diamond interchange design alternatives in accommodating future traffic growth. Examples for modeling two-level and three-level diamond interchanges were dealt with in detail. Comparisons were made between various types of diamond interchanges. Effort was made to keep the comparisons as equitable as possible although there were some inconsistencies in defining a few parameters such as the cycle lengths. It is recommended that these comparisons be carefully interpreted. They are highly problem-specific, and may only be valid for the geometric and operational conditions described in the report. Note however, that this report strongly recommends TRANSYT-7F be used as an effective tool to evaluate various design options of diamond interchanges.

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8. Herrick, G.C. and C.J. Messer. "Strategies for Improving Traffic Operations at Oversaturated Signalized Diamond Interchanges." Report FHWA/TX-92/1148-4, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1992.

APPENDIX

Sample Output for the TUDI Example Problem

1 TRANSYT-7F -- TRAFFIC SIGNAL SYSTEM OPTIMIZATION PROGRAM

RELEASE 6 OCTOBER 1988 VERSION 3.0

SPONSORED BY:
FEDERAL HIGHWAY ADMINISTRATION
OFFICE OF TRAFFIC OPERATIONS

DEVELOPED BY:
TRANSPORT AND ROAD RESEARCH LABORATORY
UNITED KINGDOM AND
TRANSPORTATION RESEARCH CENTER
UNIVERSITY OF FLORIDA

DATE OF RUN: 12/ 6/91 START TIME OF RUN: 9:53:41

INPUT DATA REPORT FOR RUN 1

FIELDS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

LINE NO.	TITLE
1)	--------------Evaluating TUDI for 1990 A.M. Peak--------------------

NETWORK CONTROL CARD

LINE NO.	CARD TYPE	SEC/ MIN CYCLE	SEC/ MAX CYCLE	CYCLE INCR.	STEP CYCLE	STEP NORMAL	LOST TIME	GREEN EXTEN.	STOP PENAL	OUTPUT LEVEL	INITIAL TIMING	PERIO LENGT	SEC(0) PERC(1)	SPD(0) TIME(1	ENGL(0 METR(	PNCH DECK
2)	1	60	90	5	3	1	2	2	-1	1	1	15	0	0	0	0

+++ 106 +++ WARNING +
+ THE SEC/STEPS FACTOR IN FIELD 6 IS TOO SMALL FOR CYCLE
LENGTHS ABOVE 60 SECONDS. IT WILL BE INCREASED TO
ALLOW A MAXIMUM OF 60 STEPS/CYCLE.

+++ 107 +++ WARNING +
+ A STOP PENALTY OF "-1" WILL RESULT IN AUTOMATIC
CALCULATION OF THE PI TO MINIMIZE FUEL CONSUMPTION.
LINK SPECIFIC DELAY OR STOP WEIGHTS ON CARD
TYPE 37 & 38 WILL STILL BE APPLIED, HOWEVER.

LINE NO.	CARD TYPE	LIST OF NODES TO BE OPTIMIZED														
3)	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0

LINKS HAVING SHARED STOPLINES

LINE NO.	CARD TYPE	FIRST SET..........				SECOND SET..................					THIRD SET...............					
4)	7	103	104	0	0	0	201	202	0	0	0	0	0	0	0	0

FIELDS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

SYSTEM MASTER DATA

LINE NO.	CARD TYPE	MASTE NODE	SYSTEM DEFAULTS YELLO	ALL-RE	SATFLO	EXTERNAL SPEED	SYSTEM PDF	FUEL FACTO	VEHIC LENGT	ORIEN-TATION	DESIRE SPLITS	% OF S 2-CYC	MBQ WEIGHT	INFLAT RATE	FUEL COST	VEHICLE OCC.
5)	10	1	4	0	1800	30	35	100	25	0	85	25	40	100	125	120

INTERSECTION 1

CONTROLLER TIMING DATA

LINE NO.	CARD TYPE	NODE NO.	OFFSET/ YLD.PT.	REF INT	INTERVAL DURATION (SECS. OR PERCE ... INT 1	INT 2	INT 3	INT 4	INT5	INT 6	INT 7	INT 8	INT 9	INT 10	INT 11	DOUBLE CYCLE
6)	13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LINE NO.	CARD TYPE	NODE NO.	START INTVL	VARIAB INTVL	YELLO INTVL	ALL-RED INTVL	MINIM. SECS.	LINKS MOVING IN THIS PHASE................							PHASE TYPE	
7)	21	1	1	1	2	0	6	105	107	-110	111	0	0	0	0	0
8)	22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
9)	23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0

