SMART CORRIDOR

PROJECT WORKBOOK

jhk & associates

24465607

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S M A R T   C O R R I D O R
W O R K S H O P

I S S U E   P A P E R S

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SMART CORRIDOR DEMONSTRATION PROJECT

ISSUE PAPER ON EXISTING TRAFFIC CONDITIONS

March 7, 1989

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SMART CORRIDOR DEMONSTRATION PROJECT
ISSUE PAPER ON EXISTING TRAFFIC CONDITIONS

INTRODUCTION

This issue paper presents a summary of existing traffic conditions within the Smart Corridor Demonstration Project study area. The following types of data are presented and summarized in this document:

- Physical Description - Including number of travel lanes, on-street parking and locations of left-turn prohibitions for the major surface streets in the corridor; and number of travel lanes for the Santa Monica Freeway.
- Traffic Volumes - AM peak hour, PM peak hour and daily approach volumes for the major surface streets in the corridor; and AM peak hour, PM peak hour and daily volumes for the freeway mainline and ramps. Volumes at selected screenlines by time-of-day.
- Level of Service and Capacity Analysis - Peak hour levels of service for surface street intersections, ramp intersections and freeway mainline segments. Evaluation of excess capacity on surface streets.
- Vehicle Occupancy Data - Peak period occupancy data for freeway on-ramps.
- Vehicle Type Data - Truck volumes and percentages and bus volumes and percentages for the surface streets; and truck volumes and percentages for the freeway mainline.
- Accident Data - Number of accidents and accident rates for surface street intersections and freeway mainline segments.

Exhibit 1 illustrates the study area, indicating the location of the freeways, major highways and secondary highways within the corridor. Along with the Santa Monica Freeway itself, there are five major surface streets paralleling the freeway on which the data in this document is focussed. These streets, and their functional classification according to the City of Los Angeles General Plan, are as follows:

- Olympic Boulevard (major highway)
- Pico Boulevard (major highway west of Crenshaw Boulevard; secondary highway east of Crenshaw Boulevard)
- Venice Boulevard (major highway west of La Brea Avenue; secondary highway east of La Brea Avenue)
- Washington Boulevard (major highway)
- Adams Boulevard (major highway)

In addition, some data is presented for portions of National Boulevard, a secondary highway which parallels the freeway in the western portion of the corridor.

PHYSICAL DESCRIPTION

Surface Streets

Exhibits 2a and 2b illustrate the mid-block number of through lanes on the major east-west surface streets in the corridor, while Exhibits 3a and 3b illustrate the same information for the major north-south streets. Exhibits 4a and 4b illustrate the locations of on-street parking on the major east-west streets, and indicate the general types of restrictions (if any) on the parking. Exhibits 5a and 5b present the same information for the major north-south streets.

As can be seen, two to three lanes are typically provided in each direction, with additional lanes provided on some segments during peak periods through the use of parking restrictions. Parking is permitted during all or a part of the day on most of the major streets in the study area.

Exhibit 6 indicates the locations of major intersections in the corridor at which left-turn(s) are currently prohibited, and identifies the particular movements which are prohibited and the periods during which the restriction is in force.

It should be noted that the Long Beach-Los Angeles light rail line is currently under construction along the section of Washington Boulevard between Figueroa Street and Long Beach Avenue. Construction activity is taking place in the northern half of the roadway, with all traffic temporarily shifted into four lanes in the southern portion of the roadway. On-street parking is not permitted.

Santa Monica Freeway (I-10)

Approximately fourteen miles of the Santa Monica Freeway is contained in the Smart Corridor study area, between Centinela Avenue on the west and the East LA interchange on the east. As illustrated on Exhibit 7, the freeway mainline provides four to five travel lanes in each direction, depending upon location. Auxiliary lanes are provided in the following areas:

- o vicinity of the La Cienega Boulevard and Venice Boulevard interchanges
- o vicinity of the La Brea Avenue interchange
- o from the Arlington Avenue interchange east to the Harbor Freeway
- o approaching the East LA interchange

In addition, 17th and 18th Streets function as parallel one-way frontage roads between the Grand Avenue and Maple Avenue interchanges in downtown Los Angeles.

TRAFFIC VOLUMES

Surface Streets

All available existing approach volume counts were obtained from the Los Angeles Department of Transportation (LADOT) for the surface streets in the corridor. These volumes were counted in either 1987 or 1988. Exhibits 8a and 8b illustrate the available 24-hour one-way approach volumes on the major surface streets in the corridor. Exhibits 9a and 9b illustrate the AM peak hour approach volumes for the surface streets, while Exhibits 10a and 10b illustrate the PM peak hour approach volumes.

The most heavily travelled east-west street is Olympic Boulevard, with daily approach volumes ranging from a low of about 14,000 vehicles per day (vpd) in the eastern end of the corridor to as much as 31,500 vpd at Overland Avenue (between Century City and the San Diego Freeway). The least travelled east-west street is Adams Boulevard, with daily approach volumes ranging between 2,600 at Fairfax Avenue to about 10,800 vpd at Crenshaw Boulevard. As might be expected, volumes during the AM peak hour are typically greater in the inbound direction towards downtown Los Angeles, while the outbound volumes are generally greater during the PM peak hour.

Santa Monica Freeway

Existing mainline and ramp volume counts were obtained from the California Department of Transportation (Caltrans) for the Santa Monica Freeway. Exhibit 11 illustrates average annual daily traffic (AADT) volumes on the freeway mainline in 1987, as obtained from the Caltrans document entitled 1987 Traffic Volumes on California State Highways. Exhibit 12 indicates daily volumes on most of the on- and off-ramps. Exhibits 13 and 14 respectively illustrate the available AM and PM peak hour directional traffic volumes both on freeway mainline segments and on the on- and off-ramps. The peak hour volumes on the mainline segments were obtained from "Main Lane Occupancy and Volume Reports" from the Caltrans Semi-Automated Traffic Management System, as counted in January or February of 1989. The peak hour and daily volumes on the ramps were obtained from Caltrans hourly traffic counts, conducted primarily in 1987.

Average daily traffic volumes on the Santa Monica Freeway within the study area in 1987 ranged from a low of about 180,000 AADT at the extreme western edge of the corridor (between Centinela Avenue and Bundy Drive) to a high of approximately 315,000 AADT between Normandie Avenue and Vermont Avenue. It is of interest to note that the 315,000 AADT on this section represented the most heavily travelled freeway segment within the Los Angeles metropolitan region in 1987.

The most heavily travelled Santa Monica Freeway ramps in the study area include the westbound off-ramp to National Boulevard (20,370 vehicles per day), the eastbound on-ramp from Washington Boulevard (18,880 vpd), the eastbound on-ramp from southbound La Cienega Boulevard (18,600 vpd), and the westbound off-ramp to Venice Boulevard (17,270 vpd).

Screenlines

In order to provide an indication of total volumes across the corridor at various places within the corridor, a screenline analysis has been performed. The screenlines were selected based on geographic location and availability of count data at each parallel facility across the screenline. The three screenlines selected for this analysis are:

- o Overland Avenue
- o Fairfax Avenue
- o Western Avenue

Olympic Boulevard, Pico Boulevard, Venice Boulevard, Washington Boulevard and the Santa Monica Freeway cross all three of the screenlines. Adams Boulevard crosses the Fairfax Avenue and Western Avenue screenlines, but not the Overland Avenue screenline.

Exhibit 15 graphs the freeway volume, total volume on the major surface streets, and overall total volume (freeway and surface street) crossing the Overland Avenue screenline in the eastbound direction by time-of-day, while Exhibit 16 presents the same data for the westbound direction. Exhibits 17, 18, 19 and 20 summarize similar data for the eastbound and westbound directions at the Fairfax Avenue and Western Avenue screenlines.

It should be noted that, due to lack of available data, the surface street totals at the Overland Avenue and Western Avenue screenlines do not include traffic on Washington Boulevard. It should also be noted that freeway volumes were not available between 12 midnight and 3 AM at the Overland screenline and between 12 midnight and 5 AM at the Fairfax screenline (in the eastbound direction), and thus are not plotted on the graphs.

LEVEL OF SERVICE AND CAPACITY ANALYSIS

Surface Street Intersections

Turning movement count data was obtained from the LADOT for major surface street intersections in the corridor, and was used as the basis for the capacity and level of service analysis. Most of the volumes used in this analysis were counted in either 1987 or 1988.

The surface street/surface street intersections selected for the level of service analysis include basically all intersections of the five major east-west streets (Olympic, Pico, Venice, Washington and Adams) with north-south streets classified as major highways. In addition, a small number of intersections of the major east-west streets with secondary highways were analyzed, as were two intersections along National Boulevard in the western portion of the study area. A total of 70 surface street/surface street intersections were identified for analysis, although existing traffic count data is available for only 63 of the 70. The 63 surface street/surface street intersections included in the analysis are shown on Exhibit 21.

The freeway ramp intersections selected for analysis consist of all signalized intersections of freeway ramps with surface streets in the corridor. A total of 34 such intersections were identified, although existing traffic count data is available for only 21 of the 34. The 21 ramp intersections included in the analysis are illustrated on Exhibit 22.

Level of service (LOS) is a qualitative measure used to describe the condition of traffic flow, ranging from excellent conditions at level of service LOS A to overloaded conditions at LOS F. Level of service definitions are included in Exhibit 23. The "Critical Movement Analysis-Planning" method of intersection capacity analysis was utilized to determine the peak hour volume/capacity (V/C) ratio and corresponding LOS for each of the intersections selected for analysis.

Exhibits 24 and 25 list the existing V/C ratios and levels of service at the analyzed surface street and ramp intersections, respectively. Exhibits 26 and 27 display the AM peak hour operating conditions by LOS category for the surface street and ramp intersections, respectively, while Exhibits 28 and 29 illustrate similar results for the PM peak hour.

Four of the 63 analyzed surface street intersections currently operate at an overloaded LOS F during the morning peak hour, 11 at a poor LOS E, and 48 at a good LOS of D or better. Overall conditions are worse during the afternoon peak hour, with 13 of the 63 surface street intersections operating at LOS F, 13 at LOS E, and 37 at LOS D or better. None of the analyzed ramp intersections operate at LOS F during the morning peak hour, 2 of the 21 operate at a poor LOS E, and 19 at a good LOS of D or better. During the afternoon peak hour, 1 of the 21 ramp intersections operate at LOS F, 2 at LOS E, and 18 at LOS D or better.

Santa Monica Freeway

Peak hour V/C ratios and levels of service for Santa Monica Freeway mainline segments were estimated by assuming an average freeway capacity of 1,750 vehicles per hour per lane. Exhibit 30 summarizes the process used to calculate the V/C ratios, while the results are plotted on Exhibits 31 and 32. It should be noted that, due to lack of available peak hour mainline traffic volume data, the level of service analysis has not been performed for the portion of the freeway east of the Harbor Freeway.

The theoretical average capacity of 1,750 vehicles per hour per lane is a figure typically used by the Caltrans project development section for evaluation of the potential need for improvements, and is based on a base capacity of 2,000 vehicles per hour per lane factored downwards for the effect of trucks, lateral clearance, lane widths, etc. This methodology is simplistic, as it does not take into account the effects of ramps and weaving maneuvers. However, it does provide an indication of the general level of congestion on the freeway.

As can be seen, utilizing a theoretical capacity of 1,750 vehicles per hour per lane, many of the sections of the Santa Monica Freeway currently experience V/C ratios approaching or greater than 1.00 during the peak periods. This indicates that the freeway is operating at or above the theoretical capacity, experiencing significant levels of congestion and delay.

Excess Capacity

In order to provide an indication of the degree to which parallel streets may be able to accommodate shifted traffic flows (the potential for which will be evaluated later in this study), existing excess capacity on the major parallel streets was estimated. The evaluation of excess capacity was based on conditions at the major intersections included in the level of service analysis above since, in urban areas, operating conditions at intersections constrain and control the capacity of streets.

The excess capacity analysis was conducted for each of the five major east-west streets (Olympic, Pico, Venice, Washington and Adams Boulevards), at each of the following north-south cross streets which intersect the parallel street:

- Sepulveda Boulevard
- La Cienega Boulevard
- Fairfax Avenue
- La Brea Avenue
- Crenshaw Boulevard
- Western Avenue
- Vermont Avenue
- Hoover Street
- Figueroa Street
- Main Street
- Central Avenue
- Alameda Street
- Soto Street

The methodology consisted of comparing the critical movements calculated for each of the intersections in the level of service analysis to a theoretical capacity of 1,500 vehicles per lane per hour of green time, and multiplying the difference by the number of lanes in the peak direction along the east-west street. This method assumes that the traffic signal at the intersection can be timed such all of the existing excess capacity is assigned to the east-west street. As such, it presents a somewhat optimistic estimate of existing excess capacity for the east-west street, as it does not allow for future traffic growth which may occur on the north-south cross street.

Exhibit 33 graphically displays the estimated existing excess capacity along each of the five major parallel streets for the eastbound (inbound) direction in the morning peak hour. Exhibit 34 displays similar information for the westbound (outbound) direction in the afternoon peak hour.

FREEWAY VEHICLE OCCUPANCY

Vehicle occupancy data was obtained from Caltrans for a number of freeway on-ramps along the Santa Monica Freeway. This data is summarized on Exhibit 35, which indicates the percent of single-occupant vehicles and the percent of vehicles with two or more occupants, during both the AM and PM peak periods, at all on-ramps for which data was available.

As can be seen, the percent of single-occupant vehicles varies from about 84% to 92% on the eastbound (inbound) on-ramps during the morning peak period. During the afternoon peak period, single-occupant vehicles account for between 70% and 88% of the traffic on the westbound (outbound) on-ramps. Note that no vehicle occupancy data was available for the eastern portion of the corridor east of the Harbor Freeway.

VEHICLE TYPE

Surface Streets

The turning movement count data obtained from the LADOT for the intersection level of service analysis also includes information on the number of both trucks and buses counted at each intersection. The truck and bus counts from LADOT are for the entire six hour count period (7 to 10 AM and 3 to 6 PM).

Exhibit 36 summarizes the existing truck volumes at each of the major surface street intersections, indicating the total six-hour intersection volume, the total six-hour truck volume, the average hourly truck volume over the six-hour period, and the truck percentage of total traffic at the intersection. Exhibit 37 presents similar information for the existing bus volumes.

Trucks typically represent about one to three percent of the total traffic at most surface street locations throughout the corridor, although the truck percentages do range as high as twelve to fourteen percent at intersections along Alameda Street and Soto Street in the industrial area in the eastern portion of the corridor.

Buses typically represent less than two percent, and often less than one percent, of the total traffic at the surface street intersections included in this analysis.

Santa Monica Freeway

Data was obtained from Caltrans regarding daily truck percentages on sections of the Santa Monica Freeway mainline in 1987. This data is summarized on Exhibit 38, which indicates the truck percentage of total freeway average daily traffic volume, by direction. Truck percentages on the freeway range from about 5.4% to 6.5% in the eastbound direction, and between 4.7% and 7.1% in the westbound direction.

ACCIDENT DATA

Surface Streets

Traffic accident reports were obtained from the LADOT for the five major east-west streets, for the three-year period between June 1, 1985 and June 1, 1988. The following segments of streets were included in the data obtained from the LADOT:

- o Olympic Boulevard
  - Sawtelle Boulevard to Century Park East (Beverly Hills border)
  - Bedford Street (Beverly Hills border) to Ardmore Avenue (east of Western Avenue)
  - Alameda Street to Soto Street
- o Pico Boulevard
  - Sawtelle Boulevard to Hi-Point Street (west of Fairfax Avenue)
- o Venice Boulevard
  - Centinela Avenue to David Avenue (east of I-10)
- o Washington Boulevard
  - Fairfax Avenue to Normandie Avenue
- o Adams Boulevard
  - Fairfax Avenue to Harvard Boulevard (east of Western Avenue)

As can be seen, the accident reports do not encompass the entire street throughout the entire corridor for any of the five major east-west streets.

Exhibit 39 summarizes the total reported number of intersection accidents in the three-year period and the accident rate per million vehicles at the major surface street intersections evaluated in this document for which accident data was available. Exhibit 40 presents the same information with the intersections ranked by the total number of accidents, while Exhibit 41 ranks the intersections by the accident rate.

As indicated in the exhibits, for those major intersections at which data was available, the intersections of Olympic Boulevard/Western Avenue and Venice Boulevard/La Cienega Boulevard had the highest number of accidents in the three-year period (48 each, or an average of about 16 per year). The intersection of Olympic Boulevard/Alameda Street, however, had the highest accident rate (0.70 accidents per million vehicles).

Santa Monica Freeway

Traffic accident reports were also obtained from the Caltrans TASAS system for the Santa Monica Freeway throughout the corridor, also for the three-year period between June 1, 1985 and June 1, 1988.

Exhibit 42 displays the total number of reported accidents in the three-year period and the actual accident rate per million vehicle miles for various segments along the Santa Monica Freeway. The exhibit also indicates the expected accident rate, which is a figure calculated by Caltrans based upon statewide data for similar highways. The expected accident rate is intended for comparative purposes, to determine whether the actual accident rate for a particular section of highway is higher or lower than that which could be expected. Exhibit 43 graphically illustrates the actual versus expected accident rates for the segments along the Santa Monica Freeway.

As indicated in the exhibits, the section between Hoover Street and the Harbor Freeway experienced the highest accident rate in the three-year period (1.79 accidents per million vehicle miles). The section between Washington Boulevard and La Brea Avenue, on the other hand, experienced the lowest rate (0.69 accidents per million vehicle miles). It is of interest to note that the actual accident rates are lower than the expected accident rates for most segments of the Santa Monica Freeway within the corridor. The exceptions to this are in the western portion of the corridor (west of National Boulevard), in the immediate vicinity of the Harbor Freeway (between Hoover Street and Maple Avenue), and between Alameda Street and Santa Fe Avenue.

SMART CORRIDOR DEMONSTRATION PROJECT

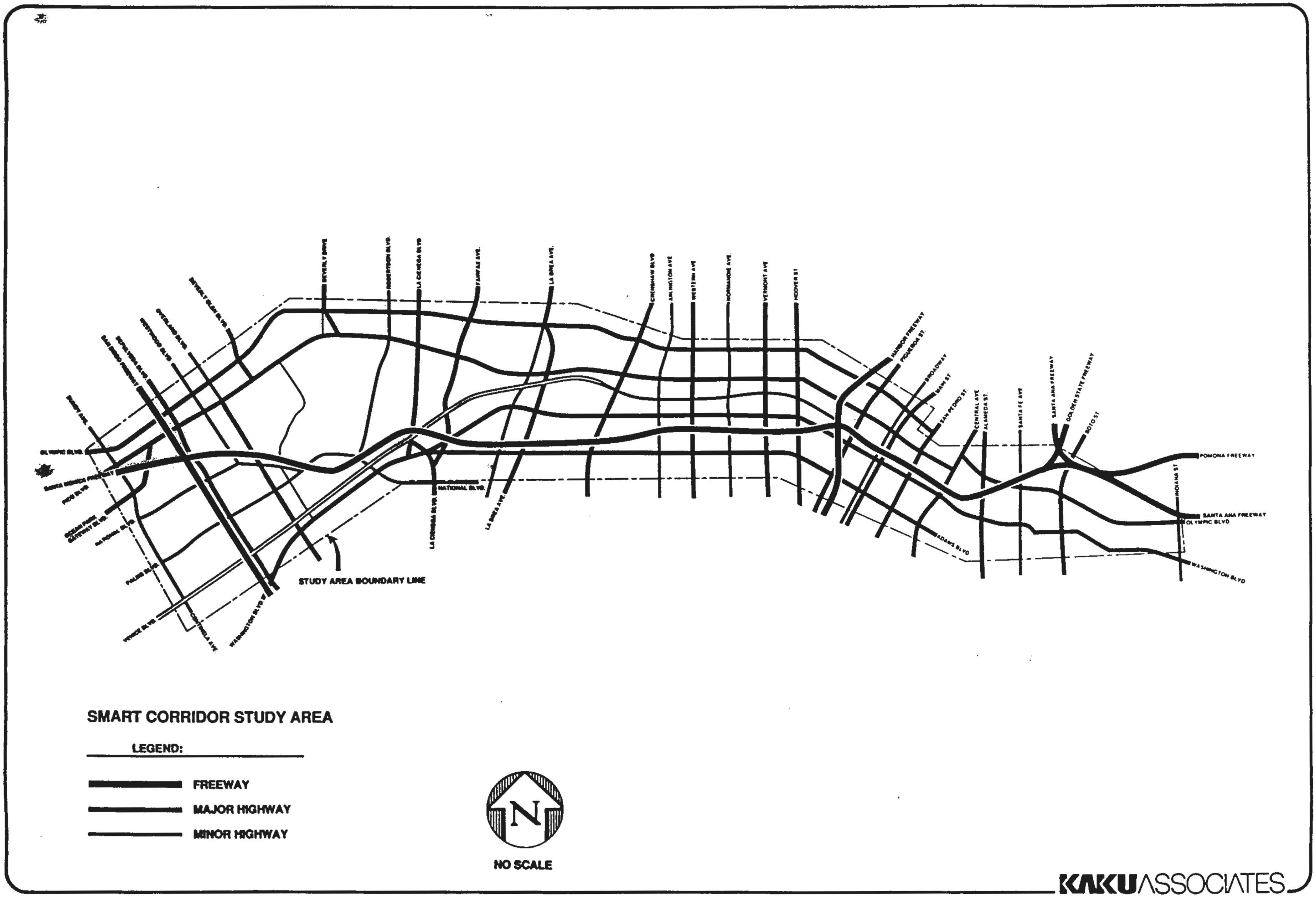
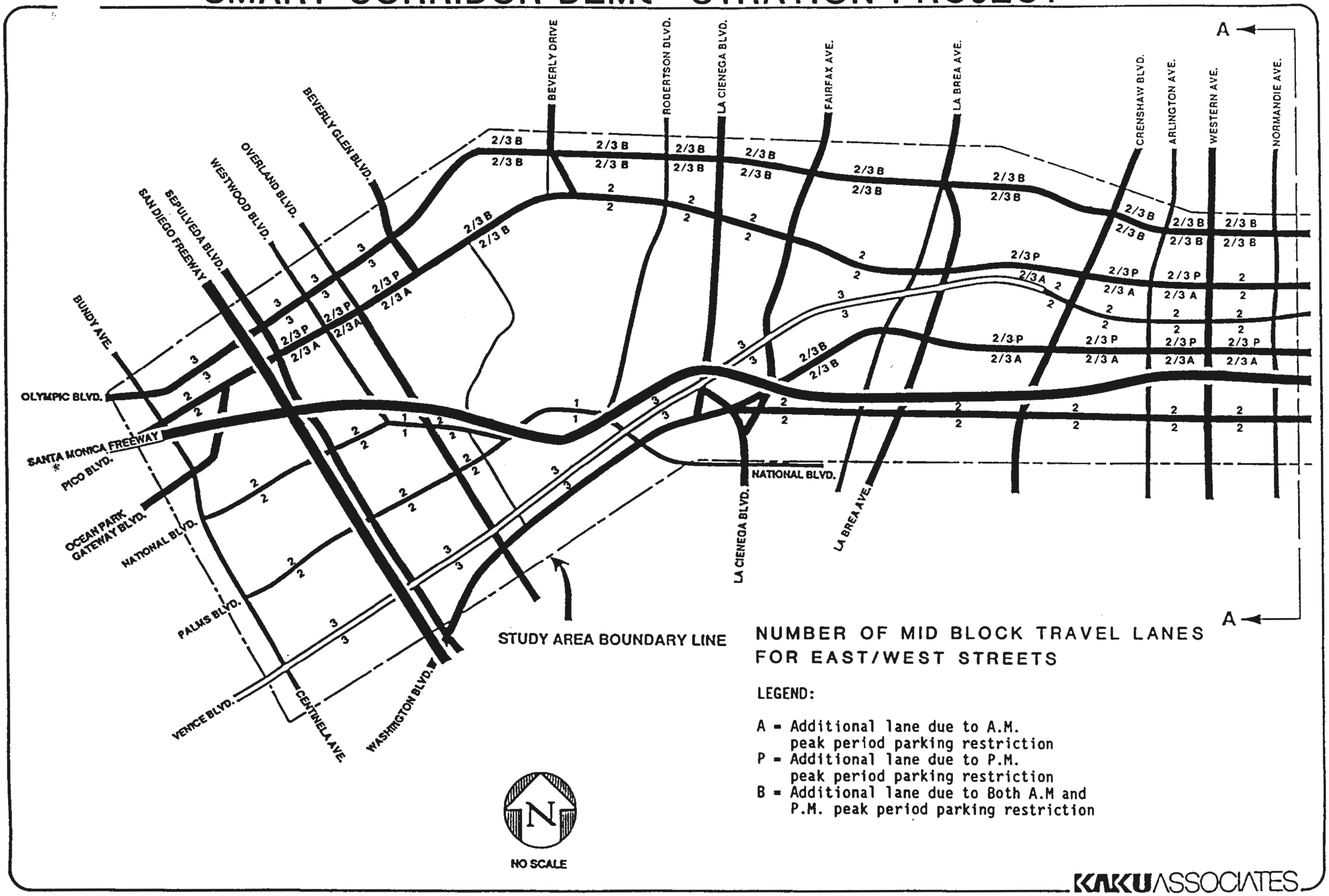


EXHIBIT 1

SMART CORRIDOR DEMC STRATION PROJECT



NUMBER OF MID BLOCK TRAVEL LANES FOR EAST/WEST STREETS

LEGEND:

A = Additional lane due to A.M. peak period parking restriction
P = Additional lane due to P.M. peak period parking restriction
B = Additional lane due to Both A.M and P.M. peak period parking restriction

KAKU ASSOCIATES

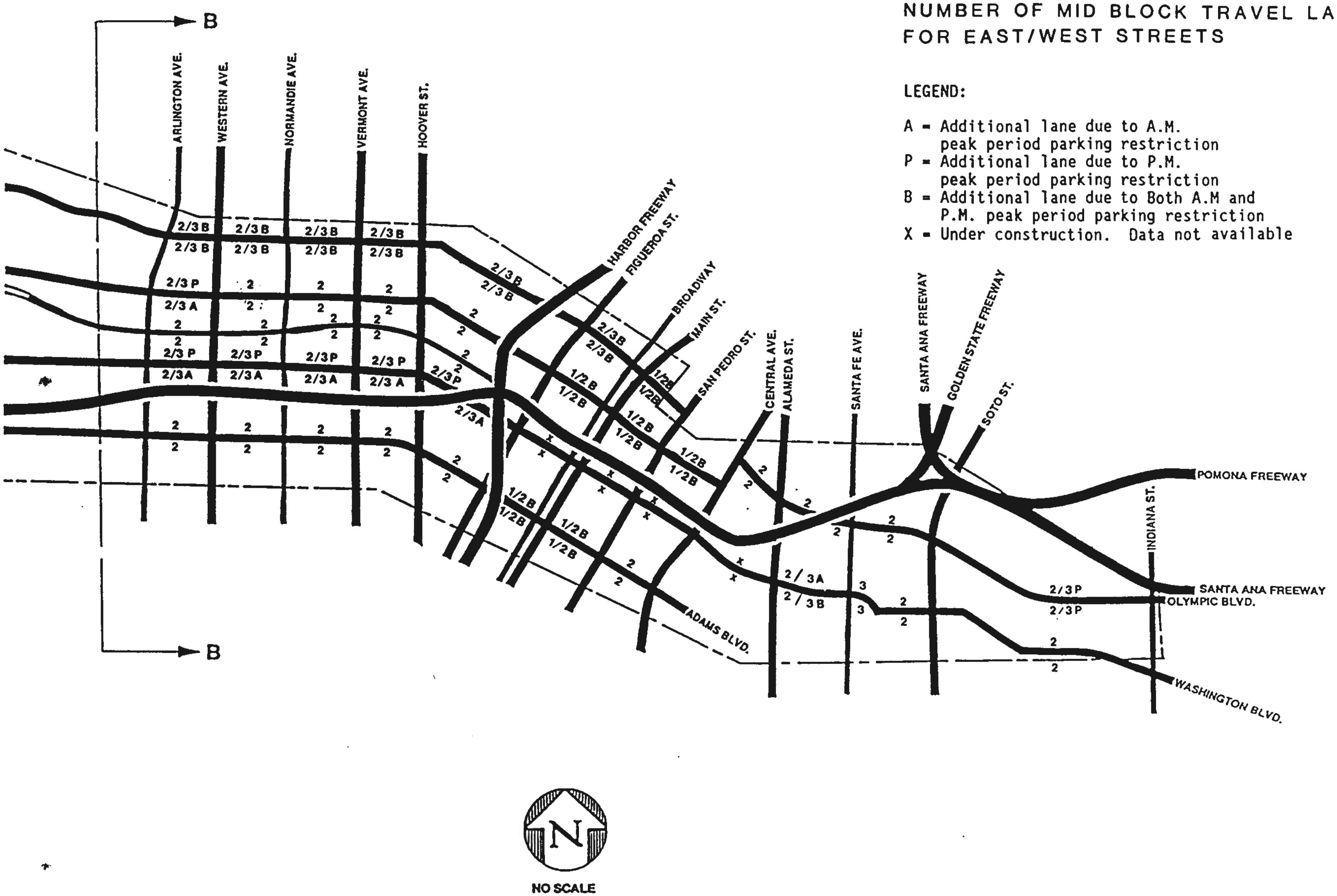
EXHIBIT 2A

SMART CORRIDOR DEMONSTRATION PROJECT

NUMBER OF MID BLOCK TRAVEL LANES
FOR EAST/WEST STREETS

LEGEND:

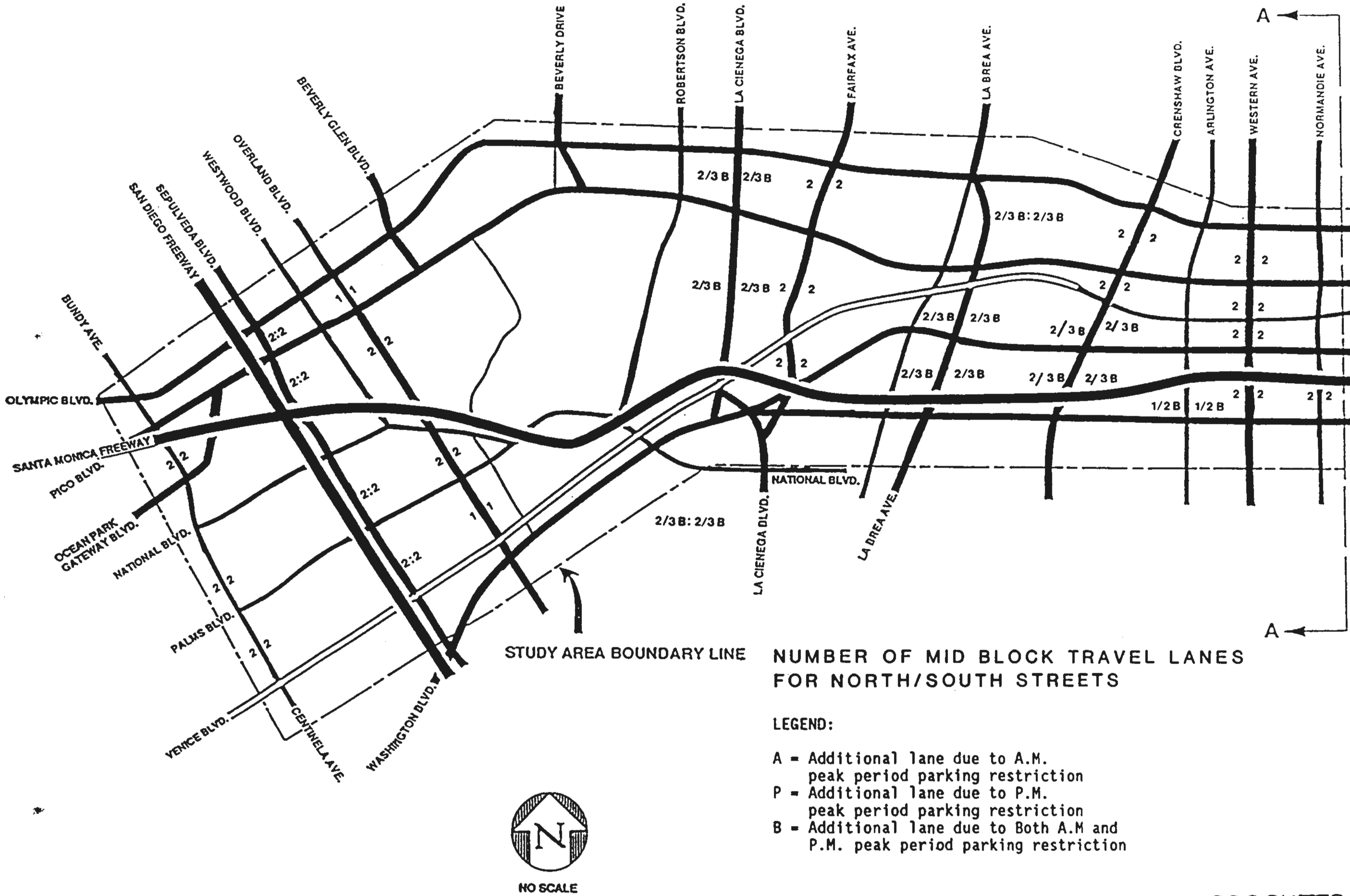
A = Additional lane due to A.M. peak period parking restriction
P = Additional lane due to P.M. peak period parking restriction
B = Additional lane due to Both A.M and P.M. peak period parking restriction
X = Under construction. Data not available



KAKU ASSOCIATES

EXHIBIT 2B

SMART CORRIDOR DEMC STRATION PROJECT



NUMBER OF MID BLOCK TRAVEL LANES FOR NORTH/SOUTH STREETS

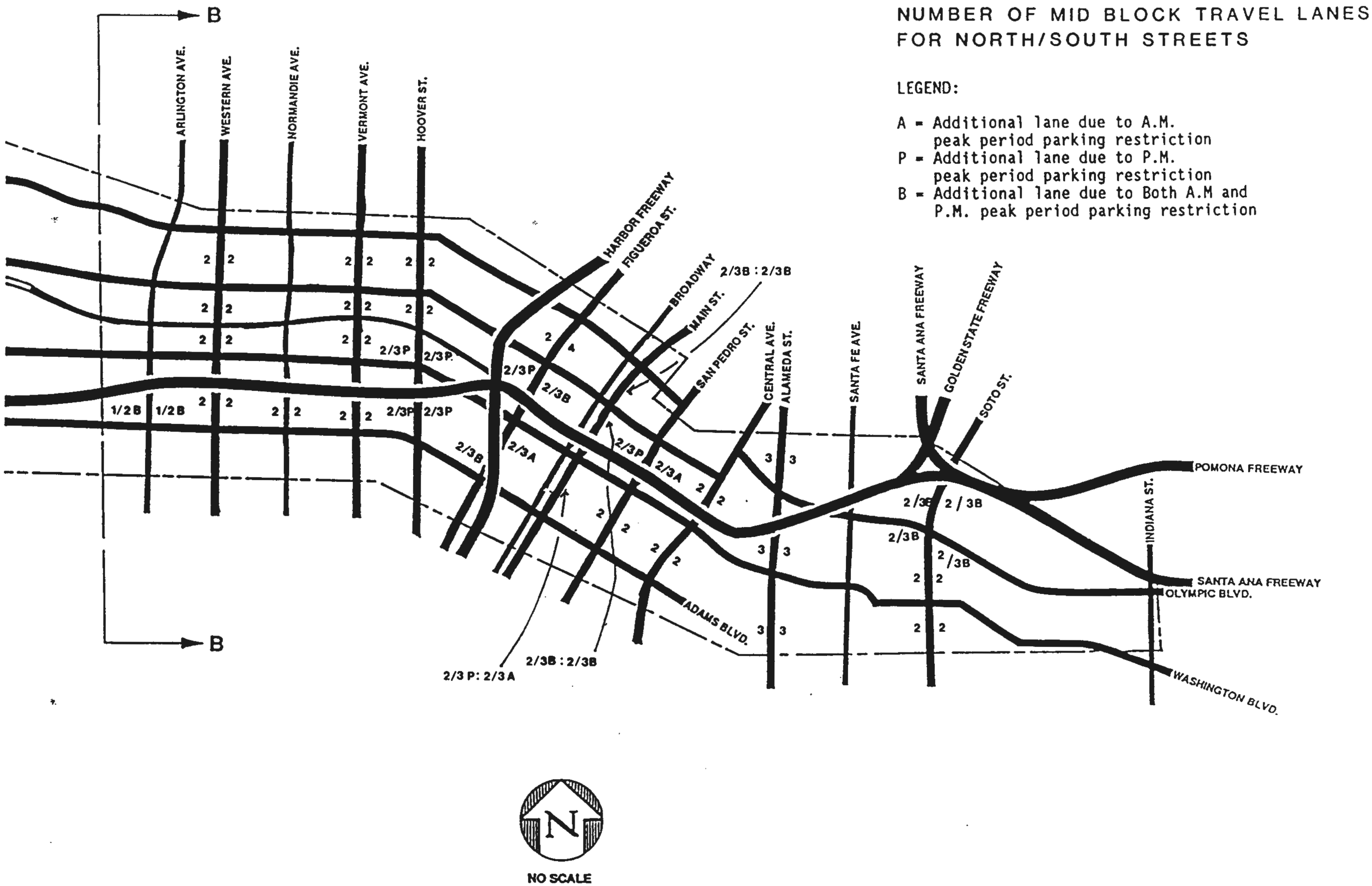
LEGEND:

A = Additional lane due to A.M. peak period parking restriction
P = Additional lane due to P.M. peak period parking restriction
B = Additional lane due to Both A.M and P.M. peak period parking restriction

