ESTUDIO DE TRANSPORTES DEL AREA METROPOLITANA DE SAN JOSE

ETAMSJ

JATS

SAN JOSE AREA TRANSPORTATION STUDY

MOPT - AMV

Costa Rica

Stage II
Final Technical Report

RAMIRO GAMBOA

REPUBLIC OF COSTA RICA

MINISTRY OF PUBLIC WORKS AND TRANSPORT

SAN JOSE METROPOLITAN AREA TRANSPORTATION STUDY

STAGE II
FINAL TECHNICAL REPORT

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UNITED NATIONS DEVELOPMENT PROGRAM

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Consultants:

ALAN M. VOORHEES & ASSOCIATES, INC.
McLean, Virginia

March 1976

RAMIRO GAMBOA

Preface

The work of this study has been done in close collaboration with the staff of the Ministry of Public Works and Transportation and under a contract monitored by the International Bank for Reconstruction and Development. However, the material in this document represents the views of the Consultant and not necessarily those of the Ministry or the Bank.

The work of the San Jose Metropolitan Area Transportation Study was divided into two stages, the first of which was further divided into two phases as follows:

- Stage I — January 1973 — July 1974
  - Phase I — January 1973 — October 1974
  - Phase II — October 1973 — July 1975
- Stage II — September 1974 — July 1975

The following reports, along with this document, comprise the results of the study:

- Stage I
  - Inception Report
  - 24 Technical Working Papers
  - Phase I Report
- Stage II
  - 4 Progress Reports
  - Tender Documents, CBD Traffic Signal System
  - Stage II Final Technical Report (this document)
  - Stage II Final Summary Report
- Entire Study
  - Final Technical Report
  - Final Summary Report

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Introduction

Chapter I

Chapter I
Introduction

This report summarizes the work concluding the San Jose Metropolitan Area Transportation Study (ETAMSJ). These studies are the product of agreements between the United Nations Development Program (UNDP), the funding agency; the International Bank for Reconstruction and Development (IBRD), the executing agency; the Government of Costa Rica; and a contract between IBRD and the firm of Alan M. Voorhees & Associates Inc. (AMV), the consultants.

1.1 BACKGROUND

These Stage II implementation studies have their roots in the earlier Stage I of the San Jose Area Transportation Study (ETAMSJ) begun in January of 1973. The ETAMSJ work resulted in recommendations for four programs—immediate, short term (1974-1976), mid term (1977-1981), and long term (1982-1990). The Mid-Term Program is the starting point for the work reported here.

Several of the mid-term projects appeared attractive enough to be pursued to determine feasibility and other projects needed to be undertaken to avoid imminent problems in the Central Business District (CBD) occasioned by planned radial highways. Nine projects were selected for study in the implementation phase; these are:

- CBD Traffic Control Plan
- CBD Traffic Signal System
- CBD Bypass
- Desamparados Corridor Busway
- Tibas Corridor Busway
- Alajuelita-Hatillo Corridor Busway
- Limon-Siquirres Highway Dispersal System
- Zapote Highway Dispersal System
- Santa Ana Expressway Dispersal System

1.2 GLOSSARY OF TERMS

The following terms and abbreviations are used throughout the report:

- ADT — Annual average daily traffic
- Central Area — is the area roughly bounded by the Torres River, 42nd Street, the Maria Aguilar River, and 25th Street
- Central Business District (CBD) — is the area bounded by Ninth Avenue, 16th Street, 14th Avenue, and 13th Street (see also Figure II-6)
- Core of the CBD — is the area bounded by Fifth Avenue, Tenth Street, Eighth Avenue, and Ninth Street
- Colon — the Costa Rican unit of currency. At the time of Stage II, the exchange rate was 8.54 colones to the U.S. dollar.
- DGP — General Direction of Planning
- DGTA — General Direction of Automotive Transport
- DGV — General Direction of Highways
- ETAMSJ — San Jose Area Transport Study
- ROW — right-of-way
- TRANSYT — Traffic Network Study Tool

1.3 THE EXISTING SITUATION

A significant portion of Stage I of ETAMSJ was devoted to the collection and analysis of information concerning overall existing transportation characteristics and conditions in the study area.[1] Such information, of course, formed a vital element in the development of the Stage I program of recommended improvements.

Certain of these transportation characteristics and conditions suggested both urgent problems and perhaps fleeting opportunities and, therefore, formed an important part of the reason for undertaking Stage II, the implementation studies reported here. These conditions included:

[1] For more details on these characteristics, the reader is referred to Chapter III of the Final Technical Report as well as other Stage I reports and documents.

- A very fine-grained system of narrow downtown streets which exhibits congestion over many hours of each workday. Such congestion impacts users of public transportation disproportionately in San Jose due to their greater numbers in individual vehicles as well as in total compared to other mode users.
- Committed plans to build new radial highway facilities emanating from San Jose's central area which did not feature adequate plans for terminal treatments in the central area and which appeared to offer opportunities for preferential and/or exclusive radial bus treatments.
- An uncoordinated and apparently inefficient central area traffic control pattern which appeared to lend itself to substantial improvement through rational re-ordering and the application of modern concepts of traffic operations and control, including traffic signals.
- An assessment that the population and employment of San Jose and its central area appears poised for rapid growth which may quickly foreclose near-term opportunities for improvement. Closely related to this is the assessment that auto ownership has been increasing rapidly and exhibits a likelihood of even an accelerated growth rate, which in turn suggests the need for prompt improvements in support of public transportation services to forestall even greater congestion and related disbenefits.
- The fact that the vital public transportation system, while possessing many virtues, has several deficiencies which might be wholly or partially remedied through the implementation projects and related policies and steps which were studied in Stage II. These deficiencies include overcrowding in some time and location, a general absence of cross-town service, failure to serve portions of the central area, and others.
- A substantial deficiency in the facilities for serving pedestrians in the central area. The very narrow sidewalks not only are inadequate for serving normal intra-CBD pedestrian movements, but also are required for use by waiting, transferring, and alighting transit patrons.

1.4 NEW FINDINGS

Data collection in Stage II was confined to only those elements of new or updated data required to support the specific Stage II studies. Because of the wide-ranging data collection program of Stage I in 1973 as well as the ongoing programs of the Department of Basic Studies in DGP, new data collection activities were required only in parts of the CBD and in the specified radial corridors. These activities covered volume and turning movement counts, including vehicle classification

counts, speed related to volume studies, pedestrian counts in certain locations, and notation of on-street and off-street parking locations, and other features of the central area street system.

Figure I–1 shows traffic volumes in the central area in 1974 as obtained from the MOPT continuing studies. Comparison of this data with similar information from previous years indicates a showing of year-to-year growth, suggesting that capacity is being reached in an increasing number of hours each day. This seems to be borne out by Figure I–2 which shows substantial flat peaking periods each day. Other illustrations of new data collected for Stage II are in Figures I–3 and I–4, which respectively show the percent of the total traffic in the central area made up by trucks and buses and the flow of pedestrians by time of day at a key central area location. Conditions in the central area are reflected in Figures I–5 and I–6 which respectively show present CBD traffic controls and parking inventory.

A few of the transportation changes from 1973 in San Jose are notable. The National Government has acted to become financial guarantor for 150 new bus sales to bus operators, which has led to a perceptible upgrading of the bus fleet. Traffic counts in the radial corridors indicate autos increasing as a percent of the total traffic volume, supporting other evidence that auto ownership is increasing rapidly. Also, it was noted that the number and location of off-street parking locations had changed considerably from when the Stage I data on this subject was collected. This reflects the transient nature of downtown parking, which tends to temporarily occupy vacant building lots and be readily displaced as buildings are razed and built.

1.5 TRANSPORT OBJECTIVES

For each of the sub-projects considered in Stage II, i.e., the central area control plan, the central area signal system, the CBD bypass, the three corridor busways, and the three radial dispersal systems, a set of specific operational objectives were developed to guide alternative development and evaluation. These operational objectives, in turn, were derived from several more broadly drawn general and operational objectives prepared as part of Stage I. Since these broader objectives are fundamental to Stage II, they are presented here again. In subsequent chapters devoted respectively to each sub-project category, the specific operational objectives developed in Stage II are presented.

General Objectives

1. To encourage use of public transit for travel to major generators in and near the central area of San Jose by application of operational measures such as bus priority regulations, coordination, and optimization of service, and by investment in new public transit facilities.

2. To improve the quality of private-vehicle street traffic in the central area only to the extent that existing street space for such traffic movement remains after complete satisfaction of the objective above. Investment in general traffic facilities will not be made in the central area, except where a small investment will allow much better utilization of existing street space.

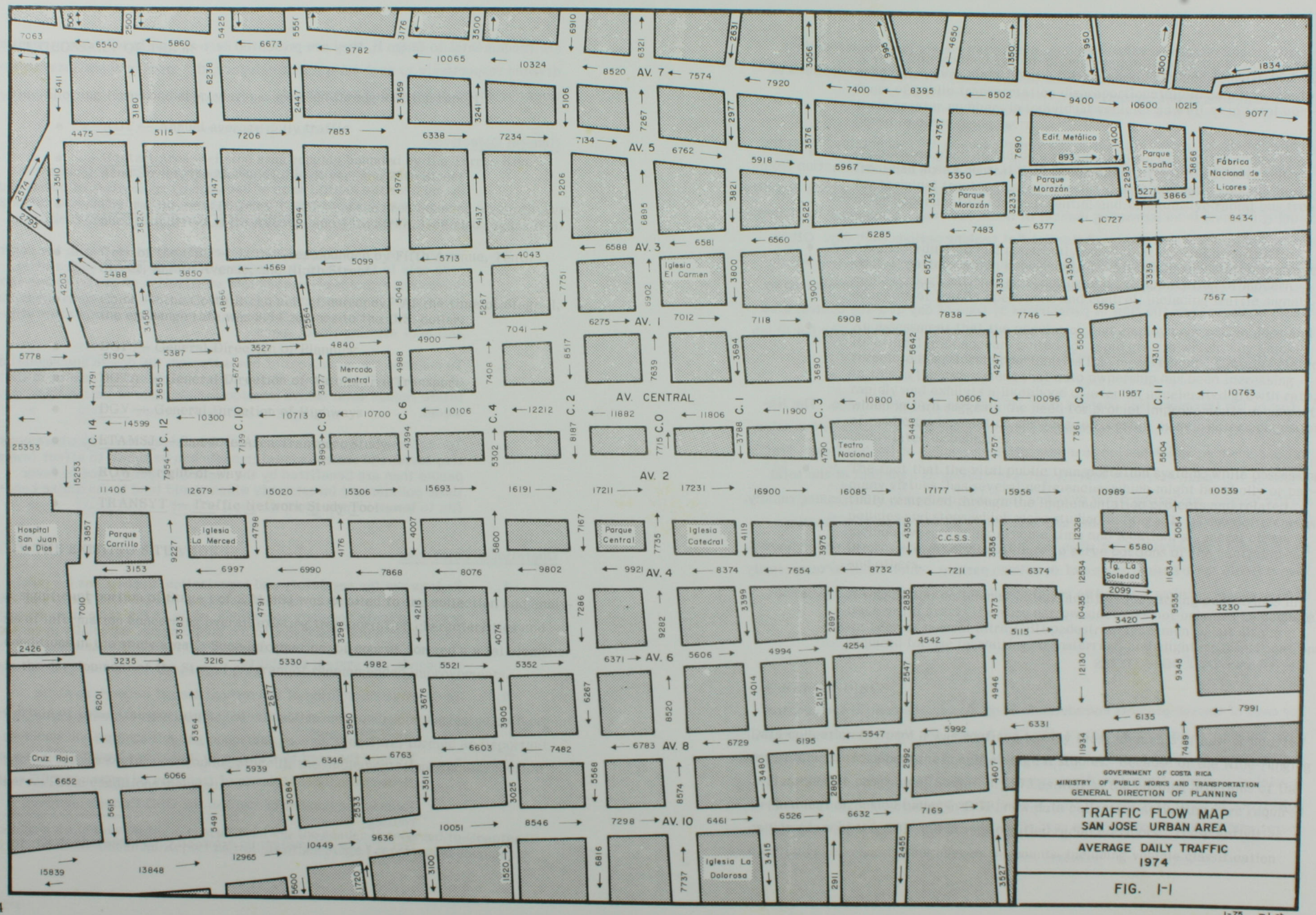
3. To enhance the movement of buses through the design and regulation of non-central area roads where such regulations can now or in the future reduce total delays (considering the time of person trips by mode).

4. To implement transportation facilities and policies only where negative social and environmental impacts can be shown to affect fewer people than are benefitted by the facility or policy, and to favor those policies and investments which would tend to maximize benefits to lower-income groups.

Operational Objectives

1. To improve the regulatory and organization mechanisms for public transportation so as to take advantage of the positive factors of the present private company operations, while at the same time making the system more responsive to the public needs, especially in respect to route changes, frequency changes, better vehicle maintenance standards, and system reliability.

2. To improve the routing of the present transit network so as to:
   - Obtain more service for major travel movements, especially non-CBD travel
   - Reduce the need to transfer by initiating through-CBD service
   - Reduce the inconvenience of transfers by improved CBD routing
   - Reduce the number of turns in the CBD through improved routing
   - Reduce bus-kilometers on crowded CBD streets through re-routing


AV. 7
AV. 5
AV. 3
AV. 1
AV. CENTRAL
AV. 2
AV. 4
AV. 6
AV. 8
AV. 10
C. 14
C. 12
C.10
C. 8
C. 6
C. 4
C. 2
C. 0
C. 1
C. 3
C. 5
C. 7
C. 9
C. 11
Edif. Metálico
Parque España
Fábrica Nacional de Licores
Parque Morazán
Iglesia El Carmen
Mercado Central
Teatro Nacional
Hospital San Juan de Dios
Parque Carrillo
Iglesia La Merced
Parque Central
Iglesia Catedral
C.C.S.S.
Ig. La Soledad
Cruz Roja
Iglesia La Dolorosa
GOVERNMENT OF COSTA RICA
MINISTRY OF PUBLIC WORKS AND TRANSPORTATION
GENERAL DIRECTION OF PLANNING
TRAFFIC FLOW MAP
SAN JOSE URBAN AREA
AVERAGE DAILY TRAFFIC
1974
FIG. I-1

I-75 m.l. ch.

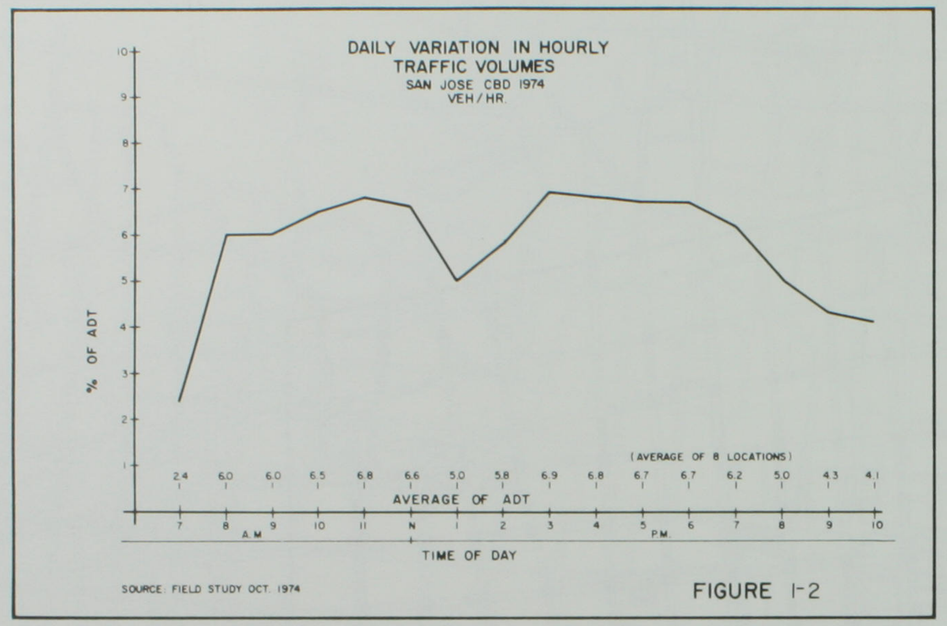


FIGURE 1-2

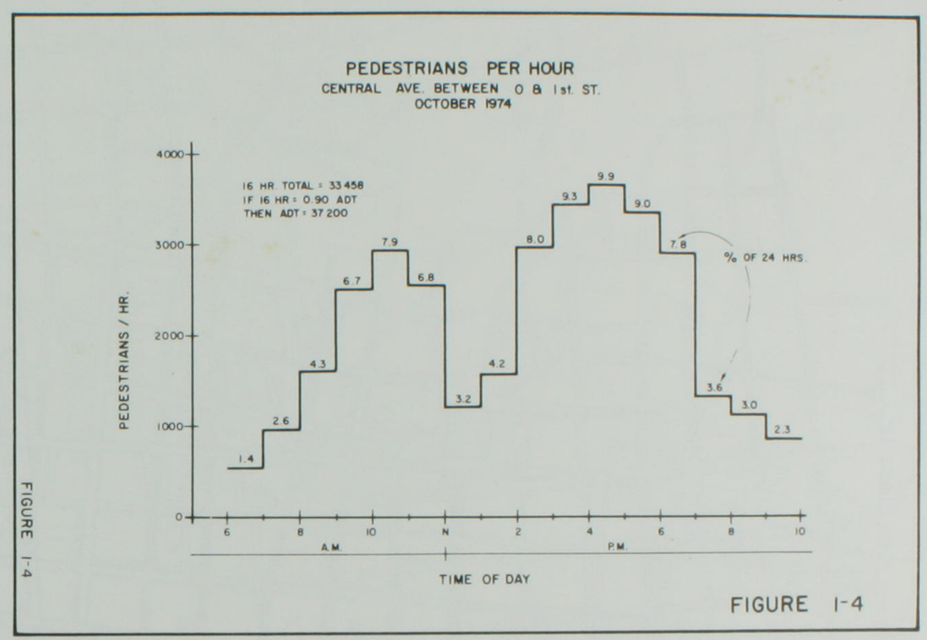


FIGURE 1-4

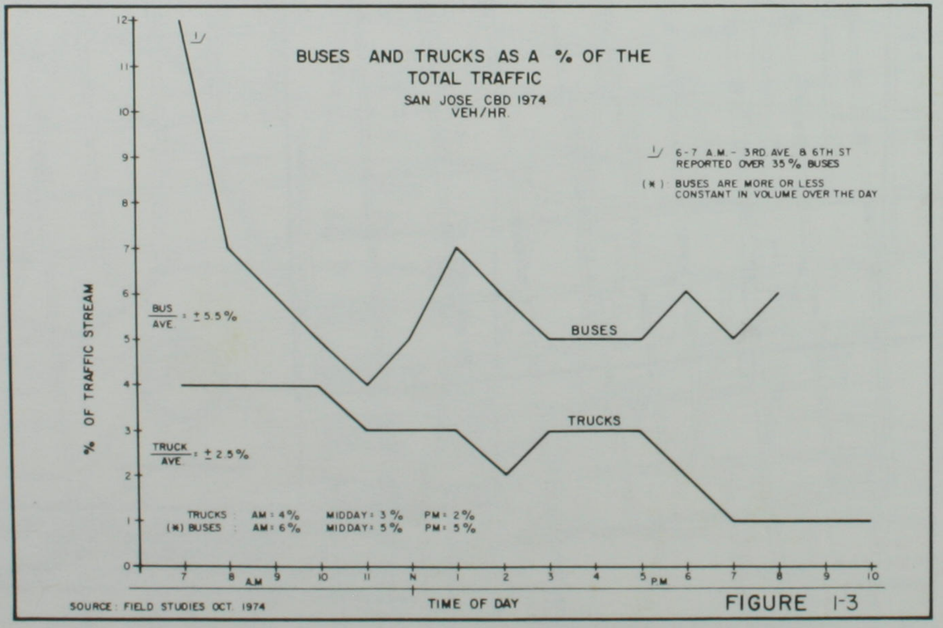
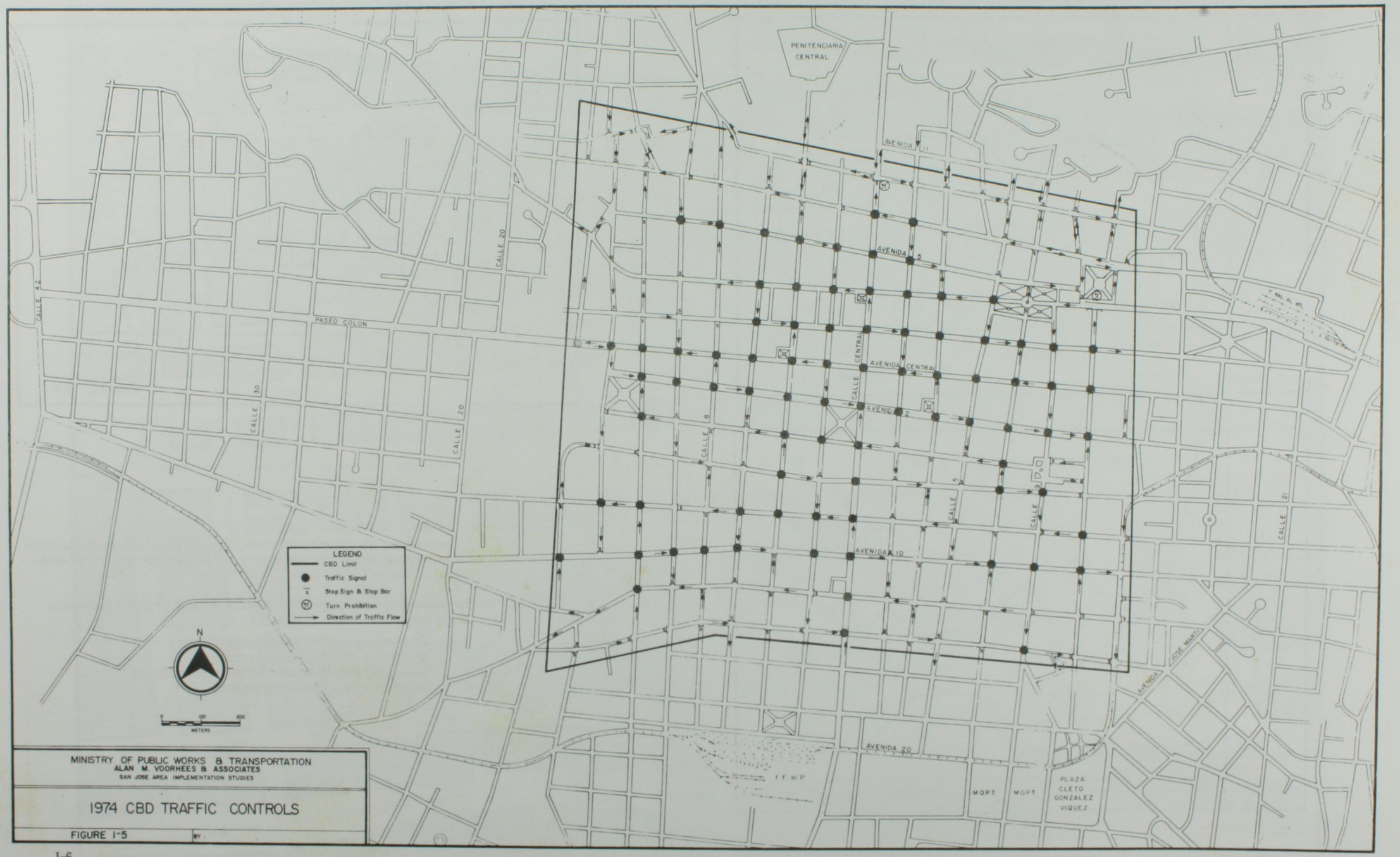


FIGURE 1-3

3. To implement bus priority schemes already identified, evaluate their effectiveness, publicize results, and try to gain acceptance of additional measures of this type.

4. To improve the existing street system through physical and operational means:

   - Eliminating traffic bottlenecks
   - Improving street system continuity
   - Reserving future arterial street rights-of-way
   - Improving the CBD signal system


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE 42
CALLE 30
CALLE 20
CALLE 8
CALLE 5
CALLE 3 BIS
CALLE 21
PASEO COLON
JOSE MARTI
F.F.G.I.P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
CBD Limit
Traffic Signal
Stop Sign & Stop Bar
Turn Prohibition
Direction of Traffic Flow
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
1974 CBD TRAFFIC CONTROLS
FIGURE I-5
BY:

PENITENCIARIA CENTRAL

AVENIDA 11

AVENIDA 10

AVENIDA CENTRAL

CALLE CENTRAL

AVENIDA 1

AVENIDA 3

AVENIDA 5

AVENIDA 7

AVENIDA 9

AVENIDA 20

CALLE 42

PASEO COLON

CALLE 30

CALLE 20

CALLE 21

CALLE 23

CALLE 25

CALLE 27

CALLE 29

F.E. al P.

MOPT

MOPT

PLAZA CLETO GONZALEZ VIQUEZ

JOSE MARTI

LEGEND

OFF-STREET PARKING (CAPACITY) → XX

FIRE STATION

AMBULANCE ENTRANCE

ON-STREET METERED PARKING

ON-STREET PARKING PROHIBITED

CBD LIMIT

N

0 100 200 METERS

MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES

1974 CBD PARKING INVENTORY (INCLUDING CRITICAL ACCESS)

FIGURE 1-6 BY:

The Central Business District Traffic Control Plan

Chapter II

Chapter II
The Central Business District Traffic Control Plan

A fundamental underpinning of all the projects studied in Stage II is a comprehensive and coordinated traffic control plan for the central business district. The current operating scheme of one-way streets, parking restrictions, and other features has evolved from a series of individual decisions over the years, and a major finding in Stage I was that conditions in that area could be substantially improved for all travelers through a comprehensive rearrangement of current control features and the judicious insertion of such new features as "bus only" streets, new parking restrictions, and streets dedicated for exclusive use by pedestrians. Indeed, two of the Stage II projects, the CBD signal system and CBD bypass, are really elements of the CBD traffic control plan, and the other projects studied, the busways and the radial dispersal system, clearly depend fundamentally on the control plan.

To guide the development of the CBD control plan, a series of operational objectives were evolved. These are:

(1) To provide for priority movement of buses through the CBD using priority lanes/streets, signal control priority, or bus routing plans which reduce walking requirements, bus turns, and transfer inconveniences

(2) To maximize the people-moving capacity of existing CBD streets

(3) To reduce total delays (minimize travel time) for people on CBD streets (in and out of vehicles)

(4) To reduce operating costs for all vehicles using CBD streets in a priority of:

- Buses
- Other vehicles

by reducing stops, delays, and increasing overall speed

(5) To reduce traffic accidents in the CBD

(6) To reduce air and noise pollution in the CBD by:

- Smoother traffic flow (fewer speed changes)
- Less idling of engines
- Reduced traffic density

(7) To provide operational flexibility for changes in traffic conditions in the future

The above objectives are also applicable to the CBD signal system and bypass projects as well, since they are essentially control plan components.

2.1 DEVELOPMENT OF THE CONTROL PLAN

The initial consideration in the development of the downtown control plan was a comparison of anticipated volumes to capacity in the central area and its approach. This was done separately for bus and other vehicles because of the special importance of transit travel. The substantial expected demand in bus usage into and through the CBD suggested that certain streets and/or lanes be given over entirely to bus use. In a typical seven-meter street of central San Jose, it was estimated that it could be operated as two lanes, with the left lane for through movements and the right one given over to boarding and alighting maneuvers. On this basis, hourly bus vehicle capacity was estimated to be about 250. Comparing this to estimated demand indicated that about four North-South streets and three East-West streets, or their equivalent, could be justified.

Once the approximate number of bus streets was known, they became given inputs to the first trial. This trial was intended to develop insights into the physical feasibilities of different locations for and configurations of the various control plan elements. Current pedestrian volumes and the location of several major generators suggested the establishment of pedestrian malls on Central Avenue and Second Street. Several streets and avenues were eliminated from further consideration as exclusive bus streets based on continuity, present use, and trip end locations.

In the second trial, several possibilities were postulated and evaluated according to such criteria as:

- Continuity of traffic and circulation
- Access to generators
- Compatibility with present traffic patterns

Of course, the above-described constraints were taken as given. As a result of this trial, the one-way street pattern was established and the "bus only" streets were selected. Remaining steps involved checking directional capacities and establishing on-street parking controls and individual intersection controls. The resulting 1980 CBD Traffic Control Plan is illustrated in Figures II–1, II–2, and II–3.

2.2 FEATURES OF THE RECOMMENDED 1980 CONTROL PLAN

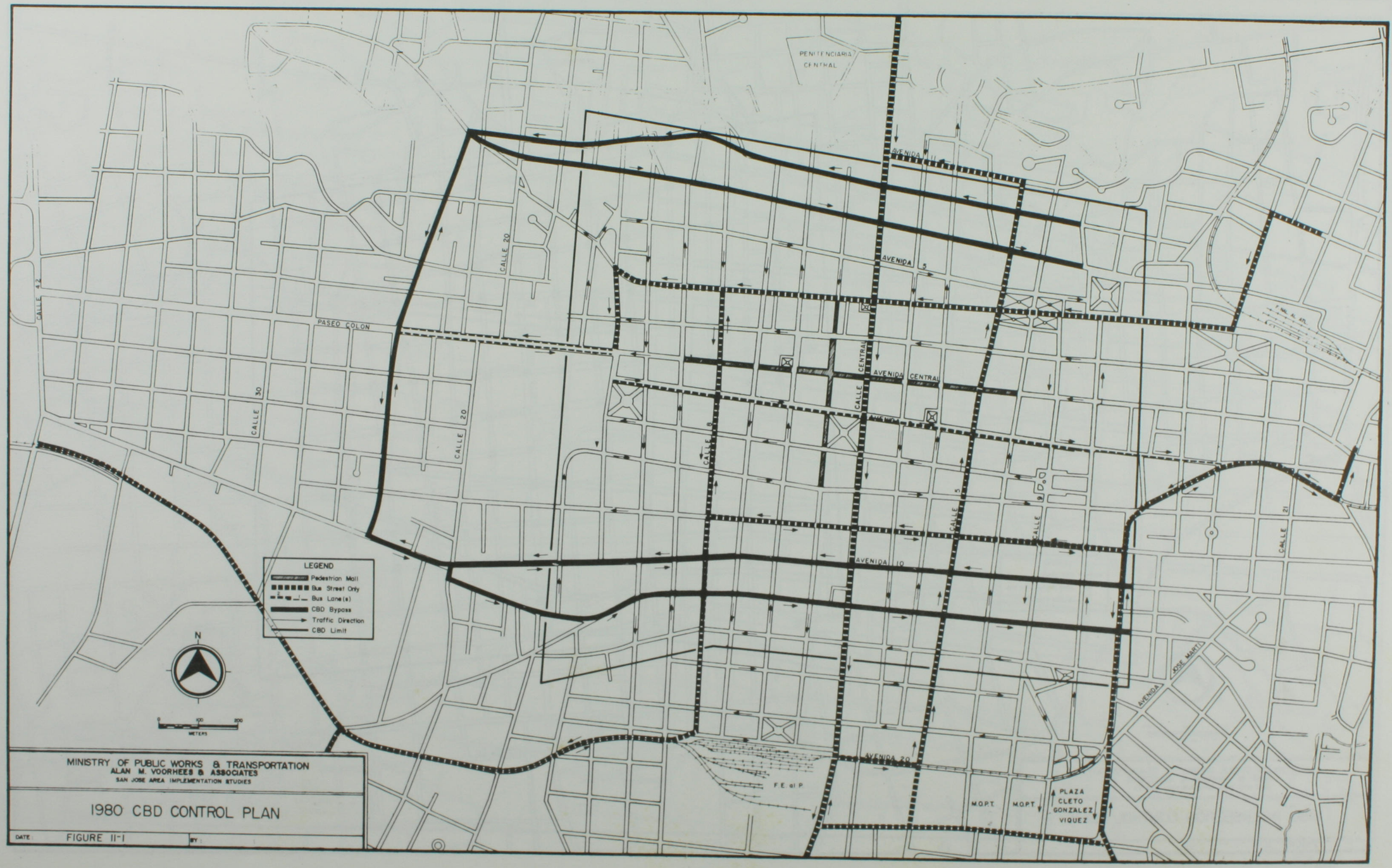
The recommended features of the 1980 CBD Control Plan include the following:

- Pedestrian malls
- Streets for the exclusive use of buses
- A bypass of the CBD core
- Traffic controls which include:
  - Signal system
  - One-way street pattern
  - On-street parking

2.2.1 Pedestrian Malls

The recommended pedestrian malls on Central Avenue and Second Street will serve some of the highest pedestrian volumes in the CBD and will connect many of the major CBD trip generators. They will provide North-South and East-West axes wherein people can walk across the CBD with much less traffic interference, noise, and fumes than is presently the case. The additional capacity provided will also relieve the overcrowded sidewalks on nearby parallel streets. There should, however, be provision for the passage of emergency, public service, and commercial vehicles under certain restricted circumstances:

- Emergency Vehicles — pass any time, only in response to emergency


PENITENCIARIA CENTRAL
AVENIDA 11
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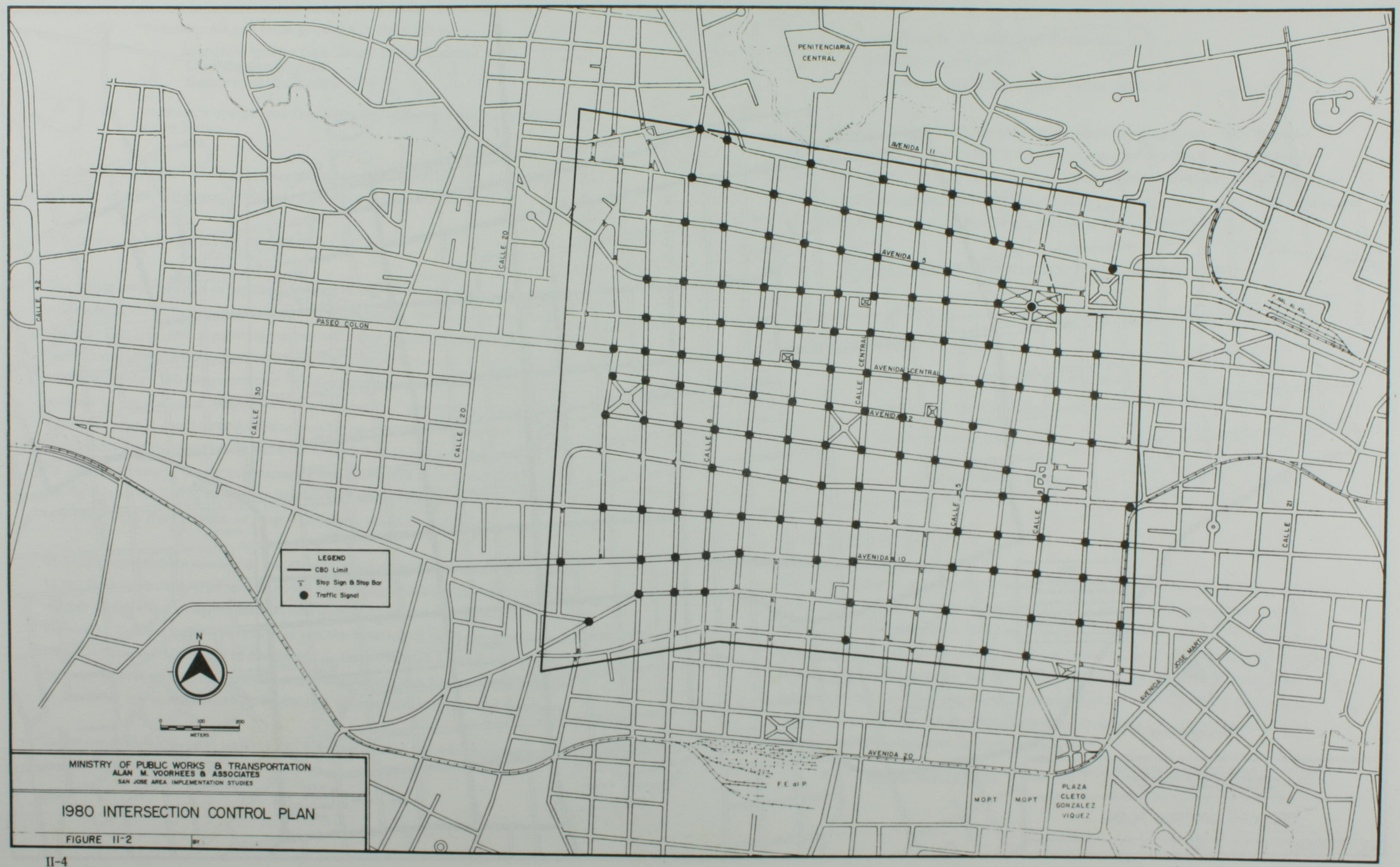
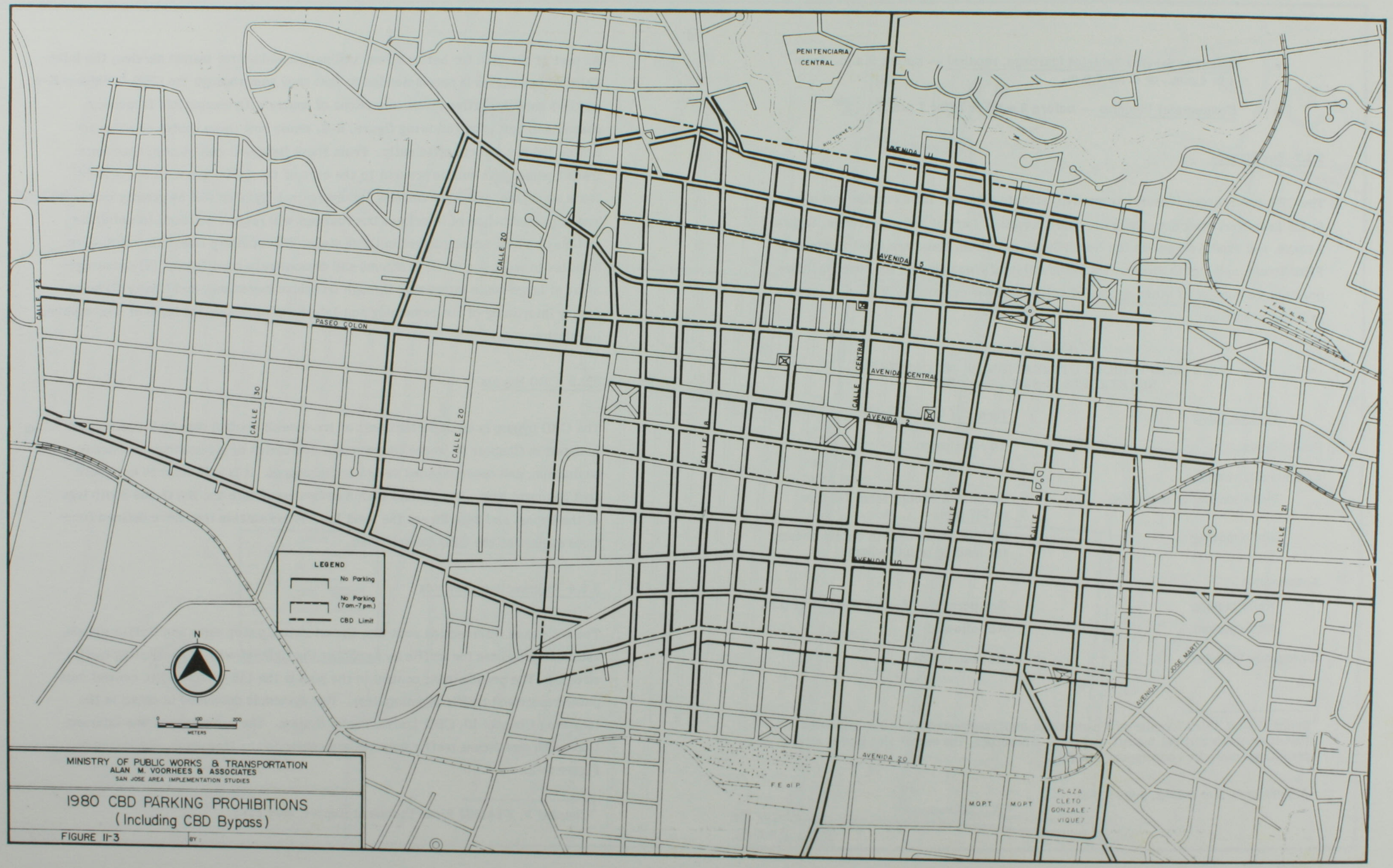
AVENIDA 20
AVENIDA JOSE MARTI
F.E. al P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
Pedestrian Mall
Bus Street Only
Bus Lane(s)
CBD Bypass
Traffic Direction
CBD Limit
N
0
100
200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
1980 CBD CONTROL PLAN
DATE
FIGURE II-1
BY


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE 42
CALLE 30
CALLE 20
CALLE 8
CALLE 15
CALLE 21
PASEO COLON
AVENIDA JOSE MARTI
F.E. al P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
CBD Limit
Stop Sign & Stop Bar
Traffic Signal
N
0
100
200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
1980 INTERSECTION CONTROL PLAN
FIGURE II-2
BY:


PENITENCIARIA CENTRAL
RIO TORRES
AVENIDA 11
AVENIDA 5
CALLE 42
PASEO COLON
CALLE 30
CALLE 20
CALLE 16
CALLE CENTRAL
AVENIDA CENTRAL
AVENIDA 2
CALLE 15
CALLE 9 DE JULIO
AVENIDA 1
CALLE 21
AVENIDA JOSE MARTI
AVENIDA 20
F.E. al P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
No Parking
No Parking (7 am.-7 pm.)
CBD Limit
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
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SAN JOSE AREA IMPLEMENTATION STUDIES
1980 CBD PARKING PROHIBITIONS
(Including CBD Bypass)
FIGURE II-3
BY:

- Essential Service Vehicles (garbage, repairs) — before 9 a.m., from 2 to 4 p.m., or after 7 p.m.
- Commercial Vehicles — before 9 a.m. or after 7 p.m.

2.2.2 Bus Streets

The CBD control plan features seven CBD streets set aside for exclusive bus use. In the East-West direction, these are Third Avenue,[1] part of Second Avenue, Eighth Avenue, and 22nd Avenue. In the North-South direction, these are Central Street, Fifth Street, and Eighth Street. The reservation of these streets for buses includes provision for access by other classes of vehicles under certain conditions as shown in Table II–1 below:

TABLE II–1

PROPOSED VEHICLE UTILIZATION OF "EXCLUSIVE" BUS STREETS IN SAN JOSE CBD

Vehicle Class	Terms of Utilization
Public Buses	No restriction
Commercial Vehicles	
While loading or unloading	Permitted except from 7-9 a.m. or 3-7 p.m.
While moving	For one block only to obtain access for loading or unloading
Automobiles	
While moving	Not permitted from 5 a.m. to 11 p.m.
While parked	Not allowed
Emergency Vehicles[2]	No restriction

[1] Evaluation of Third Avenue as a pedestrian mall, suggested by some, indicates that it provides critical transit capacity. Therefore, the use of this street as a pedestrian mall does not appear feasible.

[2] Ambulances, fire trucks, police cars

As part of the plan for better street utilization and better transit service, the interlining of bus routes is recommended so that they pass through the CBD.[1] Figures II–4 and II–5 show tentative interconnections of routes with compatible frequency characteristics. The following figure, II–6, shows how these routes combine to utilize the bus streets efficiently. From these figures it can be seen that more transit passengers will be brought to the core of the CBD than with the present route structure, and opportunities for convenient transfer will be greatly increased. The implementation of interlined bus routings will require political forcefulness and may be best accomplished in three steps: (1) voluntary interlining of 2, 4, or 6 routes to work out minor problems and demonstrate its efficacy, (2) encouragement of large-scale interlining through franchise incentives, and finally (3) mandatory interlining of the remaining non-interlined routes on the basis of new enabling legislation.

