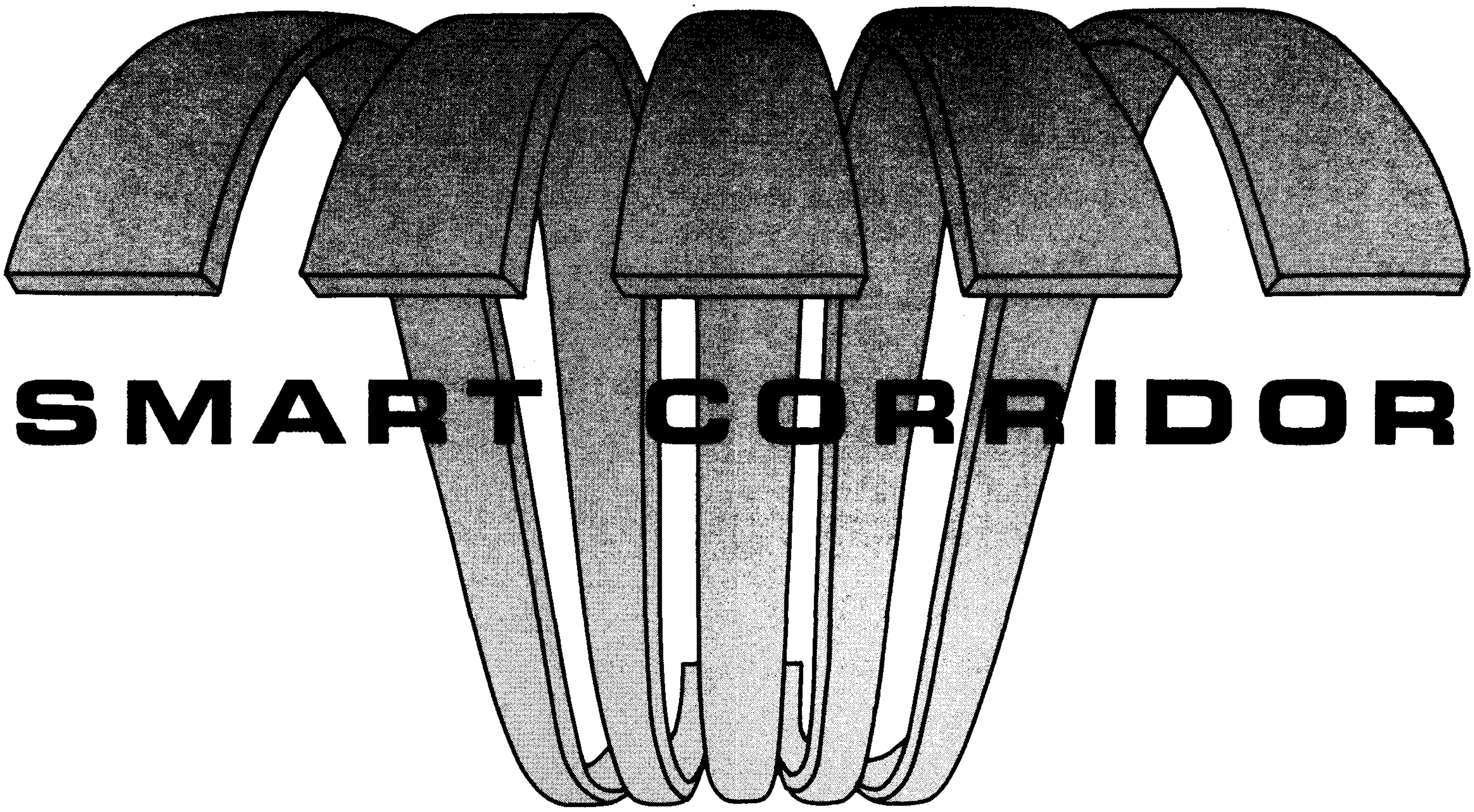

SMART CORRIDOR

PROJECT WORKBOOK 2

jhk & associates

SMART CORRIDOR

WORKSHOP II

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SMART CORRIDOR SYSTEM - OVERVIEW AND SUMMARY

This paper presents an overview of the Smart Corridor Project as currently envisioned. The overview reflects the conclusions about the individual elements as included in the working papers in this workbook. The information will serve as the basis for the project review seminar to be held on June 1. Subsequent to the meeting, the project team will review the individual recommendations to develop a final recommended program, which may vary slightly from that presented here. The program will include an implementation plan and the draft RFP's for evaluation of the project and development of the public information and education plan. A draft final report will also be prepared to document the overall project. This paper discusses the premises on which the conclusions are based, reviews the elements from the perspective of the operating agencies, then as individual components, and reviews policies which are critical to the project.

PROJECT PREMISES

Review of the current operations of the various agencies and the elements to be included in the project has resulted in several basic conclusions/premises which the consultant team believes should guide the project. These premises are stated below and serve as a foundation for discussing the overall project.

1. The majority of the elements under consideration parallel on-going activities, or are logical extensions to on-going activities, of the primary agencies. The institutions are in place to handle the activities and working relationships and "boundaries" of responsibility have been established. To the extent practical, the Smart Corridor Project should build on, strengthen, and enhance the operating agencies' capabilities to deal with the urban congestion problem rather than attempt to completely realign the operating policies. This reflects the fact that agency responsibilities appear reasonable.

2. The operating agencies (principally Caltrans District 7, Los Angeles DOT, and the California Highway Patrol) have specific charters and responsibilities to a defined constituency. The project must recognize these obligations and, to the extent practical, use them to define the constraints in which system elements must operate.

3. Given the above, it is also apparent that coordination between the agencies and presentation of a common response to the motoring public is essential. This project will greatly increase the need for coordination and for presenting information to the traveling public. Significant project resources will be required to facilitate and plan the coordinated responses to changing traffic conditions. Once implemented, continuing

process can be automated as experience and confidence grows. The development of these "rules" and operating plans is also a major effort of the project and will require significant resources, paralleling those expended in preparing for the 1984 Olympics. Selected basic operating policies are included in this paper to assist in identifying, and agreeing to, responsibilities.

GENERAL POLICIES

Inherent in the operating premises and recommendations regarding the Smart Corridor system are several basic policies affecting the various agencies. The following are typical of the policies to be established and to be reflected in the operational plans.

1. Surface street operations will be improved by the project elements. These improvements, coupled with existing conditions, result in excess capacity during several hours of the day which may be used to serve short distance trips or accommodate planned diversion during incidents. It is essential that the streets be used only to levels which will allow relatively free flow on the arterials. This will give motorists confidence in the routes when they are indicated as being available as alternates and will avoid excess travel on the streets. Under no condition should the streets be loaded to the point where diversion to residential streets is caused. Operating plans will provide for agreed levels of diversion and the ATSAC surveillance and new CCTV systems will be used to verify operating conditions on the surface streets and monitor diversion so that adjustments may be made as required.

2. The system control elements under the responsibility of the operating agencies will remain under their control. For example, Caltrans will have final control of ramp metering rates and LADOT will have final control of traffic signal timing. System operating plans may be implemented automatically where prior agreements have been set as part of the decision matrix and operating plan. Operating plans outside the agreed set may be implemented as agreed by the agencies. Where significant changes from operating plans are required because of unforeseen conditions, the agency with responsibility for the control element will have to authorize the change. This will require the agencies to establish plans for conditions which can be expected and to have staff with decision-making authority available either in their centers or on-call at all times. Conditions cannot be allowed to occur where actions are not taken because of decision makers being unavailable, or the credibility of the system will be lost.

3. The entire project represents a new level of cooperation and coordination between the involved agencies. This policy of cooperation must be "adopted" by the agencies and made known at all levels of the organizations. The policy of cooperation agreed to at management levels must be made to work at the operations level. This may require giving operational staff more latitude than is normal so that they may be a part of the solution, not part of the problem. An attitude of "what can

expected and required several elements to be out of service for extended periods of time.