KAKU ASSOCIATES

EXHIBIT 3A

SMART CORRIDOR DEMONSTRATION PROJECT



KAKU ASSOCIATES

EXHIBIT 3B

SMART CORRIDOR DEMONSTRATION PROJECT

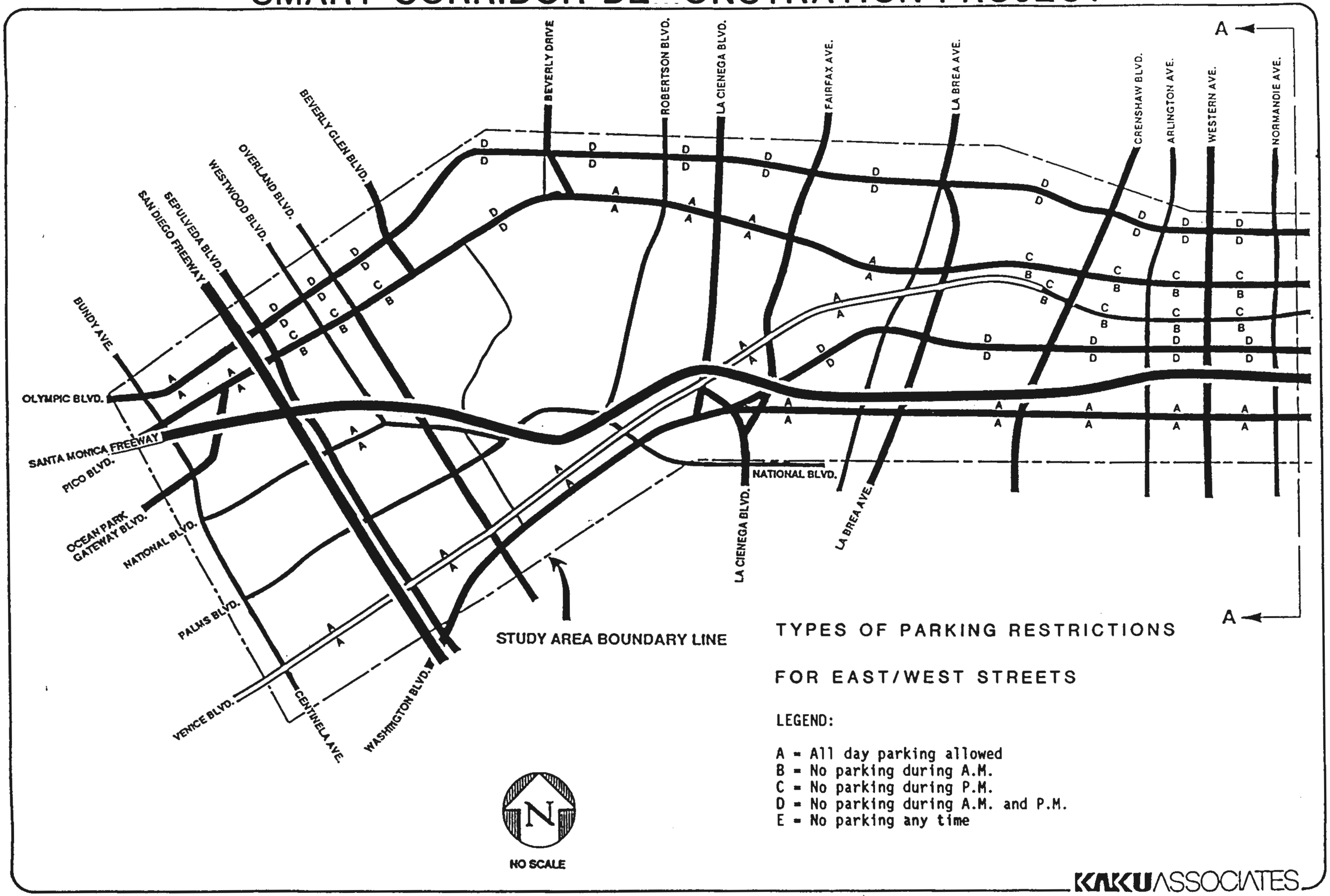
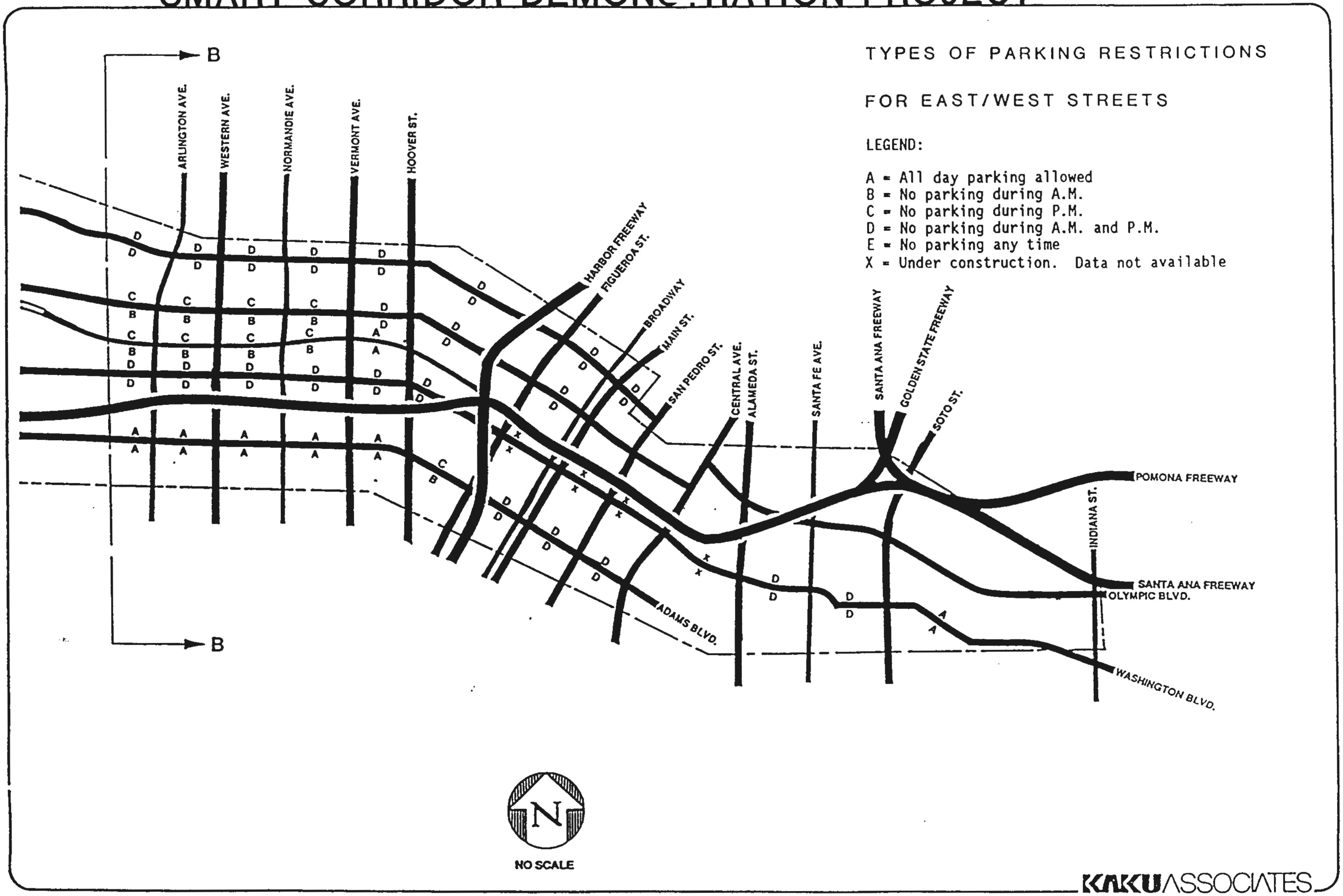


EXHIBIT 4A

SMART CORRIDOR DEMON[illegible]RATION PROJECT



EXHIBT 4B

SMART CORRIDOR DEMONSTRATION PROJECT

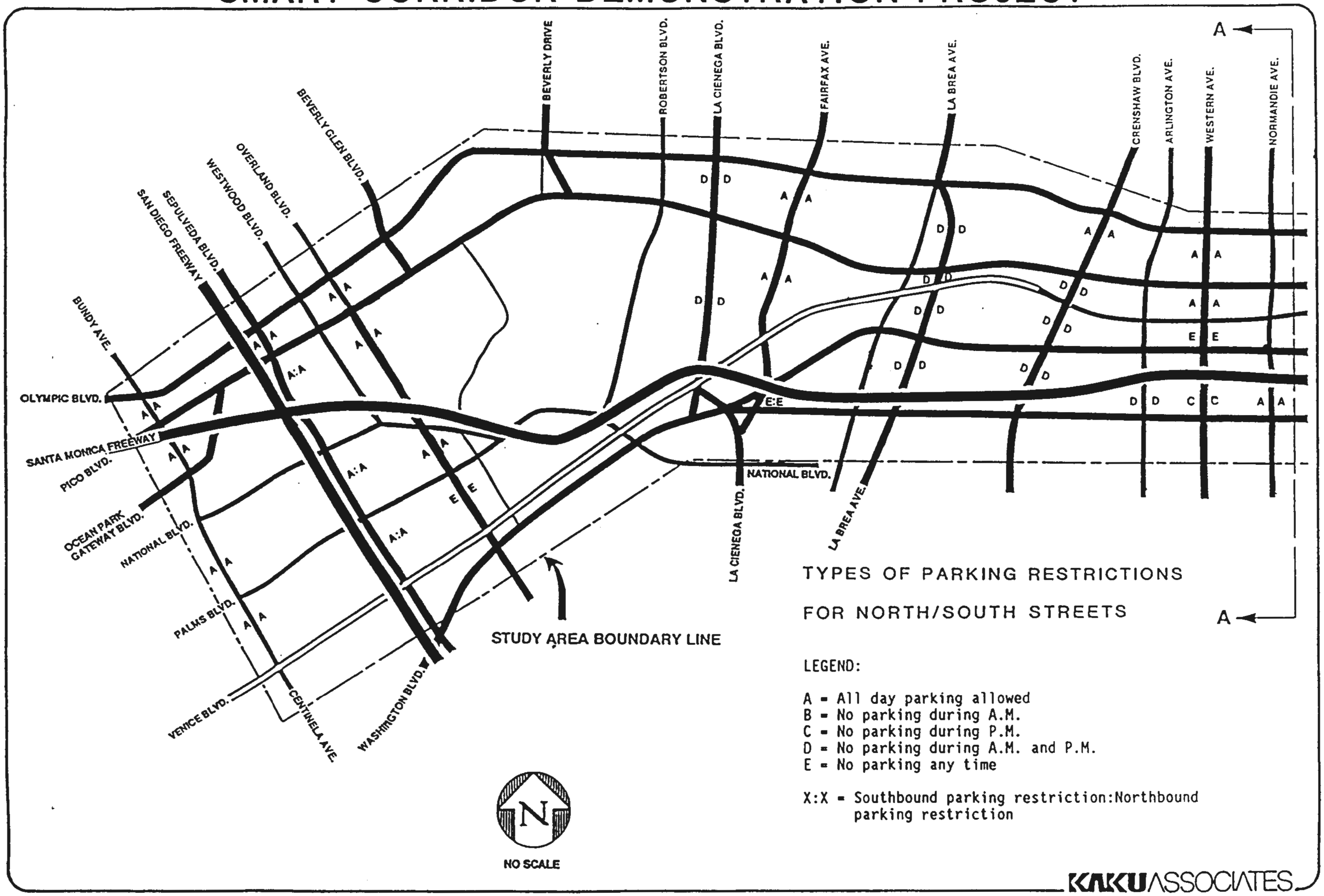


EXHIBIT 5A

SMART CORRIDOR DEMC..STRATION PROJECT

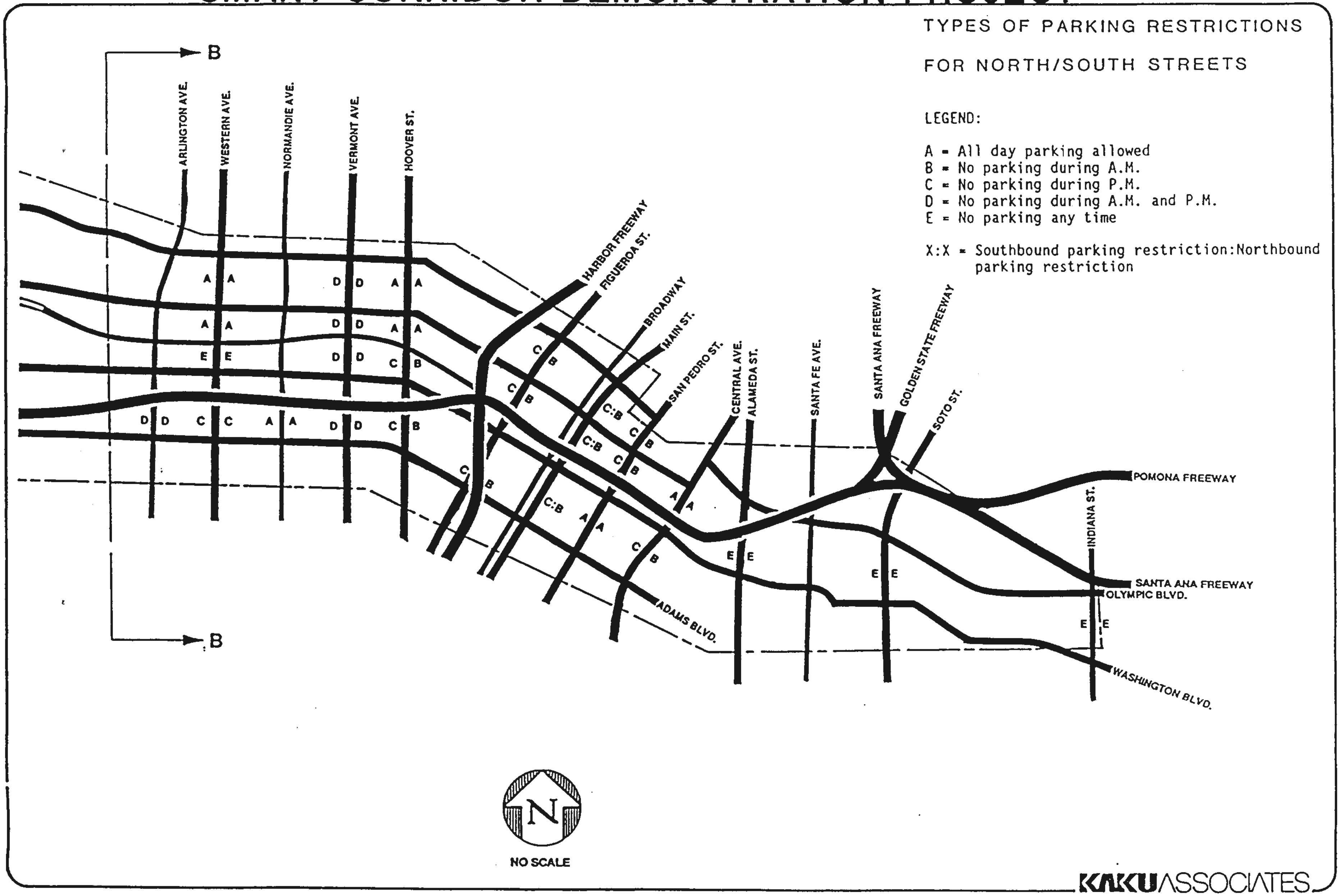
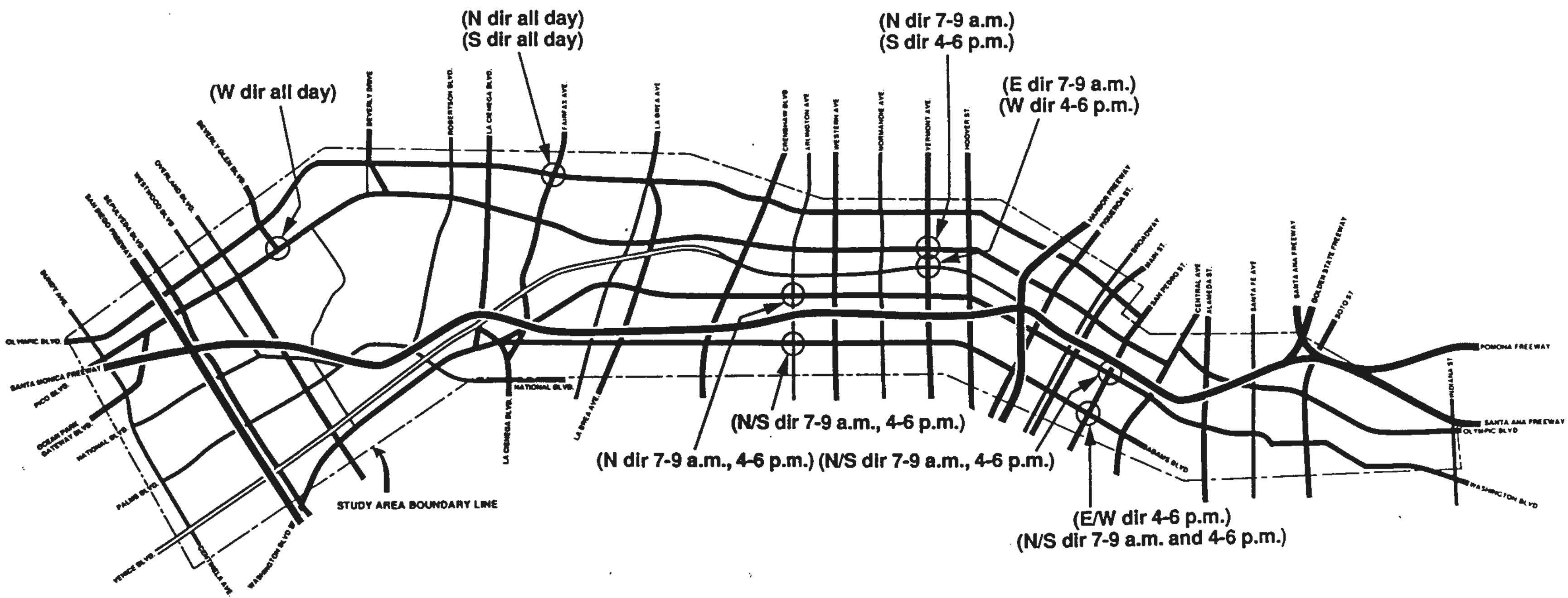


EXHIBIT 5B

SMART CORRIDOR DEMONSTRATION PROJECT



LOCATION OF LEFT TURN PROHIBITIONS

LEGEND:

○ NO LEFT TURN AT INTERSECTION

N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 6

SMART CORRIDOR DEMONSTRATION PROJECT

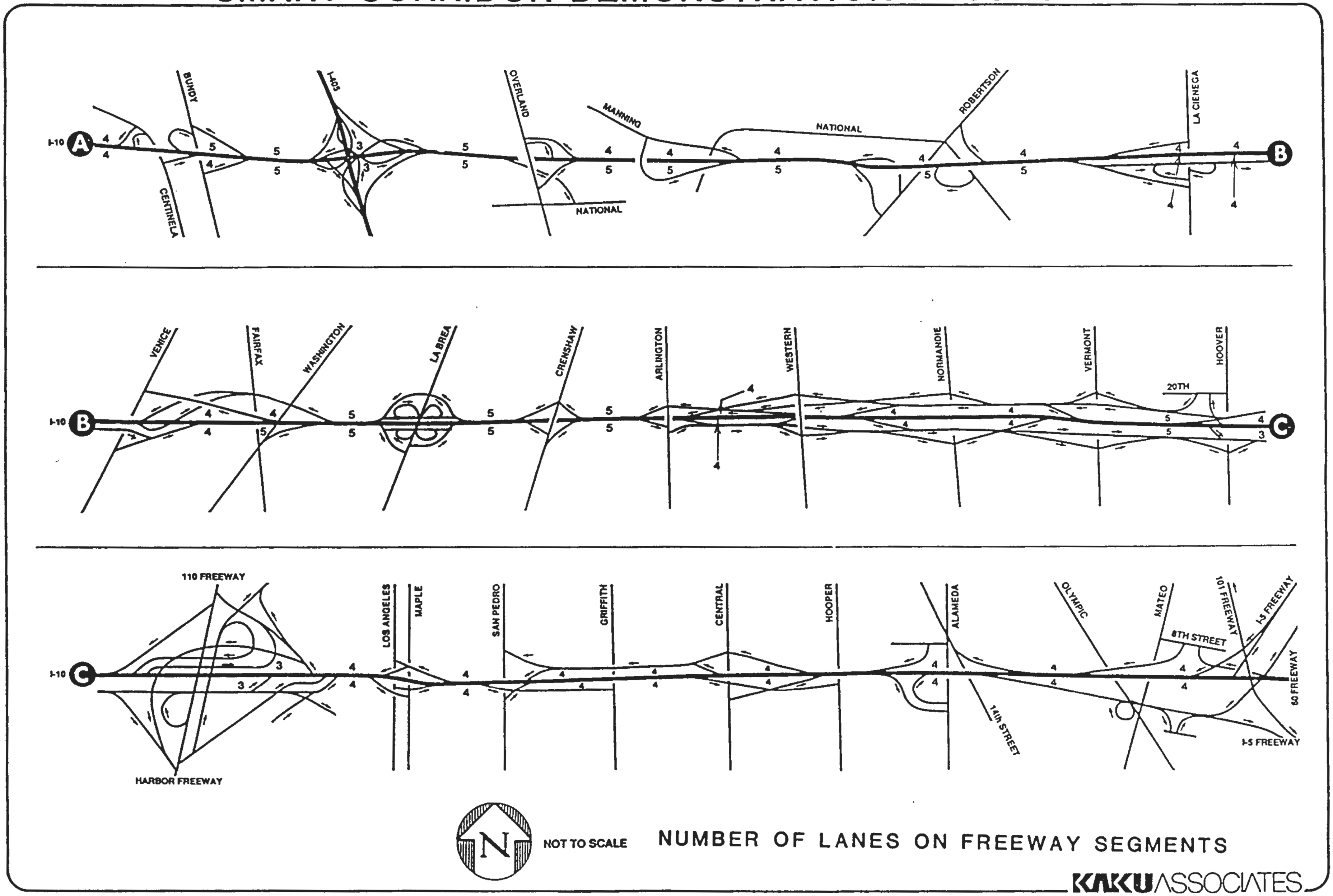
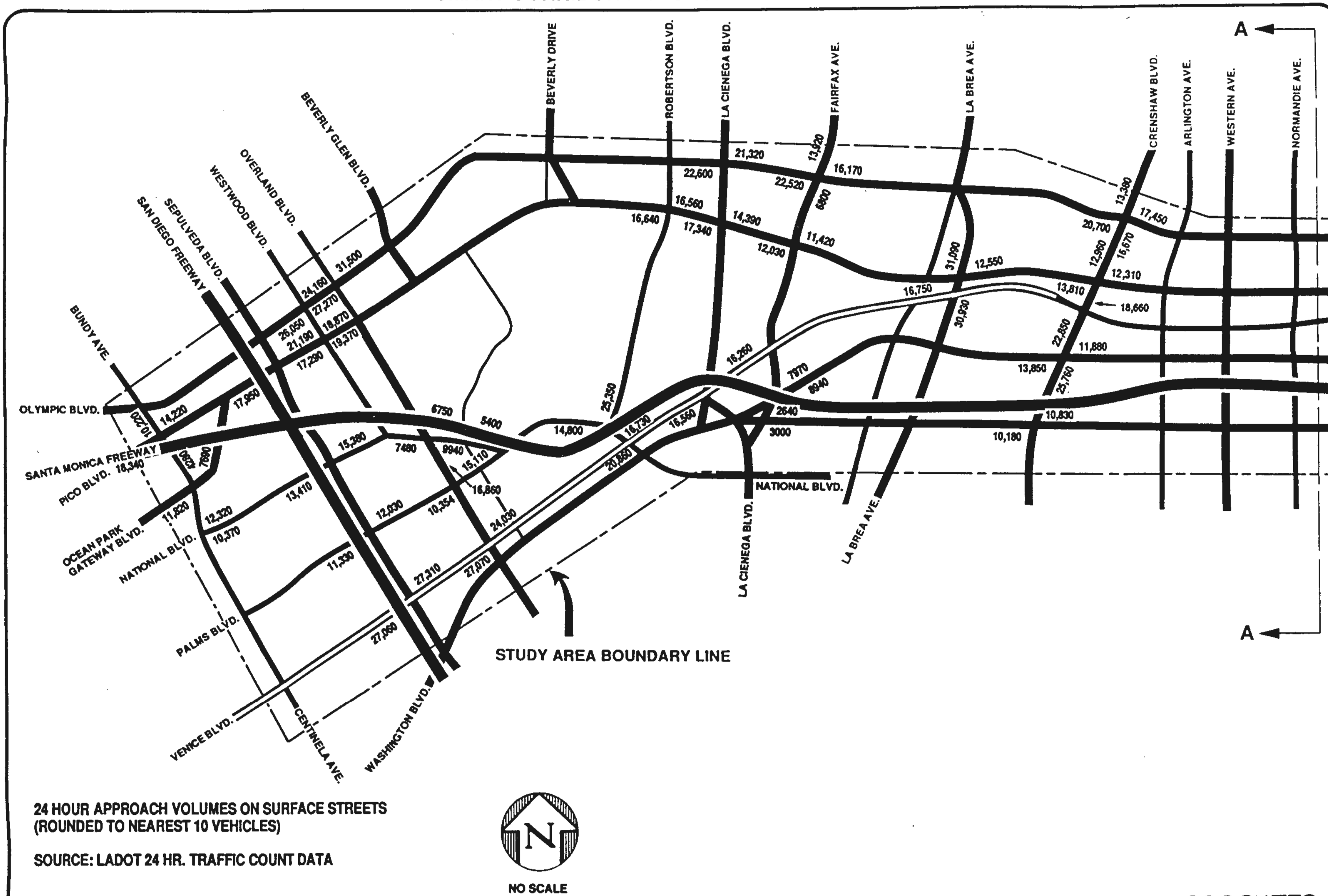


EXHIBIT 7

SMART CORRIDOR DEMONSTRATION PROJECT



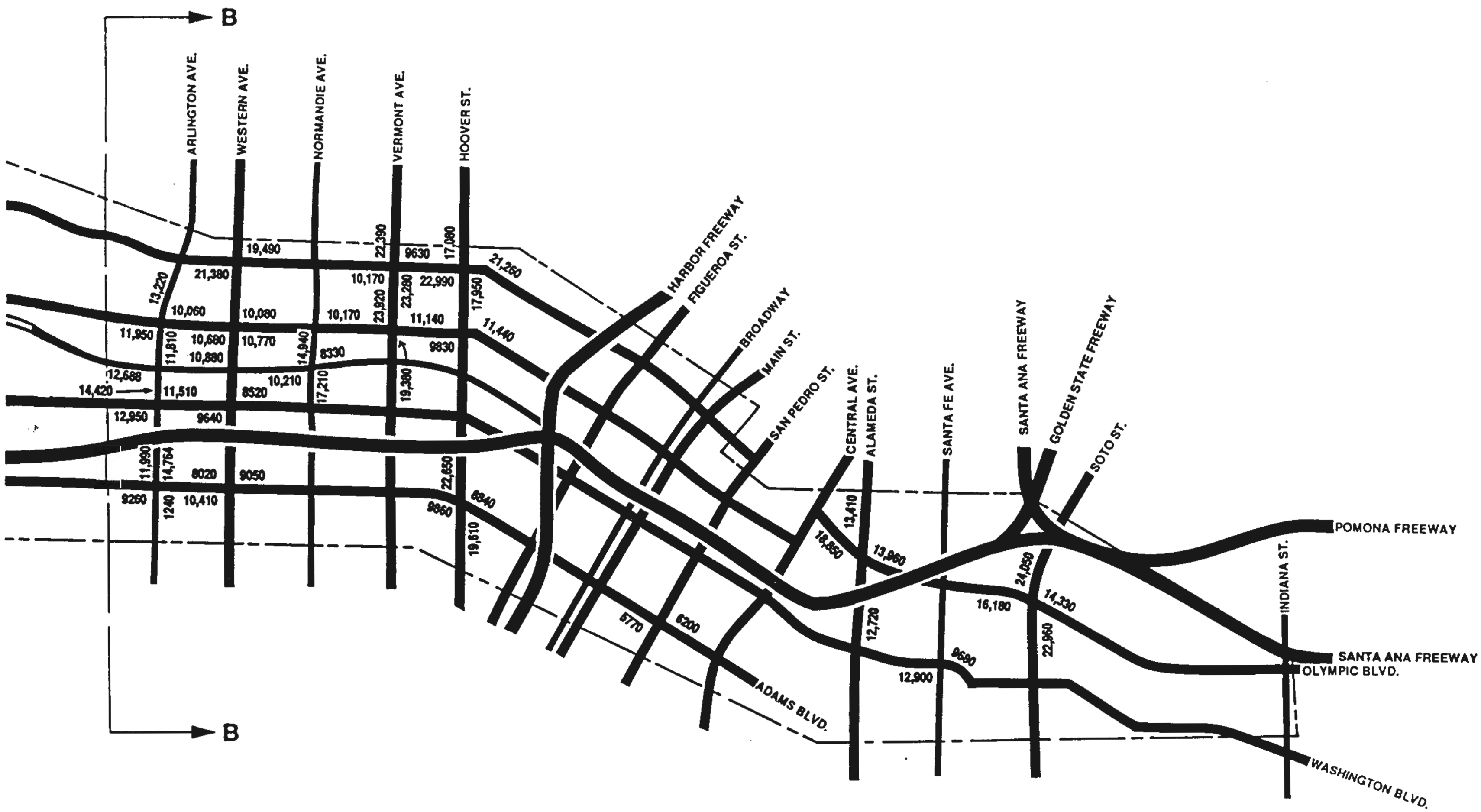
24 HOUR APPROACH VOLUMES ON SURFACE STREETS (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

KAKU ASSOCIATES

EXHIBIT 8A

SMART CORRIDOR DEMONSTRATION PROJECT



24 HOUR APPROACH VOLUMES ON SURFACE STREETS
(ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA.

N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 8B

SMART CORRIDOR DE...NSTRATION PROJECT

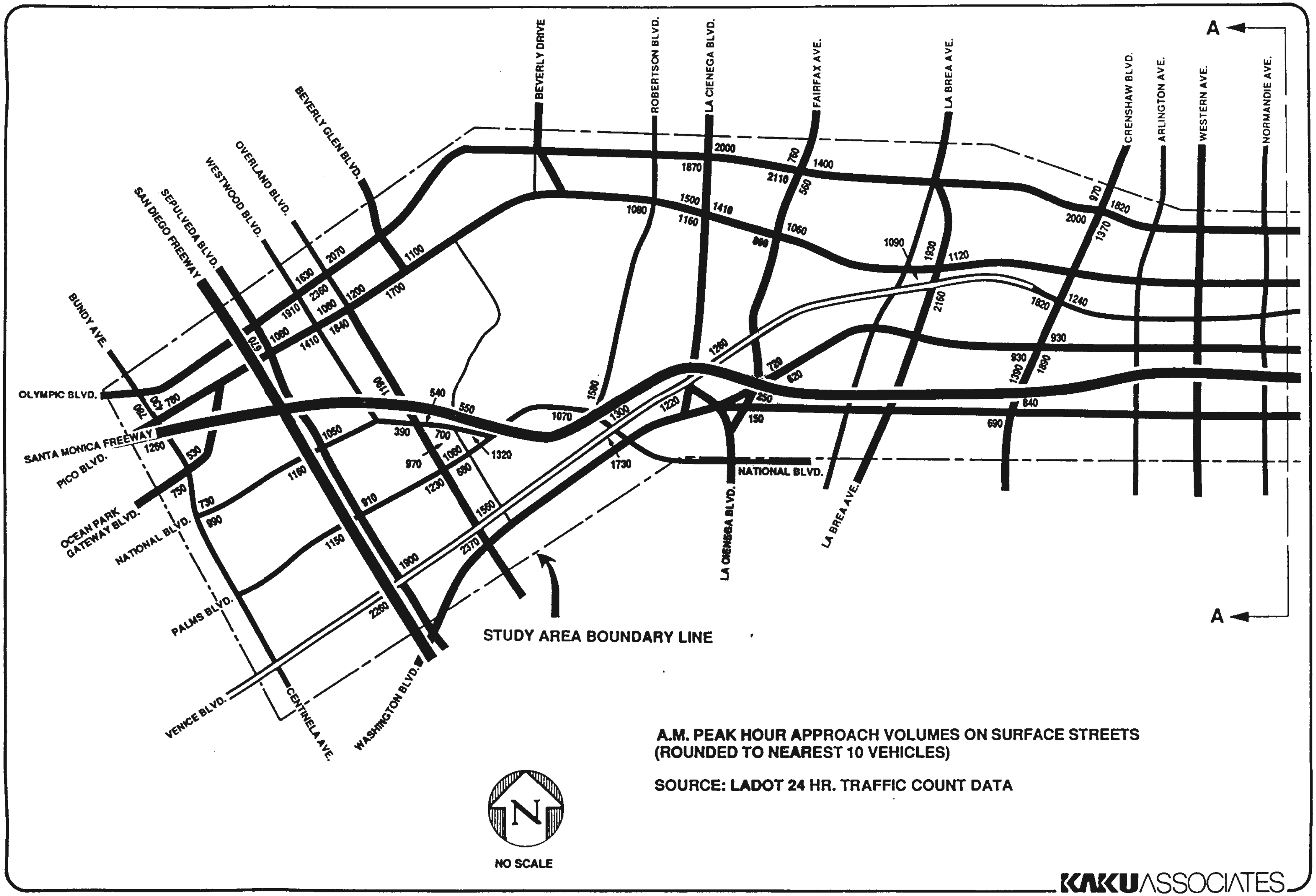
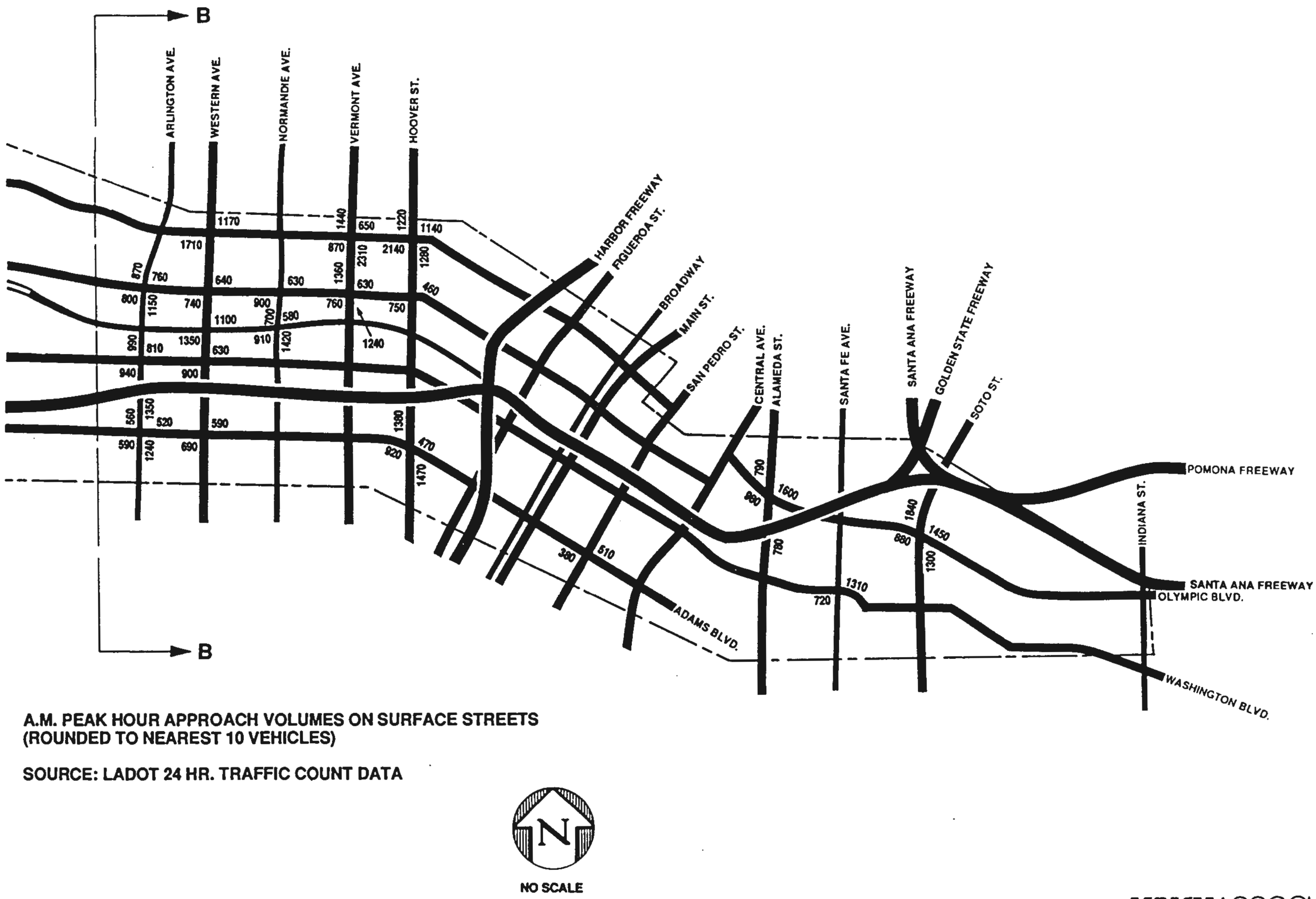