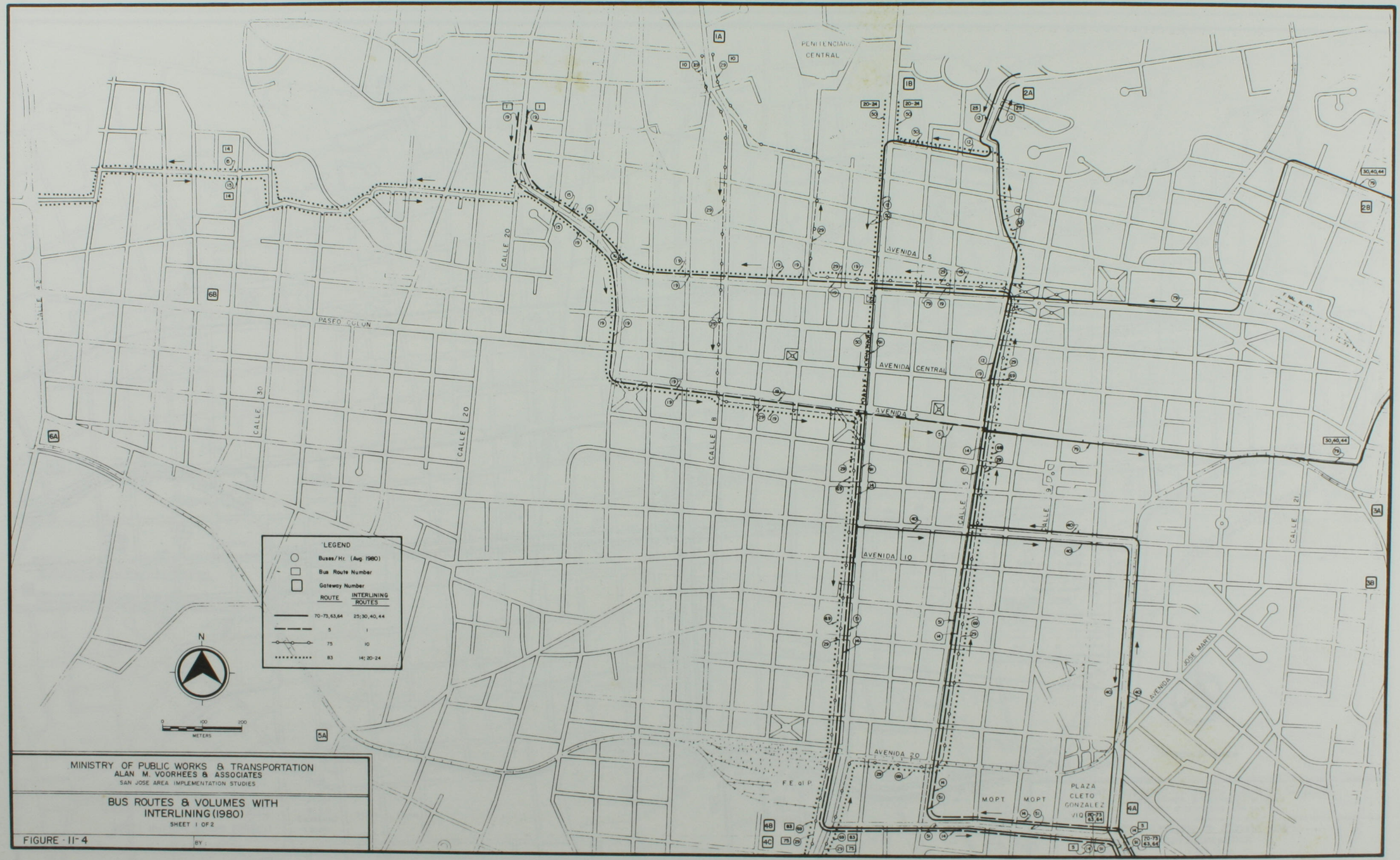
2.2.3 CBD Bypass

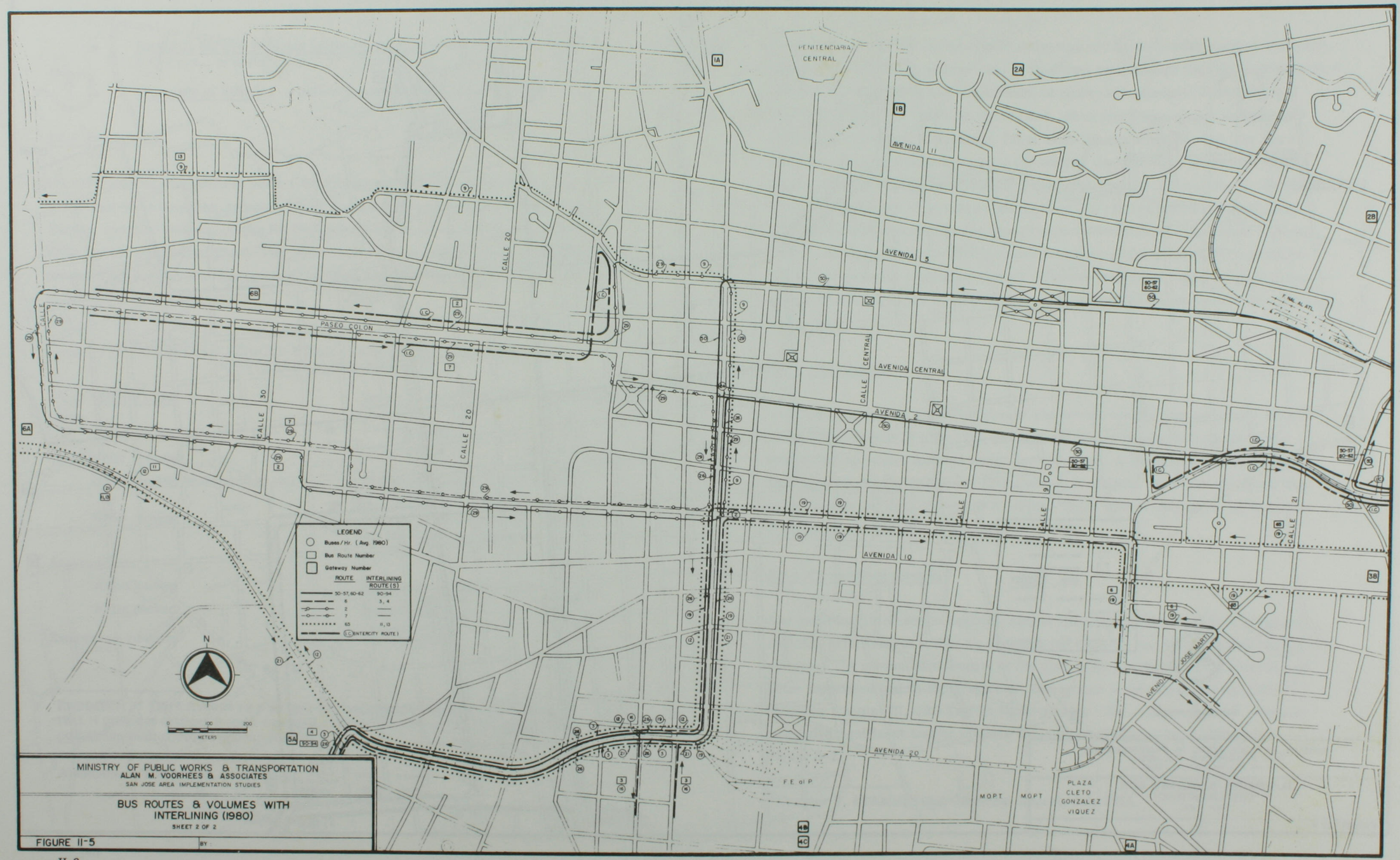
The CBD bypass is an important part of the overall control plan and is presented in detail in Chapter IV where the concept, evaluation of alternatives, economic evaluation, and recommended design are discussed. It is sufficient to note here that Seventh, Ninth, Tenth, and 12th Avenues constitute the North and South legs of the bypass and 24th Street the West leg. These streets then have defined functions as part of the CBD Control Plan.

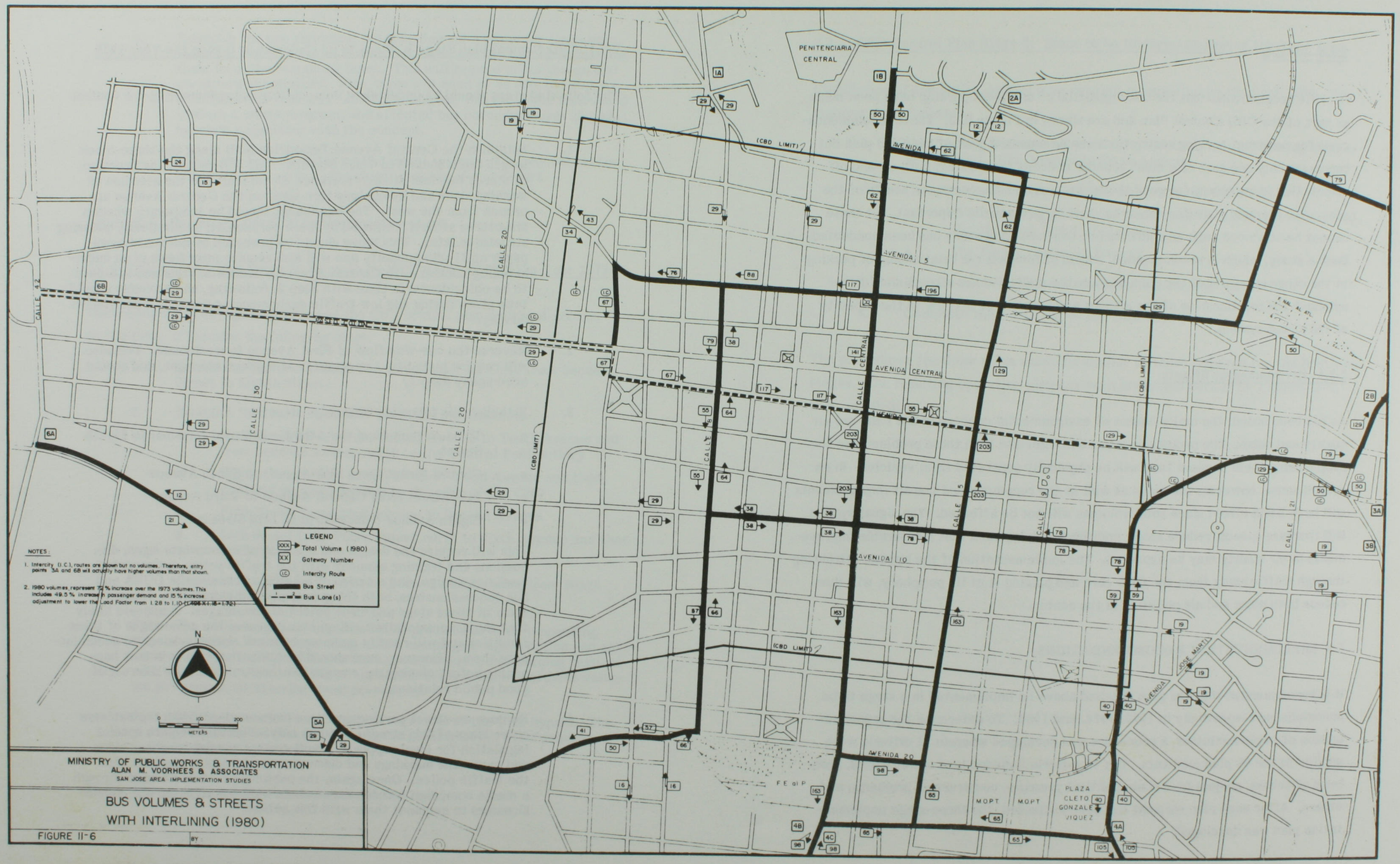
2.2.4 Intersection Controls

The individual intersection controls, almost entirely stop signs and traffic signals, establish priorities for traffic by assigning the right-of-way to conflicting traffic streams. The predominant control in the plan is the 140-intersection, central computer supervised traffic signal system. This system is described in detail in the following Chapter III, CBD Traffic Signal System. The remainder of the intersections with significant traffic volumes are controlled by stop signs, illustrated in Figure II–2.

[1] Chapter V, ETAMSJ Final Technical Report, July 1975.


PENITENCIARIA CENTRAL
1A
1B
2A
2B
3A
3B
4A
4B
4C
5A
6A
6B
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE 20
CALLE 30
CALLE 8
CALLE 5
CALLE 3 BIS
CALLE 21
PASEO COLON
JOSE MARTI
AVENIDA
F.E.G.I.P.
MOPT
MOPT
PLAZA CLETO GONZALEZ VIQ
LEGEND
Buses/Hr. (Avg. 1980)
Bus Route Number
Gateway Number
ROUTE
INTERLINING ROUTES
70-73, 63, 64
25; 30, 40, 44
5
1
75
10
83
14; 20-24
N
0
100
200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
BUS ROUTES & VOLUMES WITH INTERLINING (1980)
SHEET 1 OF 2
FIGURE - II-4
BY :


PENITENCIARIA CENTRAL
1A
1B
2A
2B
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE CENTRAL
CALLE 20
CALLE 30
CALLE 5
CALLE 9
CALLE 21
PASEO COLON
6B
6A
5A
4B
4C
4A
3B
3A
38
F.E.G.I.P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
AVENIDA JOSE MARTI
LEGEND
Buses/Hr. (Avg. 1980)
Bus Route Number
Gateway Number
ROUTE
INTERLINING ROUTE(S)
30-57, 60-62
90-94
6
3, 4
2
7
65
11, 13
(IC) INTERCITY ROUTE)
N
0
100
200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
BUS ROUTES & VOLUMES WITH INTERLINING (1980)
SHEET 2 OF 2
FIGURE II-5
BY



MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES

BUS VOLUMES & STREETS
WITH INTERLINING (1980)

FIGURE II-6 | BY

2.2.5 Parking

Specific recommendations for the regulation of on-street parking have been made as part of the CBD Control Plan and are shown in Figure II-3. These recommendations for on-street parking restrictions are an essential part of the CBD plan but represent only one part of a much broader concern for parking, both on-and off-street, that is necessary for good transportation and the economic health of the area. Policies and plans for off-street parking are equally important, but these cannot be advanced until an additional in-depth parking study has been conducted. Such a study, which is recommended, should encompass the relationship of parking to the other elements of the plan, such as the malls and bus streets and further establish the relationships of the amount and location of parking to the capacity of the street system.

2.2.6 Environmental Effects

As has been noted, the major causes of environmental concern in the CBD are air quality and noise. The pedestrian malls will alleviate both these problems for the people using them because they will be physically separated from vehicles. In an overall sense, however, the malls as well as the recommended transit improvements will have little effect since total volumes will not be affected. The signal system will increase speeds, reduce stops, and shorten delay such that measurable improvements in air quality may be expected. The implementation of the bypass, attracting through traffic away from the CBD core and placing it at its periphery, will thus reduce both noise and air pollution in the center.

2.3 IMPLEMENTATION RECOMMENDATIONS

It is recommended that the plan detailed above be implemented in a stage to be accomplished respectively in 1976, 1978, and 1980. To determine the proper sequence of implementation, a procedure was developed wherein 11 criteria were applied to the 69 plan elements. The 11 criteria included land use conflicts, problems of access, project lead time, political pressure, construction problems, and others. After each plan element had been evaluated, the three-stage implementation plan was developed.

2.3.1 CBD Control Plan Stage I: Steps to be Undertaken During the Year 1976

The following steps should be undertaken immediately in implementing the control plan:

1. Establish the Central Avenue Pedestrian Mall along the three-block length from Second to Third Streets. This will require the erection of sturdy barriers at each entrance to the mall and the erection of warning signs and mandatory turn signs on the Central Avenue approach from the west. The barricades should be temporary wooden structures at first, followed by more permanent, aesthetically-pleasing structures later. This move should be preceded by adequate newspaper and radio publicity and will also require interviews in an understanding manner with Central Avenue merchants. This act will have to be coincidental in time with Step 2, following, and probably should take place during the low traffic early morning hours of a designated Sunday.

2. Reverse the one-way flow of First Avenue to westbound. This also will require publicity, the erection of appropriate signs, and should accompany Step 1.

3. Establish the following "bus only" streets:

   - Third Avenue from the Atlantic Railroad terminal to Eighth Street
   - Central Street from 18th Avenue to Tenth Avenue
   - 14th Street from Central Avenue to Third Avenue
   - Eighth Avenue from Fourth to 14th Streets

   This will require the design and erection of appropriate signs, discussions and training sessions with the traffic police, a concerted media campaign, and a series of meetings between the DGTA and bus concessionaires, both the groups and individually, to acquaint them of these steps and their potential advantages. It appears likely that the concessionaires will quickly perceive the advantages of these facilities and will readily make appropriate route revisions to accommodate them. However, care should be taken that this is in fact happening before closing the streets to other traffic in the interest of good public relations.

4. Remove on-street parking on Paseo Colon and establish the extreme outer lanes of this street for buses only. This may require special legislation for legal support. It will require special overhead signs and pavement markings and discussions and training sessions with the traffic police. Once again, the public should be informed through a media compaign and discussions held with the affected bus concessionaires to acquaint them with this action.

5. Establish the two rightmost lanes on Second Avenue for buses only, including the erection of a non-mountable median barrier separating them from the remaining lanes. This will require minor design and construction activities. Also, signs will need to be erected and, as with the other "bus only" streets and lanes, this should be announced through a media program, and affected bus concessionaires should be made acquainted with the concept.

6. Install the recommended traffic signal system. The procedures for this are discussed in a subsequent chapter of this report.

Figure II–7 summarizes this first implementation stage.

2.3.2 CBD Control Plan Stage 2: Steps to be Undertaken During the Year 1978

The second stage of implementation of the CBD control plan builds, of course, on the first. It includes the following steps:

1. Extend the Central Avenue Pedestrian Mall westerly from Second Street to Eighth Street.

2. Establish "bus only" streets in the following locations:
   - On Central Street from Second Avenue to Tenth Avenue and from Seventh Avenue north to the Central Penitentiary
   - Eighth Street from 20th Avenue to Third Avenue and then westerly on Third Avenue to the edge of the CBD
   - Fifth Street from 22nd Avenue to Second Avenue
   - 13th Street from Plaza Viquez north to Sixth Avenue and then easterly

3. Continue the "bus only" lanes on Second Avenue west from Ninth Street to 17th Street.

Note: The above steps will require similar procedures to corresponding steps undertaken in 1976, including media campaigns, sign erection and pavement markings, dealings with the bus concessionaires, and training sessions with the traffic police. By this time, earlier experience will provide valuable guidance in undertaking these procedures.

4. Install the southern and western segments of the CBD bypass. The procedures for this are discussed in greater detail in subsequent chapters of this report.

These steps are graphically summarized in Figure II–8.

2.3.3 CBD Control Plan Stage 3: Steps to be Undertaken During the Year 1980

Completion of the entire control plan concept is expected by the year 1980. Remaining steps include:

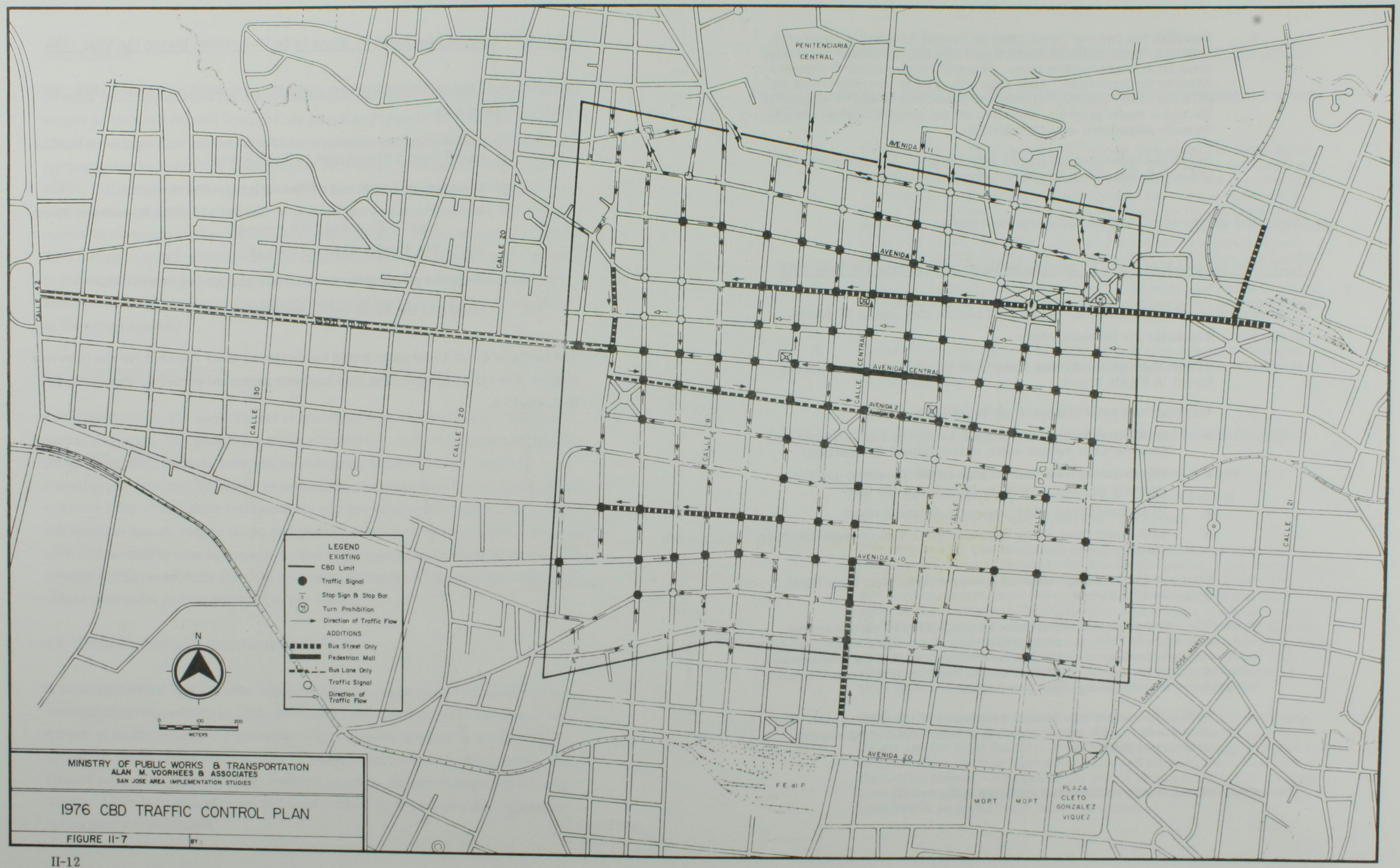
1. Establishing the remainder of the pedestrian mall by closing Second Street from Fifth Avenue to Sixth Avenue

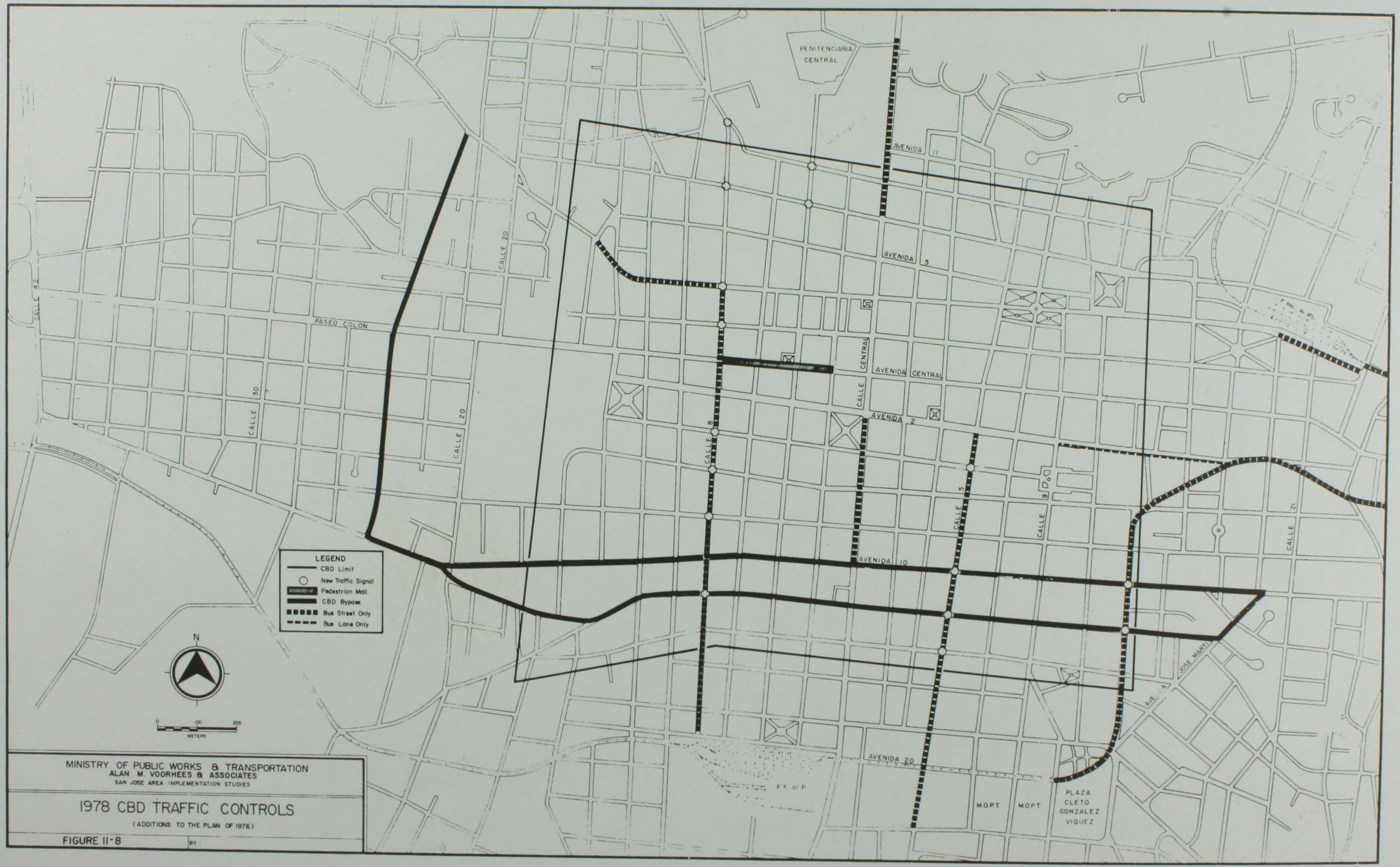
2. Completing the pattern of "bus only" streets, including:
   - The remaining portion of Central and Fifth Streets and Third, Eighth, 22nd, and 11th Avenues
   - The Pacific Railroad Busway

3. Required one-way street reversals and parking restrictions

4. Complete the North leg of the CBD bypass

The procedures for these steps would be similar to those required for the first two stages. The resulting operating plan has been presented earlier in Figures II–1, II–2, and II–3.


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 3
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE 32
CALLE 30
CALLE 20
CALLE CENTRAL
CALLE 8
CALLE 9
CALLE 21
AVENIDA JOSE MARTI
F.E. al P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
EXISTING
CBD Limit
Traffic Signal
Stop Sign & Stop Bar
Turn Prohibition
Direction of Traffic Flow
ADDITIONS
Bus Street Only
Pedestrian Mall
Bus Lane Only
Traffic Signal
Direction of Traffic Flow
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
1976 CBD TRAFFIC CONTROL PLAN
FIGURE II-7
BY:


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
CALLE CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
CALLE 32
PASEO COLON
CALLE 30
CALLE 20
20
CALLE 8
CALLE 15
CALLE 9
CALLE 21
JOSE MARTI
AVE. 6
F F al P
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
CBD Limit
New Traffic Signal
Pedestrian Mall
CBD Bypass
Bus Street Only
Bus Lane Only
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
1978 CBD TRAFFIC CONTROLS
(ADDITIONS TO THE PLAN OF 1976)
FIGURE II-8
BY

The Central Business District Traffic Signal System

Chapter III

Chapter III
The Central Business District Traffic Signal System

3.1 OBJECTIVES

The central business district (CBD) traffic signal system improvements are an integral part of the overall mid-term transport program for San Jose. Accordingly, the underlying objectives for the recommended improvements are encompassed both by the general objectives and operational objectives for transportation developed in the Stage I study and set forth in the Stage I Final Report.[1] Certain of these objectives are particularly relevant to the CBD signal system:

- To improve the quality of private vehicle, street traffic in the central area only to the extent that existing street space for such traffic movement remains after...(encouraging public transit usage)
- To encourage use of public transit for travel to major generators in and near the central area of San Jose by application of operational measures, such as bus priority regulations, coordination, and optimization of service...
- To foster regulation and investment in transportation which will give strong consideration to increasing the safety from road accidents for persons engaged in urban travel
- To improve the existing street system through physical and operational means...

3.2 EXISTING SITUATION

A total of 84 intersections in the San Jose CBD are currently controlled by traffic signals. The system is a primitive one, both in the characteristics of traffic signal display equipment installed at the intersections and in the method used to control the timing of signal operation. An elaboration of the nature of and problems resulting from the signal display deficiencies and signal control deficiencies follows.

---

[1] Alan M. Voorhees & Associates, Inc. Final Technical Report, San Jose Area Transportation Study, July 1975, pp. IV-11 and IV-12.

3.2.1 Signal Display Deficiencies

The existing installations of traffic signal display equipment are deficient on several counts:

- Most intersections have only one display of red, green, and yellow signals facing each direction from which traffic approaches. Any failure or malfunction of that one signal display set for a given intersection approach results in no information on signal status for traffic on that approach. The implicit effect is a degradation of traffic safety and efficiency.

- The signal displays are typically mounted on a mast arm over the center of the intersections, a position which makes difficult the visibility of the signal display for drivers stopped first in line on the intersection approach. The implicit effect is a degradation of traffic flow efficiency due to the potential time lag in driver perception of signal display changes.

- Most intersections have no signal displays for pedestrians, and the vehicular signal displays are usually so installed that pedestrians on only two of the four intersection crosswalks can see the signal display. The implicit effect is a degradation of pedestrian safety.

- The conditions described above fail to conform to the minimum standards for proper traffic signal installation prescribed in the Manual de Senales Viales of the MOPT, DGTA, Departmento de Ingenieria, Julio 1973.

3.2.2 Signal Control Deficiencies

The timing of the existing traffic signals in San Jose is controlled by a primitive but ingeniously operated system in which all 84 traffic signals are operated by only two master controllers. There are no timing devices installed at the individual signalized intersections. Instead, the signal display lamp relays at each intersection are wired to one of the two master controllers which times the signal cycle, split, and offset at the intersection. Each master controller is interconnected to and performs identical timing control of approximately one-half of the signalized intersections. The equipment arrangement results in a basic inability to time the traffic signals in a manner which is related to traffic volumes at different intersections. Several traffic control problems therefore exist.

- Every intersection connected to one of the two master controllers must have the same split (i.e., proportion of the signal cycle allocated to the two crossing streets). Intersection traffic volumes vary widely and, ideally, signal splits should be used which balance the degree of saturation on the crossing streets at each intersection. With the existing system, 50/50 splits at every intersection is the best timing that can be implemented. The result is malapportionment of green time to crossing streets at many intersections and unnecessary delay and congestion.

- Any given intersection must use the same signal timing all day long, every day, even though traffic volume variations throughout the day and between days require variable timing plans to minimize unnecessary delay and congestion.

- The flexibility to adjust signal offsets (the time relationship between the start of the green signal display at adjacent intersections) is severely limited. Offsets between intersections can only be set to one of four values, e.g., 0 percent, 25 percent, 50 percent, or 75 percent of the cycle length, because only two master controllers are used, and each employs 50 percent/50 percent splits. In general, the timing method now employed is to provide offsets of 25 percent between intersections. Fortunately, this so-called "quarter cycle offset" plan is fairly efficient for a central area street grid with closely-spaced signals. Nevertheless, the offsets are in no sense optimum ones for the geometric and traffic flow conditions. A more flexible system could more closely approximate optimum offsets between each pair of intersections to reduce stops and delay.

- The inflexible equipment arrangement makes it impossible to provide signal timing which favors streets with heavy or exclusive bus flows.

- The existing equipment does not have the ability to separately time the pedestrian signal displays at the few intersections where they are installed. Hence, there is no clearance interval for pedestrians to complete their street crossing maneuver prior to the change in the vehicular signal displays. This results in unnecessary interference between pedestrians and vehicles which produces traffic flow inefficiencies as well as potential pedestrian hazard.

Due in significant measure to the signal control deficiencies, a substantial amount of traffic stops and delays occurs at intersections which could be alleviated with an improved signal control system. Based on intensive studies of a representative portion of the CBD street network, discussed subsequently in this chapter, the existing overall average speed in the CBD (considering weekdays, weekends, and holidays and various periods of the day) is approximately 14 kph for autos and trucks and 8 kph for buses. It was hypothesized that substantial improvements

for both private and public transport could be achieved in the CBD through improvements in the signal control system.

3.3 RECOMMENDED SIGNAL DISPLAY IMPROVEMENTS

In order to overcome the deficiencies of the intersection traffic signal displays, it is recommended that all existing and new signal installations be upgraded to conform to uniform standards of design.

3.3.1 Number of Signal Displays

A minimum of two traffic signal display sets should be installed for each intersection approach leg carrying vehicular traffic. Because streets in the San Jose CBD are narrow (most are seven meters wide), only two signal display sets are needed for most intersection approaches.

3.3.2 Method of Installing Signal Displays

Several methods of signal display positioning and mounting were considered including the use of span wires, mast arms, pedestals, and posts. The recommended practice is to install, for each intersection approach, one mast arm-mounted signal display and one post- or pedestal-mounted signal display. Both signal displays should be positioned so to drivers they appear to be on the far side of the intersection. The mast arm-mounted signal should be positioned laterally, approximately over the center of the intersection approach path. The pedestal- or post-mounted signal display should be positioned on the far right corner of the intersection. Figure III–1 is an artist's rendering of the driver's view of the recommended signal installation.

3.3.3 Pedestrian Signal Displays

Pedestrian signal displays (walk, don't walk) should be installed at all intersection crosswalks in the CBD. The reasons for this recommendation are: the high pedestrian volumes at nearly all CBD intersections, the poor visibility of vehicular signal displays to pedestrians on some crosswalks of the many intersections of one-way

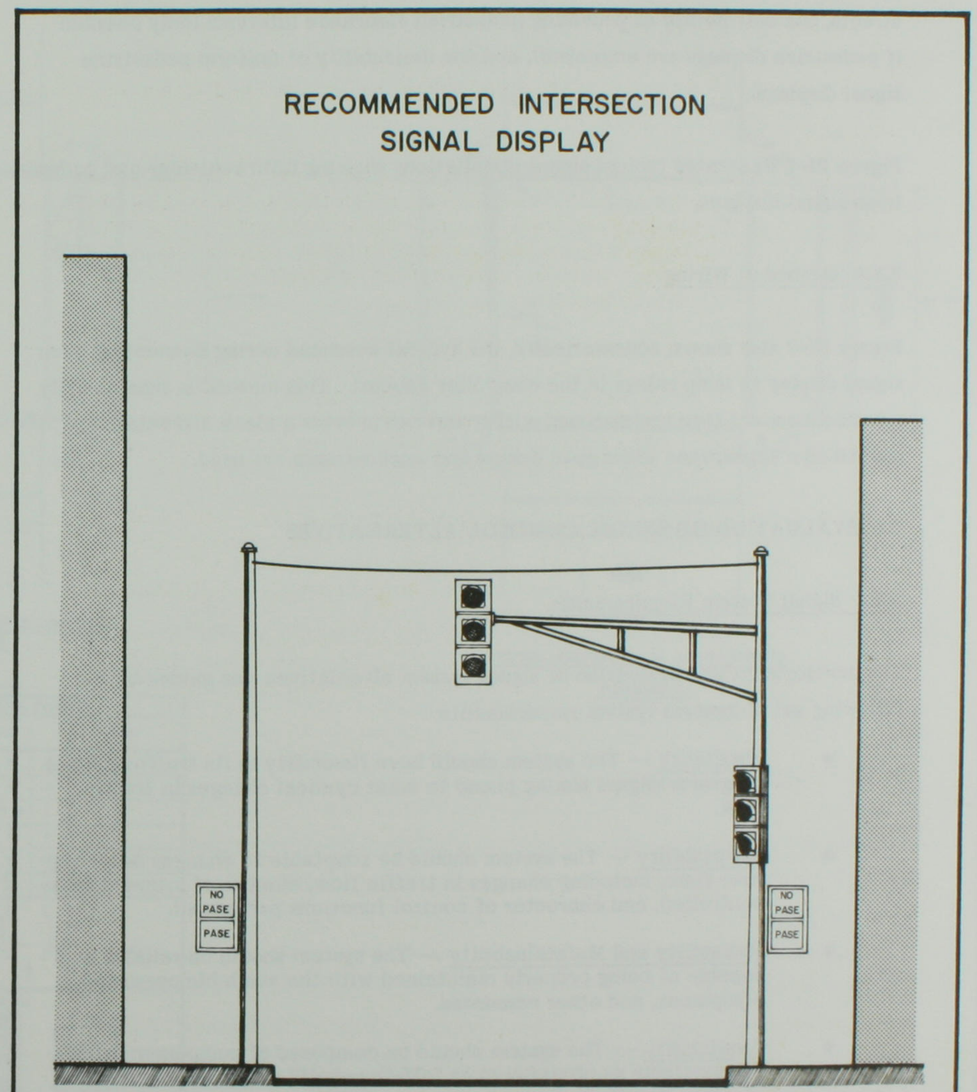


FIG. III-1

streets, the desirability of providing pedestrian clearance intervals (only possible if pedestrian displays are employed), and the desirability of uniform pedestrian signal displays.

Figure III–2 illustrates typical signal installations showing both vehicular and pedestrian signal displays.

3.3.4 Method of Wiring

Figure III–2 also shows, schematically, the typical overhead wiring connecting each signal display to lamp relays in the controller cabinet. This method is substantially more economical than underground wiring and can provide a clean and relatively unobtrusive appearance when good design and workmanship are used.

3.4 EVALUATION OF SIGNAL CONTROL ALTERNATIVES

3.4.1 Signal System Requirements

The development and evaluation of signal system alternatives was guided by the following set of general system requirements:

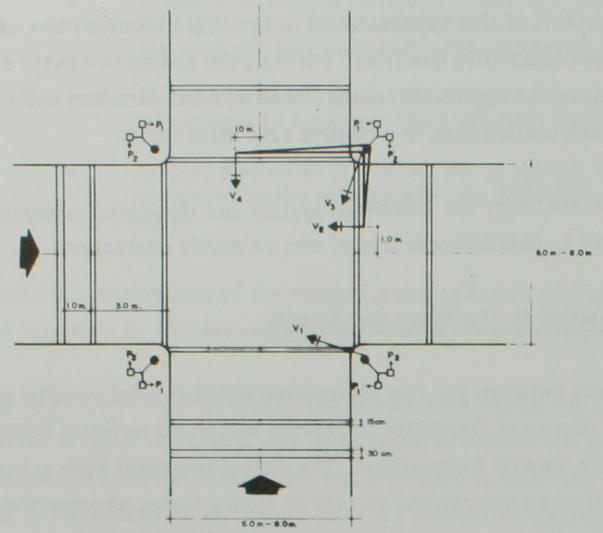
- Flexibility — The system should have flexibility in its traffic control programs (signal timing plans) to meet cyclical changes in traffic flow.
- Adaptability — The system should be adaptable to changes occurring over time, including changes in traffic flow, number of intersections controlled, and character of control functions performed.
- Reliability and Maintainability — The system should be reliable and capable of being properly maintained with the available personnel, equipment, and other resources.
- Availability — The system should be composed of components which are available as operational or "off-the-shelf" items and are capable of being installed within two years.
- Economic Feasibility — The system should be procured, installed, and operated at the lowest cost considering benefits received.

The basic weakness of the existing traffic signal control system is its inability to provide variations in signal timing at different intersections and at different times of day and days of the week for a given intersection to correspond to fluctuations in traffic volume by time and location. The key question to which a detailed analysis was addressed is: how much flexibility in signal control is economically warranted?

3.4.2 Signal Control Alternatives

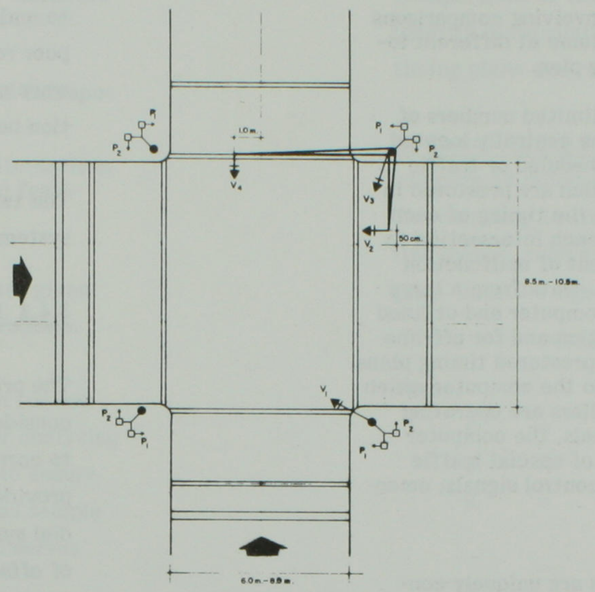
Four generic forms of master signal control were initially considered for application in the San Jose CBD. In all cases considered, the individual intersection controllers would be interconnected to a master control device to enable coordination of timing between intersections; this was implicitly believed to be essential in the CBD environment with very close spacing between signals. The following alternatives were considered.

- Single-Dial System in which each intersection's timing is operated by a single-dial intersection controller. This provides a unique split to be used at each intersection, but no variation in split is afforded for different times of day or different days of the week. All signals would be operated on a common cycle length and coordinated by a simple master controller. Up to three different offsets can be used at each intersection, but usually such systems employ only a single timing plan.
- Three-Dial System in which each intersection is equipped with a three-dial controller. Each dial can employ a different split to provide limited variation of timing to meet changes in traffic volume by time of day and day of week. Three different cycle lengths can be employed, one common cycle for dial one at all intersections, one for dial two, and one for dial three. Up to three different offsets for each dial (or a total of nine offsets) at an intersection can be used, but such systems are commonly operated with only three basic timing plans. The master controller coordinates the timing of all intersections and commands the changeovers to different dials during the day, usually on the basis of a predetermined time schedule.
- Analog Computer System in which each intersection is equipped with a special controller which, under the command of an analog master control computer, can provide three splits, six-cycle lengths, and three to eight offsets (depending on which manufacturers' equipment is used). The central analog computer receives traffic data from a limited number of sensors in the field upon which it bases selection



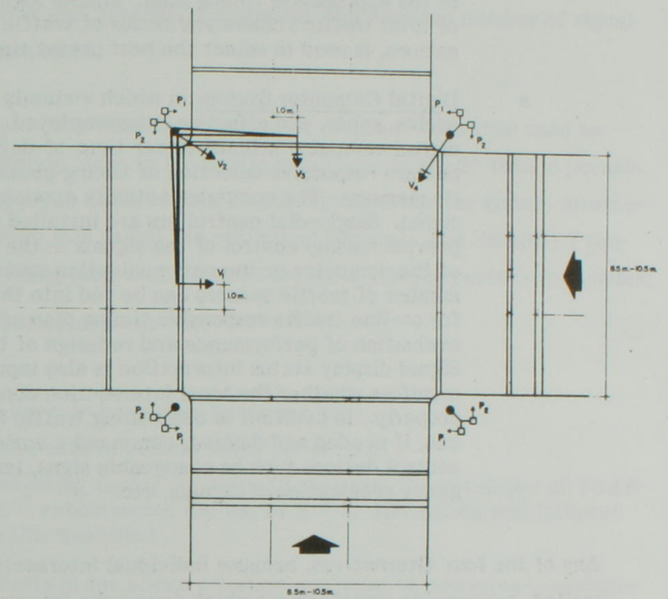
TYPICAL INTERSECTION OF 2 LANE STREETS

STANDARD A



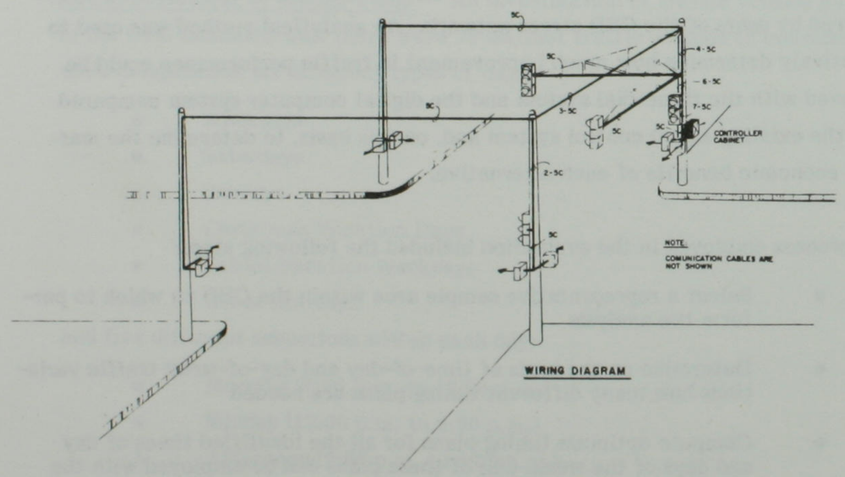
TYPICAL INTERSECTION OF 2 LANE AND 3 LANE STREETS

STANDARD B



TYPICAL INTERSECTION OF 3 LANE STREETS

STANDARD C



WIRING DIAGRAM

STANDARD SIGNAL PHASING							
SIGNAL HEAD NUMBER	PHASE A			PHASE B			FLASH
V_1	↑	↑	A	R	R	R	A
V_2	↑ ←	↑ ←	A	R	R	R	A
V_3	R	R	R	↑ →	↑ →	A	R
V_4	R	R	R	↑	↑	A	R
P_1	W	FL DW	FL DW	DW	DW	DW	DARK
P_2	DW	DW	DW	W	FL DW	FL DW	DARK
SIGNAL HEADS: V_1, V_4 (R, A, ↑); V_2 (R, A, ↓, →); V_3 (R, A, ↓, →); P_1, P_2 DON'T WALK							

NOTE· AVENUES ARE ALWAYS PHASE A

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SAN JOSE AREA IMPLEMENTATION STUDIES

CBD TRAFFIC SIGNAL SYSTEM TYPICAL INTERSECTION DESIGNS

FIGURE III-2

of the appropriate timing plan. Simple logic, involving comparisons of total traffic volume and ratios of traffic volume at different locations, is used to select the best preset timing plan.

- Digital Computer System in which virtually unlimited numbers of cycles, splits, and offsets can be employed. The centrally located digital computer utilizes either time-of-day scheduled or traffic pattern responsive selection of timing plans which are prestored in its memory. The computer actually commands the timing of each signal. Single-dial controllers are installed at each intersection to provide backup control of the signals in the event of malfunction of the computer or the communication system. Data from a large number of traffic sensors can be fed into the computer and utilized for on-line traffic responsive timing plan selection and for off-line evaluation of performance and redesign of the prestored timing plans. Signal display status information is also input to the computer which monitors whether the local intersection controllers are operating properly. In addition to controlling traffic signals, the computer can, if needed and desired, command a variety of special traffic control devices such as changeable signs, lane control signals, emergency preemption of signals, etc.

Any of the four alternatives, because individual intersections are uniquely controlled, can provide signal timing which favors the intersection approaches carrying heavy bus volumes. This is not possible with the existing system which can only operate practically with all intersections having the identical 50/50 split.

3.4.3 Preliminary Screening

A preliminary screening was performed to eliminate signal control alternatives which did not appear to warrant serious consideration for application in the San Jose CBD.

The single-dial system was eliminated from further consideration because it was not a sufficiently major step upward in flexibility compared to the existing system. While this alternative could provide each intersection with unique timing, no flexibility whatsoever was provided for time of day and day of week variability.

The analog computer system was eliminated from consideration because it affords less flexibility than the digital computer system at equal or higher capital cost. Moreover, the local controllers used with this system are complex and difficult to maintain. Many systems of this type installed in the United States have exhibited poor reliability and maintainability qualities. Further, the analog computer systems were originally conceived for application along linear arterial corridors and function better in that configuration than in a central area street grid.

The two remaining alternatives, the three-dial system and the digital computer system, were subjected to detailed operational and economic evaluations.

3.4.4 Economic Evaluation Methodology and Results

The principal difference between the two alternative signal control systems under consideration is their degree of flexibility to provide variations in signal timing to correspond to traffic volume fluctuations. The digital computer system can provide a virtually unlimited number and variety of timing plans, whereas the three-dial system can provide only three basic timing plans (with additional variations of offsets, if desired, within each plan). It was hypothesized that the digital system's greater ability to vary signal timing would lead to significantly larger increases in average network speed and correspondingly larger reductions in costs incurred by users of the CBD street network. An analytical method was used to objectively determine how much improvement in traffic performance could be achieved with the three-dial system and the digital computer system compared with the existing signal control system and, on this basis, to determine the marginal economic benefits of each alternative.

