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AUTOMATIC UPDATING of TRAFFIC VOLUME DATA for SIGNAL TIMING PLAN DEVELOPMENT

Prepared for:

Federal Highway Administration
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jhk & associates

July 1987

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16. Abstract

The purpose of this research was to test the validity of using automatically-collected traffic volumes from selected system detector sites to generate a full TRANSYT-7F data file for calculating signal network timing plans. Termed the 1.5 GC control concept, this approach assumes that volume shifts on selected links will accurately represent shifts throughout the network. Tests were run at two significantly different test sites and included several detector placement scenarios.

The essential tasks included determining from a pre-existing data set the factors to be used to designate which volume data (locations) would serve as a surrogate to represent data collected by "system detectors." Site-specific algorithms were devised to synthesize TRANSYT data from the system detector data. New turning movement volume data were then collected at all signalized intersections at the same time link volume counts were manually collected at system detector sites.

Applying the algorithms, TRANSYT-7F input files were created and signal settings were then generated using the estimated link volumes and link-to-link movement data. This TRANSYT run was then compared to the optimum settings generated using the new full TRANSYT data set.

Results from multiple TRANSYT runs for both test sites strongly suggest that the 1.5 GC approach as simulated in this research is a viable alternative to the labor-intensive conventional field data collection currently used to develop TRANSYT-7F volume data files. This allows more frequent updates of timing plans to meet changing traffic conditions.

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FINAL REPORT

VOLUME I. TECHNICAL REPORT

AUTOMATIC UPDATING OF TRAFFIC VOLUME DATA FOR SIGNAL TIMING PLAN DEVELOPMENT

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1. INTRODUCTION

This report documents the results of the research project entitled, "Automatic Updating of Traffic Volume Data for Signal Timing Plan Development" conducted for the Federal Highway Administration. The project conducted by JHK & Associates under FHWA Contract No. DTFH61-85-C-00134, was initiated September, 1985 and was completed April, 1987.

The following section presents a brief background of the factors leading to the research, the project objectives, the scope of work undertaken, and the methodology used.

BACKGROUND

The performance of a traffic control system, regardless of its purported level of sophistication, is directly determined by the signal timing at an intersection and its relationship to the timing plans at adjacent intersections. The underlying philosophy is that delay is minimized when phasing, cycle, and split most closely relate to traffic demands which are occurring at any given point in time--and, that some combination of stops and delays are minimized when cycle-split relationships and offsets between intersections are designed to accommodate current primary and secondary flows between intersections.

Traditionally, most improvements in control concepts have been related to providing "more" plans so that the plans may more accurately track conditions expected to occur on the street. To a more limited degree, procedures have been initiated to measure conditions in the field and select a plan which has been designed to accommodate the measured conditions. Parallel developments have occurred to ensure that adjacent intersections operate in a coordinated manner and to report on equipment failures which preclude the "best" plan from working in the field. The "best" plans were generally developed using manual techniques and were updated only on rare occasions. Updating the plans required extensive field data collection, manual calculations, and traveling to each intersection in the field to physically change the timing on the local controller.

The application of computer technology provided several opportunities to enhance system control. First, the number of timing plans were no longer restricted by hardware limitations at the local controller. For all practical purposes, an infinite number of plans could be provided.

Next, the central computer provided an opportunity to gather traffic volume data and store the information for future usage. The data could also be used in traffic responsive plan selection; that is, selecting a plan from a predeveloped list of plans that most closely matches current traffic conditions.

Another major opportunity presented by the computer was the ability to calculate plans using more sophisticated software models. The development of the models kept pace with the development of the control concepts; the more plans used, the more important it became to have efficient procedures for developing plans.

Initial models included SIGRID, developed by JHK's predecessor firm for the Toronto implementation; SIGOP, an enhancement of the SIGRID concept developed for the Federal Highway Administration; and early versions of TRANSYT, developed by the British at the Transportation Road Research Laboratory. The TRANSYT program has undergone continued development of the last ten years. An "Americanized" version, designated TRANSYT-7F, has become the de-facto standard for timing networks. All of these models require extensive field data collection of traffic data. For example, it has been estimated that the cost of timing a signal using the TRANSYT model is approximately $1,100. Much of this cost is associated with the data collection effort.

It appears intuitively obvious that the computer should offer the opportunity to reduce or eliminate the need for the data collection tasks and the off-line calculation of timing plans. It was assumed that software could be developed which used the traffic data from sensors, calculated new plans, and implemented the plans in real time. Such a cybernetic system would have the distinct advantage of providing more plans to most closely match conditions and to provide the plans at the time they were needed.

These assumptions led to research efforts to develop new families of control concepts, referred to as "second" or "third" generation control. In the U.S., these concepts were developed and tested under the UTCS research program. In England, they were a continuation of the TRANSYT computational philosophy and entitled

"SCOOT." Another type of algorithm was developed in Australia and became known as the "SCAT" system. These systems have met with varying levels of success. The U.S. efforts did not prove workable under the development budgets provided and did not appear to offer sufficient promise to warrant further FHWA investment at the time.

The reluctance to move further into the second generation concepts involves both practical and philosophical concerns. The practical concern is for the number of detectors that have to be installed (and maintained) and the effect that the added computational demand has on computer size and speed. Detectors have proved to be one of the less reliable components of many systems and the installation and maintenance costs are significant. Of greater concern is the question as to whether the second generation algorithms can adequately respond to the normal variations in traffic.

The "statistical quality" of traffic demand has proven to be very poor. That is, predicting what will happen in the near future based on the recent past is extremely difficult. The U.S. algorithms which were based on a prediction model were not able to compensate for the substantial variations of traffic over 15 or even five-minute periods. It would seem that any near term work in the advanced control concepts in the U.S. will concentrate on evaluating, and perhaps field testing SCOOT.

There remains a strong feeling that it may be practical to find a middle ground between the current U.S. approach to using pre-developed plans, called by time of day or by a traffic responsive mode, and the more complex second generation strategies. This middle ground, or 1.5 GC (Generation Control) system would be designed to take advantage of the computer's ability to store a large number of plans, to gather selected traffic volume information, and process traffic optimization algorithms while continuing in the normal control mode.

As envisioned, the system would not respond to short term fluctuations. Rather, it would regularly (e.g., every six months) "test" the timing that is being used against new plans calculated from the automatically-collected traffic volumes. When it appears that traffic has changed to a point where a new plan is warranted, the plan would be developed and implemented using the computer-aided techniques.

Thus, the 1.5 GC control concept takes into account the fact that traffic patterns change over time and that these changes reflect statistically significant shifts, but does not try to react to the highly volatile short term variations which may or may not be true trends.

Under the 1.5 GC control concept, it is assumed that volume shifts on selected links in the network will accurately represent shifts throughout the network. More specifically, it is assumed that only a portion of the links will have to be detectorized to provide adequate data to measure trends. This would reduce the costs of implementation over systems such as SCOOT, which require placing detectors on essentially all approaches to signalized intersections. It would also reduce the load placed on the control system for processing detector data on a once-per-second basis, as is common in U.S. systems or once-per-quarter second as with SCOOT. The manual efforts would be reduced to the initial set-up activity and then periodic updates of selected parameters. It would rarely be necessary to completely redo the TRANSYT database.

RESEARCH OBJECTIVES AND SCOPE

The critical question addressed in this research was: Can a limited number of detectors provide data representative of the entire network as used by TRANSYT? If it proves practical to use data from selected surveillance points to calibrate the entire volume and turning movement files, it should be practical to continue the automation process and implement a limited 1.5 GC concept. Conversely, if it does not appear practical to use the automatically-collected volume data or if the level of detectorization required approximates that needed for SCOOT, it is less likely that the 1.5 GC concept as now envisioned will offer significant promise.

The research builds on the hypothesis that, if you can replicate the TRANSYT results from a full data set by using a data set generated to represent system detector data, then you can also use detector data sets to update TRANSYT volumes and timing plans. Therefore, the objective of this result was to validate the automatic traffic volume data for signal timing plan development.

2. WORK PLAN

The basic research approach involved comparing optimum signal timing plans calculated from a full new TRANSYT-7F data set with timing plans calculated from selected system detector data representing the full data set. If the timing plans generated using system detector data for the first test site (Tallahassee) compared favorably with the optimum plans calculated from new complete traffic volume data, the work would then be repeated at the second test site (Los Angeles). If the comparison was unfavorable, the work at the first test site would be repeated using new rules for the choice of system detectors and revised computational algorithms.

The essential elements of the Work Plan structured for this project are depicted in Figure 2-1. The initial task included obtaining a complete TRANSYT-7F data set from the test site in Tallahassee ("before" data) and determining the factors to be used in designating which volume data (locations) would serve as a surrogate to represent data collected by "system detectors."

Using the "before" data, algorithms were then devised to synthesize the balance of the required TRANSYT-7F data from the system detector data. These algorithms were required to be specific to the individual test network and suitable for estimating both total link volumes and link-to-link counts on the "undetectorized" links, as well as link-to-link counts on the detectorized links.

The next task was to collect new turning movement volume data ("after" data) at all signalized intersections as required for operation of the TRANSYT-7F model. In addition, link volume counts were collected manually at the "system detector" locations at the same time the new turning movement counts were taken.

Applying the algorithms devised from the "before" data, TRANSYT-7F input files were created. TRANSYT-7F signal settings were then generated using those estimated link volumes and link-to-link movement data. These settings represent those that would be produced by a 1.5 GC system. This TRANSYT run was then compared to the optimum settings generated using the new full TRANSYT data set. That is, two TRANSYT evaluation outputs were compared. The first represents a 1.5 GC approach where limited new volume data from "system detectors" are factored to provide a complete volume data set. The second represents a complete

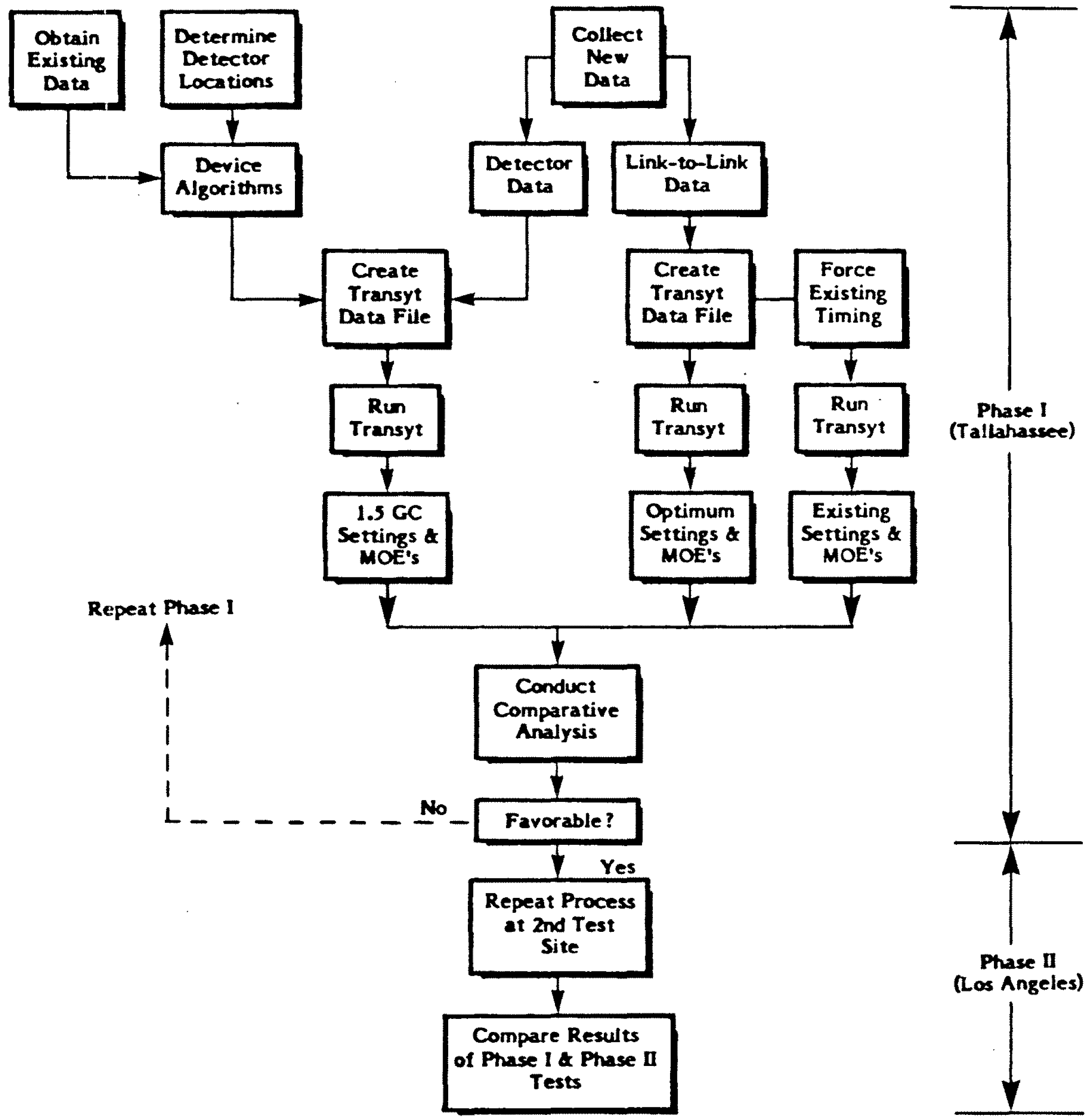

Figure 2-1
STUDY WORK PLAN

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field study of volumes as is conventionally performed for an update of timing plans. Only the "non-volume" data (e.g., geometrics, speeds, etc.) are common to both sets. This approximated an automated update system versus one which uses new manually-collected information.