EXHIBIT 9A

SMART CORRIDOR DE NSTRATION PROJECT



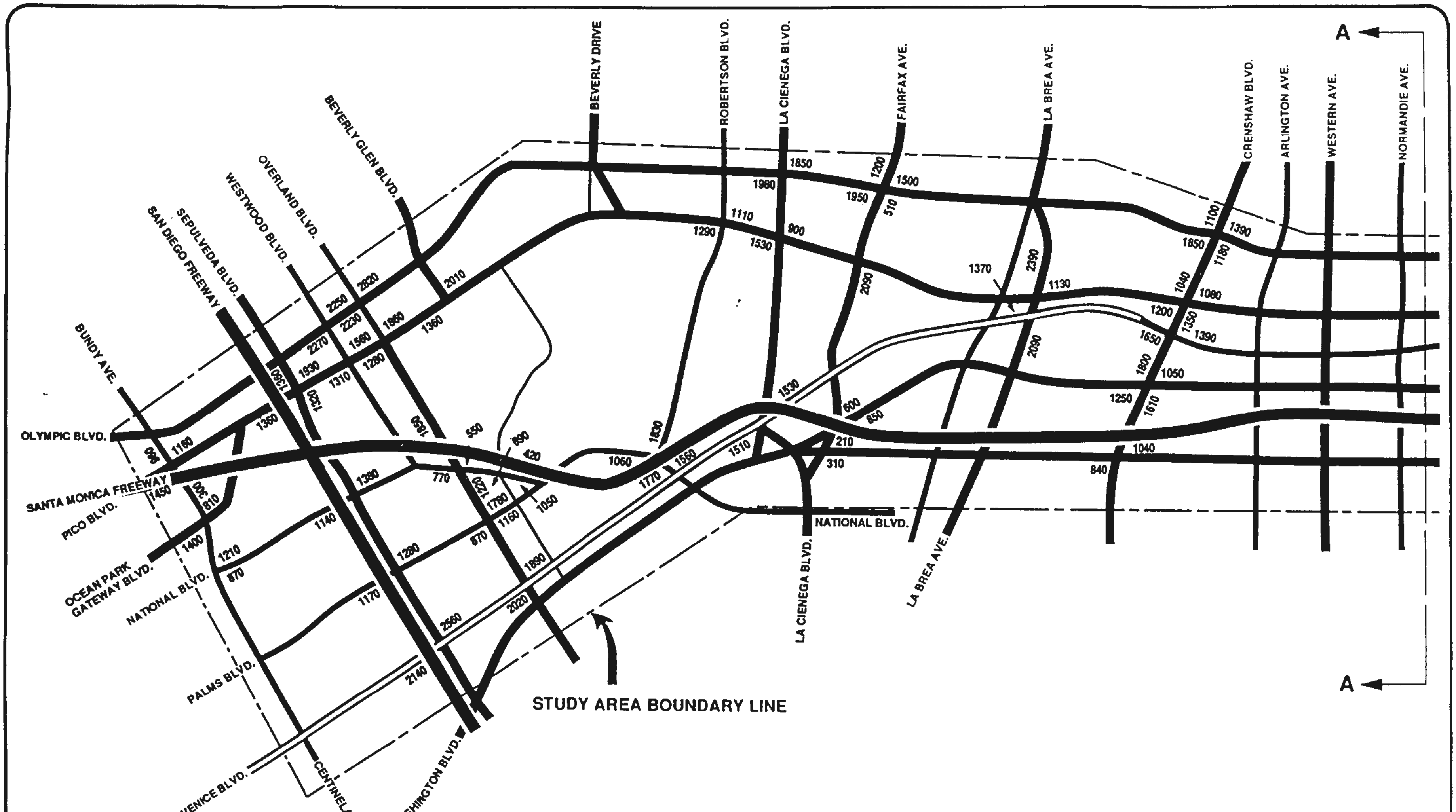
A.M. PEAK HOUR APPROACH VOLUMES ON SURFACE STREETS
(ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

KAKU ASSOCIATES

EXHIBIT 9B

SMART CORRIDOR DE ISTRATION PROJECT



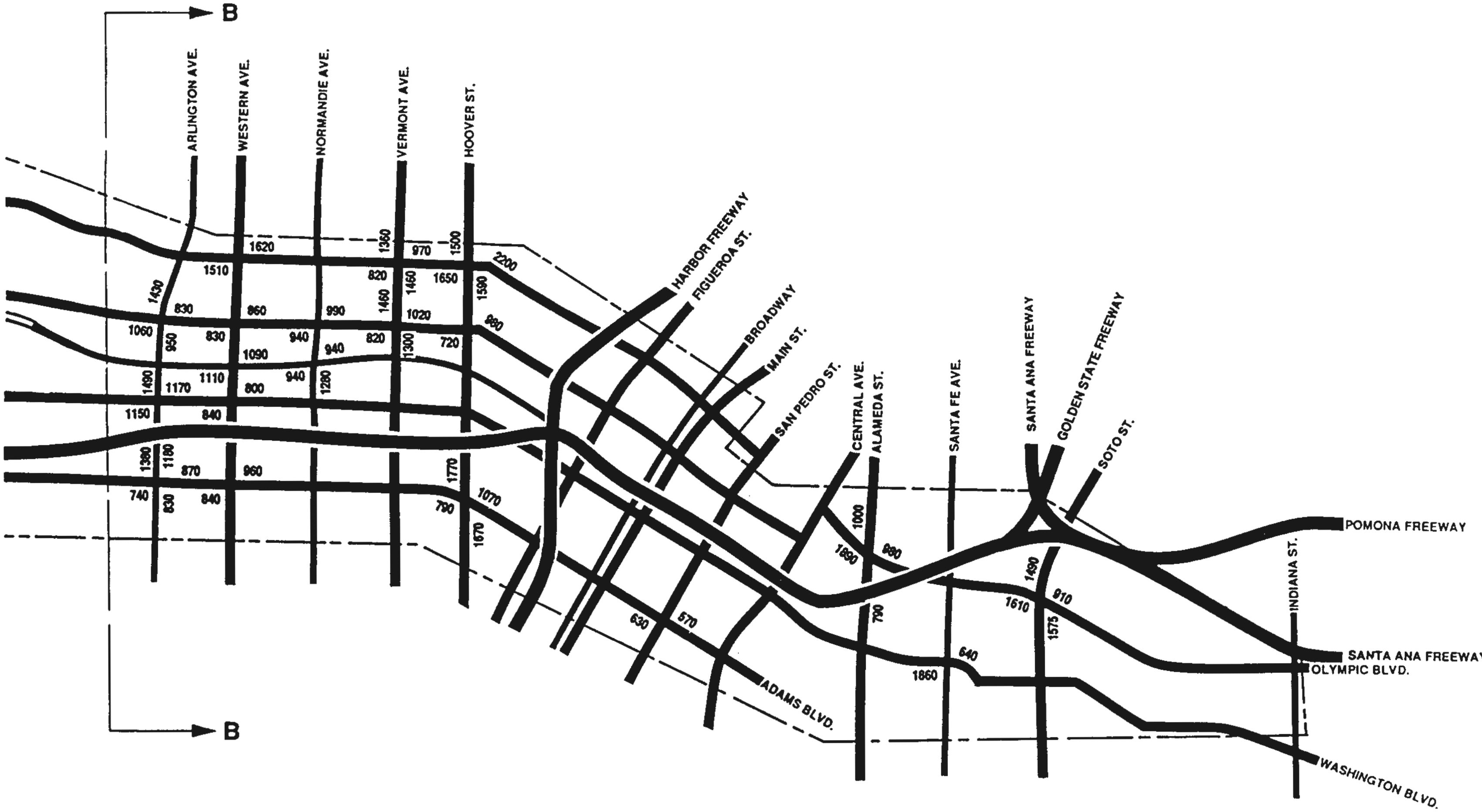
P.M. PEAK HOUR APPROACH VOLUMES ON SURFACE STREETS
(ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

KAKU ASSOCIATES

EXHIBIT 10A

SMART CORRIDOR DEMONSTRATION PROJECT



P.M. PEAK HOUR APPROACH VOLUMES ON SURFACE STREETS (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

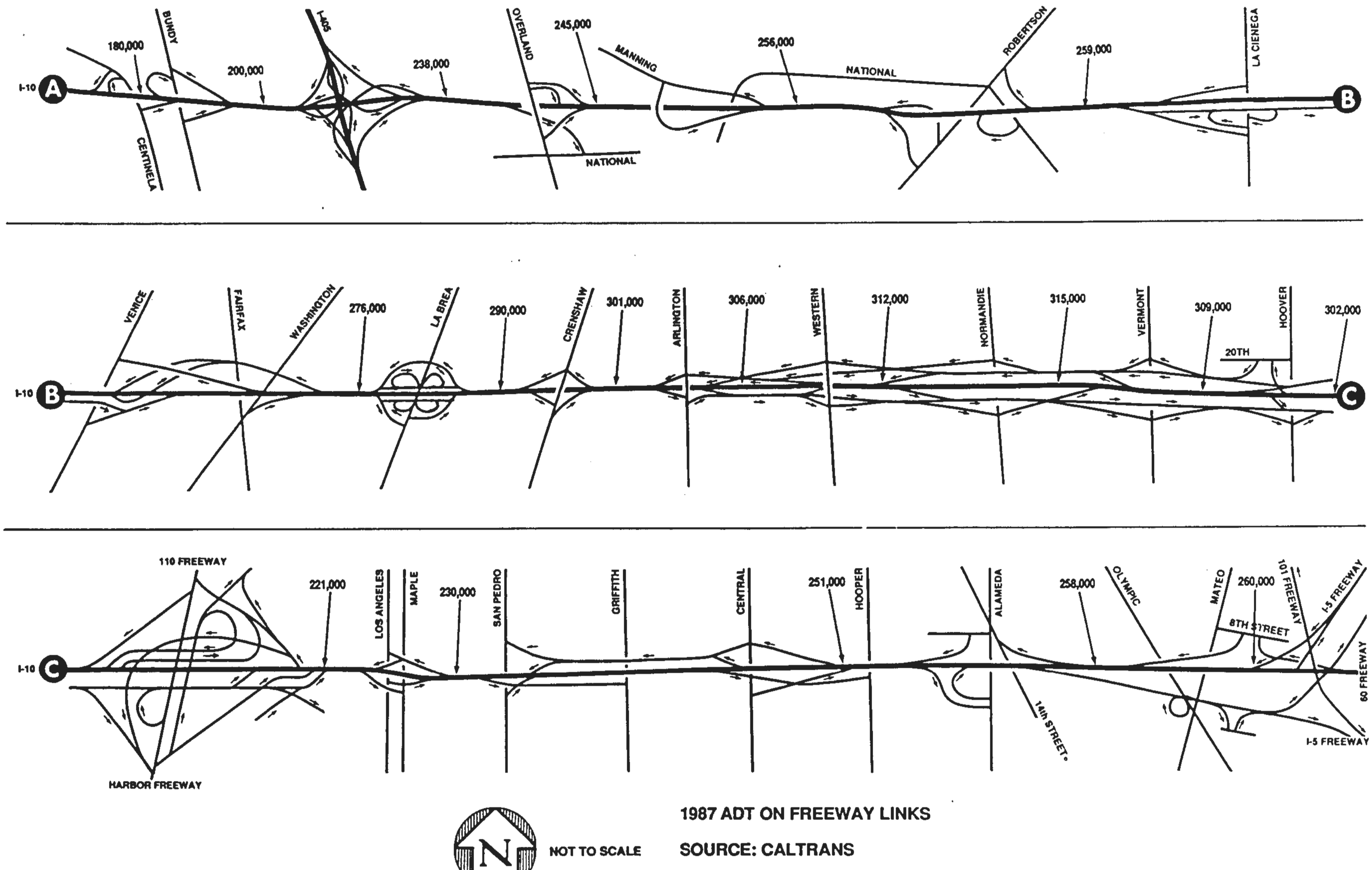
N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 10B

SMART CORRIDOR DEMONSTRATION PROJECT



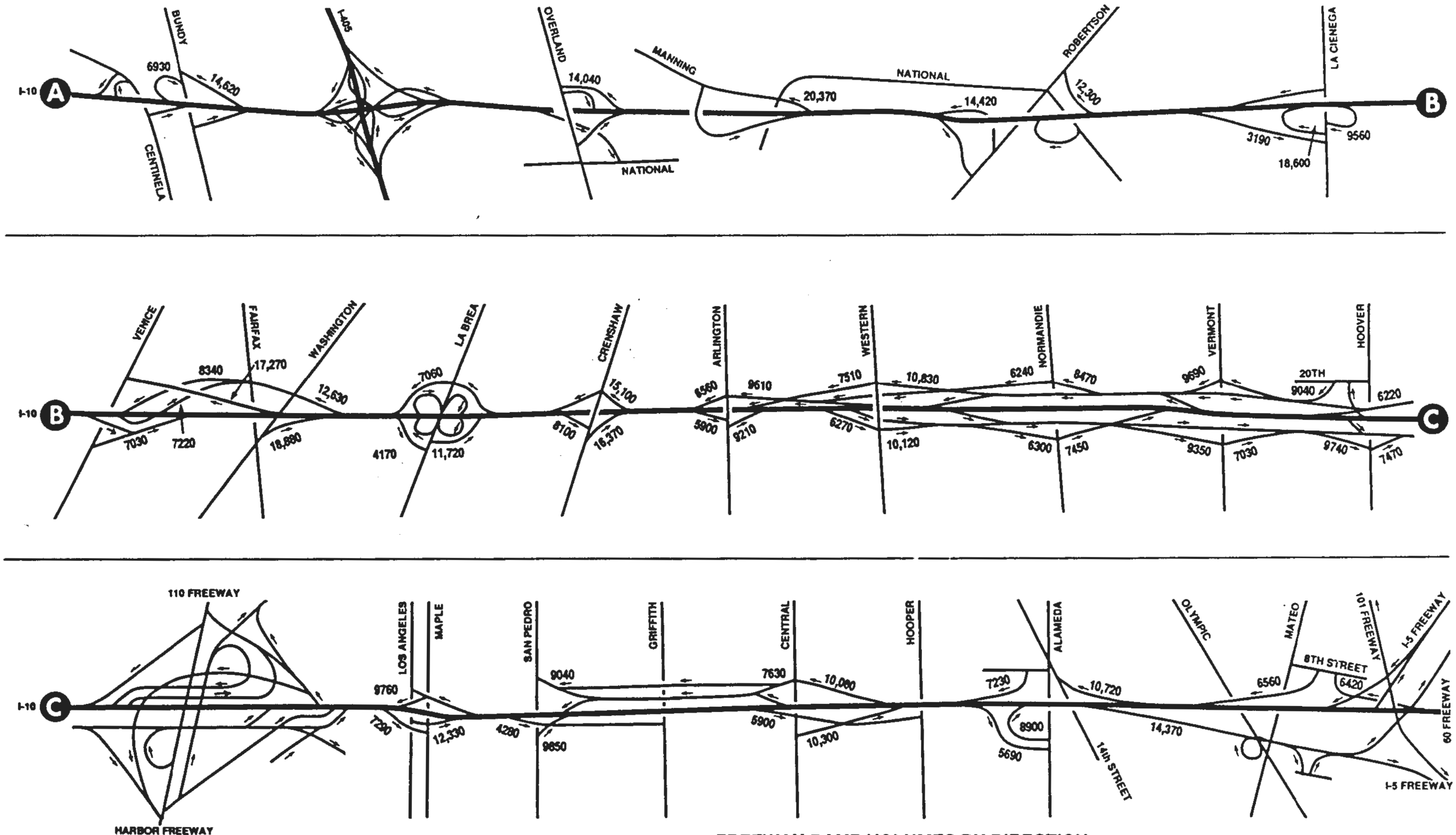
1987 ADT ON FREEWAY LINKS

SOURCE: CALTRANS

KAKU ASSOCIATES

EXHIBIT 11

SMART CORRIDOR DEMONSTRATION PROJECT



N

NOT TO SCALE

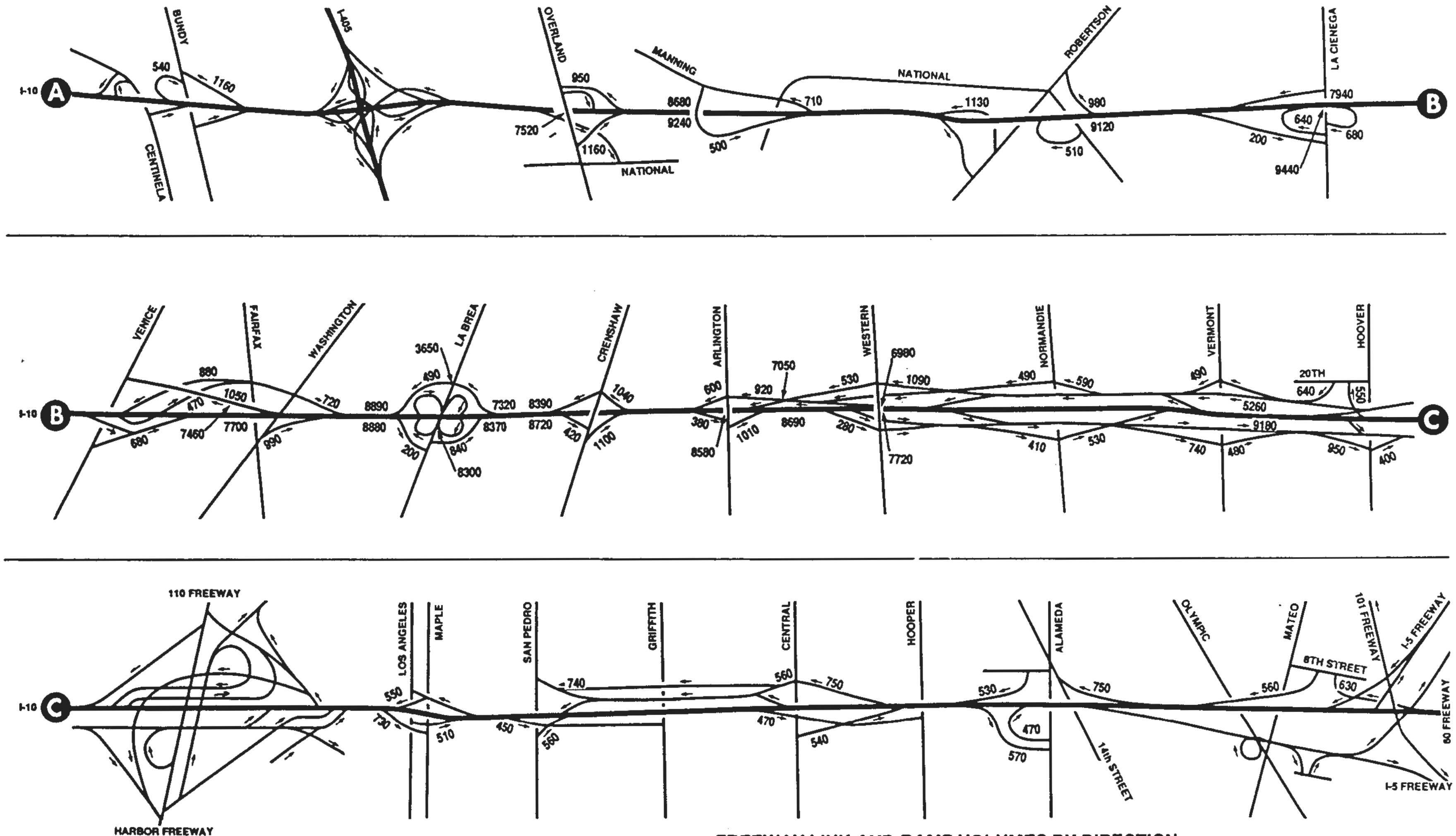
FREEWAY RAMP VOLUMES BY DIRECTION
24 HOUR (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: CALTRANS

KAKU ASSOCIATES

EXHIBIT 12

SMART CORRIDOR DE...ᴗNSTRATION PROJECT



FREEWAY LINK AND RAMP VOLUMES BY DIRECTION
A.M. PEAK HOUR (ROUNDED TO NEAREST 10 VEHICLES)

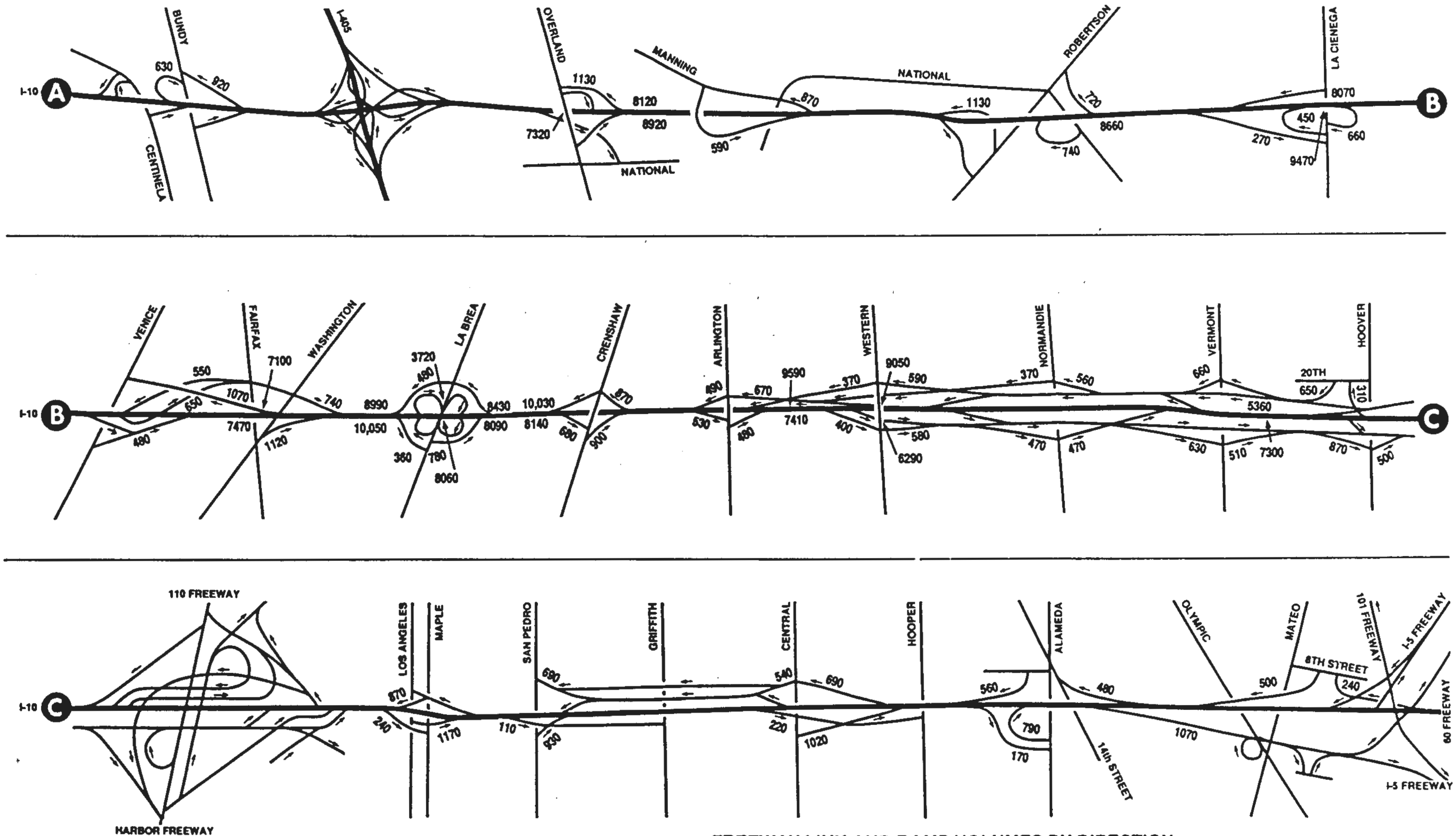
NOT TO SCALE

SOURCE: CALTRANS

KAKU ASSOCIATES

EXHIBIT 13

SMART CORRIDOR DEMONSTRATION PROJECT



NOT TO SCALE

FREEWAY LINK AND RAMP VOLUMES BY DIRECTION
P.M. PEAK HOUR (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: CALTRANS

KAKU ASSOCIATES

EXHIBIT 14

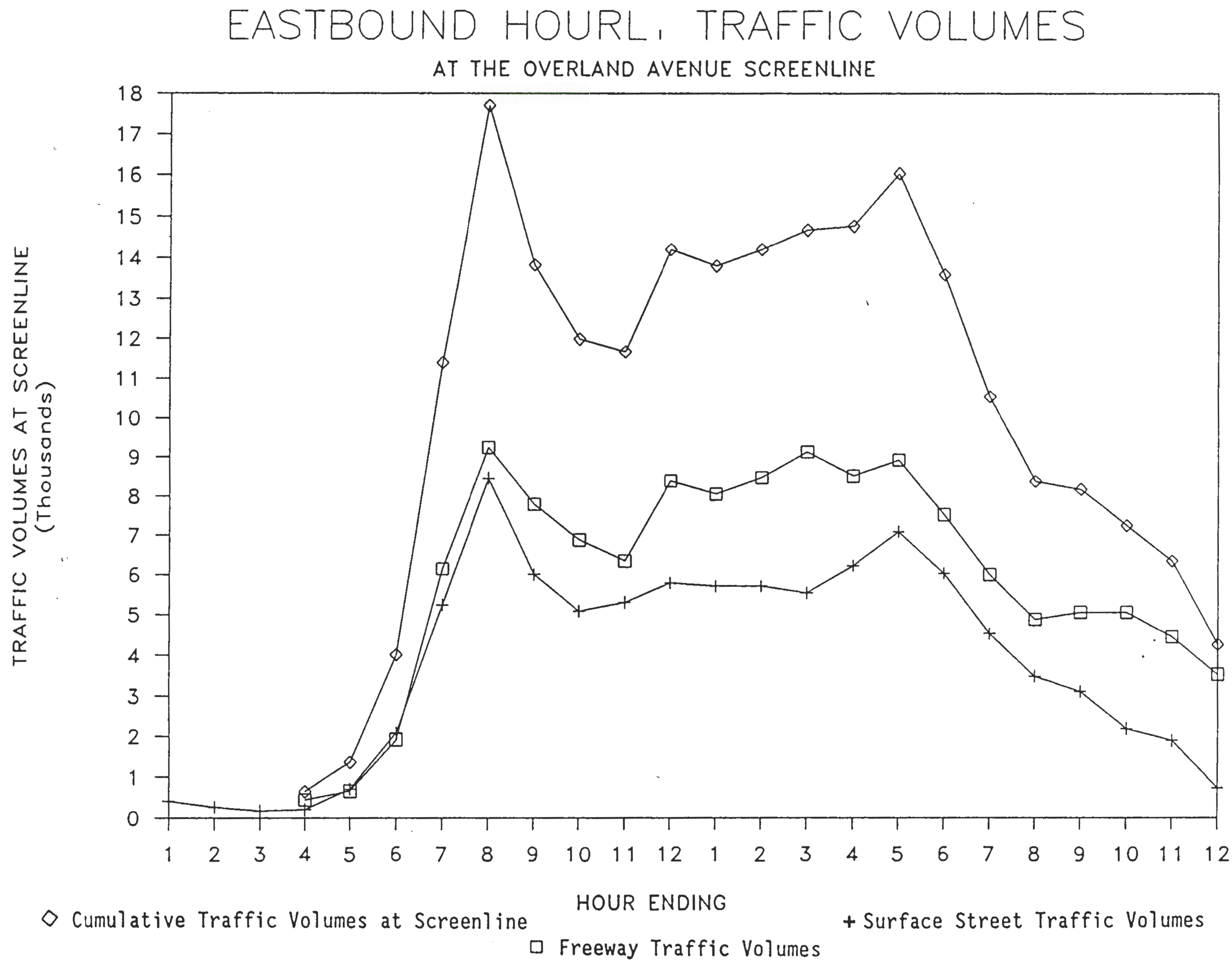

EASTBOUND HOURL, TRAFFIC VOLUMES
AT THE OVERLAND AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
◇ Cumulative Traffic Volumes at Screenline
□ Freeway Traffic Volumes
+ Surface Street Traffic Volumes

EXHIBIT 15

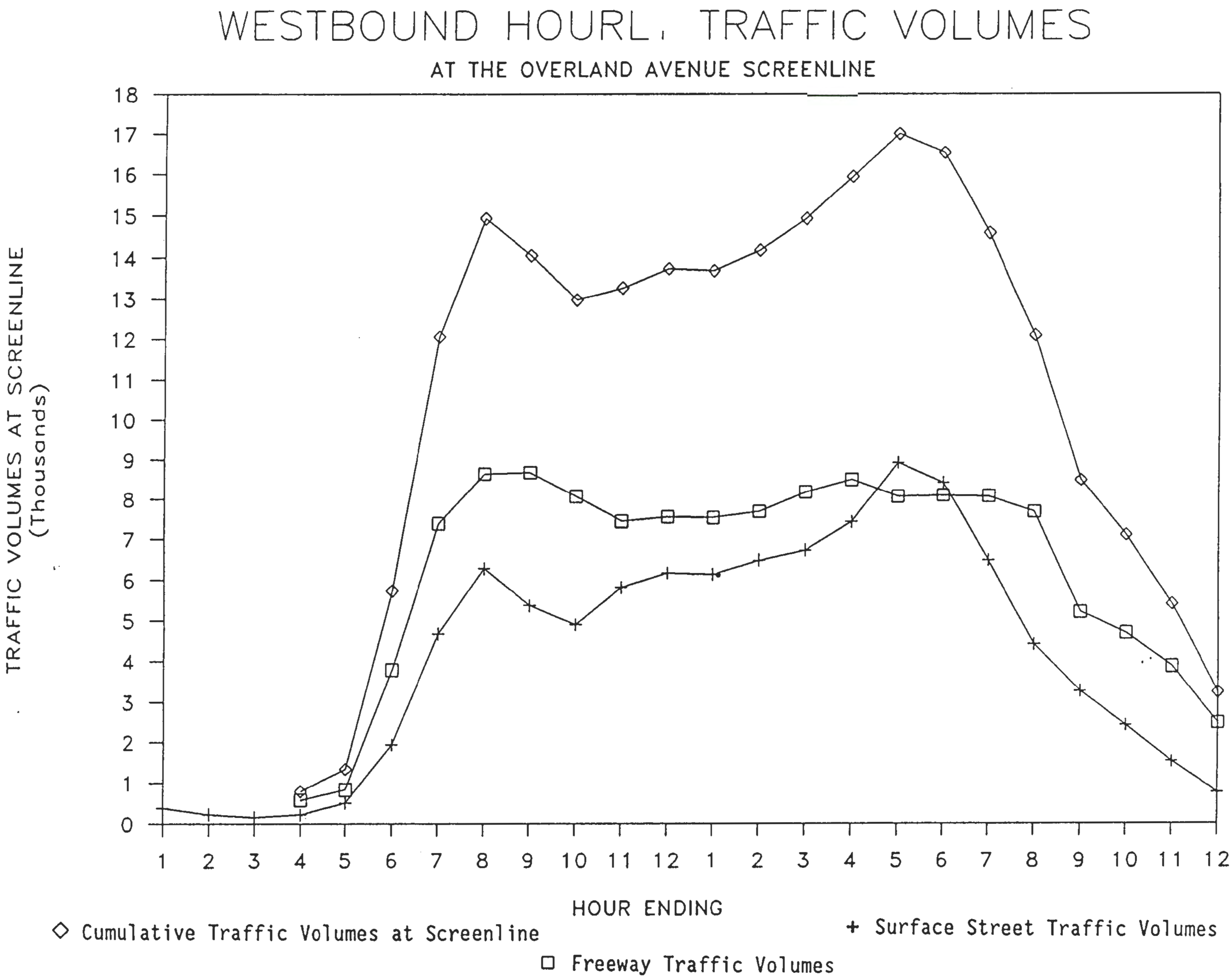

WESTBOUND HOURL, TRAFFIC VOLUMES
AT THE OVERLAND AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
◇ Cumulative Traffic Volumes at Screenline
□ Freeway Traffic Volumes
+ Surface Street Traffic Volumes

EXHIBIT 16

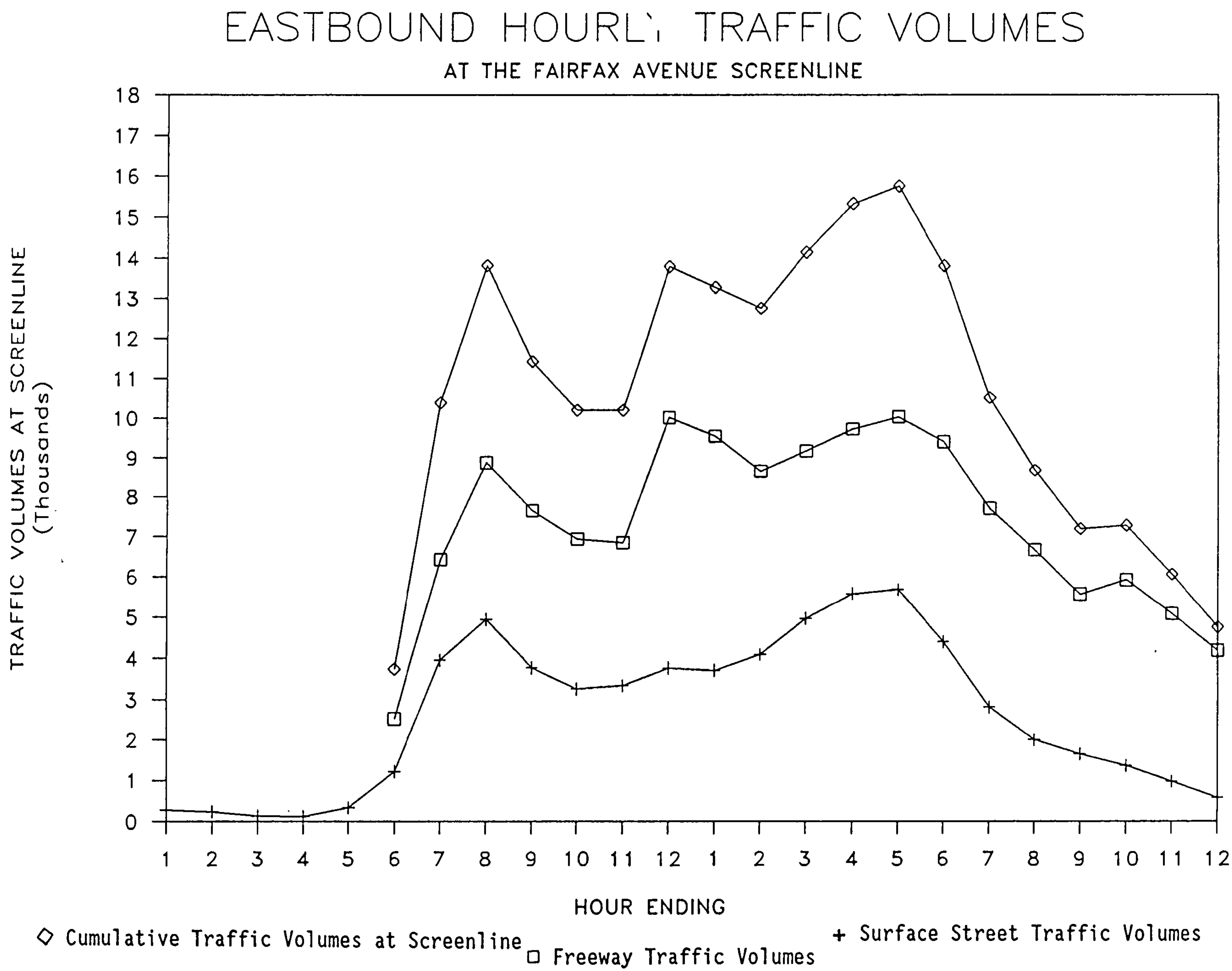

EASTBOUND HOURL`, TRAFFIC VOLUMES
AT THE FAIRFAX AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
Cumulative Traffic Volumes at Screenline
Freeway Traffic Volumes
Surface Street Traffic Volumes

EXHIBIT 17

WESTBOUND HOURL TRAFFIC VOLUMES

AT THE FAIRFAX AVENUE SCREENLINE

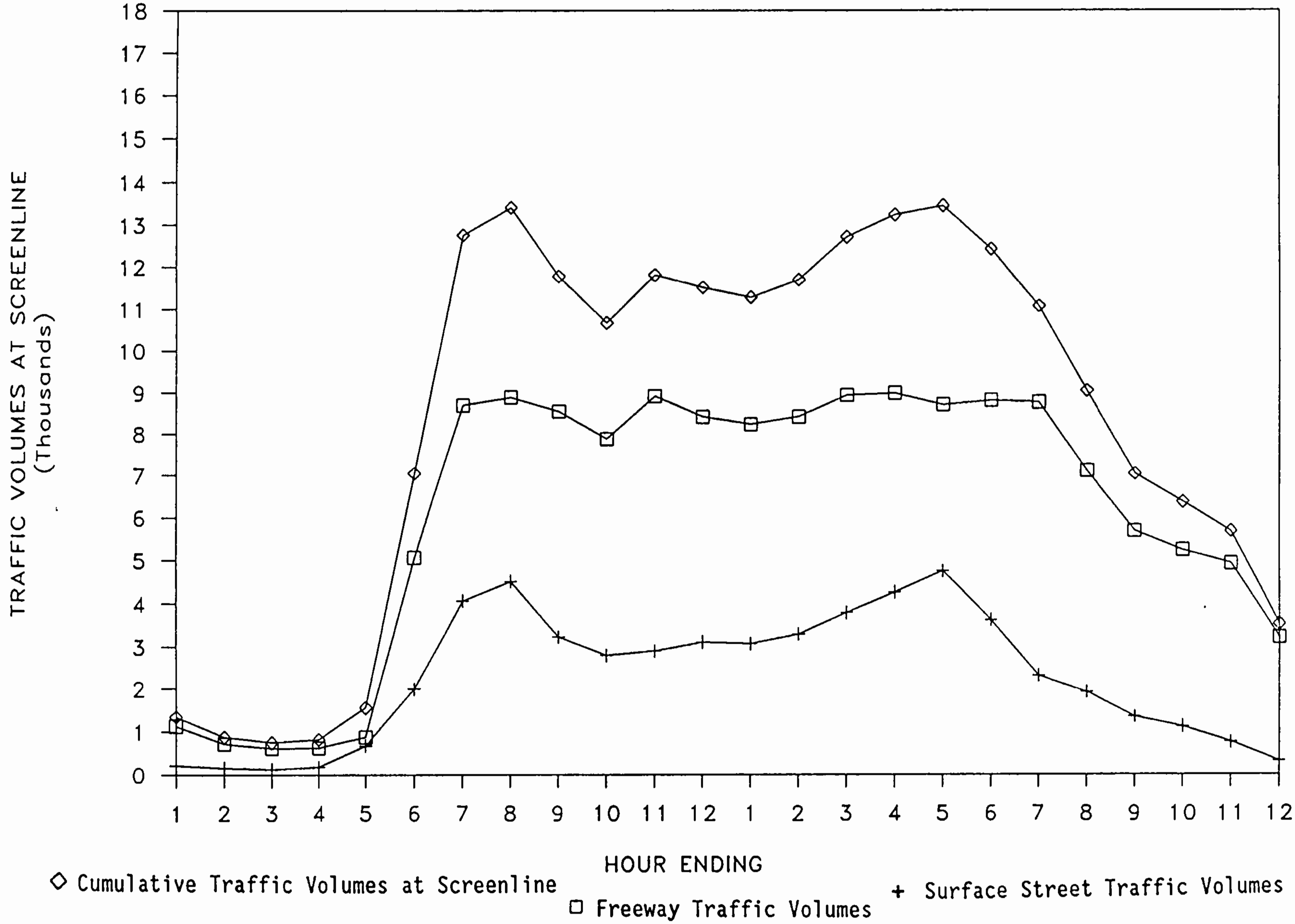


EXHIBIT 18

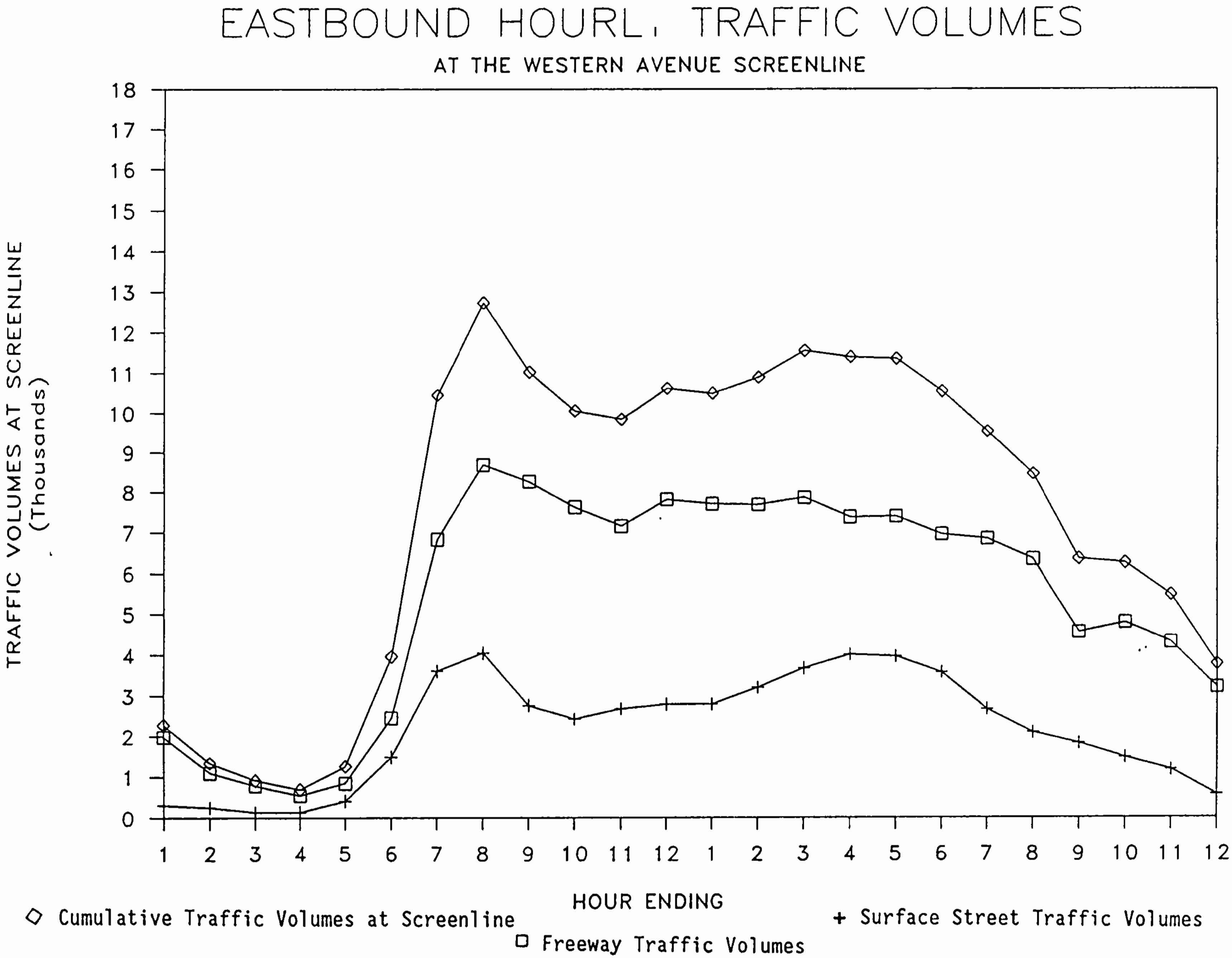

EASTBOUND HOURL, TRAFFIC VOLUMES
AT THE WESTERN AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
◇ Cumulative Traffic Volumes at Screenline
□ Freeway Traffic Volumes
+ Surface Street Traffic Volumes