The process employed in the evaluation included the following steps:

- Select a representative sample area within the CBD on which to perform the analysis
- Determine on the basis of time-of-day and day-of-week traffic variations how many different timing plans are needed
- Compute optimum timing plans for all the identified times of day and days of the week. (All of these plans can be employed with the digital computer system.)
- Determine how to apply the three basic timing plans available with the three-dial system to best fit conditions of the different times of day and days of the week

- Evaluate traffic performance resulting from the use of the unlimited timing plans (digital computer system), three timing plans (three-dial system), and a single timing plan (existing system)
- Transform traffic performance measures into user costs and extrapolate results to represent the total CBD network
- Compute benefits of the two signal system improvement alternatives compared to the null condition to determine their economic feasibility

Detailed descriptions of the economic analysis methodology and results are given in Appendix A. Briefer descriptions of analysis are presented herein, as follows.

Sample Area — A representative sample area within the CBD was chosen for use in the analysis because it was impractical to expend the time and cost for analyzing the entire CBD network. Care was exercised in selecting a sample area to ensure its representativeness. Figure III–3 is a schematic diagram of the selected sample area which lies in the north central portion of the CBD. The sample area serves approximately one-quarter of the total CBD person kilometers of travel.

Required Number of Timing Plans — An investigation of traffic volume patterns in the CBD indicated that there were 30 distinct traffic periods to consider. These were composed of six different types of days:

- Weekdays
- Saturdays
- Sundays
- Christmas Vacation Days
- School Vacation Weekdays
- Other Holidays

and five different subperiods within each day:

- Morning (7:00 a.m. to 12:00 p.m.)
- Midday (12:00 p.m. to 2:00 p.m.)
- Afternoon (2:00 p.m. to 6:00 p.m.)
- Mid-evening (6:00 p.m. to 10:00 p.m.)
- Night (10:00 p.m. to 7:00 a.m.)

Comparisons of traffic characteristics in these 30 traffic periods were made to identify close similarities and, through this process, the required number of signal timing plans was reduced to 18.

Optimum Timing Plans — The TRANSYT computer program[1] was then used to compute 18 optimum timing plans to fit traffic conditions in the 30 traffic periods. The resulting 18 timing plans could be used in the digital computer system alternative (hence, such a system was called the optimized system). The TRANSYT program finds the signal timing plan which minimizes the following performance index:

$$\text{Performance Index} = D + KS$$

where:

D = delay rate in vehicle hours per hour

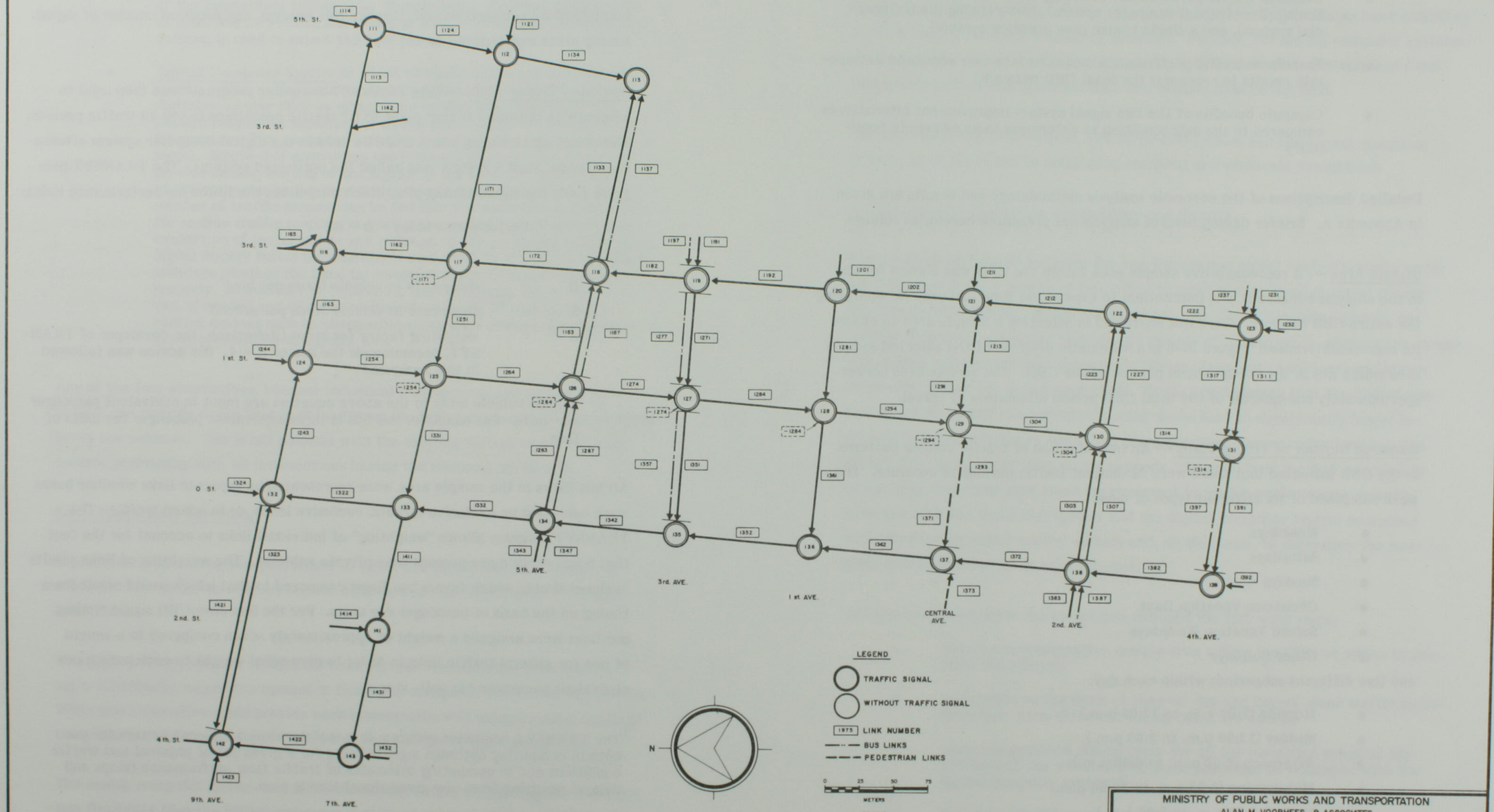
S = stops rate in vehicle stops per second

K = weighting factor for stops (Robertson, the developer of TRANSYT, recommends the use of K = 4. His advice was followed in this analysis.)

All the vehicle units in the above equation are input in equivalent passenger car units. For example, one bus is three equivalent passenger car units of flow.

All bus flows in the sample area were represented by separate links whether buses were operating on exclusive streets, exclusive lanes, or in mixed traffic. The TRANSYT program allows "weighting" of individual links to account for the fact that buses carry more persons than private vehicles. The weighting of links results in signal timing which favors bus flows compared to that which would result from timing on the basis of passenger car units. For the San Jose CBD signal timing, bus links were assigned a weight of approximately seven compared to a weight of one for general traffic links in order to give equal weight to each person per equivalent passenger car unit, viz:

[1] The TRANSYT computer program is a tool developed in Great Britain for use both in computing optimum signal timing for a given set of physical and traffic conditions and in computing estimates of traffic flow performance (stops and delays) resulting from any given signal timing plan.



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TRANSYT NETWORK 1976

FIGURE III-3 BY:

Link Type	Vehicle Occupancy	PCU Equivalency Factor	Persons Per PCU
General Traffic	1.9 persons	1	1.9
Bus	41 persons	3	13.7

$$\text{Bus Link Weight} = \frac{13.7}{1.9} \simeq 7$$

Representation of Three-Dial System — The traffic flow characteristics for the five different time periods and six different types of days were then reviewed to determine how best to apply the three basic timing plans possible in a three-dial system. The scheme selected for weekday and Saturday control was to use the Dial 1 timing plan throughout the daytime period (7:00 a.m. to 6:00 p.m.), the Dial 2 plan for mid-evening (6:00 p.m. to 10:00 p.m.), and the Dial 3 plan for night operation (10:00 p.m. to 7:00 a.m.). A somewhat different application of these same three timing plans was selected for Sundays, Christmas season, other holidays, and school vacation weekdays. The TRANSYT computer program was used to calculate three optimum timing plans for the selected application of the three-dial system.

Traffic Performance Evaluation — The traffic performance effectiveness of the three-dial system (with three timing plans) and the digital computer system timing (with 18 timing plans) was tested using the TRANSYT program's traffic flow performance estimating feature. Each of the periods of the day for the different types of days was simulated for both alternatives, and results were aggregated to yield annual average network performance statistics for the sample network. The analysis was performed for 1976 traffic volume conditions. The results of the traffic performance are presented in detail in Tables A–8 through A–11 in Appendix A. A summary of results is given in Table III–1.

TABLE III-1

SUMMARY OF CBD TRAFFIC PERFORMANCE FOR 1976

Vehicle Type	Average Speeds, kph			Percent Improvement	
	Existing System	Three-Dial System	Digital Computer System	Three-Dial System	Digital Computer System
Autos and Trucks	13.81	14.41	15.62	4	13
Buses	8.17	9.88	10.08	21	23

The estimated improvements in performance brought about by the two signal system improvement alternatives are quite impressive. The digital computer system clearly outperformed the three-dial system, as expected, showing a 13-percent improvement for autos and trucks and a 23-percent improvement for buses. It is especially noteworthy that the estimated improvement of bus performance is a higher percentage than for autos and trucks, thereby illustrating that the preferential weighting of bus links in the signal timing optimization process indeed produced positive results.

Annual reduction (for 1976) in delay to bus passengers and auto occupants (in the full CBD network), produced by the digital computer system, was also estimated, as follows:

- Bus Passengers — 2.29 million person-hours saved
- Auto Occupants — 1.30 million person-hours saved

Although the above time savings are distributed in relatively small units across a very large number of annual person trips in the CBD, the total time savings are nonetheless impressive. The totals again illustrate that the preferential signal timing for buses produces greater total benefits to bus riders than to private vehicle occupants.

User Cost Savings — The estimated average network speed values for the alternative signal system were transformed into user cost data as described in Table A–8 in Appendix A and extrapolated to represent the total CBD network. Results are given in Tables A–10 and A–11 in the Appendix and are summarized in Table III–2 for the year 1976.

TABLE III-2

SUMMARY OF CBD USER COST SAVINGS FOR 1976

Cost Savings	Thousands of Colones: Three-Dial System Versus Existing	Thousands of Colones: Digital Computer System Versus Existing
Direct Operating Cost Savings		
Autos and Trucks	1,479	3,984
Buses	234	600
Subtotal	1,713	4,584
User Time Cost Savings		
Autos and Trucks	645	1,738
Buses	2,872	3,147
Subtotal	3,517	4,885
Total User Cost Savings	5,230	9,469

Economic Feasibility — The user benefits produced by the two signal system alternatives were then estimated for the assumed 12-year life cycles of the system. These estimates systematically took into account the effects of growth in traffic demand on traffic performance. Life cycle benefits were discounted to present value assuming a 12-percent discount rate.

The capital costs of the two systems were estimated by itemizing quantities of all system components and expanding with the best available unit cost data obtained from bids for similar systems. The digital computer system capital cost was estimated at ₡11,807,000 versus the three-dial system cost estimate of ₡10,792,000. The difference of roughly one million colones is explained in the higher cost (by approximately ₡2 million) of the control center, traffic detectors, and communication system components in the digital system traded off against the more costly local controllers (by approximately ₡1 million) in the three-dial system.

For both the three-dial system and the digital computer system, the marginal annual costs of maintenance and operation compared with the null condition was assumed to be zero. This may appear on the surface to be an erroneous assumption since both the new system alternatives will obviously require more physical and operational maintenance because there would be vastly more components and more complex ones than in the existing system, and more operational attention needed to approximate optimal performance of the system. A conservatively high estimate of the absolute maintenance and operations costs of either of the two alternative systems would be roughly 10 percent of capital cost or about ₡1 million annually. However, the many unaccounted for benefits of either of the two alternative systems, at minimum, would equal and, more than likely, exceed this amount. (It is worth recalling that the user benefits which have already been systematically quantified equal nearly ₡10 million for the first year for the digital computer system.)

The unaccounted for benefits which could not be systematically quantified or translated to monetary units include the following:

- Accident reduction benefits[1] resulting from upgrading signal displays from grossly deficient to acceptable uniform standards
- Accident reduction benefits due to smoother traffic flow and reduced stops and delays in the CBD network
- Traffic performance and safety benefits resulting from the fail soft character of the improved system alternatives (wherein malfunctions affect only one intersection at a time) versus the fail hard character of the existing system (wherein malfunctions often simultaneously affect at least half the intersections in the CBD)
- Air quality improvements in the CBD network, where high concentrations of people are exposed directly to automotive emissions, brought about by smoother traffic flow and reduced stops and delays

In addition to the above unaccounted for benefits, the costs of maintaining and operating the existing system also could not be quantified due to a lack of systematic maintenance records. However, if existing signal display hardware was properly maintained, that cost alone could make up a significant fraction of the cost of the improved system maintenance.

Considering the unaccounted benefits of either of the new system alternatives and the unaccounted for costs of maintenance and operation of the existing system,

[1] There is no basis for estimating traffic accident reduction due to the non-existence of traffic accident records.

it seems reasonably conservative to assume that the sum of these would more than offset the annual maintenance and operations cost of either alternative.

Given the above assumptions, benefit-cost ratios, internal rates of return, and first-year benefits were calculated for the two signal system alternatives. The results are summarized in Table III–3. Based on these results, the digital computer system is demonstrably the preferred alternative. Either alternative is clearly economically feasible if user time costs are included as benefits. The digital computer system alternative appears to be economically justified considering only direct operating cost savings, and even the three-dial system is marginally acceptable under such conditions.

If both direct costs and time costs are considered, the digital computer system alternative has a benefit-cost ratio of 5.16, an internal rate of return of 82 percent, and a first-year benefit of 80 percent of capital cost.

3.4.5 Satisfaction of Other Requirements

As shown above, the digital computer system alternative has better economic feasibility characteristics than the three-dial system alternative. The following comparisons indicate how the two alternatives rate with respect to satisfaction of other system requirements.

- Flexibility — The digital system has greater flexibility in providing signal control to meet the cyclical variations in traffic flow.
- Adaptability — The digital system is more adaptable to changes in control requirements occurring over time due to factors such as traffic growth, network expansion, and broadening of control functions.
- Reliability and Maintainability — The three-dial system is considered slightly more reliable and easier to maintain than the digital computer system. The computer system has more complex components at the central control headquarters, incorporates many traffic sensors, and has more complex communications interface components. Conversely, the digital system has the capability of identifying malfunctioning intersections and controllers which enhances reliability and maintainability. Moreover, the most complex components are housed at the control center which facilitates maintenance.

TABLE III–3

ECONOMIC FEASIBILITY OF SIGNAL SYSTEM ALTERNATIVES

	Three-Dial System	Digital Computer System
Capital Cost (1,000 colones)	10,792	11,807
Benefit Period	12 Years	12 Years
Discounted Benefits @ 12 percent (1,000 colones)		
Operating Cost Saving	10,799	28,900
Time Saving	23,097	32,083
Total	33,896	60,983
Benefit-Cost Ratios		
Operating Cost Saving Only	1.0	2.46
Total Saving	3.14	5.16
Internal Rate of Return (percent)		
Operating Cost Saving Only	12	39
Total Saving	50	82
First Year Benefits (1,000 colones)		
Operating Cost Saving Only	1,713	4,584
Total Saving	5,230	9,469
First Year Benefit (percent)		
Operating Cost Saving Only	15.9	38.8
Total Saving	48.5	80.2

- Availability — Both the three-dial system and the digital computer system are made up of operational components which are readily available from various manufacturers of traffic control equipment and/or implementors of traffic control systems. The computer system implementation would require somewhat more time because of its added complexity, but both alternatives could be implemented within a two-year period.

3.5 SIGNAL SYSTEM IMPROVEMENT RECOMMENDATIONS

Based on the foregoing evaluation, it is recommended that the digital computer control system alternative be implemented. Accordingly, detailed design of the signal system improvements was performed in this project, and tender documents were prepared which establish the conditions for solicitation of bids for supplying and constructing the system. The recommended signal system implementation project includes installation of new signals at CBD intersections, upgrading of signal display equipment at all intersections, and installation of the digital computer control system.

Following are brief descriptions of the signal system project characteristics.

3.5.1 New Signal Installations

Traffic signals will be installed at 21 intersections in the San Jose CBD which are currently stop-sign controlled, and new signal displays will be installed at the 84 existing signalized intersections. The locations of the 105 traffic signals are shown in Figure III–4.

3.5.2 Intersection Signal Displays

As noted previously in this chapter, the signal displays at each intersection approach will conform to uniform standards consisting of two vehicular traffic signals, one mounted on the far right side of the intersection on a post, and the other on the far side of the intersection over the center of the approach, mounted on a mast arm. This design will be virtually identical for every CBD intersection approach. In addition, there will be pedestrian indications for every usable CBD crosswalk.

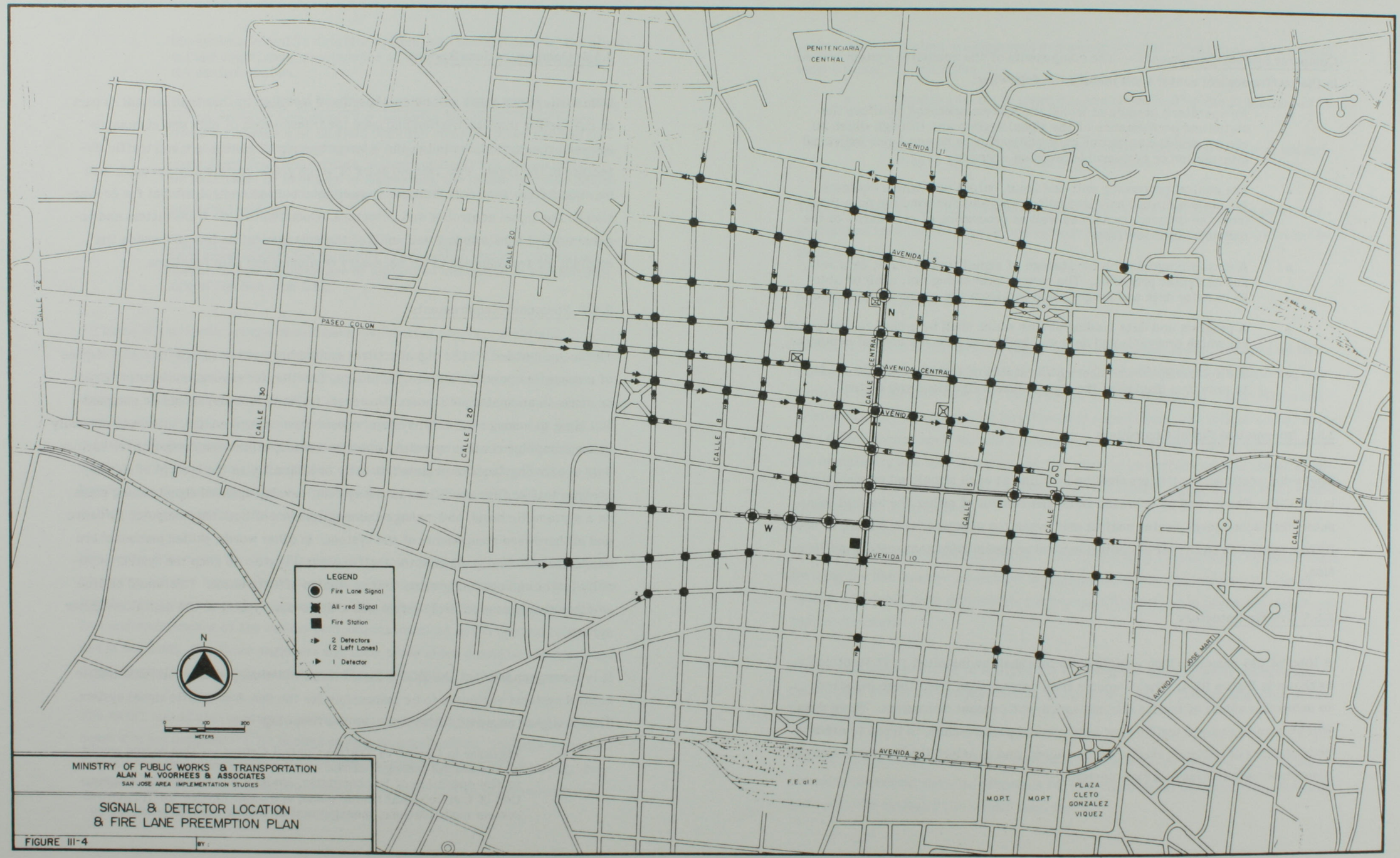
3.5.3 Computer Control System

The signal system will be under the control of a central digital computer system which has the capability to time all the CBD signals in a manner related to traffic demand fluctuations. A large number of traffic signal timing plans will be stored in computer memory and placed in effect either by a predetermined schedule, on the basis of current traffic volume and percent occupancy patterns as indicated by traffic detectors, or by manual selection by the operator of the control system.

System Size — The computer control system shall initially control 105 signalized intersections with the capacity to expand to control 200 signalized intersections. The initial system shall incorporate 75 traffic detection stations with 148 individual traffic lane detectors, and the system shall be expandable to 150 detection stations and 300 individual lane detectors.

System Functions — The computer control system's functions shall include the following:

- Addressability — This is the ability to have knowledge about, and change the status of, specific intersection signals without leaving the operator's console. A most important feature.
- Program Latitude — This is the ability to generate multiple programs (signal timing plans) for various traffic conditions, such as the 18 conditions noted in the previous section on optimization.
- Program Changeability — This is the ability to revise the basic logic of the signal timing programs occasioned by changes in street direction or the construction or removal of parts of the street system.
- Fire Lane or Emergency Vehicle Preemption — This permits emergency vehicles to obtain absolute priority over every other class of vehicle through portions of the signal system (see Figure III–3).
- Data Feedback and Processing — This is the ability to monitor the performance of the signal system and to reduce the traffic data received in the monitoring process to understandable and usable formats.
- Manual Override — The ability for the system operator to intervene in the operation of the system so as to avoid loss of performance during unusual situations.


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
PASEO COLON
CALLE 42
CALLE 30
CALLE 20
CALLE 8
CALLE 5
CALLE 3
CALLE 21
N
W
E
F.E. al P.
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
JOSE MARTI
AVENIDA
LEGEND
Fire Lane Signal
All-red Signal
Fire Station
2 Detectors (2 Left Lanes)
1 Detector
0 100 200
METERS
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SIGNAL & DETECTOR LOCATION
& FIRE LANE PREEMPTION PLAN
FIGURE III-4
BY:

Computer System Components — The components of the computer system housed in the traffic control center shall include the following:

- An operator's console at which the system operator monitors the status and performance of the signal system and through which he can request the output of data summaries or he can input individual intersection or systemwide program changes.
- The central processing unit and input/output unit which contains the basic software and processing programs for handling data input from the detector system as well as processing of commands to the individual intersections.
- A mass storage device for storage of signal timing plans, data sets, and computer programs. The central processing unit shall be able to transfer data and programs to and from the mass storage device.
- A program and data loading device which shall be a card reader/punch via which programs and data can be loaded into the central computer.
- A display map for monitoring the status of the signal system and to provide a display of the signal system functions and status.

3.5.4 Intersection Signal Controllers

Single-dial pretimed controllers shall be installed at each signalized intersection in the CBD. These shall be operated under the control of either the central computer, the second level master control unit (when the computer is off-line), or under its own control in the event of central control or communications system malfunction.

3.5.5 Traffic Detectors

A total of 148 induction loop vehicle detectors shall be installed at 75 locations as shown in Figure III–4. The computer shall process data from these detectors to determine values of traffic volume, speed, and percent occupancy. These data will be used to analyze traffic flow patterns and performance, to input to off-line computations of optimum traffic signal timing, and to select the prestored timing plan which best fits current flow patterns.

3.5.6 Communications System

Communications cable will be purchased and installed (rather than leased) as part of the system implementation and used for transmission of data and commands between the central computer and intersection signal controllers and traffic detectors in the field. Two twisted pairs of voice grade communication cable will be routed from the control center to each intersection control cabinet for connection to the signal controller and detectors. Communications transmitters and receivers will be installed at both ends of the communication link to provide the medium for transmission of all necessary command and data functions.

3.5.7 Personnel Requirements

The recommended traffic signal control system has been designed for a high degree of automatic operation and it will, in fact, function for several consecutive days, or more, in an unattended mode. However, trained personnel should be assigned full time to manage the total system, operate the control center, intervene manually in the computer control operation when warranted, utilize the computer for various data processing functions related directly or indirectly to the control of signals, analyze traffic flow conditions in the system, develop updated signal timing plans on a systematic basis, and manage the maintenance of both the computer software and all hardware components of the system. In other words, skilled personnel are needed to efficiently manage the traffic control system to keep the system physically intact and operating close to its optimum effectiveness. This would be true whether the master control system was a three-dial system or the digital computer system.

It is recommended that the DGTA assign three full-time professional level traffic control systems engineers to be responsible for the San Jose traffic signal system. Their assigned responsibilities would be the following:

- Engineer in Charge of Traffic Control Center — This person would be the overall manager of the control center, responsible for day-to-day operation of the computer, analysis of traffic data, preparation of traffic signal timing plans, and other needed traffic control system modifications, management of traffic records produced by

the automatic traffic detector system, and management of the physical and operational maintenance of the hardware and software at the control center.

- Engineer in Charge of Traffic Signal System Field Hardware — This person would be responsible for managing the physical and operational maintenance of all field installed components of the traffic signal system, including signal display hardware, intersection signal controllers, traffic detectors, and communications components. He would also be in charge of supervising the design and installation of new signalized intersections in the CBD which may be added to the initial system.

- Engineer in Charge of Non-CBD Traffic Signals — This person would have responsibility for managing the planning, design, installation, operation, and maintenance of signalized intersections located outside of the San Jose CBD.

All three of the above persons should have engineering degrees, preferably in electrical engineering, who either have some background or can be readily trained in computer systems and traffic engineering subject matter. The three engineers should be trained for the duties of all three positions so they can, when and if necessary, function interchangeably in each other's jobs without encountering great difficulties. Each engineer should have assigned to him one skilled engineering aide who can serve as his principal assistant. The engineering aides should also receive training in both control center and field component maintenance and operation so they too are capable of interchanging assignments.

The tender documents for the CBD signal system require the implementation contractor to conduct formal classroom training and on-the-job training in the traffic signal system operation and maintenance. This training will encompass the operation and maintenance of the system components installed in the control center and in the field. The three engineers and their three aides should be the recipients of all elements of the implementation contractor-supplied training program.

The MOPT should also encourage and sponsor supplemental training for the engineers who are assigned traffic control system responsibilities. Subjects covered in supplemental training should include fundamentals of traffic engineering, electronic control and communications systems, computer system programming and operation, and project management and administration. The principal sources of such training are the following:

- Regular courses or short courses conducted by the University of Costa Rica

- Specialized short courses and seminars conducted at other universities or by other outside organizations

The engineering aides should also be encouraged and supported in the pursuit of specialized training to upgrade and sustain technical skills which are relevant to their job assignments.

3.6 SIGNAL SYSTEM IMPLEMENTATION

The CBD Traffic Signal System implementation process should be based on the legal laws in force in Costa Rica, but especially on the Republic's Financing Administration Law, the Law for the Creation of the Ministry of Public Works and Transports, and its complementary laws and regulations. The acquisition of necessary materials and services will be done through international public bid. Due to the complexity and specialization of the work to be performed, the use of a pre-qualification is recommended to assure that the traffic signal system will be built by competent contractors.

A five-step process is recommended. The first step is to publish an advertisement inviting the contractors interested in implementing the 105 intersection signal system to submit their credentials for pre-qualification, as experienced signal system contractors.

The second step would be to analyze the contractors' submission of credentials, select ones who satisfy requirements, and publish a list of the pre-qualified potential bidders.

The third step would be to invite the pre-qualified contractors by a public advertisement to present detailed proposals for implementation of the project in accordance with the terms of the tender documents.

The fourth step is to enter into a contract with a consulting construction supervisor for the duration of the construction period, but including only sufficient man-months of effort to help with the selection of a contractor and to provide technical assistance in monitoring the construction process.

The fifth step is to employ a contractor for the construction of the CBD signal system. It is recommended that a single contractor be employed for the entire system to ensure system integrity and that he be allowed to subcontract only the mechanically simple work pertaining to the intersection signal displays.

Barring unforeseen delays, the first steps could be entered into immediately with the result that the contractor might be ready to commence work on the construction of the signal system by the end of 1976, with an anticipated construction time of approximately one year.

3.7 TENDER DOCUMENTS

The tender documents for the CBD signal system prepared as part of this study include a set of plans and specifications. The plans include a summary of all quantities of work to be done, or materials to be supplied, by location. Another sheet shows the general layout of the signal system, the location of the detectors and the location of the emergency vehicle preemption lanes. There are several sheets showing typical intersection standards or designs, from which the construction at any given intersection can be completed. And finally, a sheet of construction details is included for that construction which cannot readily be described in the specifications.

The specifications are written in four sections entitled: Introduction, Special Provisions, Central Controller Specifications, and General Requirements-Construction and Installation. For each item of work, the specifications contain a description of the work, the materials which are to be used, the construction methods which are to be followed, the method of measuring the work for payment, and finally, the basis of payment for that work.

Central Business District Bypass

Chapter IV

Chapter IV
Central Business District Bypass

The present street patterns of central San Jose fosters the use of scarce, constricted CBD streets by crosstown traffic having neither origin nor destination in the CBD. This fact is particularly notable on Second and Central Avenues. Complicating this condition, present and anticipated bus volumes entering the CBD are quite high and, in fact, appear to warrant the dedication of several cross-CBD streets to exclusive bus use. Total bus travel within the CBD will increase even more rapidly when the bus route interlining recommendations are implemented. Also, heavy pedestrian demands warrant the dedication of some core CBD space to this use.

This, of course, suggests the need to develop a CBD bypass, serving to remove through vehicular traffic from the CBD core. In addition, properly planned, such a bypass will improve the circulation of traffic having a trip end in the central area by permitting traffic to avoid the more congested core by traveling on the bypass to or from a point near each such trip end location. Because of this, the CBD bypass concept was included in the central area control plan. One of the purposes of the Stage II implementation studies reported here was to detail this concept in several alternatives and to evaluate them both economically and non-economically.

4.1 OBJECTIVES

As a fundamental component of the CBD control plan, it shares the control plan objectives. Although presented in an earlier chapter, these objectives are repeated here for the convenience of the reader.

1. To provide for priority movement of buses through the CBD, using priority lanes/streets, signal control priority, or bus routing plans which reduce walking requirements, bus turns, and transfer inconveniences

2. To maximize the people-moving capacity of CBD streets

3. To reduce total delays (minimize travel time) for people on CBD streets (in and out of vehicles)

4. To reduce operating costs for all vehicles using CBD streets in a priority of:

   - Buses
   - Other vehicles

   by reducing stops, delays, and increasing overall speed

5. To reduce traffic accidents in the CBD

6. To reduce air and noise pollution in the CBD by:

   - Smoother traffic flow (fewer speed changes)
   - Less idling of engines
   - Reduced traffic density

7. To provide operational flexibility for changes in traffic conditions in the future

4.2 THE EXISTING SITUATION

In addition to the traffic data, the collection of which was described earlier, information was obtained from aerial photos, and a physical inventory of 51 sections of streets which were candidates for inclusion in the bypass were made. The inventory showed that over one-third of the sections had a street width of seven to eight meters, most with parking allowed, many with poor cross sections and many with utility poles in the pavement. Only three of the 51 sections were narrower than seven meters and only one was on a right-of-way of less than nine meters. Generally speaking, two lanes were available to move traffic, except where parking, poles, or cross sections were limiting.

4.3 ALTERNATIVE LOCATIONS

Some 20 streets and avenues were considered as possible CBD bypass locations. These were evaluated by a sketch planning technique wherein the features and characteristics of each alternative were visually compared. The alternatives considered are shown in Figure IV–1. Also, each alternative location was screened and rated using eight criteria of suitability for inclusion in the bypass. These were:

- Proximity to major generators
- Connection to radial highways
- Continuity
- Existing capacity
- Existing volume
- Type of abutting land use
- Local circulation effects
- Physical restrictions

Figure IV–2 shows the results of this analysis—that Tenth and 12th Avenues were chosen for the South leg of the bypass; that Seventh and Ninth Avenues were chosen as the North leg; and that Ninth and 11th Streets would constitute the East leg while 24th Street is the West leg.

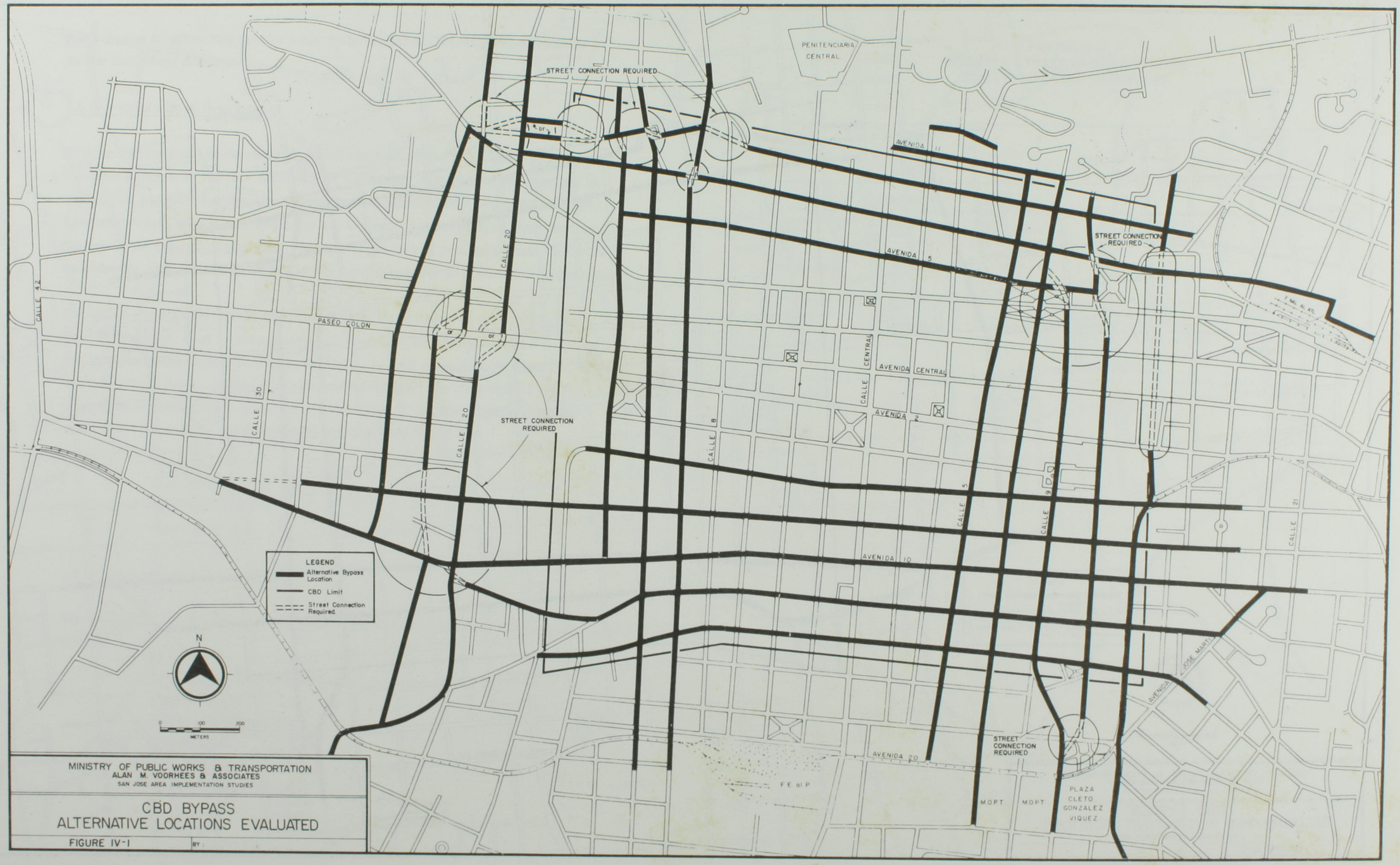
4.4 ALTERNATIVE CROSS SECTIONS

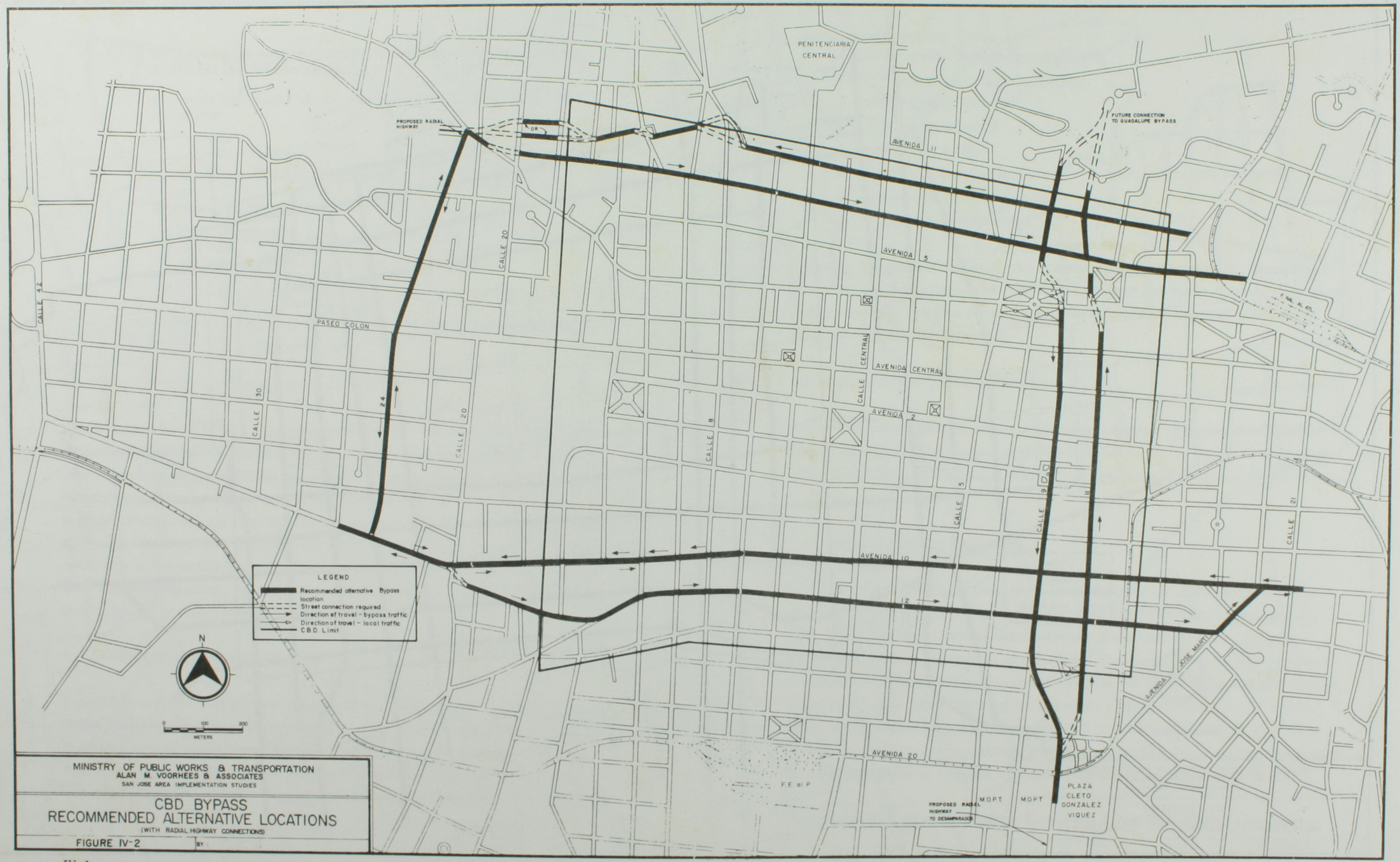
The cross section chosen determines the basic capacity, operating conditions, and cost of the bypass. An analysis of the demand for capacity, the existing supply, the desired operating conditions, and the relative costs of alternative cross sections was done.

4.4.1 Volume/Capacity Relationships

The 1980 peak-hour volume was the basis for this analysis since the bypass is part of the Mid-Term Program. This level of demand also represents the volumes of 1987 because of the effects of the circumferential (beltway) after 1980 which causes CBD through volumes to be diverted.[1] These volumes were then compared to the street capacities expected in 1980 without the bypass. The volume/capacity ratios (V/C) were then calculated for the whole CBD by summing across seven North-South and six East-West screenlines. V/C (1980) ratios ranged from .59 to 1.13 on the North-South screenlines and from .46 to .85 on the East-West screenlines. These results indicate a bypass with nominally increased capacity would have a

[1] See Figure II–1, ETAMSJ Progress Report No. 3, March 1, 1975.


PENITENCIARIA CENTRAL
STREET CONNECTION REQUIRED
AVENIDA 11
AVENIDA 5
STREET CONNECTION REQUIRED
CALLE 12
PASEO COLON
CALLE 30
CALLE 20
CALLE 20
STREET CONNECTION REQUIRED
CALLE 8
CALLE CENTRAL
AVENIDA CENTRAL
AVENIDA 2
CALLE 5
CALLE 9
CALLE 21
AVENIDA 10
AVENIDA 20
JOSE MARTI
AVENIDA
STREET CONNECTION REQUIRED
F E al P
M.O.P.T.
M.O.P.T.
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
Alternative Bypass Location
CBD Limit
Street Connection Required
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
CBD BYPASS
ALTERNATIVE LOCATIONS EVALUATED
FIGURE IV-1
BY :


PENITENCIARIA CENTRAL
PROPOSED RADIAL HIGHWAY
OR
FUTURE CONNECTION TO GUADALUPE BYPASS
AVENIDA 11
AVENIDA 5
CALLE 42
PASEO COLON
CALLE 30
CALLE 20
24
CALLE CENTRAL
AVENIDA CENTRAL
AVENIDA 2
CALLE 8
CALLE 5
CALLE 1
CALLE 21
AVENIDA 10
12
AVENIDA JOSE MARTI
AVENIDA 20
F.F. al P
MOPT
MOPT
PLAZA CLETO GONZALEZ VIQUEZ
PROPOSED RADIAL HIGHWAY TO DESAMPARADOS
LEGEND
Recommended alternative Bypass location
Street connection required
Direction of travel - bypass traffic
Direction of travel - local traffic
C.B.D. Limit
N
0 100 200
METERS
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
CBD BYPASS
RECOMMENDED ALTERNATIVE LOCATIONS
(WITH RADIAL HIGHWAY CONNECTIONS)
FIGURE IV-2
BY

good chance of attracting traffic away from the other CBD streets, especially on the East-West Avenue.

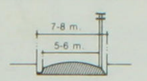
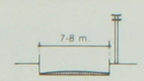
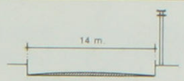
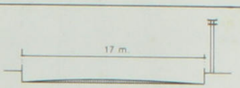
4.4.2 Possible Cross Sections

With an estimate of the demands involved, the next step was to investigate possible cross sections to see how well they fit the needs. Figure IV–3 summarizes the analysis of possible sections. From this figure it appears that seven-meter wide, two-lane streets used in one-way pairs are the most cost-effective cross section for use in the bypass. Reflecting moderate upgrading of present streets, but with no widening, this cross section is also the least disruptive to adjacent land parcels.