LINK DATA

LINE NO.	CARD TYPE	LINK NO.	LINK LENGT	SAT. FLOW	TOTAL VOL.	MID-BLK. VOL.	FIRST INPUT LINK... NO.	VOL.	SPD/T	SECOND INPUT LINK..... NO.	VOL.	SPD/T	THIRD INPUT LINK..... NO.	VOL.	SPD/T	QUEUE CAP.
10)	28	101	0	1800	125	0	0	0	0	0	0	0	0	0	0	0
11)	28	102	0	1800	180	0	0	0	0	0	0	0	0	0	0	0
12)	28	103	0	1700	75	0	0	0	0	0	0	0	0	0	0	0
13)	28	104	0	0	48	0	0	0	0	0	0	0	0	0	0	0
14)	28	105	0	5400	969	0	0	0	0	0	0	0	0	0	0	0
15)	28	107	300	3600	1005	0	202	110	21	204	200	21	207	695	21	0
16)	28	108	300	1800	360	0	207	360	21	0	0	0	0	0	0	0
17)	28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0

LINK DATA (CONTINUED)

LINE NO.	CARD TYPE	LINK NO.	ADD ST LOST-TI	GREEN EXTENS	ADJUST. MFR	SNEAKERS	FOURTH INPUT LINK NO.	VOL.	SPD/TT	OPPOSING LINKS AND PERCENTAGES.... LINK 1	%	LINK 2	%	LINK 3	%	PERM MODEL
18)	29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0

LINK DATA

LINE NO.	CARD TYPE	LINK NO.	LINK LENGT	SAT. FLOW	TOTAL VOL.	MID-BLK. VOL.	FIRST INPUT LINK... NO.	VOL.	SPD/T	SECOND INPUT LINK... NO.	VOL.	SPD/T	THIRD INPUT LINK... NO.	VOL.	SPD/T	QUEUE CAP.
19)	28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0

INTERSECTION 2

1TRANSYT-7F:-------------Evaluating TUDI for 1990 A.M. Peak---------------- PAGE 3

FIELDS:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

LINE NO.	CARD TYPE	NODE NO.	OFFSET/ YLD.PT.	REF INT	INTERVAL DURATION (SECS. OR PERCE .... INT 1	INT 2	INT 3	INT 4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	DOUBLE CYCLE
20)	13	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0

PHASE TIMING DATA

LINE NO.	CARD TYPE	NODE NO.	START INTVL	VARIAB INTVL	YELLO INTVL	ALL-RED INTVL	MINIM. SECS.	LINKS MOVING IN THIS PHASE................							PHASE TYPE	
21)	21	2	1	1	2	0	6	205	207	-209	212	0	0	0	0	0
22)	22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23)	23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0

LINK DATA

LINE NO.	CARD TYPE	LINK NO.	LINK LENGT	SAT. FLOW	TOTAL VOL.	MID-BLK. VOL.	FIRST INPUT LINK... NO.	VOL.	SPD/T	SECOND INPUT LINK..... NO.	VOL.	SPD/T	THIRD INPUT LINK..... NO.	VOL.	SPD/T	QUEUE CAP.
24)	28	201	0	1800	46	0	0	0	0	0	0	0	0	0	0	0
25)	28	202	0	0	110	0	0	0	0	0	0	0	0	0	0	0
26)	28	203	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
27)	28	204	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28)	28	205	300	3600	955	0	102	180	21	104	48	21	105	727	21	0
29)	28	206	300	1800	242	0	105	242	21	0	0	0	0	0	0	0
30)	28	207	0	5400	1055	0	0	0	0	0	0	0	0	0	0	0
31)	28	209	0	1800	137	0	0	0	0	0	0	0	0	0	0	0

LINK DATA (CONTINUED)

LINE NO.	CARD TYPE	LINK NO.	ADD ST LOST-TI	GREEN EXTENS	ADJUST. MFR	SNEAKERS	FOURTH INPUT LINK NO.	VOL.	SPD/TT	OPPOSING LINKS AND PERCENTAGES.... LINK 1	%	LINK 2	%	LINK 3	%	PERM MODEL
32)	29	209	0	0	0	0	0	0	0	205	50	0	0	0	0	0

LINK DATA

LINE NO.	CARD TYPE	LINK NO.	LINK LENGT	SAT. FLOW	TOTAL VOL.	MID-BLK. VOL.	FIRST INPUT LINK... NO.	VOL.	SPD/T	SECOND INPUT LINK... NO.	VOL.	SPD/T	THIRD INPUT LINK... NO.	VOL.	SPD/T	QUEUE CAP.
33)	28	212	0	1800	232	0	0	0	0	0	0	0	0	0	0	0

RUN CARD

LINE NO.	CARD TYPE	PI TYPE														
34)	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

--- PROGRAM NOTE --- A CARD TYPE 52 CAUSES RUN TO BE OPTIMIZED USING THE NG.
DEFAULT NORMAL OPTIMIZATION STEP SIZES.
IF CARD TYPE WAS INPUT, IT IS IGNORED.