EXHIBIT 19

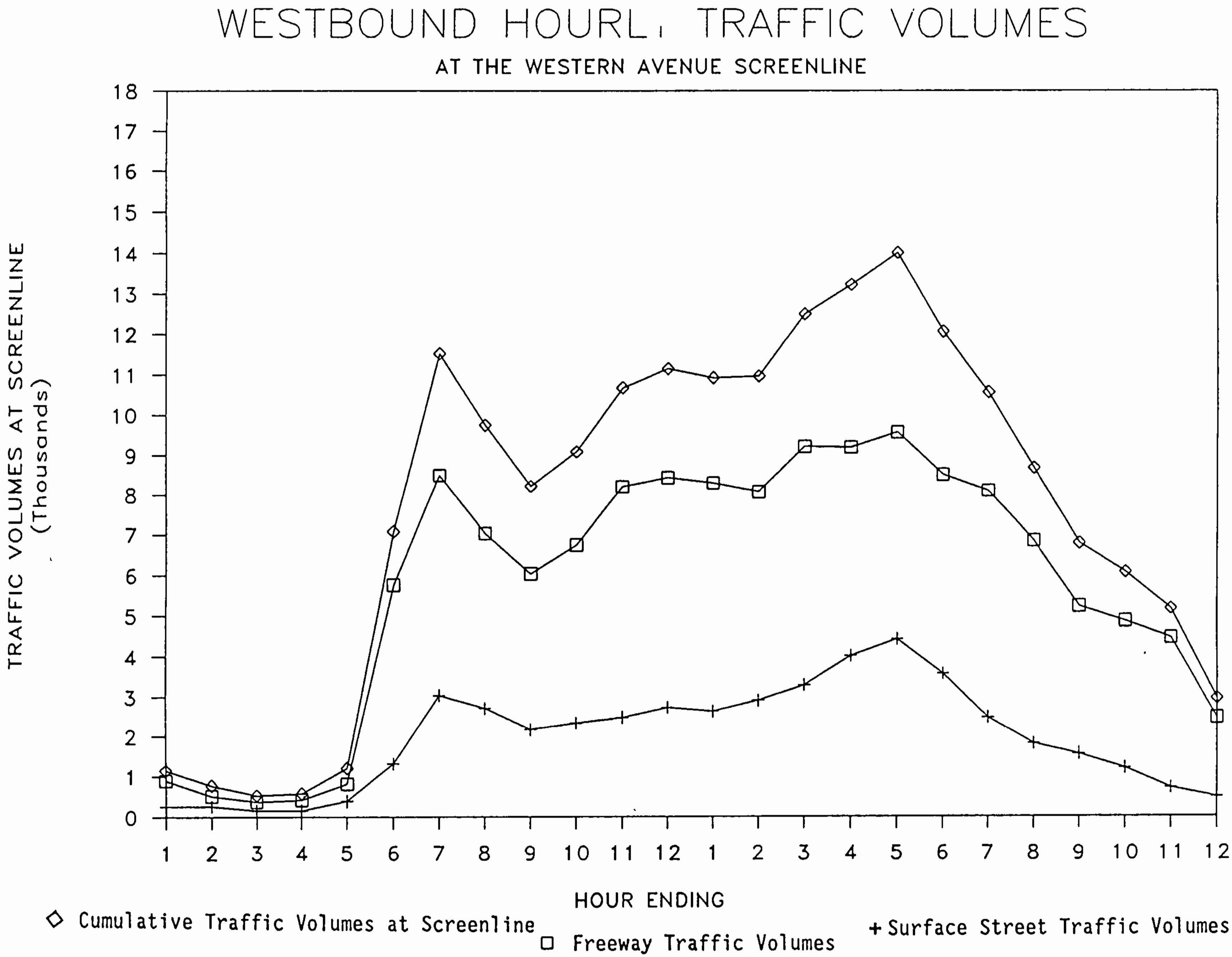
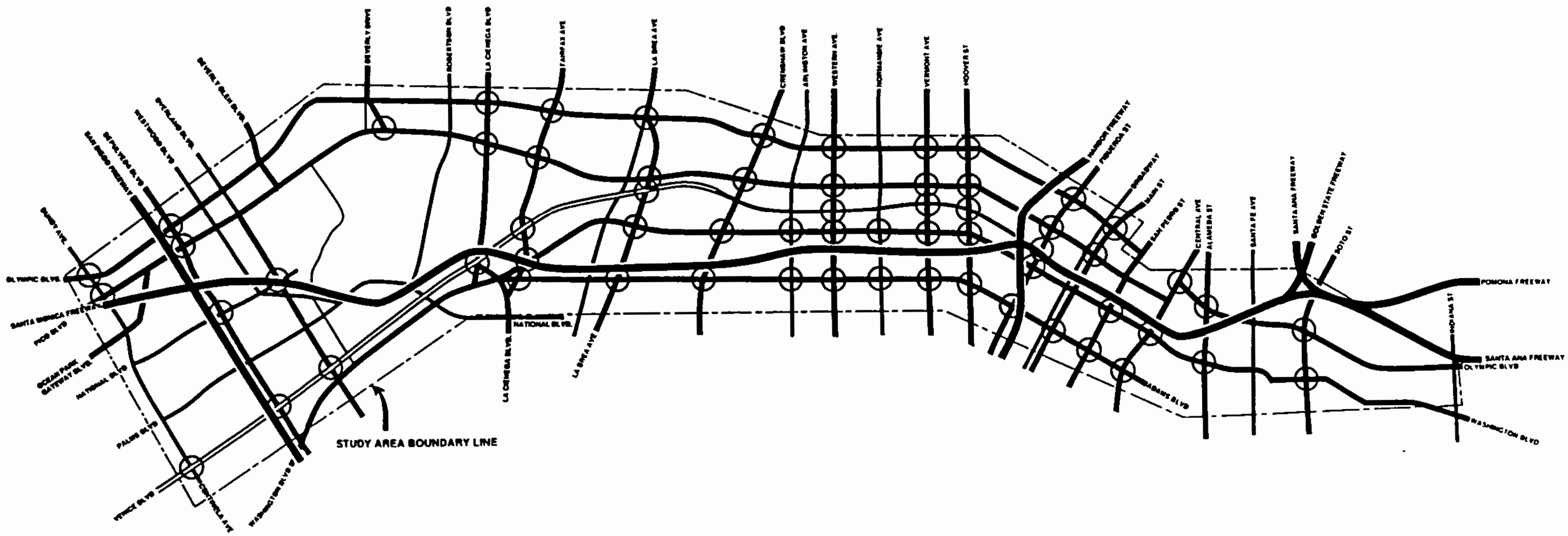

WESTBOUND HOURL TRAFFIC VOLUMES
AT THE WESTERN AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
(Thousands)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
Cumulative Traffic Volumes at Screenline
Freeway Traffic Volumes
Surface Street Traffic Volumes

EXHIBIT 20

SMART CORRIDOR DEMONSTRATION PROJECT



ANALYZED SURFACE STREET INTERSECTIONS

LEGEND:

○ ANALYZED INTERSECTION

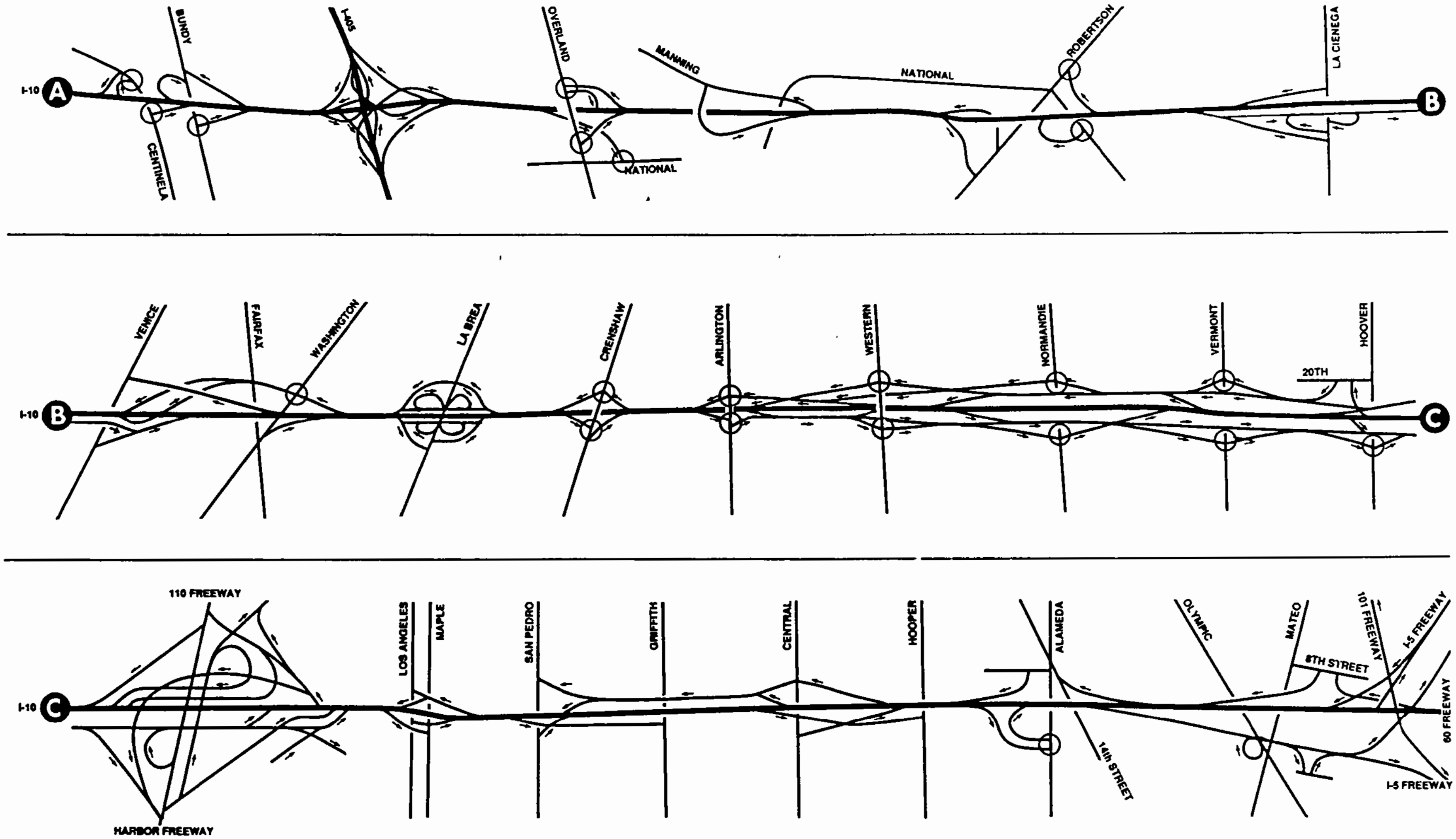
N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 21

SMART CORRIDOR DEMONSTRATION PROJECT



ANALYZED FREEWAY RAMP INTERSECTIONS

LEGEND:

○ ANALYZED INTERSECTION

NOT TO SCALE

KAKU ASSOCIATES

EXHIBIT 22

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 23
LEVEL OF SERVICE DEFINITIONS FOR SIGNALIZED INTERSECTIONS

Level of Service	Volume/Capacity Ratio	Definition
A	0.00 - 0.60	EXCELLENT. No vehicle waits longer than one red light and no approach phase is fully used.
B	0.61 - 0.70	VERY GOOD. An occasional approach phase is fully utilized; many drivers begin to feel somewhat restricted within groups of vehicles.
C	0.71 - 0.80	GOOD. Occasionally drivers may have to wait through more than one red light; backups may develop behind turning vehicles.
D	0.81 - 0.90	FAIR. Delays may be substantial during portions of the rush hours, but enough lower volume periods occur to permit clearing of developing lines, preventing excessive backups.
E	0.91 - 1.00	POOR. Represents the most vehicles intersection approaches can accommodate; may be long lines of waiting vehicles through several signal cycles.
F	Greater than 1.00	FAILURE. Backups from nearby locations or on cross streets may restrict or prevent movement of vehicles out of the intersection approaches. Tremendous delays with continuously increasing queue lengths.

Source: Transportation Research Board, Transportation Research Circular No. 212, Interim Materials on Highway Capacity, January 1980.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 24
LEVEL OF SERVICE ANALYSIS - SURFACE STREET INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	AM Peak Hour V/C Ratio	AM Peak Hour LOS	PM Peak Hour V/C Ratio	PM Peak Hour LOS
1	319	OLYMPIC & BUNDY	0.90	D	0.90	D
2	274	OLYMPIC & SEPULVEDA	1.06	F	1.04	F
3	3	OLYMPIC & LA CIENEGA	0.88	D	0.99	E
4	7	OLYMPIC & FAIRFAX	0.65	B	0.82	D
5	14	OLYMPIC & LA BREA	0.92	E	0.87	D
6	20	OLYMPIC & CRENSHAW	0.89	D	0.92	E
7	25	OLYMPIC & WESTERN	0.85	D	0.97	E
8	30	OLYMPIC & VERMONT	0.95	E	1.01	F
9	33	OLYMPIC & HOOVER	0.97	E	1.07	F
10	*	OLYMPIC & FIGUEROA	0.55	A	0.76	C
11	*	OLYMPIC & MAIN	0.41	A	0.54	A
12	*	OLYMPIC & SAN PEDRO	n/a		n/a	
13	*	OLYMPIC & CENTRAL	0.68	B	0.86	D
14	236	OLYMPIC & ALAMEDA	0.70	B	0.89	D
15	241	OLYMPIC & SOTO	0.72	C	0.76	C
16	*	OLYMPIC & INDIANA	n/a		n/a	
17	325	PICO & BUNDY	0.47	A	0.61	B
18	297	PICO & SEPULVEDA	0.87	D	0.91	E
19	295	PICO & BEVERLY GLEN	n/a		n/a	
20	63	PICO & BEVERLY	0.97	E	0.87	D
21	70	PICO & LA CIENEGA	0.88	D	0.89	D
22	72	PICO & FAIRFAX	0.53	A	0.73	C
23	78	PICO & LA BREA	0.76	C	0.94	E
24	83	PICO & CRENSHAW	0.81	D	0.89	D
25	88	PICO & WESTERN	0.68	B	0.78	C
26	93	PICO & VERMONT	0.67	B	0.88	D
27	96	PICO & HOOVER	0.59	A	0.93	E
28	*	PICO & FIGUEROA	0.47	A	0.54	A
29	*	PICO & MAIN	0.41	A	0.52	A
30	106	NATIONAL & SEPULVEDA	0.87	D	1.02	F
31	302	NATIONAL/OVERLAND/WB RAMPS	0.98	E	1.01	F
32	346	VENICE & CENTINELA	0.83	D	0.95	E
33	146	VENICE & SEPULVEDA	1.02	F	1.23	F
34	148	VENICE & OVERLAND	1.11	F	1.08	F
35	*	VENICE & CULVER	n/a		n/a	
36	156	VENICE & LA CIENEGA	1.08	F	1.13	F
37	158	VENICE & FAIRFAX	0.95	E	1.07	F
38	163	VENICE & LA BREA	0.91	E	0.95	E
39	172	VENICE & WESTERN	0.65	B	0.82	D
40	177	VENICE & VERMONT	0.74	C	0.85	D
41	180	VENICE & HOOVER	0.86	D	1.01	F
42	*	VENICE & FIGUEROA	0.40	A	0.53	A

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 24 (continued)
LEVEL OF SERVICE ANALYSIS - SURFACE STREET INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	AM Peak Hour V/C Ratio	AM Peak Hour LOS	PM Peak Hour V/C Ratio	PM Peak Hour LOS
43	*	WASHINGTON & LA CIENEGA	n/a		n/a	
44	185	WASHINGTON & FAIRFAX	0.79	C	0.84	D
45	190	WASHINGTON & LA BREA	0.94	E	1.08	F
46	194	WASHINGTON & CRENSHAW	0.90	D	0.86	D
47	198	WASHINGTON & ARLINGTON	0.75	C	0.79	C
48	201	WASHINGTON & WESTERN	0.75	C	0.85	D
49	203	WASHINGTON & NORMANDIE	0.83	D	0.92	E
50	205	WASHINGTON & VERMONT	0.74	C	0.88	D
51	*	WASHINGTON & HOOVER	0.79	C	0.97	E
52	*	WASHINGTON & FIGUEROA	0.76	C	0.82	D
53	*	WASHINGTON & MAIN	n/a		n/a	
54	*	WASHINGTON & SAN PEDRO	0.68	B	0.89	D
55	*	WASHINGTON & CENTRAL	0.88	D	1.08	F
56	*	WASHINGTON & ALAMEDA	0.72	C	0.76	C
57	*	WASHINGTON & SOTO	0.94	E	0.83	D
58	*	WASHINGTON & INDIANA	n/a		n/a	
59	207	ADAMS & FAIRFAX	0.71	C	0.81	D
60	213	ADAMS & LA BREA	0.95	E	1.01	F
61	218	ADAMS & CRENSHAW	0.92	E	0.91	E
62	223	ADAMS & ARLINGTON	0.57	A	0.81	D
63	228	ADAMS & WESTERN	0.73	C	0.86	D
64	*	ADAMS & NORMANDIE	0.70	B	0.93	E
65	*	ADAMS & VERMONT	0.74	C	0.85	D
66	*	ADAMS & HOOVER	0.49	A	0.67	B
67	*	ADAMS & FIGUEROA	0.69	B	0.93	E
68	*	ADAMS & MAIN	0.50	A	0.59	A
69	268	ADAMS & SAN PEDRO	0.52	A	0.78	C
70	270	ADAMS & CENTRAL	0.78	C	0.83	D

o Intersection #31 (National/Overland/WB Ramps) is same as intersection #74 in ramp intersection analysis.
o "n/a" indicates turning movement count data not available.
* Indicates intersection not in Smart Corridor ATSAC system.

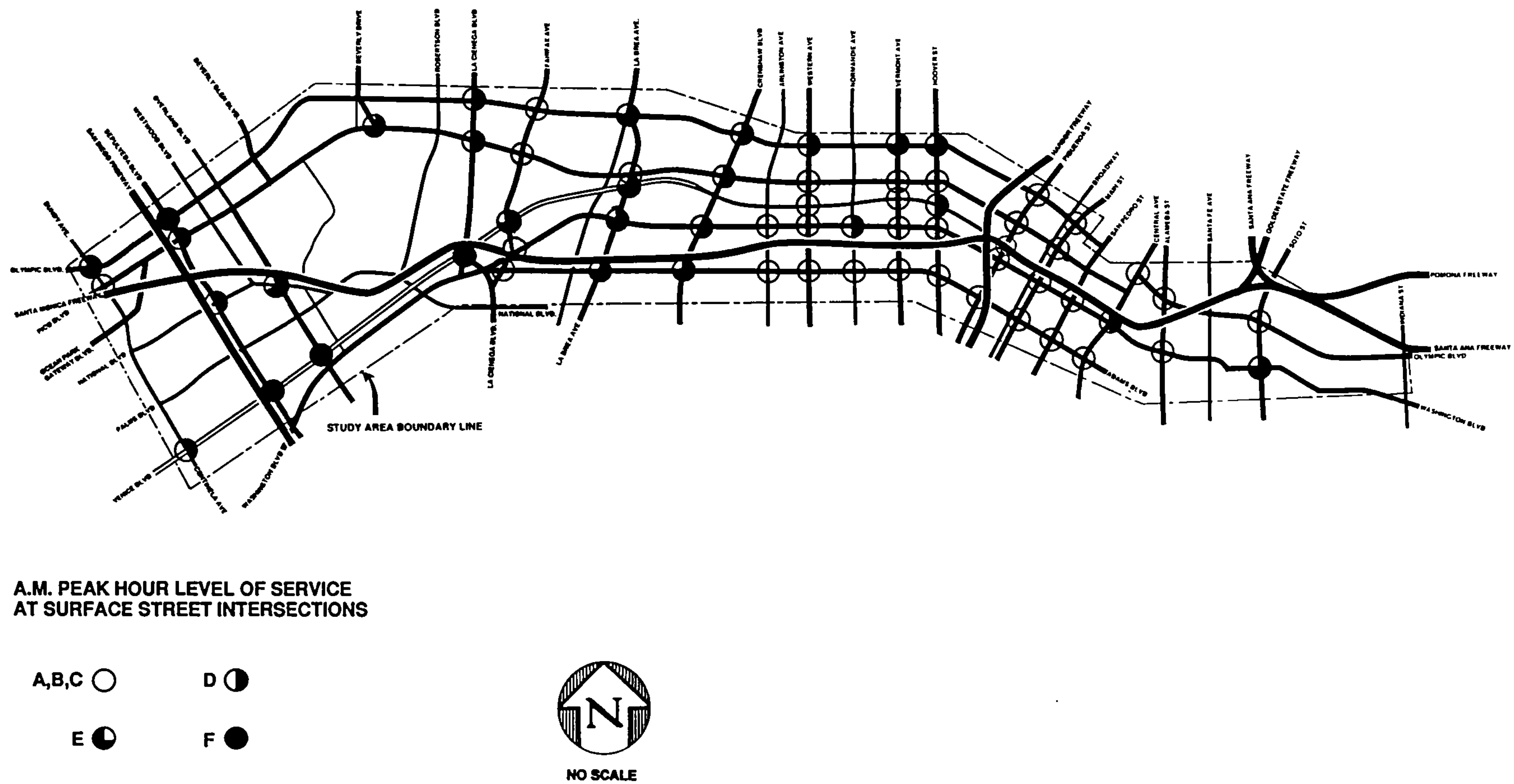
SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 25
LEVEL OF SERVICE ANALYSIS - RAMP INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	AM Pk Hour V/C Ratio	AM Pk Hour LOS	PM Pk Hour V/C Ratio	PM Pk Hour LOS
71	323	CENTINELA & WB RAMPS	0.86	D	0.98	E
72	328	CENTINELA & EB ON-RAMP	0.39	A	0.49	A
73	329	BUNDY & EB ON-RAMP	0.62	B	0.67	B
74	302	NATIONAL/OVERLAND/WB RAMPS	0.98	E	1.01	F
75	303	OVERLAND & EB ON-RAMP	0.71	C	0.66	B
76	305	NATIONAL & EB OFF-RAMP	0.70	B	0.69	B
77	136	NATIONAL & WB OFF-RAMP/MANNING	n/a		n/a	
78	139	ROBERTSON & WB OFF-RAMP/KINCARDINE	0.80	C	0.91	E
79	141	NATIONAL & EB ON-RAMP	0.38	A	0.39	A
80	143	LA CIENEGA & WB ON-RAMP/DAVID	n/a		n/a	
81	157	VENICE & WB OFF-RAMP/CADILLAC	n/a		n/a	
82	184	FAIRFAX & EB OFF/WB ON/APPLE	n/a		n/a	
83	186	WASHINGTON & WB OFF-RAMP	0.51	A	0.56	A
84	216	CRENSHAW & WB RAMPS	0.77	C	0.76	C
85	217	CRENSHAW & EB RAMPS	0.69	B	0.69	B
86	221	ARLINGTON & WB RAMPS	0.73	C	0.90	D
87	222	ARLINGTON & EB RAMPS	0.92	E	0.72	C
88	226	WESTERN & WB RAMPS	0.66	B	0.71	C
89	227	WESTERN & EB RAMPS	0.76	C	0.82	D
90	*	NORMANDIE & WB RAMPS	0.61	B	0.86	D
91	*	NORMANDIE & EB RAMPS	0.74	C	0.80	C
92	*	VERMONT & WB RAMPS	0.56	A	0.63	B
93	*	VERMONT & EB RAMPS	0.61	B	0.68	B
94	*	20TH & WB RAMPS	n/a		n/a	
95	*	HOOVER & EB RAMPS	0.55	A	0.68	B
96	*	GRAND & WB ON-RAMP/17TH	n/a		n/a	
97	*	GRAND & EB OFF-RAMP/18TH	n/a		n/a	
98	*	LOS ANGELES & WB OFF-RAMP/17TH	n/a		n/a	
99	*	LOS ANGELES & EB ON-RAMP	n/a		n/a	
100	*	MAPLE & WB ON-RAMP	n/a		n/a	
101	244	MAPLE & EB OFF-RAMP/18TH	n/a		n/a	
102	245	SAN PEDRO & WB OFF-RAMP/16TH	n/a		n/a	
103	247	CENTRAL & WB RAMPS/16TH	n/a		n/a	
104	251	ALAMEDA & EB RAMPS	0.47	A	0.61	B

o Intersection #74 (National/Overland/WB Ramps) is same as intersection #31 in surface street intersection analysis.
o "n/a" indicates turning movement count data not available.
* Indicates intersection not in Smart Corridor ATSAC system.

SMART CORRIDOR DEMONSTRATION PROJECT



KAKU ASSOCIATES

EXHIBIT 26

SMART CORRIDOR D...IONSTRATION PROJECT

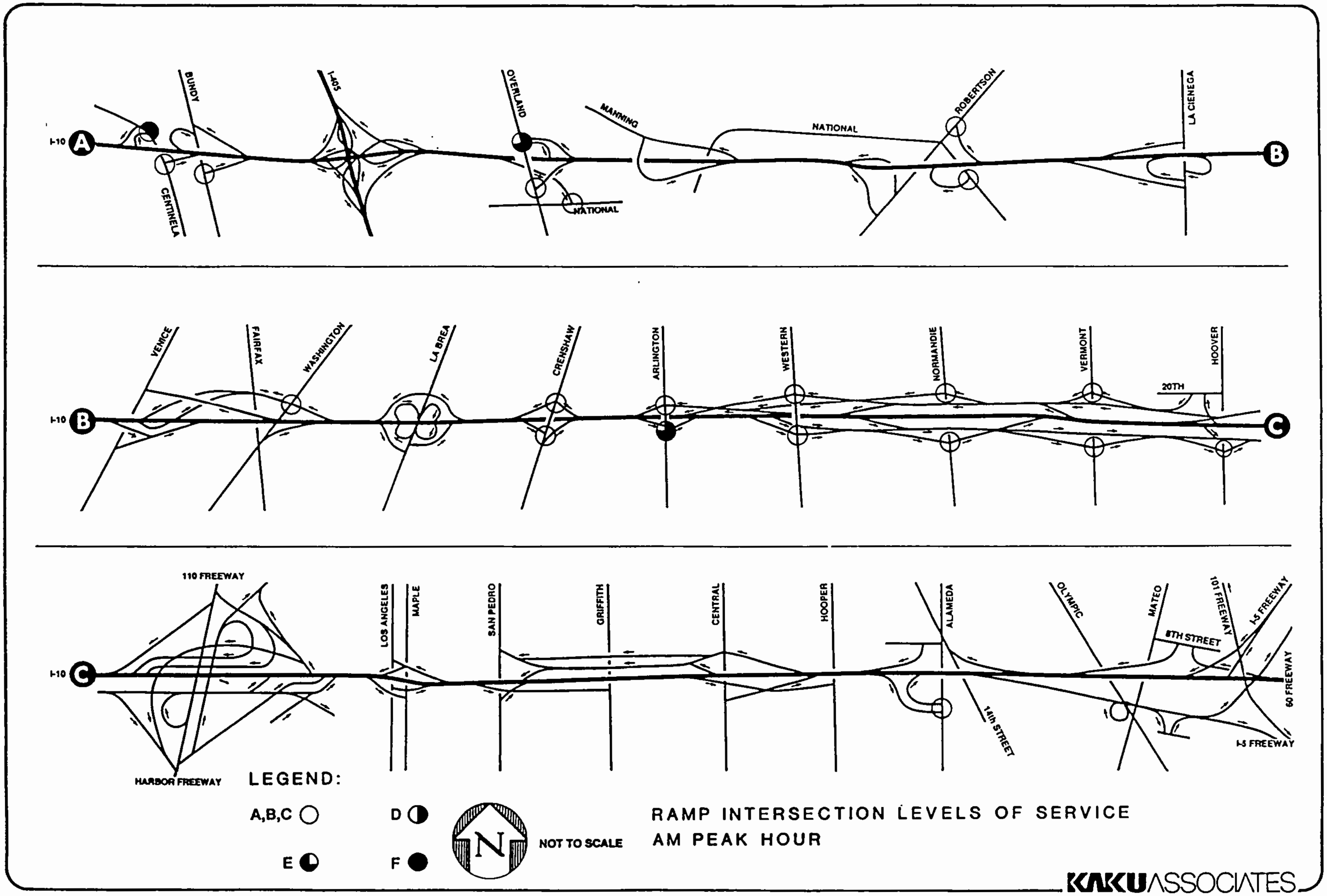
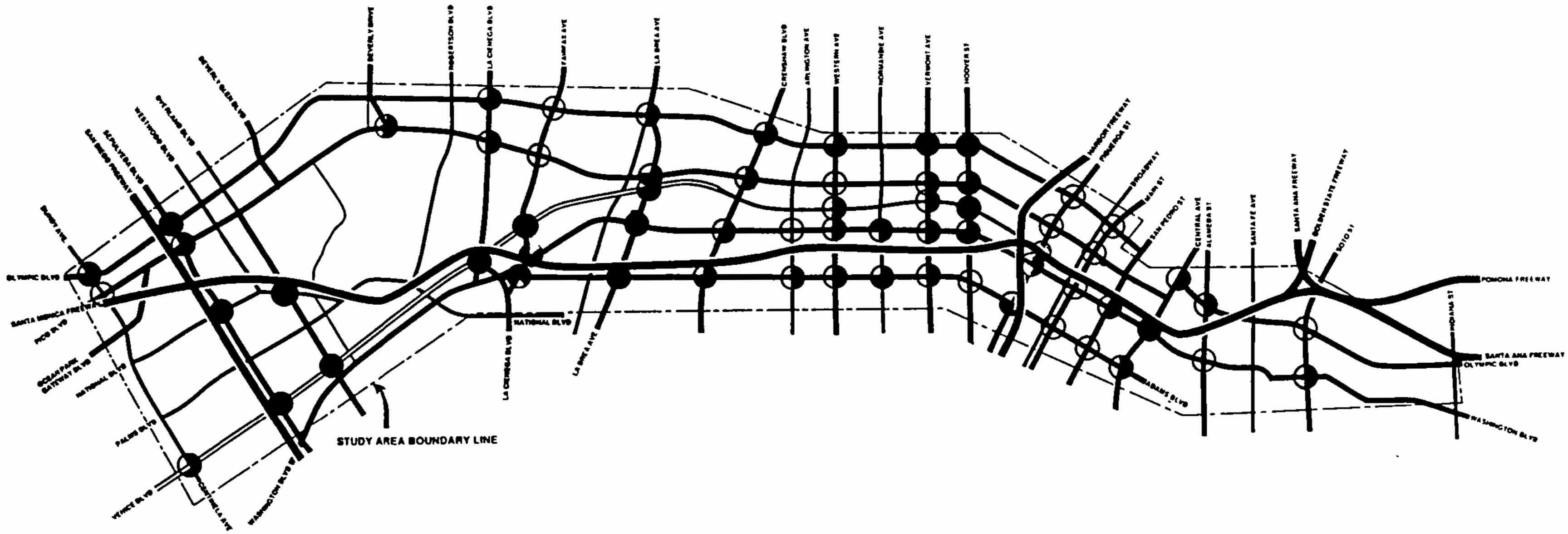