For comparative purposes, multiple TRANSYT runs were conducted for various system detector densities (scenarios) for the morning peak period and off-peak period. The primary measure of effectiveness used in the comparison was the TRANSYT-7F Performance Index which includes a measure of both stops and delays in a traffic signal network.

As a further test of the 1.5 GC concept, a TRANSYT-7F run was made using existing timing and new detector generated volumes to provide a measure of the effectiveness of the original time settings.

As the 1.5 GC-produced timing plans compared favorably with the plan prepared by conventional means, the research tasks were repeated at the second test site (Los Angeles). The results of the tests conducted at both sites, the conclusions, and recommendations are documented in the following Final Report. Detailed volume updating algorithms and detector scenario comparisons for each of the two test sites are provided in Volume 2. Technical Supplement.

3. PHASE I TEST - TALLAHASSEE

The site selected for the initial test of the validity of automatically updating of traffic volume data was Tallahassee, Florida. Tallahassee is the State Capital of Florida, and has a population of approximately 82,000 with an urbanized area population of approximately 160,000. The test site is located in the Central Business District and is representative of the downtown area of a medium sized urban area with a relatively strong commercial and private office core along with state government offices. The conditions are typical of those found in numerous cities throughout the United States where peak periods are relatively short but intense and with strong mid-day circulation.

DESCRIPTION OF TEST SITE

The general layout of the Tallahassee test site is shown in Figure 3-1. The signals operate under a UTCS-based central control system. Of the 30 signals within the test area, 25 are pretimed, 4 are traffic actuated, and one is pedestrian actuated. There are 30 traffic sensors tied into the control system in the area. The roadway network is essentially a downtown grid area. It includes two arterials and two one-way street pairs which serve as the primary access routes into the CBD. The arterials and one-way streets are connected with two-way collector streets to provide the downtown circulation system. Block spacing is irregular with several relatively short links (approximately 400 feet).

Previous to this project, traffic data were collected in March, 1984 specifically for a TRANSYT timing evaluation. Turning movement counts were taken at all intersections in the test area. They were taken on weekdays between the hours of 6:00 AM and 6:00 PM. In addition, automatic road tube counts were taken at four locations in the study area. The counts covered 24 hours a day for seven days. Timing plans were developed for six traffic conditions, two peak period plans and four off-peak period plans. The plans were developed using TRANSYT-7F, Release 3. The TRANSYT-7F network and hourly link volumes for the morning peak and mid-morning traffic conditions are shown in Figures 3-2 and 3-3.

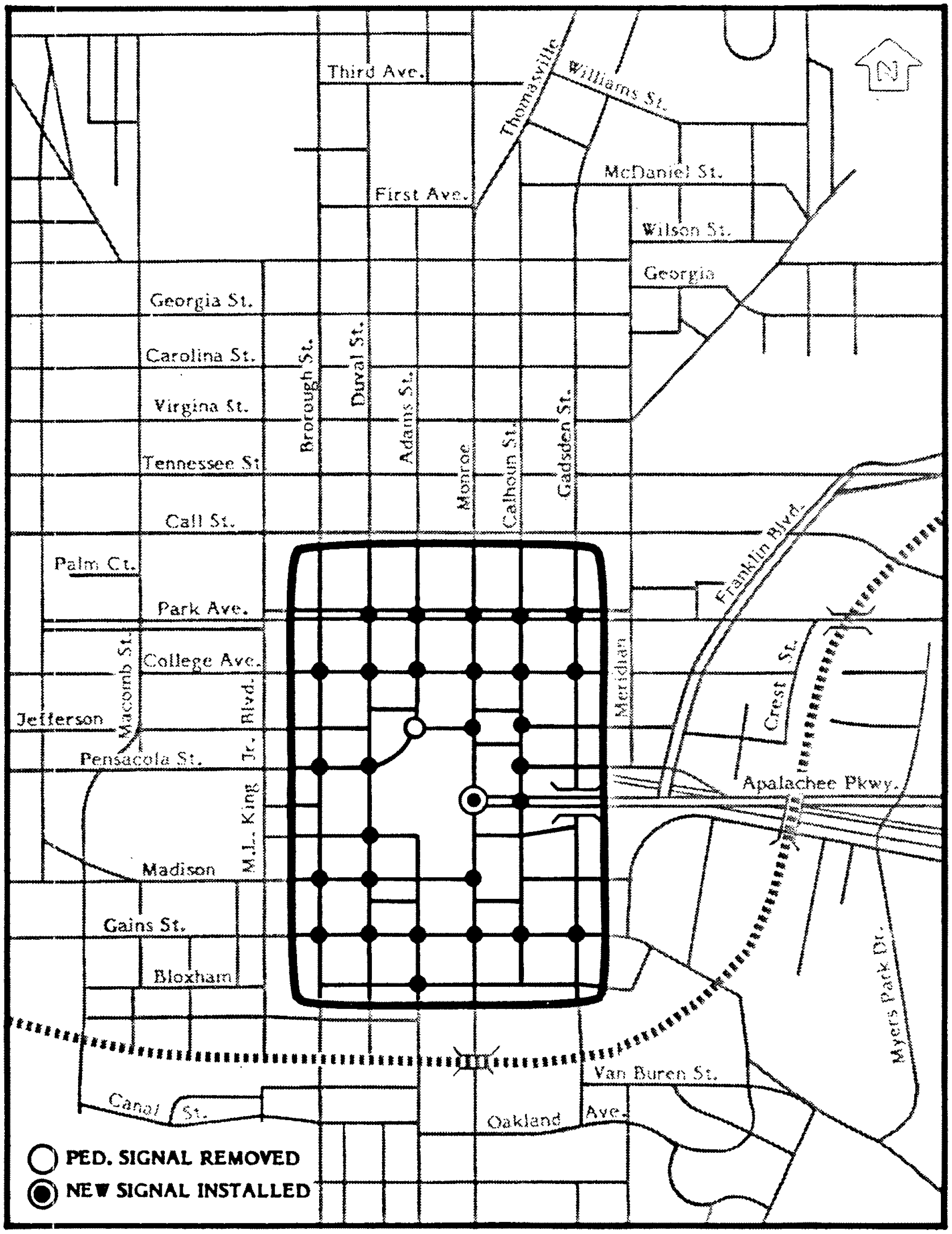

Figure 3-1

TALLAHASSEE TEST SITE

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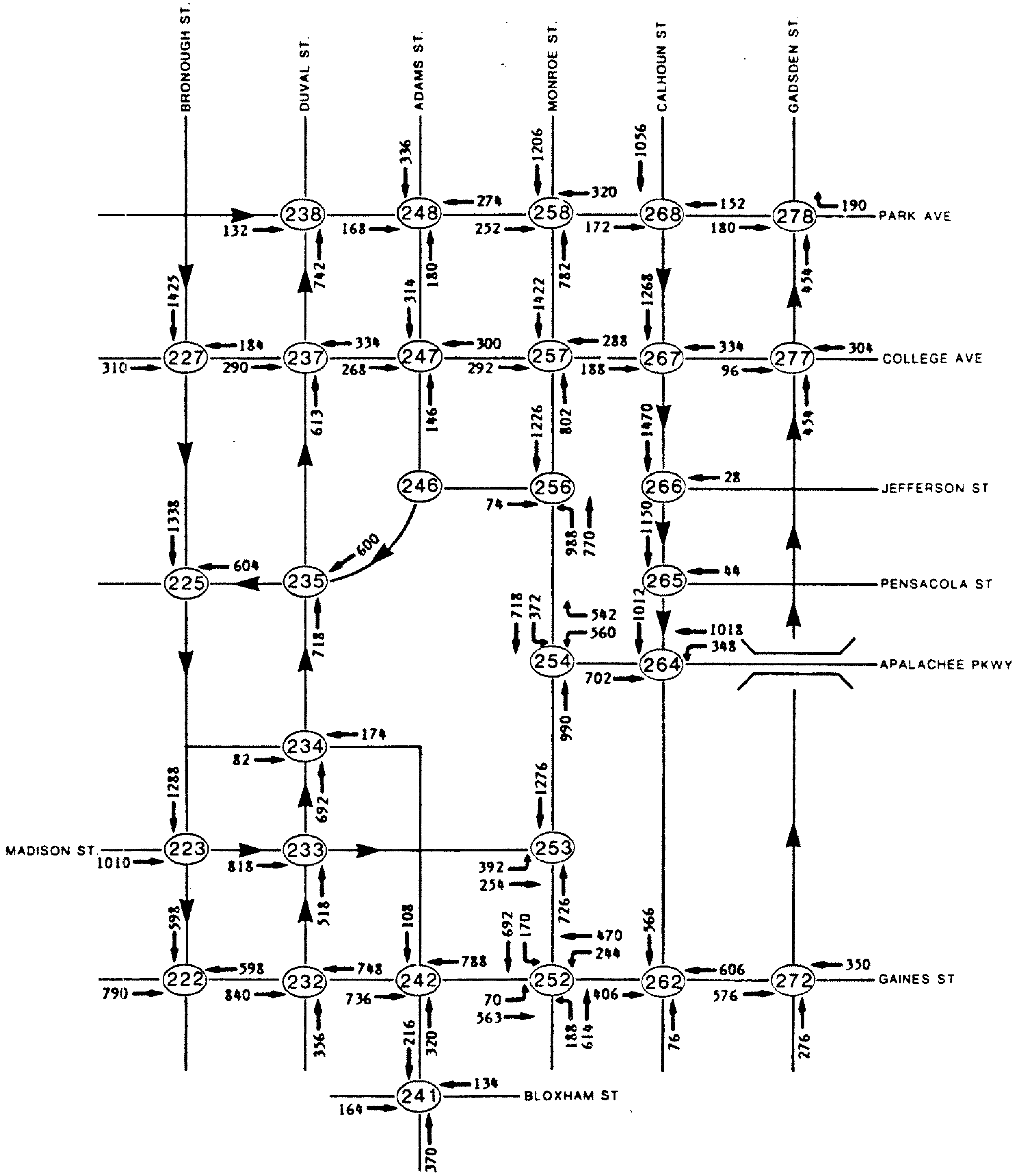

Figure 3-2

AM PEAK HOUR LINK VOLUMES

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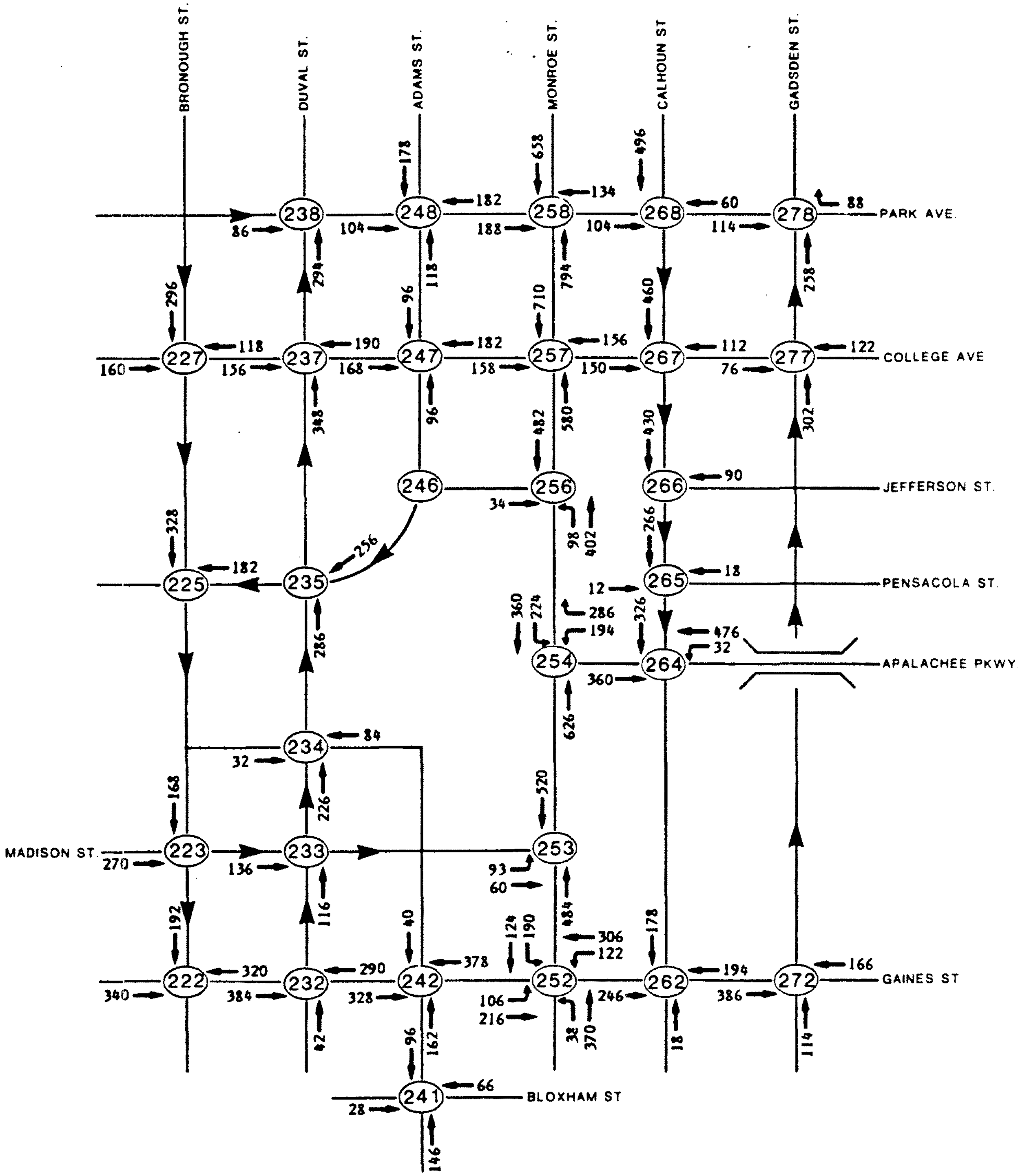

Figure 3-3

MID-MORNING LINK VOLUMES

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Since the 1984 TRANSYT-7F signal timing study, two minor changes have occurred in the study area:

- o A traffic signal was installed at the intersection of Adams Street and Jefferson Street (Intersection 246)
- o A minor street link and traffic signal were removed. Pensacola Street was closed between Calhoun and Monroe, and the pedestrian signal at Monroe and Pensacola was removed.