This cross section was used in the volume/capacity analysis of the CBD network. The "with bypass" case is summarized in Figure IV–4 which shows that V/C ratios are lower with the bypass on the bypass itself, as well as on parallel streets. These lowered V/C ratios on parallel CBD streets result from the diversion of traffic from them to the bypass, amounting to over 1,000 PCU kilometers in the peak hour. The CBD volume reductions associated with each leg are:

- North (8 percent)
- South (11 percent)
- East (4 percent)
- West (3 percent)

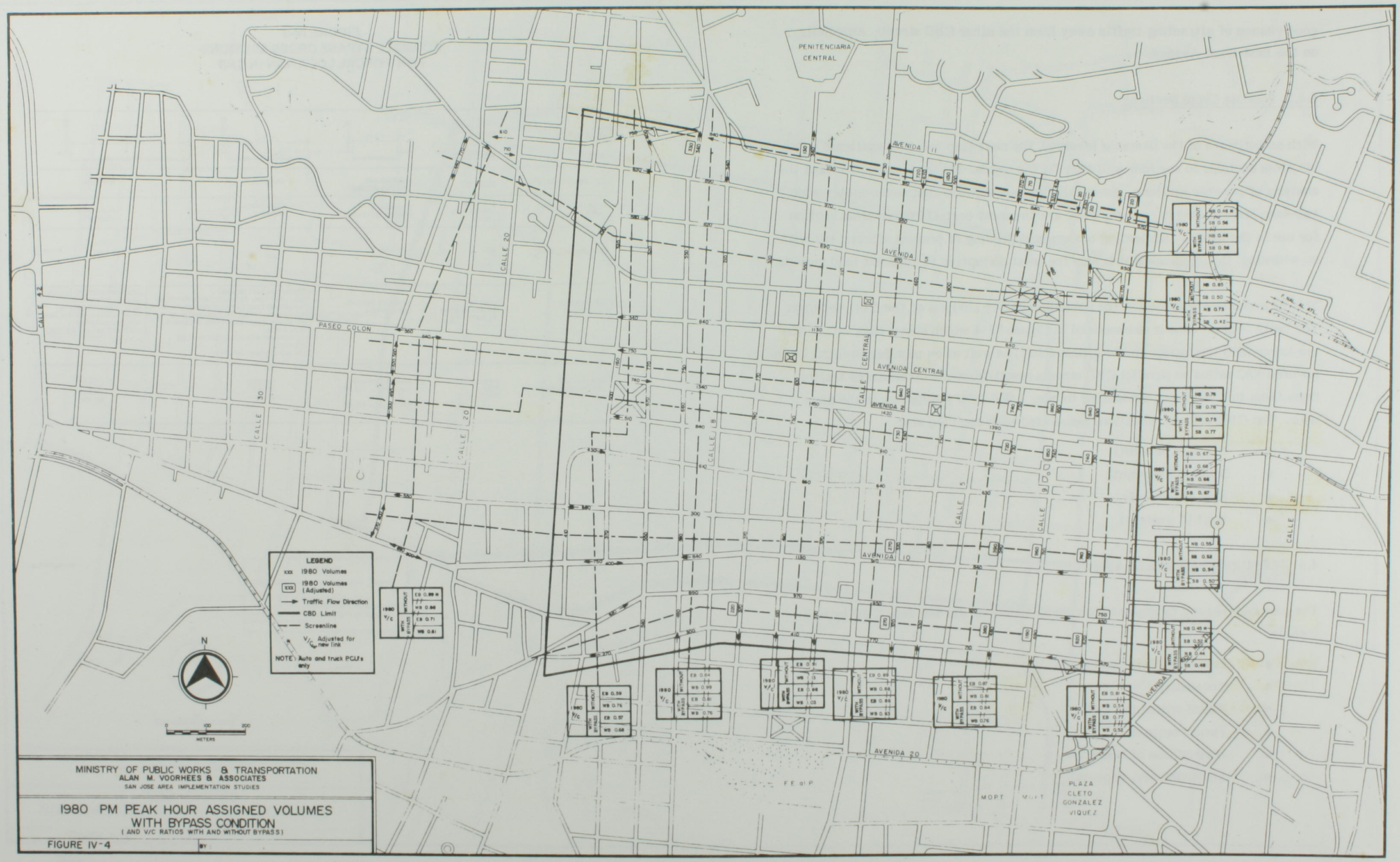
FIGURE IV-3
POSSIBLE BYPASS CROSS SECTIONS
FOR TYPICAL LOCATION IN CBD

CROSS SECTION				
STATUS/MODIFICATION	EXISTING	EXISTING AND EXISTING MODIFIED	WIDENING	WIDENING
NUMBER OF TRAFFIC LANES	ONE-WAY PAIR OF TWO LANES	ONE-WAY PAIR OF TWO LANES	FOUR LANES, TWO-WAY	FIVE LANES TWO-WAY
CAPACITY (PCU/HR)	800 + 800	1,100 + 1,100	1,650	1,925
EVALUATION COMMENT	DOES NOT SATISFY DEMAND OR CRITERIA	SATISFIES DEMAND AND CRITERIA	• DOES NOT SATISFY DEMAND • HEAVY LEFT TURN CONFLICTS WITH OPPOSING TRAFFIC AND LANE CAPACITY REDUCTION IN DIRECTION OF TRAVEL OR PROHIBITION OF ALL LEFT TURNS WHICH WILL CAUSE EXCESSIVE CIRCULATION • RIGHT-OF-WAY AND BUILDINGS MUST BE ACQUIRED • DOES NOT SATISFY CRITERIA	• DOES NOT QUITE MEET DEMAND • HEAVY LEFT TURN CONFLICTS WITH OPPOSING TRAFFIC • RIGHT-OF-WAY AND BUILDINGS MUST BE ACQUIRED • DOES NOT SATISFY CRITERIA
RELATIVE COST (CENTS/100 METERS)	CONSTR — ROW — TOTAL 0	(WHERE MODIFIED) 2(56,100 =) = 112,200 0 0 2(56,100 =) = 112,200	140,300 400,000 540,000	170,300 550,000 720,300

4.5 PERFORMANCE EVALUATION

The parameters used to evaluate the performance of the San Jose CBD bypass include:

- Level of service and speed
- Continuity
- Relief within the CBD
- Future options
- Distribution of benefits
- Environmental impacts


PENITENCIARIA CENTRAL
AVENIDA 11
AVENIDA 5
AVENIDA CENTRAL
AVENIDA 2
AVENIDA 10
AVENIDA 20
AVENIDA
CALLE CENTRAL
CALLE 42
CALLE 30
CALLE 20
CALLE 18
CALLE 16
CALLE 14
CALLE 12
CALLE 9
CALLE 7
CALLE 5
CALLE 21
PASEO COLON
F.F.C.C. AL ATL.
F.F.C.C. AL PAC.
FEGIP
MOPT
PLAZA CLETO GONZALEZ VIQUEZ
LEGEND
xxx 1980 Volumes
[xxx] 1980 Volumes (Adjusted)
Traffic Flow Direction
CBD Limit
Screenline
V/C new link Adjusted for new link
NOTE) Auto and truck PCU's only
N
0 100 200
METERS
1980 V/C WITHOUT BYPASS EB 0.89 R WB 0.96 WITH BYPASS EB 0.71 WB 0.81
1980 V/C WITHOUT BYPASS NB 0.46 R SB 0.56 WITH BYPASS NB 0.46 SB 0.56
1980 V/C WITHOUT BYPASS NB 0.85 SB 0.50 WITH BYPASS NB 0.73 SB 0.42
1980 V/C WITHOUT BYPASS NB 0.76 SB 0.78 WITH BYPASS NB 0.75 SB 0.77
1980 V/C WITHOUT BYPASS NB 0.67 SB 0.66 WITH BYPASS NB 0.66 SB 0.67
1980 V/C WITHOUT BYPASS NB 0.55 SB 0.52 WITH BYPASS NB 0.54 SB 0.50
1980 V/C WITHOUT BYPASS NB 0.45 R SB 0.52 WITH BYPASS NB 0.44 SB 0.48
1980 V/C WITHOUT BYPASS EB 0.84 WB 0.54 WITH BYPASS EB 0.77 WB 0.52
1980 V/C WITHOUT BYPASS EB 0.87 WB 0.69 WITH BYPASS EB 0.84 WB 0.76
1980 V/C WITHOUT BYPASS EB 0.89 WB 0.88 WITH BYPASS EB 0.84 WB 0.83
1980 V/C WITHOUT BYPASS EB 0.91 WB 0.73 WITH BYPASS EB 0.88 WB 0.03
1980 V/C WITHOUT BYPASS EB 0.84 WB 0.99 WITH BYPASS EB 0.81 WB 0.76
1980 V/C WITHOUT BYPASS EB 0.59 WB 0.76 WITH BYPASS EB 0.57 WB 0.68
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
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SAN JOSE AREA IMPLEMENTATION STUDIES
1980 PM PEAK HOUR ASSIGNED VOLUMES
WITH BYPASS CONDITION
(AND V/C RATIOS WITH AND WITHOUT BYPASS)
FIGURE IV-4
BY :

4.5.1 Level of Service and Speed

Of the 41 analysis sections studied, 18 have better levels of service after the implementation of the bypass, 22 maintain the same level of service, and only one is made worse. Even with 1990 volume forecasts, the bypass would have only four sections operating at capacity (Level of Service E). Improvements in speed range from a low of 1.0 kph on the West leg to 2.5 kph on the South leg. Overall, the increase is 1.9 kph (9 percent) on the bypass and 1.1 kph on the other CBD streets.

4.5.2 Continuity

The bypass alternatives selected could provide a continuous "ring" around the CBD, and almost every leg makes a direct connection into an existing or proposed radial highway. The North leg will connect to the Heredia Radial, the South leg to the Santa Ana Expressway, the East leg would connect to the proposed Desamparados Radial and Guadalupe bypass. The achieve this continuity will require the construction of additions to both the North and East legs.

4.5.3 Relief Within the CBD

One of the key functions and objectives of the bypass is to relieve the CBD streets of some of their load. The previously noted reduction in vehicle kilometers (7 percent) and increase in travel speed (5 percent) indicates that the location and cross sections selected will indeed do this. These effects will be most pronounced on the East-West avenues where relief is most needed.

4.5.4 Future Options

Establishing the CBD bypass at this time helps maintain future options for CBD transport. The recommended bypass will attract over 1,000 PCU kilometers of travel from the present CBD core streets. Instead of making this new-found capacity available to all users, the recommendation included in the Central Area control plan is to reserve this additional space for pedestrians and transit users by assigning certain streets to these specific users.

This should be viewed in light of potentially rapidly growing auto use in San Jose. If space assignments for transit users and pedestrians can be made more easily now with the implementation of a bypass system, an important precedent is established for possible future restrictions on auto use in the CBD, featuring such restrictions as:

1. Capital intensive solutions such as the Transit Plazas of Alternative C in the ETAMSJ Final Technical Report recommendations
2. Additional transport policy options such as road pricing and parking supply/rate controls

4.5.5 Distribution of Benefits

The provision of a bypass for auto users makes the implementation of the service of bus-only streets physically possible. The bus streets are the guarantee of good access to the CBD for the transit users who tend to be the lower-income segment of the population.

4.5.6 Environmental Impacts

As noted in Chapter II, the bypass was evaluated in terms of its impact on air pollution in the CBD, noise, and housing displacement. The impacts of the bypass on the streets used for that purpose will not be negative in terms of either air quality or noise because the greater capacities provide better levels of service which, in turn, mean smoother, quieter, less polluting traffic flows. The remaining CBD streets are impacted even more, and such impacts are positive. On these streets, the volumes are reduced so that levels of service are higher for reduced traffic flows giving less noise and air pollution. The displacement of housing and/or businesses is substantial in the northwest portion of the bypass along Ninth Avenue where 20 dwelling units will have to be taken. Elsewhere, land use impacts are minimal.

4.6 ALTERNATIVE ALIGNMENT DESIGNS

After the location and cross section of the bypass had been determined, there were alternatives for the alignments of certain sections to be considered. These sections

were identified by determining the scale of work to be undertaken in each section of the bypass. Levels of work were identified as:

A. Operational only, 42 percent of the bypass

B. Minor work (repaving), 15 percent of the bypass

C. Moderate work (move utilities, change crown, rebuild radius), 30 percent of the bypass

D. The major works of constructing new streets or widening, 13 percent of the bypass

It was in Level D that there were alignment options, mostly on the North and East legs. Figure IV-5 identifies the sections by type of work required, and shows the alignment alternatives. The alternative labeled number 1 is the one recommended.

The alternative alignments were evaluated on the basis of cost, ROW required, land use disruption, traffic operations, and design standards. The final selection of the preferred alignment alternative was done jointly by MOPT and consultant staff. The criteria used and their values are detailed in Table IV–4 of ETAMSJ Progress Report No. 4, May 1, 1975.

4.7 PRELIMINARY ENGINEERING

4.7.1 Design Criteria

To establish design criteria, use was made of "Especificationes Para Contratar Estudios de Carreteras, MOPT, GDV, Octubre 1964" and "Secciones Tipicas y Normas de Diseno, MOPT, Departamento Diseno de Vias, Diciembre 1973." The typical cross section used was seven meters of pavement in a 12-meter ROW. Horizontal curves of 83 meters were used to achieve a design speed of 48 kph wherever possible.

4.7.2 Application of the Design

For those sections in which only operational improvements or minor physical improvements were contemplated, the level of preliminary engineering effort needed was much less than in the sections requiring major construction effort. Where new sections were to be built, or where streets are to be rebuilt, preliminary engineering drawings at a scale of 1:1000 were prepared. These have been presented as Figures IV-8 and IV-9 of ETAMSJ Progress Report No. 4, May 1, 1975. The preliminary engineering drawings show curb lines, ROW lines, curve radii, street widths, two widths, and grades where pertinent. A parcel-by-parcel plan of ROW acquisition was prepared and the uses for access ROW were recommended.

4.7.3 Capital Costs

The capital costs for constructing the CBD bypass are shown in Table IV–1 below. Capital costs were estimated on a section-by-section, item-by-item basis and reported in Tables IV–1, IV–2, IV–3, IV–4, and IV–6 of Progress Report No. 4, May 1, 1975.

Table IV–1 shows that ROW costs are significant parts of the total costs for the North and East legs. About ₡855,000 or 12 percent of a total cost of ₡7,121,000 ($828,000) could be saved if excess ROW is sold back to private ownership.

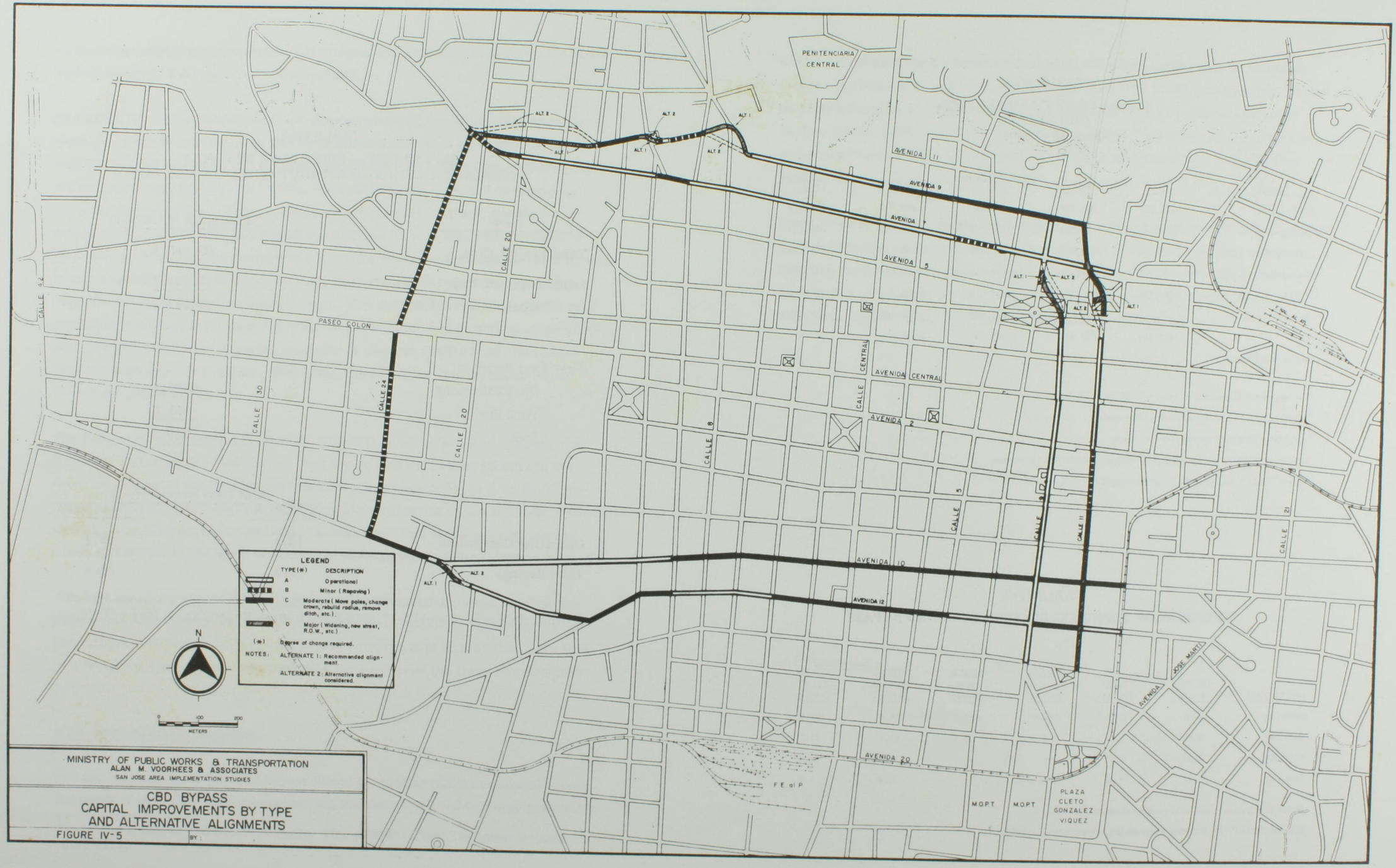
4.8 ECONOMIC EVALUATION

The methodology of the economic evaluation of the CBD bypass is summarized in Appendix A and described in detail in Progress Report No. 4. The measures of economic feasiblity are given in Table IV–2.

While the South leg is demonstrably feasible, and the West leg marginal when time savings are included, both the North leg and East leg prove infeasible on the basis of economic evaluation criteria. The North leg generates substantial benefits, but the right-of-way acquisition costs are even higher. Table IV–3 applies specifically to the analysis of the North leg.

4.9 RECOMMENDATIONS AND IMPLEMENTATION SCHEDULE

An operational bypass for the San Jose CBD appears feasible even though one leg (East) may not justify expenditures beyond simple operational measures. Based



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CBD BYPASS
CAPITAL IMPROVEMENTS BY TYPE
AND ALTERNATIVE ALIGNMENTS

FIGURE IV-5 BY :

TABLE IV–1

SUMMARY OF CAPITAL COSTS
CBD BYPASS
(In 1975 Colones)

Items	Leg of Bypass				
	West	South	East	North	Total
Construction	459,007	563,748	475,446	830,814	2,329,015
Contingency[1]	68,851	84,562	71,317	124,623	349,353
Right-of-Way	—	112,030	1,253,180	2,845,195	4,210,405
Engineering[2]	45,901	56,375	47,545	83,081	232,902
TOTAL	573,759	816,715	1,847,488	3,883,713	7,121,675
Excess Property	—	-76,800	-484,500	-293,700	-855,000
Net[3]	573,759	739,915	1,362,988	3,590,013	6,266,675
Annual Maintenance[4]	-7,545	—	-675	991	-7,229

[1]Contingency = 15 percent of construction cost.

[2]Engineering = 10 percent of construction cost.

[3]Net cost with sale of excess property taken.

[4]Change in relation to maintenance of Without Bypass (Null) condition.

Source: Table A–16, ETAMSJ Progress Report No. 4, May 1, 1975.

TABLE IV–2

MEASURES OF ECONOMIC FEASIBILITY — CBD BYPASS

Leg Analyzed	B/C Ratios		IRR		1st Year Benefit	
	Op. Cost Saving	Total Saving	Percent Op. Cost Saving	Percent Total Saving	Percent Op. Cost Saving	Percent Total Saving
South Leg	3.56	5.10	> 65.0	> 65.0	75.6	108.2
West Leg	0.80	1.12	3.5	13.0	15.1	21.7
North Leg	0.46	0.66	—	—	10.5	15.0
East Leg	0.15	0.22	—	—	3.4	4.8

Note: B/C Ratios based on 12 percent discount factor.

Source: Table IV–22, ETAMSJ Progress Report No. 4, May 1, 1975.

TABLE IV–3

NORTH LEG — FIRST YEAR BENEFITS
COMPARISON WITH AND WITHOUT RIGHT-OF-WAY COSTS

Item	Thousands of Colones
Total Project Cost	₡3,883.7
Less: Right-of-Way	2,845.2
Balance	₡1,038.5
First Year Benefits	
Op. Cost Saving	₡407.6
Time Saving	178.5
Total	₡586.1

	First Year Benefit Percents	
	With ROW	Without ROW
Operating Cost Saving	10.5	39.2
Total Savings	15.1	56.4

Source: Tables IV–6 and IV–17, ETAMSJ Progress Report No. 4, May 1, 1975.

on transport objectives, operational advantages, and economic feasibility, the South and West legs of the bypass are recommended.

The North leg fails economic tests but appears justified, based on other considerations. Without the northern leg, traffic oriented to the west from the northern half of the CBD will be forced to filter through the core area to Paseo Colon, the major facility now serving this traffic. This violates the objective of providing relief to the core area. Also, the northern portion of 24th Street, the West leg, will become less effective as a bypass because traffic will have few facilities to disperse to. The ability to implement and keep a bus-only operation on Third Avenue is also dependent on the North bypass leg, since the North bypass leg provides capacity for autos forced off Third Avenue. The continuity it provides to the west especially is a benefit in terms of access that is not included in the economic benefits. Finally, the North bypass leg is needed to disperse traffic from the Limon-Siquirres highway into the CBD. Therefore, the North leg is also recommended for implementation.

The recommended projects are shown in Figure IV–5 where the North, South, and West legs (Alternative 1) are shown. That figure also shows that all but the northern two blocks of the East leg are low-cost minor works of type A or B. Therefore, it is recommended that the signal timing and widening of the East leg in conjunction with the Desamparados radial be done when that radial is built, and the costly connection to the north be reconsidered when the Guadalupe bypass is built.[1]

The East leg of the bypass is not viewed as being operationally dependent on the other bypass legs. Users will not use it to "circle" the CBD but rather use the improved bypass streets as better paths to pass from one side to the other. The lack of a complete East leg does not jeopardize the success of the three recommended projects.

4.9.1 Implementation Schedule

The implementation of the CBD bypass should proceed as rapidly as possible given the needs of lead time for final engineering and design and right-of-way acquisition. Coordination with the CBD operational plan, which has increments to be implemented in 1976, 1978, and 1980, is also important. The South and West legs should be programmed to be in full operation by 1978 and 1979 with partial operation in time for the 1976 CBD Control Plan phase. Table IV–4 shows how the work of, and expenditures on, the CBD bypass should be programmed over the next five years.

From Table IV–4 it is seen that significant expenditures start in 1977 which permit sufficient budgetary lead time. The expenditures are spread over four years so as not to burden any one-year budget. The final item in the schedule is to review the analysis of the East leg in the light of the then operating North, South, and West legs to determine if the East leg should be reconsidered.

[1] See Project No. 13 and No. 14, Chapter VIII, ETAMSJ Final Technical Report, July 1975.

TABLE IV–4

BYPASS IMPLEMENTATION SCHEDULE AND EXPENDITURES
(In thousands of 1975 colones)

Project	1976	1977	1978	1979	1980	1981	1982
South Leg	**(112)	648	///				
West Leg	***		528	///////////////////////////////////////			
North Leg		***	(854)	(1,991)	955	//////////////////	
East Leg						***[2]	
Annual Expenditures	214	731	1,382	1,991	955	48	5,321
Construction[1]		648	528		955		2,131
(Right-of-Way)	(112)		(854)	(1,991)			(2,957)
Engineering	102	83				48	233

Notes:

xxx Construction costs, thousands of colones

(xxx) Right-of-way costs, thousands of colones

*** Engineering and design

/// Project fully operational

[1]Includes 15 percent contingency

[2]Recheck of feasibility updated when Guadalupe bypass is designed.

Radial Corridor Improvements

Chapter V

Chapter V
Radial Corridor Improvements

The development of the transportation improvement program for San Jose during Stage I revealed that a number of new major radial highways were either committed or would be required in several corridors over the next five years. Moreover, it was clear that central area capacity limitations, in addition to concern about long-term transportation objectives, required that serious attention be given to the impact of these new roads and to take those steps necessary to insure that transportation benefits be accrued both in the short and the long term. The direct connection of new high-capacity roads to narrow CBD streets would produce a capacity imbalance and an inability for traffic of any variety to appropriately utilize the newly expanded capacity. The bottlenecks thus created would also cause delays to the bus system, tending to thwart objectives related to maximizing bus use. Two concepts were developed which were believed to have promise for rationalizing these problems: (1) to prepare traffic dispersal schemes at the points where the new radial roads terminated at their inner ends, usually near the CBD, and (2) to convert the existing parallel roads to exclusive busways to reduce the congestion delays imposed on bus traffic by other vehicles.

Three corridors were identified which appeared to have high potential for traffic dispersal treatment: (1) the Santa Ana Expressway is expected to open in 1977[1] approaching the city from the west, with its inner terminal at 42nd Street. The new Alajuelita-Hatillo highway from the south is also expected to connect in 1980 to the same point as a southward extension of 42nd Street. (2) The Limon-Siquirres highway will connect to CBD streets from the north about 1978. (3) The Zapote highway should reach Plaza Viquez from the east in 1979; Plaza Viquez is also the northern terminal of a new highway to Desamparados expected by 1981.

The three new roads, Alajuelita-Hatillo, Limon-Siquirres, and Plaza Viquez-Desamparados, also happen to parallel existing roads which carry substantial amounts

[1] Road opening dates must be regarded as approximate. As used here, they relate to the last year of programmed expenditures in the Mid-Term Program presented in the Final Technical Report.

of bus traffic through developed areas and which were believed to be prime candidates for future exclusive bus use.

Initially, the two questions, traffic dispersal schemes and busways, were approached as somewhat independent elements, and separate analyses were initiated for each in this project. Subsequent analysis showed that reservation of the existing roads for exclusive or semi-exclusive bus use had only limited effectiveness, but that bus priorities could be more reliably assured through special designs to be incorporated in the traffic dispersal schemes.

This chapter briefly discusses the difficulties found related to the busway approach, then describes the development of the dispersal plans including the bus priority elements.

5.1 RADIAL BUSWAY ANALYSIS

As noted earlier, the new radial road in each of the corridors being examined is parallel to an existing radial road which carries a substantial load of bus traffic and tends to go through areas more favorable for bus passenger trip generation than the new road. However, the new road in each case is generally planned within a kilometer of the old road and connected at frequent intervals by minor connecting roads. The possibilities of reserving the old road for exclusive, or almost exclusive, bus use through forcing non-bus traffic to turn from the old road onto the connecting roads seems fairly practical from a traffic operational perspective. Local access traffic could still use the old road, but longer trips would be forced to the new facility with little inconvenience in most instances. By implementing the plan simultaneously with the opening of the new road, the probabilities of public and motorist acceptance would be increased.

A first step towards detailing the scheme consisted of developing detailed future traffic assignments which would indicate the extent of traffic diversion to the new roads even without any efforts directed toward reserving the old roads for bus traffic. Two important points emerged from this analysis:

1. Most bus traffic would, everything else being equal, tend to use the old road because most of the land development and therefore transit riders tended to live nearby.

2. Most of the private auto and truck traffic would tend to divert to the new roads anyway since the new roads had higher design standards, would be relatively free of bus traffic, and therefore could operate at higher speeds.

When new traffic assignments were prepared which incorporated assumptions about exclusive bus use on the old roads, they were only marginally different from those prepared without such assumptions. Thus, the effectiveness of the bus reservation feature in protecting buses from congestion was limited. Further, it became clear that the number of buses expected to travel the corridor in future peak hours was in excess of the number which could be accommodated on the old roads, and thus, some of the buses would have to use the new roads in any case. Thus, the arguments against the busways began to appear compelling and may be recapped as follows:

- The imposition of traffic controls to reserve the old roads for exclusive bus use would have little effect in protecting buses from congestion from other vehicles since most of the other vehicles would tend to divert from the old roads even without such controls.

- The controls would cause some inconvenience, although minor, to some travel movements.

- Some bus movements would need to use the new roads since there was insufficient capacity on the old roads for the number of buses projected in the future. Buses using the new roads would need protection from congestion beyond that which would be provided by the busway.

- Because the new roads provided so much additional capacity in the corridors where they are located, neither buses nor other traffic are likely to experience much congestion for the next 10-15 years. Thus, the need for bus priority measures throughout the corridors is limited. The exception to this is where the new roads approach the central area with its very definite capacity limitations. It is in this area that buses need protection whether using the new or the old roads.

As a result of these considerations, the focus of the bus priority examinations were relocated and integrated with the traffic dispersal analysis. The one exception

to this occurs in the Alajuelita-Hatillo corridor. Two small bus priority schemes appear warranted, apart from the corridor dispersal schemes:

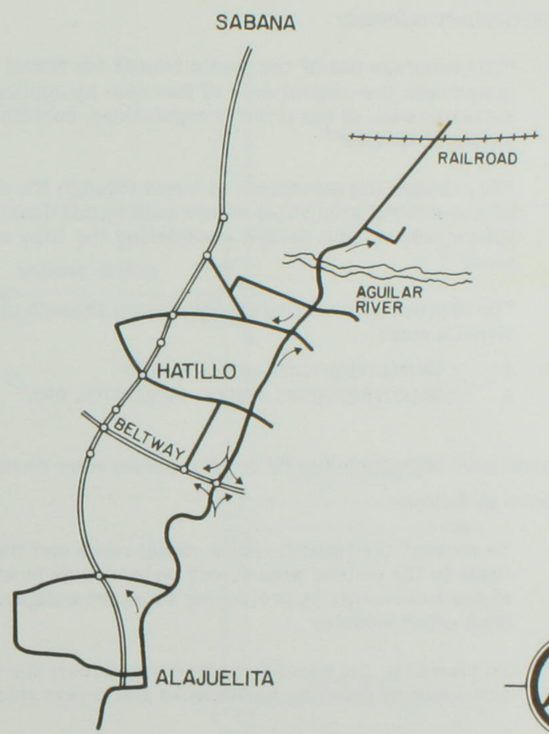
(1) The old road has a sufficiently wide cross section north of the Rio Maria Aguilar Bridge to provide for marking two uphill lanes with only one downhill. While such control will not directly provide for bus priority movements, because such a high proportion of total traffic using the road in the future will be buses, the main benefits from the measure will be directed towards bus travel.

(2) As the old road approaches the Railroad Busway (proposed for implementation after 1980, see Table 1, Final Summary Report) from the south, it should be marked for four-lane use with the right-hand, northbound lane marked for exclusive bus use.

In addition, it is to be noted that the Alajuelita-Hatillo corridor differs from the others in that the old and new roads will not intersect with the central area street system in the same general area. The new Alajuelita-Hatillo Highway has its northern terminal as a continuation of 42nd Street, whereas the old road intersects at about 20th Street. This more direct route to the CBD will cause the great majority of buses to continue to use the old road and the need for bus priority measures through the dispersal system from the south is diminished. As will be noted in the discussion on the Alajuelita-Hatillo dispersal analysis later in this section, difficulty was found in developing an assured bus priority scheme for northbound and southbound movements via 42nd Street and therefore, the need for established bus priority for the old road remains.

Projections of traffic indicate that most non-bus traffic will be diverted from the old road when the new one is opened, and bus delays related to other traffic should be minimal for several years thereafter. It is recommended, however, that a re-examination of the busway concept using the "forced turn" concept indicated in Figure V–1, be conducted by 1985. This will allow time to implement the scheme if warranted before actual congestion sets in. Delaying its implementation until then will reduce the small disbenefits associated with indirect routings imposed on trucks and autos during the intervening years before benefits from the bus priorities can begin.

ALAJUELITA CORRIDOR BUSWAY CONCEPT



LEGEND

BELTWAY RADIAL HIGHWAY

BUSWAY LATERAL ACCESS DIVERSION ROUTE

INTERCHANGE

NON-BUS FORCED TURNS

FIG. V-1

5.2 TRAFFIC DISPERSAL AND BUS PRIORITY ANALYSIS

The objectives of the traffic dispersal and bus priority (TB & BP) schemes are reflective of the general and operational objectives identified in Stage I. Of these, three are particularly relevant:

1. "To encourage use of the public transit for travel to major generators in and near the central area of San Jose by application of operational measures such as bus priority regulations, coordination, and optimization of service"[1]

2. "To enhance the movement of buses through the design and regulation of non-central area roads where such regulations can now or in the future reduce total delays, considering the time of person trips by mode"[2]

3. "To improve the existing street system through physical and operational means:

   - Eliminating traffic bottlenecks
   - Improving street system continuity, etc."[3]

Specific operational objectives for TB & BP schemes were developed consistent with the above as follows:

- To connect the identified new radial roads and the existing parallel roads to the central area street system so as to afford the priority of bus movements by protecting them from delays due to congestion from other vehicles

- To maximize the benefits to be derived from the investment in the new roads by reducing bottlenecks and delays related to their use

- To maximize traffic flow on central area streets after initially providing for assured bus mobility

- To utilize traffic control measures which will minimize special enforcement costs

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[1] General Objective No. 1, Final Technical Report, p. IV-11.

[2] General Objective No. 5, Final Technical Report, p. IV-12.

[3] Operational Objective No. 6, Final Technical Report, p. IV-12.

The above objectives must be accomplished within the constraints of minimizing the disruption caused by the schemes to existing human activities and at the lowest possible cost.

5.3 TECHNICAL ANALYSIS

Stage 1 studies provide projections of expected vehicular movements by type in each corridor for 1990 as well as numerous traffic counts on many of the roadway links in the area. To these were added a number of detailed traffic counts conducted for this project which stratified vehicular movement by direction, turning movements, time of day, and type of vehicle. Detailed traffic assignments for 1990 were prepared by disaggregating zone to zone forecasted traffic by mode to an expanded zone system and reassigning future traffic to a more refined network containing all through streets in each corridor. Future bus flows were reexamined given the overall volumes for bus passenger movement provided from Stage I forecasts, disaggregating these flows into local, express, and long distance buses, and finally assigning these to the new or old road. Bus flows near the center were , assigned considering the CBD control plan (identified and developed in an earlier chapter of this report), especially that portion relating to bus interlining and the special bus streets.

The analysis proceeded by examining the composite flows generated by the above methods and comparing them to capacities of individual links and intersections under present plans, assuming the connection of the new four-lane roads, and deficiencies noted. A series of sketch plans were then informally developed, each involving combinations of added lanes, operational controls, and regulations. The feasibility of various schemes were checked by visual inspection and reference to aerial photographs and topographic maps, as well as capacity analyses.

5.3.1 Alajuelita-Santa Ana Dispersal Analysis

Although the Alajuelita-Santa Ana dispersal takes place a bit more distant from the CBD than the other dispersal areas, it nevertheless is in many ways more complex than the other two. The main spine for any dispersal must be 42nd Street

which currently varies in cross section but basically is operating as a four-five lane arterial street connecting to the General Canas Expressway as its northern extension and dead ending just south of Tenth Avenue. The Santa Ana Expressway is planned to connect to 42nd Street just north of Sabana Sur. The difficulty of connecting an expressway type facility, a "T" intersection, to an arterial street is sufficiently complex at best, but the proximity of the intersections of Sabana Sur and Tenth Avenue make it even more difficult. The new Alajuelita Highway is planned to connect as a southern extension of 42nd Street and will thus add still another dimension to the problem with its high traffic volumes.

The establishment of bus priority schemes is also made more complex in this instance since buses operate along multiple paths and require a number of turning movements through the entire area. In addition, the main bus flows from the area served by the new Alajuelita road will, for the most part, not route through the dispersal area at all but rather follow the existing Alajuelita-Hatillo road, intersecting with the Railroad Busway just south of the CBD. As indicated, some bus priority measures are appropriate for the old road now, and the entire busway concept for the road should be reexamined by 1985 to assure that this heavy bus movement can be reliably handled.

Figure V–2 shows 1975 volume capacity ratios under existing conditions. Some problems are being experienced at the intersection of Sabana Norte and 42nd Street at present as noted by a V/C of 1.10 at that point.

Figure V–3 shows the impact by 1990 of connecting the two new highways to 42nd Street plus traffic growth expected by that time. The volume-capacity ratios shown assume that 42nd Street will be widened at those points required to obtain six traffic lanes throughout, a requirement that can reasonably be done and will be required in any event. As can be seen even with this improvement, the "without dispersal" scheme is heavily overloaded at a number of points. The dispersal scheme shown here consists of a one-way pair of streets using 42nd Street southbound and 40th Street northbound. However, some essential northbound traffic is allowed to remain on 42nd to take advantage of its width. At the south fork, northbound traffic to the Canas Expressway, Tenth Avenue, and Paseo Colon would be directed

1975 AM PEAK HOUR VOLUME - CAPACITY RATIOS
ALAJUELITA - SANTA ANA DISPERSAL

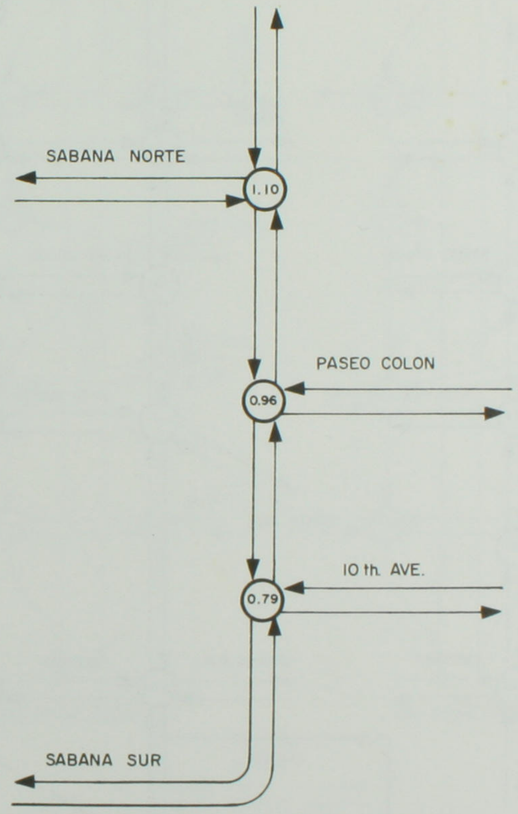

FIGURE V-2

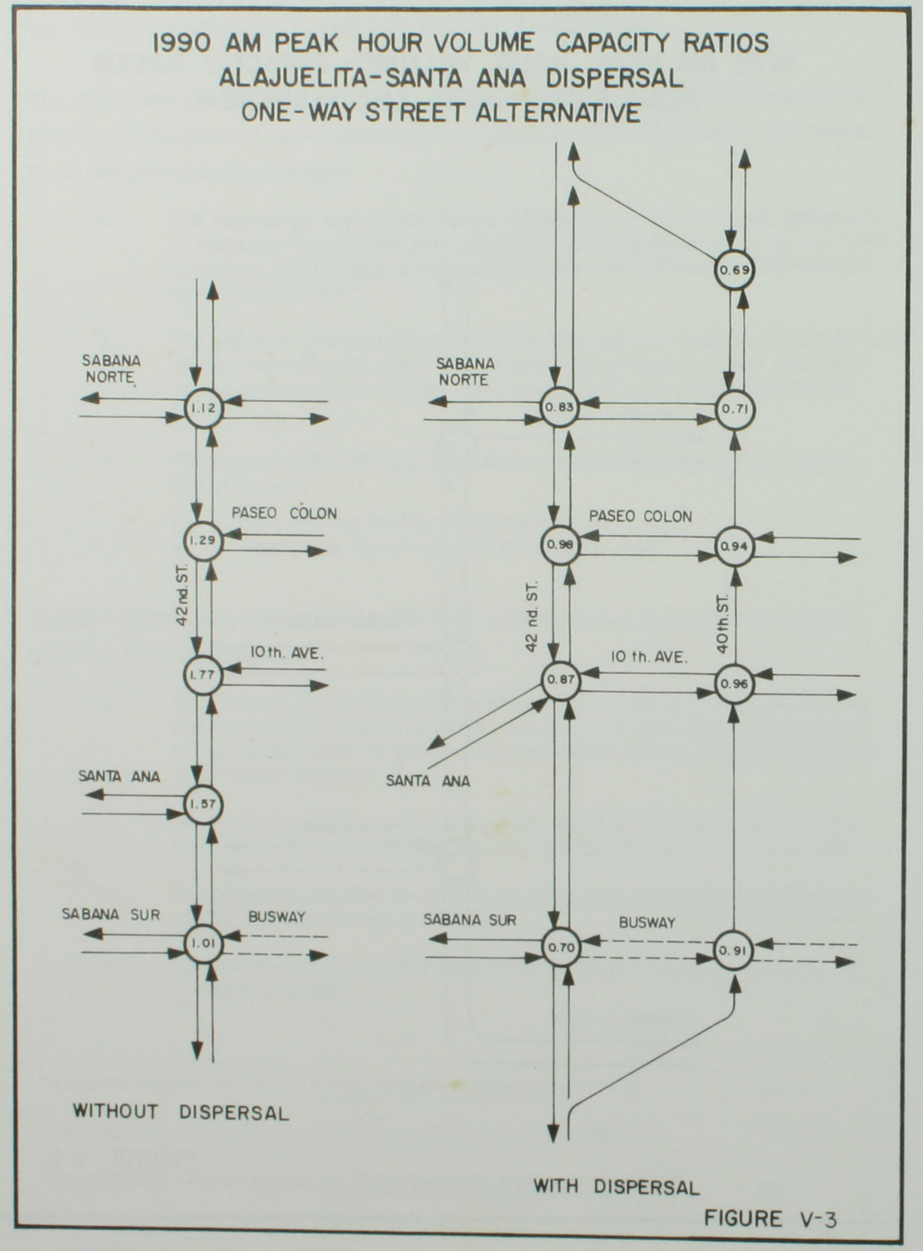

FIGURE V-3

to the right via 40th Avenue, and traffic to Santa Ana, Sabana Sur, and Sabana Norte would be directed to the left. While a.m. peak-hour traffic can be handled without difficulty, p.m. peak-hour may still experience some problems as shown in Figure V–4.

Another alternative was developed which provides still greater capacity by grade separating the through center lanes of 42nd Street. Figure V–5 shows the capacity implications of such an improvement. Figures V–6 and V–7 show schematic lane diagrams for each alternative.

It is clear that from a purely traffic movement standpoint, the grade-separated alternative is somewhat superior. However, the grade separation requires that the paved frontage roads be located very near several businesses and the National Gymnasium. The construction and right-of-way costs are more than twice as much as for the one-way street alternative. The economic analysis shown later in this chapter indicates that a much higher economic rate of return is available through the less expensive solution. Thus, the one-way street alternative is the preferred solution and is therefore recommended. Figure V–8 shows the geometric design of the entire recommended dispersal scheme.

Major bus flows associated with the two new highways operate east-west on Sabana Sur (about 600 bus trips daily) and north-south on the existing Hatillo road (about 1,000 trips daily). In the future, most bus traffic moving to and from the west will continue to use Sabana Sur since most of the passenger trips will be generated near its extensions. Those bus trips coming from the west on the Santa Ana Expressway can divert to Sabana Sur on a small access connection currently planned. Since most of the non-bus traffic will have diverted from Sabana Sur, this existing road will be uncongested, although not exclusively reserved for buses as it approaches 42nd Street. These buses will feed directly into the Railroad Busway just east of 42nd for circulation to and from the CBD. Thus, east-west bus movements are secure from interference with other traffic.