EXHIBIT 27

SMART CORRIDOR DEI...STRATION PROJECT



P.M. PEAK HOUR LEVEL OF SERVICE AT SURFACE STREET INTERSECTIONS

A,B,C ○ D ◑

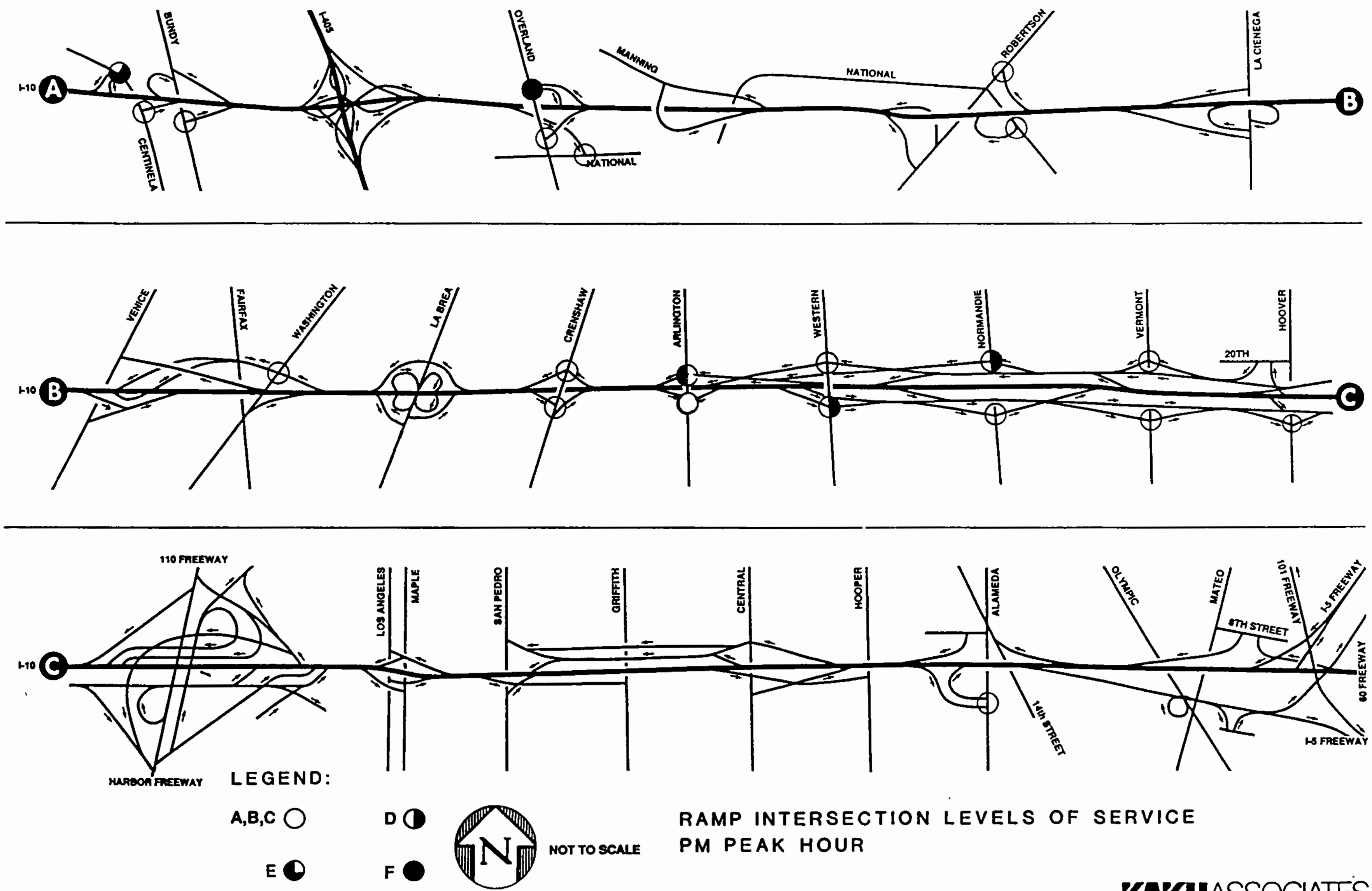
E ◕ F ●

NO SCALE

KAKU ASSOCIATES

EXHIBIT 28

SMART CORRIDOR DEMONSTRATION PROJECT



RAMP INTERSECTION LEVELS OF SERVICE
PM PEAK HOUR

KAKU ASSOCIATES

EXHIBIT 29

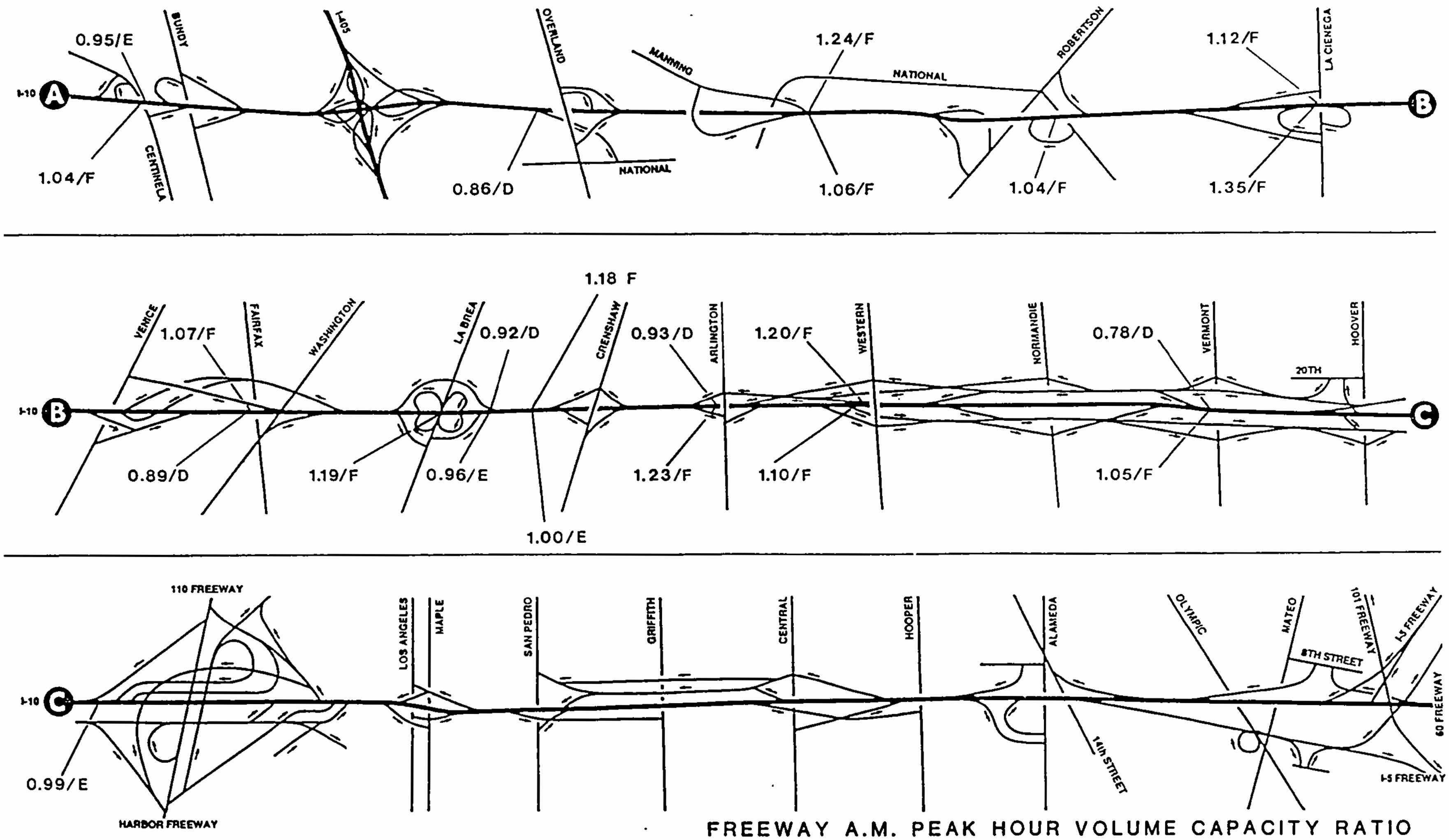
SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 30
LEVEL OF SERVICE ANALYSIS - SANTA MONICA FREEWAY MAINLINE SEGMENTS

			AM Peak Hour			PM Peak Hour		
Location	No of Lanes	Capacity	Volume	V/C Ratio	LOS	Volume	V/C Ratio	LOS
EASTBOUND								
CENTINELA	4	7,000	7,281	1.04	F	6,185	0.88	D
OVERLAND	5	8,750	7,518	0.86	D	7,507	0.86	D
MANNING	5	8,750	9,237	1.06	F	9,120	1.04	F
NATIONAL	5	8,750	9,120	1.04	F	8,664	0.99	E
LA CIENEGA	4	7,000	9,442	1.35	F	9,467	1.35	F
FAIRFAX	5	8,750	7,808	0.89	D	7,872	0.90	D
LA BREA	4	7,000	8,304	1.19	F	8,063	1.15	F
HARCOURT	5	8,750	8,373	0.96	E	8,094	0.93	D
WEST	5	8,750	8,715	1.00	E	8,140	0.93	D
ARLINGTON	4	7,000	8,584	1.23	F	8,005	1.14	F
WESTERN	4	7,000	7,720	1.10	F	7,308	1.04	F
VERMONT	5	8,750	9,180	1.05	F	8,301	0.95	E
WASHINGTON	5	8,750	8,696	0.99	E	8,722	1.00	E
WESTBOUND								
CENTINELA	4	7,000	6,644	0.95	E	6,593	0.94	E
MANNING	4	7,000	8,678	1.24	F	8,504	1.21	F
LA CIENEGA	4	7,000	7,843	1.12	F	8,097	1.16	F
FAIRFAX	4	7,000	7,458	1.07	F	7,214	1.03	F
HARCOURT	5	8,750	8,035	0.92	D	8,430	0.96	E
WEST	5	8,750	10,321	1.18	F	10,635	1.22	F
ARLINGTON	5	8,750	8,157	0.93	D	8,858	1.01	F
WESTERN	4	7,000	8,368	1.20	F	9,048	1.29	F
VERMONT	4	7,000	5,442	0.78	D	5,364	0.77	C

- Link capacity based on assumed theoretical capacity of 1,750 vehicles per hour per lane.
- Volumes from Exhibits 13 and 14.

SMART CORRIDOR DEMONSTRATION PROJECT



N

NOT TO SCALE

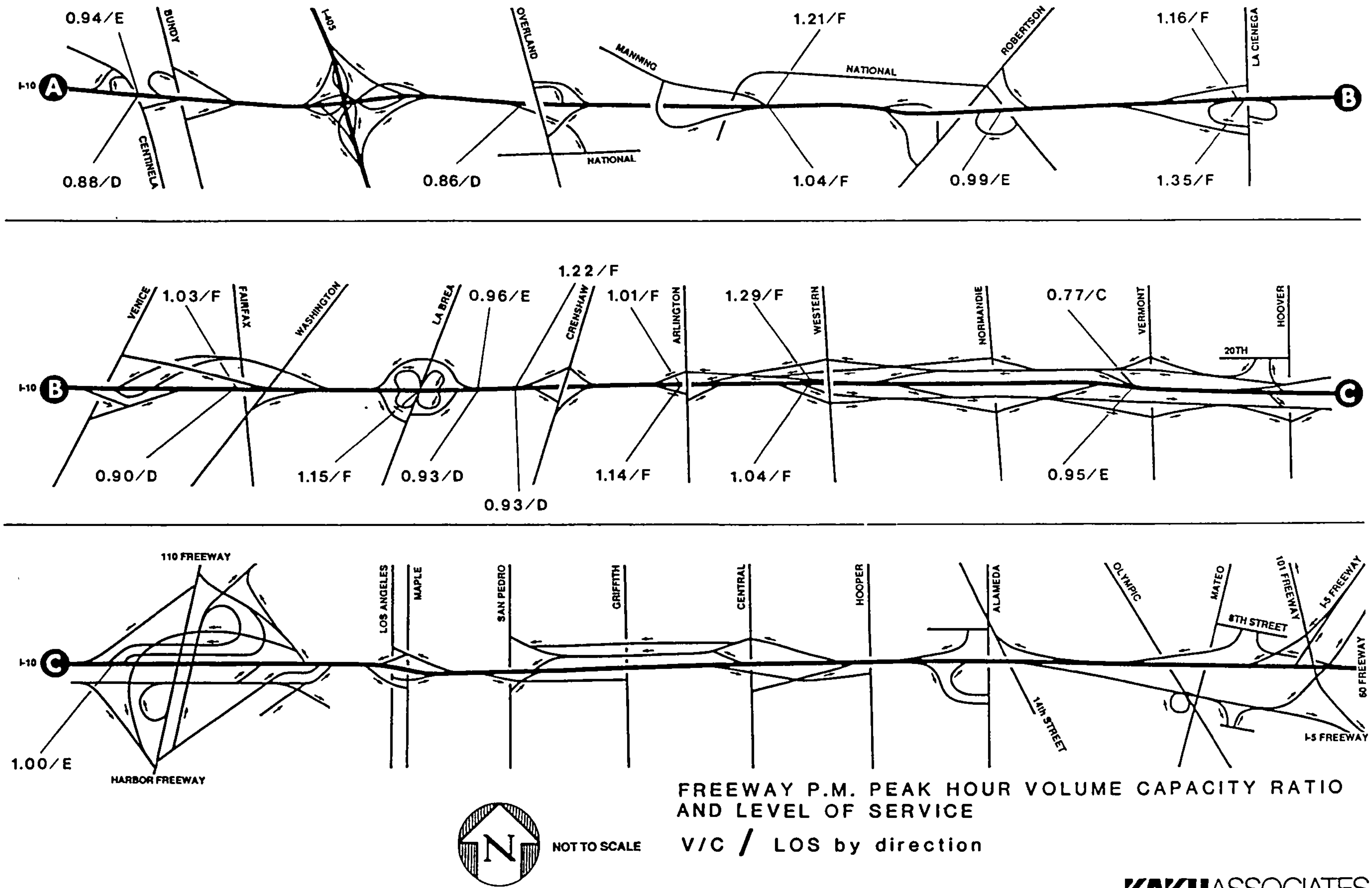
FREEWAY A.M. PEAK HOUR VOLUME CAPACITY RATIO AND LEVEL OF SERVICE

V/C / LOS by direction

KAKU ASSOCIATES

EXHIBIT 31

SMART CORRIDOR DEMON..TRATION PROJECT



FREEWAY P.M. PEAK HOUR VOLUME CAPACITY RATIO
AND LEVEL OF SERVICE
V/C / LOS by direction

KAKU ASSOCIATES

EXHIBIT 32

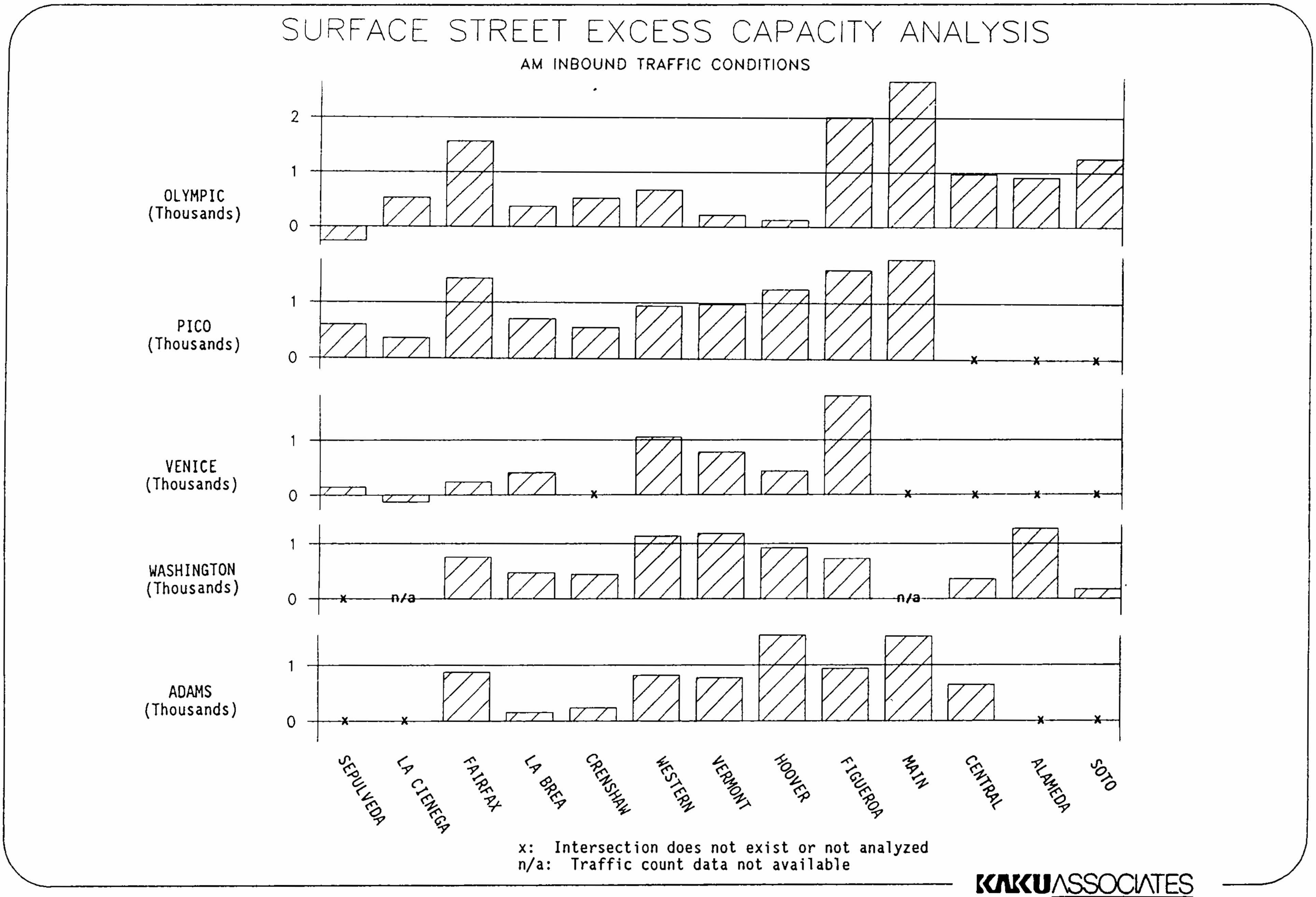

SURFACE STREET EXCESS CAPACITY ANALYSIS
AM INBOUND TRAFFIC CONDITIONS
OLYMPIC (Thousands)
PICO (Thousands)
VENICE (Thousands)
WASHINGTON (Thousands)
ADAMS (Thousands)
0
1
2
n/a
x
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
x: Intersection does not exist or not analyzed
n/a: Traffic count data not available
KAKU ASSOCIATES

EXHIBIT 33

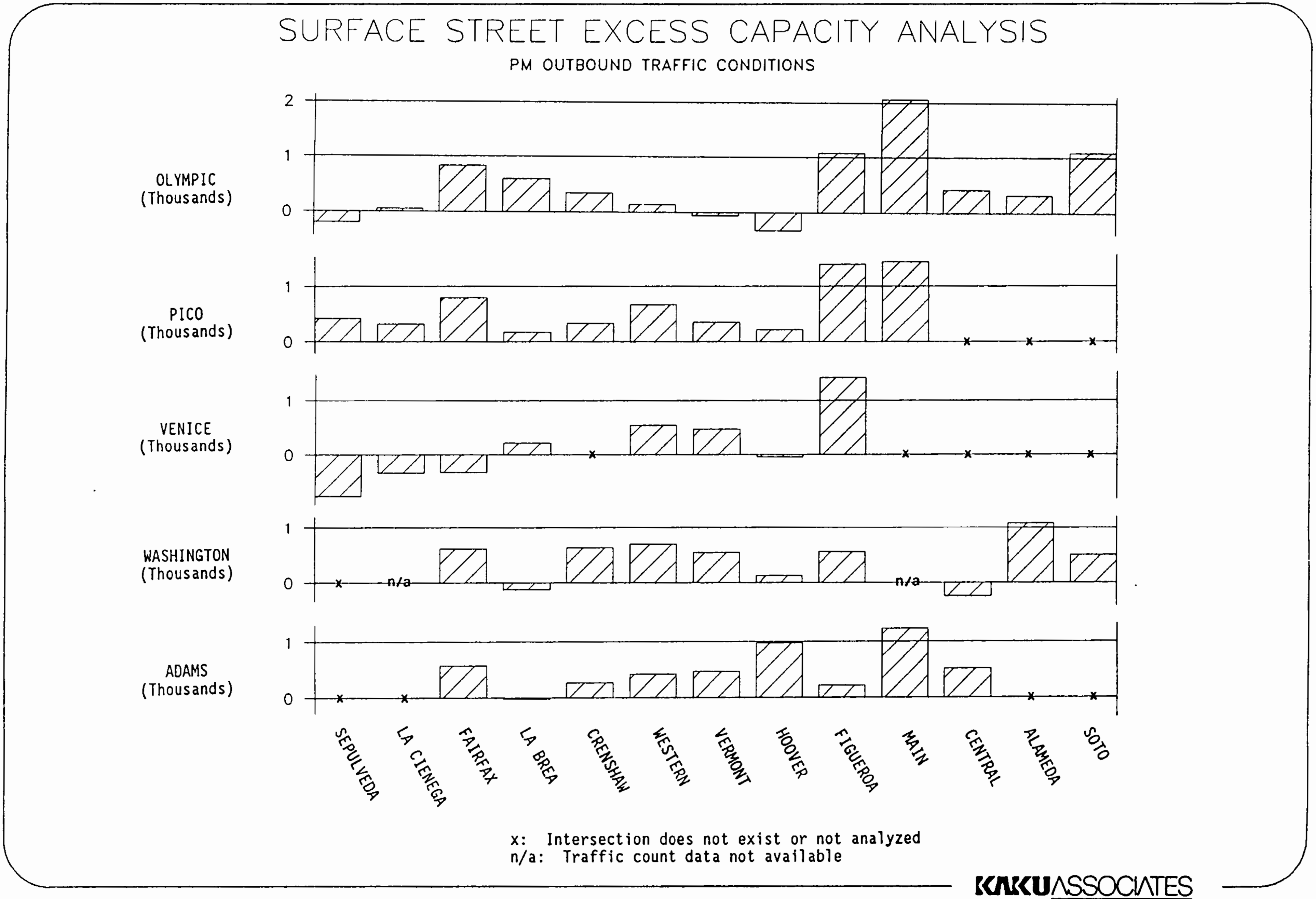
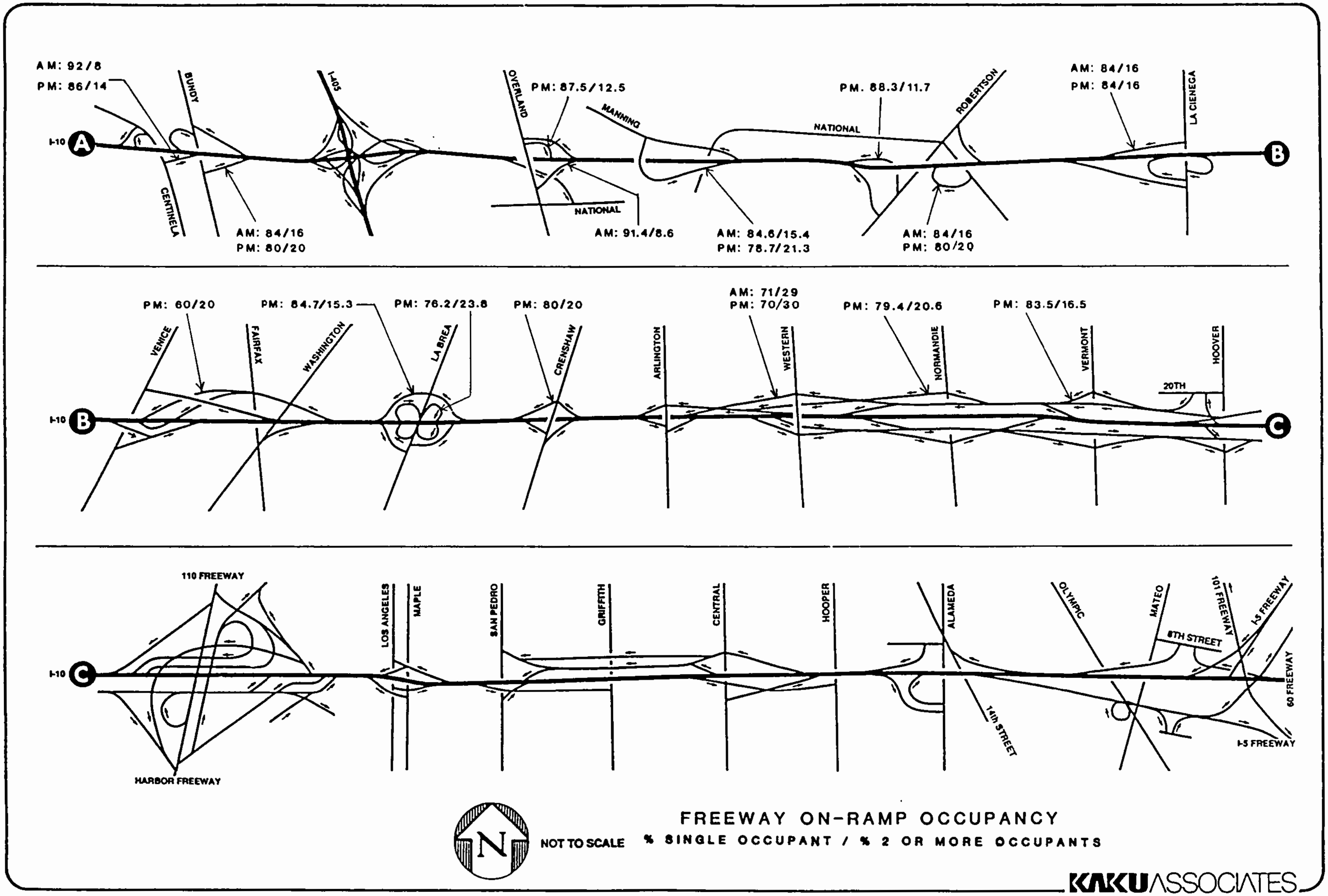

SURFACE STREET EXCESS CAPACITY ANALYSIS
PM OUTBOUND TRAFFIC CONDITIONS
OLYMPIC (Thousands)
PICO (Thousands)
VENICE (Thousands)
WASHINGTON (Thousands)
ADAMS (Thousands)
2
1
0
x
n/a
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
x: Intersection does not exist or not analyzed
n/a: Traffic count data not available
KAKU ASSOCIATES

EXHIBIT 34

SMART CORRIDOR DEMONSTRATION PROJECT



FREEWAY ON-RAMP OCCUPANCY
% SINGLE OCCUPANT / % 2 OR MORE OCCUPANTS

KAKU ASSOCIATES

EXHIBIT 35

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 36
TRUCK VOLUMES AND PERCENTAGES AT INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	6-Hour Total Volume	6-Hour Truck Volume	Average Trucks Per Hour	Truck % of Total
1	319	OLYMPIC & BUNDY	32,757	637	106	1.9%
2	274	OLYMPIC & SEPULVEDA	38,799	550	92	1.4%
3	3	OLYMPIC & LA CIENEGA	39,423	558	93	1.4%
4	7	OLYMPIC & FAIRFAX	23,865	293	49	1.2%
5	14	OLYMPIC & LA BREA	36,070	807	135	2.2%
6	20	OLYMPIC & CRENSHAW	31,877	492	82	1.5%
7	25	OLYMPIC & WESTERN	31,516	616	103	2.0%
8	30	OLYMPIC & VERMONT	33,135	529	222	1.6%
9	33	OLYMPIC & HOOVER	34,106	644	107	1.9%
10	*	OLYMPIC & FIGUEROA	23,911	471	79	2.0%
11	*	OLYMPIC & MAIN	18,540	540	90	2.9%
12	*	OLYMPIC & SAN PEDRO	n/a	n/a	n/a	n/a
13	*	OLYMPIC & CENTRAL	19,463	1,641	274	8.4%
14	236	OLYMPIC & ALAMEDA	21,702	2,709	452	12.5%
15	241	OLYMPIC & SOTO	28,596	3,494	582	12.2%
16	*	OLYMPIC & INDIANA	n/a	n/a	n/a	n/a
17	325	PICO & BUNDY	30,938	716	119	2.3%
18	297	PICO & SEPULVEDA	26,390	406	68	1.5%
19	295	PICO & BEVERLY GLEN	n/a	n/a	n/a	n/a
20	63	PICO & BEVERLY	22,107	387	65	1.8%
21	70	PICO & LA CIENEGA	32,510	844	141	2.6%
22	72	PICO & FAIRFAX	16,760	308	51	1.8%
23	78	PICO & LA BREA	31,135	741	124	2.4%
24	83	PICO & CRENSHAW	23,978	512	85	2.1%
25	88	PICO & WESTERN	22,076	645	108	2.9%
26	93	PICO & VERMONT	22,734	426	71	1.9%
27	96	PICO & HOOVER	20,299	337	56	1.7%
28	*	PICO & FIGUEROA	13,260	440	73	3.3%
29	*	PICO & MAIN	14,748	437	73	3.0%
30	106	NATIONAL & SEPULVEDA	24,241	512	85	2.1%
31	302	NATIONAL/OVERLAND/WB RAMPS	22,118	346	58	1.6%
32	346	VENICE & CENTINELA	26,816	472	79	1.8%
33	146	VENICE & SEPULVEDA	30,283	562	94	1.9%
34	148	VENICE & OVERLAND	31,543	614	102	1.9%
35	*	VENICE & CULVER	n/a	n/a	n/a	n/a
36	156	VENICE & LA CIENEGA	37,669	759	127	2.0%
37	158	VENICE & FAIRFAX	33,494	496	83	1.5%
38	163	VENICE & LA BREA	36,600	703	117	1.9%
39	172	VENICE & WESTERN	22,310	536	89	2.4%
40	177	VENICE & VERMONT	22,916	461	77	2.0%
41	180	VENICE & HOOVER	26,625	665	111	2.5%
42	*	VENICE & FIGUEROA	14,091	401	67	2.8%

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 36 (continued)
TRUCK VOLUMES AND PERCENTAGES AT INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	6-Hour Total Volume	6-Hour Truck Volume	Average Trucks Per Hour	Truck % of Total
43	*	WASHINGTON & LA CIENEGA	n/a	n/a	n/a	n/a
44	185	WASHINGTON & FAIRFAX	23,714	628	105	2.6%
45	190	WASHINGTON & LA BREA	35,753	790	132	2.2%
46	194	WASHINGTON & CRENSHAW	30,329	583	97	1.9%
47	198	WASHINGTON & ARLINGTON	21,986	434	72	2.0%
48	201	WASHINGTON & WESTERN	24,928	818	136	3.3%
49	203	WASHINGTON & NORMANDIE	25,224	479	80	1.9%
50	205	WASHINGTON & VERMONT	26,781	705	118	2.6%
51	*	WASHINGTON & HOOVER	28,327	766	128	2.7%
52	*	WASHINGTON & FIGUEROA	25,446	937	156	3.7%
53	*	WASHINGTON & MAIN	n/a	n/a	n/a	n/a
54	*	WASHINGTON & SAN PEDRO	20,692	1,258	210	6.1%
55	*	WASHINGTON & CENTRAL	22,489	1,645	274	7.3%
56	*	WASHINGTON & ALAMEDA	23,838	2,782	464	11.7%
57	*	WASHINGTON & SOTO	23,755	3,256	543	13.7%
58	*	WASHINGTON & INDIANA	n/a	n/a	n/a	n/a
59	207	ADAMS & FAIRFAX	19,148	627	105	3.3%
60	213	ADAMS & LA BREA	32,345	826	138	2.6%
61	218	ADAMS & CRENSHAW	29,405	797	133	2.7%
62	223	ADAMS & ARLINGTON	18,131	305	51	1.7%
63	228	ADAMS & WESTERN	21,369	708	118	3.3%
64	*	ADAMS & NORMANDIE	20,101	478	80	2.4%
65	*	ADAMS & VERMONT	22,148	467	78	2.1%
66	*	ADAMS & HOOVER	15,366	202	34	1.3%
67	*	ADAMS & FIGUEROA	23,186	502	84	2.2%
68	*	ADAMS & MAIN	14,354	506	84	3.5%
69	268	ADAMS & SAN PEDRO	16,994	82	14	0.5%
70	270	ADAMS & CENTRAL	16,804	1,096	183	6.5%

o 6-hour count period is 7 to 10 AM and 3 to 6 PM.
o "n/a" indicates traffic count data not available.
* Indicates intersection not in Smart Corridor ATSAC system.

o Source: LADOT, Traffic Count Summary sheets.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 37
BUS VOLUMES AND PERCENTAGES AT INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	6-Hour Total Volume	6-Hour Bus Volume	Average Buses Per Hour	Bus % of Total
1	319	OLYMPIC & BUNDY	32,757	93	16	0.3%
2	274	OLYMPIC & SEPULVEDA	38,799	70	12	0.2%
3	3	OLYMPIC & LA CIENEGA	39,423	199	33	0.5%
4	7	OLYMPIC & FAIRFAX	23,865	164	27	0.7%
5	14	OLYMPIC & LA BREA	36,070	234	39	0.6%
6	20	OLYMPIC & CRENSHAW	31,877	281	47	0.9%
7	25	OLYMPIC & WESTERN	31,516	322	54	1.0%
8	30	OLYMPIC & VERMONT	33,135	363	222	1.1%
9	33	OLYMPIC & HOOVER	34,106	191	32	0.6%
10	*	OLYMPIC & FIGUEROA	23,911	312	52	1.3%
11	*	OLYMPIC & MAIN	18,540	1,079	180	5.8%
12	*	OLYMPIC & SAN PEDRO	n/a	n/a	n/a	n/a
13	*	OLYMPIC & CENTRAL	19,463	186	31	1.0%
14	236	OLYMPIC & ALAMEDA	21,702	111	19	0.5%
15	241	OLYMPIC & SOTO	28,596	230	38	0.8%
16	*	OLYMPIC & INDIANA	n/a	n/a	n/a	n/a
17	325	PICO & BUNDY	30,938	141	24	0.5%
18	297	PICO & SEPULVEDA	26,390	137	23	0.5%
19	295	PICO & BEVERLY GLEN	n/a	n/a	n/a	n/a
20	63	PICO & BEVERLY	22,107	154	26	0.7%
21	70	PICO & LA CIENEGA	32,510	239	40	0.7%
22	72	PICO & FAIRFAX	16,760	188	31	1.1%
23	78	PICO & LA BREA	31,135	227	38	0.7%
24	83	PICO & CRENSHAW	23,978	230	38	1.0%
25	88	PICO & WESTERN	22,076	254	42	1.2%
26	93	PICO & VERMONT	22,734	366	61	1.6%
27	96	PICO & HOOVER	20,299	159	27	0.8%
28	*	PICO & FIGUEROA	13,260	379	63	2.9%
29	*	PICO & MAIN	14,748	672	112	4.6%
30	106	NATIONAL & SEPULVEDA	24,241	105	18	0.4%
31	302	NATIONAL/OVERLAND/WB RAMPS	22,118	34	6	0.2%
32	346	VENICE & CENTINELA	26,816	138	23	0.5%
33	146	VENICE & SEPULVEDA	30,283	140	23	0.5%
34	148	VENICE & OVERLAND	31,543	118	20	0.4%
35	*	VENICE & CULVER	n/a	n/a	n/a	n/a
36	156	VENICE & LA CIENEGA	37,669	124	21	0.3%
37	158	VENICE & FAIRFAX	33,494	300	50	0.9%
38	163	VENICE & LA BREA	36,600	165	28	0.5%
39	172	VENICE & WESTERN	22,310	239	40	1.1%
40	177	VENICE & VERMONT	22,916	305	51	1.3%
41	180	VENICE & HOOVER	26,625	196	33	0.7%
42	*	VENICE & FIGUEROA	14,091	282	47	2.0%

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 37 (continued)
BUS VOLUMES AND PERCENTAGES AT INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	6-Hour Total Volume	6-Hour Bus Volume	Average Buses Per Hour	Bus % of Total
43	*	WASHINGTON & LA CIENEGA	n/a	n/a	n/a	n/a
44	185	WASHINGTON & FAIRFAX	23,714	435	73	1.8%
45	190	WASHINGTON & LA BREA	35,753	170	28	0.5%
46	194	WASHINGTON & CRENSHAW	30,329	162	27	0.5%
47	198	WASHINGTON & ARLINGTON	21,986	102	17	0.5%
48	201	WASHINGTON & WESTERN	24,928	199	33	0.8%
49	203	WASHINGTON & NORMANDIE	25,224	129	22	0.5%
50	205	WASHINGTON & VERMONT	26,781	269	45	1.0%
51	*	WASHINGTON & HOOVER	28,327	175	29	0.6%
52	*	WASHINGTON & FIGUEROA	25,446	283	47	1.1%
53	*	WASHINGTON & MAIN	n/a	n/a	n/a	n/a
54	*	WASHINGTON & SAN PEDRO	20,692	158	26	0.8%
55	*	WASHINGTON & CENTRAL	22,489	113	19	0.5%
56	*	WASHINGTON & ALAMEDA	23,838	64	11	0.3%
57	*	WASHINGTON & SOTO	23,755	155	26	0.7%
58	*	WASHINGTON & INDIANA	n/a	n/a	n/a	n/a
59	207	ADAMS & FAIRFAX	19,148	167	28	0.9%
60	213	ADAMS & LA BREA	32,345	121	20	0.4%
61	218	ADAMS & CRENSHAW	29,405	172	29	0.6%
62	223	ADAMS & ARLINGTON	18,131	137	23	0.8%
63	228	ADAMS & WESTERN	21,369	217	36	1.0%
64	*	ADAMS & NORMANDIE	20,101	163	27	0.8%
65	*	ADAMS & VERMONT	22,148	290	48	1.3%
66	*	ADAMS & HOOVER	15,366	182	30	1.2%
67	*	ADAMS & FIGUEROA	23,186	263	44	1.1%
68	*	ADAMS & MAIN	14,354	86	14	0.6%
69	268	ADAMS & SAN PEDRO	16,994	173	29	1.0%
70	270	ADAMS & CENTRAL	16,804	139	23	0.8%

o 6-hour count period is 7 to 10 AM and 3 to 6 PM.
o "n/a" indicates traffic count data not available.
* Indicates intersection not in Smart Corridor ATSAC system.

Source: LADOT, Traffic Count Summary sheets.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 38
TRUCK PERCENTAGES ON THE SANTA MONICA FREEWAY

Location	Trucks as Percent of Total Volume
EASTBOUND	
EAST OF SAN DIEGO FREEWAY	6.4%
EAST OF LA CIENEGA BOULEVARD	6.5%
EAST OF HARBOR FREEWAY	5.4%
WESTBOUND	
WEST OF EAST LA INTERCHANGE	6.5%
WEST OF HARBOR FREEWAY	6.6%
WEST OF LA CIENEGA BOULEVARD	7.1%
WEST OF SAN DIEGO FREEWAY	4.7%

Source: Caltrans.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 39
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET INTERSECTIONS
(June 1, 1985 to June 1, 1988)

Study Num	ATSAC Smart Num	Intersection	Total Number of Accidents	Accident Rate (per million vehicles)
1	319	OLYMPIC & BUNDY	n/a	n/a
2	274	OLYMPIC & SEPULVEDA	22	0.22
3	3	OLYMPIC & LA CIENEGA	28	0.28
4	7	OLYMPIC & FAIRFAX	19	0.28
5	14	OLYMPIC & LA BREA	33	0.36
6	20	OLYMPIC & CRENSHAW	36	0.50
7	25	OLYMPIC & WESTERN	48	0.56
8	30	OLYMPIC & VERMONT	n/a	n/a
9	33	OLYMPIC & HOOVER	n/a	n/a
10	*	OLYMPIC & FIGUEROA	n/a	n/a
11	*	OLYMPIC & MAIN	n/a	n/a
12	*	OLYMPIC & SAN PEDRO	n/a	n/a
13	*	OLYMPIC & CENTRAL	n/a	n/a
14	236	OLYMPIC & ALAMEDA	32	0.70
15	241	OLYMPIC & SOTO	37	0.54
16	*	OLYMPIC & INDIANA	n/a	n/a
17	325	PICO & BUNDY	n/a	n/a
18	297	PICO & SEPULVEDA	23	0.33
19	295	PICO & BEVERLY GLEN	2	0.03
20	63	PICO & BEVERLY	9	0.17
21	70	PICO & LA CIENEGA	27	0.32
22	72	PICO & FAIRFAX	n/a	n/a
23	78	PICO & LA BREA	n/a	n/a
24	83	PICO & CRENSHAW	n/a	n/a
25	88	PICO & WESTERN	n/a	n/a
26	93	PICO & VERMONT	n/a	n/a
27	96	PICO & HOOVER	n/a	n/a
28	*	PICO & FIGUEROA	n/a	n/a
29	*	PICO & MAIN	n/a	n/a
30	106	NATIONAL & SEPULVEDA	n/a	n/a
31	302	NATIONAL/OVERLAND/WB RAMPS	n/a	n/a
32	346	VENICE & CENTINELA	34	0.49
33	146	VENICE & SEPULVEDA	22	0.26
34	148	VENICE & OVERLAND	31	0.39
35	*	VENICE & CULVER	5	0.08
36	156	VENICE & LA CIENEGA	48	0.58
37	158	VENICE & FAIRFAX	n/a	n/a
38	163	VENICE & LA BREA	n/a	n/a
39	172	VENICE & WESTERN	n/a	n/a
40	177	VENICE & VERMONT	n/a	n/a
41	180	VENICE & HOOVER	n/a	n/a
42	*	VENICE & FIGUEROA	n/a	n/a

EXHIBIT 39 (continued)
SURFACE STREET INTERSECTION 3-YEAR ACCIDENT SUMMARY
(June 1, 1985 to June 1, 1988)

Study Num	ATSAC Smart Num	Intersection	Total Number of Accidents	Accident Rate (per million vehicles)
43	*	WASHINGTON & LA CIENEGA	n/a	n/a
44	185	WASHINGTON & FAIRFAX	14	0.24
45	190	WASHINGTON & LA BREA	35	0.38
46	194	WASHINGTON & CRENSHAW	28	0.40
47	198	WASHINGTON & ARLINGTON	29	0.51
48	201	WASHINGTON & WESTERN	35	0.55
49	203	WASHINGTON & NORMANDIE	23	0.35
51	*	WASHINGTON & HOOVER	n/a	n/a
52	*	WASHINGTON & FIGUEROA	n/a	n/a
53	*	WASHINGTON & MAIN	n/a	n/a
54	*	WASHINGTON & SAN PEDRO	n/a	n/a
55	*	WASHINGTON & CENTRAL	n/a	n/a
56	*	WASHINGTON & ALAMEDA	n/a	n/a
57	*	WASHINGTON & SOTO	n/a	n/a
58	*	WASHINGTON & INDIANA	n/a	n/a
59	207	ADAMS & FAIRFAX	16	0.38
60	213	ADAMS & LA BREA	43	0.52
61	218	ADAMS & CRENSHAW	46	0.61
62	223	ADAMS & ARLINGTON	26	0.69
63	228	ADAMS & WESTERN	26	0.49
64	*	ADAMS & NORMANDIE	n/a	n/a
65	*	ADAMS & VERMONT	n/a	n/a
66	*	ADAMS & HOOVER	n/a	n/a
67	*	ADAMS & FIGUEROA	n/a	n/a
68	*	ADAMS & MAIN	n/a	n/a
69	268	ADAMS & SAN PEDRO	n/a	n/a
70	270	ADAMS & CENTRAL	n/a	n/a

o Intersection accidents defined as all accidents occurring within crosswalk lines, and rear end and side swipe approach accidents within 200 feet of intersection.