Neither of these changes materially affected the project.

The traffic signal system which controls the study area was designed using a UTCS-based traffic control concept. The 30 system detectors in the network represent a ratio of one detector per signal and are located as shown in Figure 3-4. In the existing system, detectors are located one each to a mid-block detector site. Detectors are located on the middle lane of three-lane approaches and the inside lane of two-lane approaches. (These detectors were not operational at the time of this study.)

DETECTOR LOCATION FACTORS

The essence of this research project was to test the validity of transforming limited detector data into a complete volume file for TRANSYT-7F. It was important to keep the number of detector locations to a reasonable limit. At the same time, it was essential that the data be reasonably complete so as not to doom the test to failure by simply "undetectorizing" the test network.

The location of the "system detectors" is considered critical to the success of any 1.5 GC traffic control system and is highly dependent on local knowledge of the particular network. Any general rules or strategies should always be superseded by the judgment of traffic engineers with local knowledge of existing traffic conditions. Local factors that should be considered include:

- o The location of intersections which tend to control the cycle length of the signal network.

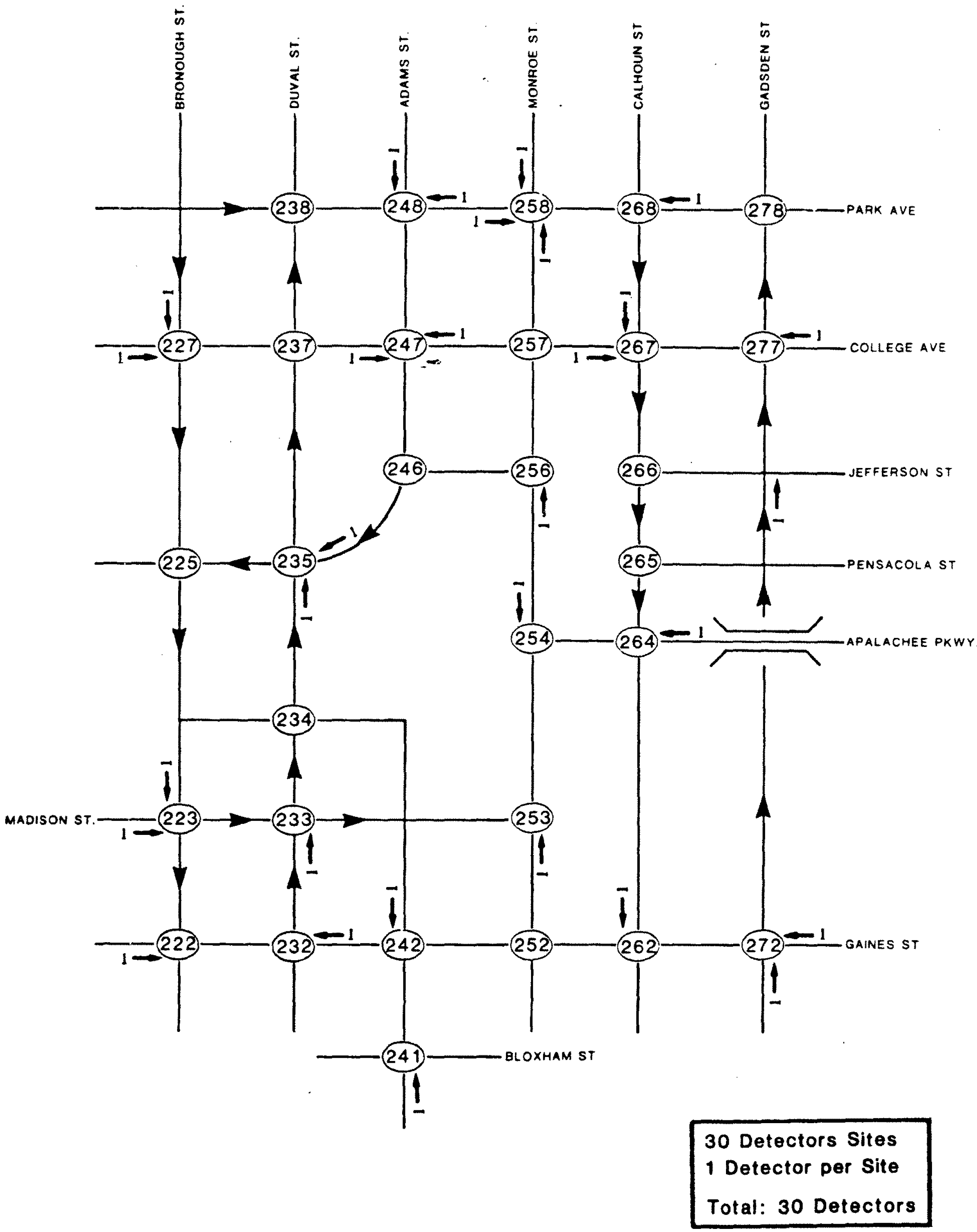

Figure 3-4

EXISTING DETECTORS

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- o The location of streets and intersections approaching capacity and therefore sensitive to changes in splits
- o The location of streets and intersections at which traffic volumes are not likely to change nor require detection.
- o Plans for future land use and street network changes that may affect traffic conditions.

For purposes of this research, a "detector site" is defined as a mid-block location where detectors are installed in order to count one direction of traffic. A two-way street requires two detector sites in order to count traffic in both directions. A "detector" is defined as a device which counts traffic in a single traffic lane. Any number of detectors may be located at a detector site, from one up to the number of lanes in the particular direction of traffic to which the detector site has been assigned.

DETECTION PLACEMENT SCENARIOS

Seven alternative scenarios of detector placement strategies were initially developed and are summarized in Table 3-1. It was determined that these scenarios covered the range of practical detector densities. The maximum detector scenario (A) requires a detector in each lane of each approach to all signalized intersections. At the other end of the spectrum, the minimum scenario (G) is one in which each street (except a minor street affecting only one intersection) has only one detector per direction along its length.

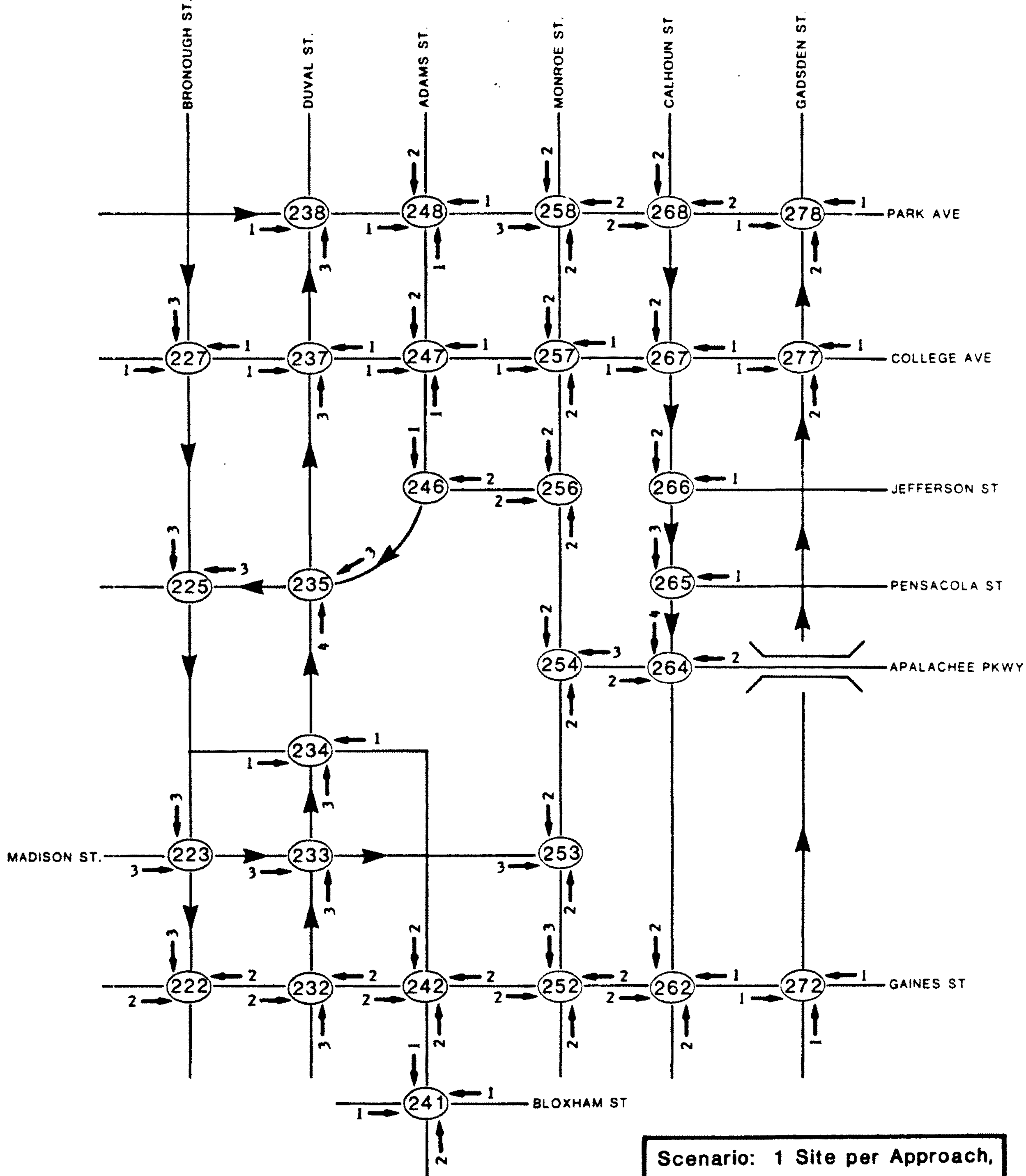
Detector locations in the first test site (Tallahassee) for the seven scenarios are shown in Figures 3-5 through 3-11. After a preliminary screening of the alternative scenarios, Scenarios A, C, and E were retained for further study. Scenarios B, F, and G were eliminated because the Tallahassee 1984 TRANSYT-7F data were not available on a lane-by-lane basis and would make comparisons extremely difficult. Scenario D was considered quite similar to Scenario E, and it was determined that only one need be studied in detail. Scenario E was selected as it would lead to examination of a broader range of detector densities.

Table 3-1

DETECTOR PLACEMENT SCENARIOS

Scenario	Description	No. of Detector Sites	No. of Detectors	No. of Detectors per Signal
A	Detectors on all intersection approaches	90	171	5.7
B	One detector per site on all intersection approaches	90	90	3.0
C	Detectors on all approach lanes at intersections of major streets	33	65	2.2
D	Two detector sites per direction for major streets; one per direction for other streets (detectors on all lanes)	33	62	2.1
E	One detector site in each direction on each street (detectors on all lanes)	25	50	1.7
F	Two detector sites per direction for major streets, one per direction for other streets (one detector per site)	33	33	1.1
G	One detector at one detector site each direction on each street	25	25	0.8

☐ Retained for further study (scenarios A, C and E are boxed in the original)



Scenario: 1 Site per Approach, All Lanes

Total: 171 Detectors (5.7 per Signal)

Figure 3-5

DETECTOR SCENARIO A

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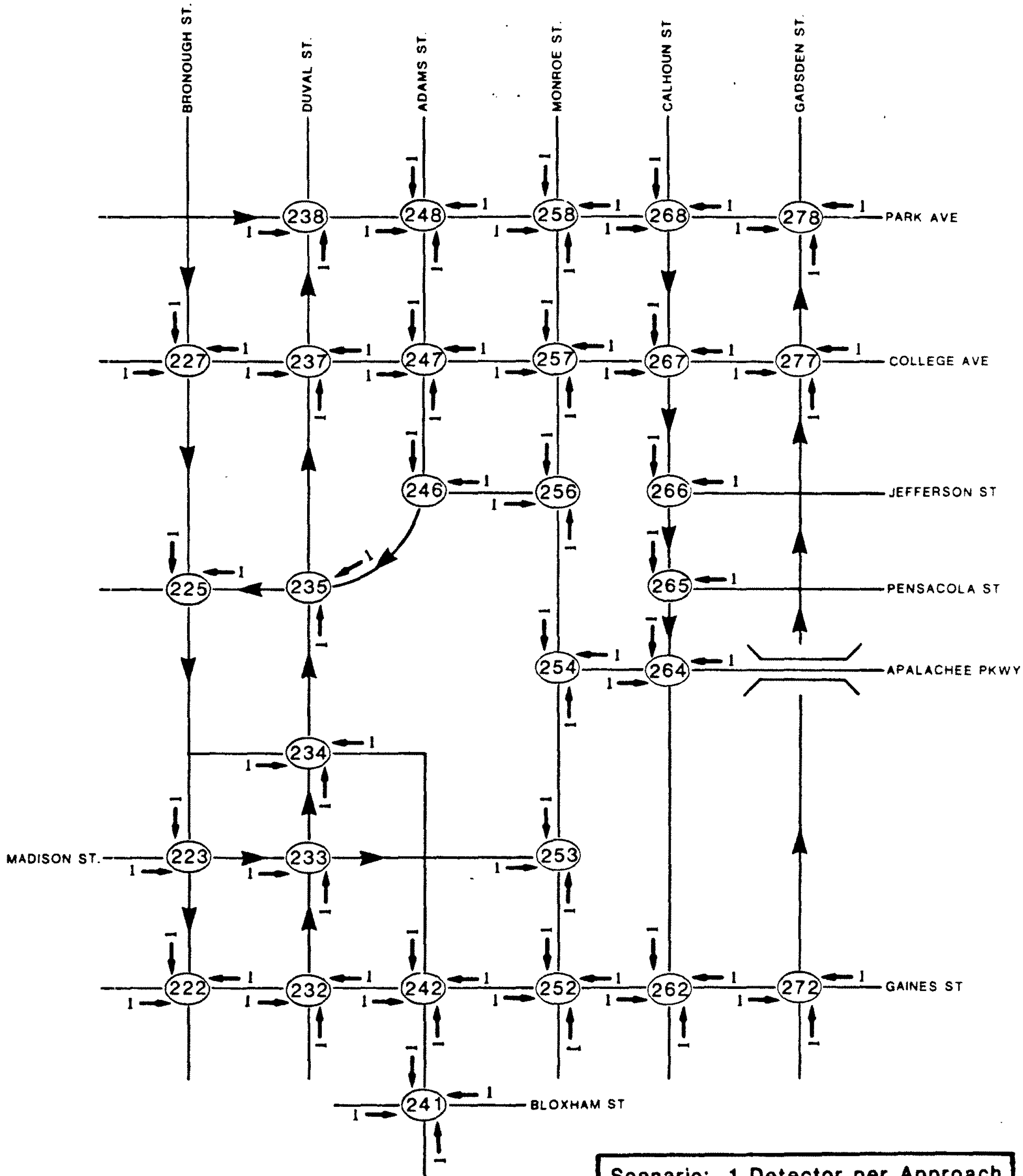