THE ABOVE WILL BE PROCESSED AFTER THE "BEST" CYCLE LENGTH HAS BEEN SELECTED.

--- PROGRAM NOTE --- NO ERRORS DETECTED. TRANSYT-7F PERFORMS FINAL PROCESSING.
IF ERRORS ARE DETECTED, FURTHER PROCESSING IS SUSPENDED.

--- PROGRAM NOTE --- THERE ARE A TOTAL OF 2 NODES AND 18 LINKS, INCLUDING BOTTLENECKS, IF ANY, IN THIS RUN.

--- PROGRAM NOTE --- THERE WERE A TOTAL OF 2 WARNING MESSAGES ISSUED IN THE ABOVE REPORT.

CYCLE EVALUATION SUMMARY PERFORMANCE

CYCLE LENGTH (SEC)	STEP SIZE (STEPS)	AVERA DELAY (SEC/VE	PERCEN STOPS (%)	FUEL CONSU (GAL/HR)	PERFOR INDEX	NUMBER SATURATED LINKS
60	20	9.74	39	32.7	25.7	0
65	22	10.3	38	33.6	26.6	0
70	23	10.49	38	33.6	26.6	0
75	25	11.6	37	35.1	28	0
80	27	11.93	37	35.4	28.4	0
85	28	12.29	38	35.9	28.9	0
90	30	13.2	38	37.3	30.2	0

BEST CYCLE LENGTH = 60 SEC. CYCLE SENSITIVITY = 5.6 %

--- PROGRAM NOTE --- TRANSYT-7F OPTIMIZES THE SYSTEM USING THE BEST CYCLE LENGTH AND HILL-CLIMB STEP SIZES AS INDICATED BY CARD TYPE 52.

<PERFORMANCE WITH OPTIMAL SETTINGS>

NODE NO.	LINK NO.	FLOW (VEH/H)	SAT FLOW (VEH/H)	DEGRE OF SAT (%)	TOTAL TRAVEL (VEH-MI	TOTAL TIME (VEH-H/H)	------- UNIFOR (VE	DELAY RAND H-H/H)	------- TOTA	AVERA DELAY (SEC/VE	UNIFORM STOPS (VEH/H;%)	MAX.BA OF QUEU (VEH/LK)	QUEUE CAPAC (VEH/L	FUEL CONSU (GA/H)	PHASE LENGT (SEC)	LINK NO.
1	101	125	1800	46	.00	.91	.81	.10	.91	26.1	107.6(86%)	2 >	0	1.26	13	101
1	102	180	1800	67	.00	1.52	1.20	.32	1.52	30.4	160.6(89%)	3 >	0	2.00	13	102
1	103	75	1700P	48	.00	.55	.49	.07	.55	26.6	64.6 (86%)	2 >	0	.76	13	103
1	104	48	103S	48	.00	.35	.31	.04	.35	26.6	41.3 (86%	103	103S	.49	13	104
1	105	969	5400	47	.00	3.85	3.74	.10	3.85	14.3	671.4 (69%	12 >	0	6.53	27	105
1	107	1005	3600	39	56.83	2.78	.03	.06	.09	.3	18.7 (2%)	2	24	2.87	47	107
1	108	360	1800	75	20.36	1.88	.39	.53	.92	9.2	74.4 (21%)	5	12	1.86	20	108
1	110	193	1800	23	.00	.00	.00	.00	.00	.0	.0 (0%)	0	0	.00	60	110
1	111	237	1800	13	.00	.00	.00	.00	.00	.0	.0 (0%)	0	0	.00	60	111