Caltrans is currently planning a major rehabilitation of the TOC and, when completed, the joint Caltrans/CHP TOC operation will serve as the focal point for the majority of control and surveillance activities. In this longer term perspective, the Smart Corridor project should encourage joint operation of the TOC and its use as the major source of reliable traffic information, combined with the surface street information developed principally by LADOT.

The initial implementation presents a more complicated issue. As noted in the review of basic premises, the project team believes that building on existing services provides the best opportunity for short term success. This results in the need to share the responsibility of providing motorist information and build on current plans to improve the service to the media yet provide a coordinated response to the media and motorist. As a final perspective, each involved agency desires to, and should, remain visible in its role in responding to traffic congestion and this needs to be reinforced by the methods used to provide information to the public and media.

This leads to a special set of premises regarding the public information elements of the project, namely:

1. Public information, including media contacts, fall within the purvue of all agencies. Care must be taken to "coordinate" information handling, rather than "control" it.

2. A process for joint operation of the elements needs to be established. One agency might take primary responsibility for the coordination role, but all should be involved in managing the information distributed. It is suggested that a special coordination/policy committee be established with management level representatives of Caltrans, CHP, and LADOT to coordinate this element. The committee should meet regularly to develop operating policies and agree on information dissemination procedures. Joint meetings with media representatives are also suggested.

3. Care should be exercised throughout the process in "sourcing" information so that all agencies maintain visibility and receive the positive image associated with active involvement in responding to urban congestion.

With these premises in mind, the project team has developed basic conclusions regarding the initial configuration of the public information element of the Smart

Corridor project. Much of the initial coordination is shown through the CHP because of their current role with commercial radio. Some elements are shown with both CHP and Caltrans involvement, indicating shared responsibilities.

SMART CORRIDOR SYSTEM OVERVIEW

As noted earlier, the project team has developed basic conclusions regarding essentially all elements of the project. These elements have not yet been fully developed as a program, however, it is practical to identify the Smart Corridor System as it currently is envisioned. Exhibit 1 is an overall concept layout of the project (presented in an earlier seminar) and Exhibit 2 summarizes the basic system functions to be provided, with primary agency responsibility noted. Additional exhibits will present the specific system elements noted for LADOT, Caltrans, and the CHP respectively. The exhibits also indicate basic relationships between the Smart Corridor elements and other existing systems. The following discussions summarize the agency responsibilities.

Los Angeles Department of Transportation

Exhibit 3 summarizes the LADOT system elements. The Smart Corridor components are to be an overlay to the existing successful ATSAC signal project. As shown, the ATSAC system supervisor and two area computers are currently operational. Both the Coliseum area and the CBD area computer include traffic signals which will be controlled under operating plans for the Smart Corridor. A third area computer will be provided and is shown as the ATSAC Smart Corridor area computer. The ATSAC Smart Corridor area computer will provide functions identical to those of the other area computers, as well as include modifications to control certain other field elements such as CMS. By the time the ATSAC Smart Corridor area is controlled, additional area computers will have been provided for the Airport area, and the Hollywood/Westwood area of the City.

It is expected that a Smart Corridor database node processor (a powerful workstation processor) will be connected to the ATSAC supervisory computer. This will allow information to be gathered and exchanged with all of the area computers influenced by Smart Corridor decisions. In addition, the project will add an expert system component to ATSAC. Although the initial implementation will be for the Smart Corridor area, it is anticipated that similar procedures will be used in other congested areas where ATSAC is applied. For this reason, the expert system

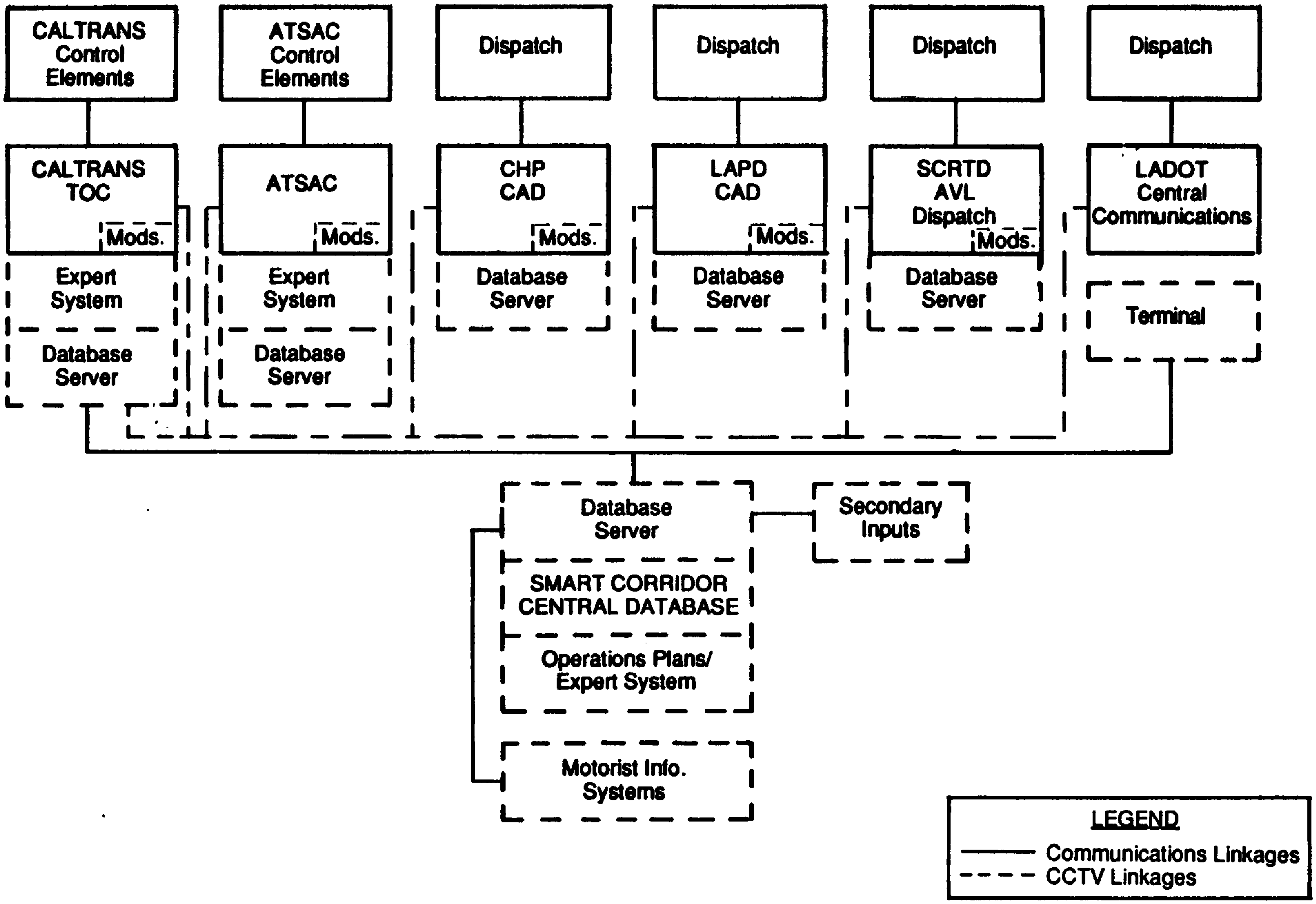

Exhibit 1
Overall Concept Layout

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Exhibit 2

SMART CORRIDOR BASIC SYSTEM FUNCTIONS

SMART CORRIDOR SYSTEM (LADOT/Caltrans/CHP/Steering Committee)

Operations Plans
Decision Matrix/Expert System

LOS ANGELES DOT

Traffic Signal Control
Surface Street CMS
Surface Street HAR
ATSAC Expert System
Surface Street CCTV
Surface Street Incident Response Team
Traffic Engineering Improvements
Intersection and Parking Control
DOT Communications Network
Operations Plans
CATV
Cooperative Public Information with CHP

CALTRANS

Freeway Surveillance
Ramp Metering
Connector Metering
Freeway CMS
Freeway HAR
Freeway CCTV
Freeway Major Incident Management Team
Caltrans Communications Network
Accident/Enforcement Site Development
Operations Plans
Evaluation Program
Motorist Information System
- FM/SCA Digital Radio
- Teletext
- Pathfinder
- Cooperative Public Information with CHP