Scenario:	1 Detector per Approach
Total:	90 Detectors (3 per Signal)

Figure 3-6

DETECTOR SCENARIO B

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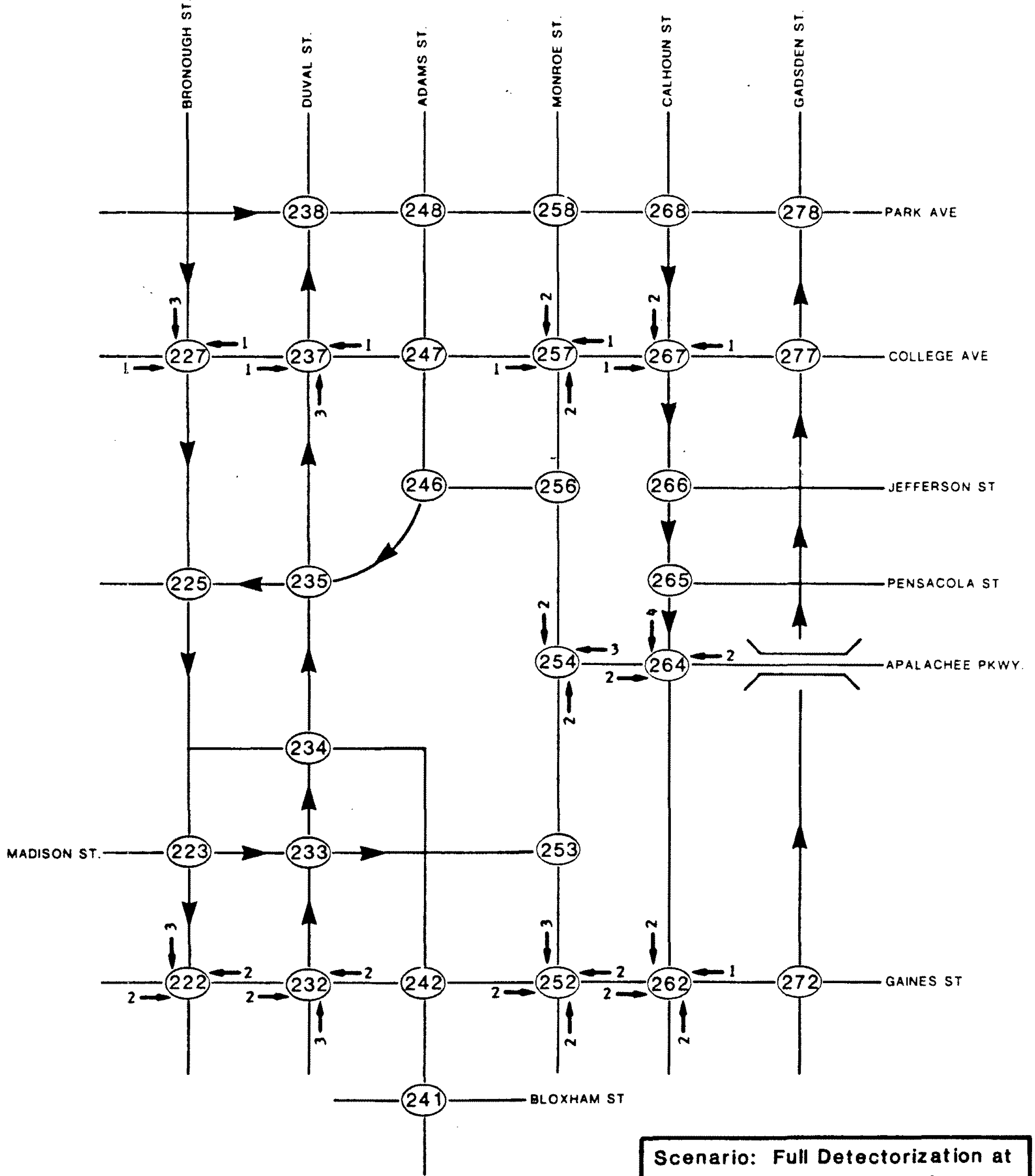

Scenario: Full Detectorization at Major Intersections (LA-type Methodology)

Total: 65 Detectors (2.2 per Signal)

Figure 3-7

DETECTOR SCENARIO C

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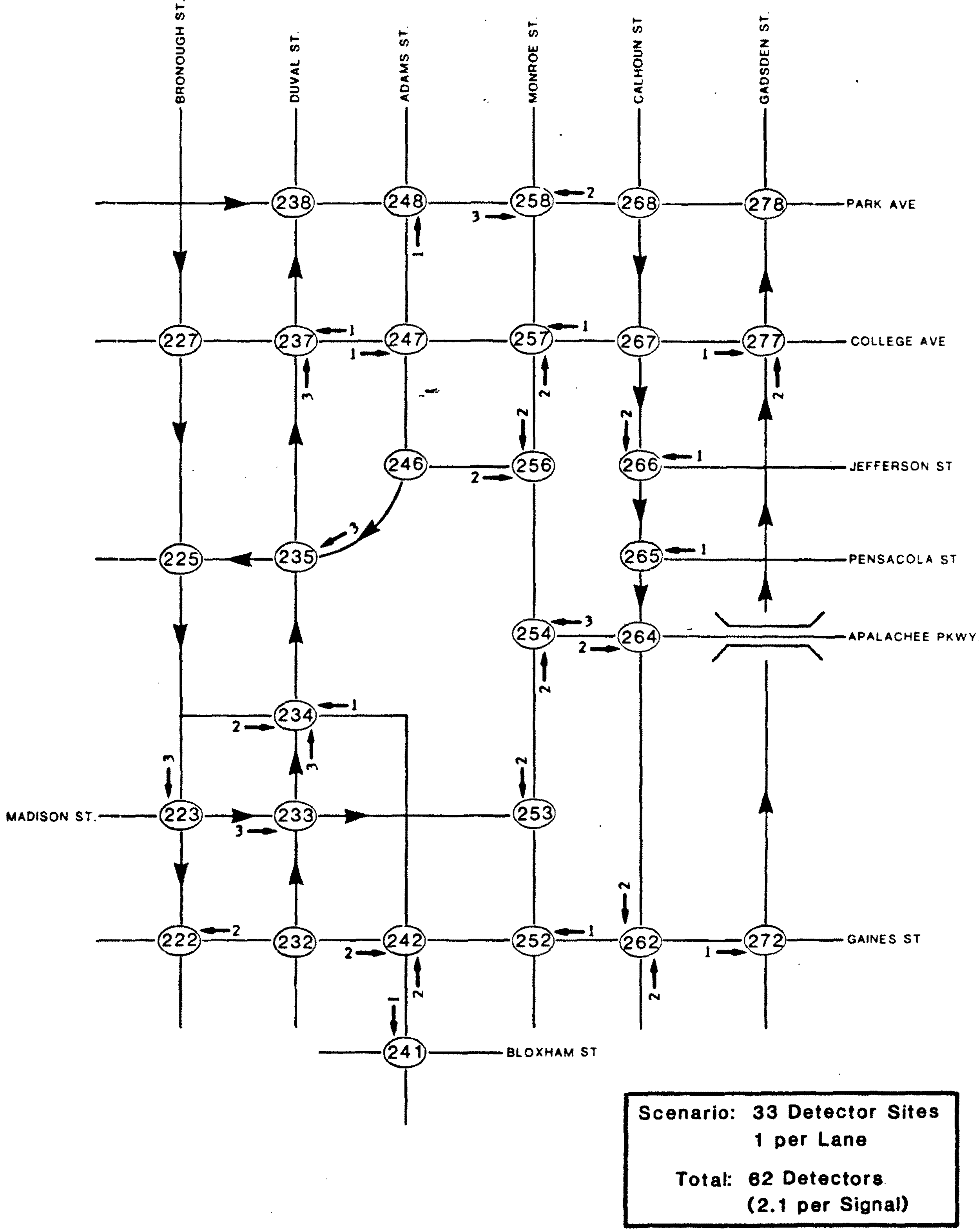

Figure 3-8

DETECTOR SCENARIO D

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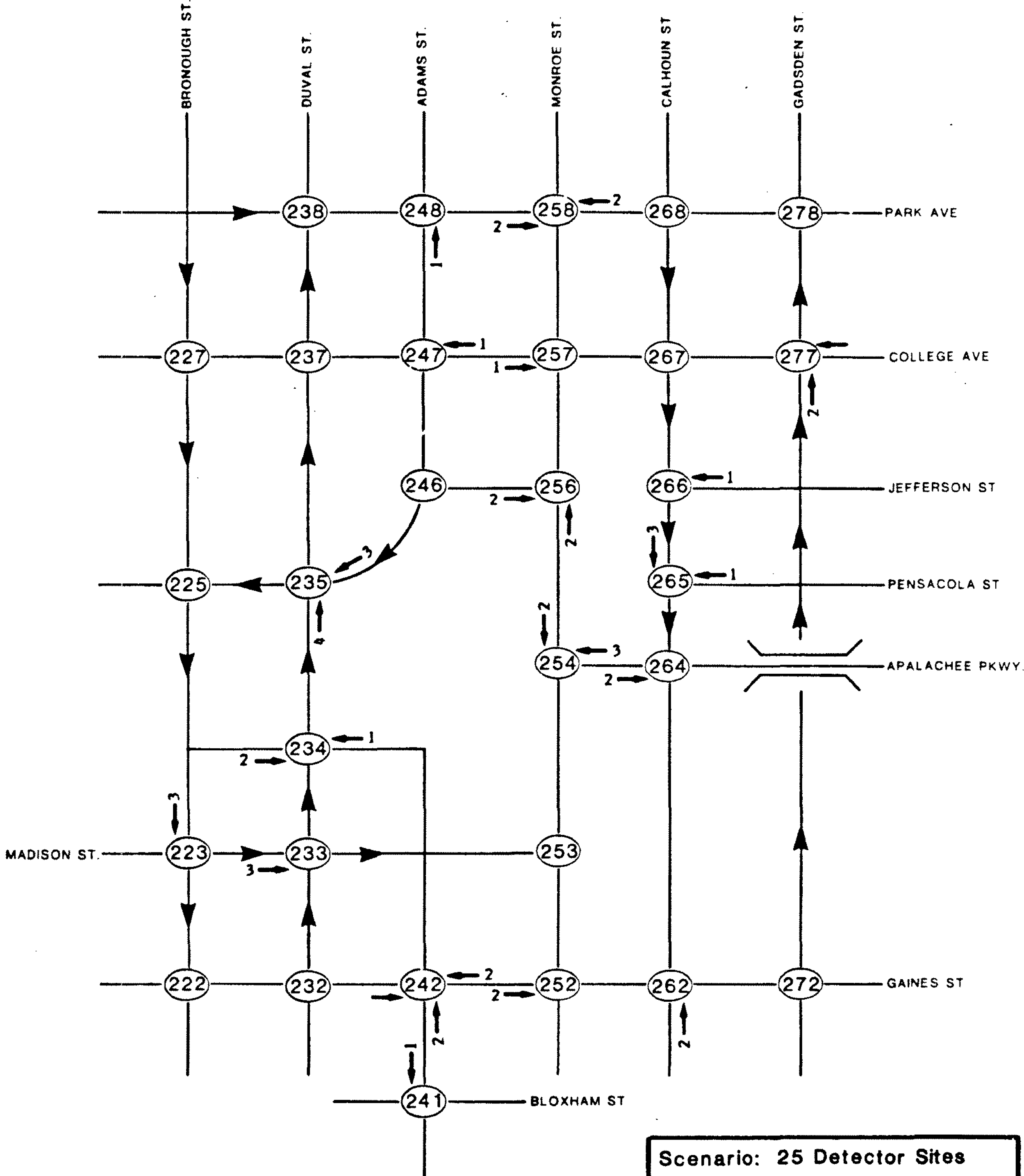

Scenario: 25 Detector Sites
1 Detector per Lane

Total: 50 Detectors
(1.7 per Signal)