1 :		3192	MAX =	75	77.18	11.84	6.97	1.22	8.19	9.2	1138.6(36%			15.77	PI =	12.0
2	201	46	1800P	43	.00	.29	.27	.02	.29	22.9	38.0 (83%)	2 >	0	.42	16	201
2	202	110	201S	43	.00	.70	.64	.06	.70	22.9	90.8 (83%)	201	201S	1.02	16	202
2	203	200	1800	56	.00	1.37	1.20	.17	1.37	24.7	168.7(84%)	3 >	0	1.94	16	203
2	204	200	1800	56	.00	1.37	1.20	.17	1.37	24.7	168.7(84%)	3 >	0	1.94	16	204
2	205	955	3600	40	54.00	2.67	.04	.07	.11	.4	12.0 (1%)	1	24	2.73	44	205
2	206	242	1800	47	13.68	1.13	.37	.11	.48	7.1	39.5 (16%)	1	12	1.12	21	206
2	207	1055	5400	62	.00	5.35	5.10	.25	5.35	18.3	833.0(79%)	15 >	0	8.52	23	207
2	209	137	1800	15	.00	.00	.00	.00	.00	.0	.0 (0%)	0	0	.00	60	209
2	212	232	1800	13	.00	.00	.00	.00	.00	.0	.0 (0%)	0	0	.00	60	212
2 :		3177	MAX =	62	67.68	12.88	8.83	.84	9.67	11.0	1350.8 (43%)			17.68	PI =	14.4

<SYSTEM WIDE TOTALS INCLUDING ALL LINKS>

TOTAL DISTANC TRAVEL (VEH-MI/ (VEH-MI/	TOTAL TRAVEL TIME (VEH-H/	TOTAL UNIFOR DELAY (VEH-H/	TOTAL RANDO DELAY (VEH-H/	TOTAL DELAY (VEH-H/	AVERA DELAY (SEC/VE	TOTAL UNIFORM STOPS (VEH/H-%)	TOTAL FUEL CONSUM (GA/H)	OPERATING COST	PERFORMANCE INDEX	SPEED (MI/H)
144.87	24.72	15.80	2.06	17.86	10.10	2489.4(39%)	33.45	105.01	26.44	17.14

NOTE: PERFORMANCE INDEX IS DEFINED AS:

PI = DELAY + STOPS

NO. OF SIMULATIONS = 7 NO. OF LINKS = 87 ELAPSED TIME = 232.1 SEC.

1--------------Evaluating TUDI for 1990 A.M. Peak---------------- CYCLE: 60 SECONDS, 60 STEPS PAGE 6

TRANSYT-7F SIGNAL CONTROLLER SETTINGS

NETWORK-WIDE SIGNAL TIMING DATA

SYSTEM CYCLE LENGTH = 60 SECONDS

MASTER OFFSET REFERENCE LOCATION = INTERSECTION NO. 1 START OF INTERVAL 1.

THIS INTERVAL IS OFFSET 34 SECONDS FROM SYSTEM TIME BASE

INTERSECTION CONTROLLER SETTINGS

INTERSECTION 1 PRETIMED - SPLITS OPTIMIZED

INTERVAL NUMBER : 1 2 3 4 5 6

INTVL LENGTH(SEC): 23 4 9 4 16 4
INTVL LENGTH (%): 37 7 15 7 27 7

PIN SETTINGS (%): 100/0 37 44 59 66 93

PHASE START (NO.): 1 2 3

INTERVAL TYPE : V Y V Y V Y

```
SPLITS   (SEC):     27    13    20
SPLITS    (%):      44    22    34


LINKS MOVING :  105   101   107
               107   102   108
              -110   103  -110
               111   104   111
               110
               111

OFFSET =  0 SEC.  0 %.

THIS IS THE MASTER CONTROLLER.

+++ 193 +++ WARNING +
+          THE OFFSET FALLS WITHIN 1% OF AN INTERVAL
          CHANGE POINT AT THE START OF INTERVAL NO. 1.
1-------------Evaluating TUDI for 1990 A.M. Peak---------------        CYCLE:  60 SECONDS,  60 STEPS  PAGE  7



-----------------------------------------
INTERSECTION   2  PRETIMED - SPLITS OPTIMIZED
-----------------------------------------

INTERVAL NUMBER :  1  2  3  4  5  6

INTVL LENGTH(SEC):  19  4  12  4  17  4
INTVL LENGTH  (%):  31  7  20  7  28  7

PIN SETTINGS (%):     100/0 31 38 58 65 93

PHASE START (NO.):     1       2       3

INTERVAL  TYPE :     V  Y  V  Y  V  Y

SPLITS   (SEC):       23     16     21
SPLITS    (%):        38     27     35


LINKS MOVING :      205   201   205
                  207   202   206
                 -209   203  -209
                  212   204   212
                  209
                  212

OFFSET =  30 SEC.  50 %.
1-------------Evaluating TUDI for 1990 A.M. Peak---------------        CYCLE:  60 SECONDS,  60 STEPS  PAGE  8

  LINE    CARD
  NO.     TYPE
  35)      90     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

--- PROGRAM NOTE --- END OF JOB!
   1
```