Source: LADOT, Traffic Accident Reports, August 1988.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 40
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET INTERSECTIONS, RANKED BY NUMBER OF ACCIDENTS
(June 1, 1985 to June 1, 1988)

Study Num	ATSAC Smart Num	Intersection	Total Number of Accidents	Accident Rate (per million vehicles)
7	25	OLYMPIC & WESTERN	48	0.56
36	156	VENICE & LA CIENEGA	48	0.58
61	218	ADAMS & CRENSHAW	46	0.61
60	213	ADAMS & LA BREA	43	0.52
15	241	OLYMPIC & SOTO	37	0.54
6	20	OLYMPIC & CRENSHAW	36	0.50
45	190	WASHINGTON & LA BREA	35	0.38
48	201	WASHINGTON & WESTERN	35	0.55
32	346	VENICE & CENTINELA	34	0.49
5	14	OLYMPIC & LA BREA	33	0.36
14	236	OLYMPIC & ALAMEDA	32	0.70
34	148	VENICE & OVERLAND	31	0.39
47	198	WASHINGTON & ARLINGTON	29	0.51
3	3	OLYMPIC & LA CIENEGA	28	0.28
46	194	WASHINGTON & CRENSHAW	28	0.40
21	70	PICO & LA CIENEGA	27	0.32
62	223	ADAMS & ARLINGTON	26	0.69
63	228	ADAMS & WESTERN	26	0.49
18	297	PICO & SEPULVEDA	23	0.33
49	203	WASHINGTON & NORMANDIE	23	0.35
2	274	OLYMPIC & SEPULVEDA	22	0.22
33	146	VENICE & SEPULVEDA	22	0.26
4	7	OLYMPIC & FAIRFAX	19	0.28
59	207	ADAMS & FAIRFAX	16	0.38
44	185	WASHINGTON & FAIRFAX	14	0.24
20	63	PICO & BEVERLY	9	0.17
35	*	VENICE & CULVER	5	0.08
19	295	PICO & BEVERLY GLEN	2	0.03

o Intersection accidents defined as all accidents occurring within crosswalk lines, and rear end and side swipe approach accidents within 200 feet of intersection.

Source: LADOT, Traffic Accident Reports, August 1988.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 41
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET INTERSECTIONS, RANKED BY ACCIDENT RATE
(June 1, 1985 to June 1, 1988)

Study Num	ATSAC Smart Num	Intersection	Total Number of Accidents	Accident Rate (per million vehicles)
14	236	OLYMPIC & ALAMEDA	32	0.70
62	223	ADAMS & ARLINGTON	26	0.69
61	218	ADAMS & CRENSHAW	46	0.61
36	156	VENICE & LA CIENEGA	48	0.58
7	25	OLYMPIC & WESTERN	48	0.56
48	201	WASHINGTON & WESTERN	35	0.55
15	241	OLYMPIC & SOTO	37	0.54
60	213	ADAMS & LA BREA	43	0.52
47	198	WASHINGTON & ARLINGTON	29	0.51
6	20	OLYMPIC & CRENSHAW	36	0.50
32	346	VENICE & CENTINELA	34	0.49
63	228	ADAMS & WESTERN	26	0.49
46	194	WASHINGTON & CRENSHAW	28	0.40
34	148	VENICE & OVERLAND	31	0.39
45	190	WASHINGTON & LA BREA	35	0.38
59	207	ADAMS & FAIRFAX	16	0.38
5	14	OLYMPIC & LA BREA	33	0.36
49	203	WASHINGTON & NORMANDIE	23	0.35
18	297	PICO & SEPULVEDA	23	0.33
21	70	PICO & LA CIENEGA	27	0.32
3	3	OLYMPIC & LA CIENEGA	28	0.28
4	7	OLYMPIC & FAIRFAX	19	0.28
33	146	VENICE & SEPULVEDA	22	0.26
44	185	WASHINGTON & FAIRFAX	14	0.24
2	274	OLYMPIC & SEPULVEDA	22	0.22
20	63	PICO & BEVERLY	9	0.17
35	*	VENICE & CULVER	5	0.08
19	295	PICO & BEVERLY GLEN	2	0.03

o Intersection accidents defined as all accidents occurring within crosswalk lines, and rear end and side swipe approach accidents within 200 feet of intersection.

Source: LADOT, Traffic Accident Reports, August 1988.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 42
SANTA MONICA FREEWAY 3-YEAR ACCIDENT SUMMARY
(June 1, 1985 to June 1, 1988)

Freeway Segment	Total Number of Accidents	Actual Accident Rate (per million vehicle miles)	Expected Accident Rate* (per million vehicle miles)
CENTINELA AVE - BUNDY DR	53	1.04	1.00
BUNDY DR - SAN DIEGO FWY	273	1.38	1.09
SAN DIEGO FWY - OVERLAND AVE	378	1.62	1.24
OVERLAND AVE - NATIONAL BLVD	228	1.16	1.15
NATIONAL BLVD - ROBERTSON BLVD	154	0.86	1.17
ROBERTSON BLVD - VENICE/WASHINGTON	252	1.09	1.18
VENICE/WASHINGTON - LA BREA AVE	300	0.69	1.27
LA BREA AVE - CRENSHAW BLVD	294	1.07	1.31
CRENSHAW BLVD - ARLINGTON AVE	306	1.11	1.34
ARLINGTON AVE - WESTERN AVE	153	1.01	1.39
WESTERN AVE - NORMANDIE AVE	162	1.09	1.37
NORMANDIE AVE - VERMONT AVE	201	1.30	1.41
VERMONT AVE - HOOVER ST	146	1.08	1.36
HOOVER ST - HARBOR FWY	311	1.79	1.78
HARBOR FWY - MAPLE AVE	291	1.63	1.36
MAPLE AVE - SAN PEDRO/CENTRAL	193	0.90	1.18
SAN PEDRO/CENTRAL - ALAMEDA ST	114	0.91	1.19
ALAMEDA ST - SANTA FE AVE	138	1.45	1.25
SANTA FE AVE - EAST LA I/C	338	1.20	1.94

* "Expected Accident Rate" is calculated by Caltrans based upon statewide data and indicates an average accident rate which might typically be expected for similar highways across the state, thus providing an indication of whether a particular section of highway has a higher or lower incidence of accidents than the statewide average for similar highways.

Source: Caltrans, TASAS Selective Record Retrieval and Selective Accident Rate Calculation, February 1989.

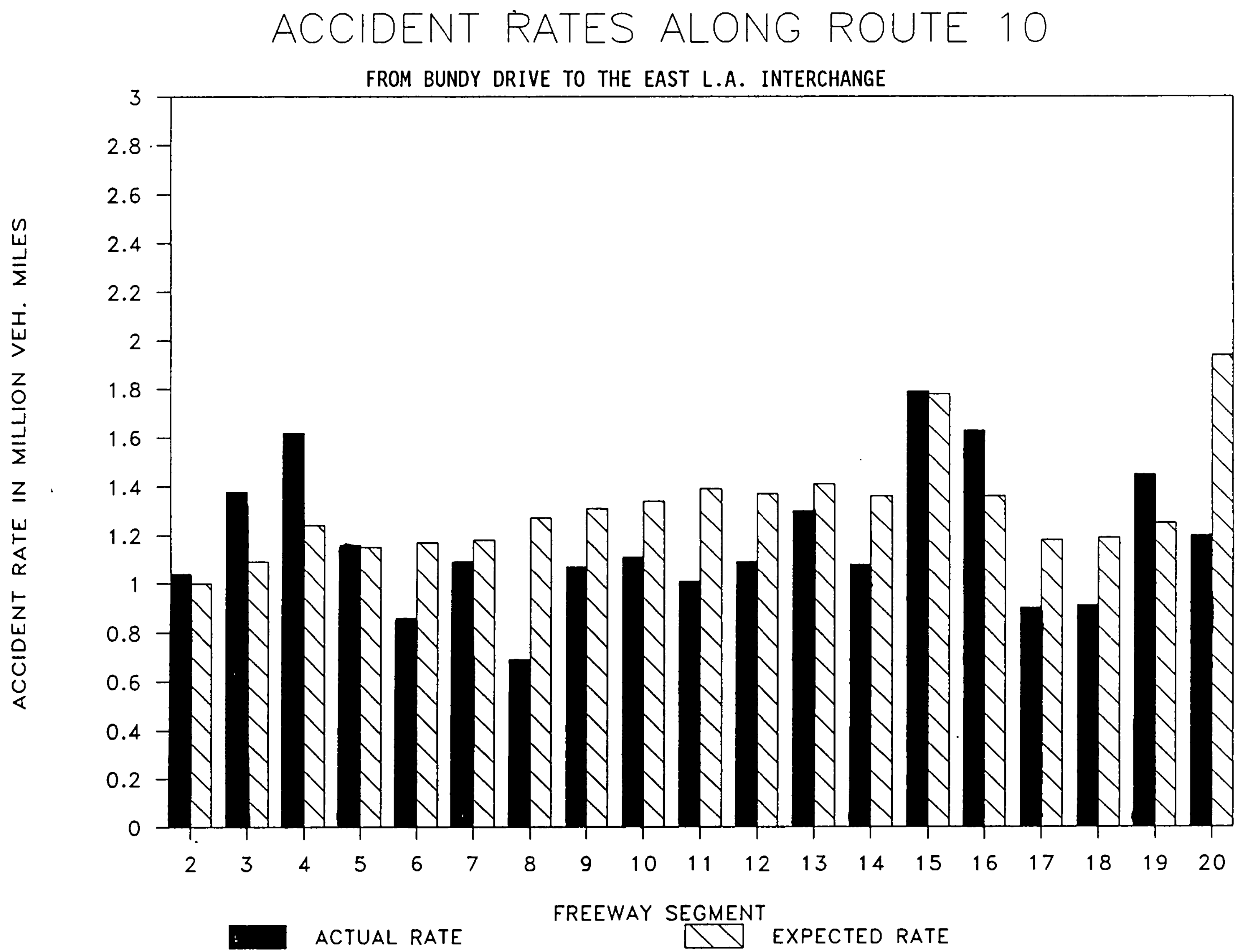

ACCIDENT RATES ALONG ROUTE 10
FROM BUNDY DRIVE TO THE EAST L.A. INTERCHANGE
ACCIDENT RATE IN MILLION VEH. MILES
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
FREEWAY SEGMENT
ACTUAL RATE
EXPECTED RATE

EXHIBIT 43

EVALUATION OF SYSTEM COMPONENTS AND ALTERNATIVES

Prepared by

JHK & Associates

March 1989

Discussion Paper

Evaluation of System Components and Alternatives

Introduction

An important task in the Smart Corridor Demonstration Project is the preliminary assessment or evaluation of the various system components being considered for implementation. The goals of this evaluation task is to provide necessary criteria to determine which elements offer the greatest promise and should be implemented in the corridor. In addition, the evaluation results may provide useful information regarding placement of certain components within the corridor. Evaluation of certain proposed system components prior to implementation presents a difficult task. Little information, either practical or theoretical, are available to identify potential impacts of such components as highway advisory radio (HAR), silent radio, or videotext. Therefore, both direct and indirect evaluation methods must be used. For some components, such as ramp metering, sufficient information is available to directly analyze the impacts with simulation or manually. Other components will require a more indirect approach, where a range of values or "what if" scenarios must be analyzed to estimate the impacts. In the following discussion, the overall evaluation approach, including measures of effectiveness (MOE's) and analytical methods is presented. Several key issues which will be addressed during the evaluation process are also briefly discussed.

Evaluation Objectives

The primary objective of the evaluation process is to identify the potential operational impacts of each of the candidate system components. Candidate components are summmarized in Exhibit 1. These components are divided into three general categories; operator control, operator information, and driver information. Driver information components are further classified as either field information or pre-trip planning. The impacts of each of these components on traffic flow within the corridor will be used to select or prioritize system components. The operational impacts of the components on each of the different roadway facilities within the corridor are of concern. Therefore, the analytical methods for each of the different facilities within the corridor must be integrated. In other words, the output from a freeway analysis may be used as the input to an arterial analysis and vice versa.

Exhibit 1
Smart Corridor
Candidate System Components

Operational Elements	System Function			
			Driver Information	
	Operator Control	Operator Information	Field Information	Pre-Trip Planning
Ramp Metering				
- Freeway Ramps	X			
- Freeway-to-Freeway Connectors	X			
CCTV on Surface Streets		X		
Highway Advisory Radio			X	
Changeable Message Signs on Surface Streets			X	
ATSAC Signals	X			
Intersection Signal/ Ramp Meter Coordination	X			
In-Vehicle Navigation	X	X	X	X
Changeable Message Signs in Garage or Building			X	X
Computer Bulletin Board				X
Dial-In Services				X
Cellular Telephone		X	X	
Commerical Radio			X	X
Commercial TV				X
Videotext				X
Surface Street Capacity Improvements				
Control System Improvements	X	X		
- Expert System				
- Caltrans				
- ATSAC Center				

Exhibit 1
Smart Corridor
Candidate System Components

Policy Elements	Operator Control	Operator Information	Driver Information: Field Information	Driver Information: Pre-Trip Planning
Freeway Service Patrol	X	X		
Freeway Incident Management Team	X	X		
Surface Street Incident Management Team (Temp. Street Capacity Imprmts.)	X	X		
Enforcement and Accident Investigation Sites	X			
Central Database Operations	X	X		
Control Elements	X	X		

System Function

- Inter-Agency Control Coordination
- Inter-Agency Information Exchange
- Central Database System
- Modifications/Replacement of Existing Agency Communication Systems
- Inter-Agency Video

The evaluation to be performed is directed towards identifying impacts on the existing traffic conditions within the Smart Corridor, and not on determining the potential effect of a given component in a universal sense. Therefore, even though a particular component, such as HAR is known to have been beneficial in previous applications, its impact on traffic operations within the Smart Corridor is of interest only. At the same time, the Smart Corridor is to serve as a model for tansferring results to other corridors. This use will be considered during the Smart Corridor analysis.

Measures of Effectiveness

The MOE's to be used for the evaluation must be capable of representing several aspects of traffic operation. In general, the MOE's must represent the efficiency of the network, defined as throughput and speed. The preliminary MOE's which were selected are listed below.

Freeway Operation	Ramp Operation	Surface Street Operation
Speed	Delay	Speed
VMT		VMT
VMTPH		VMTPH
Delay		Delay
		Number of Stops

In addition, secondary MOE's, including fuel consumption, vehicle emissions, and safety will also be used to evaluate the system.

Evaluation Issues

Peak Period/Off-Peak Period Analysis

Evaluation of impacts of system components on both peak period and off-peak period traffic conditions will be performed. The benefits on off-peak traffic periods may be even more significant since there is greater excess capacity in the corridor during off-peak periods. As discussed later in this paper, however, the analytical tools which are available for this project are geared towards the peak traffic period. Therefore, the impacts during the off-peak periods are expected to be estimated from information obtained from peak period analyses.

Extrapolation of Findings

Evaluation of certain system components, such as intersection signal/ramp meter coordination or CCTV on surface steets may require an initial microscopic analysis on one area or one arterial. These results may then be extrapolated to quantify the impacts on the entire corridor. The extrapolation will be based on traffic and physical conditions found on each facility within the corridor. A spreadsheet will be used for this task. Similarly, where analysis provides only partial or incomplete results, it may be necessary to extrapolate the findings to provide more comprehensive coverage.

Identification of Driver Divergence Potential

Probably the most difficult part of the evaluation process will be to determine the potential for diversion which the driver information components of the system offer. For this study, is is generally assumed that the freeway is the preferred route of choice and hence, diversion is defined as drivers leaving the freeway for an alternate route on the surface streets. Even for primary components such as CMS or HAR, very little data are available. For other components, such as commercial radio and TV or videotext, essentially no information is available on driver response. For example, a preliminary marketing evaluation performed by JHK & Associates in the Washington D.C. area estimated that if available, 20% of drivers in the area would use a dial-in traffic information service. However, there is very little basis to support this or from which an estimate of the number of drivers who will follow the information provided by a dial-in service can be made. Therefore, analysis of the impacts of the driver informational components will take a more indirect path than ramp metering or CCTV. The analysis approach would involve the testing of a range of driver response in order to estimate the feasibility of a given component. This process will be analytical, however, the test ranges will reflect judgement and logical boundary limits.

Some information on the factors which affect driver response has been documented in a recent paper prepared at the Institute of Transportation Studies (ITS) as part of the PATH program. The results of a driver survey suggest that,

- o The preferred route taken in the Smart Corridor is freeway biased.
- o The primary reason for selecting a particular route is shortest travel time. However, other reasons, such as driver comfort should also be considered.

- o A small percentage of drivers without real-time in-vehicle traffic information divert frequently in response to congested conditions.

- o More drivers would be willing to divert to alternate routes if real-time traffic information were available.

- o The average driver would divert from a freeway if the delay due to an incident was 15-20 minutes and if the time saved bypassing an incident was 5-10 minutes.

In the evaluation, some thought must also be given to what types of trips within the corridor are more likely to be diverted. There are three trip types within the corridor; internal, internal/external, and external/external. When attempting to capture trips before entering the freeway, one would hypothesize that more internal/internal trips could be diverted than external/external trips. A review of OD tables will provide information on the number of each trip type within the corridor. A special detailed run of OD tables for the corridor is being undertaken by SCAG for the project.

Appropriate Diversion Amount

In addition to determining the potential for diversion in the corridor by various system components, it is also necessary to consider what amount of diversion is too much. If too many drivers divert from the freeway in response to the driver informational components, traffic flow on the surface streets will suffer and driver confidence will be reduced. Therefore, it is important to determine whether it is possible to divert only certain numbers of drivers, as congestion on the freeway demands and excess capacity on the surface streets allows.

System Evaluation

Although the individual operational components proposed for the Smart Corridor will be evaluated, the interrelationship between these components within a system should also be considered. For instance, the use of low power highway advisory radio may be greatly diminished by the absence of changeable message sign to alert the driver of a potential problem and a source for alternate route information. Evaluation of the potential interrelationships system components prior to implementation, especially driver informational, will be extremely difficult. This type of evaluation is seen as more qualitative then quantitative. A relationship matrix will be developed to note dependencies.

Evaluation Approach

The evaluation process will be performed using both direct and indirect analysis techniques. Various scenarios of control conditions will be tested to provide a more comprehensive understanding of the impacts expected from the various control components. Exhibit 2 presents a general overview of the evaluation approach, the desired objectives, MOE's, and analytical methods.

Ramp metering will be analyzed using the FREQ simulation mode. Several scenarios, including minimum, maximum, and optimum metering rates will be tested to determine the sensitivity of the existing freeway conditions on ramp metering. The capability of the model to simulate diversion in response to ramp metering will be useful in providing an estimate of the amount of diversion which can be expected to occur. This diversion information can then be used as input to the TRANSYT model for analysis of the surface street system. Analysis of freeway ramp metering will also indicate whether connector ramp metering is justified. The same analysis scenarios would be used to test connector ramp metering strategies. In all cases, data on resulting queues will be developed so that impact on delays, surface streets, and serving freeways can be identified and mitigation measures developed.

Operator information components, such as CCTV on surface streets, will be analyzed microscopically at first, and the results used to estimate the impact on the entire corridor. For instance, based on previous experience with CCTV in identifying freeway incidents or unusual traffic conditions, the impact on a particular intersection with a simulated incident could be tested using TRANSYT. These results would then be extrapolated to include all surface streets and intersections within the corridor where CCTV would be implemented.

Evaluation of driver information components will involve more of a "what if" approach. Available information on factors affecting driver diversion and route choice will be used as a basis for the evaluation. For instance, in evaluating dial-in services or other pre-trip planning components, a range of percentages of drivers who normally use the corridor and might use the traffic information provided will be tested. OD tables for the corridor will be used to determine the type and number of trips which are available for diversion. The diverted trips can then be reassigned to the freeway or surface streets and the operational impact analyzed using FREQ and TRANSYT. It is anticipated that due to the sheer number of different scenarios which are possible, only a small number will be tested and the results used to extrapolate the impacts across the entire corridor.

Evaluation of the field informational components will be the most difficult, however, a range of scenarios will be tested. OD tables will be used to perform a more microscopic study on certain scenarios.

Exhibit 2
Evaluation Approach

Element	Objectives	Primary Measures of Effectiveness	Secondary Measures of Effectiveness	Evaluation Methods
Operator Control Components:				
o Ramp Metering - Freeway Ramps	Determine impact on freeway and arterial traffic flow and ramp delays.	Speed VMT VMTPH Delay # Stops Queues	Fuel Consumption Vehicle Emissions Accidents/ Safety	FREQ10PC Spreadsheet
o Freeway-to-Freeway Connectors	Determine impact on all freeway traffic flow (I-10, I-405, I-110).	Speed VMT VMTPH Queues	Fuel Consumption Vehicle Emissions	FREQ10PC Spreadsheet
o ATSAC Signals	Determine impact on surface streets.	Delay # Stops	Fuel Consumption Vehicle Emissions	TRANSYT-7F Spreadsheet Earlier - Results
o Intersection Signal/ Ramp Meter Coordination	Determine impact on ramp delays and arterial traffic flow.	Delay # Stops	Fuel Consumption Vehicle Emissions	TRANSYT-7F Spreadsheet
Operator Information Components:				
o CCTV on Surface Streets	Determine the impact on arterial traffic flow.	Delay # Stops	Fuel Consumption Vehicle Emissions	TRANSYT-7F Spreadsheet

Exhibit 2 (cont.)
Evaluation Approach

Element	Objectives	Primary Measures of Effctiveness	Secondary Measures of Effectiveness	Evaluation Methods
Driver Information Components: o Field Information Components - HAR - CMS (surface streets) - In-Vehicle Navigation - Cellular Telephone - Commercial Radio	Determine the potential for diversion of drivers in the corridor and the subsequent impact on freeway and arterial traffic flow.	Speed VMT VMTPH Delay # Stops	Fuel Consumption Vehicle Emissions	FREQ10PC TRANSYT-7F Spreadsheet
o Pre-Trip Planning Components - In-Vehicle Navigation - CMS (Garage or Building) - Computer Bulletin Boards - Dial-In Services - Commercial Radio - Commercial TV - Videtext	Determine the potential for diversion of drivers prior to entering the corridor and the subsequent impact on freeway and arterial traffic flow.	Speed VMT VMTPH Delay # Stops	Fuel Consumption Vehicle Emissions	FREQ10PC TRANSYT-7F Spreadsheet
o Surface Street Capacity Improvements	Determine the impact on surface street capacity of maximizing the available capacity through removal of on-street parking and repositioning of bus stops.	Speed VMT VMTPH Delay	Fuel Consumption Vehicle Emissions	TRANSYT-7F Spreadsheet

Exhibit 2 (cont.)
Evaluation Approach

Element	Objectives	Primary Measures of Effctiveness	Secondary Measures of Effectiveness	Evaluation Methods
o Control System Improvements - Expert System - Caltrans Center - ATSAC Center	Determine impact on freeway and arterial trafic flow and ramp delay.	Speed VMT VMTPH Delay # Stops	Fuel Consumption Vehicle Emissions	Spreadsheet
o Freeway Service Patrol	Determine impact on freeway traffic flow and ramp delay.	Speed VMT VMTPH Delay	Fuel Consumption Vehicle Emissions Accidents/Safety	Spreadsheet
o Freeway Incident Management Team	Determine impact on freeway traffic flow and ramp delay.	Speed VMT VMTPH Delay	Fuel Consumption Vehicle Emissions Accidents/Safety	Spreadsheet
o Surface Street Incident Management Team (Temp. Street Capacity Improvements)	Determine impact on arterial traffic flow.	Delay # Stops	Fuel Consumption Vehicle Emissions	Spreadsheet

One example might be to assume that a certain number of drivers on the freeway divert in response to information provided by HAR, and then analyze the operational impacts on the freeway and surface streets. A range of values or scenarios would be tested.

Evaluation Methods

Three different analysis methods will be used to perform the evaluation. These include computer simulation models FREQ10PC, TRANSYST-7F, and PATHNET, spreadsheet analysis, and an evaluation matrix.

Simulation Models

FREQ10PC will be used to directly analyze the impact of freeway ramp metering and freeway connector ramp metering on the Santa Monica freeway. It provides for the analysis of different ramp metering strategies including optimization. FREQ also allows for dynamic diversion in response to ramp delays. As output, FREQ provides information on mainline, ramp, and parallel arterial traffic operation. These include mainline and arterial travel times, ramp delays, speed profiles, density profiles, V/C profiles, fuel consumption, and vehicle emission.

As with many models, the time required for start-up and calibration can be quite lengthy. FREQ is no exception. Fortunately, the Smart Corridor has already been modeled and calibrated in a previous study conducted by the Institute of Transportation Studies (ITS) at UC-Berkeley. This FREQ model which was used for the study of potential benefits of in-vehicle information systems, covers the section of the Santa Monica freeway (I-10) from the San Diego freeway (I-405) to the Harbor freeway (I-110) for the time period 6:00 a.m. to 10:00 a.m. Both the eastbound and westbound directions have been modeled. The traffic counts used for this model represent the years 1984-1988.

Exhibits 3 and 4 provide a comparison between the travel times observed on the freeway and those produced by FREQ for both the eastbound and westbound directions. Although differences in travel times reach as high as 2-3 minutes, overall, the model results compare favorably with the actual "real life" data. Therefore, it is reasonable to apply this existing FREQ model for the evaluation of certain elements of the Smart Corridor system. The data produced for the morning peak period could be used to estimate the impacts during other time periods.

Evaluation of the surface street system within the Smart Corridor will primarily be accomplished with TRANSYT-7F. The TRANSYT model provides as output travel times, delays, fuel consumption, and average speeds.

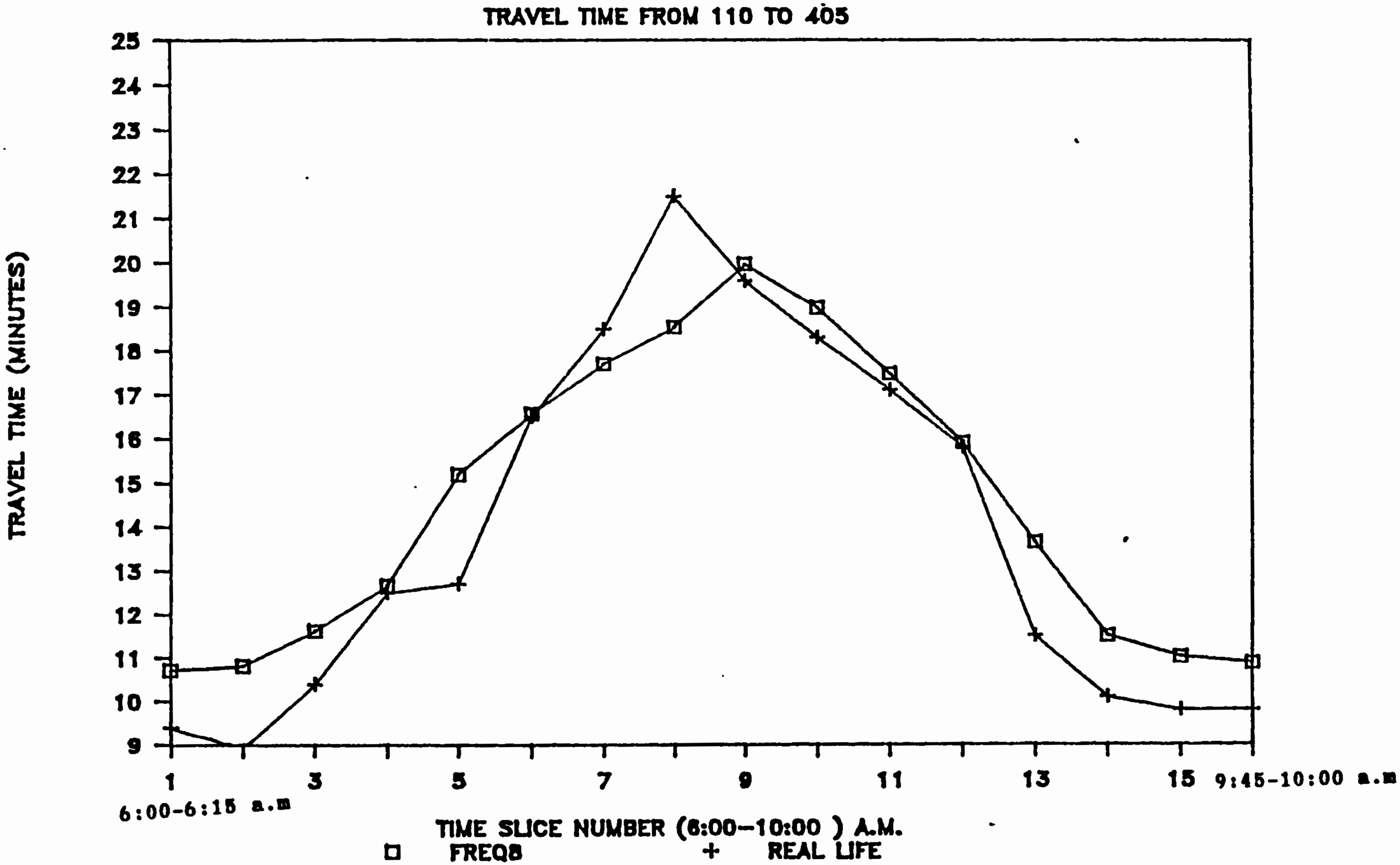


Exhibit 3
EB Santa Monica
Calibration of FREQ

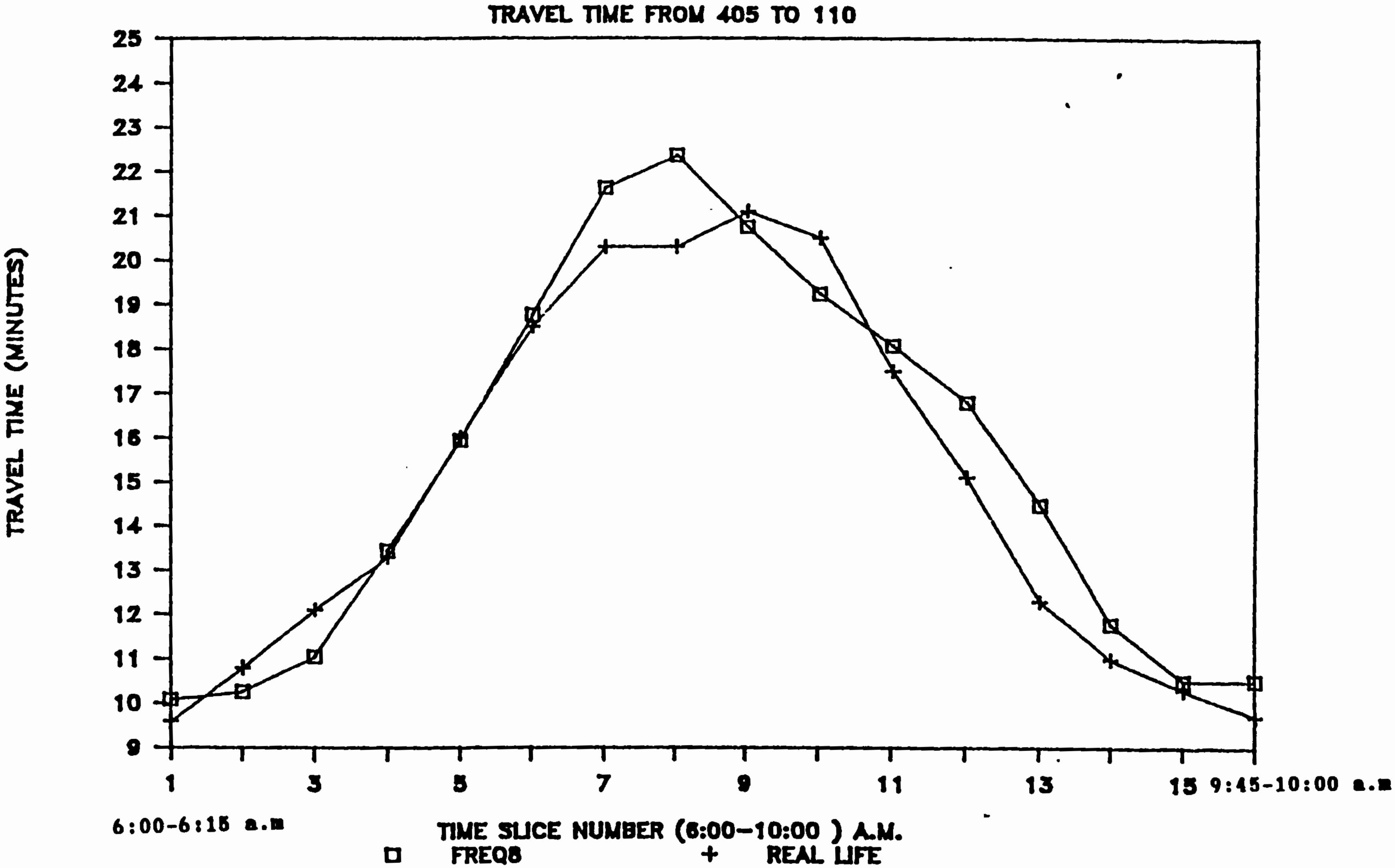


Exhibit 4
WB Santa Monica
Calibration of FREQ

Similar to FREQ, due to the limited amount of time available for the system element evaluation, the TRANSYT model used for the previously mentioned ITS study will be applied to the Smart Corridor project. The existing TRANSYT network is composed of 80 signalized intersections and 560 links. Exhibits 5 thru and 6 provide comparisons between the observed and simulated travel times for the three east-west arterials included in the existing model.

In addition to FREQ and TRANSYT which simulate traffic flow on the freeway and surface streets independently, the network model PATHNET will be used to link the two models. PATHNET was developed at ITS and is utilized to determine the shortest or least costly path through the corridor and tabulate the cost of user specified routes. Although PATHNET is not integrated with FREQ and TRANSYT to allow for dynamic analysis of the corridor, it is still a useful analytical tool.

Spreadsheet Analysis

In order to translate the microscopic evaluations of certain system components into corridor wide parameters, extrapolations will be made. To aid in this "number crunching" task, a computerized spreadsheet will be used. The spreadsheet will be limited to the major arterials within the corridor, where diversion is considered to be most probable.

Evaluation Matrix

In order to aid in the decision making process, a preliminary evaluation matrix has been developed. The matrix is presented in Exhibit 7 and contains a preliminary set of evaluation criteria. Additional components/criteria will be added as the evaluation process progresses.