Figure 3-9
DETECTOR SCENARIO E

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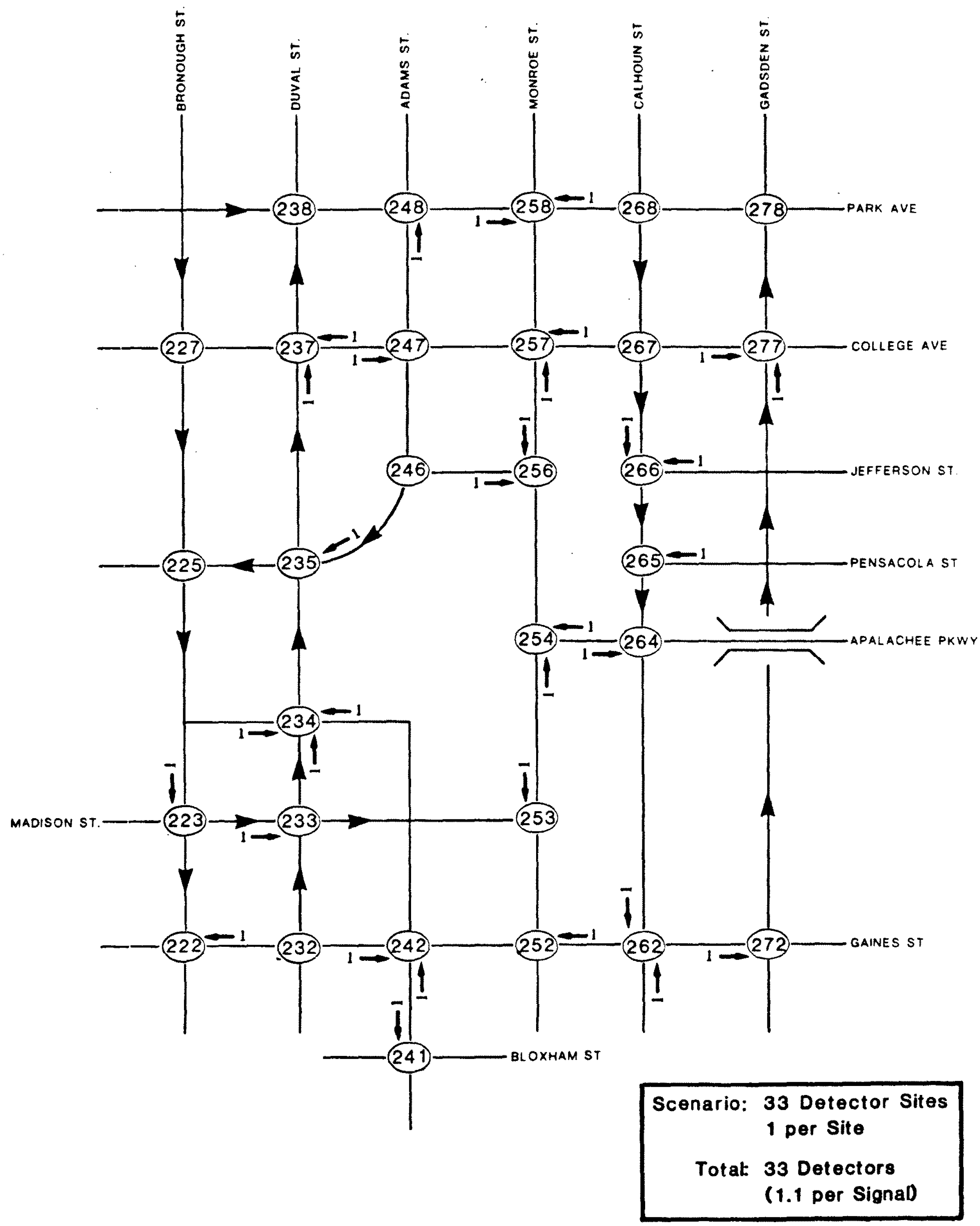

Figure 3-10

DETECTOR SCENARIO F

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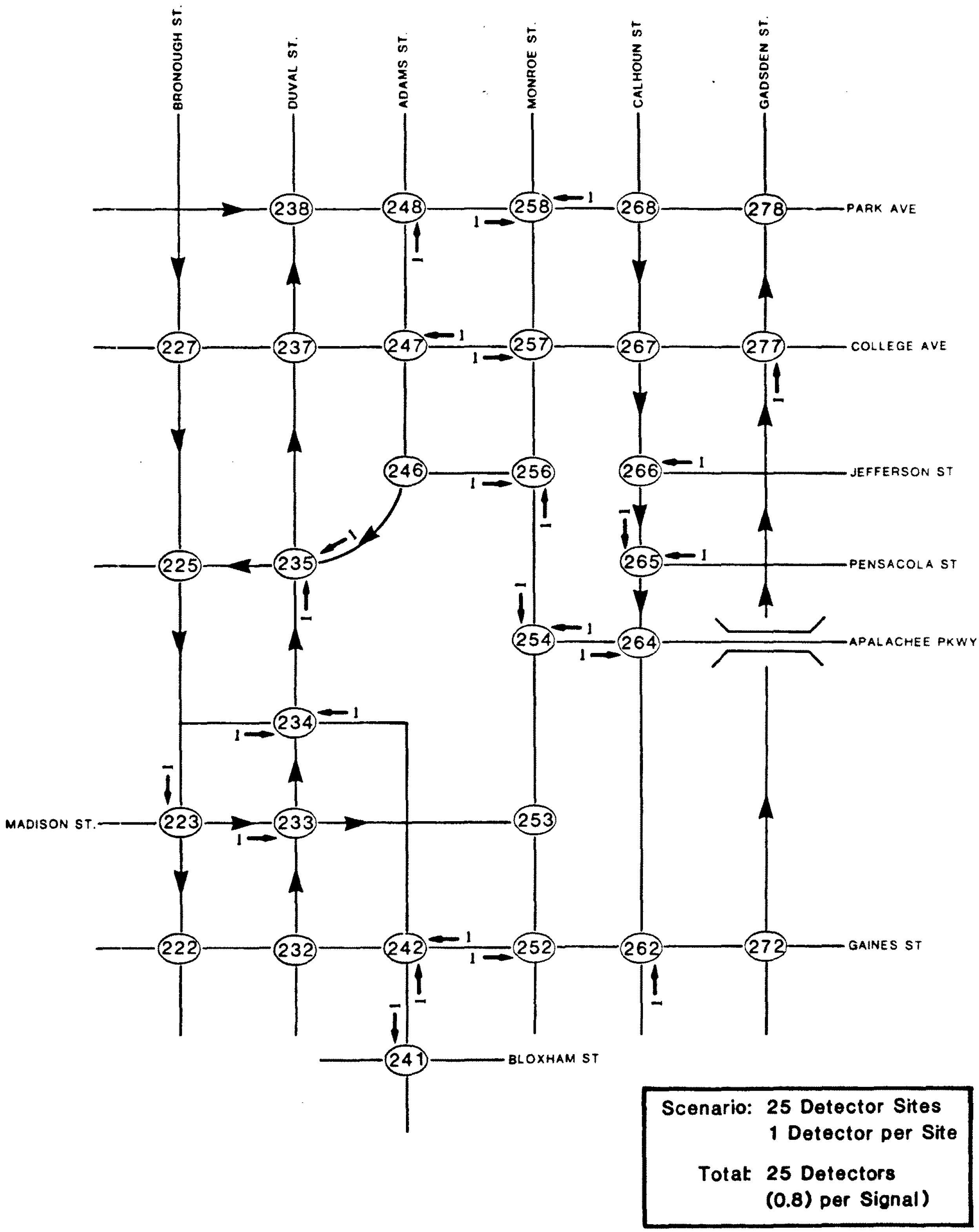

Figure 3-11
DETECTOR SCENARIO G

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DEVELOPMENT OF ALGORITHMS

As in the case of detector placement strategies, local knowledge of traffic conditions is very important in devising volume updating algorithms. The following discussion describes the general methodology and approach used to develop the algorithms for the Tallahassee test site.

Overall Approach

In developing algorithms for the updating of traffic volumes, it is important to remember that TRANSYT-7F requires volume data in the form of link to link volumes. This format is somewhat different from more typical traffic counts which are expressed in link volumes or peak hour turning movements. For illustrative purposes, a sample TRANSYT-7F network is shown in Figure 3-12 and will be used as an example in this discussion. The volume on a particular TRANSYT-7F link (for example, link 605) can be expressed as the sum of individual link to link volumes, as shown below:

$$V_{605} = x_{605} + t_{505}\ V_{505} + l_{503}\ V_{503} + r_{501}\ V_{501} \qquad (2\text{-}1)$$

where:

V_n = Total volume on link n.

x_n = Correction factor for cases where the sum of link input volumes does not equal total link volume.

t_n = Fraction of through traffic on link n.

l_n = Fraction of left turning traffic on link n.

r_n = Fraction of right turning traffic on link n.

The methodology used essentially involves calculating updated link volumes, V', from the sum of updated link to link input volumes. This can be expressed as follows for the example link 605:

$$V'_{605} = x'_{605} + (t_{505}\ V_{505})' + (l_{503}\ V_{503})' + (r_{501}\ V_{501})' \qquad (2\text{-}2)$$

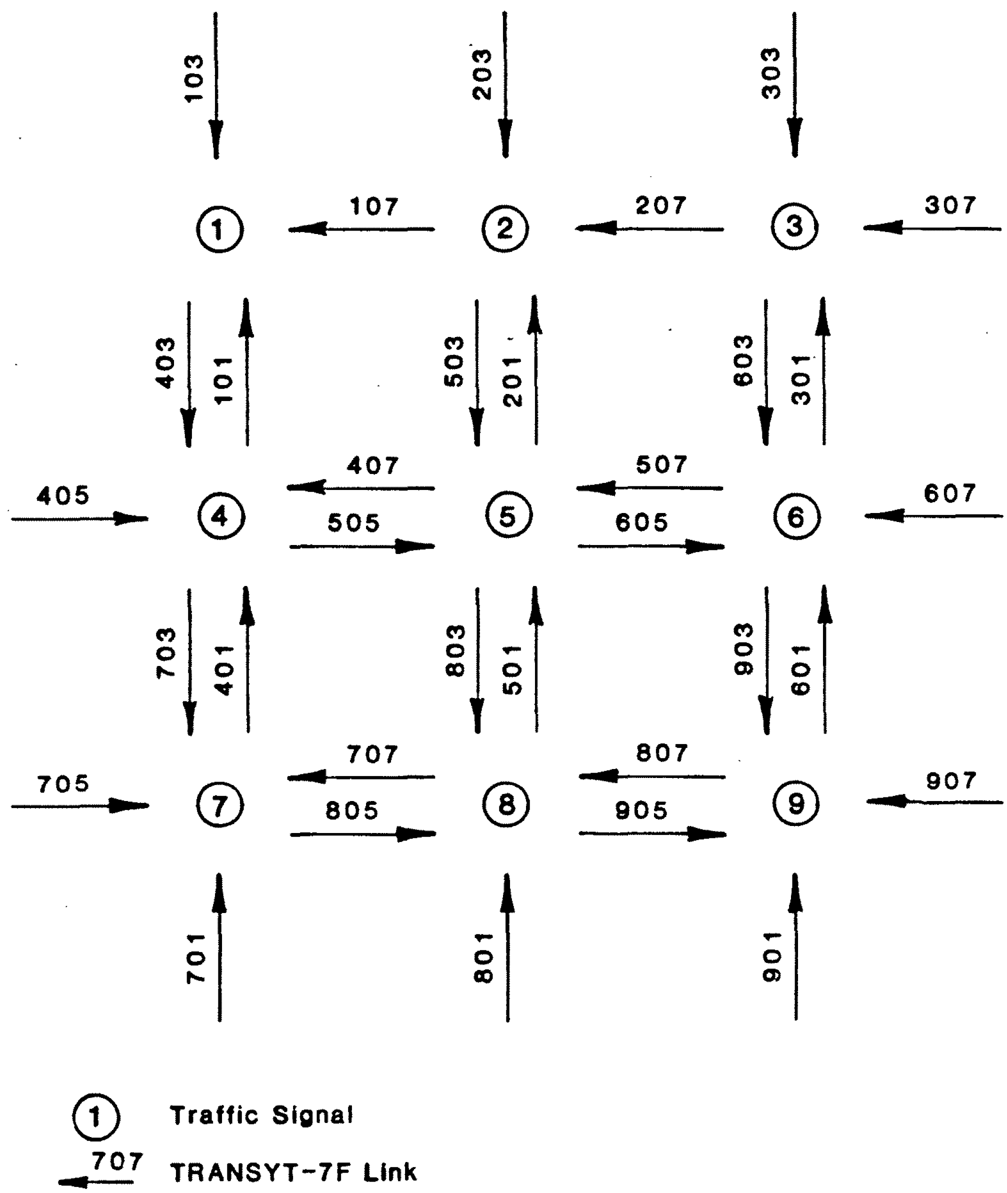

Figure 3-12
SAMPLE TRANSYT-7F NETWORK

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The calculation of the link-to-link volumes relies heavily on the theory that detector data can be used to increase or decrease link volumes on a proportional basis. The simplest case is that in which all approaches are detectorized. The traffic volume on each input link would be assumed to increase or decrease on a proportional basis. For example, the through movement input to example link 605 would be calculated as follows:

$$(t_{505}\,V_{505})' = \left(\frac{D'_{505}}{D_{505}}\right) t_{505}\,V_{505} \qquad (2\text{-}3)$$

where:

D'_{505} = Current detector count on link 505

D_{505} = Previous detector count on link 505

Some judgement is required when information is desired on a link that is not detectorized. The calculation of $(t_{505}\,V_{505})'$ from the example above is more difficult if there were no detector on link 505. In this situation, one possibility would be to use detector data from a nearby link on the same street. It would also be possible to use the average proportional increase or decrease of two or more nearby detectors on the same street. Another alternative would be to use the sum of input links to the link in question. For example, the through movement input to link 605 could be calculated using detector data from links 405, 403, and 401 using the following equation:

$$(t_{505}\,V_{505})' = t_{505}\left[\left(\frac{D'_{405}}{D_{405}}\right)(t_{405}\,V_{405}) + \left(\frac{D'_{403}}{D_{403}}\right)(t_{403}\,V_{403}) + \left(\frac{D'_{401}}{D_{401}}\right)(t_{401}\,V_{401})\right] \qquad (2\text{-}4)$$

Another alternative is to use the average growth in the area obtained by summing all detectors and determining a ratio of current to previous volumes.