Bus traffic from the south will, as previously noted, continue to use the existing Alajuelita-Hatillo road. Traffic projections indicate no congestion interference

1990 PM PEAK HOUR VOLUME CAPACITY RATIOS
ALAJUELITA-SANTA ANA DISPERSAL
ONE-WAY STREET ALTERNATIVE

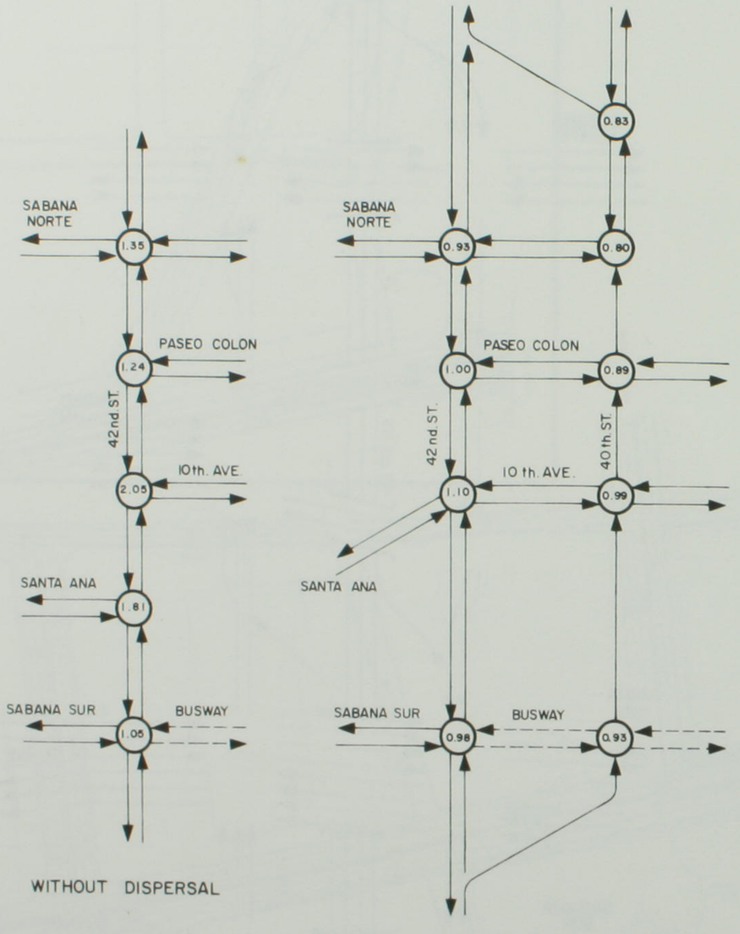

FIGURE V-4

1990 PEAK HOUR VOLUME CAPACITY RATIOS
ALAJUELITA - SANTA ANA DISPERSAL
GRADE SEPARATED ALTERNATIVE

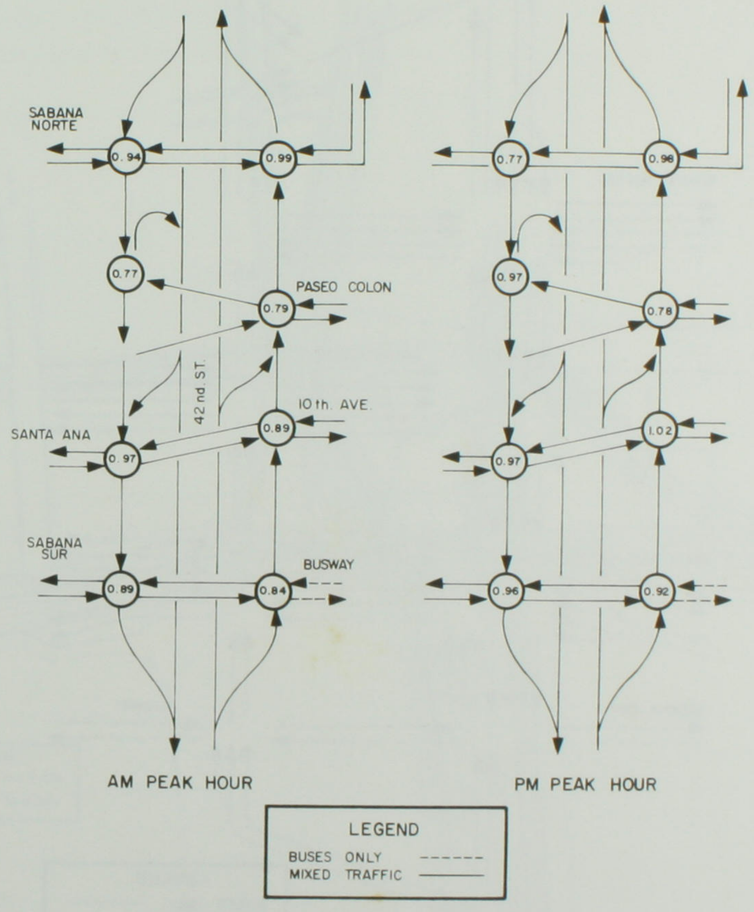

FIGURE V-5

SCHEMATIC LAYOUT
ALAJUELITA - SANTA ANA DISPERSAL AREA
ONE-WAY STREET ALTERNATIVE

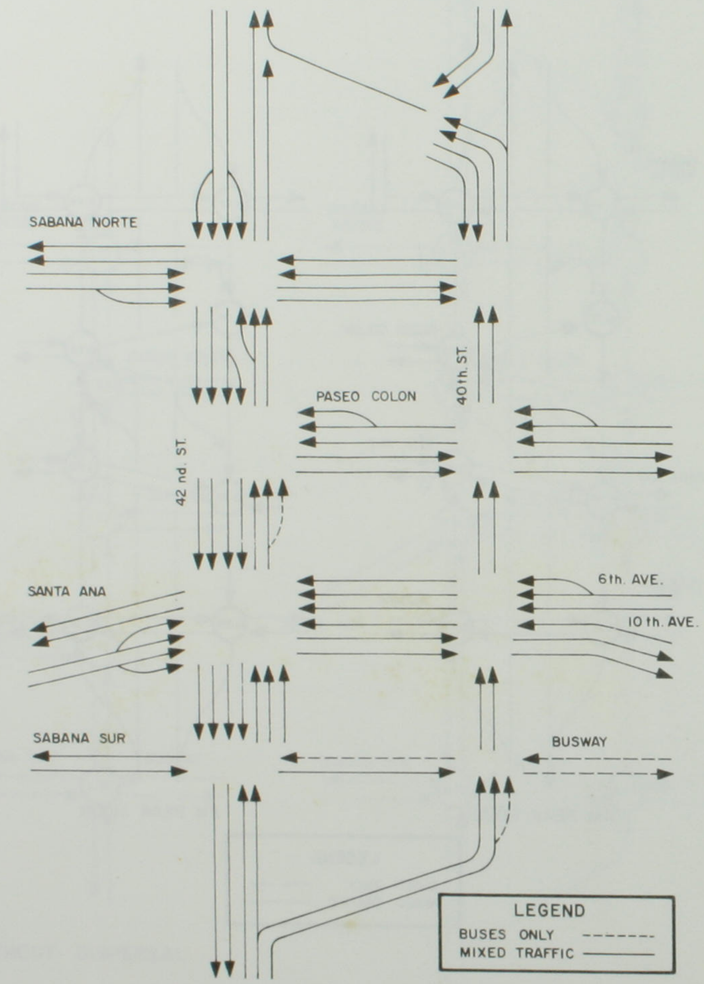

FIGURE V-6

SCHEMATIC LAYOUT
ALAJUELITA - SANTA ANA DISPERSAL AREA
GRADE SEPARATED ALTERNATIVE

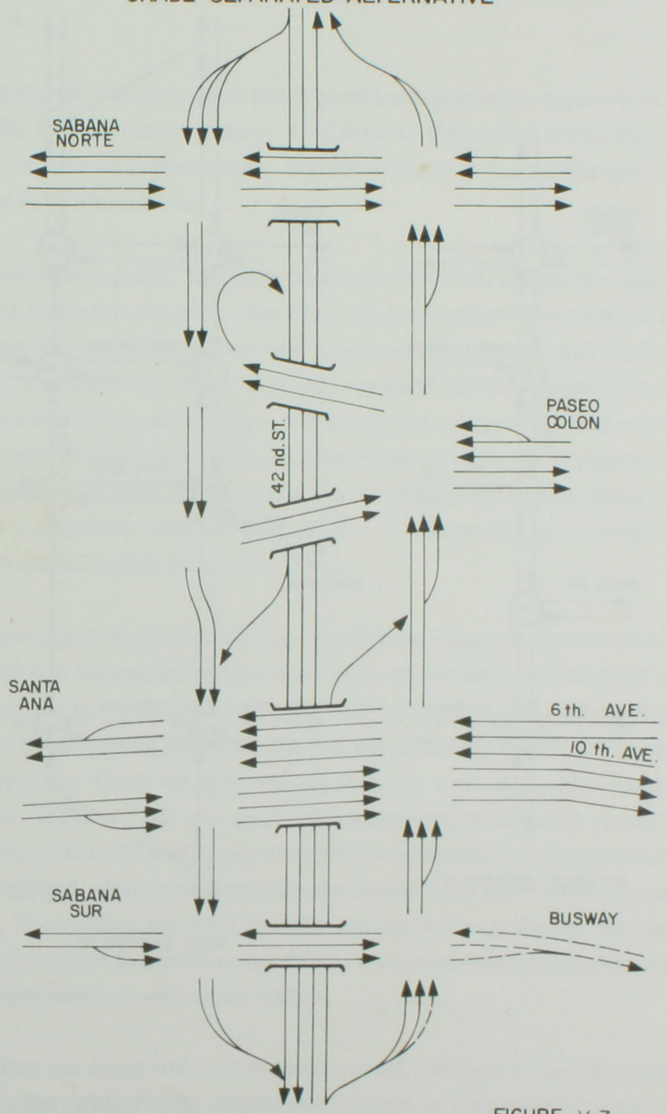

FIGURE V-7

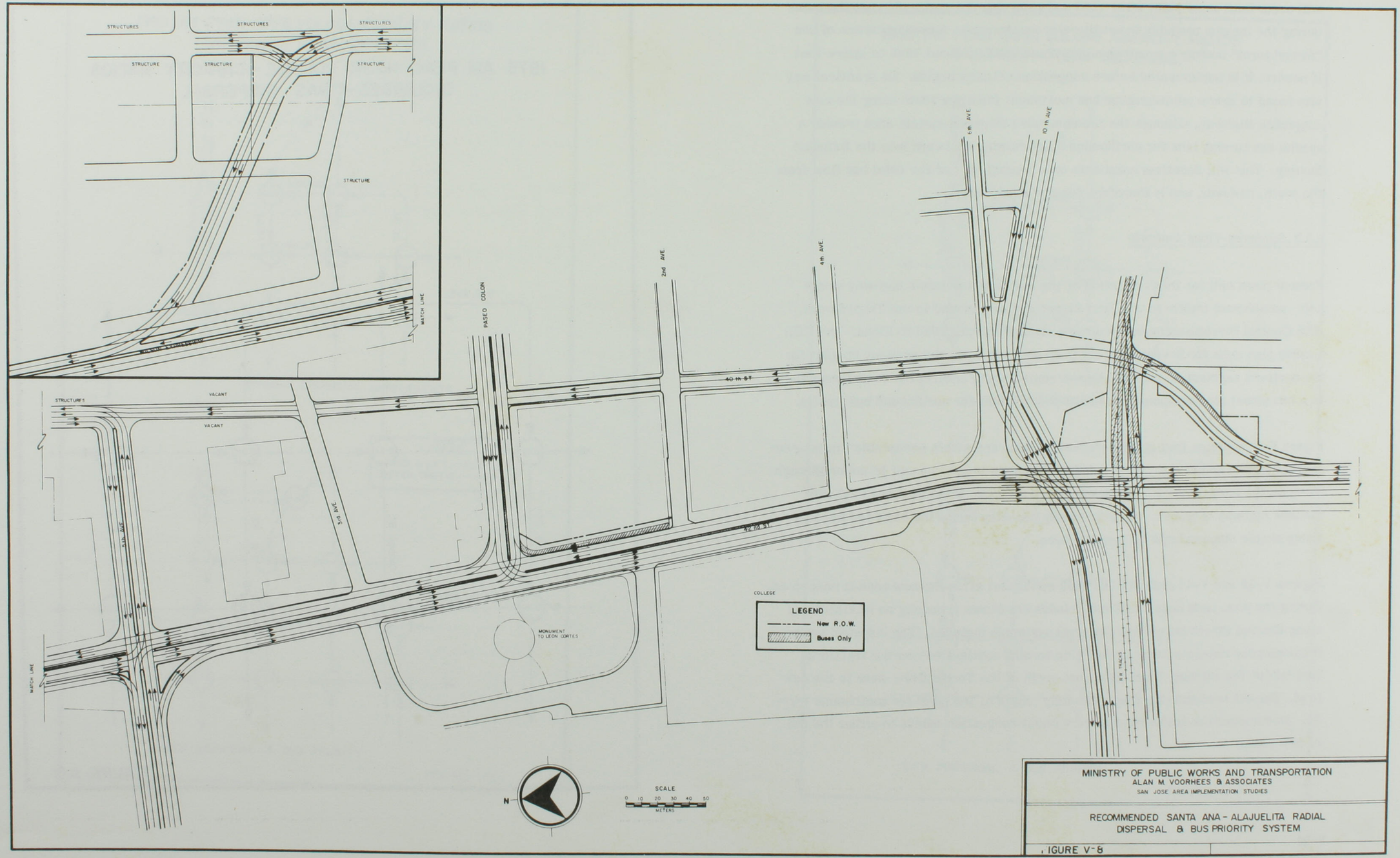

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FIGURE V-8

will occur until some point after 1990 and reserving the entire old road for buses during the interim probably is not therefore warranted. A reexamination of the "forced turns" busway concept should be conducted by about 1985 to insure that if needed, it is implemented before congestion actually begins. No practical way was found to insure uninterrupted bus movement from the south using the new Alajuelita Highway, although the recommended dispersal system does provide a special bus turning lane for northbound buses turning eastward into the Railroad Busway. This will doubtless constitute only a small part of the total bus flow from the south, however, and is therefore deemed acceptable.

5.3.2 Siquirres-Tibas Analysis

Present plans call for the connection of the new highway into a one-way street pair: southbound traffic to use First Street and northbound to use Third Street, with Central Street continuing to connect to the existing road to Tibas. The CBD control plan calls for Seventh and Ninth Avenues to form the one-way couplet for the northern segment of the CBD bypass route. Central Street is to be converted to a bus street for southbound buses and Fifth Street for northbound bus traffic.

Figure V–9 indicates that volume-capacity ratios are within acceptable limits under current traffic conditions. First and Third Streets do not connect to major through roads on the north and therefore are and will continue to be underutilized until the new highway is connected. This excess capacity forms the basis for the relatively simple dispersal system possible here.

Figures V–10 and V–11 indicate the 1990 conditions after the new road is connected. During the p.m. peak hour, traffic overloads are shown primarily on intersections along Central Street before the dispersal system is included. The dispersal system recommended corrects this imbalance by forcing southbound non-bus traffic to turn left of the existing Tibas Road just north of the Torres River over to the new road. The old road then becomes "bus only" south of the river for southbound traffic. Northbound bus traffic can move without congestion delays to either the old or new roads.

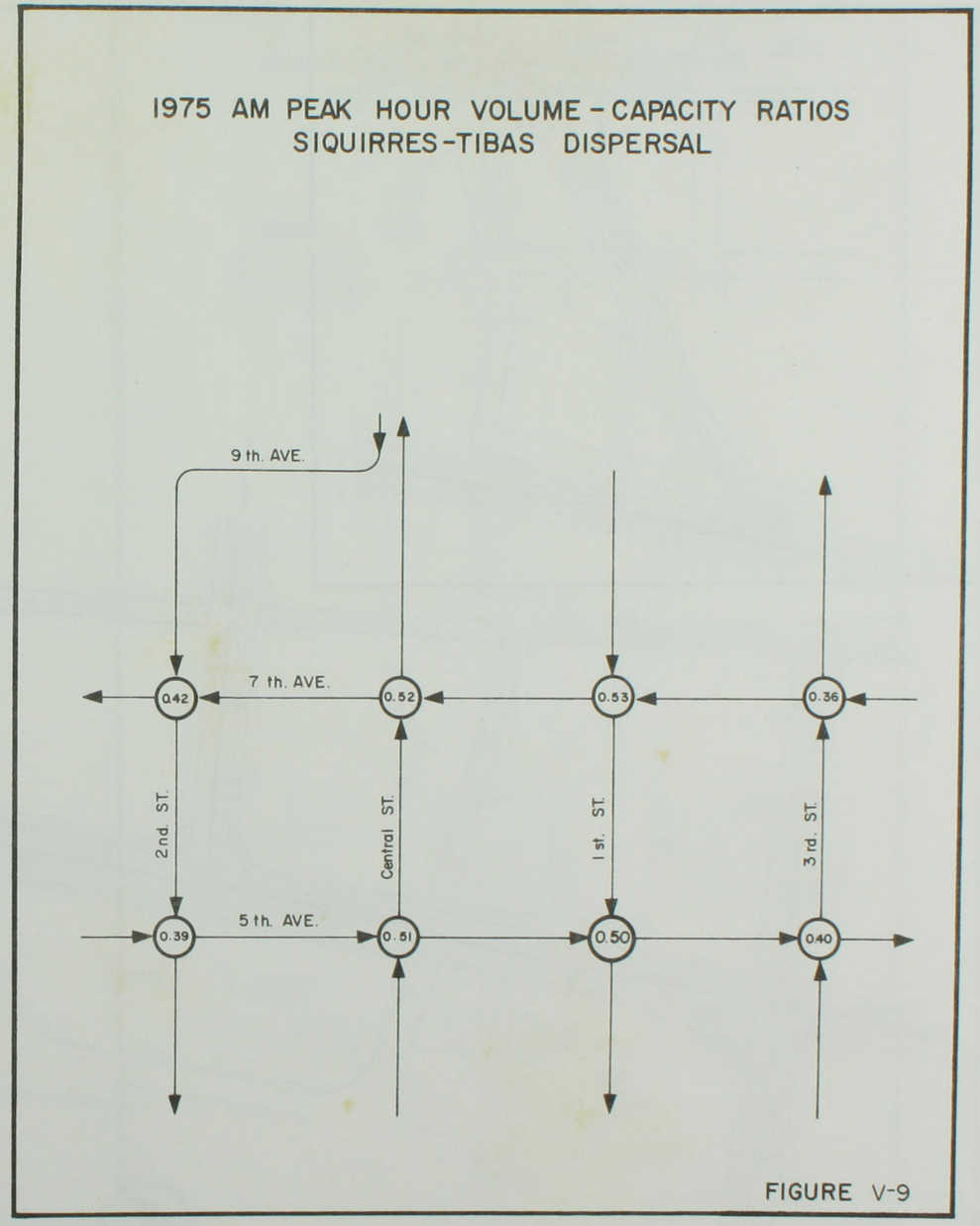
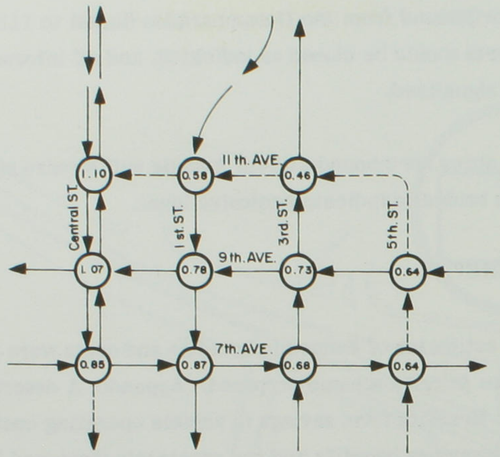
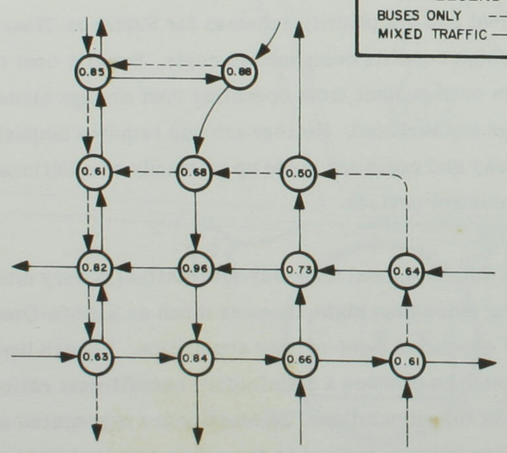


FIGURE V-9

1990 AM PEAK HOUR VOLUME CAPACITY RATIOS
SIQUIRRES - TIBAS DISPERSAL



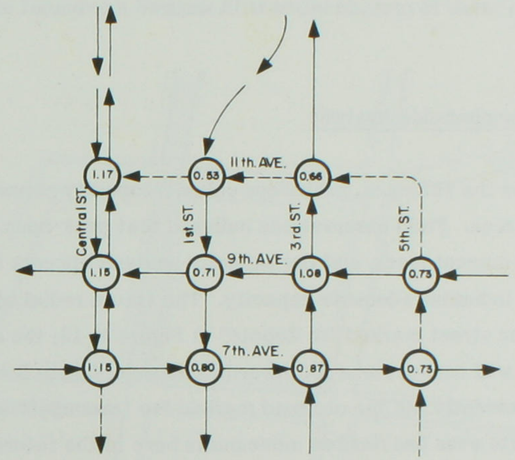
WITHOUT DISPERSAL IMPROVEMENTS



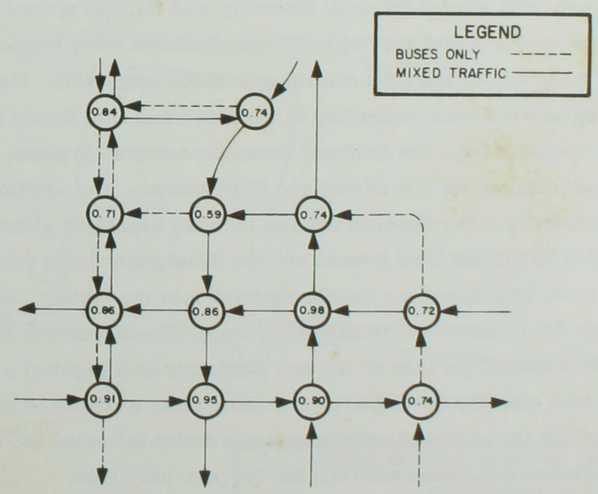
WITH DISPERSAL & BUS PRIORITY

FIGURE V-10

1990 PM PEAK HOUR VOLUME CAPACITY RATIOS
SIQUIRRES - TIBAS DISPERSAL



WITHOUT DISPERSAL



WITH DISPERSAL & BUS PRIORITY

FIGURE V-11

Figure V–12 shows the geometric design and details of the traffic controls required to implement the scheme. Shading indicates areas which are reserved for buses only. A relatively small number of restrictive controls are required to implement the scheme which tends to provide buses with assured movement along with benefits to motorists.

5.3.3 Zapote-Desamparados Analysis

Figure V–13 shows the 1975 a.m. peak-hour volume/capacity ratios in the Plaza Gonzalez Viquez area. Field observations indicate that peak-hour traffic moves adequately under current loads, and the capacity analysis appears confirmed in that Figure V–13 indicates adequate capacity. The future radial highway to Zapote will connect to the street marked "to Zapote" in Figure V–13; the new radial Desamparados Highway will connect as a southward extension of 11th Street. Heavy bus movements currently use the old road marked "to Desamparados," and future projections indicate even heavier bus movements here in the future.

Figure V–14 shows the 1990 a.m. peak-hour volume capacity ratios for two conditions: (1) without special dispersal elements, and (2) with special dispersal treatment. It can be noted that the "without" case includes other elements recommended as part of Stage 1 or of the CBD control plan contained herein. Thus, the Desamparados Highway is shown connecting to the Ninth and 11th Street one-way pair through a transition lane, the Railroad Busway is assumed in place, and exclusive bus lanes are assumed on 13th Street and 22nd Avenue. The additional control features assumed for the dispersal scheme includes expansion of non-bus prohibitions on 13th Street and 22nd Avenue and the development of a two-way street on 18th Avenue to connect the Zapote Highway into the system. It further requires forced turns for all autos and trucks off of the old Desamparados Road at 24th Avenue and a special bus lane on the new Desamparados Highway at 22nd Avenue. The additional capacity developed by the added lanes as assumed by the scheme are apparent in the improved volume capacity ratios indicated in Figure V–14. Figure V–15 shows the same material for the p.m. peak hour.

The recommended dispersal plan is shown in Figure V–16. Bus priority lanes are shown as shaded. The scheme can largely be accommodated within existing rights-of-way around Plaza Gonzalez Viquez. Additional right-of-way will be needed for the transition northbound from the Desamparados Radial to 11th Street at 18th Avenue. Minor streets should be closed as indicated, and all intersections facing the Plaza should be signalized.

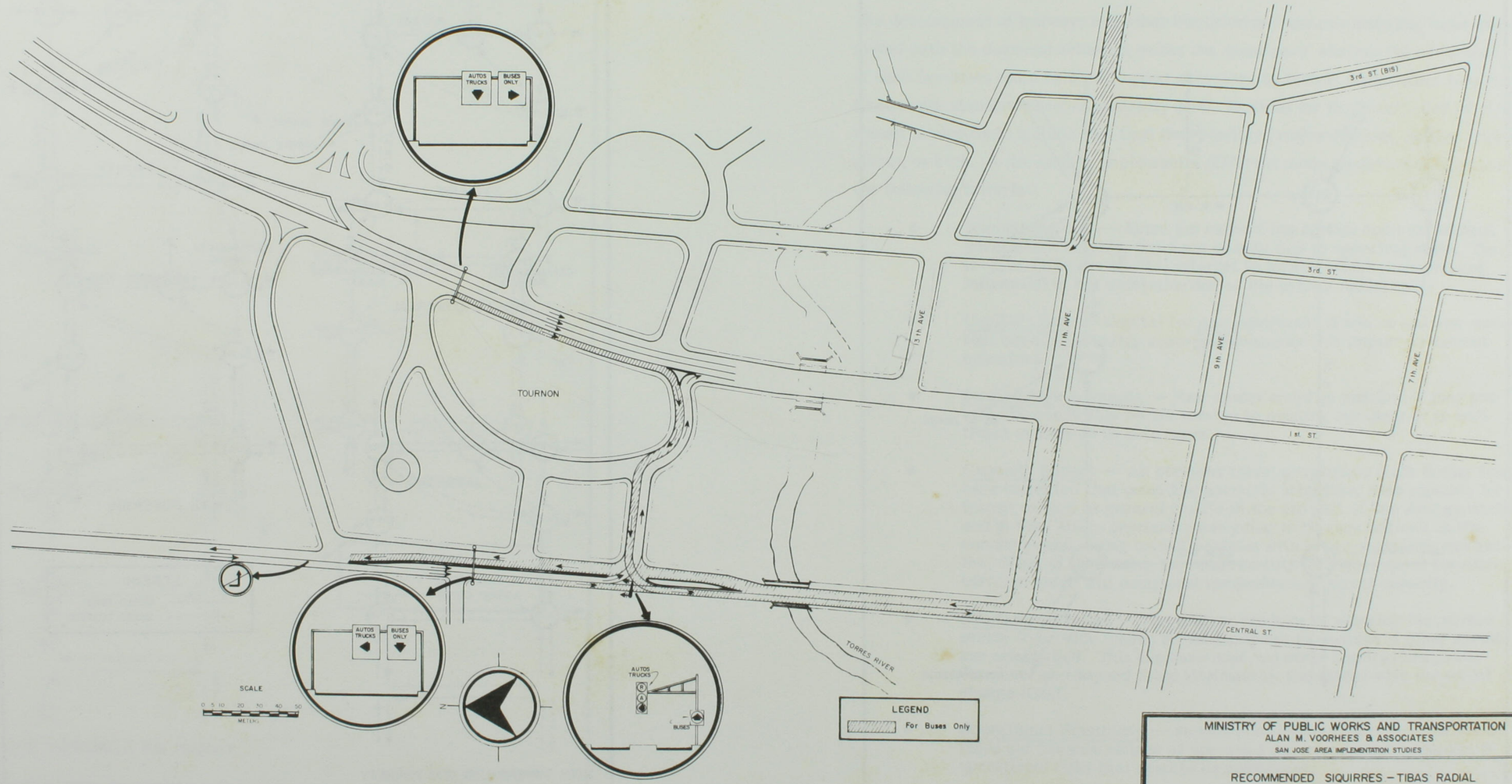
The forced turn for autos northbound at 24th Avenue will require signs, pavement markings, and a sign bridge to indicate exclusive lanes.

5.4 ECONOMIC BENEFITS

Order of magnitude estimates of economic benefits and costs were prepared for each dispersal and bus priority scheme proposed. Appendix A describes basic methodologies employed. Benefits from savings in vehicle operating costs were prepared separately from time savings benefits and are separately displayed in Table V–1. In an effort to assess benefits conservatively, the benefit stream was only accumulated from 1982 through 1990 for each system.

As shown, the dispersal and bus priority schemes for Siquirres-Tibas and Zapote-Desamparados show high benefits compared to costs. Benefit-cost ratios greater than four result from each project from operating cost savings alone and even higher if time savings are included. Neither scheme requires acquisition of very much new right-of-way and costs are made up primarily of additional pavement and costs of traffic control devices.

The Alajuelita-Santa Ana Dispersal (one-way alternative) is very much more expensive, however, costing more than eight times as much as Zapote-Desamparados primarily because of expensive right-of-way acquisition. Though benefits are high, they are not high enough to produce a satisfactory benefit-cost ratio unless time savings are included in the calculations. If benefits are aggregated over a 20-year time span and a salvage value is applied to the newly acquired rights-of-way, a benefit-cost ratio of 1.05 results even if time savings are excluded.



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RECOMMENDED SIQUIRRES – TIBAS RADIAL
DISPERSAL & BUS PRIORITY SYSTEM

FIGURE V-12

1975 AM PEAK HOUR CAPACITY RATIOS
ZAPOTE DISPERSAL

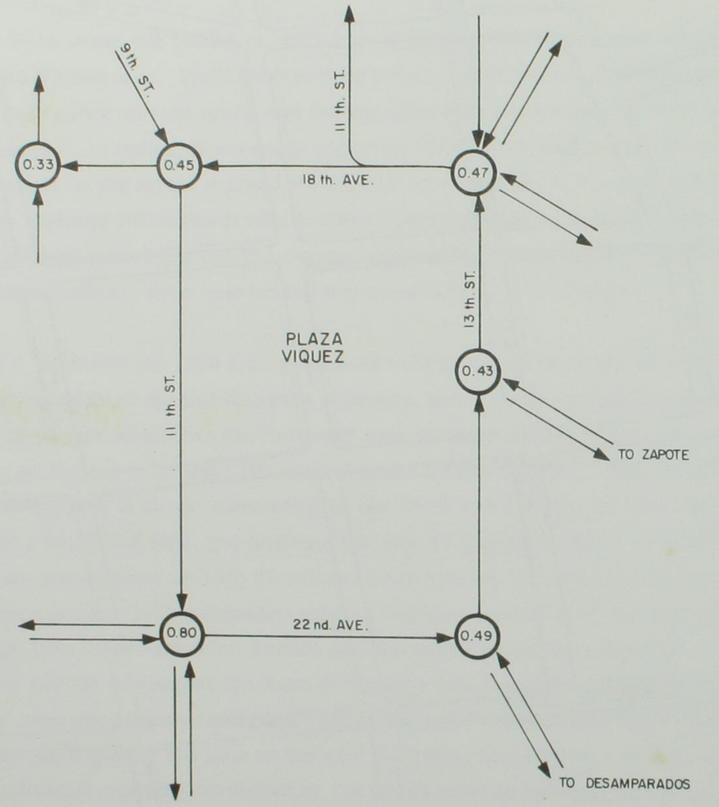
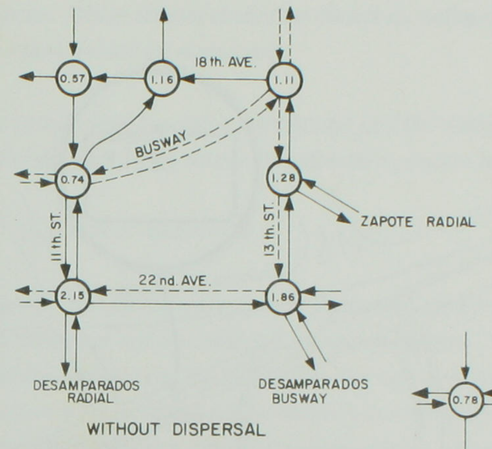
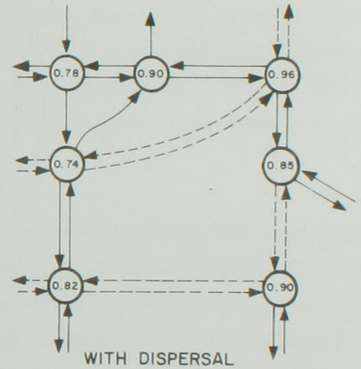


FIGURE V-13

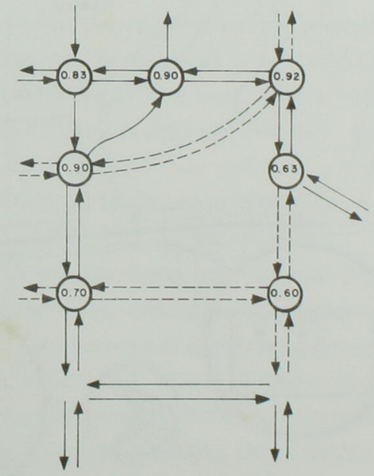
1990 AM PEAK HOUR VOLUME- CAPACITY RATIOS
ZAPOTE - DESAMPARADOS DISPERSAL



WITHOUT DISPERSAL



WITH DISPERSAL



WITH DISPERSAL & BUS PRIORITY

LEGEND
- BUSES ONLY
- MIXED TRAFFIC

FIGURE V-14

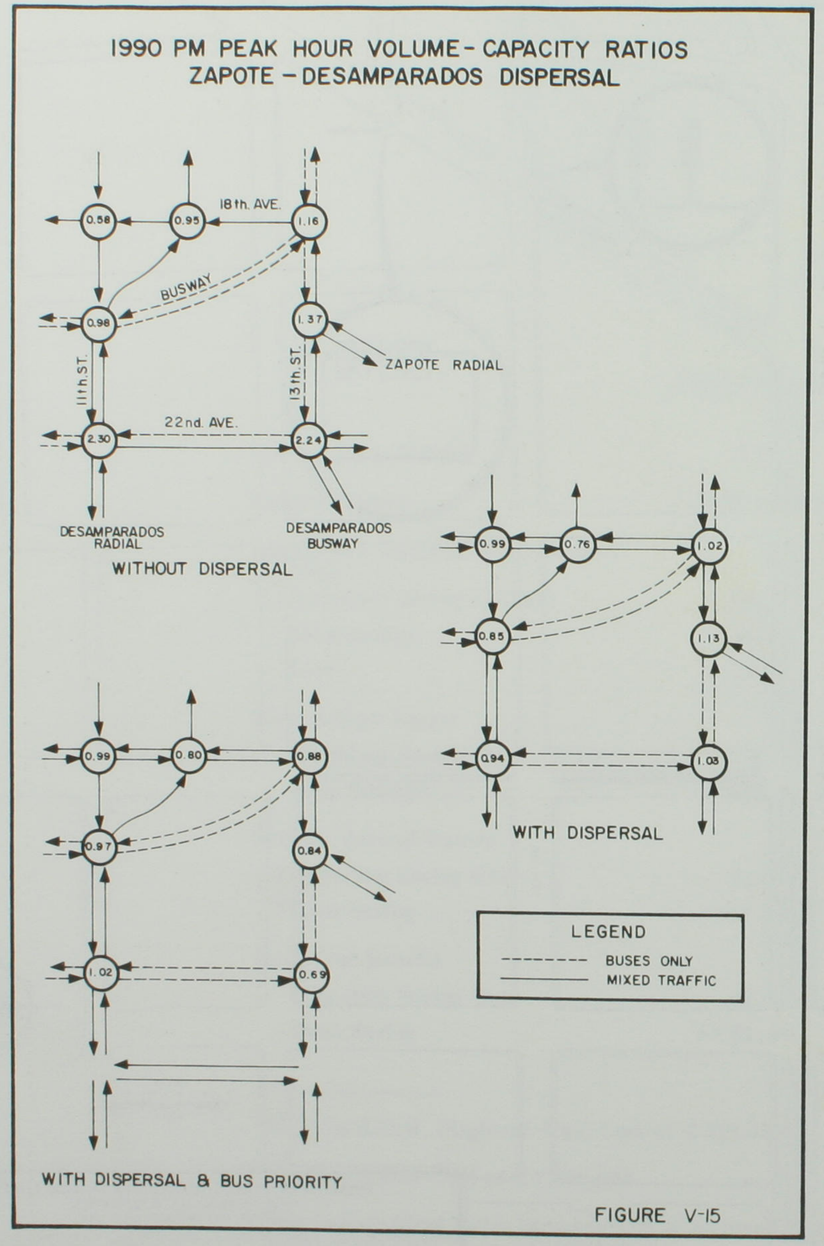


FIGURE V-15

The Alajuelita-Santa Ana Dispersal using the grade-separated alternative is seen as simply too costly to be considered given the benefits which appear somewhat more limited than achieved by the one-way plan.

5.5 SUBMODAL ANALYSIS

The development of busways and other bus priority measures including those associated with the dispersal schemes, raises the question of whether the existence of such facilities could be used to good advantage by transit modes other than the fixed-route standard coaches currently used. Reasons for implementation of other transit modes could include cost (and thus possibly fare) reductions, service improvements, or both. A decision to implement a different mode should consider at least the following criteria:

- Operating Costs — Since the current bus system operates without government subsidy, fares are closely tied to operating costs. The level of fares are of vital interest to lower-income users and are influential in the determination of the overall modal split.

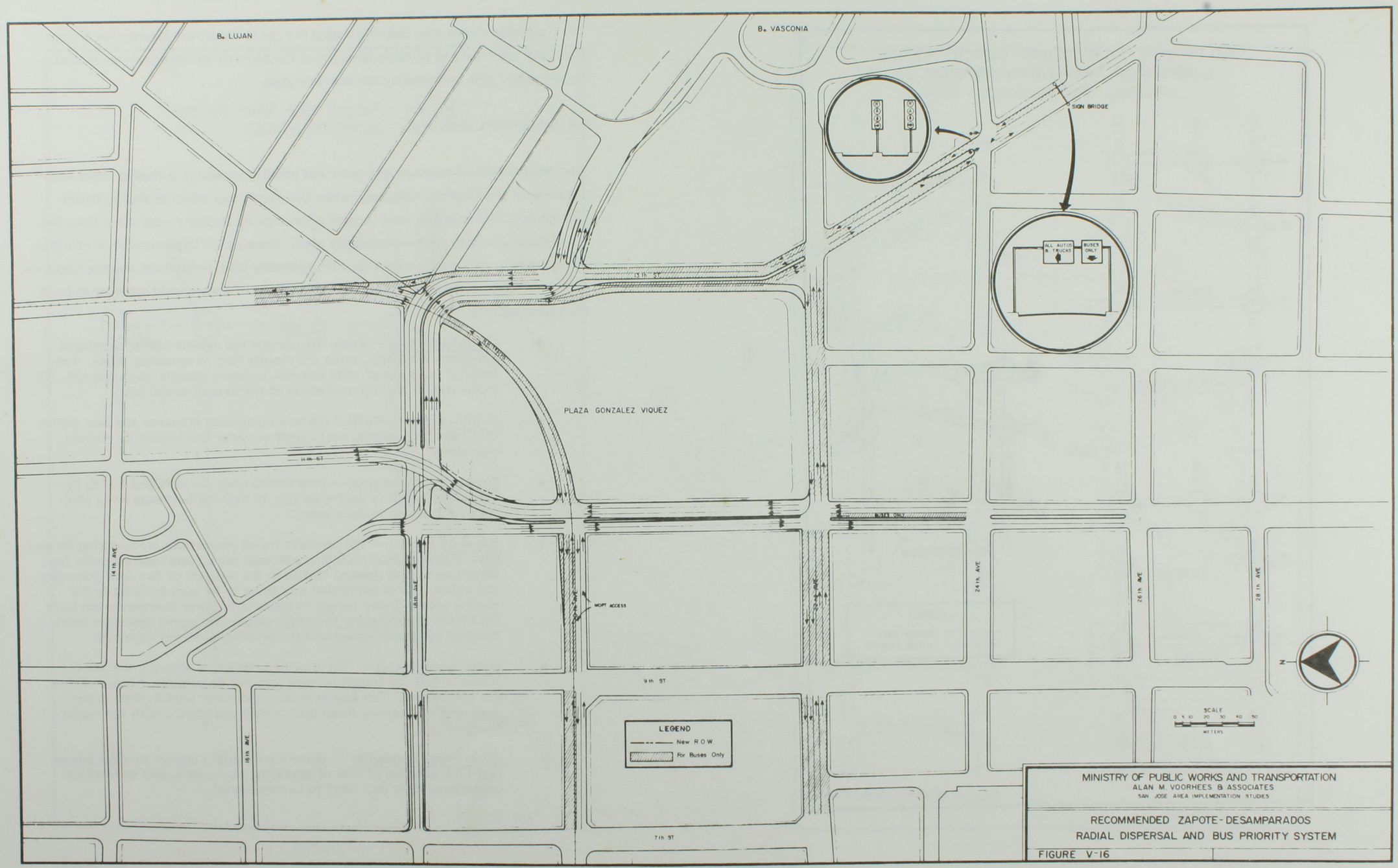
- Capital Costs — Capital for new equipment is scarce and new modes that have high startup costs must consider this impact on current operators.

- Service Improvements — New modes could be justified if they provided demonstrably better service to existing bus users or as additional attraction to auto users.

- Capacity Impact — All previous travel projections made during Stage I have indicated that providing adequate street and road capacity for transit as well as general traffic in the old part of San Jose generally and in the CBD in particular was going to be very difficult in the coming years. Using transit vehicles with lower occupancy can have the effect of increasing the requirements for street space for each traveler which will compound the problem of street capacity.

- Institutional Issues — The present practice of allowing the private sector to provide transit service may not be possible if other modes are established. This can have cost and other implications in San Jose over and beyond those intrinsically associated with the modal change itself.

- Operational Feasibility — Some modes might appear to offer advantages but because of lack of operating experience may necessitate operational risks that need to be considered.


B. LUJAN
B. VASCONIA
SIGN BRIDGE
ALL AUTOS & TRUCKS
BUSES ONLY
PLAZA GONZALEZ VIQUEZ
11th ST
14th AVE
16th AVE
18th AVE
20th AVE
22nd AVE
24th AVE
26th AVE
28th AVE
BUSES ONLY
MOPT ACCESS
9th ST
7th ST
LEGEND
New R.O.W
For Buses Only
SCALE
0 5 10 20 30 40 50
METERS
N
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RECOMMENDED ZAPOTE-DESAMPARADOS
RADIAL DISPERSAL AND BUS PRIORITY SYSTEM
FIGURE V-16

TABLE V-1

SUMMARY OF FEASIBILITY MEASURES
DISPERSAL AND BUS PRIORITY SYSTEMS

	Siquirres-Tibas	Zapote-Desamparados	Alajuelita-Santa Ana	
			One-Way Street Alternative	42nd St. Grade Separation
Capital Cost (₡ 1000)	279.5	1,337.6[1]	10,700.6[2]	25,317.4
Benefit Period	1979 - 1990	1983 - 1990	1982 - 1990	1982 - 1990
Discounted Benefits @ 12 Percent Per Year				
Operating Saving (₡ 1000)	2,005.4	5,363.1	4,867.2	3,813.2
Time Savings	5,913.5	14,457.3	7,394.8	5,505.6
Total	7,918.9	19,820.4	12,262.0	9,318.8
Benefit/Cost Ratios				
Operating Saving Only	7.17	4.01	0.45[3]	0.15
Total Saving	28.33	14.82	1.15	0.37
Internal Rate of Return				
Operating Saving Only	57.7%	60.0%	---	---
Total Saving	>> 57.7%	>> 60.0%	15.0%	---
First Year Benefit				
Operating Saving Only	37.5%	55.7%	4.9%	1.6%
Total Saving	>> 37.5%	>> 55.7%	12.8%	4.1%

[1] Includes R.O.W. (Right-of-Way) Cost of ₡ 312.000

[2] Includes R.O.W Cost of ₡ 7,700,000

[3] The Benefit/Cost Ratio becomes 1.05 when benefits are accumulated over 20 years and a salvage value of ₡798,000 is applied to newly acquired right-of-way.

The Stage I studies have analyzed the effectiveness of the present bus operation and found that the system offered reasonably good service at a low fare. Certain deficiencies were found including:

- Overloading — Some corridors during the peak hours experience severe overloading such that most passengers must stand and many are by-passed by buses so full that they will not stop.
- Maintenance — Buses are often dirty and ill-kept in appearance. Engines need repair to reduce exhaust emissions and noise.

Among recommendations made to correct these and other deficiencies was to develop premium bus service which stops less often, offers more deluxe equipment, and carries few or no standees but charges a premium fare. Such a proposal recognizes that the bus user population is not homogeneous, nor are users' desires for system improvements identical. Some would prefer a low fare even though service might be marginal; others would prefer to pay more to get better service. This latter group, if not satisfied, are the ones most likely to purchase an automobile and thus compound the broader transport problem.

Fortunately, the provision of physical facilities to provide busways or bus priorities for standard-size coaches does not preclude the use of such facilities in the future by other high-occupancy vehicles. Nevertheless, it is useful to know as much as possible at the outset about the potential use of the facilities by other type vehicles.

5.5.1 Modes Examined

In order to determine the feasibility for introduction of new transit modes, eight transit modes or modal combinations were examined. Six were fixed-route modes, including the standard bus; two were demand responsive. A system of routes for each mode was proposed for the Tibas corridor. Capital and operating costs were prepared. The impact on the capacity of the street system was estimated. Other more subjective factors were also evaluated. Appendix B provides a full description of these issues.

5.5.2 Standard Bus

The standard bus is the descriptor used for the bus vehicle type now being used in San Jose. Standard buses tend to be very efficient in their consumption of scarce street space with each having a capacity of 50 or more considering standees; they average more than 40 passengers per vehicle as they enter the central area. One bus has the impact of about three cars in the consumption of street capacity.

5.5.3 Mini-Bus

The mini-bus is considered here as a 21-passenger vehicle smaller and therefore more maneuverable than the standard coach. Carrying smaller loads means fewer stops for loading with a result of higher overall speeds. Mini-buses are more consumptive of street capacity (per passenger carried) however, and since the driver's cost must be spread over fewer passengers, operating costs tend to be higher.

5.5.4 Jitney (Fixed Route)

Jitneys are considered here to be standard-sized sedans with a five-passenger capacity. As operated in Caracas and San Juan, Puerto Rico, jitneys provide a higher level of service than buses at a premium fare. While operating basically in a fixed-route manner, they require few stops for loading and can provide operating speeds similar to the automobile. Some route flexibility is employed by drivers who sometimes detour a few blocks to provide passengers with a short walk to their ultimate destinations. They are even less efficient in use of street space than mini-buses, and costs per passenger are higher.

5.5.5 Electric Trolleybus

The heavy volume of buses on selected routes in San Jose have led some to suggest that there might be advantages to substituting trolleybuses for diesel-gas buses now in operation. Trolleybuses are similar to regular buses except that they use electric power drawn from overhead wires strung along the route. Benefits suggested from such a substitution include lower operating costs (especially since

the recent oil price increases), less noisy operation, and less air pollution. Some of Costa Rica's international trade partners have suggested that they produce the trolleybus for San Jose to offset their purchase of local agricultural products. A detailed analysis was prepared as part of Stage I and is reported in the Final Technical Report, July 1975, p. V-10.

5.5.6 Standard Bus Plus Mini-Bus Feeder

The demand-responsive and jitney systems examined provide advantages of higher service levels through reduced waiting and walking times, but have the disadvantage of higher operating costs. To examine the potential for gaining some of these service benefits without all the cost disadvantages, a combination system was investigated utilizing standard bus routes for trunk lines which are served by six mini-bus feeder routes in outlying areas.

5.5.7 Combination Mini-Bus and Standard Bus

For reasons similar to those expressed in the previous paragraph, a combination system utilizing six mini-bus routes (serving the lower-density areas) along with two standard bus routes was examined. In this case, each route is independent, and they do not interact as feeders.

5.5.8 Demand-Responsive Mini-Bus

Demand-responsive use of transit refers to tailoring the supply of transit to the actual demand. This has been accomplished elsewhere through the "dial-a-ride" concept where vehicles pick up and deliver passengers door-to-door, door-to-common destinations, or common origin-to-diverse destinations. The demand is identified through phone calls to a central dispatching facility. Vehicles of different types are used, although mini-buses have the advantage of being able to carry large groups which sometimes occur when schools or large employment locations dismiss while still being small enough to perform their more typical mission of responding to individual calls.

5.5.9 Demand-Responsive Jitney

This mode was examined to determine the potential for using large standard sedans in demand-responsive mode.

5.5.10 Cost and Service Calculations

Of the six criteria earlier presented for deciding on the introduction of new transit modes, four were compared by preparation of quantified measures. These included estimates of capital costs, operating costs, service improvements, and capacity impact.

Capital costs were based on actual prices for various vehicles in Costa Rica. For the trolleybus, costs from a recent proposal from the Soviet Union to Costa Rica were used.

Operating costs for standard coaches and for mini-buses were based on actual operating cost data experienced in San Jose. Jitney operating costs were based on actual automobile operating costs for Costa Rica with labor costs equivalent to bus operator wages added. Trolleybus costs were developed by disaggregating standard diesel bus costs into categories of expense and adjusting item by item for those expense classes expected to be different. Comparisons were then made to actual trolleybus operating costs from their cities.

Operating speeds for standard and mini-buses were based on actual experience in San Jose. For jitneys, the relationship between auto and jitney speeds as observed in other cities was applied to San Jose auto speeds. Trolley speeds were assumed the same as diesel bus speeds.

5.5.11 Modal Comparisons

Table V-2 summarizes the comparisons of the modal combinations examined. The table has been constructed to compare each alternative to the base case, i.e., the standard fixed route bus now in operation. Any such brief comparative display

must suffer from oversimplification, but at the least it provides a useful check list and a basis for a discussion of the attributes of those compared.

One thing that stands out is the fact that from a cost perspective, the standard fixed route bus is most favored. Those systems using smaller vehicles suffer on almost all cost counts when compared on a cost per passenger or cost per seat mile basis. More labor and fuel are consumed for each unit of transportation produced. Jitneys with a small passenger capacity operate as cheaply as buses in some cities (e.g., San Juan, Puerto Rico) but this occurs when the jitneys are operated by individual owner-operators where the buses are operated by government authorities. San Jose already enjoys the low costs associated with owner-operators, and jitneys cannot therefore have the special institutional advantage when compared to buses in San Jose that they do in San Juan.

Electric trolleybuses are the same size vehicles as standard buses. Potential differences in costs stem from differences in costs of electric power vs. petroluem fuel and the costs of maintenance not only of the vehicles but of the overhead electric line. A further potential difference is the higher costs for purchase of electric buses although this is offset to some extent by the longer service life. Comparisons shown in Table V–2 were made based on fuel prices after the recent OPEC increases, and there can be little doubt that trolleybus operation in San Jose must cost significantly more than diesel buses. A number of critical assumptions must be made in conducting any such cost comparisons, and some must inevitably be made such that reasonable analysts may disagree. However, the cost disadvantage of trolleybuses spring from several sources, and it is difficult to develop a mix of assumptions which do not lead to the same conclusions.[1]

The substitution of trolleybuses for diesels would result in a significant increase in the costs of supplying bus transportation to San Jose. Unless the government were prepared to supply the extra money, fares would have to rise which might discourage ridership and tend to reduce the competitiveness of bus travel to other modes, especially the private car. This cost would be incurred by the riders without a corresponding benefit of faster or more frequent service. Delays in the most crowded part of the city could even be greater than at present due to the inability of buses to bypass one another at heavy loading points. Lack of routing flexibility with changing patronage patterns or during emergency street closings may also be considered passenger disbenefits.