CALIFORNIA HIGHWAY PATROL

Call Boxes
Tow/Patrol Services
Cellular Traffic Call-in
Public Information (In conjunction with Caltrans)
- Commercial Radio
- Commercial Television
- Dial-in Telephone
- Computer Bulletin Board
- Silent Radio

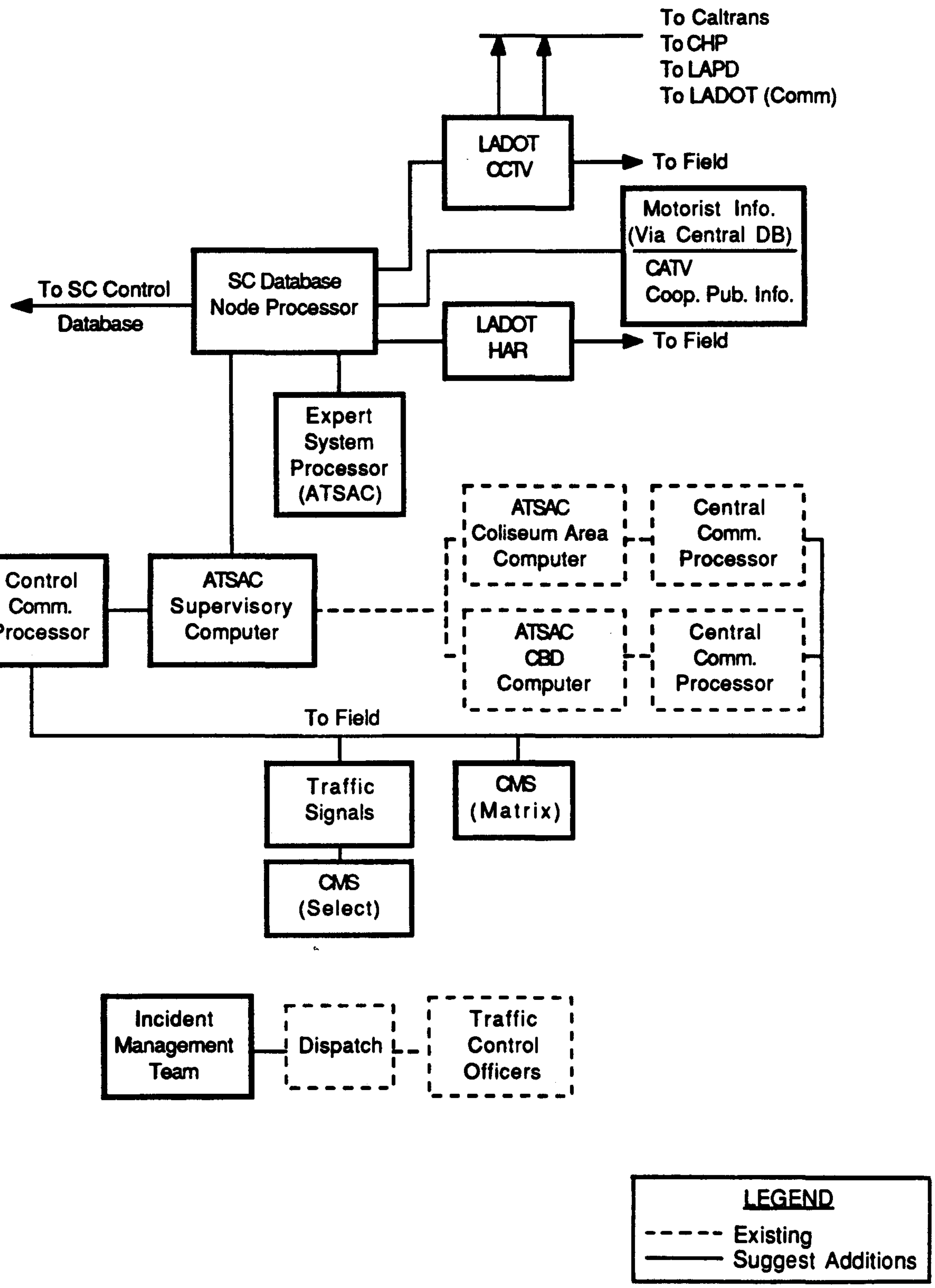

Exhibit 3
LADOT System Elements

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processor is also connected to the ATSAC supervisory computer and linked with the Smart Corridor database node processor. The expert system processor will also use the workstation approach.

The Smart Corridor database node processor will be networked with the Smart Corridor central system. The Smart Corridor node processor will also provide control information to a LADOT highway advisory radio (HAR) system so that prestored messages may be selected for operation. The HAR system will be a stand-alone device, but linked to the node processor for control and selection purposes.

The LADOT CCTV system will also be a stand-alone system. The CCTV system will be linked to the Smart Corridor database so that information on camera selection, direction, and prepositioned points can be fed directly to the CCTV control. As previously discussed, the system will allow 8 to 24 cameras to be connected to the central system from each of the hubs. The mechanism for selecting these cameras may also be included as part of the Smart Corridor database.

The exhibit also shows that the CCTV images will be provided to Caltrans, the CHP, LAPD, and the LADOT communications center. It is expected that the LAPD and LADOT communications center CCTV will be mimic images of screens being controlled from the ATSAC center.

For Caltrans and the CHP it is suggested that means be provided to select and control the LADOT cameras. A priority mechanism will be provided so that the primary agency will have priority access to the CCTV images. However, if additional images were available, the secondary agencies (Caltrans and the CHP) could select and control a camera from their location. Again, the primary agency would have controls to allow it to take the camera over for its use, if required. In the initial implementation with Caltrans, the communications will be via dedicated fiber optics and there will be no difficulty in transferring the images. It will be necessary to make special arrangements for the CHP in the period between when the Smart Corridor system becomes operational and a fiber trunk can be installed to the CHP communications center.

In addition to the traffic signals which will be directly connected to the ATSAC area computers, changeable message signs are also to be provided. Two forms of CMS control are envisioned. One is a full matrix changeable message sign, special central control software will be required and the cental communications processors at ATSAC will have to be modified for the CMS control. It is expected that the CMS will be controlled using Model 170 controllers to allow standard interfaces to be provided and coordinated with the generic CMS sign control being proposed by Caltrans.

The second type of CMS uses either blankout messages or a limited number of pre-selected messages. For this type, the CMS can be operated directly through the special function capabilities of the local ATSAC intersection controllers and requiring no special modification to the software. As noted, the project also includes areas currently under control by the Coliseum and CBD computers. Two alternatives are available for providing CMS control in these areas. The area computers may be updated with the software to be used for the Smart Corridor area computer and have identical capabilities of CMS control or the appropriate communications lines from these areas may be assigned directly to the Smart Corridor area computer.

In addition to these primary control and surveillance functions, LADOT will use its Parking Enforcement communication division to dispatch traffic and parking control officers to work with the incident management team. Information to and from the communication center will be provided through a workstation and node processor. Provisions will be made for the communications center to serve as a secondary source of Smart Corridor information and provide input directly into the Smart Corridor database system.

Although much of the activity shown for LADOT follows special event handling and normal ATSAC signal control, several new features, including the Smart Corridor database, expert system, CCTV, HAR, and CMS will be added. These all fall within the normal operation of the Department. LADOT will also be responsible for, and coordinate, any use of CATV since they are the franchising agency for this service. They will also participate in the cooperative public information element.

Not shown on the exhibit is the dedicated communications network to be provided as part of the project. This network includes major trunks for the Smart Corridor area and for future expansion. It also includes the communications distribution network for ATSAC and other control elements. The communications network proposed by the consultant team uses sophisticated digital switching techniques similar to that used by the telephone industry. The communications system will place significant added burden on the maintenance requirements of the Department. Special staff will have to be provided to maintain the sophisticated electronics equipment. The Smart Corridor system will place added operational requirements parallel to any other significant increase in the number of intersections under control. The expert system will somewhat reduce the ATSAC operator requirements, however, this will not offset the simple increase in the number of elements being controlled.