---------------Evaluating AGI for 1990 A.M. Peak------------------------

1	95	115	0	0	0	2	2	-1	1	1	15	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	4	0	1800	30	35	100	25	1	85	25	40	100	125	120
16	1	0	0	0	4	0	4	0	4	0	4	0	4	0	0
21	1	1	1	2	0	19	101	102	109	110	111	-112	0	0	0
22	1	3	3	4	0	5	101	103	109	110	-111	-112	0	0	0
23	1	5	5	6	0	10	103	104	109	110	-111	112	0	0	0
24	1	7	7	8	0	10	105	106	-109	110	111	112	0	0	0
25	1	9	9	10	0	5	105	107	-109	-110	111	112	0	0	0
26	1	11	11	12	0	6	107	108	109	-110	111	112	0	0	0
28	101	0	3600	1035	0	0	0	0	0	0	0	0	0	0	0
28	102	0	1800	310	0	0	0	0	0	0	0	0	0	0	0
28	103	0	3600	1334	0	0	0	0	0	0	0	0	0	0	0
28	104	0	1800	228	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	727	0	0	0	0	0	0	0	0	0	0	0
28	106	0	1800	242	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	695	0	0	0	0	0	0	0	0	0	0	0
28	108	0	1800	360	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
29	109	0	0	0	0	0	0	0	105	50	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
29	111	0	0	0	0	0	0	0	103	50	0	0	0	0	0
28	112	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
29	112	0	0	0	0	0	0	0	101	50	0	0	0	0	0
50	0														
90															

--------------Evaluating AGI for 2010 A.M. Peak---------------------------

1	90	105	5	3	1	2	2	-1	11	1	15	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	4	0	1800	30	35	100	25	1	90	25	40	100	125	120
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	14	101	102	109	110	111	-112	0	0	0
22	1	3	3	4	0	10	101	103	109	110	-111	-112	0	0	0
23	1	5	5	6	0	14	103	104	109	110	-111	112	0	0	0
24	1	7	7	8	0	10	105	106	-109	110	111	112	0	0	0
25	1	9	9	10	0	10	107	108	109	-110	111	112	0	0	0
28	101	0	5400	1869	0	0	0	0	0	0	0	0	0	0	0
28	102	0	3600	502	0	0	0	0	0	0	0	0	0	0	0
28	103	0	5400	1808	0	0	0	0	0	0	0	0	0	0	0
28	104	0	3600	412	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	760	0	0	0	0	0	0	0	0	0	0	0
28	106	0	1800	394	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	1160	0	0	0	0	0	0	0	0	0	0	0
28	108	0	1800	480	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	247	0	0	0	0	0	0	0	0	0	0	0
29	109	0	0	0	0	0	0	0	105	50	0	0	0	0	0
28	110	0	1800	349	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1800	428	0	0	0	0	0	0	0	0	0	0	0
29	111	0	0	0	0	0	0	0	103	33	0	0	0	0	0
28	112	0	1800	419	0	0	0	0	0	0	0	0	0	0	0
29	112	0	0	0	0	0	0	0	101	33	0	0	0	0	0
50	0														
90															

--------------Evaluating SPUI w/o Frontage Roads for 1990 A.M. Peak----------

1	100	120	5	0	0	2	2	-1	1	1	15	0	0	0	0
2	1														
10	0	4	2	1800	30	35	100	25	1	90	25	40	100	125	120
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	10	102	104	109	110	111	112	0	0	0
22	1	3	3	4	0	10	105	107	109	110	111	112	0	0	0
23	1	5	5	6	0	10	106	108	109	110	111	112	0	0	0
28	102	0	3600	310	0	0	0	0	0	0	0	0	0	0	0
28	104	0	3600	228	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	727	0	0	0	0	0	0	0	0	0	0	0
29	105	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	106	0	1800	242	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	695	0	0	0	0	0	0	0	0	0	0	0
29	107	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	108	0	1800	360	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
28	112	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
52	0														
90															

--------------Evaluating SPUI w/o Frontage Roads for 2010 A.M. Peak--------------