On the other hand, passengers would get improved riding comfort through the use of new urban-style electric coaches, and pedestrians would be benefitted by significant reductions in noise and air pollution. Some reduction in fuel impacts would result especially if added electric power requirements can continue to be hydrogenerated. The government might also receive some benefit in its trade relations with some of its customers for Costa Rican agricultural products. The issue then is whether these benefits are greater than the disbenefits. Clearly, the question transcends that of providing better transportation. The major benefits involving environment and international trade have only peripherial relationship to urban transport, and the real value of such items can only be arrived at through the normal channels of political debate.

The problem is further complicated by the fact that some of the benefits, particularly those relating to the environment, can be obtained by tighter regulation of the diesel fleet at a fraction of the cost of new trolleybuses. This would be accomplished by the requirements for better engine tune-ups, better noise mufflers, and environmental pollution packages on all coaches. It would appear that these measures might be enacted prior to the investment in trolleybuses. Nevertheless, trolleybuses can operate cleaner and quieter than diesels at their best and, in the final analysis, the value of these improvements is the political question that must be resolved in the trolleybus decision.

Another superior attribute of the standard fixed route bus is its efficiency in use of scarce street space. The "Capacity Impact" column of Table V–2 indicates the effect of using smaller transit vehicles carrying a fixed number of passengers (Tibas transit passenger flows) through critical points in the street network during

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[1] This conclusion is borne out by other analyses of this subject. See, for example, "Light Rail/Diesel Bus/Trolleybus Analysis," R. Gustafson and C. Blake, Tri-County Metropolitan Transit District, Portland, Oregon, 1974.

TABLE V-2

COMPARISON OF ALTERNATE TRANSIT MODES FOR THE TIBAS CORRIDOR

Mode	Capital Cost Percent of Std. Bus	Fare[1] Percent of Std. Bus	Capacity[2] Impact Percent PCU Increase	Service		Percent Reduction in User Time	Operational Feasibility
				Comfort	Convenience		
FIXED ROUTE							
Standard Bus	100	100	0	Fair	Fair	0	Good
Mini-bus	110	241	8	Good	Fair	32	Good
Jitney	190	744	33	Good	Good	40	Good
Electric Trolley	276	129	0	Fair	Fair	0	Fair
Std. Plus Mini-Feeder	88	150	0	Fair	Fair	16	Good
Combination Mini and Std.	111	165	5	Fair	Fair	18	Good
DEMAND RESPONSIVE							
Mini-bus	225	368	39	Good	Good	13	Poor
Jitney	296	1,496	59	Good	Good	29	Poor

[1] Assumes that fares will be adjusted to meet operating cost

[2] Computed for Tibas Corridor at the point of CBD dispersal: $\frac{\text{(PCU Using Ride - PCU Using Bus)}}{\text{Total PCU for All Modes}}$

peak periods. It can be seen that use of mini-buses in place of standard vehicles would add 8 percent to the traffic load, and use of jitneys would add 33 percent. The demand-responsive modes do even more poorly because occupancy of these modes tends to be even lower. Given the difficult problems anticipated in even maintaining the current level of service on the street system and near the central area over the next 15 years, it would appear that strong consideration must be given to this factor.

On the other hand, if higher level service could result in a lower proportion of total travel taking place in private cars, then this somewhat offsets the higher number of transit vehicles required. The ideal solution is to obtain the higher level service while sacrificing transit vehicle occupancy the least. Since one of the worst features of the present bus operation is the extreme overloading which occurs on many routes during peak hours, then any premium service, even one using standard-size coaches, will require a reduction in transit vehicle occupancy. Stage I has recommended such premium service using mini-buses which it is believed represent a significant improvement in the level of service without too great a sacrifice in street capacity. If even 25 percent of all passengers in the Tibas Corridor were to convert to mini-buses, this would only reduce the people-moving capacity at critical points in the corridor by 2 percent. A similar shift to jitneys would have more than a 7 percent impact. It is concluded that the premium bus service recommendations made as part of Stage I should be implemented as a matter of some urgency, but that even smaller vehicles such as jitneys should not be encouraged at this time.

The demand-responsive modes were shown by the analysis to provide good service but to have severe cost disadvantages and to be inefficient in use of street space. Experience with this mode in the United States confirms this conclusion. The limited telephone availability represents an additional problem with this mode and accounts for the "poor" rating given under "operational feasibility" in Table V-2.

The combination modes using mini-buses with larger buses provide a measure of time savings but at an even higher cost. The density of transit use in the relatively small area which constitutes the San Jose Metropolitan Area allows reasonable

frequencies of service using larger buses. Again, the use of mini-buses as premium service along and in addition to regular service is a preferred solution.

5.6 IMPLEMENTATION

Implementation of the dispersal and bus priority schemes are in each case associated with the opening of major radial roads, and the ultimate need for them must be determined by progress on these road construction projects. However, consideration should be given to reserving the right-of-way required for the dispersal improvements particularly in the case of Alajuelita-Santa Ana and Zapote-Desamparados where additional right-of-way is more critical to the proposed solution.

5.6.1 Siquirres-Tibas

The Limon-Siquirres Highway is expected to open in 1978, and the dispersal and bus priority scheme should be implemented at that time. One complicating aspect of concern is the period 1978 to 1980 during which time the dispersal scheme will be in operation but the bus streets on Central Street and Fifth Street will not yet have been established. This should not present any particular problem, however, since First and Third Streets can be coupled to the new road for auto traffic and buses which under current routing patterns now reach the old Tibas Road can continue present patterns until the bus streets are established. The section of bus street across 11th Avenue east of Third Street will not be required until 1980, however.

5.6.2 Alajuelita-Santa Ana

The Santa Ana Expressway is expected to open in 1977, and the Alajuelita-Hatillo Road is not expected until 1980. The Railroad Busway is not programmed until after 1981. Since 42nd Street carries little traffic south of Sabana Sur until the Alajuelita Road is connected, and since most of the traffic from this new road will have formerly come through the same area on Sabana Sur, the Santa Ana Expressway can be successfully connected to 42nd without other special treatment until 1980. The dispersal scheme should be programmed for implementation by 1980 to correspond to the connection of the Alajuelita Road as an extension of 42nd Street. The special bus lanes should be added at the same time although they cannot be fully utilized until the completion of the Railroad Busway after 1981.

5.6.2 Zapote-Desamparados

The Zapote Highway will open in 1979, followed by the opening of the Desamparados Highway in 1981 with the Railroad Busway to be opened after 1981. The dispersal system in this area should be implemented in two steps: (1) the 18th Avenue, 11th Street, and the 13th Street portions north of the Zapote connection should be completed by late 1979 or 1980 to correspond with the opening of the Zapote Road, (2) the remainder of the system to be open by 1981 to correspond with the opening of the Desamparados Road. By developing the initial step before the Zapote connection is made, the problems of construction under the heavier traffic conditions brought on by the new road are reduced.

Chapter VII discusses more details of the implementation process.

Transit Operational Considerations

Chapter VI

Chapter VI
Transit Operational Considerations

Because of the importance of maintaining and improving public transit to the successful attainment of both short- and long-range transportation objectives in San Jose, it is necessary to examine the impacts on the transit system of the various transportation projects proposed in the preceding chapters. Possible impacts to be examined include:

- Passenger walking and waiting times
- Passenger travel times
- Changes in transit patronage
- Bus routing changes
- Bus frequency changes
- Modification of bus vehicles
- Regulatory changes

6.1 CBD CONTROL PLAN

One of the major activities undertaken in Stage II which in turn serves as a principal underpinning of much of the subsequent work on signal improvements and highway dispersal plans is the development of a central area control plan. Features of this plan include the designation of one- and two-way streets, the location of a CBD bypass system, locations where on-street parking is to be controlled or eliminated, the location of exclusive pedestrian facilities, and the designation of a more limited number of streets in the central area where buses are to be operated and which ultimately will be devoted exclusively to bus use. There are numerous advantages to street traffic as a result of the implementation of this scheme, including a more rationalized flow of traffic within the CBD, and the diversion of non-CBD-destined traffic from CBD streets.

However, the principal advantages of the CBD control plan will accrue to transit users and pedestrians by virtue of the bus priority features incorporated in the plan and the expanded space devoted to pedestrian movement. It is important

to note that more than three out of four persons in the CBD come by bus and that during peak pedestrian hours, a significant proportion of the pedestrians in the CBD are on their way to and from bus stops.

The CBD control plan changes the present bus routing in the CBD from the pattern of routes terminating and requiring a loop turnaround within the CBD to a linking or "interlining" pattern which allows buses to approach and travel through the central area. The advantages of interlining include the virtual elimination of the long walking distances presently required for many passengers desiring to transfer from one radial line to another, the reduction of walking distances for patrons having trip origins or destinations within the CBD due to the improved distributional features of the plan, and the reduced number of bus turns in the narrow streets which contributes to reduced congestion and the possibility of at least some bus patrons avoiding a transfer by virtue of having both origin and destination on a single interlined radial route. The lines have been grouped onto a limited number of streets which then can be devoted exclusively to bus use.

The effect of the provision of central area bus streets and its attendant pattern of interlined bus routes on the various service level and operational factors are described below.

6.1.1 Passenger Walk and Wait Times

Passenger walking distances within the central area would be substantially reduced. For passengers transferring in the central area, such walking distances would be virtually eliminated, since the passing through of each radial route plus the co-location of the routes on only a few streets bring virtually all routes into direct contact with one another.

For passengers having their origin or destination in the central area, walking distances will be reduced although not eliminated. Analysis of the interlining scheme indicates that central area coverage under the improved bus route scheme will be increased by some 58 percent, or from 51 percent to 81 percent of the central area based on an assumed coverage area of 300 meters on each side of a bus line.

This clearly implies a reduced average walking distance as well as, no doubt, substantial reduction of many of the very long walking distances imposed by the present system.

With the exception of short, intra-central area trips, waiting times would not be affected by this scheme since they are a function of service frequencies which is an unrelated factor. Intra-central area trips may be benefitted, however, due to the co-linearity of several bus routes on a single dedicated bus street. To the extent that such a traveler's origin and destination are served by more than one route, average frequencies would be improved. Such trips, however, constitute less than 10 percent of all transit trips, and only some of these would be affected. Therefore, this improvement can be considered minor.

Data collected and analyzed in support of the mode split model development indicates that the average bus trip consists of 15 minutes on the vehicle plus 13 minutes of walk and wait time. Of this 13 minutes, approximately one-half can be ascribed to each end of the trip. Of the 6 1/2 minutes ascribed to the central area portion of the trip, only the walk time portion would be affected, since wait time is a function of service frequency which is not affected by the scheme. Data is not available to permit a rigorous assessment of the improvement brought about by this scheme, but an approximate savings of one to two minutes or about 5 to 8 percent of the average trip time seems reasonable. Though small, such a savings is significant, especially since travelers are known to perceive walk and wait time as having two to three times the value of time on-board a vehicle. The fact that some of the remaining walking will take place over more pleasant, less-congested walking facilities should also reduce the psychological impedence related to walking.

6.1.2 Transit Speed

Aside from savings in walking, some time will be saved by transit passengers as a result of bus speed increases which will occur as a result of reduced delay from the signal system (discussed later) and from the congestion protection provided from the bus streets. Each bus street provides a two-lane bus roadway which will allow buses to begin moving as soon as loading or unloading of passengers is completed.

Under current conditions, a bus must often wait until the slowest bus in the queue is ready to move since congestion in the other street lanes precludes the possibility of pulling to the left. This reduced loading time is translated into a reduction in delay and an increase in speeds which benefit both bus passengers and operators.

The short blocks in the CBD indicate that buses should not be required to stop but about every three blocks. Further, the number of buses on each bus street will preclude the possibility of all buses stopping at each block anyway, due to loading capacity limitations. Since each bus will stop only every three blocks on the average (this every third block stop arrangement is not very different from present practice), then three intersections will be passed between stops, and the ability to use the left lane to bypass loading buses should be a significant advantage.

6.1.3 Bus Frequency Changes

This scheme in and of itself has no effect on service frequencies since these are clearly a function of demands and/or policy requirements established by transit operating authorities. Speed increases, of course, permit higher frequencies for a given amount of bus service provided, although the decision to provide higher frequencies or to reduce bus-miles of service (and hence, cost) should be a function of demand or scheduling factors. The small increases in speed occasioned by this scheme are sufficiently small that this is somewhat a moot point.

6.1.4 Modification of Bus Vehicles

A comparative evaluation based on cost and operating considerations of various transit submodes is contained in Chapter V. The basic conclusion is that fixed-route, fixed-schedule transit services are most appropriate for San Jose, although smaller bus vehicles have application for provision of premium service, as recommended elsewhere. No modification of that conclusion based on this scheme appears warranted.

6.1.5 Regulatory Changes

The principal regulatory change occasioned by the scheme relates to the need to combine routes into logical, interlined pairs. No current regulations prohibit this, but clearly some effort on the part of DGTA, the regulatory authority, will be required to effect this change. It should be noted that it is not necessary to merge transit operators, merely transit routes. Thus, each operator would provide an amount of service in two interlined corridors equal to the amount formerly provided in the single corridor.

Throughout the Stage I and Stage II study programs, the question is whether the existing owner-operator scheme for providing bus service currently prevailing in San Jose is sufficiently flexible and responsive to the public welfare. The requirement for individual operator-companies to develop and implement the interlining plan set forth here will require a high degree of cooperation and provide a test of the current institutional mechanisms' responsiveness to public needs. DGTA currently has the legal and administrative authority to require these changes and the implementation of the post of Transit Users' Ombudsman recommended in Stage I should help DGTA in its efforts to insure operator cooperation.

6.1.6 Effect on Patronage

A mode split model for auto-owning households was developed under Stage I. This was used as a part of a "policy-sensitive" model series aimed at assessing the impact of a series of potential policy changes affecting travel time and/or costs by the various modes on the total travel by each mode. The mode choice model functioned by comparing total trip "costs" including both time and money costs for the two respective modes, auto and transit, and determining a likely split between these two modes for eligible trips (those produced by auto-owning households) based on current observations.

Assuming a one- to two-minute average reduction in walk and wait time for central area destined trips, application of this relationship indicates a 1 1/2 to 3 percent shift of eligible trips from auto to transit. Based on 1990 forecasts, this amounts

to about 1,100 to 2,300 more daily transit trips and correspondingly fewer daily trips by private auto destined to the central area out of a total of 155,000.

The effect of the bus speed increases on transit patronage was not directly estimated, but it can be expected to be less than that estimated from the decreased walking distance. It can be observed that a two-minute savings in walking time has the same impact on patronage as a five-minute savings in on-bus travel time. Since a bus currently takes about 10 minutes to cover the 1.3 km distance crossing the CBD, it would take a doubling of bus speeds to save five minutes. Since the speedup from the bus lanes is likely to be much less than a doubling, less than five minutes will be saved, and the impact on patronage will be less than that estimated for the walking distance saving.

The impact in the longer run of providing for reliable bus movement, undelayed by ordinary vehicle congestion, is significantly more subtle than these calculations would suggest. If, in years to come, street congestion delays from private cars become much larger than under current conditions, then the impact of the bus streets and other improvements would be larger than indicated. It is also important to recognize that most of the bus users today are captive riders who do not have access to a car anyway. The impact of service improvements on patronage in such conditions cannot be expected to be large, and in any case would be less than in the future when more "choice" riders can be expected.

The more significant impact of improving bus speeds will be the reduction in operating costs accrued by bus operators, which has the potential impact on holding transit fares lower than otherwise would be possible. This will be discussed more fully later in this chapter.

6.2 TRAFFIC SIGNAL SYSTEM

The analysis of the traffic signal system assumed that the CBD traffic control plan was in effect including the special exclusive bus streets. Table VI-1 shows the effect of the improved signal system on the test network that was simulated

TABLE VI-1
EFFECT OF SIGNAL IMPROVEMENTS ON VEHICLE SPEEDS[1]

Vehicle Type	Speed Without Improvement (Km./Hr.)	Speed With Improvement (Km./Hr.)	Difference Km./Hr.	Difference Percent
Autos/Trucks	13.8	15.6	1.8	13
Buses	8.2	10.1	1.9	23

[1]Results are for Transyt Model Network which, while believed representative of the entire CBD, is smaller than the CBD.

in the TRANSYT program. While all traffic can be expected to gain speed improvements, the bus network gains even more. The 1.9 km/hour speed increase for buses represents a 23 percent increase.

The impact of this on patronage is limited because the portion of the total trip which takes place within the CBD is not large. The distance across the CBD is approximately 1.3 km and takes about 9.5 minutes at today's speeds. The same trip would take about 7.7 minutes at the faster rate. Considering that most passengers only penetrate the CBD, not pass through it, the time savings for the average person would be less than 1 minute (1.8 min. x 1/2).

The more significant impact of the time savings will likely be in the form of reduced operating costs to bus operators. A significant portion of bus operating costs are related more to elapsed time the bus is in operation than to distance covered. For example, operator wage costs are wholly related to time instead of distance. Thus, if the bus can be operated at twice the speed, the wage component per bus km is cut in half. Some portion of fuel costs, maintenance, and administrative overhead costs will also be reduced per bus km if speeds can be increased. Examination of the components of bus operating costs in San Jose indicates that about 25 percent of all costs can be considered time-related. If speeds can be increased

by 20 percent, then costs can be cut by about 5 percent (0.20 x 0.25). This decrease only applies for that portion of total operating costs occurring in the CBD, of course, but it nevertheless is not insignificant.

6.3 RADIAL DISPERSAL AND BUS PRIORITY PLANS

The recommended plans for traffic dispersal and related bus priority treatments will have the principal effect of increasing line haul speeds for buses over what would have been the case in the absence of these improvements in these affected corridors, especially during peak periods. Also, the existence of the new radial highways themselves will offer some opportunities for route restructuring, fairly limited in the near term but increasing as new development related to the new highways occurs. The anticipated effects on or opportunities offered by these improvements to the various transit service level and operational factors mentioned earlier are described below.

6.3.1 Passenger Walk and Wait Time

The projects do not directly impact on passenger walk and wait times since they do not, in and of themselves, bring transit services closer to desired passenger origins or destinations.

6.3.2 Passenger Travel Times and Patronage Changes

Table VI–2 shows that significant increases in bus speeds are estimated to occur by 1990 if the dispersal and bus priority schemes are implemented. The speeds shown, however, are applicable only to the area assumed to be influenced by the improvements, generally an area about .5 to 1.0 km on either side of the dispersal area. While the increases are large, it must be noted that they apply only during peak traffic hours during which time, in the absence of the improvements, one can expect large increases in delays and congestion. In the inbound morning peak hour particularly, long queues can be expected without the improvements.

The actual time savings to the transit patron, however, can be expected to be about

TABLE VI-2

1990 PEAK-HOUR TRANSIT SPEED INCREASES RELATED TO AND IN VICINITY OF RADIAL DISPERSAL AND BUS PRIORITY SCHEMES

Item	Corridor		
	Siquirres-Tibas	Zapote-Desamparados	Alajuelita-Santa Ana
Average Bus Speed, Null Case, kph	16.80	12.89	20.95
Average Bus Speed, Improved Case, kph	37.33	37.01	39.67

one minute for each trip. The effect of this on patronage can be expected to be small, especially since most patrons are captive. However, all patrons, including captives, can benefit from the improvements.

6.3.3 Bus Routing Changes

The existence of the new radial highways in the respective corridors offers, in the short term, the possibility of creating new express routes from the farther reaches of each corridor directly to the central area. Such routes would feature buses circulating in outlying residential areas and then travelling non-stop on the higher speed facility to downtown, reversing the pattern in the evening. Later, as the supporting systems of feeder and collector streets become established and adjacent development takes place, entirely new routes intended to serve these new areas could be developed.

6.3.4 Regulatory Changes

No regulatory changes appear warranted by the projects although enforcement of the bus priority measures will be called for. The anticipated advantages and benefits to all travelers resulting from these facilities will be largely diminished if they are not carefully preserved for exclusive bus use.

6.4 CONCLUSIONS

The cumulative benefits from all the transit improvements proposed, while each may be small, can be significant. Order of magnitude estimates of time savings for each trip related to each improvement could be approximated as follows:

Bus Streets:	1 minute	3-minute savings in bus
Signal Systems:	1 minute	
Dispersal and Bus Priority:	1 minute	2-minute savings out of bus
Reduced Walking Time in CBD:	2 minutes	

As indicated earlier, the typical transit trip to the CBD takes about 15 minutes time in the bus and another 13 minutes waiting and walking. Based on this, the total savings might approximate five minutes of a total 28-minute trip, or a reduction of about 18 percent. This reduction would not apply to non-peak-hour trips or to trips which come through corridors without bus priority dispersal features. Patronage could be expected to increase during peak hours for those corridors impacted by about 2-3 percent. Bus operating costs for those corridors impacted would be reduced by about 3-4 percent during peak hours and about 2-3 percent during most other times. It is useful to note that most of the savings are related to the central area improvements which impact almost all lines and all passenger trips, not just selected corridors.

Project Implementation And Management

Chapter VII

Chapter VII
Project Implementation And Management

In the preceding chapters covering the several project categories examined in Stage II, a portion of each has been devoted to the specific implementation steps required to bring the recommendations into being. The purpose of this chapter is to summarize these steps, to set forth a recommended time table for implementation, and to recommend staffing changes in the several public agencies affected by the project recommendation. The tasks, the responsibilities for them, and an approximate time schedule for each is shown in Table VII–1. Figure VII–1 indicates the location of each broad project category.

7.1 PROJECT ELEMENTS

The implementation steps are summarized for each project element below.

7.1.7 CBD Control Plan

The CBD Control Plan consists of many individual elements of traffic control. Some require minor construction work, but most are operational in nature. Since each element requires an individual treatment for implementation, they will be discussed individually below.

Pedestrian Malls — The implementation of the pedestrian malls, first on Central Avenue and later on Second Street, is largely an operational measure which can be undertaken directly by DGTA as they have in the past by using Transit Police to man barricades at the closure points. Figures II–7, II–8, and II–1 show the incremental steps for amplifying the mall from 1976 through 1980.

Bus Streets — Bus streets are another innovative traffic operational measure which can be introduced in steps in San Jose. First, prohibit right or left turns onto the bus street by cars and trucks at two or three central area intersectons. This will make the bus street difficult to use for autos but not impossible. Second, prohibit

TABLE VII-1

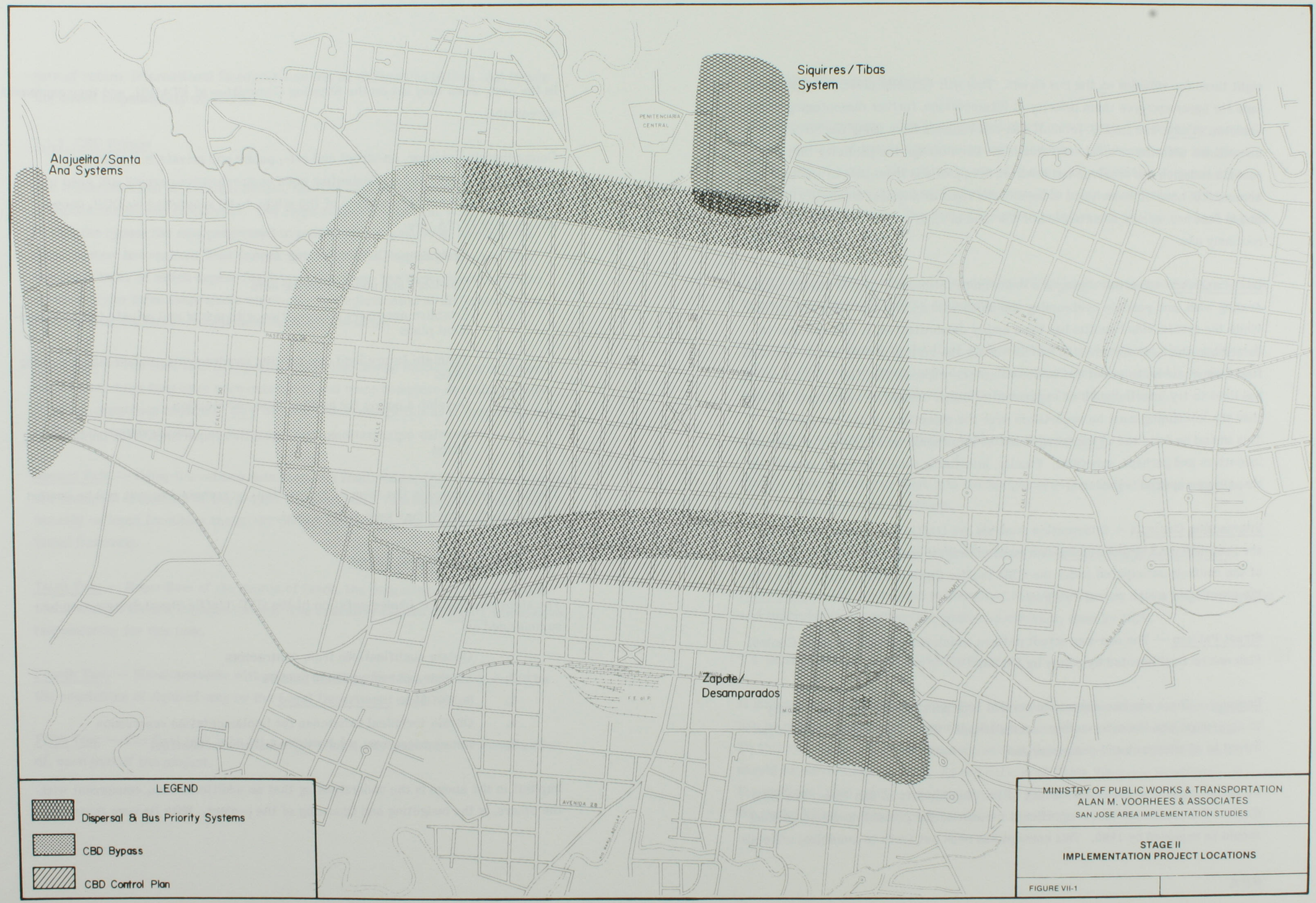
PROJECT IMPLEMENTATION RESPONSIBILITIES

Implementation Activity	Activity Timing and Responsibility: Detailed Studies	Final Design	Revise Economic Evaluation	Budget & Financing	Budget & Financing	Acquire ROW	Let & Supervise Contract	Implement by Policy	Construct With Own Forces
CBD Control Plan									
Pedestrian Mall		V - 75							T - 76
Bus Streets	P - 76								
Intersection Controls								T - 76	
Street Pattern								T - 76	
Parking, Comprehensive	P - 76								
Parking, On Street								C - 76	
CBD Traffic Signal System				M - 76	M - 76		T - 77		
CBD Bypass									
South Leg		V - 75	P - 75	M - 76	M - 76	L - 76	V - 77		
West Leg		V - 76	P - 76	M - 76	M - 76		V - 78		
North Leg		V - 77	P - 77	M - 77	M - 77	L - 78	V - 80		
East Leg			P - 81						
Radial Traffic Dispersal Systems									
Siquirres/Tibas		V - 75	P - 75	M - 76	M - 76	L - 76	V - 77		
Bus Priorities		T - 75	P - 75	M - 76	M - 76	L - 76	V - 77		
Alajuelita/Santa Ana		V - 76	P - 76	M - 77	M - 77	L - 77	V - 79		
Bus Priorities		T - 76	P - 76	M - 77	M - 77	L - 77	V - 79		
Zapote/Desamparados		V - 78	P - 78	M - 79	M - 79	L - 80	V - 81		
Bus Priorities		T - 78	P - 78	M - 79	M - 79	L - 80	V - 81		

Legend

Responsibilities:
- M = MOPT
- P = DGP
- T = DGTA
- V = DGV
- C = City of San Jose
- L = Legal Department MOPT

Timing:
- 75 - 82 = 1975 - 1982


Siquirres / Tibas System
Alajuelita / Santa Ana Systems
Zapote / Desamparados
PENITENCIARIA CENTRAL
CALLE 30
CALLE 20
AVENIDA 28
LEGEND
Dispersal & Bus Priority Systems
CBD Bypass
CBD Control Plan
MINISTRY OF PUBLIC WORKS & TRANSPORTATION
ALAN M. VOORHEES & ASSOCIATES
SAN JOSE AREA IMPLEMENTATION STUDIES
STAGE II
IMPLEMENTATION PROJECT LOCATIONS
FIGURE VII-1

right turns for vehicles on the bus street. This will virtually clear the right-hand lane for buses and give them priority at intersections, further discouraging other vehicles. Third, and finally, prohibit non-bus vehicles from using bus streets in accordance with the schedule in Table II-1. Even though the publicity that this recommendation has received has resulted in objections from part of the business community, none of these tasks is beyond the legal or physical capability of DGTA and in fact are merely an extension of the kind of traffic control measures they routinely use.

Bus Interlining — Bus interlining is a much more formidable task in that it requires dealing with, and possibly overcoming the objections of, the bus concessionaires. While the systemwide benefits has been amply demonstrated, it still remains to determine which bus owners will "suffer" under the system and by how much. The first task would be to select bus owner volunteers representing four to six existing bus lines to try interlining on an experimental basis. Should no volunteers appear, then the interlining must be undertaken over the objections of the bus owners. This should be followed by encouragement of large scale by a program of franchise incentives and perhaps, sanctions. Finally, interlining should be made mandatory through new special legislation.

Intersection Controls — Intersection controls are traffic operations tools which are routinely used by DGTA to assign right-of-way at specific locations. None of the controls anticipated under the CBD Traffic Control Plan require more than the erection of a sign or traffic signal.

Street Pattern — The one-way street pattern which is a part of the CBD Control Plan can be implemented by policy by DGTA.

Parking — There are two aspects to central area parking, one of which is easy to implement and the other rather more difficult. They may respectively be referred to as on-street and comprehensive.

On-street parking is the responsibility of the Municipality of San Jose. The CBD Control Plan indicates that a significant amount of the present on-street parking should be removed by 1980. This concept has been put forth to municipal officials in the past, when they sat on the Steering Committee of ETAMSJ, and they expressed agreement.

Comprehensive parking, on-street and off-, public and private is a much more complicated matter and implementing good comprehensive parking will need to begin with a study. The elements of the study, to be supervised by DGP, cooperatively with DGTA, are:

1. Designate a Central Parking Area
2. Inventory and update parking data
3. Establish necessary coordination with public and private CBD development plans
4. Estimate future land use, parking requirements, and on-street parking losses
5. Develop a policy for parking type and location
6. Develop organizational and legislative requirements for implementation

Technical assistance in the form of a consultant or technical expert will be needed for this study, which may take about a year.

7.1.2 CBD Traffic Signal System

The steps required for implementation of the CBD Traffic Signal System may be summarized as:

1. Obtain qualifications from contractors
2. Publish a list of qualified bidders
3. Solicit bids
4. Obtain technical assistance for implementation supervision
5. Let and supervise a turn-key construction contract

Implicit in the above is the understanding that an additional task, concurrent with the others, is the budgeting and financing of the project. With its very favorable

rate of return, international financing may not be difficult to obtain. All this is the direct responsibility of DGTA.

7.1.3 CBD Bypass

The implementation of the CBD bypass, like the CBD signal system, is a civil work of significant capital investment. The steps of implementation, however, differ in that the bypass has only progressed to preliminary engineering, whereas the signal system has reached final design. Since the CBD bypass consists of four legs, only three of which appear feasible at this time, the implementation tasks really apply to three subprojects which may be implemented at different times. Nonetheless, the tasks to implement each are the same.

First Task — The first task is to perform the final design studies using more accurate base maps than have been obtainable and more complete detailing of construction quantities required. DGV can and should design this as it does other road and street constructions.

Second Task — Using the refined data from the final design, DGP would then revise the economic evaluation of the project or subproject. This evaluation would presumably be input for either the MOPT budget or the basis for application for external financing.

Third Task — Regardless of the source of funds, the budgeting and financing are the next steps toward implementation. The executive offices of MOPT would have responsibility for this task.

Fourth Task — Simultaneously with or very shortly after the third task should be the acquisition of right-of-way by the Legal Department of MOPT.

Fifth Task — The final task is to let a contract for, and supervise the construction of, each part of the project.

7.1.4 The Dispersal Systems

The dispersal systems vary from typical street construction or widening projects in that certain of the constructed or improved lanes will be set aside for the exclusive use of buses. The ultimate use of the bus-only facilities does not affect the implementation tasks used to bring them into being except that DGTA needs to review final designs. The tasks for implementation are similar to those for the bypass discussed above.

First Task — Final design, wtih review by DGTA to guarantee good design for bus operations—basically a DGV responsibility.

Second Task — Based on the final design, DGTA should undertake preparation of plans to enforce bus priority features. This would include the development of a scheme of traffic control devices plus training of traffic police.

Third Task — Revised Economic Analysis—done by DGP.

Fourth Task — Enter project into the budget and/or arrange for financing; the work of MOPT executive offices.

Fifth Task — Acquisition of right-of-way by the Legal Department of MOPT.

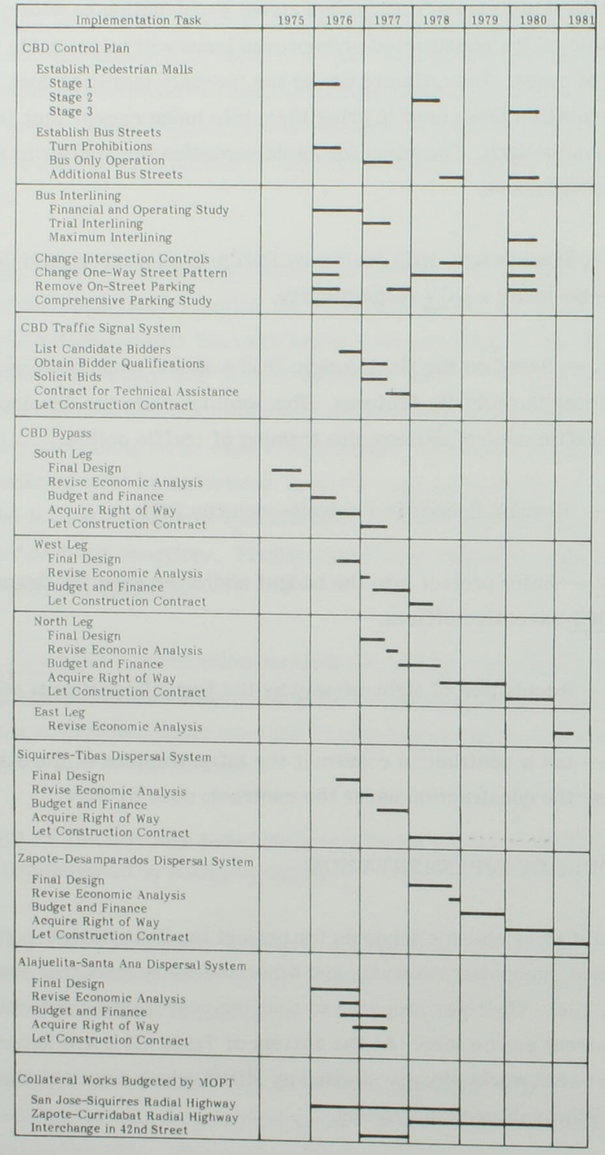
Sixth Task — Let a contract to construct the infrastructure of the dispersal system and supervise the construction under the contract; done by DGV.

7.2 SCHEDULE OF IMPLEMENTATION

It is important to establish a schedule for project implementation so that budgets can be planned, manpower reserved, and other necessary resources assembled. To this end, Table VII–2 was prepared so that the year-by-year activities which should be current can be seen. At the bottom of Table VII–2 are listed some of the pertinent civil works already planned by MOPT which relate to the work on the radial highway dispersion systems.

TABLE VII-2

IMPLEMENTATION TASK SCHEDULE



7.3 PERSONNEL REQUIREMENTS

The works recommended here represent projects of three types, each of which is the province of one of the sections of MOPT. These are projects which involve only traffic operation, policies and equipment, which can be and have been the responsibility of DGTA. Other projects are regular roadway constructions and are common to the work of DGV. Finally, several studies need to be made to advance ideas to the project stage. These studies should probably by supervised by DGP, as has been past practice.

7.3.1 DGTA

Personnel requirements related to the traffic signal recommendations fall on DGTA. As stated in Chapter III, three additional signal engineer positions are recommended, relating respectively to the traffic control center. The traffic signal systems field center, the traffic signal systems field hardware, and the non-CBD traffic signals. Each of these professional level positions should be supported by one sub-professional engineering aide position, resulting in a net increase of 36 professional and 36 sub-professional man-months each year.

The operational changes in the CBD and the bus priority functions of the radial dispersion systems will accrue to the Department of Traffic Engineering. This department, with its diverse functions and nationwide responsibilities, is severely understaffed. Two more professional engineers are needed in this Department, one to assist with all the operational changes to take place in San Jose and the other to specialize in transit operations and transit priority applications. The latter will have to deal specifically with the tasks and studies associated with bus route interlining.

The organizational structure of DGTA should be noted in respect to the work to be undertaken. The recent reorganization of DGTA into Engineering and Administration Sub-Directions is a much improved structure and should serve well to accomplish the necessary tasks.

7.3.2 DGP

The main work of DGP resulting from these recommendations will be to supervise the studies of CBD parking and to revise the economic evaluation of construction projects as better cost estimates are obtained as a result of final design. The organization of DGP into departments for Economics, Project Evaluation, and Basic Studies is well suited to this work. Personnel requirements for this work consists of six to ten man-months of work in revising economic evaluations over the next four years and about 16 man-months of professional effort in collaborating on the transit and parking studies. It is in this later area that additional engineering manpower could be profitably used. A separate Urban Transport Planning Sub-Direction should be inaugurated within DGP to deal with ongoing transportation planning in San Jose.[1]

7.3.3 DGV

The DGV will undertake the design and construction supervision of some ₡ 17 million of construction over the next six years if all the projects recommended here are built. This represents a special challenge, since the work is virtually all urban in character. As urban design and design standards are becoming a more significant factor in DGV work, it is recommended that one engineer-designer from DGV be given the responsiblity and training to develop an urban design section or team to address metropolitan San Jose or other urban area projects. Whether this position is staffed from within DGV or a person recruited from outside, it represents a recommendation for a net increase of one professional staff members for DGV.

[1] See Chapter IX ETAMSJ Final Technical Report, July 1975.

Appendices

Appendix A
Methods Of Economic Analysis

The economic evaluations of the physical system changes and operational improvements which comprise the main sections of this report have required the development of specific economic methodologies and have included many detailed calculations. Much of this work has already been documented in a series of Technical Working Papers and Progress Reports which have been issued during the course of the study. While this appendix is intended to provide a complete analytical background, it summarizes to some extent material already submitted and presents in greater detail additional analyses applicable to the Final Report. Main topical headings are:

- Basic Operating and Congestion Costs
- Time Value Consideration
- Traffic Signal System Analysis
- Analysis of the CBD Bypass
- Analysis of Traffic Dispersal Systems Including Bus Priorities
- Effects of Varying Economic Life

BASIC OPERATING AND CONGESTION COSTS

The basic operating costs of typical motor vehicles in Costa Rica were estimated in the initial phase of this study by the staff of the Direccion General de Planificacion in conjunction with the Consultant. These costs have been reviewed again, modified as deemed appropriate (and as described below) and compared for reasonableness with similar costs developed in Panama late in 1974. Operating cost equations were then developed to permit the calculations of direct economic operating costs as a function of overall travel speed under urban congested conditions in Costa Rica.

Financial Operating Cost Comparisons

The Costa Rican (automobile financial) operating costs in Table A–1 have been abstracted from Table IV–9 of Progress Report No. 4 dated May 1, 1975, and are as developed in the initial phase with one important modification; as originally calculated, the depreciation charge was based on an entirely new vehicle fleet while the depreciation charges included in the costs of Table A–1 are 50 percent of the original allocations to reflect a vehicle fleet actually, on the average, five or six years old.

TABLE A–1

FINANCIAL OPERATING COSTS OF AUTOMOBILES
LEVEL TANGENT PAVED ROADS

Speed (kph)	Financial Operating Costs: Costa Rica Colones/km	Costa Rica U.S. Cents/km	Panama U.S. Cents/km	Ratios: Costa Rica to Panama
10	0.645	7.50	N.A.	—
20	0.479	5.57	N.A.	—
30	0.431	5.01	6.25	0.80
40	0.410	4.77	5.59	0.85
50	0.405	4.71	5.27	0.89

Currency conversion — 1 colon = 11.63 U.S. (Panama) cents.

Sources and References — Files of Direccion General de Planificacion. Table IV–9 of Progress Report No. 4 (May 1, 1975), "Highway Feasibility Study of Tocumen-Chorrera," BERGER-CODISA, January 20, 1975, is the source of Panamian costs.

The comparisons of Table A–1 support a conclusion that typical Costa Rican automobile operating costs, as modified, are reasonable (if not conservative) by the standard of a credible relationship with similar costs developed independently in Panama during the same time period.

An analogous comparison has been prepared for Costa Rican truck financial operating costs. (The Costa Rican costs, as originally calculated, have been modified to reduce the depreciation charges by 50 percent and to eliminate the driver's wage cost.) This comparison is given in Table A–2.

TABLE A–2

FINANCIAL OPERATING COSTS OF TRUCKS
LEVEL TANGENT PAVED ROADS

Speed (kph)	Financial Operating Costs: Costa Rica Colones/km	Costa Rica U.S. Cents/km	Panama U.S. Cents/km	Ratios: Costa Rica to Panama
10	0.931	10.83	N.A.	—
20	0.739	8.59	N.A.	—
30	0.683	7.94	11.10	0.72
40	0.677	7.87	10.74	0.73
50	0.696	8.09	10.88	0.74

Additional Reference: Table IV–11 of Progress Report No. 4, May 1, 1975.

As in the case of automobiles, the comparison between Costa Rican and Panamanian truck financial operating costs appears reasonable, and, given the variations in the two vehicle fleets and cost factors, suitable for the purposes of this report.

In the initial study phase, a third vehicle category, "buses," was developed; this grouping has been eliminated in the present analysis, and the cost factors developed for trucks have been used for buses. There are two valid reasons for this procedure. Because buses are only a small proportion of the total vehicle fleet in developed countries, the references often used in field work do not separate buses as a distinct vehicle category with specific operating characteristics. A second, more persuasive reason, is that buses in Costa Rica and Central America generally are of the "school bus" type, bus coachwork mounted on a truck chassis, so that they generally

correspond with six-wheel trucks in overall characteristics. In subsequent discussions, the single category, "trucks/buses," will be considered.

Economic Operating Costs in Costa Rica

Table A–3 shows the economic costs of automobile operations in Costa Rica at different speeds. This table is based on Table 2 of Technical Working Paper No. 22, "Economic Analysis of Projects," with depreciation at 50 percent of the level previously used.

Similar cost data for the truck/bus category derived from Table 3 of Technical Working Paper No. 22 (without driver's wage and with depreciation at 50 percent of the original level) are reproduced as Table A–4.

Direct comparisons between operating cost elements and total economic costs in Costa Rica and Panama are not possible since only Panamanian financial cost data are available. Based on the financial cost comparisons already provided, and, judgmentally, on the overall magnitudes of the economic operating costs obtained, these costs can be considered realistic.

Congestion Cost Relationships — Costa Rica

The development of cost equations suitable for deriving vehicle economic operating costs at different speed levels under congested conditions in Costa Rica involved a two-step procedure. The first step was the determination of the general relationship between costs at different speeds based on studies in other countries;[1] the second step required the development of symmetrical relationships based on the economic costs in Costa Rica.

Costs under congested conditions at different speeds from the two sources are shown as index numbers in Table A–5. Considering the widely different, independent sources and differing methodologies, the comparability of the Australian and

[1] "Cost of Urban Car Travel," Australian Road Research Board, Special Report No. 5, 1970, and the already cited "High Feasibility Study of Tocumen-Chorrera, Berger-Cadisa," January 20, 1975.

TABLE A–3

ECONOMIC OPERATING COSTS OF AUTOMOBILES
LEVEL TANGENT PAVED ROADS

Cost Elements	Selected Speeds (colones/kilometer) 10 kph	20 kph	30 kph	50 kph
Motor Fuel	₡0.274	₡0.175	₡0.148	₡0.134
Tires	0.004	0.009	0.014	0.027
Oil	0.014	0.008	0.006	0.006
Maintenance	0.032	0.033	0.035	0.040
Depreciation	0.090	0.077	0.068	0.056
TOTAL	₡0.414	₡0.302	₡0.271	₡0.263
TOTAL (U.S. Cents)	4.81¢	3.51¢	3.15¢	3.05¢

x1.3

TABLE A–4

ECONOMIC OPERATING COSTS OF TRUCKS/BUSES
LEVEL TANGENT PAVED ROADS

Cost Elements	Selected Speeds (colones/kilometer) 10 kph	20 kph	30 kph	50 kph
Motor Fuel	₡0.412	₡0.282	₡0.243	₡0.224
Tires	0.015	0.032	0.050	0.093
Oil	0.036	0.023	0.019	0.016
Maintenance	0.119	0.119	0.125	0.146
Depreciation	0.321	0.248	0.207	0.165
TOTAL	₡0.903	₡0.704	₡0.644	₡0.644
TOTAL (U.S. Cents)	10.50¢	8.19¢	7.49¢	7.49¢

x1.3

TABLE A–5

COMPARISON OF CONGESTION COST INDICES

Travel Speeds		Congestion Cost Indices					
		Australia			Panama		
mph	kph	(A)	(B)	(C)	(D)	(E)	(F)
5	8.0	1.98	1.92	1.88	1.88	1.84	1.69
8	12.8	1.45	1.42	1.40	1.40	1.38	1.31
12	19.2	1.15	1.14	1.13	1.13	1.13	1.10
16	25.6	1.00	1.00	1.00	1.00	1.00	1.00
20	32.0	0.91	0.92	0.92	0.92	0.92	0.94
24	38.4	0.85	0.86	0.87	0.87	0.87	0.90
28	44.8	0.81	0.82	0.83	0.83	0.84	0.87

Sources: (Australia) "Cost of Urban Car Travel." Australian Road Research Board Special Report No. 5, 1970.