The City will also be a major participant in developing operating plans for the Smart Corridor system. References have been made that this activity parallels the work done for the 1984 Olympics. The sheer number of traffic signals involved in the overall planning will require significant engineering to develop appropriate timing. Also, developing appropriate sign messages and HAR messages will require significant planning. Major work will be required in calibrating the expert system and in developing the decision matrix to be used as part of the Smart Corridor central system.

Caltrans System Elements

Exhibit 4 summarizes the system elements which are recommended for Caltrans. Overall, the Caltrans portion of the project most closely resembles the activities currently being undertaken by any of the agencies. That is, most of the Smart Corridor features are similar to those of the SATMS at the existing traffic operations center (TOC). As noted by the dashed lines, Caltrans currently provides ramp metering and system surveillance. CMS sign control is also operated through the TOC and a dispatch function for the major incident management teams is coordinated through the TOC. Caltrans also has direct experience with using HAR and CCTV.

The Smart Corridor project will include ramp metering at additional locations in the project area and connector ramp metering at the junction of I-10 and I-405. Caltrans has initiated a project in the Smart Corridor area to rehabilitate the surveillance system so that coordinated ramp metering and incident detection can be used. A project is also underway to replace the CMS signs in the corridor and this is considered a part of the Smart Corridor project.

As shown on the exhibit, the existing SATMS is expected to be replaced in the future to provide increased computer capability, increased user access and display, and integrated sign control. Portions of this replacement project may be included as part of the overall Smart Corridor system work, however, it is not expected to be completed until after the Smart Corridor project becomes operational. As with the

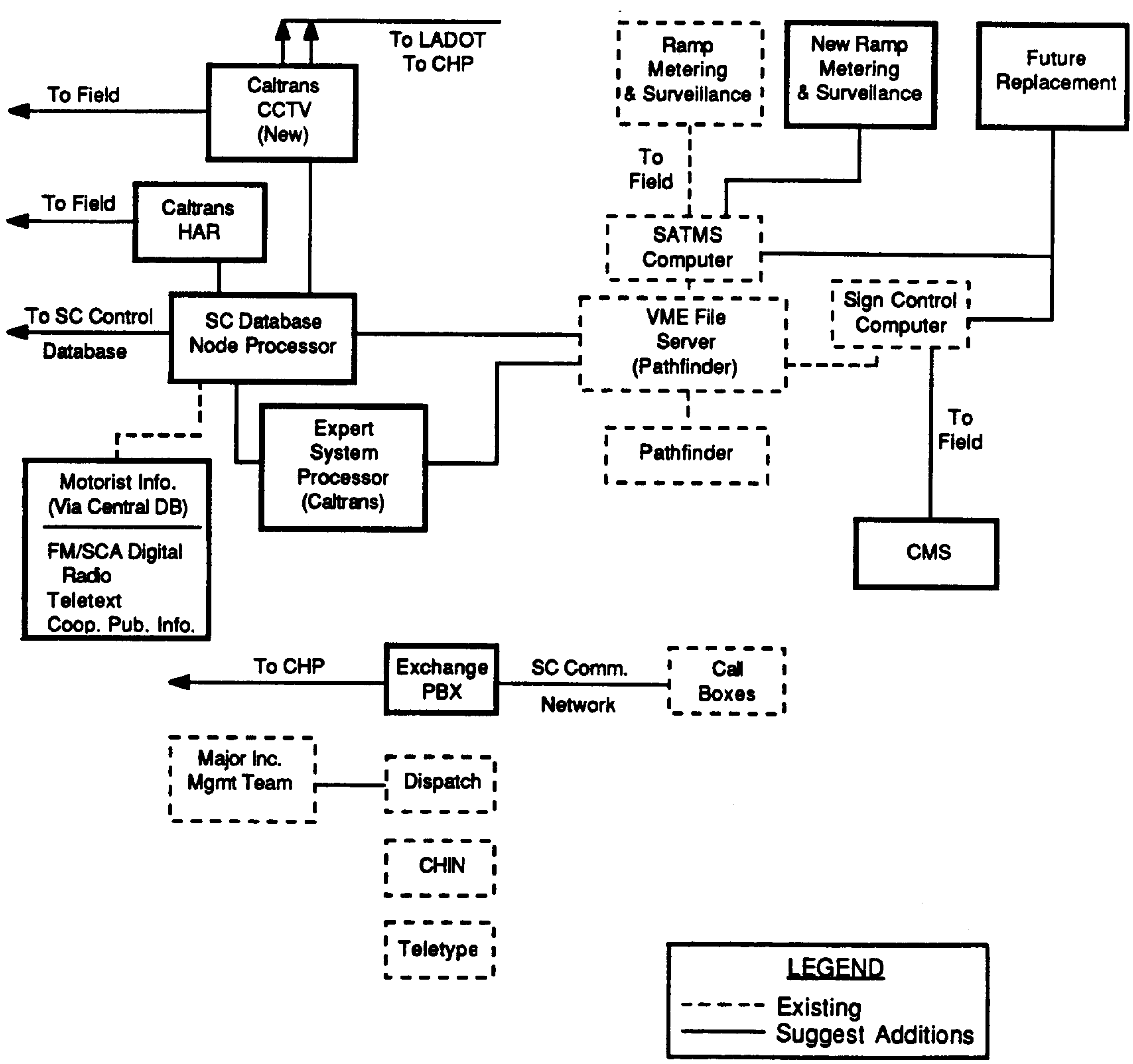

Exhibit 4
CALTRANS System Elements

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ATSAC system, it is proposed to install a workstation based Smart Corridor database node processor. This processor will serve as the interface between the other agencies and the SATMS system. It is expected that the workstation will be connected to a file server which is to be installed under the Pathfinder project (in association with the Anaheim Intertie project).

It is also proposed to provide Caltrans with an expert system processor using workstation technology. This will also be connected to the Smart Corridor database system and the SATMS file server. The expert system is to be applied initially in the Smart Corridor area but is also expected to have an application to the entire District 7 area. The initial implementation will be in a limited form because of limited accessibility to information from the SATMS system. It will be upgraded in operational capability when the replacement system is installed.

Also shown as a new element is the Caltrans HAR system connected directly to the Smart Corridor workstation. As with ATSAC, the Caltrans HAR will be a stand-alone device with program selection directed from the node processor. The project team also recommends replacement of the existing Caltrans CCTV system under the Smart Corridor project. The current system is reaching the end of its useful life and has operational limitations associated principally with camera mounting heights. Field tests indicate that significant improvement in viewing area can be made if the cameras are mounted 45' to 65' above the pavement. This mounting height may be attained by placing 45' poles on the overcrossings or placing pole extenders on top of existing sign bridges. It is understood that the original implementation of CCTV on the Santa Monica freeway used cameras at lower mounting heights to avoid public concern for visual or "big brother" surveillance. The project team believes that CCTV is sufficiently well accepted now that the increased mounting heights will not cause public concern.

It is also recommended that color CCTV cameras be used to provide additional clarity, especially during daylight hours. The original problems associated with color cameras, including clarity at night and cost, have been eliminated by recent developments in color camera technology.

Caltrans will share the responsibility with the LADOT in developing the required operations plans and decision matrix. This will add a significant operational planning burden to the workload of the Caltrans staff and will, as with LADOT, require additional personnel or the use of consultants to develop the database required for the Smart Corridor system. Additional funding is also suggested as part of the project for the major incident management team to increase its availability during the Smart Corridor demonstration project.

It is also proposed that the Caltrans CCTV images be made available to LADOT and the CHP. It is suggested that LADOT and the CHP have the ability to select and control cameras remotely with the priority being established such that Caltrans may take over control of its cameras and pre-empt the operation of the other agencies. When Caltrans is controlling the cameras, no other agencies would be able to assume control.

It is also recommended that Caltrans install its own communication network. This is recommended as a fiber optic trunk and involves significant electronics at field located communications hubs. This again requires a significant commitment to maintenance and places a requirement on staff availability and training. The options are to provide the well trained staff as part of Caltrans maintenance capabilities or to use contract maintenance for the more complex telecommunications elements.