1	100	120	5	0	0	2	2	-1	11	1	15	0	0	0	0
2	1														
10	0	4	2	1800	30	35	100	25	1	90	25	40	100	125	120
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	10	102	104	109	110	111	112	0	0	0
22	1	3	3	4	0	10	105	107	109	110	111	112	0	0	0
23	1	5	5	6	0	10	106	108	109	110	111	112	0	0	0
28	102	0	3600	502	0	0	0	0	0	0	0	0	0	0	0
28	104	0	3600	412	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	760	0	0	0	0	0	0	0	0	0	0	0
29	105	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	106	0	3600	394	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	1160	0	0	0	0	0	0	0	0	0	0	0
29	107	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	108	0	3600	483	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	247	0	0	0	0	0	0	0	0	0	0	0
28	110	0	1800	349	0	0	0	0	0	0	0	0	0	0	0
28	111	0	1800	428	0	0	0	0	0	0	0	0	0	0	0
28	112	0	1800	419	0	0	0	0	0	0	0	0	0	0	0
52	0														
90															

------------Evaluating SPUI with Frontage Roads for 1990 A.M. Peak---------

1	100	120	5	0	0	2	2	-1	1	1	15	0	0	0	0
2	1														
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	4	2	1800	30	35	100	25	1	90	25	40	100	125	120
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	10	102	104	109	110	111	112	0	0	0
22	1	3	3	4	0	10	105	107	109	110	111	112	0	0	0
23	1	5	5	6	0	10	106	108	109	110	111	112	0	0	0
24	1	7	7	8	0	10	101	103	109	110	111	112	0	0	0
28	101	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
29	101	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	102	0	3600	310	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1800	246	0	0	0	0	0	0	0	0	0	0	0
29	103	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	104	0	3600	228	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	727	0	0	0	0	0	0	0	0	0	0	0
29	105	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	106	0	1800	242	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	695	0	0	0	0	0	0	0	0	0	0	0
29	107	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	108	0	1800	360	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
28	112	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
50	0														
90															

---------------Evaluating SPUI with Frontage Roads for 2010 A.M. Peak--------

1	60	100	5	0	0	2	2	-1	1	1	15	0	0	0	0
2	1														
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	4	2	1800	30	35	100	25	1	90	25	40	100	125	120
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	10	102	104	109	110	111	112	0	0	0
22	1	3	3	4	0	10	105	107	109	110	111	112	0	0	0
23	1	5	5	6	0	10	106	108	109	110	111	112	0	0	0
24	1	7	7	8	0	10	101	103	0	0	0	0	0	0	0
28	101	0	1800	396	0	0	0	0	0	0	0	0	0	0	0
29	101	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	102	0	3600	502	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1800	400	0	0	0	0	0	0	0	0	0	0	0
29	103	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	104	0	3600	412	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	760	0	0	0	0	0	0	0	0	0	0	0
29	105	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	106	0	3600	394	0	0	0	0	0	0	0	0	0	0	0
28	107	0	3600	1160	0	0	0	0	0	0	0	0	0	0	0
29	107	0	2	0	0	0	0	0	0	0	0	0	0	0	0
28	108	0	3600	483	0	0	0	0	0	0	0	0	0	0	0
28	109	0	1800	247	0	0	0	0	0	0	0	0	0	0	0
28	110	0	1800	349	0	0	0	0	0	0	0	0	0	0	0
28	111	0	1800	428	0	0	0	0	0	0	0	0	0	0	0
28	112	0	1800	419	0	0	0	0	0	0	0	0	0	0	0
50	0														
90															

---------------Evaluating TUDI for 1990 A.M. Peak------------------------

1	60	90	5	3	1	2	2	-1	1	1	15	0	0	0	0
2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	103	104	0	0	0	201	202	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	0	85	25	40	100	125	120
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	6	105	107	-110	111	0	0	0	0	0
22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0
28	101	0	1800	125	0	0	0	0	0	0	0	0	0	0	0
28	102	0	1800	180	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1700	75	0	0	0	0	0	0	0	0	0	0	0
28	104	0	0	48	0	0	0	0	0	0	0	0	0	0	0
28	105	0	5400	969	0	0	0	0	0	0	0	0	0	0	0
28	107	300	3600	1662	0	202	110	30	204	200	30	207	695	30	0
28	108	300	1800	360	0	207	360	30	0	0	0	0	0	0	0
28	110	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
13	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	2	1	1	2	0	6	205	207	-209	212	0	0	0	0	0
22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0
28	201	0	1800	46	0	0	0	0	0	0	0	0	0	0	0
28	202	0	0	110	0	0	0	0	0	0	0	0	0	0	0
28	203	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	204	0	1800	200	0	0	0	0	0	0	0	0	0	0	0
28	205	300	3600	955	0	102	180	30	104	48	30	105	727	30	0
28	206	300	1800	242	0	105	242	30	0	0	0	0	0	0	0
28	207	0	5400	1055	0	0	0	0	0	0	0	0	0	0	0
28	209	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	50	0	0	0	0	0
28	212	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
52	0														
90															