(A) AUTO, GW 20001b, Report Table XXII

(B) AUTO, GW 25001b, Report Table XXIV

(C) AUTO, GW 30001b, Report Table XXVI

(Panama) "Highway Feasibility Study of Tocumen-Chorrea," BERGER-CODISA, January 20, 1975.

(D) TYPICAL AUTO

(E) PICK-UPS, PANEL TRUCKS

(F) MEDIUM TRUCKS/BUSES

Equations:

Y = financial cost, U.S. cents/km
X = travel speed (kph)

For (D): $Y = 6.59 + \frac{113.4}{x}$

For (F): $Y = 15.8 + \frac{184.2}{x}$

Panamanian indices is remarkable. The equations for Panamanian autos (D) and medium trucks/ buses (F) are the bases for the Costa Rican cost curves.

The relationships between level tangent paved road operating costs (financial costs in Panama, economic costs in Costa Rica can be tabulated as shown in Table A–6 for autos and trucks/buses.

TABLE A–6

RATIOS: COSTA RICAN ECONOMIC COSTS TO PANAMANIAN FINANCIAL COSTS

Speed (kph)	Ratios	
	Autos	Trucks/Buses
30	0.50	0.67
40	0.54	0.68
50	0.58	0.69

Note: From Tables IV–10 and IV–12 of Progress Report No. 4, May 1, 1975.

The "reference" speeds used in calculating depreciation costs in Costa Rica were 40 kph for trucks/buses and 48/50 kph for autos. At this speed level, depreciation charges are the same whether such charges are considered speed-related or invariant with speed. The ratios at these inflection points, 0.58 for autos and 0.68 for trucks/buses, were selected to adjust the Panamanian (financial) congestion cost equations to give Costa Rican economic costs. Since one colon is equivalent to 11.63 U.S. (or Panamanian) cents, the equations from Table A–5 can be rewritten for Costa Rica:

Y = Economic Operating Cost (colones/kilometer)

X = Overall Travel Speed (kph)

Autos

$$Y = 6.59 \left(\frac{0.58}{11.63}\right) + \frac{113.4}{x} \left(\frac{0.58}{11.63}\right)$$

$$Y = 0.329 + \frac{5.66}{x}; \text{ Equation One}$$

Trucks/Buses

$$Y = 15.8 \left(\frac{0.68}{11.63}\right) + \frac{184.2}{x} \left(\frac{0.68}{11.63}\right)$$

$$Y = 0.924 + \frac{10.77}{x}; \text{ Equation Two}$$

In many of the urban traffic networks, the vehicle stream consists of 97 percent passenger cars and 3 percent trucks. Proportionate combination of the foregoing equations yields:

$$Y = .347 + \frac{5.81}{x}; \text{ Equation Three}$$

TIME VALUE CONSIDERATIONS

In economic analyses, a value is often ascribed to time savings as a criterion for appraising the absolute feasibility of projects or for making a selection among alternative proposals. In an urban situation, such as in San Jose, significantly large "time-savings" can be calculated which reflect small time savings distributed among large numbers of auto and bus passengers. Under these circumstances, while time savings have been estimated and included in the analyses, their ultimate usefulness in economic evaluation must be considered limited.

The factors used in calculating time values are tabulated in Table A–7.

TABLE A–7

FACTORS USED IN TIME VALUE CALCULATIONS

Cost Factor	Units	Quantity
Average Wage Rate	Colones/Hour	₡5.25
Truck Driver Wage	Colones/Hour	₡3.80
Bus Driver Wage	Colones/Hour	₡3.95
Auto Occupants	Persons/Car	1.9
Bus Passengers	Passengers/Bus	40

The average Costa Rican wage rate was determined in the initial phase of the study; bus and truck driver wages are the legal minimums as of December 5, 1974; auto occupants and bus passengers were determined from traffic surveys and cordon counts carried out in San Jose. The egalitarian assumption has been made that the travel time of both auto occupants and bus passengers can be valued at 25 percent of the average wage rate. Finally, the auto/truck vehicle stream is composed of 97 percent autos and 3 percent trucks.

Time-related hourly costs can be calculated as:

		Colones/Hour
Auto/Truck Traffic		
Autos — ₡5.25 x .25 x 1.9 x 0.97	=	₡ 2.419
Trucks — ₡3.80 x 0.03	=	0.114
		₡ 2.533
Buses — ₡3.95 + 40 x ₡5.25 x .25	=	₡56.450

The foregoing values have been used throughout the study to assess the cost of time and time-savings.

TRAFFIC SIGNAL SYSTEM ANALYSIS

The economic benefits of the contemplated alternative signal system improvements were determined by comparing operating and time costs under the improved conditions with the cost performance of the existing system. (Chapter III describes the physical characteristics of the systems, the applicability of the TRANSYT Model, and the selection of the sample network for analysis.) Using the TRANSYT Model output, total benefits for base year 1976 were first determined, and projected annually in proportion to anticipated traffic levels over the nominal 12-year system life.

The TRANSYT Model Output and Cost Calculations

Given inputs such as vehicle (moving) speeds, traffic volumes, and link distances, the TRANSYT Model provides, as output, the system parameters shown in Table A–8. (The example shown is an optimized Sunday nighttime hour used in subsequent calculations.) Two alternative operating cost calculations are shown, a direct method based on the TRANSYT overall travel speed output and the cost equations previously developed in this appendix, and an alternate method which involves the calculation, as discrete entities, of the moving cost, stopping cost, and idling cost as estimated from Winfrey relationships. (The latter method is the original methodology proposed and is described in considerable detail in Chapter VI of Progress Report No. 2.) The operating costs calculated by the different methods are in substantial agreement (about 4 percent difference), but the direct method has a considerable advantage in ease of application and more reproducible results over wide speed ranges. (It is virtually impossible to calculate the economic effects of small speed changes by interpolation of Winfrey data which are provided in 5 mph (8 kph) increments.) The direct method thus represents a significant improvement in technique over the methodology originally contemplated and has been used throughout the traffic signal system analysis.

The TRANSYT output and the foregoing methodology permit direct comparison of operating (and time) costs of the null ("do-nothing") condition and two alternative candidate signal systems, an optimized system[1] and a more rudimentary three-dial system. Operating and time costs were calculated for 18 typical time periods selected to represent the annual range of traffic conditions in San Jose. The results of these calculations are shown in Table A–9 which is the basis for summary Tables A–10 and A–11; Table A–10 compares the null condition with the optimized condition; Table A–11 compares the null condition with the three-dial signal system.

The optimized signal system provides a 6.1 percent improvement (savings, benefits) in auto/truck operating costs; the corresponding improvement for buses is 11.2 percent.

[1] Or one that has a very large number of timing control strategies that can be called into operation depending on traffic conditions.

TABLE A–8

EXAMPLE OF TRANSYT MODEL OUTPUT
SUNDAY NIGHTTIME HOUR-OPTIMIZED-1976

Item	Parameter	Units	Buses	Other	Total
1	Total Distance Traveled	Vehicle-km/hr.	48.47	1,161.65	1,200.12
2	Total Time Spent	Vehicle-hrs./hr.	4.68	50.77	55.45
3	Total Uniform Delay	Vehicle-hrs./hr.	0.37	17.39	17.76
4	Total Random Delay	Vehicle-hrs./hr.	0.02	0.61	0.63
5	Total Stops	Vehicles/second	0.05	1.74	1.79
6	Speeds (Overall)	Kilometers/hr.	10.35	22.68	21.64
	Derived Parameters[1]				
7	Moving Speed[2]	Kilometers/hr.	11.30	35.14	32.38
8	Number of Stops	Stops/hr.	180	6,264	6,444
9	Time per Stop (Average)	Seconds/stop	7.80	10.30	10.30

Notes:

[1] Derived from TRANSYT Output as described in Table 1, Chapter VI, Progress Report No. 2.

[2] Element of TRANSYT Input, also calculable from Output.

Calculation of Operating Cost Directly from TRANSYT Output (Automobile/Truck as Example)

1. Unit Operating Cost can be calculated from Equation 3. (Speed from Line 6)

$$Y = 0.347 + \frac{5.81}{x} \; ; = 0.347 + \frac{5.81}{22.68} = 0.603 \text{ ¢/km}$$

2. Total distance = 1,151.65 x 0.603 = ¢694.44/nighttime hour
(Note that time costs are calculable as the product of Line 2 and the unit time values developed in the calculations following Table A–7.)

Alternate Calculation of Automobile/Truck, Operating Costs

(Original methodology developed in Chapter VI, Progress Report No. 2, January 1, 1975)

Operating Costs on level tangent paved roads (97 percent autos, 3 percent trucks) can be developed from Tables IV–10 and IV–12 of Progress Report No. 4 at speed of 35.14 kph as 0.278 colones/km.

Excess cost of stops (from Winfrey Tables A–1 and A–8) = 21.4 percent of cost on level tangent paved road.

Idling cost is 12.91 percent of running cost (per hour) at 40 kph (Progress Report No. 2).

1. Moving cost = 1,151.65 x 0.278 = 320.2 colones

2. Stopping cost = 6,264 x 0.214 x .278 = 372.7 colones

3. Idling cost = 40 x .278 x .1291 x (17.39 + 0.61) = 25.8 colones

TOTAL 718.7 colones

Automobile Operating Cost — Sunday night hour

Direct Method	694.4 colones
Original Method	718.7 colones

TABLE A-9

CALCULATION OF HOURLY OPERATING AND TIME COSTS
TYPICAL HOUR COSTS (ANNUALIZED) BASE YEAR 1976

NULL CONDITION (EXISTING SIGNAL SYSTEM)

Number	Time Period	Number of Hours	Percent of Year (hrs.)	Vehicle-km/hr.		Overall Travel Speeds (km/hr.)		Annual Op. Cost (¢/year)		Annual Time Cost (¢/year)	
				Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses
	Normal Weekdays										
1	A.M. Peak	855	9.76	3,574.37	129.45	12.30	18.22	2,504,028	247,283	629,355	760,082
2	Midday	442	5.05	2,954.64	96.65	13.46	8.01	1,016,878	96,911	245,763	301,062
3	P.M. Peak	684	7.81	3,618.37	96.65	10.85	7.80	2,184,117	152,365	577,796	478,440
4	Evening	684	7.81	2,650.25	96.65	14.32	8.11	1,364,520	148,876	320,653	460,152
5	Night	2,682	30.62	1,282.75	4.55	18.35	9.07	2,283,080	25,766	474,898	75,950
	Saturdays										
6	A.M. Peak	235	2.68	3,281.41	96.65	13.54	8.00	589,474	51,564	144,260	160,267
7	Midday	94	1.07	3,208.93	96.65	12.64	7.92	243,318	20,749	60,447	64,754
8	P.M. Peak	508	5.80	3,179.27	65.49	12.53	7.60	1,809,316	77,886	326,494	247,109
9	Evening	388	4.43	2,396.50	96.65	15.45	8.24	672,324	83,664	152,446	256,904
	Sundays										
10	A.M. Peak	260	2.97	2,320.18	96.65	16.67	8.39	432,994	55,477	97,513	169,074
11	Midday	104	1.19	2,199.08	96.65	16.73	8.49	158,785	22,039	34,627	66,833
12	P.M. Peak	208	2.37	2,261.40	96.65	16.71	8.48	326,765	44,107	71,302	133,824
13	Evening	298	3.40	1,939.14	96.65	18.27	8.82	384,284	61,782	80,117	184,337
14	Night	738	8.43	1,151.65	48.47	19.53	8.96	547,764	76,049	110,233	225,364
	Christmas Holidays										
15	A.M. Peak	150	1.71	3,865.64	96.65	11.49	7.83	494,410	33,337	127,829	104,519
16	Midday	60	0.68	3,462.15	96.65	11.75	7.85	174,797	13,314	44,781	41,701
17	P.M. Peak	120	1.37	3,894.53	96.65	10.17	7.70	429,156	26,939	116,399	85,027
	School Vacation										
18	A.M. Peak	250	2.85	3,143.68	96.65	14.16	8.09	595,186	54,493	140,589	168,600

Note: Vehicle-kilometers and overall travel speeds from TRANSYT Output.

Table A–9, Continued

OPTIMIZED CONDITION

Number	Time Period	Number of Hours	Percent of Year (hrs.)	Vehicle-km/hr.		Overall Travel Speeds (km/hr.)		Annual Op. Cost (¢/year)		Annual Time Cost (¢/year)	
				Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses
	Normal Weekdays										
1	A.M. Peak	855	9.76	3,574.37	129.45	13.72	10.62	2,354,621	214,511	564,218	588,312
2	Midday	442	5.05	2,954.64	96.65	14.98	9.95	959,679	85,713	220,826	242,362
3	P.M. Peak	684	7.81	3,618.37	96.65	11.96	9.83	2,061,116	133,515	524,171	379,637
4	Evening	684	7.81	2,650.25	96.65	16.16	10.29	1,280,777	130,277	284,143	362,666
5	Night	2,682	30.62	1,282.75	4.55	21.48	10.02	2,124,353	24,392	405,381	68,749
	Saturdays										
6	A.M. Peak	235	2.68	3,281.41	96.65	15.13	9.86	563,701	45,796	129,100	130,034
7	Midday	94	1.07	3,208.93	96.65	13.96	10.22	230,208	17,969	54,732	50,181
8	P.M. Peak	508	5.00	3,179.27	65.49	14.09	8.22	1,226,401	74,330	290,346	228,471
9	Evening	388	4.43	2,396.50	96.65	17.49	10.26	631,539	74,014	134,665	206,324
	Sundays										
10	A.M. Peak	260	2.97	2,820.18	96.65	17.96	10.26	404,475	49,597	85,079	138,258
11	Midday	104	1.19	2,199.08	96.65	19.13	10.42	148,821	19,677	10,283	54,454
12	P.M. Peak	208	2.37	2,261.40	96.65	19.42	10.23	303,943	39,740	61,352	110,931
13	Evening	298	3.40	1,939.14	96.65	21.17	10.38	359,111	56,497	69,142	156,634
14	Night	738	8.43	1,151.65	48.47	22.68	10.35	512,647	70,275	94,922	195,098
	Christmas Holidays										
15	A.M. Peak	150	1.71	3,865.64	96.65	12.62	9.74	468,156	29,426	116,383	84,023
16	Midday	60	0.68	3,462.15	96.65	13.02	9.96	164,778	11,629	40,413	32,867
17	P.M. Peak	120	1.37	3,894.53	96.65	11.01	10.03	408,786	23,170	107,519	65,275
	School Vacation										
18	A.M. Peak	250	2.85	3,143.68	96.65	15.93	10.23	559,355	47,764	124,968	133,331

Note: Vehicle-kilometers and overall travel speeds from TRANSYT Output.

Table A–9, Continued

THREE-DIAL SYSTEM

Number	Time Period	Number of Hours	Percent of Year (hrs.)	Vehicle-km/hr.		Overall Travel Speeds (km/hr.)		Annual Op. Cost (¢/year)		Annual Time Cost (¢/year)	
				Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses	Autos/Trucks	Buses
	Normal Weekdays										
1	A.M. Peak	855	9.76	3,574.37	129.45	13.15	10.54	2,410,718	216,337	588,674	597,882
2	Midday	442	5.05	2,954.64	96.65	13.76	9.71	1,004,588	86,855	240,405	248,353
3	P.M. Peak	684	7.81	3,618.37	96.65	11.53	9.28	2,105,955	137,807	543,720	402,137
4	Evening	684	7.81	2,650.25	96.65	14.52	10.02	1,354,390	132,141	316,236	372,438
5	Night	2,682	30.62	1,282.75	4.55	19.21	9.55	2,234,314	18,640	453,637	72,132
	Saturdays										
6	A.M. Peak	235	2.68	3,281.41	96.65	14.12	9.52	584,882	46,682	138,334	134,678
7	Midday	94	1.07	3,208.93	96.65	13.20	9.56	237,436	100,679	57,883	53,646
8	P.M. Peak	508	5.80	3,179.27	65.49	13.18	10.28	1,272,383	65,595	310,392	182,688
9	Evening	388	4.43	2,396.50	96.65	15.50	10.09	671,196	74,678	151,954	209,800
	Sundays										
10	A.M. Peak	260	2.97	2,320.18	96.65	15.73	10.14	432,141	49,909	97,141	139,895
11	Midday	104	1.19	2,199.08	96.65	16.55	10.15	159,649	19,953	35,004	55,903
12	P.M. Peak	208	2.37	2,261.40	96.65	16.62	10.15	327,651	39,907	71,688	111,805
13	Evening	298	3.40	1,939.14	96.65	17.84	10.22	388,713	56,964	82,048	159,086
14	Night	738	8.43	1,151.65	48.47	20.27	9.38	538,534	74,124	106,208	215,273
	Christmas Holidays										
15	A.M. Peak	150	1.71	3,865.64	96.65	12.20	9.23	477,346	30,312	120,389	88,666
16	Midday	60	0.68	3,462.15	96.65	12.46	9.46	168,944	11,960	42,229	34,604
17	P.M. Peak	120	1.37	3,894.53	96.65	10.70	8.88	415,931	24,783	110,634	73,728
	School Vacation										
18	A.M. Peak	250	2.85	3,143.68	96.65	14.87	9.68	579,789	49,209	133,876	140,906

Note: Vehicle-kilometers and overall travel speeds from TRANSYT Output.

TABLE A–10

NULL CONDITION VERSUS OPTIMIZED CONDITION
YEAR 1976

Item	Null	Optimized	Improvement KPH	Improvement Percent
Overall Speeds (kph)				
Autos/Trucks	13.81	15.62	1.81	13
Buses	8.17	10.08	1.91	23
	(Thousands of Colones)			
Direct Operating Costs				
Autos/Trucks	₡15,720.2	₡14,762.5	₡ 957.7	
Buses	1,292.6	1,148.3	144.3	
Subtotal	₡17,012.8	₡15,910.8	₡1,102.0	
Time Costs				
Autos/Trucks	₡ 3,755.5	₡ 3,337.6	₡ 417.9	
Buses	3,984.0	3,227.6	756.4	
Subtotal	₡ 7,739.5	₡ 6,565.2	₡1,174.3	
Cost Summary				
Autos/Trucks	₡19,475.7	₡18,100.1	₡1,375.6	
Buses	5,276.6	4,375.9	900.7	
TOTAL	₡24,752.3	₡22,476.0	₡2,276.3	

Note: Cost and savings for model only — not total network.

TABLE A–11

NULL CONDITION VERSUS THREE-DIAL SYSTEM (1976)

Item	Null	Three-Dial	Improvement KPH	Improvement Percent
Overall Speeds (kph)				
Autos/Trucks	13.81	14.41	0.60	4.3
Buses	8.17	9.88	1.71	20.9
	(Thousands of Colones)			
Direct Operating Costs				
Autos/ Trucks	₡15,720.2	₡15,364.6	₡ 355.6	
Buses	1,292.6	1,236.4	56.2	
Subtotal	₡17,012.8	₡16,601.0	₡ 411.8	
Time Costs				
Autos/Trucks	₡ 3,755.5	₡ 3,600.5	₡ 155.0	
Buses	3,984.0	3,293.6	690.4	
Subtotal	₡ 7,739.5	₡ 6,894.1	₡ 845.4	
Cost Summary				
Autos/Trucks	₡19,475.7	₡18,965.1	₡ 510.6	
Buses	5,276.6	4,530.0	746.6	
TOTAL	₡24,752.3	₡23,495.1	₡1,257.2	

Note: Costs and savings for model only -- not total network.

Total operating cost benefits in the base year are 1.1 million colones. Substantial time value savings are also achieved, some 19 percent in the case of buses.

While the three-dial system provides cost savings over the existing system, operating cost savings are only some 37.4 percent of the savings possible with the optimized system. Total benefits (operating cost and time savings for auto/trucks and buses) are 55 percent of the savings attainable with the optimized signal system.

Benefits in Future Years

Additional TRANSYT Peak-Hour Runs were made to check two fundamental premises— first, the ability of the optimized signal system to continue to provide benefits as traffic volumes increase, and second, to determine the relationship between traffic volumes and operating and time benefits. The results of these runs are summarized briefly in Table A–12 which compares the ratios of operating cost and time benefits with vehicle kilometers in the peak-hour period of selected future years.

TABLE A–12

VEHICLE-KILOMETER, OPERATING AND TIME BENEFIT RATIOS
PEAK HOURS, 1976, 1980, AND 1990
(NULL CONDITION VS. OPTIMIZED SYSTEM)

Item	Ratios 1976	Ratios 1980	Ratios 1990
Vehicle Kilometers	1.00	1.15	1.28
Operating Cost Benefits	1.00	1.06	1.15
Time Cost Benefits	1.00	1.19	1.30

The ratios indicate that while the optimized system continues to provide operating cost benefits as traffic increases, the benefits are less than directly proportional to the increased traffic. (More vehicles are receiving lower unit benefits.) Time

cost benefits increase at a somewhat greater rate than traffic volumes. Least-square trends were developed from these ratios to proportion benefits in future years relative to traffic volumes.

Traffic growth in the San Jose area served by the signal system is not expected to experience uninterrupted growth in future years because of traffic diverted to the circumferential highway. A graphical portrayal of the traffic growth trend appears as Figure II–1 in Progress Report No. 3, March 1, 1975. This forecast growth and the benefit/traffic relationships were used to calculate annual benefits in the 12-year forecast period of signal system life. The traffic and benefit factors used are shown in Table A–13.

TABLE A–13

TRAFFIC/BENEFIT FACTORS
(OPTIMIZED VS. NULL CONDITION, 1976 BASE YEAR)

	Traffic/Benefit Factors		
Year	Traffic	Operating Cost Benefit	Time Cost Benefit
1976	1.00	1.00	1.00
1977	1.04	1.01	1.05
1978	1.07	1.03	1.08
1979	1.11	1.05	1.13
1980	1.15	1.06	1.19
1981	0.93	0.96	0.93
1982	0.97	0.98	0.98
1983	1.00	1.00	1.00
1984	1.04	1.01	1.05
1985	1.07	1.03	1.08
1986	1.11	1.05	1.13
1987	1.15	1.06	1.19

Measures of Economic Feasibility

The TRANSYT Model, as heretofore discussed, includes 24 percent of the total signal system to be improved. (Chapter III describes and elaborates the criteria used to select this sampling.) Total benefits are thus estimated at 4.16 times the benefits calculated directly from the TRANSYT output. This factor, together with the benefits calculated in Tables A–10 and A–11 and the annualizing factors of Table A–13, permit the calculation of discounted and undiscounted benefits over the 12-year (1967-1987) system life.

TABLE A–14

DISCOUNTED AND UNDISCOUNTED BENEFITS
12-YEAR SYSTEM LIFE

	Benefits (Thousands of Colones)	
System	Discounted (12 Percent)	Undiscounted
Optimized System		
Operating Costs	₡28,899.5	₡ 56,112.2
Time Costs	32,083.2	62,577.6
TOTAL	₡60,982.7	₡118,689.8
Three-Dial System		
Operating Costs	₡10,799.3	₡ 20,968.2
Time Costs	23,097.3	45,050.8
TOTAL	₡33,896.6	₡ 66,019.0

(The benefits for the optimized signal system were calculated directly; the benefits for the three-dial system were related to the calculated benefits based on the 1976 relationships determined from Tables A–10 and A–11. This procedure tends to favor the three-dial system which is operationally the less flexible of the two alternatives.)

The capital costs of the alternate signal systems are ₡11,807,000 for the optimized system and ₡10,792,000 for the three-dial system. (While the three-dial system requires ₡2,000,000 less in central control equipment, this saving is offset by an additional ₡1,000,000 in local control equipment.) These capital costs have been used to calculate the measures of economic feasibility (see Table A-15).

The optimized alternative is demonstrably the preferred choice, although the three-dial system is at least marginally acceptable. Substantial time savings are also available; expressed as hours, these can be estimated for Alternative No. 3 as:

Bus passengers (and driver)

$$\frac{₡756.4 \times 4.16 \times 1{,}000 \times 41}{₡56.45} = 2.29 \text{ million hours in 1976}$$

Auto occupants

$$\frac{₡417.9 \times 4.16 \times 1{,}000 \times 1.9}{2.533} = 1.30 \text{ million hours in 1976}$$

Although the time savings above represent small unit savings distributed among large numbers of users, the total hourly savings are impressive.

ANALYSIS OF THE CBD BYPASS

The economic analysis of the CBD bypass was discussed at length and in considerable detail in Progress Report No. 4, May 1, 1975; specific reference can be made to Tables IV–11 through IV–23 and the accompanying text. Since that time, neither the physical systems, the economic evaluations, nor the conclusions derived therefrom have changed. A brief methodological summary seems sufficient and appropriate in this Appendix.

The criteria for selection of the bypass routes (and overall system objectives) have been described in Progress Reports No. 3 and No. 4 and in Chapter IV of this report. The study network consisted of 143 uni-directional network links, 41 in the four-leg bypass system itself and 102 in the city streets affected by diversion to the bypass. Traffic assignments from city streets to bypass routes were made on the

TABLE A–15

EVALUATION OF SIGNAL SYSTEM ALTERNATIVES

	System	
	Alternative No. 2 (Three-Dial)	Alternative No. 3 ((Optimized)
Capital Cost (thousands of colones)	10,792.0	11,807.0
Benefit Period (12 years)	1976-1987	1976-1987
Discounted Benefits—12 Percent (thousands of colones)		
Operating Cost Saving	10,799.3	28,899.5
Time Saving	23,097.3	32,083.2
Total	33,896.6	60,982.7
B/C Ratios		
Operating Cost Saving Only	1.0	2.46
Total Saving	3.14	5.16
IRR (percent)		
Operating Cost Saving Only	12	39
Total Saving	50	82
First-Year Benefit[1] (thousands of colones)		
Operating Cost Saving	1,713.1	4,584.3
Total Saving	5,230.0	9,469.4
First-Year Benefit (percent)		
Operating Cost Saving	15.9	38.8
Total Saving	48.5	80.2

Note:

[1]First-year benefits are developed by expanding the first-year benefits of Tables A–10 and A–11 to total network benefits.

basis of equalizing as far as possible the volume/capacity (V/C) ratios on complementary routes and links; the speed performance of each link at different traffic volumes was characterized by the development of speed vs. volume/capacity curves based on field surveys. (The curves used appear as Figures IV–2, IV–3, and IV–4 of Progress Report No. 4.) These inputs, together with link distances, provided the bases of the economic evaluation.

Given the "with and without" system parameters, overall travel speeds were developed for each link. These speeds in turn were used to calculate link travel times, and with the operating cost/speed equations developed in this Appendix, to compute operating costs in each link. Hourly benefits were converted to daily benefits, annualized, and projected for future years based on anticipated traffic volumes in San Jose.

The benefit analyses were based on an eight-year useful system life; the measures of economic feasibility on this basis, abstracted from Table IV–22 of Progress Report No. 4, are as shown in Table A–16. The reason the first year's benefits are estimated as higher than I.R.R. (internal rate of return) is because of the reduced traffic load in the CBD expected for a period after the Beltway opens.

TABLE A–16

MEASURES OF ECONOMIC FEASIBILITY — CBD BYPASS

	B/C Ratios		IRR (percent)		1st-Year Benefit (percent)	
Leg Analyzed	Op. Cost Saving	Total Saving	Op. Cost Saving	Total Saving	Op. Cost Saving	Total Saving
South Leg	3.56	5.10	65.0	>65.0	75.6	108.2
West Leg	0.80	1.12	3.5	13.0	15.1	21.7
North Leg	0.46	0.66	—	—	10.5	15.0
East Leg	0.15	0.22	—	—	3.4	4.8

Note: B/C ratios based on 12 percent discount factor.

As noted in Progress Report No. 4, "One project (the South leg) is very attractive because substantial benefits are achieved at minimal capital outlay. Another project (the West leg) can be considered marginal; it appears reasonably attractive only if time savings are included."

As can be noted in Tables A-25 and A-26 however, expending the number of years over which benefits are accumulated changes the measures such that the West leg becomes feasible even including benefits from time savings; the North leg becomes feasible if time savings plus operating savings are included; the East leg remains infeasible.

ANALYSIS OF TRAFFIC DISPERSAL BUS PRIORITY SYSTEMS

The methods used to perform the economic evaluations of the three traffic dispersal systems, both with and without bus priority, are basically the same as the procedures developed to evaluate both the alternative traffic signal systems and the four legs of the CBD bypass. The 1990 peak hour, representing the worst traffic condition in the realistically foreseeable future, was selected for detailed study with and without the proposed physical improvements and operational changes. Because operating cost and time saving benefits do not vary in direct proportion to traffic volumes, additional analyses were made at selected percentages of the peak-hour level. In all, a total of 1,145 link analyses were performed as shown in Table A–17.

Since the methodology of performing the link analyses has already been described, it may be useful at this point to explicate the dynamic performance of the physical systems (and operational changes) and the derivative economic effects. Since average operating speeds (null vs. improved conditions) are the most effective single indicators of system performance in terms of both operating and time costs, Table A–18 was prepared to indicate network speed changes with and without improvements. The example is the Alajuelita dispersal system both with and without bus priority.

Speeds of both autos and buses are increased by both the dispersal system alone and by the dispersal system with bus priority. The "with bus priority" system is

TABLE A–17

NUMBER OF LINK ANALYSES
DISPERSAL AND BUS PRIORITY SYSTEMS

Dispersal System	Number of Links	Number of Analyses	Total Link Analyses
Siquirres-Tibas	40	8	320
Zapote-Desamparados	34	9	306
Alajuelita-Santa Ana	46	9	414
42nd Street Expressway	35	3	105
TOTAL	155		1,145

the most effective in increasing speeds of both vehicle classes, buses benefitting more than autos as would be expected from the intent of system design.

Table A–18 also shows that reduced traffic levels, represented as percentages of the peak hour, are about equally effective in increasing travel speeds as the dispersal system with bus priority. As a final observation, the speed improvements at lower traffic levels are much less than during the peak hour. Because they occur at higher speeds (lower operating costs), system benefits at off-peak periods are only fractionally related to peak-hour benefits.

The economic implications of Table A–18 can be illustrated in Table A–19. The operating and time cost benefits (null vs. the preferred "with bus priority" dispersal) for Alajuelita are shown as a percentage of peak-hour benefits. Total benefits at 80 percent of peak-hour traffic are only about 17 percent of peak-hour benefits; at the 60 percent traffic level, the benefit percentage drops to 3.7 percent. It can also be noted that the percentage drop in bus benefits is less than for autos.

TABLE A–18

SPEED PERFORMANCE — ALAJUELITA DISPERSALS
OVERALL TRAVEL SPEEDS — KPH

Traffic Percent of Peak Hour	Vehicle Type	Existing Network Speed	Improved Systems Speeds	
			Dispersal Only	Dispersal and Bus Priority
100	Auto	23.41	38.86	42.27
	Bus	20.95	30.67	39.67
80	Auto	47.30	51.41	52.13
	Bus	40.66	43.95	51.17
60	Auto	55.45	57.04	57.70
	Bus	48.22	49.21	48.09

Traffic Percent of Peak Hour	Vehicle Type	Speed Improvement Over Existing Network			
		Absolute	Percent	Absolute	Percent
100	Auto	15.45	66.0	18.86	80.6
	Bus	9.72	46.4	18.72	89.4
80	Auto	4.11	8.7	4.83	10.2
	Bus	3.29	8.1	10.51	25.8
60	Auto	1.59	2.9	2.25	4.1
	Bus	0.99	2.1	4.87	10.1

Note: Autos include 3 percent trucks.

The level of benefits ascribed to autos compared with bus benefits is of interest. Table A–20 shows operating and time cost benefits (and applicable percentage distribution) for all the dispersal systems with bus priority. Except for Zapote-Desamparados, where low initial (null) bus speeds are susceptible to very great improvement, the autos receive the greater operating cost benefits because of

TABLE A–19

COMPARISONS OF HOURLY BENEFITS
AT DIFFERENT TRAFFIC LEVELS — ALAJUELITA

Type of Benefit	Traffic Level Percentage of Peak-Hour Benefit 100	80	60
Operating Cost Benefits			
Autos/Trucks	100	15.8	1.8
Buses	100	25.6	5.2
Total Op. Cost Benefits	100	18.2	2.6
Time Cost Benefits			
Autos/Trucks	100	8.2	2.2
Buses	100	18.0	5.1
Total Time Cost Benefits	100	15.8	4.4
Total Benefits			
Autos/Trucks	100	13.4	1.9
Buses	100	19.2	5.1
GRAND TOTAL	100	16.7	3.7

Note: The relationships shown are taken from the analysis of the Alajuelita Dispersal System with bus priority.

their larger proportion in the total vehicle stream. When time cost savings are included, the buses, as might be expected, realize most of the benefits.

A final illustrative table (Table A–21) shows the growth of benefits with time. The Siquirres-Tibas dispersal and bus priority system is the selected example.

TABLE A–20

DISTRIBUTION OF PEAK-HOUR BENEFITS
BUS PRIORITY AND DISPERSAL SYSTEMS

Type of Benefit	Alajuelita Colones	Alajuelita Percent	Zapote Colones	Zapote Percent	Siquirres Colones	Siquirres Percent
Operating Cost Benefits						
Autos/Trucks	1,129.49	29.4	577.47	8.4	598.91	19.2
Buses	358.22	9.4	961.18	14.0	363.30	11.6
Total Op. Cost Benefits	1,487.71	38.8	1,538.65	22.4	962.21	30.8
Time Cost Benefits						
Autos/Trucks	516.89	13.5	297.41	4.3	260.82	8.3
Buses	1,826.46	47.7	5,042.06	73.3	1,903.79	60.9
Total Time Cost Benefits	2,343.35	61.2	5,339.47	77.6	2,164.61	69.2
Total Autos/Trucks	1,646.38	43.0	874.88	12.8	859.73	27.5
Total Buses	2,184.68	57.0	6,003.24	87.2	2,267.09	72.5
TOTAL BENEFITS	3,831.06	100.0	6,878.12	100.0	3,126.82	100.0

The somewhat irregular growth in benefits during the early years is attributable in part to the construction of the circumferential highway. (The effects of the circumferential highway have already been noted in the CBD bypass and signal system analyses.) The most noteworthy aspect of Table A–21 is the 56.2 percent increase in benefits in 1989 followed by an additional 49.7 percent in 1990 as the network becomes increasingly congested.

TABLE A–21

SIQUIRRES-TIBAS DISPERSAL AND BUS PRIORITY
GROWTH OF ANNUAL TOTAL BENEFITS

Year	Total Benefits	Annual Increase	Annual Percent Increase
	(Thousands of Colones)		
1979	₡ 477.8		
1980	587.0	₡ 109.2	22.9
1981	707.7	120.7	20.6
1982	801.6	93.9	13.3
1983	956.0	154.4	19.3
1984	1,107.0	151.0	15.8
1985	1,294.6	187.6	16.9
1986	1,629.0	334.4	25.8
1987	1,916.4	287.4	17.6
1988	2,167.2	250.8	13.1
1989	3,385.6	1,218.4	56.2
1990	5,069.6	1,684.0	49.7

Capital Costs

The capital costs of the dispersal systems and the dispersal systems with bus priorities vary from about a quarter million colones at Siquirres-Tibas to over 25 million for the expressway alternative at Santa Ana-Alajuelita. The costs were calculated on the basis of unit prices for individual classes of work using quantities measured from the 1:100 plan drawings.

Typical unit costs included the following in Table A–22:

Costs for bridges, right-of-way traffic control devices other than signals, and other miscellaneous items were calculated individually depending on the project. Contingencies were then added as 20 percent of the construction costs. Table A–23

TABLE A–22

TYPICAL UNIT CONSTRUCTION COSTS

Item	Unit	Unit Cost (₡)
Pavement (including base etc.)	Sq. meter	125.00
Curbs, Sidewalks, and Minor Drainage (2 sides)	Meter	260.00
Islands	Sq. meter	80.00
Traffic Signals, New	Each	100,000.00
Traffic Signals, Revised	Each	20,000.00

TABLE A–23

RADIAL DISPERSAL SYSTEMS
CAPITAL COSTS
(Thousands of Colones)

System	Pavement, Islands, Curbs, Etc.	Traffic Control & Utilities	Bridges & Structures	Right-of-Way	Total[1]
Siquirres-Tibas:					
Dispersal and Bus Priority	118	120	—	—	280
Zapote-Desamparados:					
Dispersal Only	488	96	—	312	1,013
Dispersal and Bus Priority	578	277	—	312	1,338
Alajuelita-Santa Ana:					
Dispersal Only	1,621	645	—	7,298	10,017
Dispersal and Bus Priority	1,791	645	—	7,698	10,701
42nd Street Expressway	5,820	960	18,457	80	25,317

[1]Includes 20 percent of construction cost as a contingency except for the 42nd Street grade-separated alternative.

is a summary of the capital costs associated with each alternative. The possible salvage value of rights-of-way were considered to be small enough that they are of no consequence in the final analysis.

Summary of Feasibility Measures

The overall economic effect of the benefit calculations typical in the preceding tables can be summarized in Table A–24.

The Tibas dispersal and bus priority system is immediately recognized as economically feasible; a combination of high benefits and minimal capital cost produce an IRR (based solely on operating cost savings) of 57.7 percent. In the Zapote case, both the dispersal only and dispersal with bus priority alternatives are also clearly feasible; the dispersal with bus priority is the preferred choice. Regarding Alajuelita: the 42nd Street grade-separated alternative can be dismissed as infeasible because of very high capital costs and less attractive benefits than are provided by the one-way system with bus priority.

Supplementary Analysis

To set all three dispersal systems with bus priority in time perspective, Table A–25 was prepared. The Siquirres-Tibas system is scheduled for construction in 1978, followed by Alajuelita in 1981 and Zapote-Desamparados in 1982. Total operating and time cost benefits in 1990 are almost 50 times the benefits of 1979 from Siquirres-Tibas alone. Considering all the systems as a single entity, the IRR based solely on operating cost savings is 12 percent and 48 percent when time savings are included.

EFFECTS OF VARYING ECONOMIC LIFE ON ECONOMIC INDICES

In order to assure that conservative estimates of economic benefits were made for purposes of developing economic feasibility indices and because travel forecasts, prepared as part of Stage I and which were the basis for analyses conducted in Stage II, only extended to 1990, some projects were attributed benefits for only a short period. For example, since the Alajuelita Dispersal is not expected to be implemented until 1980 or 1981, benefits were assumed for 1982 for the first full year and total benefits accumulated only for nine years. Further, no salvage value was ascribed to additional right-of-way acquired for the project.

In order to observe the effect of assuming a more liberal 20-year accumulation of benefits and a reasonable salvage value of land, Tables A–26a and A–26b were prepared. Both of these tables are based on the assumption that benefits beyond 1990 continued at the 1990 rate. Table A–26a is based on both operating and traveler time savings while Table A–26b includes operating costs only for two critical projects. One of the latter, the Alajuelita Dispersal, which had a B/C ratio of 1.15 when total savings (including time savings) were included, increases to 2.65 when benefits are accumulated for 20 years and land is included in salvage. B/C for this project using only operating cost savings is 1.05.

TABLE A-24

SUMMARY OF FEASIBILITY MEASURES
DISPERSAL AND BUS PRIORITY SYSTEMS

	Capital Cost (₡1,000)	Benefit Period	Discounted Benefits—12 percent (Thousands of Colones)			B/C Ratios		IRR (percent)		1st-Year Benefit (percent)	
			Op. Saving	Time Saving	Total Saving	Op. Saving Only	Total Saving	Op. Saving Only	Total Saving	Op. Saving Only	Total Saving
Siquirres-Tibas:											
Dispersal and Bus Priority	279.5	1979-1990	2,005.4	5,913.5	7,918.9	7.17	28.33	57.7	>>57.70	37.5	170.9
Zapote-Desamparados:											
Dispersal Only	1,012.7[1]	1983-1990	2,315.8	981.2	3,297.0	2.29	3.25	39.4	51.00	39.2	47.4
Dispersal and Bus Priority	1,337.6[1]	1983-1990	5,353.1	14,457.3	19,820.4	4.01	14.82	60.0	>>60.00	55.7	188.7
Alajuelita-Santa Ana:											
Dispersal Only	10,016.6[2]	1982-1990	2,242.5	3,376.2	5,618.7	0.22	0.56	—	2.25	1.8	4.8
Dispersal and Bus Priority	10,700.6[3]	1982-1990	4,867.2	7,394.8	12,262.0	0.45	1.15	—	15.00	4.9	12.8
42nd Street Expressway	25,317.4	1982-1990	3,813.2	5,505.6	9,818.8	0.15	0.37	—	—	1.6	4.1

[1]Includes R.O.W. (Right-of-Way) cost of ₡312.000

[2]Includes R.O.W. cost of ₡7,300,000

[3]Includes R.O.W. cost of ₡7,700,000

TABLE A–25

UNDISCOUNTED CAPITAL COSTS AND BENEFITS
ALL DISPERSALS WITH BUS PRIORITY SYSTEMS

(Thousands of Colones)

Calendar Year	Discount Year	Investment			Operating Cost Benefits				Total Benefits			
		Siquirres	Zapote	Alajuelita	Siquirres	Zapote	Alajuelita	Total	Siquirres	Zapote	Alajuelita	Total
1978	0	279.5										
1979	1				104.9			104.9	477.8			477.8
1980	2				130.8			130.8	587.0			587.0
1981	3			10,700.6	159.9			159.9	707.7			707.7
1982	4		1,337.6		182.5		522.8	705.3	801.6		1,367.6	2,169.2
1983	5				222.7	745.2	876.9	1,844.8	956.0	2,524.1	2,167.1	5,647.2
1984	6				262.0	659.4	338.6	1,255.0	1,107.0	2,183.2	961.2	4,251.4
1985	7				313.0	745.2	525.9	1,584.1	1,294.6	2,524.1	1,374.3	5,193.0
1986	8				408.4	858.9	755.7	2,023.0	1,629.0	2,976.1	1,890.9	6,496.0
1987	9				491.7	1,074.5	954.2	2,520.4	1,916.4	3,892.1	2,348.7	8,157.2
1988	10				563.3	1,264.0	1,197.0	3,024.3	2,167.2	4,704.4	2,901.5	9,773.1
1989	11				947.8	1,665.7	1,831.7	4,445.2	3,385.6	6,525.6	4,523.0	14,434.2
1990	12				1,482.9	2,703.8	2,593.2	6,779.9	5,069.6	11,373.4	6,518.9	22,961.9
Undiscounted Totals:		279.5	1,337.6	10,700.6	5,269.9	9,716.7	9,591.0	24,577.6	20,099.5	36,703.0	24,053.2	80,855.7

Note: IRR (Internal Rates of Return):
Operating Cost Benefits = 12 percent
Total Benefits (incl. time) = 48 percent

TABLE A–26a

EFFECTS OF VARYING ECONOMIC LIFE BASED ON BOTH OPERATING AND TIME SAVINGS

(Monetary Values in Thousands of Colones)

	Project							
	CBD	CBD Bypass				Dispersal System		
	Signal System	South Leg	West Leg	East Leg	North Leg	Alajuelita	Limon-Siquirres	Desamparados Zapote
Sum of Discounted Benefits for 8 Yrs.	—	3,777	564	383	2,495	--	--	19,819
For 9 Yrs.	—	--	--	--	—	12,289	--	--
For 12 Yrs.	60,975	4,744	708	482	3,135	17,935	7,918	33,772
For 20 Yrs.	74,583	5,750	857	583	3,801	26,247	14,381	48,273
Capital Costs	11,807	817	574	1,847	3,884	10,700	280	1,338
Benefit/Cost Ratios Without Salvage Value for Shortest Life	5.16	4.62	0.98	0.21	0.64	1.15	28.33	14,82
For 12-Yr. Life	5.16	5.81	1.23	0.26	0.81	1.68	28.33	25.24
For 20-Yr. Life	6.32	7.04	1.49	0.32	0.98	2.45	51.36	36.08
Salvage Value of ROW After 25 Years	0	12	0	130	295	798	0	32
Benefit/Cost Ratios With Salvage Value for Shortest Life	5.16	4.69	0.98	0.22	0.70	1.24	28.33	15.17
For 12-Yr. Life	5.16	5.89	1.23	0.28	0.87	1.81	28.33	25.86
For 20-Yr. Life	6.32	7.14	1.49	0.34	1.06	2.65	51.36	36.96

TABLE A–26b

EFFECTS OF VARYING ECONOMIC LIFE FOR TWO SELECTED PROJECTES BASED ON OPERATING COST SAVINGS ONLY

(Monetary Values in Thousands of Colones)

	Project	
	CBD Bypass North Leg	Alajuelita Dispersal System
Sum of Discounted Benefits for 8 Years	1,747	
For 9 Years		4,866
For 12 Years	2,196	7,113
For 20 Years	2,662	10,420
Capital Costs	3,884	10,700
Benefit/Cost Ratios Without Salvage Value for Shortest Life	0.45	0.45
For 12-Year Life	0.57	0.66
For 20-Year Life	0.69	0.97
Salvage Value of ROW After 25 Years	295	798
Benefit/Cost Ratios With Salvage Value for Shortest Life	0.49	0.49
For 12-Year Life	0.62	0.72
For 20-Year Life	0.74	1.05

Appendix B
Examination Of Alternative Transit Modes For Corridors, Employers, Transit Priorities

The development of busways and other bus priority measures, including those associated with the dispersal schemes, raises the question of whether the existence of such facilities could be used to good advantage by transit modes other than the fixed-route standard coaches currently used. Reasons for implementation of other transit modes could include cost (and thus possibly fare) reductions, service improvements, or both. A decision to implement a different mode should consider at least the following criteria:

- Operating Costs — Since the current bus system operates without government subsidy, fares are closely tied to operating costs. The level of fares are of vital interest to lower-income users and are influential in the determination of the overall mode split.

- Capital Costs — Capital for new equipment is scarce, and new modes that have high start-up costs must consider this impact on current operators.

- Service Improvements — New modes could be justified if they provided demonstrably better service to existing bus users or as additional attraction to auto users.

- Capacity Impact — All previous travel projections made by ETAMSJ have indicated that providing adequate street and road capacity for transit, as well as general traffic in the old part of San Jose generally and in the CBD in particular, was going to be very difficult in the coming years. Using transit vehicles with lower occupancy can have the effect of increasing the requirements for street space for each traveler which will compound the problem of street capacity.

- Institutional Issues — The present practice of allowing the private sector to provide transit service may not be possible if other modes are established. This can have cost and other implications in San Jose over and beyond those intrinsically associated with the modal change itself.

- Operational Feasibility — Some modes might appear to offer advantages but because of lack of operating experience may necessitate operational risks that neded to be considered.