Given the availability of the jurisdiction-owned cable network, it is anticipated that the call boxes will be tied directly into the distribution network and returned to the Caltrans TOC. The CHP, as the responsible agency for answering call boxes, will need to receive the information automatically. This requires an exchange/PBX operation at the TOC to switch the calls automatically to the CHP dispatchers.

Caltrans will also be responsible for the systems elements of motorist information served through the recommended Smart Corridor central database system. This includes a recommended demonstration of FM/SCA digital radio broadcasts to special radio receivers and continuation of a Pathfinder and teletext components as applicable. Caltrans will also share responsibility with the CHP for the cooperative public information program.

Caltrans also currently operates an information system known as the California Highway Information Network (CHIN). CHIN is a dial-in telephone system which provides information on the major freeway routes. The system is used primarily for planned lane closures, major weather, and incident data. Because of its area of coverage, it is expected that CHIN will remain in operation during the Smart Corridor demonstration project but that more complete data will be made available through a separate dial-in motorist information component of the Smart

Corridor project. As the area of coverage and capabilities of the Smart Corridor system are extended, it should be practical to replace the functions of the CHIN system with the Smart Corridor dial-in system.

As noted, the overall Smart Corridor system elements for Caltrans closely parallel today's operations. Added resources will be required to more aggressively pursue freeway operations and coordination with the overall Smart Corridor system. However, no major realignment of responsibilities are required.

CHP System Elements

Exhibit 5 summarizes system elements which may be integrated with CHP operations. Central to the CHP components is the concept that a major part of the Smart Corridor project is an improved public information element. The diagram shows the Smart Corridor central database system and Smart Corridor expert system or decision matrix connected with the CHP system elements. The overall design of the Smart Corridor system is such that the central element will be useable by all major agencies and that the location of the system is transparent to the user. That is, the system might be adjacent to the user or remote. Building on the concept that system elements should reflect an extension of the normal operation of the agency, it is expected that Caltrans and LADOT will maintain all database associated with their activities, and that this would be maintained from their offices, but, housed in the Smart Corridor central database system. The data could include "source" credit so that it was acknowledged when passed on by the motorist information element. Caltrans and LADOT will also be responsible for developing the majority of the decision matrix items to be included as part of the Smart Corridor expert system, and that this would be maintained through each agency's operating center.

All of the elements noted as "new" and located under the CHP CAD computers on the diagram, may be housed at any location with connections to the operating agencies handled through the communications network and display terminals. The consultant team has recommended initial placement of the system at CHP primarily because this is expected to be the access point for dealing with commercial radio, commercial TV, and the other cooperative public information components. As discussed, the cooperative public information function could also be assigned to Caltrans, especially when the TOC upgrade is completed. The recommendation for the initial housing at the CHP reflects most closely today's activities, not a strong

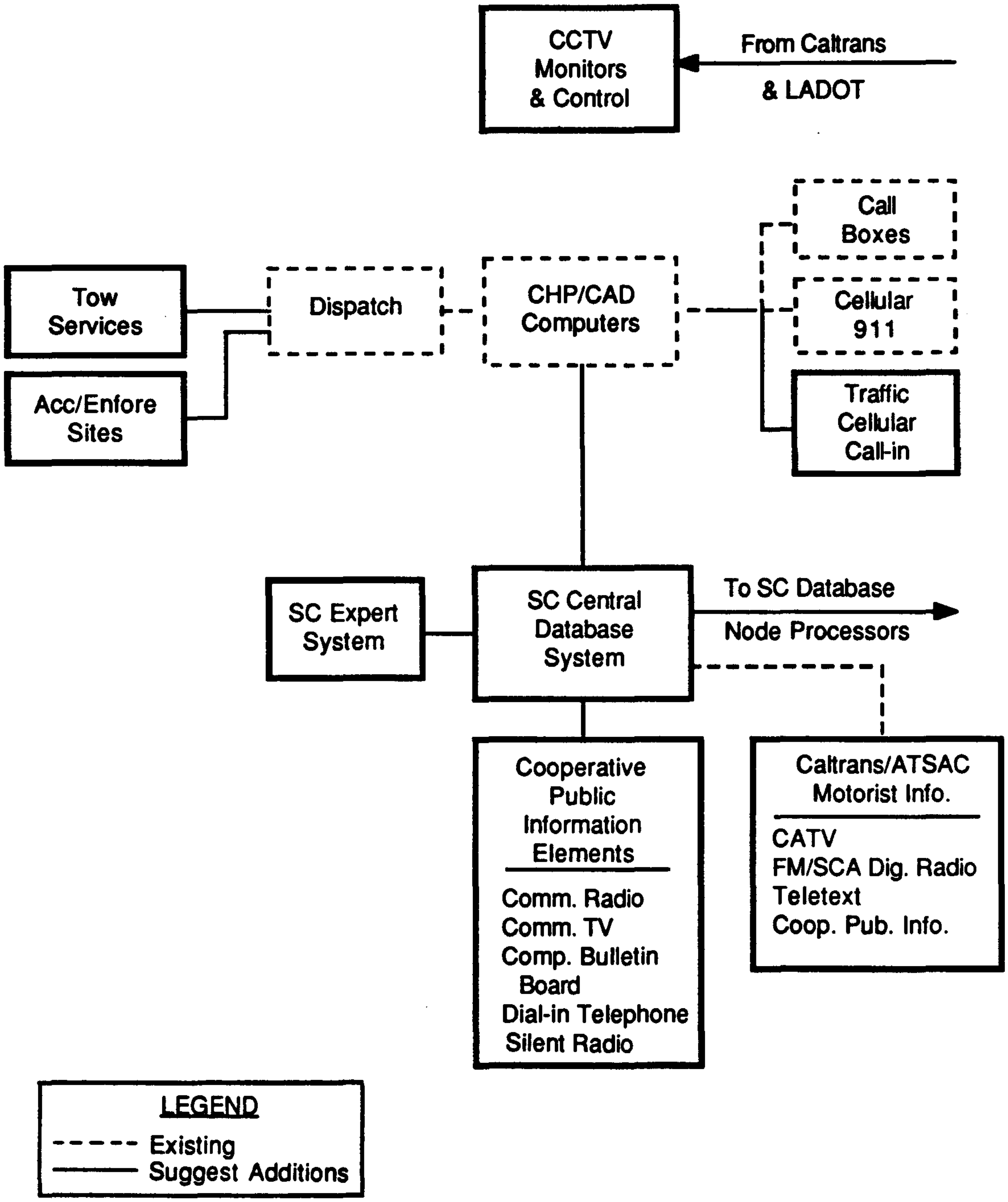

Exhibit 5

CHP System Elements

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sense of "ownership" by any of the agencies. This recommendation builds on the fact that the CHP is currently a primary agency involved in providing traffic information to the public through the commercial radio network. The CHP are also embarking on a program to automate radio station contacts and allow access to a traffic information database. This planned extension of the commercial broadcast information system may be totally with the Smart Corridor central database system.

The CHP is also currently responsible for handling calls through the call box system and the cellular "911" system. These involve approximately 30,000 contacts per month. The call box system is being upgraded and the CHP is upgrading its operator/dispatch capability. It is understood that approximately 60% of the calls currently received deal with general traffic information rather than a true emergency. The consultant team suggests that the secondary sources of information, available through a traffic cellular call-in function, is a logical extension of the cellular "911" and call box operation. In level of hierarchy, "911" would be first responded to, then call boxes and then the traffic information calls. As discussed under the paper on cellular call-in, it is recommended that a separate number be developed for this service and that the service be provided at no cost to motorists. This might, in fact, reduce the misuse of the "911" emergency numbers.

It is recognized that some of the local radio stations and traffic services are currently providing a cellular call-in number for "tipsters" and are basing much of their traffic report on this source. There are significant questions regarding the reliability of tipster information and part of the Smart Corridor project will be to evaluate its effectiveness.