---------------Evaluating TUDI for 2010 A.M. Peak-------------------------

1	80	85	5	3	1	2	2	-1	1	0	15	0	0	0	0
2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	103	104	0	0	0	201	202	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	0	85	25	40	100	125	120
13	1	0	1	25	4	18	4	25	4	0	0	0	0	0	0
21	1	1	1	2	0	6	105	106	107	-110	111	0	0	0	0
22	1	3	3	4	0	6	101	102	103	104	110	111	0	0	0
23	1	5	5	6	0	6	107	108	-110	111	0	0	0	0	0
28	101	0	1800	300	0	0	0	0	0	0	0	0	0	0	0
28	102	0	1800	262	0	0	0	0	0	0	0	0	0	0	0
28	103	0	1666	100	0	0	0	0	0	0	0	0	0	0	0
28	104	0	0	150	0	0	0	0	0	0	0	0	0	0	0
28	105	0	3600	760	0	0	0	0	0	0	0	0	0	0	0
28	106	0	1800	394	0	0	0	0	0	0	0	0	0	0	0
28	107	300	3600	1662	0	202	200	30	204	302	30	207	1160	30	0
28	108	300	3312	480	0	208	480	30	0	0	0	0	0	0	0
28	110	0	1800	349	0	0	0	0	0	0	0	0	0	0	0
29	110	0	0	0	0	0	0	0	107	50	0	0	0	0	0
28	111	0	1530	428	0	0	0	0	0	0	0	0	0	0	0
13	2	8	5	24	4	13	4	31	4	0	0	0	0	0	0
21	2	1	1	2	0	6	205	207	208	-209	212	0	0	0	0
22	2	3	3	4	0	6	201	202	203	204	209	212	0	0	0
23	2	5	5	6	0	6	205	206	-209	212	0	0	0	0	0
28	201	0	1653	96	0	0	0	0	0	0	0	0	0	0	0
28	202	0	0	200	0	0	0	0	0	0	0	0	0	0	0
28	203	0	1800	300	0	0	0	0	0	0	0	0	0	0	0
28	204	0	1800	302	0	0	0	0	0	0	0	0	0	0	0
28	205	300	3600	1172	0	102	250	30	104	162	30	105	760	30	0
28	206	300	3312	394	0	106	394	30	0	0	0	0	0	0	0
28	207	0	3820	1160	0	0	0	0	0	0	0	0	0	0	0
28	208	0	1580	480	0	0	0	0	0	0	0	0	0	0	0
28	209	0	1530	247	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	50	0	0	0	0	0
28	212	0	1530	419	0	0	0	0	0	0	0	0	0	0	0
50	0														
90															

-------Evaluating Three-Level Diamond for 1990 A.M. Peak--------

1	30	60	5	3	1	2	2	-1	1	1	15	0	0	0	0
2	1	2	3	4	0	0	0	0	0	0	0	0	0	0	0
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	1	85	25	40	100	125	120
12	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	6	105	111	0	0	0	0	0	0	0
22	1	3	3	4	0	6	103	104	-111	0	0	0	0	0	0
28	103	300	1800	606	0	408	360	30	403	246	30	0	0	0	0
28	104	300	1800	228	0	403	228	30	0	0	0	0	0	0	0
28	105	0	3600	242	0	0	0	0	0	0	0	0	0	0	0
28	111	0	1800	237	0	0	0	0	0	0	0	0	0	0	0
29	111	0	0	0	0	0	0	0	103	100	0	0	0	0	0
12	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	2	1	1	2	0	6	205	206	-209	0	0	0	0	0	0
22	2	3	3	4	0	6	201	209	0	0	0	0	0	0	0
28	201	0	3600	510	0	0	0	0	0	0	0	0	0	0	0
28	205	300	1800	228	0	104	228	30	0	0	0	0	0	0	0
28	206	300	1800	242	0	105	242	30	0	0	0	0	0	0	0
28	209	0	1800	137	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	100	0	0	0	0	0
12	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	3	1	1	2	0	6	301	302	-312	0	0	0	0	0	0
22	3	3	3	4	0	6	307	312	0	0	0	0	0	0	0
28	301	300	1800	442	0	206	242	30	201	200	30	0	0	0	0
28	302	300	1800	310	0	201	310	30	0	0	0	0	0	0	0
28	307	0	3600	360	0	0	0	0	0	0	0	0	0	0	0
28	312	0	1800	232	0	0	0	0	0	0	0	0	0	0	0
29	312	0	0	0	0	0	0	0	301	100	0	0	0	0	0
12	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	4	1	1	2	0	6	407	408	-410	0	0	0	0	0	0
22	4	3	3	4	0	6	403	410	0	0	0	0	0	0	0
28	403	0	3600	474	0	0	0	0	0	0	0	0	0	0	0
28	407	300	1800	310	0	302	310	30	0	0	0	0	0	0	0
28	408	300	1800	360	0	307	360	30	0	0	0	0	0	0	0
28	410	0	1800	193	0	0	0	0	0	0	0	0	0	0	0
29	410	0	0	0	0	0	0	0	407	100	0	0	0	0	0
37	9999	103	104	205	206	301	302	407	408	0	0	0	0	0	0
40	103	0	104	0	205	0	206	0	301	0	302	0	407	0	0
40	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0														
90															