Exhibit 5
Eastbound Thru Links Travel Times
Adams Boulevard

EB THRU LINK TRAVEL TIMES (sec/veh)
FOR INDIVIDUAL INTERSECTIONS

CUMULATIVE DISTANCE (mi)	ADJUSTED L.A. FIELD STUDY	TRANSYT SIMULATION INAL CALIBRATION	ARITHMETIC DIFFERENCE
1.1	153.1	150.6	-2.5
2.1	134.8	125.1	-9.7
3.1	140.9	129.5	-11.4
3.6	59.4	69.0	+9.6
4.1	91.4	76.0	-15.4
4.6	71.9	78.6	+6.7
5.0	59.3	61.5	+2.2
5.5	114.7	80.2	-34.5
	825.5	770.5	

Washington Boulevard

EB THRU LINK TRAVEL TIMES (sec/veh)
FOR INDIVIDUAL INTERSECTIONS

CUMULATIVE DISTANCE (mi)	ADJUSTED L.A. FIELD STUDY	TRANSYT SIMULATION INAL CALIBRATION	ARITHMETIC DIFFERENCE
0.1	33.6	29.8	-3.8
0.6	58.3	63.2	+4.9
1.4	105.3	111.1	+5.8
2.4	125.6	126.3	+0.7
3.1	110.2	119.1	+8.9
3.6	58.5	72.9	+14.4
4.1	78.3	73.9	-4.4
4.6	85.2	81.3	-3.9
5.1	62.2	58.5	-3.7
5.9	106.8	107.2	+0.4
	824.0	843.3	

Exhibit 6
Eastbound Thru Link Travel Times
Venice Boulevard

EB THRU LINK TRAVEL TIMES (sec/veh)
FOR INDIVIDUAL INTERSECTIONS

CUMULATIVE DISTANCE (mi)	ADJUSTED L.A. FIELD STUDY	TRANSYT SIMULATION FINAL CALIBRATION	ARITHMETIC DIFFERENCE
0.2	33.6	44.9	+11.3
0.9	97.2	100.8	+3.6
1.5	68.9	72.7	+3.8
2.0	110.1	90.2	-19.9
2.2	35.3	22.0	-13.3
2.9	124.4	103.0	-21.4
3.2	55.0	61.0	+6.0
3.5	51.6	46.1	-5.5
4.2	81.7	80.8	-0.9
5.0	82.9	89.4	+6.5
5.4	68.9	75.0	+6.1
6.0	113.0	91.0	-22.0
6.6	95.4	87.6	-7.8
7.1	136.8	69.2	-67.6
7.6	61.8	70.3	+8.5
8.1	98.9	79.6	-19.3
8.5	96.0	67.0	-29.0
9.5	143.3	134.2	-9.1
	1554.2	1384.8	ABS=261.6 TOT

Exhibit 7
Evaluation Matrix

Element Alternative	MOE	Operational Impacts Frwy	Ramps	Art.	Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
1. No Build (Existing Conditions)	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
2. Ramp Metering o Freeway Ramps Optimized	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
	Safety/Accidents							
Minimum Metering Rates	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
	Safety/Accidents							

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Exhibit 7 (cont)
Evaluation Matrix

Element Alternative	MOE	Operational Impacts			Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
		Frwy	Ramps	Art.				
Maximum Metering Rates	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Safety/Accidents							
Selected Ramp Closure	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Safety/Accidents							
o Connector Ramps Optimized	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
	Safety/Acccidents							
Minimum Metering Rates	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
	Safety/Accidents							

Exhibit 7 (cont)
Evaluation Matrix

Element Alternative	MOE	Operational Impacts Frwy	Ramps	Art.	Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
Maximum Metering Rates	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emission							
	Safety/Accidents							
3. CCTV on Surface Streets	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
4. Highway Advisory Radio	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emission							
5. Commercial Radio/ TV	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							

Exhibit 7 (cont)
Evaluation Matrix

Element Alternative	MOE	Operational Impacts Frwy	Ramps	Art.	Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
6. Dial-In Services	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
7. Changeable Message Signs on Surface Streets	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							
8. Changeable Message Signs in Garages or Buildings	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							

Exhibit 7 (cont)
Evaluation Matrix

Element Alternative	MOE	Operational Impacts Frwy	Ramps	Art.	Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
9. Cellular Telephone	Speed VMT VMTPH Delay # Stops							
10. In-Vehicle Navigation System	Speed VMT VMTPH Delay # Stops Fuel Consumption Vehicle Emissions							
11. Videotext	Speed VMT VMTPH Dealy # Stops Fuel Consumption Vehicle Emissions							

Exhibit 7 (cont)
Evaluation Matrix

Element Alternative	MOE	Operational Impacts Frwy	Ramps	Art.	Imp. Cost	User Cost	Adv./ Disadv.	Comment/ Recomm.
12. PC Computer Bulletin Boards	Speed							
	VMT							
	VMTPH							
	Delay							
	# Stops							
	Fuel Consumption							
	Vehicle Emissions							

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DISCUSSION PAPER
CENTRAL DATA BASE SYSTEM

Prepared by:

JHK & Associates

March 1, 1989
Project No. 7315

CENTRAL DATA BASE SYSTEM

Among the chief goals of the Smart Corridor Project (SC) are the facility to improve the level of inter-agency co-ordination and the ability to provide easy access to the traffic status within the test area. These goals require access to common data currently maintained by various agencies. Primary issues surrounding these common data are discussed in the following paragraphs.

MAINTAINED DATA

The data maintained by the system can be grouped into three broad classes -- static, dynamic, and historical. Static data are data that, in general, changes slowly over time. Static data are used to drive graphic displays, modeling software, detection algorithms, etc. Static data typically include the following:

Geo-based data items (links, nodes, capacities, etc.)
On-line policy manuals and agreed upon response plans
System parameters (detection thresholds, smoothing constants, etc.)

Dynamic data are collected in real time and provide the basis for incident detection and system evaluation. These data include:

Once per cycle volume and occupancy data from ATSAC
30 second volume and occupancy data from CALTRANS
Device status (controller, detector, etc.)
Meter rates
CAD incident reports (primarily CHP and LAPD)
Status reports from SCRTD
Actions taken on incidents
System log
Operator entries

Historical data are a collection and synthesis of real time data stored in a way to achieve a balance between usefulness and efficiency. Historical data should include:

15 minute detector data over time
System log
Incident reports

The above list of data categories is very general. A more complete version will depend upon the actual requirements of the various high-level Smart Corridor functions.

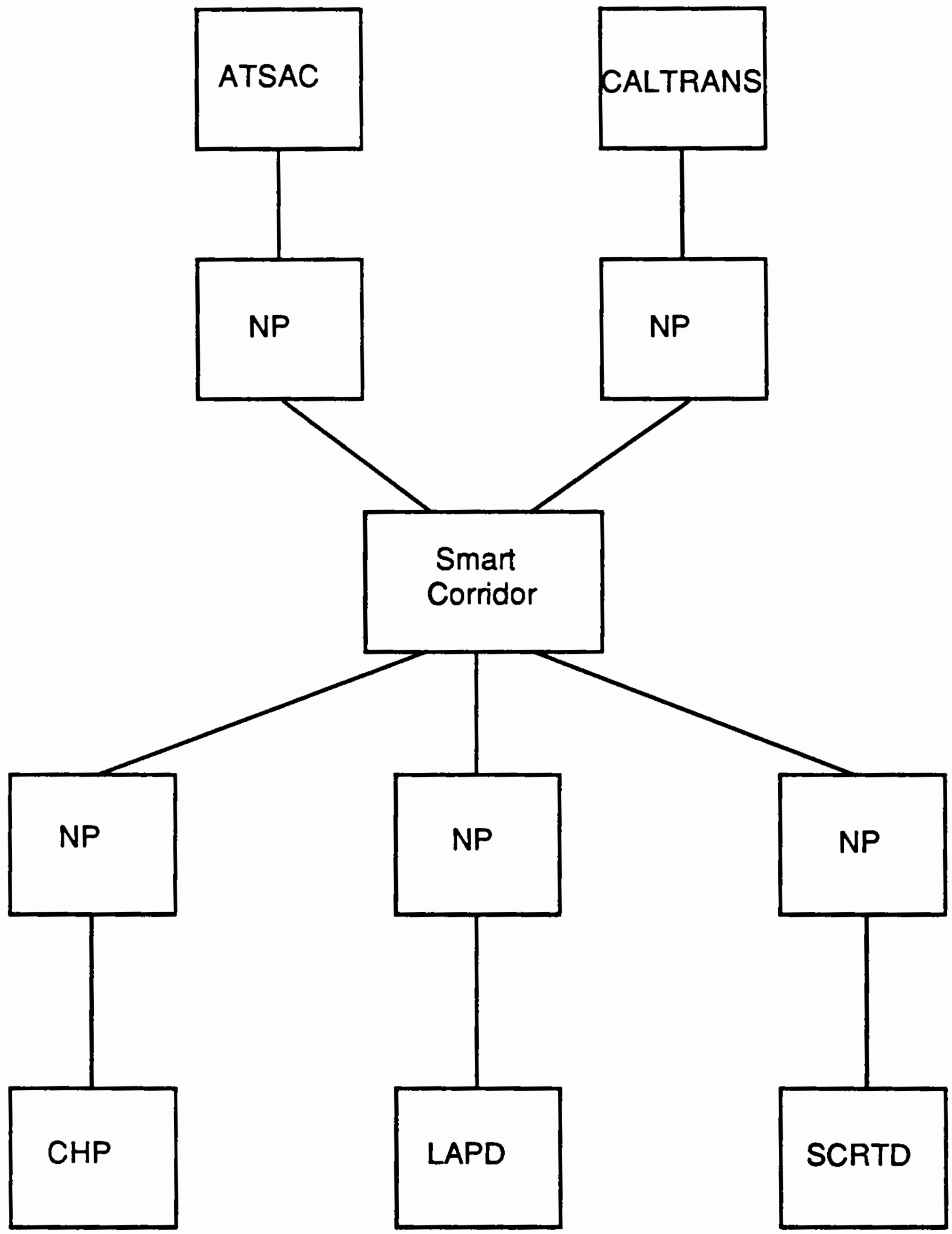
DATA COLLECTION

Data can be collected in several different ways. One approach would have data extraction and communication software written for each installation and integrated into existing software. However, this approach suffers from several problems. Data collection within the system will be made difficult by the wide range of software and hardware in use by the participating agencies -- site specific software would be required. This difficulty is compounded by the dynamic nature of the component systems -- several of the systems have been in place for some time and are either in the process of being replaced or may be replaced in the next few years. A related consideration is that the age of some of the older systems makes new software development very expensive. Finally, in many cases existing hardware is running at maximum capacity in regard to processing power or communications capabilities. There is very little CPU time and/or communications bandwith available to collect and transfer the required data.

A second approach is depicted in Figure 1. In this approach each agency is supplied with a local processing unit (node processor) to provide data extraction, communication and any additional processing required by the Smart Corridor System. This approach allows flexibility in terms of functionality but does not greatly burden existing processing. It also provides for minimal disruption of local processing during integration. The type and power of each local processor will be determined by the data extraction and user interface requirements of a given site. Site specific software is still required but the majority would reside on the node processor and code for the local system could be minimized.

CONTROL METHODS

The influence exerted by SC upon the participating agencies could occur at many different levels. The most invasive approach would be for SC software to actually take over the control functions of ATSAC, CALTRANS, etc. and issue commands, meter rates, etc. to local controllers. Such a duplication of effort would not be desirable or feasible.



NP - Node Processor

FIGURE 1 - HARDWARE

A completely opposite approach would have SC monitor the conditions of all arterials and freeways and inform agencies of congestion and allow them to take what ever action they deem necessary. Such an approach would not optimize traffic flow within the system.

An approach lying somewhere in between these two extreme is probably most acceptable. For any response to be effective it must be agreed upon by the participating agencies and these agencies must be reliable informed that the invoking condition has been observed. In this approach agencies agree upon standardized responses to numerous conditions. These responses are "built" using on-line modeling software, experience, legal considerations and common sense.

Once a response is established each agency is responsible for devising those operations required to accomplish the response. Agency specific responses would include:

CALTRANS	--	special meter rate values
ATSAC	--	special timing plans
CALTRANS	--	special messages signs
CHP/LAPD	--	special deployment of officers
LADOT	--	dispatch of arterial response teams
CALTRANS	--	dispatch of freeway response teams
CALTRANS/CHP	--	dispatch of freeway service team
LADOT	--	deployment of traffic control personnel

Such an approach could best be described as a central recognition and decision support interface. SC serves as central site for gathering information describing traffic flows within the system and the recognition of system wide problems. The central data base serves as a place to store condition/response plans that all participating agencies have agreed to execute under these conditions.

Once informed of an existing condition and the selected response, several methods of implementation are possible. The plan could be enacted automatically, the plan could be enacted automatically but the local operator would have the option to cancel or delay the plan or the agency could be required to take a specific action to enact the plan. A combination of the latter two approaches would probably be the most desirable. In any case, each agency is responsible for taking (or not taking) the agreed upon actions and informing central SC of its choice.

DATA FLOWS

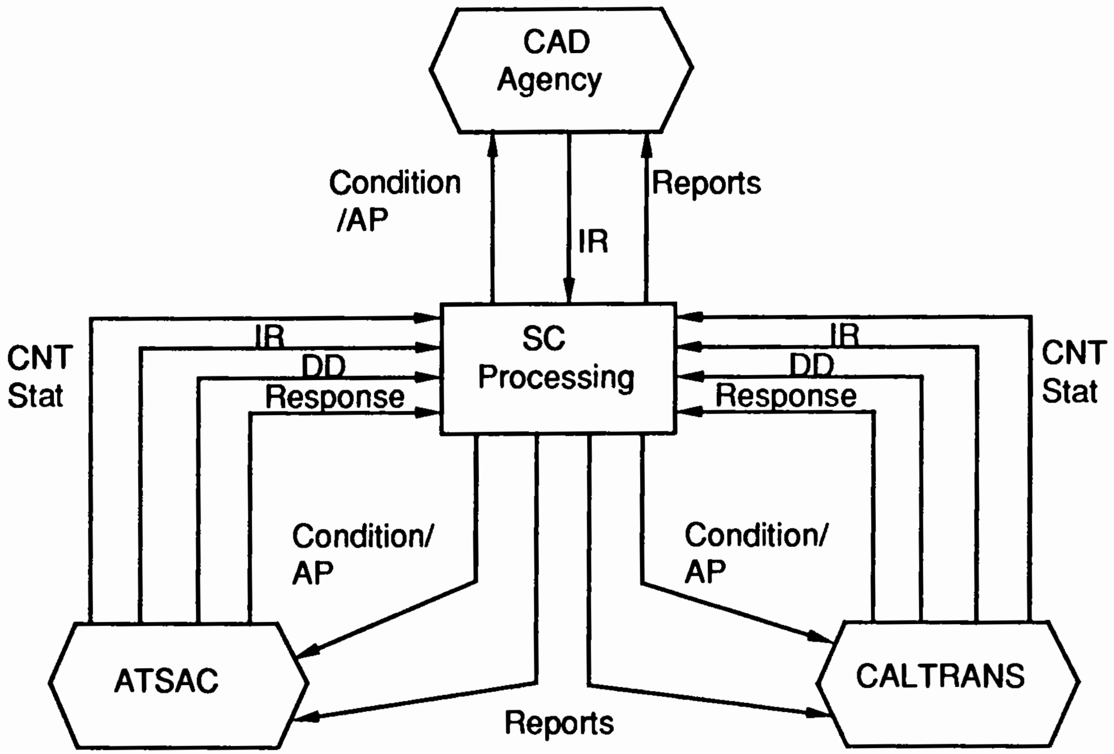
In order to accomplish the levels of desired congestion detection and response, data must be exchanges between the participating agencies.

The paragraphs below briefly describe the minimal flows that must be involved. Figures 2.a and 2.b provide a high level representation of data flows within the Smart Corridor system. Figure 2.a provides an overall view of data flow between SC and different agencies. From this diagram, controller status, detector data, and incident reports are provided to the Smart Corridor processing software by ATSAC and CALTRANS, CAD agencies and SCTRD provide incident reports. Smart Corridor processes provide reports and condition/action plans to each agency. Finally, each controlling agency must inform SC of its actions based on information supplied to it by SC.

Figure 2.b provides a slightly more detailed view of a potential central data base and support software. From this diagram a central data base provides data for the basic components of the Motorists Information system, (MI) potential on-line modeling, in-vehicle navigation and operator interface. (The flows from ATSAC, CALTRANS, etc. are not shown on this diagram.)

A composite data structure referred to as "System Status" is provided to the MI processing software. This information can then be presented to system users in numerous formats. In-vehicle navigation is treated as a separate function because of the potential for retrieving data from the navigation system. The operator interface provides data base access for maintenance, reporting and graphics display. Modeling software may also be provided to facilitate optimizations using 1.5GC, TRANSYT and FREQ. (Participating agencies would probably maintain there own operational modeling software on their own computers. However, future modeling software that would take both freeway and arterial traffic flows into consideration would best fit here.) Finally, software to analyze corridor incident detection is presented. This function is responsible for correlation and analysis of Incident Reports provided by all of the participating agencies and selection of an appropriate response plan.

It should be noted that incident detection processing can also be provided by both CALTRANS and ATSAC. The local mechanisms would provide improved detection processing for the agency as well as input to the SC process. (The function of this software should be classified as "expert system". It is presented here due to its intensive data requirements.)



ABBREVIATIONS

AP - Alternate Plan
CNT Stat - Controller Stat
DD - Detector Data
IR - Incident Report
MI - Motorist Information
SC - Smart Corridor

Note : MI Detail Presented in Figure - 2.B

SYMBOLS USED :

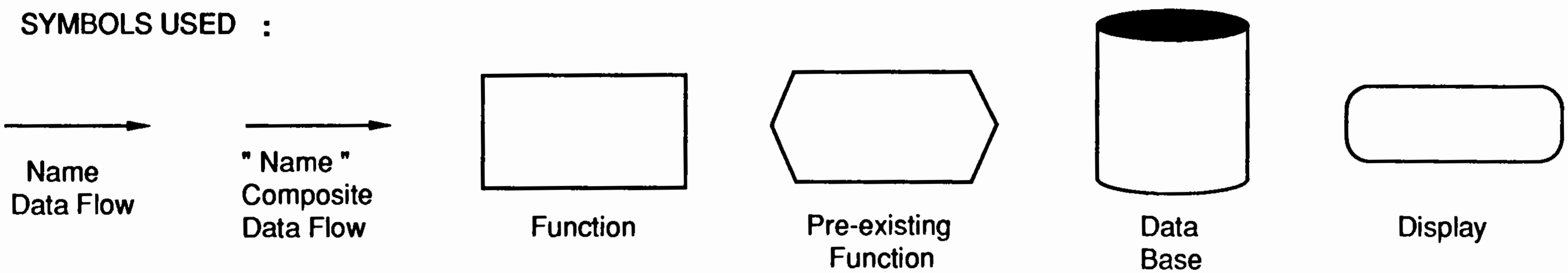


FIGURE 2.A - AGENCY INTERFACE

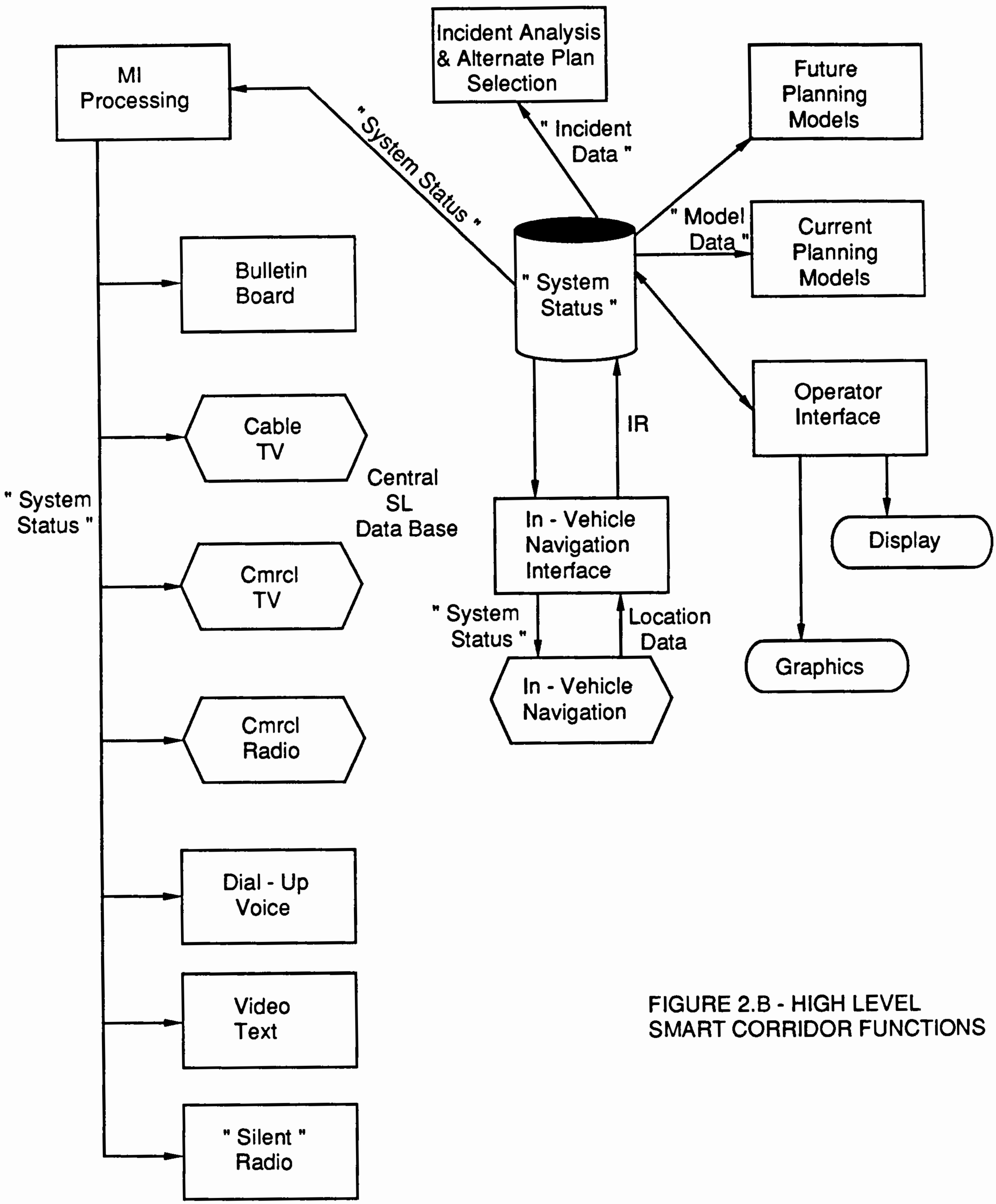


FIGURE 2.B - HIGH LEVEL SMART CORRIDOR FUNCTIONS

SMART CORRIDOR/AGENCY INTERFACE

Given the type of control described above, some form of SC agency interface will be required. The majority of the changes to local operations required for the interface should be provided by the node processor described above. The required interfaces can be broadly grouped into those related to agencies that do no real-time control of traffic systems and those that do.

Figure 3 presents a high-level description of an interface for a CAD agency. (The interface for SCRTD would be very similar.) In this diagram, the functions labeled as "Local Detection and Response" and "Interface Processing" would be responsible for extraction of Incident Reports from the dispatch system, deciding what to transfer to the Smart Corridor system and then providing the mechanism for data transfer. Once SC has established that a condition exists and selected the appropriate response, the local incident detection mechanism would also be responsible for informing the agency of the condition and its expected response. The agency would also be able to query the data base as to "System Status" through the report interface.

Figure 4 presents a description of the interface between ATSAC and central SC. (The CALTRANS/SC interface would be very similar.) This diagram is made more complicated by the different types of data that must be exchanged and the types of operations being performed by the local processing. From the figure, data are extracted from the local data base by an interface processor. Incidents are detected and reported to SC by local detection processing. The "Incident Analysis and Alternate Plan Selection" function residing on the central SC hardware is responsible for gathering data from all sources, continually "looking" for congestion and once a condition exists informing the agency of the selected response. The local detection function also has the responsibility of aiding the local control software in performing its operations. System reports are also available from the report interface.

Figure 4 also presents processing for Smart Corridor based methods that can be used to control traffic flows. In particular, advisory radio and enhanced changeable message signs would be provided. Placement of these functions at this level, rather than in actual the central SC processing, removes some of the complexity from the central software and is in keeping with current policies in which CALTRANS maintains messages signs and CCTV.

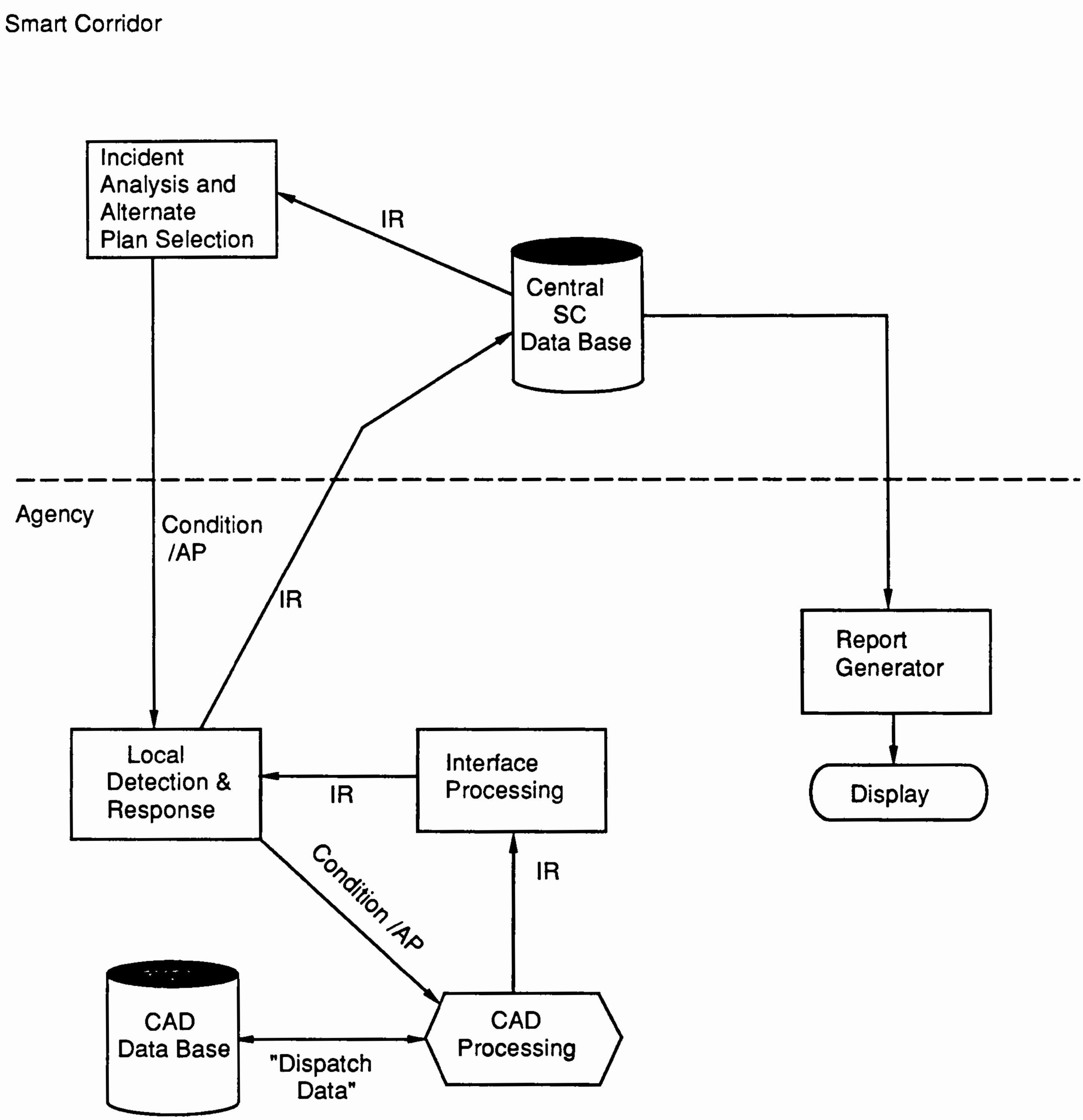


FIGURE 3 - CAD INTERFACE

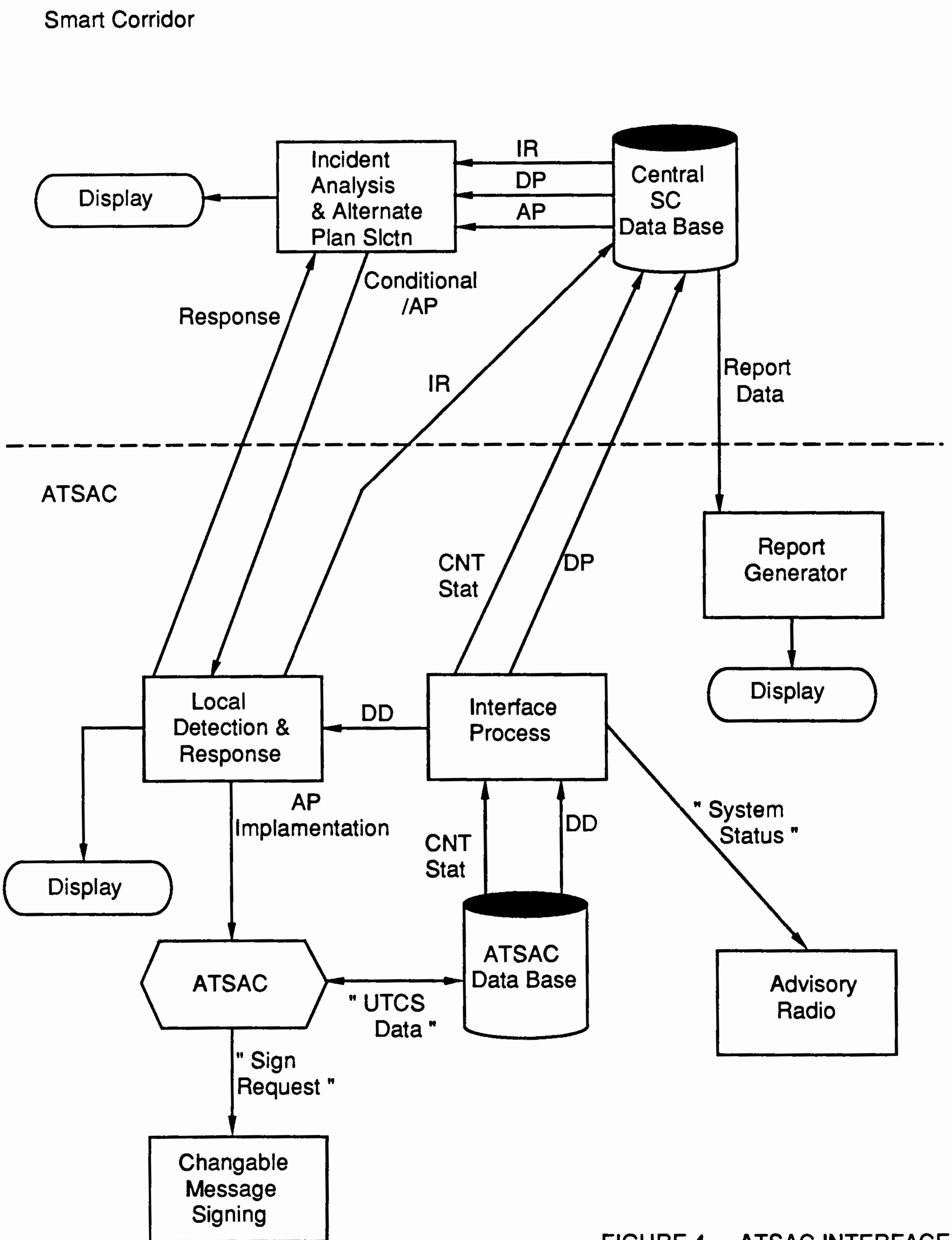


FIGURE 4 - ATSAC INTERFACE

SMART CORRIDOR DEMONSTRATION PROJECT:
CONCEPTUAL DESIGN STUDY

Expert System for Incident Detection and Response

Summary of Current Detection and Response Procedures and Potential Expert System Opportunities

Working Paper SGR-WP-89-1
February 27, 1989

Stephen G. Ritchie
714/856-4214

INTRODUCTION

The objective of this element of the Conceptual Design Study is to identify and evaluate opportunities for expert systems technology to provide decision support to the staffs of the Los Angeles Automated Traffic Surveillance and Control (ATSAC) Center, and the Caltrans District 7 Traffic Operations Center (TOC). This support is for detecting and responding to non-recurring congestion (incidents) on the surface street and freeway system in the Smart Corridor. A preliminary design document for such a system is also to be prepared.

Incidents are events that disrupt the orderly flow of traffic, and cause non-recurring congestion and motorist delay. Non-recurrent congestion can be caused by accidents, spilled loads, stalled vehicles, maintenance or construction activities, and special events.

Knowledge-Based expert systems (KBES) computer programs are a product of artificial intelligence (AI) research, and address ill-structured problems where numerical algorithmic solutions are not available, are impractical or are inadequate. Expert systems emulate human problem-solving that involves specialized knowledge, judgement and experience.

This working paper presents a brief summary of current surveillance procedures employed for detecting non-recurring congestion, current and proposed responses to verified incidents, and initial identification of potential expert system opportunities.

SUMMARY OF CURRENT PROCEDURES FOR INCIDENT DETECTION

ATSAC

Currently, incident detection in the ATSAC system is non-automated, and depends on operator presence, vigilance and experience.

The present system monitors approximately 400 system detectors. Every 1 or 3 minutes, these detectors provide occupancy and volume data. Some detectors also provide speed data. The Smart Corridor Project area encompasses over 400 signalized intersections, 89 of which are now under control of ATSAC. Over 1,000 detectors will likely be added to the ATSAC system due to the Smart Corridor Project alone. Inclusion of additional areas may add hundreds of intersections and several thousand detectors to ATSAC in the future.

In the present system, three levels of map or display are provided. The network-level shows about one third of the 400 system detectors ("critical" ones), a more detailed sub-network display is available, and the intersection-level shows all detectors assigned to each approach.

Incident detection is triggered by a detector occupancy exceeding a threshold, for example, 30%. When this happens, the network map shows a flashing red signal for that detector, to command the attention of the operator. The operator must then review the identified "problem," and attempt to verify an incident condition before determining a response. This review may entail several steps of extracting data and querying the system to more precisely identify the problem condition. Such problem conditions may also represent false alarms, where normal conditions temporarily exceed problem identification thresholds.

As a coarse model of the incident detection process used by experienced operators, ATSAC staff have derived the algorithm illustrated in Figure 1. Typical values of T_1, T_2, T_3 and T_4 are stated to be 30%, 300 vph, 15% and 20%, respectively. ATSAC staff acknowledge the simplicity of this algorithm and the need to include additional operator heuristics, localized characteristics and possibly historical data, in order to enhance the performance of an automated version of this incident detection process.

Incident verification by ATSAC operators is said to be rarely achieved, currently. Only one closed circuit TV camera is available for this purpose, although several more cameras are to be installed (still far too few for complete incident verification purposes). Additional verification sources include city employees in the field, Caltrans TOC, and commercial radio broadcasts.

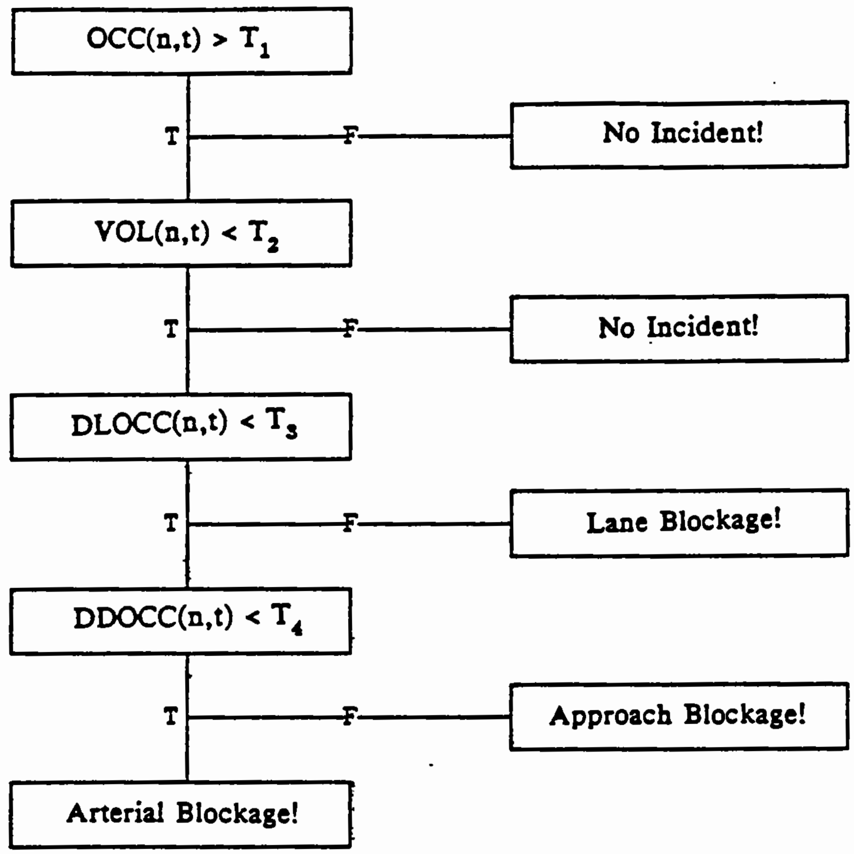
Caltrans TOC

Significant involvement of Caltrans District 7 in freeway surveillance and control, including incident detection, dates back at least to the "42-mile loop" project (involving the Santa Monica, Harbor and San Diego freeways), conducted between 1971-74. In 1974-76, FHWA sponsored a major research project entitled, "Development and Testing of Incident Detection Algorithms." This project developed new algorithms, based in part on extensive data from the Los Angeles freeway system (Payne et al., 1976). Subsequently, a subset of these algorithms was implemented in the Semi-Automated Traffic Management System (SATMS) in Los Angeles. A current project now aims to calibrate these selected algorithms to obtain operational useful performance. The calibration focuses on determining appropriate zone-specific occupancy threshold levels (Arceneaux et al., 1989).

SATMS includes approximately 700 directional freeway miles, 934 instrumented locations or stations (typically involving a full set of loops across the pavement, plus those at on/off ramps), and about 5,000 detectors providing 30 second occupancy data. Functionally, SATMS supports real-time ramp control and incident detection.

Unusual flow conditions or incidents identified by the algorithms are indicated by a flashing red light at the station location on a wall map at the TOC. Operators can then call up on their terminal displays real-time traffic flow information (volume, speed and occupancy) to assist in analyzing the condition. Computerized CHP information about on-going incidents can also be accessed.

For verification purposes, operators can access a limited number of closed circuit TV cameras, as well as seek input from field personnel or the CHP.



OCC(n,t)	:	Occupancy at location n, for time interval t (%)
VOL(n,t)	:	Volume at location n, for time interval t (veh/hr)
LOCC(n,t)	:	Occupancy of detector adjacent to location n, for time interval t (%)
DOCC(n,t)	:	Occupancy of detector downstream of location n, for time interval t (%)
DLOCC(n,t)	:	Lateral detector occupancy difference : OCC(n,t) - LOCC(n,t)
DDOCC(n,t)	:	Downstream detector occupancy difference : OCC(n,t) - DOCC(n,t)

Source: Han and May (1988).

Figure 1 Model of ATSAC operator incident detection process

INCIDENT RESPONSE

ATSAC

If an incident on the surface street system is verified, the ATSAC operator can respond by interactively modifying traffic signal timing, to override regular signal cycles and expedite traffic flow through, or around, congested areas and intersections. In addition, Traffic Control Officers can be dispatched to assist in clearing intersections, and traffic signal maintenance crews can be dispatched to restore traffic signal equipment to normal operating status, if necessary. However, ATSAC staff indicate that if an incident cannot be verified, but an experienced operator believes that an incident condition exists, signal timing is sometimes modified in an attempt to improve traffic conditions.

Caltrans TOC

For major incidents (involving 2 or more freeway lanes closed for 2 hours or more), the operator can roll the Major Incident Traffic Management Team (MITMT), which is on call day or night. Team members meet at the incident site with maintenance personnel, the CHP and representatives of other involved agencies, to establish a unified command post and to develop a co-ordinated incident management plan. In such cases, accident management and control rests with the CHP, while traffic control around the incident rests with Caltrans. Pre-determined alternate routes and traffic control plans can be implemented. Ground-mounted changeable message signs (CMS), centrally controlled through the TOC, are used to replace mobile truck-mounted CMS placed earlier for end of queue protection. CMS on approaching freeways in the vicinity of the incident can be activated. The TOC also provides traffic information to several commercial radio stations.