Making the assumption that call boxes, "911" and cellular call-in are handled through the CHP and then entered into the Smart Corridor system using their CAD capability, it is also reasonable to extend that service to provide for a normal dial-in telephone information service system. With the elements of commercial radio, commercial TV, and dial-in telephone being logical extensions of the current operation of the CHP, it next seems logical for all of the central database related public information elements to come from that one source. It is recommended that the public information element be a shared responsibility with Caltrans and LADOT with a joint policy and management committee.

Again, the system structure is such that it can be transparent to the system as to where the source of information is from, and how it is distributed. In that light, responsibility for segments of the public information program may rest either with Caltrans, the CHP, or LADOT and simply be dispatched through the Smart Corridor central database system. It is recommended that Caltrans take primary responsibility for the motorist information components, such as Pathfinder, teletext, and FM/SCA digital radio and that LADOT retain responsibility for CATV access and coordination.

Although tow services can be monitored by either Caltrans or the CHP, it is recommended that the CHP continue operating the tow services in the Smart Corridor area and be responsible for accident investigation and enforcement at the recommended sites. This falls within the CHP's current responsibility. This assumes continued funding support by the CHP. Should funding be transferred to Caltrans, they should become the contract manager for the tow services. Also noted on the exhibit are CCTV monitors and remote controls from Caltrans and LADOT. This reflects the availability of the video images at the CHP dispatch center and the CHP's ability to control the cameras when the primary operating agencies are not using all cameras.

Operation of the Smart Corridor central database system requires significant communications from the other agencies, especially Caltrans and LADOT. As noted in the communications report, a direct tie is expected in the future as part of the Caltrans and LADOT fiber optics trunk network. Prior to the availability of this trunk network it will be necessary to lease high speed data lines as part of the Smart Corridor project. Also, the amount of CCTV information will be restricted until the trunk network is provided. Planning should continue for joint operation of the TOC with the potential to relocate the Smart Corridor database to the upgraded TOC when it is implemented.

SCRTD Elements

The principal activity for SCRTD is sharing information. The Smart Corridor database system will receive information from SCRTD's dispatch and automatic vehicle location (AVL) system. Emphasis will be placed on receiving exception reports and in receiving SCRTD CAD entered data as to causes for congestion and delay. The Smart Corridor decision matrix will also include limited operational information for transmitting to SCRTD, when unusual conditions or diversions occur. This will allow SCRTD to modify its operation in accordance with pre-agreed response plans. All of the exchange is expected to occur through a Smart Corridor database node system using a workstation approach. SCRTD will receive the general congestion and graphic information available from the Caltrans, ATSAC, and the CHP so that they may relate the information to problems they are noting as part of their system.

SUMMARY OF CONCLUSIONS

The following is a summary of the conclusions reached by the project team. The conclusions reflect a review of the individual elements and may be changed somewhat as the overall implementation program is developed. The individual elements are addressed in separate working papers included herewith. The conclusions are addressed in the general order shown on Exhibit 1.

Smart Corridor System

1. The heart of the Smart Corridor System are operations plans which include preplanned responses to expected conditions. The plans will include signal timing, metering rates, sign messages, HAR messages, public information messages, incident response team actions, etc. The plans will have to be developed prior to the operation of the system to insure that it is successful at the beginning of the demonstration. The plans will then continue to be refined during the life of the demonstration project and during the operational stage. Because the system is to be linked to all of the operating agencies, it will be transparent to the user where the system is located. Each agency will be responsible for updating and maintaining its part of the central database system.

2. The operations plans are to be selected by a decision matrix and expert system using information from all of the agencies to select the plan appropriate to known conditions. The rules for selection and the decision matrix elements will be defined by the agencies as part of the operations planning process and will reflect pre-agreed conditions. The central system will then advise the operating agencies as to a suggested response and will request confirmation when the action is taken. In initial stages it is expected that most responses will require an operator action, however the system is to be designed to allow automated implementation within agreed constraints and when specifically enabled by the agencies. It is expected that the automated approach will become more common as experience with the system is gained and confidence in the plans is achieved. Where unusual conditions are experienced, Caltrans, LADOT, and the CHP will be linked via the system so that agreement on responses can be reached. There does not appear to be a need for the agencies to be co-located for the Smart Corridor project, given the capabilities of information sharing and communications.

3. The project team does not recommend a separate Smart Corridor control center given the on-going activities of the primary agencies, the

relationship of Smart Corridor to these on-going activities, and the capability for automated information exchange. The separate center would increase staffing needs, isolate the project from the on-going activities of the agencies, and reduce the likelihood of the system concepts being accepted for broader application. It is the project team's strong opinion that the corridor functions need to be integrated with the normal operation of the agencies if they are to be broadly applied.

Los Angeles Department of Transportation

1. A workstation database system (Sun 3/80) is to be provided to link the ATSAC system, and other system elements to the central database system. The workstation will serve as the focal point for gathering and exchanging corridor information and identifying LADOT responses to identified conditions.

2. The project is to include 312 new traffic signals in Los Angeles that are to be tied to the ATSAC system. In addition, approximately 26 corridor signals located in Culver City are to installed and operate under the ATSAC system, assuming final agreements are reached between the agencies. A decision is pending by Beverly Hills as to the inclusion of selected signals in the project. If Beverly Hills concurs, approximately 9 signals will be included. The project includes a new computer for the Smart Corridor area of ATSAC and related communications and control hardware. The project also includes an expansion of the ATSAC control center to provide space for the added system elements and communications hardware. A recommendation is made to operate the center 24 hours per day, 7 days per week when the Smart Corridor signals are on-line.

3. Changeable message signs will be included at approximately 175 surface street locations. The majority of the signs will be simple message signs to indicate that the HAR system is operating, to identify or "trailblaze" alternate routes, and to indicate status of the freeway. These simpler signs will be used at approximately 170 of the locations and will be controlled through the special function capability of the ATSAC system. In addition, 5 full matrix changeable message signs are recommended at locations where primary diversion may occur. These signs will require software modifications to the ATSAC system to allow them to be integrated with the supervisory and area computers. Unless conditions change significantly, the signs are expected to be of the high intensity LED type to minimize operating costs and maintenance. Where feasible, new proposed CMS may be integrated with existing static guide signs.

4. Major emphasis is placed on using the new technology, low powered AM radio concepts for motorist information for the project. The conclusion is that the HAR system offers significant potential for the investment. Very specific motorist information may be provided and a large number of zones can be accommodated. Because the technology is new, it is recommended that a pilot test be conducted as an initial work phase to prove the operating capability of the system. Approximately 17 zones with a total of 170 transmitters are recommended for application on City streets.

5. An expert system module is recommended for the ATSAC system. The expert system is recommended as a stand alone system supported by the ATSAC system and the Smart Corridor database system. The system is to operate on a powerful workstation and be built around a commercially available real time expert system shell. (Sun 3/80; G2 Expert System).

6. Extensive use of CCTV on surface streets is recommended as part of the project. Twenty-nine locations have been identified and field verified. CCTV is recommended as an integral part of the diversion scheme, permitting visual inspection of the arterials to verify available capacity and to identify problem areas. This will minimize the potential for recommending routes that are congested and will assist in insuring that the information given to the motorist is accurate. This is essential for two reasons, first to avoid overloading City streets and secondly to improve motorist acceptance of information because of its accuracy and timeliness. CCTV will also be used to verify incident conditions, parking violations, etc. so that they may be responded to quickly. Color, solid state cameras are recommended and they are to be mounted at a height of approximately 45 feet using a modified traffic signal pole. One building mount location is recommended.

7. Funding of increased surface street incident management and planning is included in the project. The funding will allow LADOT to respond to major incidents in support of the freeway incident management team and to provide increased response during special events.

8. Traffic engineering improvements in the corridor have been identified by LADOT and are recommended for implementation to increase the available capacity on surface streets.

9. The LADOT intersection and parking control communications unit is to be equipped with a workstation (386 PC) to allow access to the common database and to allow them to enter information on conditions that are reported from the field. The unit is also to be considered when developing operations plans and the tie with the system will allow them to be informed of actions they are expected to take.