In any case, the specific equations for updating link to link traffic volumes would be selected individually for each link in the network by the traffic engineer(s) responsible for setting up the 1.5GC system. In order to be consistent with the 1.5GC concept, the value for any link-to-link volume would be a function of the detector data and the original TRANSYT-7F database.

Algorithms for Tallahassee Test Site

Traffic volume data for input to TRANSYT-7F were developed for the AM peak and AM off-peak periods for each of the three scenarios. In general, the guidelines discussed above were followed. Specifically, five rules were developed for updating traffic volumes, depending on the availability of detector data. These rules are listed below in the typical order of preference.

Rule 1: Traffic volumes for a given link were calculated based on detector data for that link.

Rule 2: Traffic volumes for a given link were calculated by summing projected input volumes from upstream links.

Rule 3: Traffic volumes were calculated based on detector data for a nearby link.

Rule 4: Traffic volumes were calculated based on the average detector results from more than one nearby link.

Rule 5: Traffic volumes were calculated based on an overall average proportional increase in traffic throughout the network.

In general, the rule selected for a given link was applied to both the AM peak and AM off-peak periods. This rule was applied to link total volumes as well as link-to-link input volumes.

The use of the rules described above led to a volume updating equation for each link total volume and each link-to-link volume for each of the three detector scenarios. These equations are presented in Appendix A of the Technical Supplement.

A great deal of judgement was applied in selecting equations for updating volumes. In some cases, special modifications were made to the rules described. The most common special cases were those in which vehicles entered and exited the street network at mid-block parking decks. During the AM peak period, a significant number of vehicles left the network at mid-block locations to enter parking facilities. In some cases, the location of detectors relative to parking decks and intersection approaches caused difficulties in calculating the traffic volumes. The detector data were adjusted for parking decks in these cases, based on the previous TRANSYT-7F data set. Other special modifications included:

- Elimination of detector data where erroneous data were suspected.
- Modification of traffic volume updating equations to reflect turning movements where the proportional increase of traffic on origin and destination links varied considerably.

Special modifications to the volume updating algorithms are documented in Appendix B of the Technical Supplement.

The resulting algorithms were applied to the new detector data to provide updated volume data for the TRANSYT-7F model.

NEW DATA COLLECTION

New traffic volume and link-to-link traffic movement data were collected for the street network within the Tallahassee test site. Specifically, turning movement counts were made at all the 30 signalized intersections. These counts were made on weekdays (Tuesday, Wednesday, Thursday) using crews of two persons for each location during both the AM peak and AM off-peak periods. In addition, automatic road tube counters were placed at four locations and counters were taken continuously for a seven-day period, thus replicating the counts collected for the 1984 TRANSYT timing project.

Link volume counts were also collected manually at the "system detector" locations designated for the various scenarios. These data were collected during the same time periods that adjacent intersection turning movements were taken and represents the updated link volumes that would normally be collected by the system detectors.

The raw field data from these counts were converted to the link-to-link files through the application of the algorithms. Other inputs as required for the operations of the TRANSYT-7F model were also developed. Remaining TRANSYT-

7F data such as speeds, saturation flows, etc. were assumed to be the same as the 1984 pre-existing data set.

COMPARATIVE ANALYSIS OF 1.5 GC TIMING PLANS

The TRANSYT-7F model was run for the three 1.5 GC scenarios for the two time periods using the various data sets to obtain timing plans for comparative purposes. These various TRANSYT runs can be categorized as follows:

- o 1.5 GC - These include 1.5 GC scenarios A, C, and E in which algorithms were applied to the detector data to obtain updated link-to-link volumes to produce updated timing plans for the various detector densities.
- o Optimum - Represents the timing plans that would be produced by TRANSYT-7F using conventional 1986 field-collected data sets.

Summary results of the comparative analysis of the various timing plans generated by TRANSYT-7F for the Tallahassee test site are presented in Table 2-2. The TRANSYT-7F Performance Index, which was used as the primary measure of effectiveness in the analysis is a measure of both stops and delay in a traffic signal network that the TRANSYT-7F program itself uses to compare timing plans.

These results indicate that the timing plans produced under 1.5 GC using automatically updated volume data compare favorably with timing plans prepared through conventional means. As may be expected, the table shows a correlation between detector density and performance index. However, all three detector scenarios (A, D, and E) produced acceptable results for both the peak and off-peak periods. A detailed link-by-link comparative analysis is provided in Appendix C of the Technical Summary.

At this point in the project, it was determined that the results showed sufficient promise to warrant proceeding with Phase II and repeating the process at the second test site in Los Angeles.

Table 3-2

SUMMARY OF RESULTS

Time Period	Scenario	Number of of Detectors	Number of Detectors Per Signal	Preferred Cycle Length (sec)	Average Delay (sec/veh)	Total Uniform Stops (%)	TRANSYT-7F Performance Index*
AM Peak	Optimum	--	--	85	13.1	45%	438.7
	A	171	5.7	100	14.4	42%	443.8
	C	65	2.2	115	15.4	41%	451.3
	E	50	1.7	105	15.1	42%	452.0
	"Existing"**	--	--	80	18.6	46%	527.6
AM Off Peak	Optimum	--	--	65	9.6	42%	211.9
	A	171	5.7	65	10.0	42%	215.2
	C	65	2.2	65	9.7	41%	210.1
	E	50	1.7	70	10.3	42%	220.8
	"Existing"**	--	--	75	14.5	42%	255.8

* A TRANSYT-7F stop penalty of 35 was specified.

** Refers to a scenario in which original TRANSYT-7F timing plans developed from 1982 volume data were used with 1986 volumes. For comparative purposes, this scenario simulates the results of retaining the original timing plans with no use of 1.5 GC.

4. PHASE II TEST - LOS ANGELES

The work in Phase I was repeated at a second test site located in Los Angeles, California. The two test sites are extremely dissimilar. They are located on opposite sides of the country, they are at the limits of the likely population ranges for significant 1.5 GC work, they are totally different in street geometry, the land uses which drive the traffic patterns are significantly different, and the level of traffic and congestion are different scale values. The level of detectorization is also significantly different. The differences are of such magnitude that they provide reasonable and convenient boundaries for testing concepts.

The common feature is that both networks were timed using TRANSYT within the last several years, the data sets were available, and the cities were willing to cooperate in the research project.

LOS ANGELES TEST SITE

Los Angeles is located in the second largest urban area in the United States with over seven million population. The City has jurisdiction over more than 3,000 signalized intersections and has embarked on a program to modernize much of that system. The City has used TRANSYT to time its network signals for several years and is currently retiming several areas using TRANSYT-7F, Version 4.

The Los Angeles test site is in the Coliseum area to the south of the Central Business District. The layout of streets and signalized intersections is illustrated in Figure 4-1. The area includes 29 signalized intersections with 82 system detectors. The area was brought under computer control in August, 1984 using the Enhanced Version of the UTCS software. The area is the site chosen for a test of the traffic responsive algorithm. Data were gathered for the test area in February and March, 1984 and were used specifically for input to the TRANSYT timing model. The signals were timed using TRANSYT-7F, Version 4. The data included turning movement counts taken for the weekday hours of 6:00 - 9:00 AM, midday from 11:00 AM - 2:00 PM, and 3:00 - 6:00 PM. The TRANSYT-7F network for the study is shown in Figure 4-2.