For less severe incidents that don't require the MITMT, responses can include activating CMS (ground-based or mobile), implementing or modifying ramp metering, and dispatching tow trucks.

Proposed Additional Smart Corridor Responses

In addition, the following possible response options have been identified for the Smart Corridor, and may have to be co-ordinated in any decision support system for incident response:

- co-ordination of ramp meters and traffic signal timing
- changeable message signs on surface streets, approaches to freeway access ramps, and in parking garages
- implementation of traffic detours
- dispatch of tow trucks
- highway advisory radio
- telephone call-in messages
- cable TV messages
- commercial radio/TV traffic reports
- in-vehicle navigation system messages
- traffic condition reports and information displays in major buildings, fleet dispatch centers and computer bulletin boards

INITIAL IDENTIFICATION OF POTENTIAL EXPERT SYSTEM OPPORTUNITIES

With respect to non-recurring congestion, Dunnett et al. (1985) state:

> "...the most important element in reducing delays associated with incidents is the time factor - time for deteciton, time to identify the specific type of response required, response time, time required to take corrective action to restore roadway capacity, and time needed for dissipation of queues and restoration of flows."

Opportunities for expert systems to provide decision support to ATSAC System and TOC operators and to reduce the times noted above, are likely to be particularly effective.

Clearly, as the breadth and scope of the ATSAC system is vastly expanded to the Smart Corridor concept for both freeway and surface street systems, it becomes increasingly difficult if not overwhelming for a human operator to detect and review "problem" locations, verify incidents, and develop and implement appropriate response strategies. Expert systems can provide an automated approach to reduce the operator involvement needed to identify true problem locations, determine applicable and consistent courses of action, and even implement a response plan, thereby reducing traffic delays associated with incidents.

Although incident detection on surface streets is regarded as much more difficult than for freeways, the need for automation of this function in ATSAC is apparent. The integration of algorithmic and knowledge-based heuristic methods in a real-time expert system environment is likely to be necessary. Initial investigation of some of these issues has been undertaken by Han and May (1988). However, if the expert system is to receive detector outputs directly, an ability to monitor and process thousands of variables in real-time is required, prescribing special needs for hardware and more particularly software. Alternatively, an off-line system could focus on only those locations identified by the main computer as potential incidents. In either case, the unique characteristics of each area or detector location may need to be incorporated, stratified perhaps by time of day and surrounding network conditions.

An opportunity exists for expert system guidance on verification procedures for each suspected incident, particularly if additional closed circuit TV cameras are installed within the ATSAC system. It would then be beneficial for the operator to be directed to the most appropriate camera(s) for verification purposes. An ability to automatically integrate field-calls about incident conditions would be useful.

Opportunities also exist for automating the generation of guidance for alternative response strategies and then selection of one strategy. Even if some elements of this are not particularly "expert," automation can save time and reduce subsequent traffic delays. Selection amongst pre-determined timing plans, minor changes to existing signal timing, and even generation of new timing plans could be required here, in addition to selection and integration of the additional Smart Corridor responses alluded to earlier.

In the case of Caltrans' TOC, expert system opportunities also appear to exist for incident detection, verification and response. However, if ongoing efforts for detection algorithm calibration are successful, resulting in acceptable false alarm rates and detection times, it would be appropriate to concentrate on verification and response opportunities.

An off-line expert system, linked to the TOC computer but running on a separate hardware platform, could advise the operator of the incident location, which cameras to use for verification, unique characteristics of the detector station or area including relevant historical data, as well as additional verification sources. Current Caltrans incident response procedures need to be reviewed in greater depth, but it is apparent that, as for the case of surface streets, development of appropriate response strategies can be quite complex and involve considerable judgement, as well as procedural familiarity. The situation is made even more complex by the possible need to incorporate the additional Smart Corridor Responses identified earlier. This is clearly a situation where expert decision support to effect timely response could be most useful.

Finally, and quite fundamentally, there are expert system opportunities for developing corridor response strategies that would involve the combination of ATSAC and TOC responses to form optimal, integrated corridor-wide responses. Such corridor responses generated by an expert system could possibly allow for blocking or veto by either ATSAC or the TOC, without which implementation would take place. Additional expert system opportunities exist for assisting operators in monitoring and evaluating the effect of such corridor strategies.

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MISCELLANEOUS ISSUE PAPERS

Prepared by

JHK & Associates

SMART CORRIDOR WORKSHOP

March 7-8, 1989

TRAFFIC OPERATIONS PLAN

The emphasis of the Smart Corridor project to date has been on the development of issues and candidate hardware and software components for the system. The purpose of this brief paper is to carry forward the very critical element of the project related to actually making the Smart Corridor work -- the operations plans which will be used when the "system" is in place.

During the period that the system is being implemented, it will be necessary to develop all of the operational plans that will be used by the various system components during the initial period of operation. It is recognized that the Smart Corridor project will "mature" over time as experience is gained, however the initial operation will go a long way toward determining the success of the system. If traffic is diverted from the freeway and the traffic signals are not timed specifically for the planned diversion, delays will be substantial and credibility will be lost instantly. If the system alters metering rates and motorists are not given the information needed to properly plan their routes and diversion is not caused, excessive queues will result and congestion will occur on the City streets, resulting in instant problems with the political entities.

On the other hand, if plans are well developed, the public is well informed and educated, and system start-up is well sequenced, initial successes can be achieved. If there are sufficient intial successes, public and political acceptance of minor failures can be expected since initial credibility will have been established. A directly parallel experience is the results of the planning for the 1984 Summer Olympics. Advance planning covered major contingencies, the public was kept informed, and success built from success.

To develop the operational plan, all of the Smart Corridor agencies will have to be involved and coordination will have to be maintained as the several components of the project are administered by the various implementing agencies. Typical of the elements that must be included in the operational plan are:

1. Public Information and Education. The project is to include a public information and education program. This work needs to be seen as a part of the larger operational plan for bringing the systme into operation. It needs to

consider not only an explanation of the elements of the system but also create the proper public expectations as to what the results of the system will be and how they will be seen in the field.

2. Signal Timing. Specific timing for the signals in the corridor, including sections of the Coliseum and CBD systems, will have to be developed for each of the scenarios to be implemented. Given the large number of traffic signals impacted by the project, the work in this task is significant and results in a large ATSAC database effort.

3. Ramp Metering Rates. As with traffic signals, plans will have to be developed for setting the meter rates at each ramp under each of the expected scenarios. This is also a significant effort and will impact the operation of the existing system because of the extensive database work and the loading of the system.

4. Ramp Meter/Traffic Signal Interties. A special subset of plans for the signals and ramp meters and sets of rules for their implementation will have to be developed and agreed to for the coordinated operation of these system elements.

5. Sign Messages. Detailed planning will be required to develoop the complete library of sign messages for the Caltrans and surface street CMS components. The project is breakiing ground in the use of sign messages to cause limited diversion and significant thought must be given to the large number of potential messages. Some work in this area has been undertaken by Conrad Dudek Associates for LACTC, however the work will not result in the specific database but rather establish guidelines for developing the actual messages. The LACTC work clearly indicates the level of effort that will be required to develop final messages and the importance of the message to achieving the specific objective.

6. HAR Messages. Parallel to the above is the development of messages for any HAR system which may be included in the project. The project is again breaking ground in new areas of application. Further, it is possible that several zones of the system may be developed, each required messages tailored to the application. Decisions on levels of automation, voice synthezation, voice library, etc. need to be made and included in the Smart Corridor database.

7. Other Motorist Information Messages. The project is expected to include several other forms of motorist information and direct interties to commercial broadcast facilities. The messages provided over these systems must be directed at the specific audience of the media, be

accurate, and timely, if these innovative elements are to succeed. Although some experience exists in each of the areas, significant work is required to develop the final message form and content.

8. Incident Management/Motorist Services Plans. Caltrans has developed plans for major incidents which might occur in the corridor. It is likely that incident management will be expanded in the corridor area and that refined plans will be required. Further, it is expected that LADOT will also implement some form of incident management in the corridor. These plans will require significant traffic engineering work if they are to be effective. They will also require significant coordination between impacted agencies and plan agreement must be reached. As well, specific operations plans for any recommended motorist servies will have to be developed. If the services follow the form of the current test, documents defining requirements will be needed so that the services can be procured.

9. Enforcement Plans. Specific plans for the use of enforcement personnel will also have to be developed. In some cases, these plans are integral to the incident plans referenced above. In other cases, they will relate to specific operations plans and diversions included within the general goals of the project. For example, plans for increased parking enforcement may be required where regular diversion to a street with peak hour restrictions is planned. Further, assignment of traffic control officers to critical intersections on diversion routes may have to be scheduled even thought the specific plan has not been implemented-- they may be assigned "in case". This again requires coordinated planning. Special enforcement may also be required for elements such as changed ramp metering strategies. If slower rates are used, it may be necessary to increase enforcement to maintain an acceptable violation rate.

10. Decision Matrix/Expert Systems. It is likely that expert system elements will be added to ATSAC, the Caltrans TOC and to the central database system. The development of these features involves not only the "system" but the "rules" governing the system. The rules will have to reflect direct traffic operations and engineering experience and will have to be developed and tested prior to system implementation. Agreement on the rules and on any central decision support matrix will be a major element in increasing the efficiency in implementing "corridor decisions" by the major control systems, especially the Caltrans TOC and ATSAC. A significant level of efficiency and automation may be achieved through these systems if confidence and agreement is achieved. The development of the rules, decision matrix, and support elements of the

Smart Corridor project will require significant operational planning.

SUMMARY

The above discussion is presented as representative of the operational planning activities which must be undertaken as part of the Smart Corridor implementation effort. The activities require significant work and coordination between agencies. A parallel to the efforts related to the Olympics is appropriate.

COORDINATION OF CONTROL CENTER IMPROVEMENTS

In order to successfully manage the traffic demands in the Smart Corridor, there is a specific need to coordinate the activities and operations of the Caltrans TOC and ATSAC. There are plans by both Caltrans and LADOT for modifications, expansions, and improvements to both control centers. All of these plans must be incorporated into the design for the coordination of the two centers in order to operate the Smart Corridor.

Operational Improvements at ATSAC:

Changes currently underway for ATSAC include the instrumentation of the Harbor and Ventura corridors. There are also plans to expand the operations of the center to other areas as well as to integrate the intersections in the Smart Corridor.

The communications requirements for the planned addition of 315 signals in the corridor and other signals in adjacent geographic areas have been mapped out. Consideration still needs to be given to the communications requirements for surface street changeable message signs, CCTV, HAR, etc. which may be incorporated into the overall system design.

It should be recognized that ATSAC is not to be considered a stand alone system. It is an integral part of the Smart Corridor and will in the future incorporate such new technologies and enhancements as expert systems.

In order to provide continuous control over signals throughout the corridor, it will be important to have the signals within the corridor boundaries in Beverly Hills and in Culver City operate in conjunction with the rest of the corridor. This may be accomplished by bringing the signals in question under the control of ATSAC. There is also the possibility of ATSAC controlling all of the signals in both jurisdictions. This could be accomplished while the cities to retain operational control of the signals.

ATSAC at present needs to redefine how incidents are handled and how decisions are made regarding interfacing with Caltrans, the CHP, etc. A part of this decision making process should include consideration of incident verification techniques and how the City will respond to incidents.

Operational Improvements at the Caltrans TOC:

Caltrans plans to go through a complete upgrade of the TOC, field hardware, and software within the next three to four years. The existing computer system is operating at capacity, and in order to add additional features or to interface with the system, some significant modifications will be required.

Caltrans is also faced with losing their microwave licenses which are currently used for CCTV coverage. They also have plans to provide interties between the District offices in southern California. Caltrans is therefore undertaking a major comprehensive communications study which is intended to define their long term communications needs and develop a design and plan to accommodate these needs including providing links between Districts 7, 8, 11, and 12. A review of intertie requirements for the Smart Corridor, Pathfinder, and the Anaheim and Pasadena signal systems is also underway. It is expected that this effort will result in an interim solution to feed the Smart Corridor project while the new system is implemented. In order to avoid an overlap in design activities, the Smart Corridor effort will need to coordinate with these communications plans.

CCTV

Closed-circuit television is currently in use in the corridor by Caltrans to provide visual inspection of suspected incident sites. There are 12 cameras located on the Santa Monica freeway between Santa Monica and downtown. The video picture is transmitted to the Caltrans TOC where it can be viewed on video monitors. The controls for the CCTV cameras (pan, tilt and zoom) are located at the TOC. The video from any one of the cameras is also transmitted from the TOC to the CHP Communications Center located on Vermont Avenue at the Hollywood freeway.

The communications media used for the CCTV video signal is primarily microwave from the cameras to the TOC. The signal from the TOC to the CHP office is also via microwave.

LADOT is also currently using CCTV to monitor traffic in the Civic Center area of downtown. The camera is located atop the City Hall South building. It is interconnected to ATSAC via direct coaxial cable.

CCTV is typically used on freeways in response to non-recurring congestion detected by the surveillance system to verify that an incident has occurred. It is also used to determine what type of services or incident management team should be dispatched to remove the incident as soon as possible.

LADOT would like to expand its use of CCTV on surface streets for incident verification. The ATSAC system notifies the operator of the presence of congestion (possible incidents) by indicating that the affected detectors are experiencing occupancy above a specified threshold. Currently, the only way to verify the incidents is through notification by another agency or by the Department's traffic patrol. CCTV coverage of the surface streets controlled by the ATSAC system would provide the ability to identify incidents and take appropriate action. For instance, CCTV on surface streets would provide the traffic engineer/system operator with a live picture of areas where excessive congestion is being reported by the control system. The engineer/operator would be able to evaluate the situation visually and to modify the signal timing or take other action as needed. The CCTV would therefore be performing a function similar to the incident verification role it serves on freeways in that it provides confirmation of trouble spots and furnishes information to the engineer/operator enabling that person to take appropriate action.

CCTV is also currently being used at ATSAC to fine-tune signal operation in a limited section in the Civic Center area. This use of the CCTV has proved valuable because it enables the traffic engineer to observe in real time the effect of changes made to signal timing and to adjust the timing to obtain optimum flow and operation of a signal or set of signals.

It is LADOT's current policy to include CCTV in the plans for all system expansions. It is not foreseen however that CCTV would be used to provide complete coverage due to the high cost of implementation, especially the communications. Plans are to only install cameras at critical locations. In the corridor, it would also be desirable to look at ramp locations where diversion might occur.

The same cameras that are used for CCTV coverage may also be applicable, in the future, for CIC applications using image processing techniques. Data which could be provided through this application would include traffic volumes, turning movement counts, and occupancy.

CCTV is also used in Canada to verify the availability of excess capacity before route diversion is implemented. Sharing of camera images by Caltrans, ATSAC, and the CHP should also be considered as part of design evaluations.

For initial estimating purposes, approximately 75 CCTV camera locations may be needed to provide to coverage of the arterial streets in the Smart Corridor area at a cost of approximately $2 Million. This does not include communications implications.

CHANGEABLE MESSAGE SIGNS

It is anticipated that changeable message signs (CMS) will be used extensively on both the freeways and on surface streets as a motorist information source in the Smart Corridor. Caltrans currently has 12 CMS installed (6 on the Santa Monica and 2 on the San Diego Freeways), and they have plans for the installation of two more. There are plans to relocate some of their existing signs on the Santa Monica. There are no CMS presently installed on surface streets. Their use on surface streets would be to capture motorists before they enter the freeway to inform them of the status of the freeway, and possibly suggest alternate routes.

There are concerns that CMS are an expensive method of communicating with the motorist, and that their viability is shortlived since there are other technologies on the horizon (e.g., in-vehicle route guidance).

The cost of CMSs can be kept down by selecting character matrix signs instead of the more expensive full matrix types. Small surface street CMSs could be used in conjunction with existing route signs to indicate the condition of various roadways or to identify the alternate route.

The clarify and length of the messages to be displayed by the CMSs are a concern. Their length is necessarily limited to the size of the sign, and the size of the sign is proportional to its cost. The products of the CMS message study being conducted by C. Dudek are being reviewed for defining the messages that will be displayed in the Smart Corridor.

Another potential application of CMSs is in large garages or in buildings leading to garages in the downtown area where they can be viewed by motorists exiting the area. The signs would be installed in garages which accommodate for example, over 500 vehicles. As a part of the Smart Corridor, it is proposed that this application of CMSs be tested.

One of the issues involved in using communication devices in garages or building lobbies is "who pays for it?" Other issues include the provision of access to the signs for maintenance and whether there should be a requirement for new development to include provision for such devices.

HIGHWAY ADVISORY RADIO

Highway Advisory Radio (HAR) has application to situations where the message to be conveyed to the motorist is too complex to be accommodated on a CMS or other written visual means such as Silent Radio. HAR can broadcast prerecorded messages of varying lengths, and the equipment is relatively inexpensive. There are two frequencies which the FCC has allocated to public service transmissions: 530 and 1630 KHz. The latter of these two frequencies will cease to be available for this type of application in the near future. HAR transmission can be via leaky coax or over normal air waves at low power.

Typically, HAR transmitters broadcast at 10 watts of power and have an area of coverage of approximately 3 miles. The current system in use at the Los Angeles International Airport transmits on 530 A.M. at the full power allowed. It can often be received in the corridor and may interfere with a Smart Corridor system. Three transmitters are also being installed in the Pasadena area which may interfere with the corridor (they are not currently operational).

Lower wattage transmitters do not need to be licensed by the FCC and transmission can be made at any unused frequency. Transmitters are available at 0.1 watt output which have a range of approximately 2000 feet. Use of this low wattage transmission will permit transmitters at various locations throughout the corridor to broadcast different messages on different frequencies. The motorist, via CMSs located at strategic sites, could be directed to tune to a specific frequency to listen to surface street information, and a different frequency to listen to freeway conditions. This may offer greater potential for the overall corridor by allowing several frequencies to be used. A review of available A.M. space is currently underway.

New technology in HAR equipment will also permit the synchronization of broadcasts from two or more transmitters. This feature will allow the entire corridor to receive the same message from different transmitters, and the messages will not be distorted from lack of synchronization.

COMPUTER BULLETIN BOARDS
and
TELEPHONE DIAL-IN

Two of the technologies available for potential use in the Smart Corridor are computer bulletin boards and telephone dial-ins which can be accessed by motorists from their homes or offices to pre-plan their trips. Information available from each source would be obtained from the common data base.

Caltrans presently operates a dial-in service called CHIN, California Highway Information Network, which provides information on freeway conditions. It operates by having the caller identify the roadway on which he wants information by entering the route number on a touch tone phone. Pre-recorder messages are then announced to the caller. Caltrans will be devoting more resources to this project in the near future to upgrade the service and ensure that the information provided to the motorist is accurate and current.

The recorded messages available to the dial-in service associated with Smart Corridor could also be automatically sent to the media, both radio and TV. The CHP will soon be implementing a media interface which will include a telephone dial-in as a part of their new system upgrade. A dial-in service associated with the Smart Corridor should be coordinated with both the Caltrans and CHP services.

VIDEO-TEXT

Video-text technology uses a portion of a TV channel's bandwidth to transmit information and display it at the bottom of the television screen. The information can be transmitted in conjunction with commercial TV channels or cable TV.

Caltrans is involved in a project which will test this technology in the near future. The broadcast information will be available to anyone with a TV equipped to receive and display it. There are a number of commercially available televisions which now incorporate this feature (e.g., Zenith now produces a TV equipped with this option). The Caltrans test may prove this technology to be applicable to the Smart Corridor; however, the test is not being conducted specifically for application in the corridor.

The advantage from the user's point of view is that the information is received for free if one has the appropriate equipment. The sender of the information pays the price of the transmission.

The Smart Corridor project is investigating the information which can be transmitted and will consider this need as part of development of the common database.

RAMP METERING

Any ramps on I-10, the 110, and the 405 in the corridor which are not currently metered can be viewed as "opportunities" for enhancement to the operations of the freeways. Most metered ramps now operate in an isolated mode although a "regional" overlay is now possible with the system. Incident detection is also being reinstituted in the corridor and detectors are being refurbished where required. Further enhancement to freeway operations could possibly be provided by this system wide operation of the ramps and the expansion of the hours of operation to off-peak as well as during the peaks.

One of the primary issues regarding the operation of ramp metering is the development of back-ups on surface streets. Mitigating measures might include geometric changes to the ramps and approaches on the surface streets to the ramps to accommodate more vehicles and enhanced selective enforcement of metering violators. Consideration might be given to developing a more sophisticated strategy for metering which would balance the back up at ramps between many ramps. This strategy should include consideration of the affected surface streets and is expected to include coordinating the operation of the signals with the ramps. Also, there is the possibility of closing ramps where entering traffic has a severe weaving maneuver which causes problems on the main line.

A policy issue regarding ramp metering concerns whether there should be a policy to keep the freeway free flowing at the expense of the ramps and the surface streets. One method of keeping the freeway flowing is to reduce the metering rate at ramps. This strategy would cause more traffic to divert by increasing the motorists wait at ramps and could potentially create larger back ups at the ramps which could spill back onto the surface streets. If this policy is promulgated, mitigations as discussed above must be implemented and the motorist information systems must be used to divert traffic away from congested ramps.

FREEWAY CONNECTOR METERING

There are two interchanges in the Smart Corridor with freeway connectors which present the opportunity for connector metering: the northbound and southbound approaches on I-405 to I-10; and the northbound and southbound to I-10 from the Harbor Freeway.

The issues involved in the metering of connectors include the desire not to degrade the operation of the 405 and 110 mainlines. Increased delay on these two roadways is not an acceptable trade-off for improvements to the I-10 freeway.

There are also potential safety problems associated with connector metering due to the development of queues of traffic at the meters. It would be necessary to ensure that sufficient storage capacity exists on the connector to accommodate the expected queues.

At the same time, if connectors are not metered, there is the question of whether ramp metering alone will be sufficient to divert enough traffic to achieve free flowing traffic on the freeways. This aspect of the problem will be investigated by JHK by running the FREQ program to simulate freeway operations with and without connector metering.

Another issue of connector metering is the sense that some motorists will be metered twice if this strategy is implemented. This second metering however may have exactly the desired effect of inducing motorists to divert to alternate routes to avoid the metered connectors.

The issue will be investigated at two levels. First, is it possible to do so without impacting the crossing freeways -- simply can resulting queues be accommodated on existing or improved connectors and is it safe to do so? Secondly, if it is possible, what are the impacts on the freeway and other ramp meter locations verses delay to those on the connector.

ROUTE DIVERSION

The assumed policy toward route diversion is that, if there is spare capacity in the corridor, it may be used to divert motorists from more congested routes. The emphasis is on diverting freeway traffic to surface streets since it is usually the freeway that is overloaded and the surface streets have the excess capacity, except during non-peak periods with a major surface street incident.

Additional capacity on surface streets may be achieved in some areas of the corridor where parking restrictions may not already be in effect. It is LADOT's current policy to remove parking where flow could be improved and this has been done throughout much of the corridor. Other locations will be identified during the conduct of the project.

Route diversion caused by ramp metering, CMS, etc., raises issues regarding the "balancing" of the network. The goal is to balance the network by achieving approximate equal travel times on all routes. There is the possibility however of 'over-diverting' thereby overloading the surface streets. Therefore, there is not only the problem of not diverting enough traffic to achieve balance, but also of diverting too much traffic.

Another issue develops if motorist information sources direct motorists to divert, and drivers find that the alternate route is congested. The issue of reliability of information and credibility by the motorists is created.

A technical issue of diversion pertains to the timing of signals on the surface streets to which traffic is being directed. It will be necessary to ensure that the timing on the signals is designed to accommodate the traffic demands which are expected to be diverted.

In order to evaluate the effectiveness of the route diversion techniques, the central database will be reviewed to determine available alternatives. This will be the needed feedback loop which will provide information to the operators and decision support systems so they can determine whether further diversion is desired.

IN-VEHICLE NAVIGATION

The FHWA project for the evaluation of Pathfinder is currently underway. The equipment being tested is the ETAK Navigator, and the testing will be conducted in the Santa Monica Corridor. For the project, 25 ETAK equipped vehicles are being furnished by GM in order to conduct an evaluation of the effectiveness of the technology.

The project includes plans for the ATSAC system and Caltrans' TOC to provide information to the Pathfinder computer which will then be formatted for broadcast to the ETAK equipped vehicles. The information displayed to the driver will consist of visual and oral identification of areas of congestion. The intent is to give the motorist enough information to enable him/her to select the best route between origin and destination.

ETAK is only one of many in-vehicle navigation system technologies being reviewed in various countries around the world. When evaluating this type system for potential use in the Smart Corridor, only the viability of the concept is to be evaluated, not a specific hardware configuration.

SCRTD is also installing a vehicle locating system which will equip their busses with on-board devices. Their system uses a sign-post technology as opposed to dead-reckoning which is used by ETAK to track the location of the vehicle. Regular voice radio transmission will also be provided.

The Smart Corridor project needs to concern itself with the "post-Pathfinder" needs of in-vehicle navigation system. Broadcast alternatives for general use are being reviewed and the central database system needs to be designed to create the needed data, or to accept input, from a variety of systems.

POLICY ISSUES

Freeway Service Patrol

CHP is currently involved in a demonstration project which is evaluating the effectiveness of freeway service patrols. The project was initiated on September 1st of 1988 and will continue for one year. The service is being tested on the Santa Monica freeway. The initial evaluation results have been very positive.

One of the MOEs for the evaluation of the freeway service patrol is the accident rates on the freeway. When incidents occur resulting in congested conditions, there is a high incidence of accidents at the back of the queued traffic. In previous years and on other freeways not involved in the demonstration project, the accident rates for congestion related collisions have been ever increasing. For instance, during the month of September, 1988, the number of congested related collisions on the Harbor Freeway, which does not have a service patrol, increased by 31% over the same month last year. The rate on the Santa Monica freeway for the same period however decreased by a substantial 25%.

Caltrans recognizes the benefits to be accrued through the use of service patrols and is looking at ways to implement them throughout the LA basin. Additionally, LACTC is examining the possibility of a 1/2 cent sales tax which would go partially to a service patrol. The measure could go to ballot in 1989 or 1990.

Freeway Incident Management Teams

Caltrans currently has a Major Incident Response Team (MIRT) available for incidents which are defined to be "major" meaning that there is a blockage of two or more lanes and the incident is expected to take two or more hours to be cleared. One of the issues regarding incident management teams is whether this criterion for the definition of an incident which warrants the issuance of a call to a MIRT type team should be reviewed and possibly made more lenient.

The present MIRT team is not dedicated to the Santa Monica freeway but rather serves all of the freeways in the LA basin. As part of the Smart Corridor project, the potentiality of dedicating a team solely to the Smart Corridor freeways on a 24 hour/7 day per week basis will be examined from a cost benefit perspective.

Surface Streets Incident Management Team

The current operations of LADOT could support an incident management team since there is effectively such a structure already in place which functions during special events. The operation could be expanded, but the criteria would have to be established which would define the type of incidents, duration, etc. to which the team would respond and the times/days during which the team should be available for response.

During the 1970s, there was a joint operation of Caltrans and LADOT which would respond to major incidents when diversion from the freeway was required. This type of operation has application in the Smart Corridor and could be revitalized.

Accident Investigation Sites

Policy issues in this category include the use of push bumpers to remove accidents and disabled vehicles from the freeway to special sites off the freeway or at least out of the travel lanes. The existing CHP policy is to remove the vehicles from the freeway whenever possible. There are no existing areas specially designated as accident investigation sites. Such sites would ideally would have telephones installed and would be out of view from freeway motorists thereby reducing the gawking factor.

There is a conflict with the concept of removing the CHP activities from the view of motorists however since one goal of enforcement is visibility of the officer and motorist while the ticket is being issued.

Culver City/Beverly Hills

The boundaries of the Santa Monica Freeway encompass small areas of two cities toward the west end of the Santa Monica Freeway. These cities, Beverly Hills and Culver City, have not been directly involved with the Smart Corridor project to date. Both cities have traffic signals on arterial streets in the corridor: 9 in Beverly Hills on Olympic Boulevard and 26 in Culver City on Washington. It would be desirable to bring these signals under the control of ATSAC as part of the Smart Corridor in order to provide continuous control of the arterials throughout the corridor.

Both cities have been approached by LADOT regarding incorporating their signals within the corridor into the ATSAC system. The situation in each city is different and each has separate issues to address in considering this offer/opportunity.

Beverly Hills

The section of Olympic Boulevard which traverses Beverly Hills lies just to the east of Century City. It is a segment of roadway approximately 1.7 miles in length. It is an important link in the corridor which would serve as an alternate route to I-405 to I-10 traffic to the structure of the

The controllers on Olympic Boulevard are in need of replacement but no plans have yet been formulated by the City to undertake this task. There is no existing coordinated operation of signals; however, there are no serious complaints from citizens regarding their current operation nor does the City feel that their replacement is a pressing issue.

The City of Beverly Hills is basically agreeable to placing the nine signals on Olympic under the control of the LADOT system, but has voiced a few concerns. The City did not apply for funding through LACTC to assist in the costs associated with placing the signals on the ATSAC system, and there is no money budgeted for this effort. It is estimated by LADOT that the cost per signal will be approximately $50,000. This figure includes control and communications equipment, the cost of interconnect, and LADOT's expense associated with bringing the signal on line. Beverly Hills needs to identify funding which could be applied to this venture before they can consider the proposal.

Another issue in turning control of the signals on Olympic Boulevard over to LADOT is the timing that would be implemented. There is a program in the City of Beverly Hills called "Liveable Streets", and one of the goals of this program is to implement timing which would minimize delay to the City's residents, especially on side streets. The City traffic engineer is therefore concerned that timing patterns implemented by LADOT might not satisfy this objective. This issue could be resolved by the City of Beverly Hills and LADOT agreeing to jointly develop the time-of-day patterns that would be implemented on a regular basis or by granting the right of approval to the City of Beverly Hills of patterns developed by LADOT. It is recognized that special patterns would need to be developed and implemented to accommodate the extra demand that would be experienced under diversion route conditions.

Culver City

An extensive section of Washington Avenue which contains 26 signalized intersections is located within the city of limits of Culver City. Approximately five of these locations are coordinated by a small signal system. The remainder are a mix of controller types all operating in an isolated mode. The City has no specific plans for expansion of their system.

As with Beverly Hills, the City has been approached by LADOT regarding the possibility of adding their signals which are on the Smart Corridor arterial (Washington Boulevard) to the ATSAC system. The City has already applied to LACTC for the funding to accomplish this task. The City Engineer, however, has not received approval from his superiors or the City Council to accept LADOT's proposal.

The same concerns regarding signal operation and timing were voiced in Culver City as were expressed in Beverly Hills, specifically relative to maintenance responsibility and liability. Again, these are issues which can be resolved through discussions between representatives from Culver City and LADOT.

Summary

It is recommended that LADOT submit specific proposals to both cities regarding their proposition to place the subject Smart Corridor signals under the control of the

ATSAC system. Neither city has yet approached its council about the subject, and a formal proposal from LADOT would provide the support material needed by the transportation officials in both cities to ask for approval from their respective councils. The Director of Transportation and Engineering in Beverly Hills and the City Engineer in Culver City both agree that the first step toward placing their signals under the control of ATSAC should be in the form of a formal proposal from LADOT which defines the expected costs, maintenance and operational responsibilities, and any associated liabilities.

APPLICATION OF VIDEO DETECTION IN THE SMART CORRIDOR PROJECT: REVIEW - POTENTIAL - ISSUES

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Introduction

The concept of using video image processing for traffic surveillance and control is not new. Because of its conceptual appeal, research in this area was initiated in the mid 70's in the U.S. and abroad (most notably in Japan, France and England). Despite the major worldwide efforts to develop a machine vision system for traffic surveillance and control, a real time fieldable device having the capabilities and performance required for practical applications has been elusive. Even though claims to the contrary have surfaced in recent years concrete functionality performance and reliability verification is still lacking. Because of this, no real installations are presently known.

The breadboard system for vehicle detection through video imaging recently developed at the University of Minnesota is the most mature known device available to date; this was manifested in recent live benchmarks in several U.S. and European cities. Because of its advanced developmental stage, it was tentatively selected for implementation in the largest and most visible European projects in Barcelona, Seville and Madrid; these are related to the 1992 Olympic games and world fare in Spain. The system will also be implemented in the I-394 and 35-W freeways in Minneapolis, for incident detection while its use as a vehicle counting classification device is currently being negotiated with another state.

The success of the system lies in its simplicity, effectiveness and instant verification. More specifically, in contrast to other more futuristic concepts the Minnesota system simply emulates loops, a large number of which can easily be placed within the field of the camera's view through interactive graphics. Furthermore, in recent tests its performance matched or exceeded that of loops in vehicle counting, speed measurements and extraction of certain measures of effectiveness. More extensive testing and calibration is currently underway in I-35W in Minneapolis where two units are collocated with loops for continuous long term testing and verification. A live demonstration of this is scheduled during the June semiannual meeting of the freeway operations committee in Minneapolis.

2. Status

The status of the Minnesota system today is in the advanced breadboard state i.e., it is the third generation breadboard design produced so far; the first generation was introduced in Fall 1987. Unlike other experimental systems, the Minnesota system operates in real time and provides visual and numerical detection verification. Numerical results generated by the system in addition to presence/passage signals include volumes, occupancy, speed, total travel, total travel time and headways. Software for additional data extraction such as delays, stops, energy consumption, density and queue lengths has been developed and is being tested, along with additional software for automatic distance calibration. The system is not locked to any particular camera type i.e., it accepts input from a variety of cameras that are commonly installed in freeways and urban streets throughout the world. The system currently requires only a PC (IBM /386 compatible) and allows placement of up to 16 detectors within the field of the camera's view. This number is expected to increase to at least 40 by December 1989. This implies that up to 4 cameras can easily be processed simultaneously with only one system. Currently the PC is being replaced with a "black box" that is easier to replicate while being more compact and portable. Despite this, it is not currently designed to withstand severe temperatures although this problem can easily be resolved in short time if needed. In addition to the PC only a portable keyboard and/or a mouse are needed on a temporary basis along with a TV monitor for placing the detectors or changing their position. The detectors are represented by straight lines that fit the geometry of the road and can be placed either across or along the direction of travel; the latter may be needed for minimizing occlusion caused by poor camera placement, or for area detection. Detection lines can be placed in minutes and can be changed or moved as often as desired. Once a detection line is placed an initialization interval of a few seconds to a few minutes is needed (depending on traffic conditions) before it becomes functional. Unlike other experimental systems the one developed in Minnesota operates effectively under congested and adverse weather conditions, as well as during rapid lighting changes and at night.

3. Potential Applications

The practical applications of the video detection system described here are many. The main advantages lie in the employment of cameras that allow multiple wireless detection and the fact that such a system is essentially a wide area detection device. Therefore it should not be viewed simply as a replacement of loops, which will continue to serve their intended purpose for a while, but rather as a device that leads to new potential applications which due to cost and complexity considerations could not realistically or effectively be attempted with existing hardware. In addition, the video detection system discussed here can quickly be installed or connected to existing cameras for multiple wide area detection without disruption of traffic operations. Another important consideration is its multiple function capability i.e., the ability of performing several functions simultaneously; for instance detection, control, surveillance, counting/classification, traffic parameter and MOE extraction functions can all be performed simultaneously.

Specific functions that can be of interest to the smart corridor project include:

- Multiple detection on freeways and arterials
- Critical intersection control (i.e., implementation of OPAC)
- Incident detection
- Generation of data banks (in conjunction with loops) for vehicle guidance/navigation
- Derivation of traffic parameters for surveillance and control (including queue length)
- Continuous performance monitoring to determine the effectiveness of control schemes (i.e. stops, delay, energy consumption, etc)
- Study of traffic stream flow characteristics
- Vehicle counting at intersections (including turning volumes)
- Safety analysis/reconstruction
- Freeway ramp control
- Integration with real time control systems/controllers, (including 2nd and 3rd generation control)

Of the above functions only multiple vehicle detection is completed along with the derivation of traffic parameters, while incident detection is scheduled to begin in Spring 1989. The remaining applications require additional software development which can be completed in reasonably short time.

4. Issues

The smart corridor project is undoubtedly the most ambitious and visible current project in the U.S. that favorably compares with European and Japanese projects. In view of this and the desire to come up with new, more effective solutions as we enter the 21st century, it becomes evident that employment of new technology is unavoidable. However, new technology requires experimentation, patience and long term planning; as the European and Japanese plans demonstrate, overnight results with new innovative technology could only be coincidental. Thus a long term view and objectives that can be reached in small steps is in order and machine vision is no exception. It should be remembered that serious attempts to implement machine vision for traffic detection started in the mid 70's; 15 years later we begin to realize some practical results.

There should be no doubt that the machine vision technology perfectly suits at least the innovation objective of the smart corridor project. However, caution should be exercised in how the technology is used and for what purpose. It is the author's experience that once people get acquainted with the basic notion of machine vision, they tend to ignore technical difficulties and aided by various claims (often unsubstantiated) have a tendency to ignore reality. A case in point is the use of 3-D analysis, vehicle tracking, image understanding and other state of the art but still evolving techniques in machine vision. Although it is tempting to employ such approaches for vehicle detection, they are still too complex, costly, and largely unproven in hostile environments such as roadway scenes where weather, lighting, congestion, poor video and occlusion problems can occur in many combinations. In view of such considerations the machine vision system developed at the University of Minnesota was deliberately kept simple, inexpensive flexible and functional. Once its practicality and effectiveness is proven in the initial field applications, more complex designs can be attempted. In the meantime, the most important applications (mentioned above) can begin to be developed and implemented.

Concluding, the author of this document feels confident that the video detection system discussed here, is the most advanced available today and ready for field testing (currently underway). However, prior to its possible implementation to the smart corridor project, some basic questions need to be answered. Some of them are:

1. Of the video detection functions and applications mentioned earlier which are the most suitable for the smart corridor project?

2. What are really the performance requirements for these applications?

(overspecification can be costly).

3. Given the fact that video detection represents new technology and offers the advantages mentioned earlier what is the acceptable cost of the selected functions/applications?

4. If machine vision is to be used for control purposes what are the detection requirements?

5. Is it desirable to use the video detection system as an evaluation device?

6. What traffic data really need to be collected in the smart corridor project?

7. Assuming that there is commitment and willingness, to take reasonable risks for trying promising new technologies what project resources can realistically be allocated to machine vision?

Finally before concluding this section, it should be mentioned that, in the authors opinion, given the momentum of the European and Japanese research initiatives in traffic technologies, there are few areas in which the U.S. is currently still leading. Machine vision is one of these few.