10. A jurisdiction owned fiber optic trunk network is recommended for the project. The network will provide direct communication to the two hubs in the project area and will allow for extension to the other hubs along the trunk. The trunk is suggested to run in Caltrans right of way where applicable to minimize damage by street openings and construction. A separate conduit and pull box network is recommended to reduce maintenance concerns. The communications network and electronics are of a high technology and will place a significant burden on the City maintenance operations. It will be essential to provide specially qualified and trained staff to handle the more complex equipment or contract maintenance will be required. The new technology equipment is significantly more complex than standard signal equipment and staff requirements must reflect this difference.

11. Operations plans, as referenced earlier, are the element of the system which will determine the effectiveness of the technology being applied. Without the plans, the equipment is useless. Significant resources are

recommended to be applied to this part of the Smart Corridor project. The resources can be provided by additional City staff or through outside contract.

12. LADOT is to share responsibility with the CHP and Caltrans for the overall cooperative information program. They are expected to take primary responsibility for CATV access.

Caltrans

1. The freeway surveillance and control system in the Smart Corridor area is to be made fully operational for the project. This includes rehabilitating the detection system, providing required communications connections and modifications, and calibrating the incident detection system. The majority of this work is underway or in the bid stage.

2. Consideration should be given to the addition of ramp meters at westbound Grand Avenue, Maple, Central, Alameda, and Santa Fe in order to achieve more complete control in the project area. Additionally, a more restrictive entry policy is recommended once the diversion routes are made available. This will allow the freeway to operate more efficiently and reduce overall congestion. Preliminary analyses indicate that sufficient short term diversion can be handled to allow the freeway to be operated at average speeds exceeding 40 miles per hour.

3. The project team believes that connector metering is a very important element of potential corridor control. Connector ramp metering is recommended for the San Diego freeway connectors to the eastbound Santa Monica freeway - north and southbound I-405 to eastbound I-10. Sufficient storage space and metering capacity can be made available for metering during the majority of congested conditions without adverse impact to the San Diego freeway. Some diversion is also expected for trips to the westerly section of the corridor. The connector meeting can serve as a pilot test for the Los Angeles area and demonstrate its potential. Metering at the I-110 interchange to westbound I-10 is also recommended but will require significant modification to the freeway interchange. Current connectors do not provide adequate storage and may be difficult to modify. It is suggested that a decision on metering at this location be deferred until a more complete design study can be completed by Caltrans.

4. Caltrans is in the process of modernizing the changeable message signs on the Santa Monica freeway. The existing signs are to be replaced with six strategically located signs. The signs will be of the bulb matrix type and are to be controlled with Type 170 controllers. The sign locations have been coordinated with the needs of the Smart Corridor project and will directly support diversion to the primary corridor arterials. The project is to be designed by consultant and Caltrans has initiated the contracting process. The signs should be available in advance of Smart Corridor project needs.

5. The project team recommends extensive coverage of the freeway using the new technology HAR as discussed for LADOT. The system would be used to provide more detailed information on freeway and street conditions and to support diversion recommendations. Approximately 5

zones with a total of 50 transmitters are recommended for freeway application. Final implementation should follow the recommended pilot test to insure that adequate coverage is provided.

6. It is recommended that the existing CCTV system be replaced under the project. The new system will use the dedicated communications network, solid state color cameras and higher mountings. A total of 14 cameras will be used to replace the existing 13 cameras.

7. Project funding is recommended to increase the availability of the major incident management team to respond to incidents in the corridor. The existing resources only allow responses to incidents of two or more hours and effecting two or more lanes. With the improved opportunity to coordinate response of the City and Caltrans and to implement traffic control and motorist information, this goal should be halved. The incident management team can use the system in support of their field activities, allowing the team to concentrate on refining operations plans to meet the conditions of the incident.

8. A new, Caltrans owned communication system is recommended as part of the project. The network is to serve as a trunk for the corridor, provide expansion capability to handle system extensions, and include a distribution network for the devices in the corridor. The system recommendations are similar to those for the LADOT system, namely a fiber optic trunk, fiber optic and twisted wire pair distribution network, and electronics based on telephone industry standards.

9. Fifteen accident and enforcement sites have been tentatively identified for inclusion in the project. The sites are primarily on or adjacent to Caltrans facilities, but out of site of freeway motorists, and it is recommended that Caltrans be the implementing agency.

10. Caltrans will also have major responsibility for developing operations plans and decision matrix data for the project. Significant pre-operations planning is required and direct integration with City operations plans are needed. The work will require several person years of effort and can be provided by Caltrans staff or through contract.

11. The Smart Corridor project is to serve as a demonstration of the effectiveness of the technology and the cooperative efforts of the operating agencies. As such, it is important to document the process and the effectiveness of the implemented system. An extensive evaluation effort will be required and is recommended as either a Caltrans or LACTC managed task, as proposed by the agencies. The recommended evaluation effort is significantly more complex and expensive than that originally envisioned. An extensive public information and education plan is also required and is suggested to be administered by LACTC.

12. No immediate application of video image detection is proposed for the Smart Corridor project. Instead, a cooperative research project with FHWA is suggested to develop incident detection, traffic surveillance, and critical intersection control applications software. This would build on the work being done by Minnesota DOT.

13. Caltrans is to share responsibility with the CHP for the overall cooperative public information program. They are expected to serve in a lead role for the following:

    a. A demonstration project to provide traffic information to motorists through an adaptor to the car radio is recommended. The project will use an existing commercial FM/SCA digital radio service to provide voice synthesized messages to the motorist. The recommended demonstration parallels an element of the Pathfinder project (real time verbal information) but does not include visual map information or two way communications. The system is less expensive than Pathfinder and could be made available at several locations in California with limited public investment. The recommended project is seen as a cooperative public/private demonstration to assess the feasibility of private sector support for motorist information.

    b. Caltrans is planning a demonstration of teletext, with potential testing in 1990. The project is to include operation of the system for six months and a test of its success. The project team believes the technology offers several opportunities, including use in buildings and garages. A longer term potential is for use in the home or office as teletext becomes more commonly provided in television sets and/or adaptors are found to be cost effective by the public. It is recommended that the Smart Corridor database and public information system be designed to directly feed the teletext system on the assumption that it will prove effective. If it does not, the connection is simply not completed.

    c. In-vehicle navigation is a complex potential element of the Smart Corridor project. Research and development is underway as part of the Pathfinder project and a full evaluation will be conducted during 1990. The results of the evaluation will address many of the issues of the utility of the system, however many issues related to market potential and the practicality of collecting two way data from a large fleet will not be fully resolved. Further, future developments, including those in Europe and Japan, are expected to push the technology to the point where it could be used as part of a comprehensive route guidance system. The potential of the technology appears very high, especially as an on-board receiver of broadcast real time data coupled with an intelligent on-board map and vehicle location system. Such a system would allow the navigation device to receive areawide information, determine the portion applicable to the specific trip and verbally or visually present the information.

       Given the current Pathfinder project and other planned tests of the technology it is recommended that the Smart Corridor information base be set up to "feed" a real time in-vehicle navigation system but that no specific ties to the system be recommended until a likely direction is known. The Smart Corridor system could then directly contribute the information needed by the navigation system and the system would have the responsibility for formatting the information into the specific broadcast technique being used.

As a point, the system recommended in Item a. above is one method to be considered for broadcast of information to in-vehicle devices and the results of the test will be transferable.

California Highway Patrol

1. It is recommended that the call boxes on the Santa Monica freeway be tied to the dedicated communications network, returned to the Caltrans TOC, and then be switched to the CHP communications center. It is expected that this will be the first step in the longer term replacement of leased telephone lines throughout the Los Angeles County area as the Caltrans communications network is extended.

2. A dedicated cellular call-in system is recommended to receive traffic information from this secondary source and enter it into the central database. The system is recommended to be free to the caller and use a special telephone number. Although some uncertainty as to the usefulness of the information exists (because of the confusion of the caller) the resource appears potentially valuable because of the extensive coverage by motorists with cellular telephones. The system warrants a test and documentation as to its utility. Given the current CHP handling of cellular "911" and the call box system and their 24 hour per day operation, it is reasonable to include this element with the CHP.