-------------Evaluating Three-Level Diamond for 2010 A.M. Peak-------------

1	30	60	5	3	1	2	2	-1	1	1	15	0	0	0	0
2	1	2	3	4	0	0	0	0	0	0	0	0	0	0	0
4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	107	108	0	0	0	203	204	0	0	0	305	306	0	0	0
7	401	402	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	4	0	1800	30	35	100	25	0	85	25	40	100	125	120
12	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	1	1	1	2	0	6	105	111	0	0	0	0	0	0	0
22	1	3	3	4	0	6	103	104	107	108	-111	0	0	0	0
28	103	300	1800	470	0	408	320	30	403	150	30	0	0	0	0
28	104	300	1800	412	0	403	412	30	0	0	0	0	0	0	0
28	105	0	5400	696	0	0	0	0	0	0	0	0	0	0	0
28	107	300	1850	410	0	408	160	30	403	250	30	0	0	0	0
28	108	300	0	100	0	403	100	30	0	0	0	0	0	0	0
28	111	0	1800	428	0	0	0	0	0	0	0	0	0	0	0
29	111	0	0	0	0	0	0	0	103	100	0	0	0	0	0
12	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	2	1	1	2	0	6	203	204	205	206	-209	0	0	0	0
22	2	3	3	4	0	6	201	209	0	0	0	0	0	0	0
28	201	0	5400	898	0	0	0	0	0	0	0	0	0	0	0
28	203	300	1800	250	0	104	100	30	105	150	30	0	0	0	0
28	204	300	0	94	0	105	94	30	0	0	0	0	0	0	0
28	205	300	1800	482	0	104	312	30	105	170	30	0	0	0	0
28	206	300	1850	300	0	105	300	30	0	0	0	0	0	0	0
28	209	0	1800	247	0	0	0	0	0	0	0	0	0	0	0
29	209	0	0	0	0	0	0	0	205	100	0	0	0	0	0
12	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	3	1	1	2	0	6	301	302	305	306	-312	0	0	0	0
22	3	3	3	4	0	6	307	312	0	0	0	0	0	0	0
28	301	300	1800	500	0	206	300	30	201	200	30	0	0	0	0
28	302	300	1800	402	0	201	402	30	0	0	0	0	0	0	0
28	305	300	1850	290	0	206	94	30	201	196	30	0	0	0	0
28	306	300	0	100	0	201	100	30	0	0	0	0	0	0	0
28	307	0	5400	830	0	0	0	0	0	0	0	0	0	0	0
28	312	0	1800	419	0	0	0	0	0	0	0	0	0	0	0
29	312	0	0	0	0	0	0	0	301	100	0	0	0	0	0
12	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21	4	1	1	2	0	6	401	402	407	408	-410	0	0	0	0
22	4	3	3	4	0	6	403	410	0	0	0	0	0	0	0
28	401	300	1850	345	0	302	170	30	307	175	30	0	0	0	0
28	402	300	0	70	0	307	70	30	0	0	0	0	0	0	0
28	403	0	5400	812	0	0	0	0	0	0	0	0	0	0	0
28	407	300	1800	507	0	302	332	30	307	175	30	0	0	0	0
28	408	300	1850	410	0	307	410	30	0	0	0	0	0	0	0
28	410	0	1800	349	0	0	0	0	0	0	0	0	0	0	0
29	410	0	0	0	0	0	0	0	407	100	0	0	0	0	0
50	0														
90															