Earlier studies by ETAMSJ have analyzed the effectiveness of the present bus operation and found that the system offered reasonably good service at a low fare. Certain deficiencies were found including:

- Overloading — Some corridors during the peak hours experience severe overloading such that most passengers must stand and many are bypassed by buses so full that they will not stop.
- Maintenance — Buses are often dirty and ill kept in appearance. Engines need repair to reduce exhaust emissions and noise.

Among recommendations made to correct these and other deficiencies was to develop premium bus service which stops less often, offers more deluxe equipment, and carries few or no standees but charges a premium fare. Such service recognized that the bus user population is not homogenous, nor are their desires for system improvements identical. Some would prefer a low fare even though service might be marginal; others would prefer to pay more to get better service. This latter group, if not satisfied, are the ones most likely to purchase an automobile and thus compound the broader transport problem.

Fortunately, the provision of physical facilities to provide busways or bus priorities for standard size coaches does not preclude the use of such facilites in the future by other high-occupancy vehicles. Nevertheless, it is useful to know as much as possible at the outset about the potential use of the facilities by other type vehicles.

MODES EXAMINED

Eight transit modes or modal combinations were examined as part of the study. Six were fixed-route modes, including the standard bus; two were demand responsive. A description and discussion of each modal concept follows.

Standard Bus

A full description of bus operation in San Jose is provided in the Final Technical Report of ETAMSJ. While overloading and equipment maintenance are unsatisfactory, fares are low, and service frequency is high, especially on the radial corridors being herein examined. Buses are frequently delayed in traffic especially in the CBD; significant delays result from loading and unloading along curbs in the central area. Some streets have peak-hour loading volumes of 150 buses per hour in one direction. The buses tend to be very efficient in their consumption of scarce street space with each having a capacity of 50 or more considering standees; they average more than 40 passengers per bus as they enter San Jose. One bus has the impact of about three cars in the consumption of street capacity.

Mini-Bus

The mini-bus is considered here as a 21-passenger vehicle smaller and therefore more maneuverable than the standard coach. Carrying smaller loads means fewer stops for loading with a result of higher overall speeds. Mini-buses are more consumptive of street capacity (per passenger carried) however, and since the driver's cost must be spread over fewer passengers, operating costs tend to be higher.

Jitney (Fixed Route)

Jitneys are considered here for analysis to be standard-sized sedans with a five-passenger capacity. As operated in Caracas and San Juan, Puerto Rico, jitneys provide a higher level of service than buses at a premium fare. While operating basically in a fixed-route manner, they require few stops for loading and can provide operating speeds similar to the automobile. Some route flexibility is employed by drivers who sometimes detour a few blocks to provide passengers with a short walk to their ultimate destinations. They are even less efficient in use of street space than mini-buses, and costs per passenger are higher.

Electric Trolleybus

The heavy volume of buses on selected routes in San Jose have led some to suggest that there might be advantages to substituting trolleybuses for diesel-gas buses now in operation. Trolleybuses are similar to regular buses except that they use electric power drawn from overhead wires strung along the route. Benefits suggested from such a substitution include lower operating costs (especially since

the recent oil price increases), less noisy operation, and less air pollution. Some of Costa Rica's international trade partners have suggested that they produce the trolleybus for San Jose to offset their purchase of local agricultural products. Because of the heavy interest in this mode, the analysis and discussion of trolleybuses presented here is somewhat more elaborate than for other modes. Potential benefits and disbenefits for trolleybuses are discussed in the following paragraphs.[1]

Reduced Air Pollution — Air pollution resulting from automotive traffic is a significant problem in San Jose. Diesel buses, while accounting for only a small proportion of the vehicle-kilometers of travel on San Jose streets nevertheless contribute to this pollution problem. Even the casual visitor to the central area during peak hours cannot help but notice the black diesel smoke pouring out of the lower left side of many of the coaches. The narrowness of many streets and the very constricted sidewalks often mean black smoke belched directly onto one's clothes and person. While the diesel fumes tend not to be toxic (i.e., harmful to health in the same sense that carbon monoxide is), it is nevertheless unpleasant and dirty. Trolleybuses would eliminate this problem leaving only the growing pollution problem which will result from unrestricted use of private cars. Trolleybuses emit no fumes from the vehicles themselves. Since approximately 70 percent of the electricity produced in Costa Rica is generated from hydroelectric sources (as opposed to fossil-fueled steam plants which create their own pollution) and the country has potential for further hydroelectric development through construction of additional dams and turbine power plants, the shift to trolleybuses would definitely be an improvement from the standpoint of urban air purity.

It should be noted that a significant part of the pollution problem from current disel buses could be eliminated by requiring better engine maintenance and the utilization of air pollution exhaust packages on existing coaches. There is no physical reason why the current diesel fleet must continue to emit filth at current rates since the technology exists to significantly reduce it at a cost that would only be a fraction of the cost of trolleybuses. Nevertheless, it must be recognized that at best the diesel fleet will cause more local pollution than trolleybuses.

Reduced Noise — As with air pollution, the current diesel fleet is noisy, and in dors that constitute downtown San Jose, the bus noise is an unpleasant fact. While some significant reduction in noise could be effected through the requirements for more effective sound muffler devices on buses, it must be conceded that trolleybuses operate at a substantially reduced noise level compared to the quietest diesel or gasoline bus. When stopped for loading, trolleybuses are virtually silent and, when moving at low speeds, they are sufficiently quiet that they sometimes are hazardous to unwary pedestrians.

It is not known how much of an irritant the combined effects of noise and air pollution are to the typical San Jose resident. To the extent that it is an irritant, justification can be made for expenditures for trolleybuses even through they might exceed the current custs of diesel bus transportation.

Reduced Street Congestion — Some have suggested that trolleybuses because of their larger size and carrying capacity might reduce street congestion in San Jose. Presumably, if each bus could carry more people, the number of coaches would fall, thus reducing total street congestion.

Larger buses should be given consideration in San Jose. Studies have shown that bus overcrowding is one of the main problems in the present system, and larger vehicles would tend to reduce this problem in addition to having the potential for requiring fewer total buses on the streets. While typical trolleybuses are not significantly larger than many buses currently used in San Jose, some cities are using articulated trolleybuses which employ eight axles, bend around turns, and carry a much larger passenger load. It is not at all clear, however, that it is feasible to operate larger vehicles than are presently used in view of the delays and problems associated with turns in the very narrow streets in Central San Jose. While recommendations have been made which reduce the bus turning maneuvers in the CBD,

[1] Some of this material on trolleybuses is repeated from Final Technical Report, p. V-10.

there will always be some turns remaining, and larger buses would only make the turning problem more difficult.

Even if it were deemed wise to introduce larger vehicles, they could be either trolleybuses or diesel, since both are available. Probably, the most effective vehicle would be a double-deck bus seating 80 passengers and with a total capacity of over 100. While its horizontal dimensions and therefore its maneuverability is not greatly different than buses currently used, such buses are currently available only with diesel power. Such a vehicle is not recommended because of its cost (some three times the cost of present San Jose buses). Their existence, however, serves to diminish the argument for trolleybuses on grounds of congestion reduction.

Increasing Fuel Oil Prices — The world-wide shortage of fuel oil and the accompanying price increases have caused renewed interest in trolleybuses which avoid oil price problems. It seems clear, however, that the real objective should be to provide good transportation at the lowest possible cost. Since fuel represents only about 20 percent of the total cost of providing bus transportation in San Jose, even with fuel oil prices at current levels, it is evident that more than fuel prices must be considered in making a comprehensive comparison of costs of trolley and diesel buses. Even from the narrow perspective of fuel costs, however, it will be shown that the costs of electricity for trolleybuses would equal or exceed that of fuel oil for diesels.

Balance of Payments and International Trade — The use of diesel buses has an adverse impact on Costa Rica's balance of payments since many buses are produced from outside the country, and even those assembled within Costa Rica include many components made elsewhere. In addition, all of the oil must be purchased externally since Costa Rica has none of its own.

Substitution of trolleybuses would not improve the situation greatly. First, all of the trolleybuses would have to be purchased externally, and, since the cost for each coach is three to four times that of a diesel unit, the original purchase price would impact unfavorably. Special maintenance facilities and power substation and distribution components would have to be acquired external to Costa Rica as would the equipment required for the marginal increases in power production required. (It is noteworthy that severe power shortages were experienced in the summer of 1973 due to diminished rainfall and available hydroelectric power sources.) No analysis has been made of how these aspects trade off, either in the short or long run, nor is it known how important the balance of trade problem will be in the future of Costa Rica.

Some of Costa Rica's international trade partners have suggested that they produce the trolleybuses for Costa Rica to offset their purchase of Costa Rican agricultural products. The importance of this quid pro quo in international trade is unknown, but it is another factor which must be considered.

Reduction in Operating Flexibility — Trolleybuses are constrained in their operation by the necessity of always maintaining the physical connection with the overhead electrical power distributor. This limitation can work severe restrictions in an operating system. The first restriction results from the fact that coaches operating in sequence on the same line cannot bypass one another. This limitation would be severe in Costa Rica due to the heavy loads carried on selected central area streets. Several streets carry 1,500 to 2,500 buses per day. At these volumes, buses must load simultaneously at curb stops and, when boarding is complete, must be able to move out without waiting for those in front of the line. Trolleybuses would be forced to wait until the last and slowest bus was ready to move, causing reduced bus capacity and additional delays in an already delayed system. Operation through use of moving platoons of buses might help overcome this problem, but such methods are essentially untried in Costa Rica and anywhere else at these volumes, and the outcome is problematical at best. It would be possible to use trolleybuses only on selected lines. Streets in the central city which carry multiple lines then would be carrying a mix of trolleybuses and diesel buses. Coaches could bypass one another except for trolleybus bypassing trolleybus. Thus, a limited use of trolleybuses would probably not reduce capacity.

A lack of flexibility, however, would be felt in minor reroutings required to avoid street construction or traffic accidents. Construction would have to be performed with bus traffic remaining or else special temporary wire would have to be erected,

either method increasing total construction costs. Rerouting buses to account for longer-term changes in traffic demands, route extensions, or street changes would also be more difficult and costly.

Reducing Labor Efficiency — One of the obvious efficiencies of the San Jose bus system today is the flexibility of labor that comes from the multiplicity of small entrepreneurs who offer service as drivers, service personnel, maintenance mechanics, and management, simultaneously. Maybe these functions are not being performed as well as might be desired but costs are kept low, and many if not most of the systems' users prefer to keep costs and thus fares as low as possible. It is difficult to see how the introduction of trolleybuses could allow this system to continue. The trolleybuses themselves would require a financial investment in new equipment, wire, substations, and maintenance facilities which probably only the government would be willing to undertake. Maintenance would have to be performed by transit specialists using unfamiliar and new equipment. In short, the trolleybuses would most likely require the organization of an operational mechanism with sufficient size and human and financial resources to construct, operate, and maintain the system.

The Final Technical Report of ETAMSJ discusses the question of the best organizational mechanism for operating buses in San Jose, and this discussion will not be repeated here. It is believed, however, based on experience in many countries, including several in Latin America, that the economies of scale that come from larger operating units, especially those when a company is government-owned, do not offset the decreased labor efficiency of larger operational units and that the result is a higher operating cost. Many countries have private and public companies operating side by side, and the operating costs from the public companies are often more that double those of the private companies. Thus, the introduction of trolleybuses would likely result in operating inefficiencies that have no intrinsic relationship to the hardware differences between trolleys and diesel buses.

Environmental Impact — Reductions in noise and air pollution have already been cited as arguments for trolleybuses. However, trolleybuses have an unfavorable impact on the visual amenities of a city in their requirement for a dense network of overhead wires on many major streets. Many cities are working to place general overhead wiring underground to improve appearances. Trolleybus wiring must of necessity be left overhead with the greatest concentration in the most crowded areas of the city.

It must be noted that most of the major commercial streets in San Jose are cluttered with overhead advertising signs extending over the streets. Many of these would have to be removed were trolleybuses to be introduced. However, the existence of these signs suggests that most Costa Ricans do not find the overhead clutter objectionable and thus might not object to overhead trolleybus wires.

Increased Costs

It is generally hard to get good relevant cost data concerning trolley and diesel buses. Many cities in North American presently using trolleys have old equipment and, in some instances, have deferred maintenance sufficiently so that the equipment is often in poor condition. They have also long since depreciated the equipment, whereas their diesel fleets tend to be somewhat newer.

Cost estimates were prepared for both trolley and diesel buses for a 12-kilometer line assumed to run from one side of San Jose, through the central business district, to the other. Thirty buses—a fairly heavy line for San Jose—were assumed and an average of 4,330 bus kilometers per bus per month was assumed (the same as 1970 San Jose average). The following table shows fundamental assumptions used for this cost comparison for both trolleys and diesels.

	Trolley	Diesel
Line Length (kilometers)	12	12
No. of Buses	30	30
Km/Mo./Bus	4,330	4,330
Opport. Cost of Capital (percent)	12	12
Bus Cost/Bus	$ 50,000	$23,300
Bus Life (years)	20	10

	Trolley	Diesel
One Way Elec. Line (Inst.)	$ 60,800/mi.	—
Substations — 4 50,000	$200,000	—
Maintenance & Storage Facilities	$540,000	—
Electric Line Maintenance	$.07/bus km	—
Power/Fuel Cost	$.03/kwh	$.453/gal.
Power/Fuel Consumption	.208 mi/kwh	5.96 mi/gal.

The next table shows the annual cost for each type of bus. Since the cost of installing a new system of trolleybuses in San Jose would require a new fleet of coaches, overhead wires, substations, maintenance, and storage facilities, the opportunity costs of capital are substantial and therefore are a significant part of the total cost of a trolley operation. A new fleet of diesel buses, on the other hand, would not require the overhead wires or additional maintenance facilities.[1] Since the vehicles themselves cost less, the costs of capital are substantially less for diesel systems than for trolleys. The difference in the depreciation between the two types of buses is not great because, generally speaking, the trolleybuses last twice as long as the diesels, and the other capital facilities including the maintenance facilities have a very long life.

Operating cost for drivers' wages, administration, and other general overhead items were assumed to be the same for both models. Vehicle maintenance was assumed the same, based on data from other cities. Fuel and power cost was calculated, based on 1974 power costs and fuel costs after OPEC increases and on average electricity consumption rates for trolleys and diesel fuel by diesels. Route maintenance is an item which would apply only to trolleybuses, and it was based on costs of such maintenance from other cities.

[1]It is recognized that the existing diesel maintenance facilities have costs but since they are used for maintenance of private vehicles of all kinds in most cases, an estimate of their costs, probably quite small, for a given bus line may be ignored.

	Trolleys	Diesel
Cost of Capital	$ 453,800	$ 83,900
Depreciation	114,100	69,900
Operating Costs		
Fuel or Power	140,300	73,300
Route Maintenance	68,600	0
All Other	294,600	294,600
Subtotal	503,500	367,900
TOTAL	$1,101,400	$521,700

Based upon these inputs, it can be seen that the costs of trolleybus operation would be roughly twice that of diesel. While other assumptions could be made about the relative costs of some of the items used in the analysis, it seems almost inevitable that trolleybuses must be significantly more expensive. This analysis assumed that electric power for trolleybuses would be somewhat higher in Costa Rica (about $.03/kwh) than is the case in some U.S. cities using trolleybuses (about $.01/kwh in Seattle);[1] even if they were equal, it is clear that the cost of capital, depreciation, and route maintenance would tend to favor diesel buses. None of the cost comparisons have considered any additional inefficiencies introduced with trolleybuses stemming from the likely requirement that trolleybuses be operated by a government-sponsored company or its equivalent.

Other assumptions could be made with respect to length of line and volume of vehicle which would alter the relative costs somewhat. Higher volumes of buses using the fixed-line facilities spread this cost over more units, reducing the extra

[1]Analysis of typical residential rates in the U.S. shows poer costs varying from a low of $.04-.05/kwh (Cleveland, Nashville, Atlanta) to $.10-.12 (Detroit, Chicago) compared to about $.025/kwh in San Jose (after the May 1974 increase). However Seattle had a residential rate of $.04/kwh but was only charging the trolleybuses $.01. Apparently the trolleybuses have a subsidized rate of about 25 percent of the residential rate. The estimated cost of power for trolleybuses given to AMV by Instituto Costarricense de Electricidad was $.03/kwh before the May 1974 increase. Assuming a 50 percent increase, this would be $.04/kwh for trolleys or about 60 percent higher than the residential rate.

costs per unit for this item. However, the higher costs of trolleybuses spring from several sources, and it is difficult to develop a mix of reasonable assumptions that would show trolleybuses with equal or lower costs than standard buses.[1]

Standard Bus Plus Mini-Bus Feeder

The demand-responsive and jitney systems tend to produce higher service levels through reduced waiting and walking times, but then also tend to have higher costs. To examine the potential for gaining some of the service benefits without all the cost disadvantages, a system utilizes three standard bus routes served in outlying areas with six mini-bus feeder routes.

Combination Mini-Bus and Standard Bus

For reasons similar to those expressed in the previous paragraph, a combination system utilizing six mini-bus routes (serving the lower density areas) along with two standard bus routes was examined.

Demand-Responsive Mini-Bus

Demand-responsive use of transit refers to tailoring the supply of transit to the actual demand. This has been accomplished elsewhere through the "dial-a-ride" concept where vehicles pick up and deliver passengers door-to-door, door-to-common destinations, or common origin-to-diverse destinations. The demand is identified through phone calls to a central dispatching facility. Vehicles of different types are used. Mini-buses have the advantage of being able to carry large groups which sometimes occurs when schools or large employment locations dismiss, while still being small enough to perform their more typical mission of responding to individual calls.

[1] This conclusion is borne out by other analyses of this subject. See, for example, "Light Rail/Diesel Bus/Trolley Bus Analysis," R. Gustafson and C. Blake, Tri-County Metropolitan Transit District, Portland, Oregon, 1974.

Demand-Responsive Jitney

This mode was examined to determine the potential for using large standard sedans in demand-responsive mode.

Examination of Costs and Services

To compare the eight submodes listed above, the estimated 1990 a.m. peak-hour bus PCU demand in the Tibas corridor was converted to bus passengers using factors of one bus = three PCU and an average of 40.87 passengers per bus.

The Tibas corridor included cross-town and regional transit demand as well as demand for movement to the CBD. For simplicity, only the CBD travel was used in the comparisons.

Routes were laid out in the Tibas corridor (and the other corridors as well) to provide a route within 400 meters of any point within the corridor area of influence (which itself corresponded to the analysis subzones grouped around the radial highways).

The comparisons were then made by applying the alternative modes to the corridor demand and calculating costs. Note that this approach does not give consideration to incremental changes in transit demand that might result from changes in levels of transit service. However, these increments are probably of little significance in view of the wide differences in costs that were found among the submodes.

A seat capacity of 50 was selected for the standard bus since this is the average in San Jose today and reflects available vehicle sizes. The seat capacity of the trolleybus was set as equal for comparative purposes. A recent Russian proposal for trolleybuses in San Jose suggested larger buses (91 passengers including standees). However, since larger diesel buses are also available, there is no reason to select different values for the two types. It should be noted that larger vehicles could likely encounter trouble turning on San Jose's narrow downtown streets, and penetration of the downtown area is considered essential.

The load factor (ratio of total passengers to seated passengers) is now at 1.2 in the Tibas corridor, a level that corresponds to an overall improvement in this existing critical problem of bus overcrowding in San Jose. The load factor was considered in the comparisons when calculating the number of vehicles required to serve the 1990 a.m. peak demand. The value of 1.2 was allowd to vary slightly up and down to achieve a reasonable number of round-trips during the peak hour.

A load factor of 1.0 is necessary for the jitney. It was also applied to minis in view of present practice in San Jose and in recognition of the additional level of comfort usually desired in mini-bus operation.

Average peak-hour speeds were based on existing operations. Standard buses average 17 kph in the Tibas corridor. Mini-buses on the Heredia route achieve 22 to 28 kph averages, depending on direction of travel. Experience in Caracas, Venezuela, shows that jitneys operate at or near auto speeds.

Experience in the U.S. with demand-responsive mini-buses shows average speeds around or less than those of fixed-route operations. Therefore, demand mini-bus speed was selected equal to fixed-route standard buses, and demand jitney speed arbitrarily set between auto speed and demand-mini.

Operating costs, in colones per kilometer, are more or less based on the ₡1.55 value that is produced by the cost-speed curves developed for the overall economic analysis of the various projects being studied for possible implementation in San Jose. This value is for a standard-size bus, and is equal to the operating-cost for trucks at the same speed.

Comparisons by cost category (labor, fuel, etc.) between standard buses and mini-buses in San Jose showed that minis were operating at less expense in every category (about 94 percent overall) except for labor and tires. Therefore, 90 percent of the operating cost of a standard bus at the same speed was used for mini-buses. The actual cost experienced in San Jose has been, coincidentally, ₡1.23 per km, not including administration costs.

For jitneys, comparisons were developed using auto costs plus labor. This resulted in a jitney cost 1.78 times auto cost at the same speed, also without administrative costs. For comparison, 1971-19872 data for taxis in San Jose showed ₡1.25 per km operating costs.

Experience in the U.S. has shown that demand-responsive operation adds almost 25 percent to operating costs to cover the dispatching operation. This factor was applied to both mini-buses and jitneys operating in the demand-responsive mode. All operating costs include depreciation, but not administrative costs that vary widely from company to company.

Operating costs for the trolleybus were compared to standard bus using data from the previously-mentioned Russian proposal plus data from Technical Working Paper 15. Costs by category tended to balance out with the diesel bus except for depreciation which was higher due to the larger capital investment needed for trolleys. Capital costs are based on recent surveys of San Jose availability and cost, plus data on trolleys from the Russian study. For trolleys, vehicle cost must be augmented by a factor of ₡712,000 per km of route for overhead power supply, slightly higher than used in Working Paper No. 15. The cost of maintenance yard facilities was not included for any submode, even though the trolleybuses would require special facilities.

The number of vehicles needed was calculated using the person-trip demand, the vehicle capacity, and the round-trip time between each of eight service areas and the CBD. With this determined, the vehicle-kilometers of travel were a function of the number of vehicles, the number of round trips in the peak hour, and the round-trip distance. From the vehicle-kilometers come total operating costs for the 1990 a.m. peak hour.

Speed was important in the number of round trips that could be accomplished. When demand-responsive vehicles were traveling in a line-haul mode (after pickup and delivery in their service area) they were assigned the higher fixed-route speed.

A special calculation was needed to estimate demand-responsive costs. A key statistic in "dial-a-bus" operation has proven to be the productivity of the bus, expressed in passengers per vehicle-hour. There is a maximum value that is a function of the size and density of the service area and the size of the vehicle. For this analysis, demand-responsive mini-buses were estimated to have productivities ranging from 21 to 63 passengers per hour, depending largely upon how many circuits could be completed in an hour. This is well above the maximum of 15 passengers per vehicle-hour experienced today. Demand-responsive jitneys were assigned productivities of 10 to 20 passengers per hour.

A summary of some of the more important assumptions and intermediate calculations is shown in the following table:

Factor	Fixed-Route Standard Bus	Fixed-Route Mini-Bus	Demand-Responsive Mini	Fixed-Route Jitney	Demand-Responsive Jitney	Fixed-Route Trolley Bus
Seats	50	21	21	5	5	50
Load Factor	1.2	1.0	1.0	1.0	1.0	1.2
Peak-Hour Speed (kph)	17	24	17	26	21	17
Cost/km	₡1.55	₡1.23	₡1.74	₡0.96	₡1.34	₡2.01
Unit Cost	₡300,000 per vehicle	₡165,000	₡170,000	₡80,000	₡85,000	₡400,000 plus power supply

User costs were equated to time costs at ₡0.022 per minute. Passenger time included walk time to cover 200 meters (2.7 minutes), wait and/or transfer time at one-half the vehicle headway, and travel time in the vehicle at the particular vehicle's speed. It was assumed that demand-responsive operation eliminated walk time (correct) and eliminated wait time (not correct). Wait does occur in demand-responsive operation (from the time of the call to pickup time), but it occurs at the origin under presumably better conditions than at a bus stop.

Table B-1 shows the result of these various calculations. Each submode was tested for the situation where passenger collection took place by that mode alone in each of the eight service areas with a direct run to the CBD. Combinations of submodes were then tested.

The results show rather conclusively that the demand-responsive modes tend to be much more costly. Most dial-a-ride systems currently in operation tend to recover less than half of their costs from passenger revenue.

Previous studies have indicated that demand-responsive services fit best in areas of low transit trip density, clearly not the situation in San Jose. From another standpoint, demand-responsive operation depends upon communication, and the availability of phones is low as can be seen from the table below, which compares the ratio of phones per family without consideration for the sharing of those phones in places other than the home.

ESTIMATED RATIO OF TELEPHONES TO FAMILIES

Corridor	Ratio: 1975 Phones/ 1973 Families
Tibas	0.53
Alajuelita	0.41
Desamparados	0.66

Overall Evaluation

Table B-2 summarizes the evaluation for the various modes examined. The table has been constructed to compare each alternative to the null or base case, i.e., the standard fixed-route bus now in operation. Values shown for capital costs and fares were adapted from Table B-1. The "capacity impact" column indicates the extent to which the corridor's congestion would be increased by increasing the number of transit vhicles necessary to carry passengers in lower-occupancy transit modes. The "operational feasibility" column distinguishes the low phone availability in the Tibas corridor—about half of all homes have phones—and the adverse impact this has on the availability of this mode to many even it if were implemented.

TABLE B–1

1990 A.M. PEAK-HOUR ESTIMATED COSTS

Mode	Vehicle Minutes	Number of Vehicles	Capital Cost	Operating Cost	User Time Cost	Op. Cost Increment	User Cost Increment
Fixed Route:							
Standard Bus	396	30	₡ 9,000,000	₡ 614	₡2,062	₡Base	₡Base
Mini-Bus	1,205	60	9,900,000	1,482	1,407	+868	-655
Jitney	4,760	214	17,120,000	4,570	1,244	+3,956	-818
Trolley	396	30	24,830,000	796	2,062	+182	0
Demand Responsive:							
Mini-Bus	1,645	119	20,230,000	2,263	1,794	+1,649	-268
Jitney	6,858	313	26,610,000	9,189	1,465	+8,575	-597
Standard With Mini Feeder	671	35	7,935,000	920	1,726	+306	-336
Combined Mini and Standard	770	45	9,990,000	1,015	1,686	+401	-376

TABLE B–2

COMPARISON OF ALTERNATE TRANSIT MODES FOR TIBAS CORRIDOR

Mode	Capital Cost Percent of Standard Bus	Fare[1] Percent of Standard Bus	Capacity[2] Impact Percent P.C.U. Increase	Service			Operational Feasibility
				Comfort	Convenience	Percent Reduction in User Time	
Fixed Route:							
Standard Bus	100	100	0	Fair	Fair	0	Good
Mini-Bus	110	241	8	Good	Fair	32	Good
Jitney	190	744	33	Good	Good	40	Good
Electric Trolley	276	129	0	Fair	Fair	0	Fair
Standard Plus Mini-Feeder	88	150	0	Fair	Fair	16	Good
Comb. Mini and Standard	111	165	5	Fair	Fair	18	Good
Demand Responsive:							
Mini-Bus	225	368	39	Good	Good	13	Poor
Jitney	296	1,496	59	Good	Good	29	Poor

[1] Assumes that fares will be adjusted to meet operating cost.

[2] Computed for Tibas corridor at the point of CBD dispersal; $\frac{\text{(P.C.U. using mode - P.C.U. using bus)}}{\text{Total P.C.U. for all modes}}$

The "service" column has three parts: "comfort" distinguishes the generally higher level of comfort of the smaller vehicles and of the higher level of standees which would use buses compared to mini-buses or jitneys. "Convenience" refers to ability of jitneys and demand-responsive modes to bring passengers more closely to their ultimate destinations reducing walking distances. The column "percent reduction in user time" uses the "user time cost" data in Table B–2 and relates each mode to the standard bus providing an overview of the relative time savings provided by each mode.

The demand-responsive modes appear inappropriate for the Tibas or any of the other busway corridors at least for transporting people to and from the central area because of their adverse impact on congestion, their poor cost performance, and their inapplicability because of lack of phone service. There may be a place for demand-responsive service for intra-corridor travelers, in which case they should be allowed to use the busway if they choose. It seems the cost and the fares which would be necessitated will tend to hold down the use of demand-responsive modes in these corridors for the foreseeable future.

The jitney provides significantly better service for a premium fare. The need for a premium service at a premium fare has been recommended by ETAMSJ, and there is little doubt that jitneys could provide such service as they do in other Latin American cities. It would be desirable to provide the better service with higher-occupancy vehicles, however, if at all possible. As shown in Table B–2, mini-buses would add 8 percent to the traffic load in the corridor and jitneys 33 percent compared to use of standard coaches. Since overloading is such a problem, real emphasis should be placed on implementing deluxe service at higher fares using regular and mini-buses. Only after a demonstration of the lack of attraction for this type service should jitneys be encouraged. Experience in San Jose thus far does not suggest any reasons for pessimism about the success of deluxe bus service.

The substitution of trolleybuses for diesels would result in a significant increase in the costs of supplying bus transportation to San Jose. Unless the government were prepared to supply the extra money, fares would have to rise which might discourage ridership and tend to reduce the competitiveness of bus travel to other

modes, especially the private car. This cost would be incurred by the riders without a corresponding benefit of faster or more frequent service. Delays in the most crowded part of the city could even be greater than at present due to the inability of buses to bypass one another at heavy loading points. Lack of routing flexibility with changing patronage patterns or during emergency street closings may also be considered a passenger disbenefit.

On the other hand, passengers would get improved riding comfort through the use of new urban style electric coaches, and pedestrians would be benefited by significant reductions in noise and air pollution. Some reduction in fuel impacts would result especially if added electric power requirements can continue to be hydro-generated. The government might also receive some benefit in its trade relations with some of its customers for Costa Rican agricultural products. The issue then is whether these benefits are greater than the disbenefits. Clearly, the question transcends that of providing better transportation. The major benefits involving environment and international trade have only peripherial relationship to urban transport, and the real value of such items can only be arrived at through the normal channels of political debate.

The problem is further complicated by the fact that some of the benefits, particularly those relating to the environment, can be obtained by tighter regulation of the diesel fleet at a fraction of the cost of new trolleybuses. This would be accomplished by the requirements for better engine tune-ups, better noise mufflers, and environmetal pollution packages on all coaches. It would appear that these measures might be enacted prior to the investment in trolleybuses. Nevertheless, trolleybuses can operate cleaner and quieter than diesels at their best and, in the final analysis, the value of these improvements is the political question that must be resolved in the trolleybus decision.

In summary, the implementation of busways and bus priority facilities does not suggest that any special emphasis should be placed on establishing new modes. The case for deluxe bus service at a premium fare had earlier been established, and the development of bus priority facilities is quite compatible with such recommendations. Special demand-responsive and/or taxi service could also be allowed to use priority facilities where such facilities have excess capacity above that required to accommodate regular and deluxe bus service. This would tend to always be true during selected off-peak periods and at all periods on selected portions of each busway. Beyond that, consideration can be given to allowing any high-occupancy automobile to use the facilities where excess capacity is available. This is currently done on the Shirley Busway outside Washington, D.C. Such possible future use does not in itself suggest any special design consideration in the facilities themselves.

Appendix C
High-Occupancy Vehicle Priorities On Radial Highways

The scheme for the development of busways paralleling new radial highways and the proposed application of bus priority techniques, such as bus-only lanes and bus-only streets, in radial highway dispersal areas are steps to enhance public transit in the San Jose area. Similar efforts are being planned and implemented in many urban areas around the world in recognition of limits to the role of individual automobile transportation in congested urban areas, in recognition of limits to energy supplies and the need for more efficient travel modes, and in recognition of adverse environmental impacts often generated by an excess of individual vehicles.

Certainly, the high-volume capacity ratios estimated for the radial highway dispersal areas by 1990 point out the importance of early consideration of further mode shifts than those now estimated for 1990.

The busway or bus priority schemes in this report are a step towards increased efficiency in the usage of the new radial highway systems. A key conclusion of the busway analysis is that buses should take advantage of the high level of service offered by the new radial highways.

But, what are the potentials for even more efficient use? One alternative has been reviewed which would attempt to achieve increased use of high person-occupancy vehicles by providing an exclusive lane on new radial highways.

The per lane capacity of radial highways has been applied in three classes:

A.	4-lane access controlled:	1,450 PCU/hour
B.	4-lane partial control:	1,130 PCU/hour
C.	4-lane no control:	810 PCU/hour

For these three classes, the person capacity per lane can be estimated as:

Class A.	Auto at 1.4 persons:	2,030 persons/hour
	Bus at 60.0 persons	29,000 persons/hour
	Carpool at 4.0 persons	5,800 persons/hour
Class B.	Auto at 1.4 persons	1,580 persons/hour
	Bus at 60.0 persons	22,600 persons/hour
	Carpool at 4.0 persons	4,520 persons/hour
Class C.	Auto at 1.4 persons	1,130 persons/hour
	Bus at 60.0 persons	16,200 persons/hour
	Carpool at 4.0 persons	3,240 persons/hour

The group listed as "carpool" could include shared-taxi (jitney) or any other group occupancy auto-type vehicle.

Obviously, the more use of bus or pool vehicles (at the occupancies assumed), the greater the efficiency of the highway in terms of person-carrying capacity. If one lane of a four-lane radial highway is reserved for high-occupancy vehicles and the other for autos, the person capacity of the auto lane would vary from an estimated 1,130 persons per hour to 2,030 persons per hour. The person-capacity of the high-occupancy lanes would depend on the mix of bus and carpool vehicles, as illustrated in Figure C-1.

In terms of radial highway volumes presently estimated for the 1990 a.m. peak hour, person volumes are:

	Alajuelita	Limon-Siquirres	Desamparados
Auto:	$1,670(1.4) = 2,340$	$2,490(1.4) = 3,490$	$2,360(1.4) = 3,300$
Bus:	$\frac{450(60)}{3} = \frac{9,000}{11,340}$	$\frac{280(60)}{3} = \frac{5,600}{9,090}$	$\frac{440(60)}{3} = \frac{8,800}{12,100}$

If the number of PCU's (with buses = 3) in each of the two lanes in one direction is more or less balanced, the person-volumes are:

	Alajuelita	Limon-Siquirres	Desamparados
Auto:	$514(1.4) = 720$	$407(1.4) = 570$	$586(1.4) = 820$
Bus:	$\frac{531(60)}{3} = \frac{10,620}{11,340}$	$142(60) = \frac{8,520}{9,090}$	$118(60) = \frac{11,280}{12,100}$

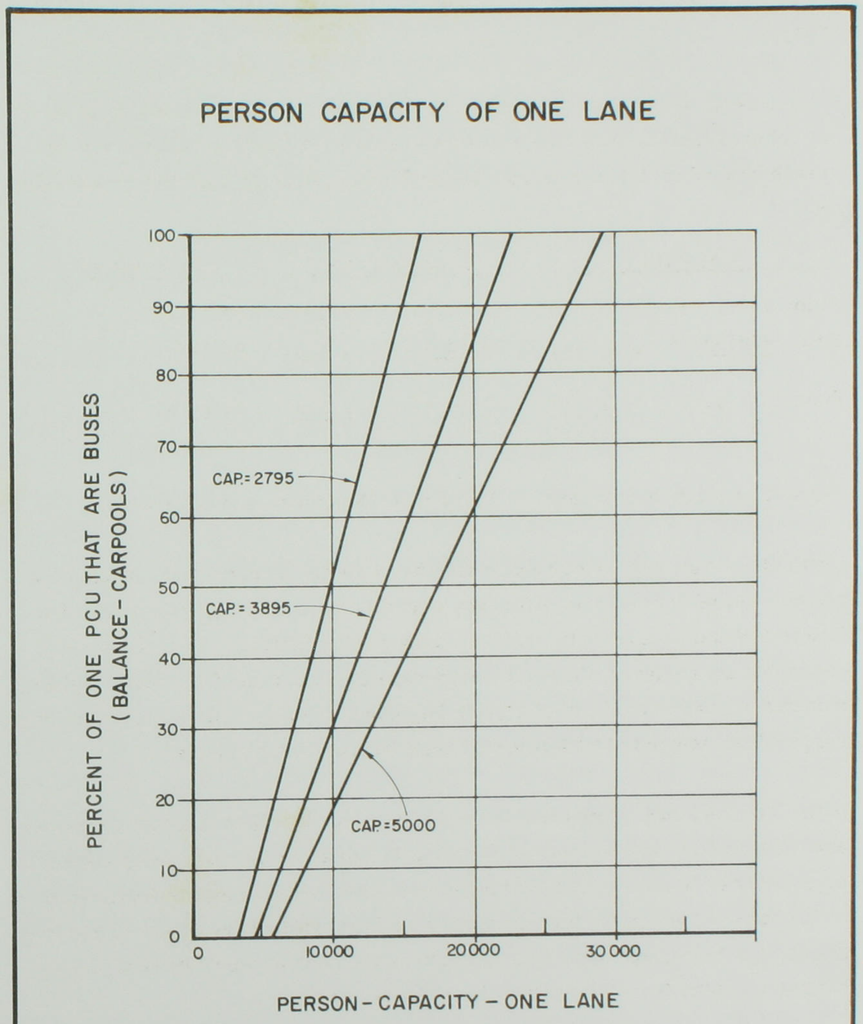


FIGURE C-1

The shifts of person volumes are 14 percent, 32 percent, and 21 percent respectively.

If the carpool vehicles are considered as supplementing the presently estimated bus volumes (that is, leave the bus volume at the 1990 estimated level and fill in with carpool vehicles to balance the PCU's in each lane), then the person volumes are:

	Alajuelita		Limon-Siquirres		Desamparados	
Auto:	767(1.4)	= 1,070	854(1.4)	= 1,200	906(1.4)	= 1,270
Bus:	$\frac{450(60)}{3}$	= 9,000	$\frac{280(60)}{3}$	= 5,600	$\frac{440(20)}{3}$	= 8,000
Pool:	317(4.0)	= $\frac{1,270}{11,340}$	574(4.0)	= $\frac{2,300}{9,100}$	496(4.0)	= $\frac{1,980}{12,050}$

Percentage shifts in this case are 11 percent, 25 percent, and 17 percent.

Certainly, a high-occupancy vehicle lane has potential to carry large numbers of persons, probably at greater efficiency than otherwise (although this conclusion is untested and involves total trip time among other factors). Also, if lane PCU capacities are balanced, the total person-capacity potential of the radial highway is increased and/or the level of service improved. However, there are severe physical problems associated with reserved lanes on four-lane highways.

If the left-hand lane is reserved, the right-hand lane is left to serve autos, trucks, and ramp traffic. Unless mode shifts occur in sufficient numbers, congestion is most likely to be increased in that right-hand lane. This reduces the efficiency of the reserved lane when high-occupancy vehicles must weave across to and from ramps. For buses, passenger load facilities in the medium would be required (including turnouts) to avoid crossing the unreserved lane.

If the right-hand lane is reserved, then the ramp traffic would interfere with the high-occupancy volume.

The use of reserved lanes is much more feasible for highways with three or more lanes in one direction. There seem to be serious obstacles to the application of reserved lanes on lesser roadways. If these roadways are of the arterial type, as portions of the radial highway are, then reserved lanes conflict with intersection traffic. Reserved lanes or arterials have been seen to be most productive on one-way streets—usually counter-flow.

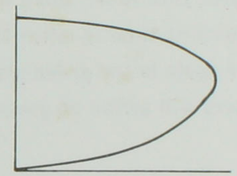
For access-limited facilities, the counter-flow reserved lanes, using the roadway opposite in direction to the major flow, have been proven effective in several applications. In the case of the radial highway studied, the minor directional volume (which would be restricted to one lane by the use of a counterflow lane for high-occupancy vehicles) exceeds the capacity of one lane except in the case of the Limon-Siquirres highway.

In summary, there are physical problems to the use of a reserved lane on a four-lane highway. Advantages might be gained only if a modal split can be achieved where PCU demand is balanced between the reserved and non-reserved lanes. The reserved lane itself could help achieve such a modal split, but there are many other factors involved.

Appendix D
When Volume Exceeds Capacity

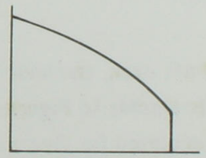
In Chapter VIII, several situations were encountered where it was necessary to describe the behavior of a traffic stream for conditions where the V/C ratio exceeded 1.00, and where the assumption that all trips beyond that limit are deferred is not applicable. The derivation of a speed versus V/C curve to describe this situation is given below.

In computer-based analyses, such as capacity restraint assignment, this problem is often overcome by changing the shape of the speed-volume curve. The basic curve approximates a parabola, i.e.:

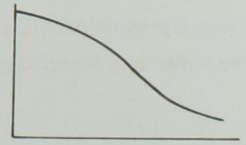


Capacity at level of service "E" is assumed at the right end of the curve. Observations for short time periods show that beyond "E" capacity both speed and volume drop, and the curve doubles back to zero.

These observations are usually for 15 minutes or less. For a full hour, the curve has been depicted thus:



For capacity restraint purposes, the curve is modified so:



This latter shape is attractive since the impact of traffic pressure that exceeds a V/C of 1.00 can be computed. The formulation of such a V/C versus speed curve was accomplished by using queueing theory through a hypothetical corridor intersection.

To estimate such a situation, a signalized intersection is assumed with one lane entering and a 60-second cycle, split evenly. A 1/2 mile approach is assumed with a flow speed of 30 mph.

The book Statistics and Highway Analysis discusses examples where the first vehicle stopped in a queue requires 3.8 seconds to enter an intersection when the light turns green, plus 2.0 seconds to accelerate to speed. The second requires 4.1 seconds, the third 2.7, and other 1.7 seconds each. Therefore, if we let traffic arrive evenly (at a specified flow rate), some will be stopped by a red signal and will require varying amounts of time to enter the intersection based on the units above. Others will arrive early in the green phase and will have to wait behind a decreasing queue. Others will arrive on green and pass through the signal unimpeded.

If such a model is tested at increasing levels of input flow, the total travel time for the half mile plus the queue delay can be easily totaled. After a certain flow rate, the situation is reached where the queue cannot be dissipated and vehicles are captured for an extra red cycle. The number captured then increases with each cycle until the input is relieved. This exact calculation was made for flow rates from 100 to 1,300.

Since actual input rates are not even, the hour was divided into 12 five-minute periods with a volume profile similar to Figure 3.10 of the Highway Capacity Manual. The rates and delays were tabulated for five-minute periods and totaled for the hour.

The calculations showed that the signal would work under the assumed ideal conditions up to a passenger car volume of something like 875 per hour without sustained queues.

Converted to V/C ratios, the data plotted are seen in Figure D–1. The solid line is the calculated actual production of the signal, and the dotted line is the V/C ratio representing the pressure on the intersection. The actual calculated productive curve is very similar to those in the Highway Capacity Manual, at least close enough to indicate that even though V/C in excess of 1.00 cannot exist, a volume trying to get through can exist in excess of the "1.00" volume.

The dotted curve in Figure D–1 smoothed, was converted to percentages of speed at V/C = 1.00 for increasing V/C greater than 1.00 for application in the economic analysis.

Since this analysis is an attempt to get closer to realism, some maximum V/C must be selected that is close to the actual point where trips become deferred.

It was found that a V/C = 1.20 has many good characteristics as a cut-off point. Queue length would be approaching a mile. Delay, when added to an average work trip length of 21 minutes, increases trip time to 30 minutes—well into the higher percentiles of the trip length distribution. The delay itself averages nine minutes.

Therefore, the process for economic analysis utilizes the curve in Figure D–1 up to a V/C of 1.20, beyond which trips are "deferred," and are assumed to be generated when the improvement is made.

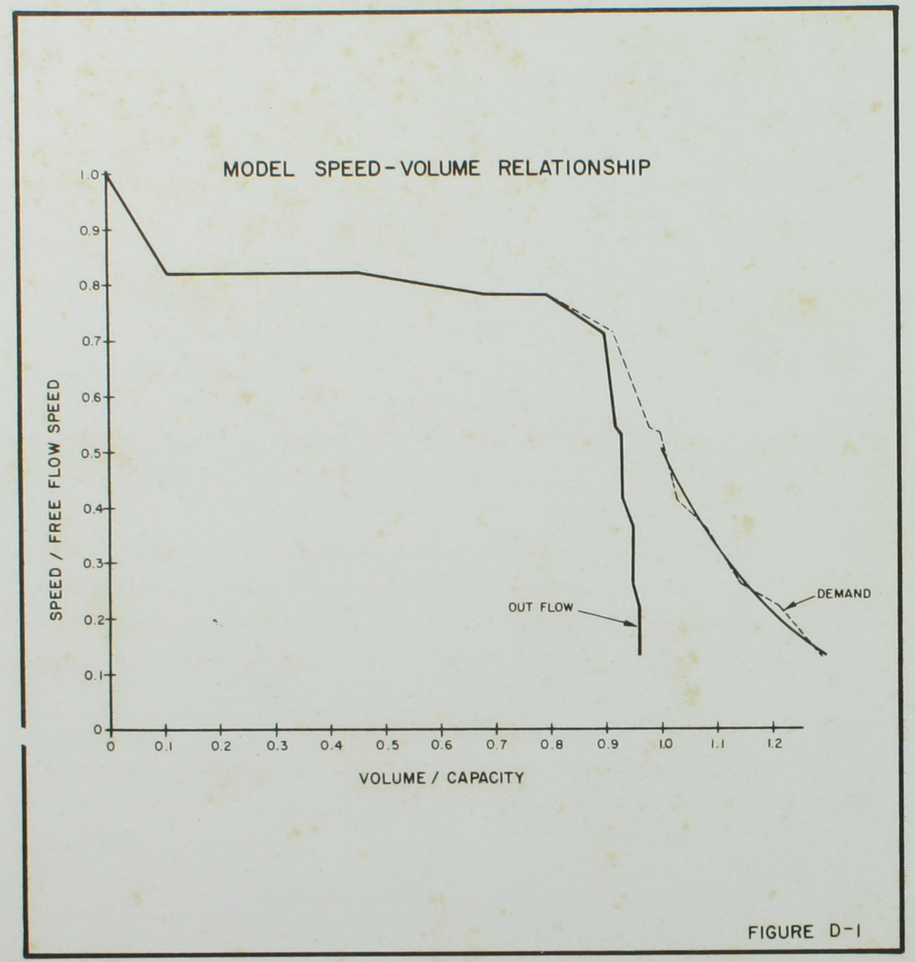

MODEL SPEED-VOLUME RELATIONSHIP
SPEED / FREE FLOW SPEED
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
VOLUME / CAPACITY
OUT FLOW
DEMAND

FIGURE D-1

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