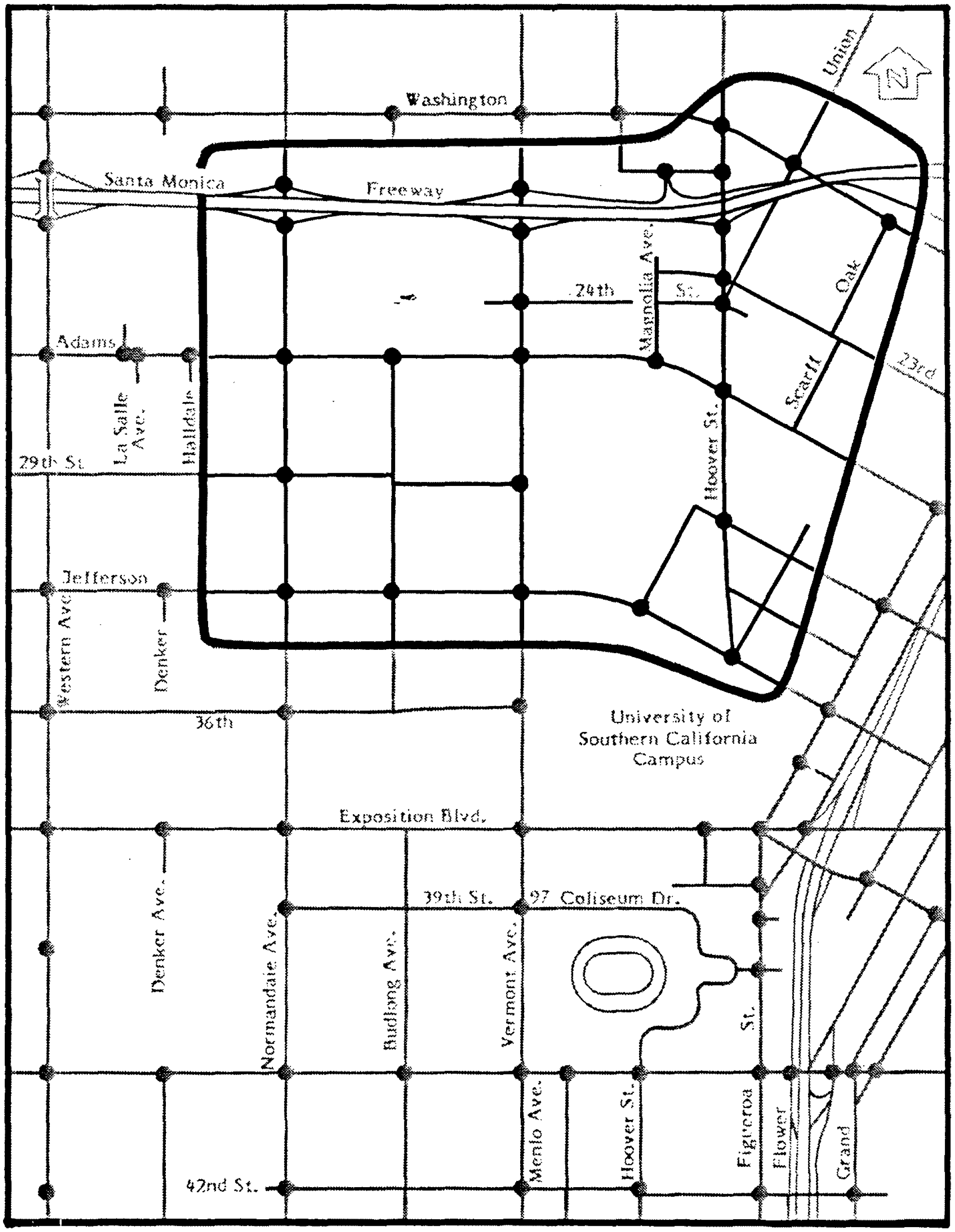


Figure 4-1

LOS ANGELES TEST SITE

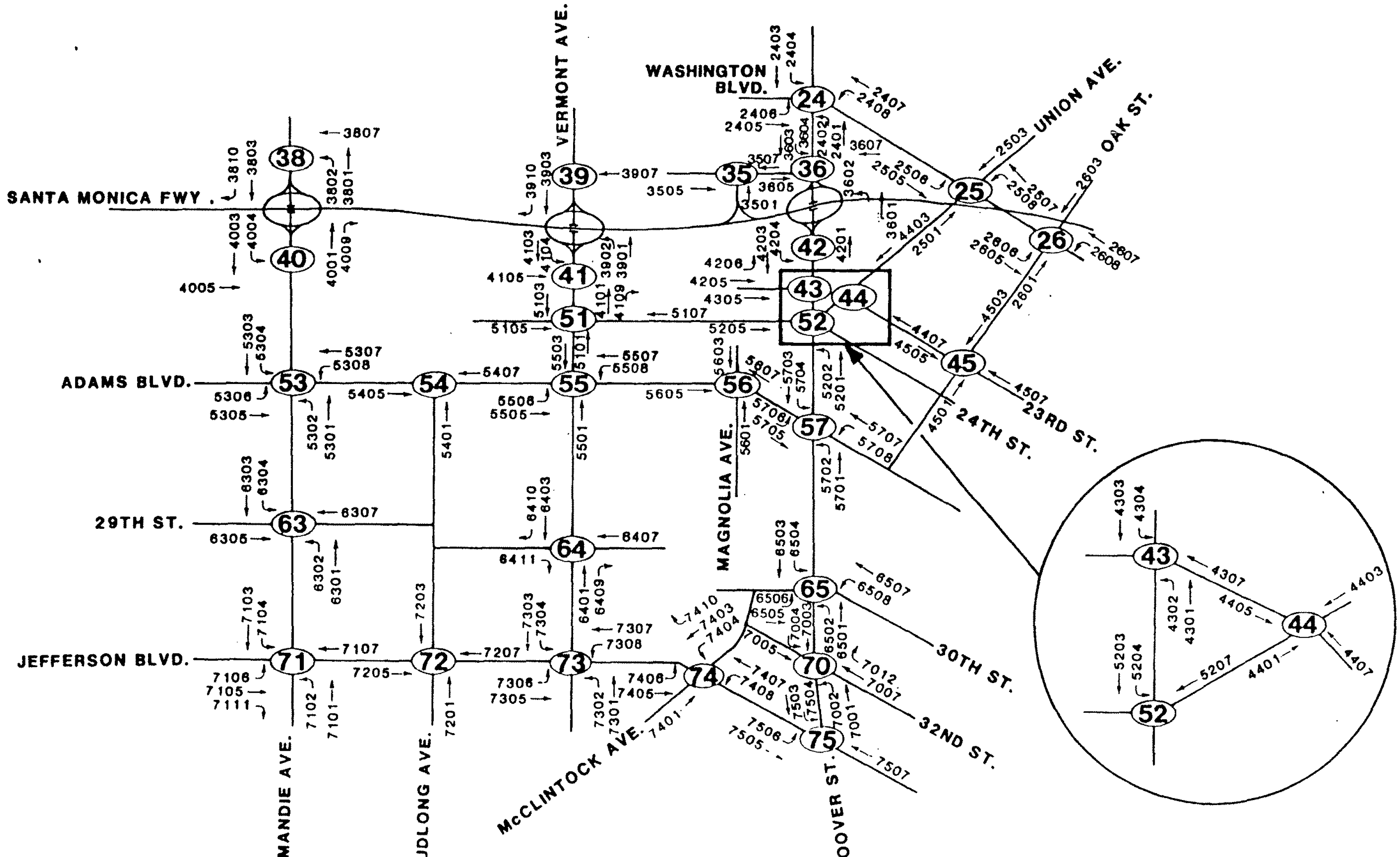


Figure 4-2
1.5 GC TRANSYT 7F
L.A. Coliseum West, Network

The test area includes several major arterials that serve traffic headed to the CBD and which provide access to the Santa Monica Freeway. The network also provides access to the Coliseum and to the University of Southern California. Block spacing is somewhat irregular with the majority of the intersections over 600 feet apart. The area is mixed commercial and light industry. The network is congested during the peak periods of the day and moderately traveled throughout the daylight hours. The network is heavily detectorized.

Although this portion of the city is always undergoing some change, there have not been any developments since the data were gathered that would alter the basic network operation.

DETECTOR LOCATION FACTORS

As with the Tallahassee test site, the designation of detector sites required local knowledge of the geometry and traffic characteristic of the specific network. The same local factors were considered in identifying detector sites for detectors to be designated as system detectors.

DETECTOR PLACEMENT SCENARIOS

The three alternative scenarios (A, C, and E) used for the Phase I Tallahassee test were also used for the Phase II Los Angeles test. The description and details of these scenarios are summarized in Table 4-1. The location of the designated detectors for each of the three scenarios is shown on Figures 4-3 through 4-5.

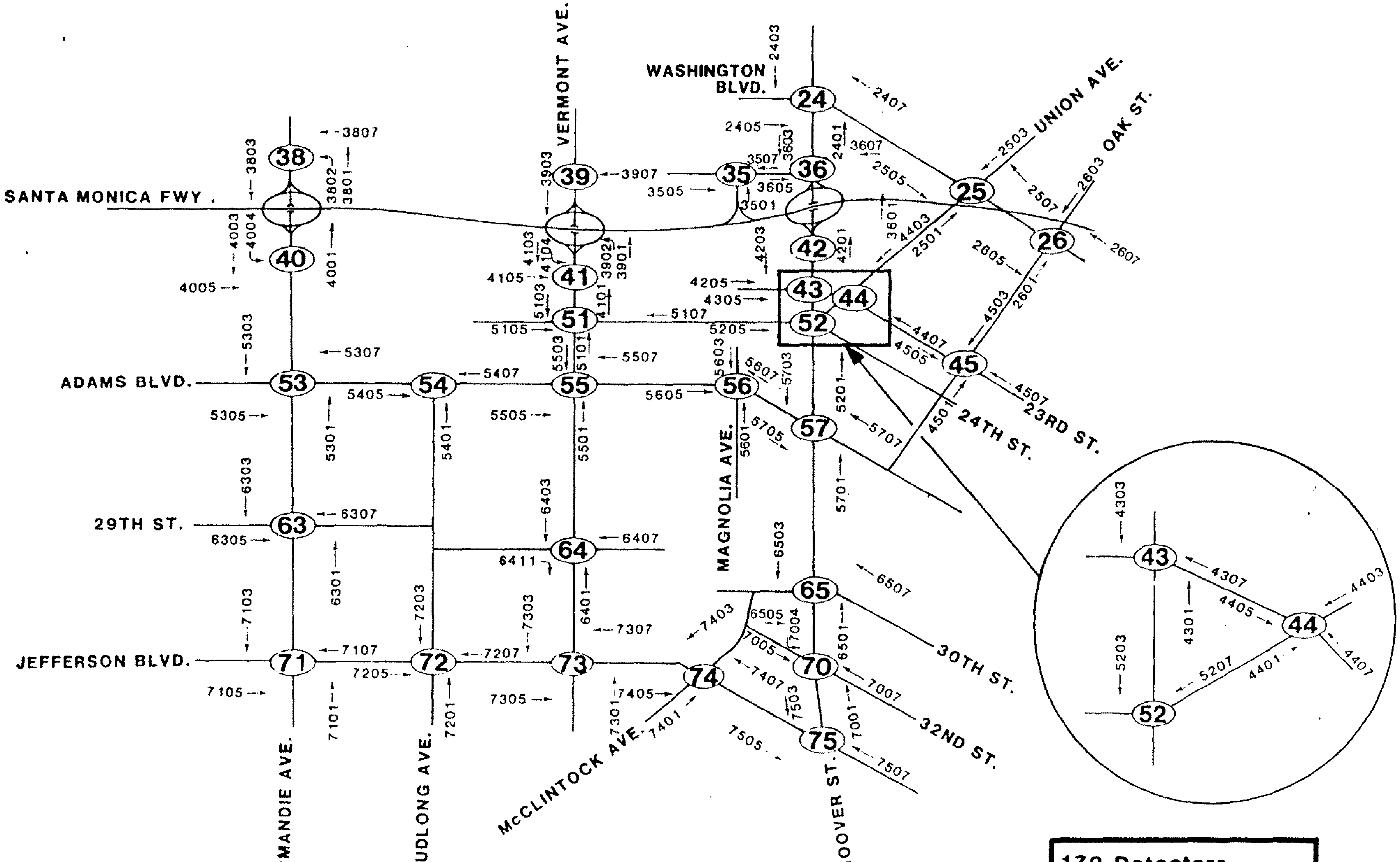
DEVELOPMENT OF ALGORITHMS

Using the same general procedures and rules developed during the Phase I test (and described in Section 3), volume updating algorithms were developed for the AM peak and AM off-peak periods for each of the three scenarios for the Los Angeles test site. Equations for each link total volume and each link-to-link volume are presented in Appendix E.

Table 4-1

DETECTOR PLACEMENT SCENARIOS

Scenario	Description	No. of Detector Sites	No. of Detectors	No. of Detectors per Signal
A	Detectors on all intersection approaches	100	172	5.9
C	Detectors on all approach lanes at intersections of major streets	42	82	3.0
E	One detector site in each direction on each street (detectors on all lanes)	32	49	1.7



172 Detectors
5.9 Detectors/Signal

Figure 4-3
L.A. Coliseum West
SCENARIO A DETECTOR LOCATIONS

jhk & associates

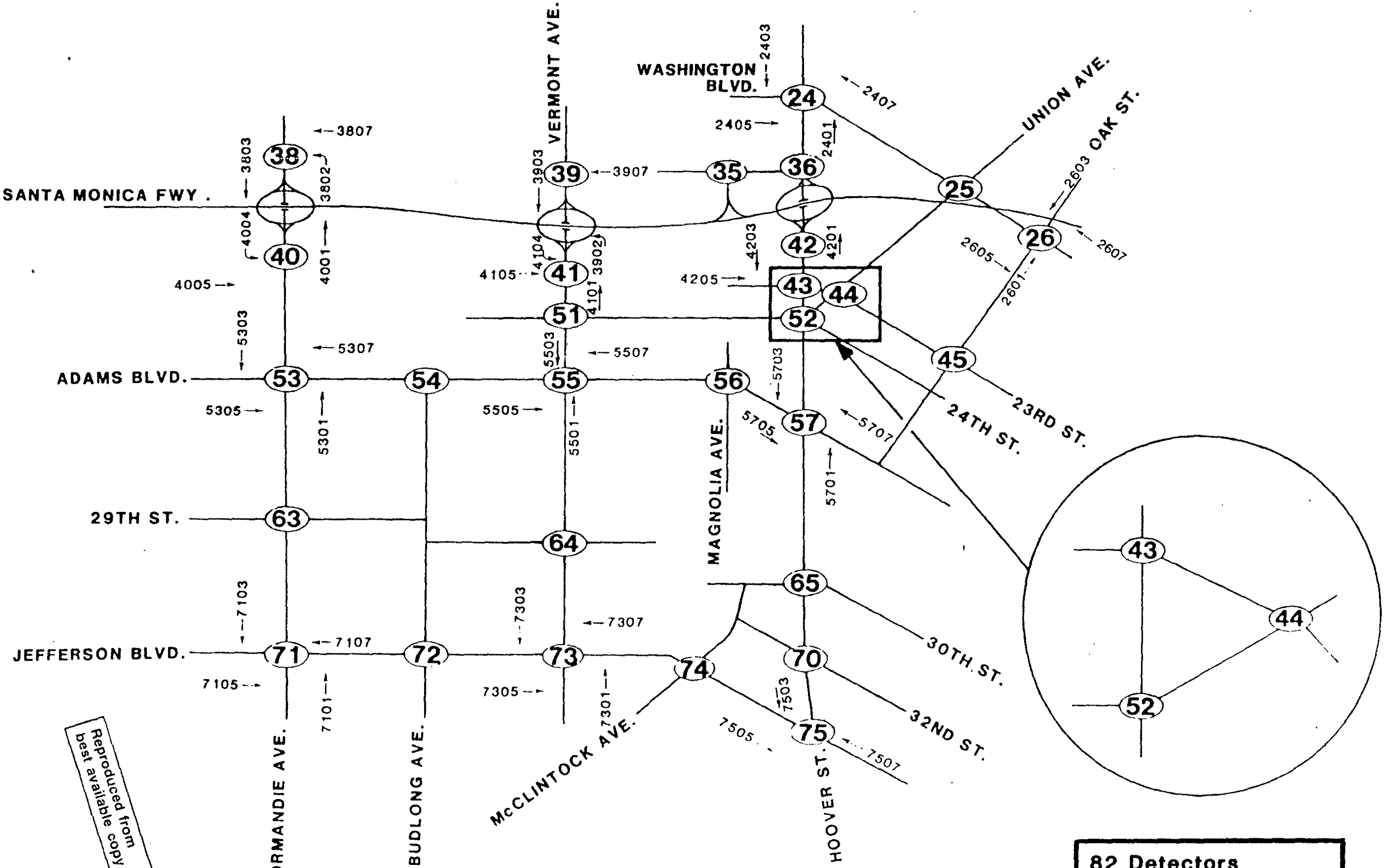


Figure 4-4
L.A. Coliseum West
SCENARIO C DETECTOR LOCATIONS

82 Detectors
3.0 Detectors/Signal

jhk & associates

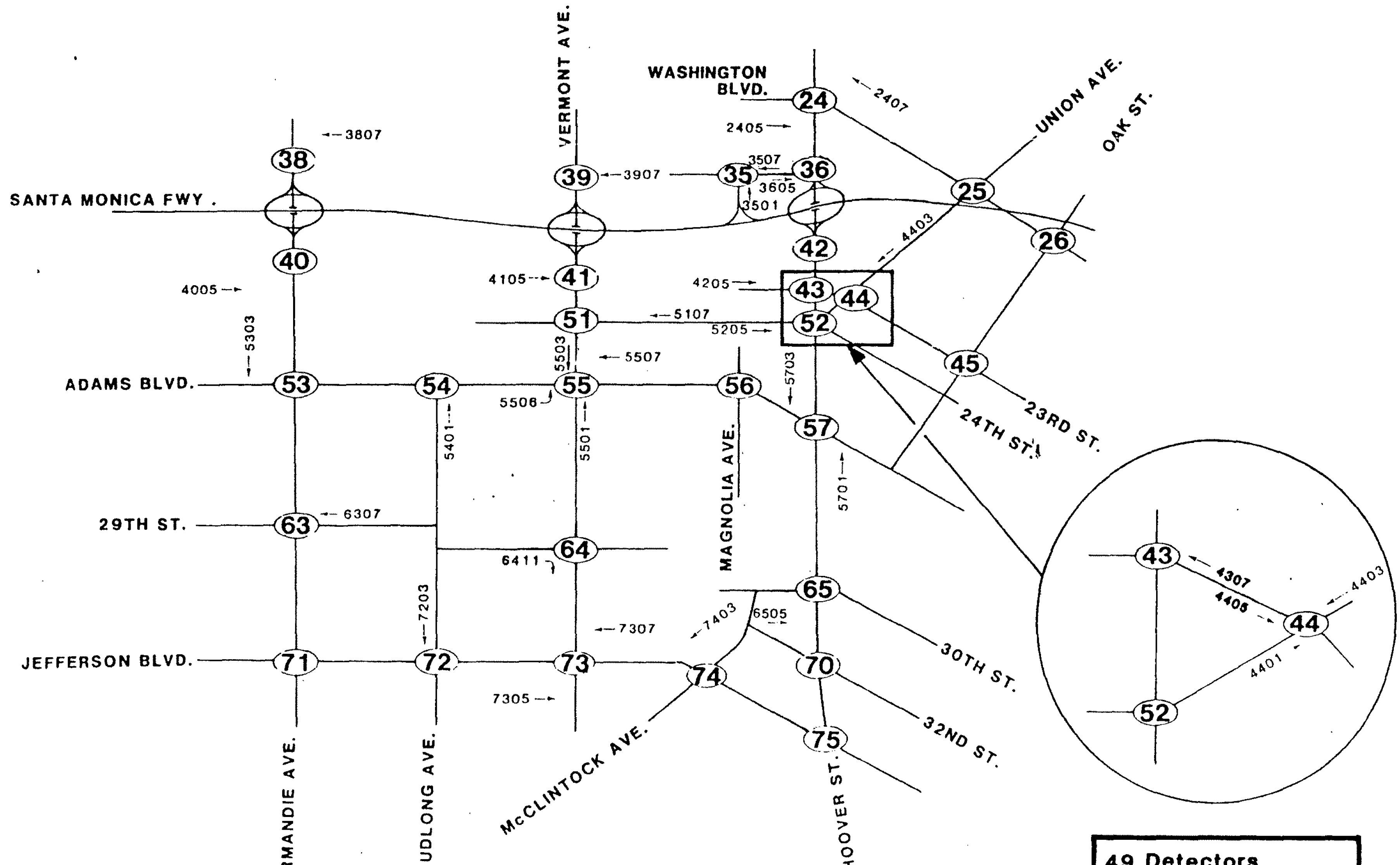


Figure 4-5
L.A. Coliseum West
SCENARIO E DETECTOR LOCATIONS

jhk & associates

NEW DATA COLLECTION

New traffic volume and link-to-link traffic movement data were collected for the street network within the Los Angeles test site in the same manner as that used in Tallahassee. Specifically, turning movement counts were made at all the 29 signalized intersections. These counts were made on weekdays (Tuesday, Wednesday, Thursday) using crews of two persons for each location during both the AM peak and AM off-peak periods.

Link volume counts were also collected manually at the "system detector" locations designated for the various scenarios. These counts were only taken at those locations where sources or sinks (intersecting streets, driveways, parking facilities, etc.) existed between the detector site and the intersection. The sum of the turning movement counts was used where no sources or sinks existed. These data were collected during the same time periods that adjacent intersection turning movements were taken and represent the updated link volumes that would normally be collected by the system detectors.

The raw field data from these counts were converted to the link-to-link files through the application of the algorithms. Other inputs as required for the operation of the TRANSYT-7F model were also developed. Remaining TRANSYT-7F data such as speeds, saturation flows, etc. were assumed to be the same as the 1984 pre-existing data set.

COMPARATIVE ANALYSIS OF 1.5 GC TIMING PLANS

As in the Phase I test, the TRANSYT-7F model was run for the three 1.5 GC scenarios for the two time periods to obtain timing plans for comparative purposes (See Section 3). A summary of the comparative analysis of the timing plans generated by TRANSYT-7F for the Los Angeles test site are presented in Table 4-2. A detailed link-by-link analysis is provided in Appendix F of the Technical Supplement.

Table 4-2

SUMMARY OF RESULTS

Time Period	Scenario	Number of of Detectors	Number of Detectors Per Signal	Preferred Cycle Length (sec)	Average Delay (sec/veh)	Total Uniform Stops (%)	TRANSYT-7F Performance Index*
AM Peak	Optimum	--	--	70	10.6	45%	315.5
	A	172	5.9	70	10.0	45%	332.6
	C	82	3.0	90	12.7	45%	364.9
	E	49	1.7	90	23.6	45%	515.9
	"Existing"	--	--	65	29.0	46%	579.7
Off Peak	Optimum	--	--	65	8.9	43%	201.5
	A	172	5.9	75	11.6	47%	264.6
	C	82	3.0	70	11.4	46%	261.1
	E	49	1.7	70	10.3	45%	245.8
	"Existing"	--	--	60	10.5	47%	227.3

* A TRANSYT-7F stop penalty of 35 was specified.

** Refers to a scenario in which original TRANSYT-7F timing plans developed from 1982 volume data were used with 1986 volumes. For comparative purposes, this scenario simulates the results of retaining the original timing plans with no use of 1.5 GC.

5. CONCLUSIONS AND RECOMMENDATIONS

While TRANSYT-7F has proved an effective tool for generating signal timing plans, it requires an extensive effort to collect accurate traffic volume counts on every link in the network and turning movement counts at every intersection. The high cost of collecting these data has served as a deterrent to retiming signal networks on a timely basis. The purpose of this research was to validate an approach (1.5 GC) to automatically update traffic volume data for signal timing plan development. The 1.5 GC approach involves a one-time cost for installing system detectors, collecting a full traffic volume data set, and developing algorithms. Subsequent testing of existing timing plans and retiming activities would simply involve developing a new TRANSYT data file by applying the algorithms to current detector data and conducting TRANSYT runs to obtain optimum signal settings.

The results of the two tests (Tallahassee and Los Angeles) strongly suggests that the 1.5 GC approach as simulated in this research is a viable alternative to the labor-intensive conventional field data collection currently used to develop TRANSYT-7F volume data files.

CONCLUSIONS

Table 5-1 presents the combined results of the two tests. As the two test cities were purposely significantly different, a comparison of results between the two sites is of little value. However, by comparing the "existing" settings to the "optimum" and then with the various detector location scenarios for each site, several conclusions are immediately obvious.

First, it is obvious that both systems should be retimed. In Tallahassee, delay in the AM peak has increased by 42% and by 51% in the off-peak since the signals were retimed in 1984. In Los Angeles, a severe increase of 174% has been experienced in the AM peak while the off-peak shows a modest increase of 18%.

In Tallahassee, the average delay for the three scenarios were much closer to the optimum than the existing timing. The performance index for Scenario A during the AM peak period is within 1.2% of the optimum with Scenario C, slightly higher with a 2.9% difference and Scenario E with a 3.0% difference. These low values

Table 5-1

COMPARISON OF TEST RESULTS

AM PEAK

Scenario	Avg. Delay (sec/veh)/* Tallahassee	Avg. Delay (sec/veh)/* L.A.	Total Uniform Stops (%) Tallahassee	Total Uniform Stops (%) L.A.	Performance Index/* Tallahassee	Performance Index/* L.A.
Optimum	13.1	10.6	45%	45%	438.7	315.5
A	14.4/9.0	10.0/-5.7	42	45	443.8/1.2	332.6/5.4
C	15.4/17.6	12.7/19.8	41	45	451.3/2.9	364.9/15.7
E	15.1/15.3	23.6/122.6	42	45	452.0/3.0	515.9/63.5
Existing**	18.6/42.0	29.0/173.6	46	46	527.6/20.3	579.7/83.7

AM OFF-PEAK

Scenario	Avg. Delay (sec/veh)/* Tallahassee	Avg. Delay (sec/veh)/* L.A.	Total Uniform Stops (%) Tallahassee	Total Uniform Stops (%) L.A.	Performance Index/* Tallahassee	Performance Index/* L.A.
Optimum	09.6	08.9	42%	43%	211.9	201.5
A	10.0/4.2	11.6/30.3	42	47	215.2/1.6	264.6/31.3
C	09.7/1.0	11.4/28.1	41	46	210.1/-0.8	261.1/29.6
E	10.3/7.3	10.3/15.7	42	45	220.8/4.2	245.8/22.0
Existing**	14.5/51.0	10.5/18.0	42	47	255.8/20.7	227.3/12.8

/*Percent change from Optimum
**1986 volume tested against original 1982 timing plans

compare with the 20.3% between the existing and the optimum. For the AM off-peak, the values in the performance index are approximately half of the AM peak for all cases. These values strongly support the contention that detector data can be used to update signal timing.

In Los Angeles, the existing delay is almost three times the optimum delay in the AM peak. Sensitivity among the scenarios in the AM peak appears to be critical. During this time period, delay ranges from slightly less than optimum for Scenario A to more than twice the delay for Scenario E. Likewise, the performance index shows very good results for Scenarios A and C, but lesser results for Scenario E.

The results for the AM off-peak in Los Angeles are not as clear. The trend seems to be reversed with Scenario E performing best, followed by Scenario C, then Scenario A. All three scenarios have higher performance indices than the existing. Delays, though relatively small, show a similar pattern. Careful examination of the node volumes presented in Appendix F indicate a few highly saturated nodes. This implies a breakdown in the algorithms under these conditions. This reinforces the need to carefully develop algorithms which may vary during different times of the day.

One of the primary conclusions of this study is that 1.5 GC detectors must be installed at the time of the original TRANSYT-7F study in which the full volume data set is collected. This allows future (new) detector data to be compared directly to original (old) detector data to determine the proportional increase of traffic on individual street links. In the current study, proportional increases in traffic were determined through comparison of new detector data with old TRANSYT-7F data rather than old detector data.

Accuracy is of critical importance in 1.5 GC signal timing. This is true in all TRANSYT-7F signal timing work, but is especially true in the case of 1.5 GC because there are fewer opportunities to check accuracy of the data than in conventional TRANSYT-7F signal timing studies. Traffic volumes in a conventional TRANSYT-7F signal timing study can be checked by comparing turning movements from adjacent intersections. This is not true in the case of 1.5 GC. In this research study, a portion of the data entry and data manipulations were done by hand. Discrepancies were noted in the data at several locations. It is, therefore, necessary to develop procedures for checking and rechecking data to ensure accuracy. In practical applications of 1.5 CG, it is expected that most of the data manipulations will be conducted by a computer-controlled system. In these applications it will be necessary to ensure that the system has been installed properly and that the components are operating satisfactorily. A detector malfunction would be a particularly serious problem, since individual detectors may provide data to project traffic volumes for several nearby links.

Experience has shown that link-to-link input volumes are an important part of the data required by TRANSYT-7F. Users of 1.5 GC should pay careful attention to developing good algorithms for these volumes. In this research study, algorithms for developing link-to-link volumes were set up in the same way as the algorithms used to estimate total link volume.

Local knowledge and engineering judgement play a key role in the use of 1.5 GC. It is doubtful that any set of general guidelines for detector placement or volume updating algorithms could be developed to apply to all street networks. The detector location strategies and algorithms described in this research may, however, provide a useful starting point for 1.5 GC users.

RECOMMENDATIONS

The fundamental issue of whether 1.5 GC detector data can be effectively used to update traffic volume data to generate signal timing plans has been resolved by this research. It is therefore recommended that reseach in this area be continued in two phases. The first phase would consist of comparing actual detector data with field counts to determine variability and then to use these data to refine the algorithms to portray current conditions. Additional TRANSYT-7F runs would be made to calibrate the algorithms and ensure effective timing plan development.

The second phase is to create the full algorithm data base and actually run the 1.5 GC programs on the ATSAC supervisor when installed in Los Angeles. This will provide an actual test of 1.5 GC in that the after data collected live will be approximately one year after the calibration data. Specific descriptions of the recommended phases are presented below.

Phase I

Data were collected by the ATSAC System at the 100 detector sites in the Coliseum West area at the same time that the field counts were being made. These data have not been used in the analysis to date, but do provide a unique opportunity to utilize real detector data in the analysis. It is recommended that the detector data be used with the current algorithms to form input data for TRANSYT-7F. Runs would be made to compare the results of actual detector data with the pseudo counts used in the study.

The actual detector counts would also be compared with the manual counts where possible. The manual counts were taken on a lane-by-lane basis at the actual detector sites at all locations where there was a potential variation in count between the detector and the signalized intersection, such as an intersecting street or a major driveway. This will give a lane-by-lane comparison at these locations. All other locations where there was no intervening source or sink, only the turning movement counts at the intersection are available. Therefore, the total street count can be compared to the sum of the detector loops.

Once the comparisons of detector counts to field counts is made, refinements to the algorithms can be developed. This is particularly true at locations where there are sources and sinks between the detector and the intersection. Additional TRANSYT-7F runs should be made with the adjusted set of algorithms to determine the sensitivity to relatively small changes in the algorithms.

These last TRANSYT-7F timing plans would simulate the base line timing plans of a new 1.5 GC system because they are based upon actual detector counts and field data counts taken at the same time. This would be the procedure followed when first installing a 1.5 GC system in a new area.

Phase II

After the Supervisor computer is installed in Los Angeles and the 1.5 GC program is integrated with the enhanced UTCS program, the ATSAC project will be able to perform 1.5 Generation Control in real time and on a real section of a complex network. The primary algorithms for the Coliseum West area have been developed as part of this research project and would be refined under Phase I of the follow-on work. In addition to the primary algorithms, there are default algorithms that must also be developed to handle missing or malfunctioning detectors. In order to make this demonstration as realistic as possible, it is recommended that the development of these default algorithms be undertaken at this time.

Assuming that the Supervisor computer has been installed and integrated, the 1.5 GC program has been integrated and tested, and the algorithms have been entered by late September or early October 1987, an after study one year later than the base line study could be undertaken. It is recommended that a turning movement field study be conducted at the 29 signalized intersections in the Coliseum West area.

At the same time, the automated 1.5 GC program would be exercised using the detectors in the area and the stored algorithms. The resultant timing plans would not be implemented on the street, but would be stored for further analysis. The comparative function between the newly computed timing plans and the existing timing plans would be noted.

After the field data are reduced and entered into the TRANSYT format, new optimum timing plans would be computed off-line. The machine-generated timing plans would be compared with those computed from the field data. It is hypothesized that the two should be quite similar. A second comparison should be made of the turning movements generated by the 1.5 GC from the algorithms and those actually observed in the field.

The size of the network in the Los Angeles 1.5 GC TRANSYT-7F program is being expanded to 100 intersections. It may be desirable to run a 1.5 GC test on a 100-intersection network in the Coliseum area (which currently contains 119 intersections).