3. Preliminary information from the test of providing freeway patrol services on the Santa Monica freeway is very positive. The operation, handled under contract to the CHP, is reducing response times and has a reported benefit cost ratio of approximately 6 to 1. It is recommended that the program be continued throughout the Smart Corridor demonstration project. The current implementation, using contract services and CHP administration, appears effective and no procedural changes are suggested unless funding is transferred to Caltrans. It is possible that additional hours of operation are warranted and the budget should allow for this, with a final decision being made after the test is completed and evaluation data are reviewed.

4. As noted in the earlier section of this working paper, it is recommended that the public information elements of the project be initially jointly coordinated through the CHP. This allows the recommended system elements to build on the activities currently coordinated by the CHP. As a by-product of this recommendation, it is suggested that the CHP house the Smart Corridor central database system. This does not imply CHP control of the decision making process or load the responsibility of data updating with them. Instead it combines the system and its database with the public information elements which will continually access the database. Data from Caltrans and ATSAC should be "sourced" as part of the reporting process so that joint recognition is given. Within the context of the public information system, the following elements are recommended.

    a. An extension of the planned CHP-commercial radio information system is proposed to access all of the information available through the Smart Corridor system. This will allow more complete information to be provided and facilitate the integration of the

CHP, Caltrans, LADOT, and SCRTD information. Commercial broadcasters will receive comprehensive information from one reporting source. It is recommended that the data be made available at no cost but that the stations continue to pay for any hardware or leased communications facilities.

b. The system will also provide information that is valuable to commercial television stations. In some applications, the TV broadcasters will simply use the data in the form used by the radio stations. It is also recommended the color graphic information be made available to the commercial TV stations for "live" use as part of their broadcasts. As with commercial radio, it is recommended that the data be made available at no cost but that the stations bear all direct expense for connecting to the system.

c. A high technology telephone dial-in system is recommended for inclusion in the public information element of the project. The system would include information developed by the Smart Corridor central database and limited other data as made available as part of the data supplied to the media. The system would be implemented only for the Smart Corridor area but be designed for expansion to the rest of the region if proved effective and well used. A limited number of lines (20) are recommended for the initial implementation because of the lease costs and unknown usage levels.

d. The central database system will be constructed to allow access from computer bulletin board services through dial-up connections. The dial-up connection could also be used by individuals, however concern exists for the number of connections which are practical with the recommended system configuration. It is recommended that emphasis be placed on providing feeds to specific bulletin board services and allow them to distribute the information. Commercial videotext is seen as a variation of the bulletin board use and would be treated as one service to be fed.

e. It is recommended that Silent Radio be treated as a commercial radio operation, with access to all of the public information elements. This will allow them to include traffic information in their 5 to 15 minute message cycles but will not require any special relationship to be established. The use of Silent Radio as a dedicated sign over their communications network is not recommended because of the availability of alternative technologies which appear more applicable, namely teletext.

Future Elements

In addition to the elements noted above, it is important for the project to be designed to allow implementation of more automated operations planning techniques. The effort required to develop the special plans (if they are to cover a vast majority of the conditions) will be significant as has been noted. Keeping the plans current will also require continuing effort and there will be a number of conditions which cannot be foreseen that will require action using the Smart Corridor system. Experience with operation will facilitate planning and will allow the expert system to become more useful.

At the same time, development should be initiated in cooperation with the FHWA to provide on-line operations planning techniques. These would include corridor simulation models, near term forecasting techniques, and optimization modeling, all designed for real-time use. The work will be "research and development" in nature so the overall Smart Corridor project should not depend on early success of the effort. Instead, development should occur as the Smart Corridor system becomes operational so that it may be tested against developed plans. When the operational modeling is proved effective, it can then be used to greatly automate planning for new conditions, planning in other corridors, and serve as the basis for future real-time optimization and control.

SMART CORRIDOR

CONCEPTUAL DESIGN STUDY

SYSTEM CONFIGURATION

Prepared By:
JHK & Associates

May 1989

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1 - INTRODUCTION

THE ROLE OF THE SMART CORRIDOR SYSTEM

A previous document ("Discussion Paper: Central Data Base System") presented various options as to how the Smart Corridor System could interact with existing systems such as ATSAC, SATMS and the dispatch systems. During the course of the conceptual design study, it has been decided that the scenario which will form the basis of operation of the Smart Corridor is as follows:

a. The SC system serves as a central site for gathering information describing traffic flows within the network and recognizing area-wide problems

b. The SC serves as a repository for condition/response plans

c. Each agency is responsible for devising, executing and maintaining the response plans

d. The SC is accessible to other systems to provide real-time information on traffic conditions in the network

The Discussion Paper mentioned above presents the basic concepts which are built upon in this document.

The purpose of this document is to examine software and hardware alternatives for the Smart Corridor project. In order to achieve this goal it is first necessary to develop a more detailed description of the Smart Corridor System and its functionality. However, this document should not be conceived as a design or functional description for the Smart Corridor System.

The layout of this document is organized in several sections. The next section provides abbreviations, terms and conventions that will be used throughout the remainder of the document. The list of terms is not exhaustive, but is primarily intended to provide a basis for future discussions. Specifics related to the presentation of the system description and abbreviations used in that description are provided.

Section 3 presents a design outline for a proposed Smart Corridor System. While this design is still at a very high level, with many details yet to be finalized, it presents the system in greater detail than previously provided. The "design" section makes use of data flow diagrams, functional descriptions and data definitions to formalize the system process. This section makes no assumptions as to hardware requirements.

Section 4 presents an evaluation of possible system configurations in order to derive a recommended system architecture. Section 5 then takes the functions as defined in Section 3 and distributes them through the system architecture. With this combination of functions and their location in the system, Section 5 goes on to present recommendations for system software.

From the system configuration and software requirements defined in the foregoing sections, Section 6 derives inter-system communication needs and translates them into communications equipment. In addition, an example is given of systems hardware which provide the required environment.

Section 7 presents provisional cost estimates for the system hardware, software and communication elements derived in the foregoing sections.

2 - DEFINITIONS AND CONVENTIONS

TERMINOLOGY

This document makes use of terminology that may be unique or that is used in a special way in the current context. In order to provide a common framework for future discussion a list of terms is provided below. (A list of abbreviations is provided in Table 2-1).

Link - a unique section of roadway (arterial or freeway); the smallest section of roadway that may be addressed by the Smart Corridor System, usually from one intersection to the next (see Figure 2-1)

Segment - A contiguous group of links, usually linear in nature

Area - A grouping of links that might not be contiguous

Congestion - The constriction of flow within the roadway network, due to demand being greater than realized capacity

Measure of Congestion - Some composite measure of the degree of congestion along a link or group of links. This measure will be used in reporting and display applications, the exact measure has yet to be defined

Incident - Unplanned occurrence that reduces the capacity of a link or links

Incident Report - The mechanism that identifies an incident to the Smart Corridor System, there may be several incident reports for each individual roadway incident

Event - Planned or know occurrence that reduces the capacity of a link or links, in general the Smart Corridor processes will treat events as future incidents

User - Any person who accesses the information stored within the Smart Corridor System (see further discussion below)

Response Plan - Those actions initiated by Smart Corridor processes in response to incidents

Within the design description presented below several conventions are utilized. The initial description of the SC system is one that generally follows data flow diagramming (DFD) practices common in the software development industry. (Figure 2-2 provides the symbols that are used for later diagrams). In this presentation the, initial focus is on data that exist within the system and then on the components that

TABLE 2-1

ABBREVIATIONS

IR - Incident Report

DD - Detector Data

RP - Response Plan

MI - Motorist Information

ES - Expert Systems

SS - System Status

TI - Traffic Information

SC - Smart Corridor

SCC - Smart Corridor Central

SC_ATSAC - Smart Corridor Functions at ATSAC

SC_SATMS - Smart Corridor Functions at SATMS/CALTRANS

SC_SCRTD - Smart Corridor Functions at SCRTD

DB - Data Base

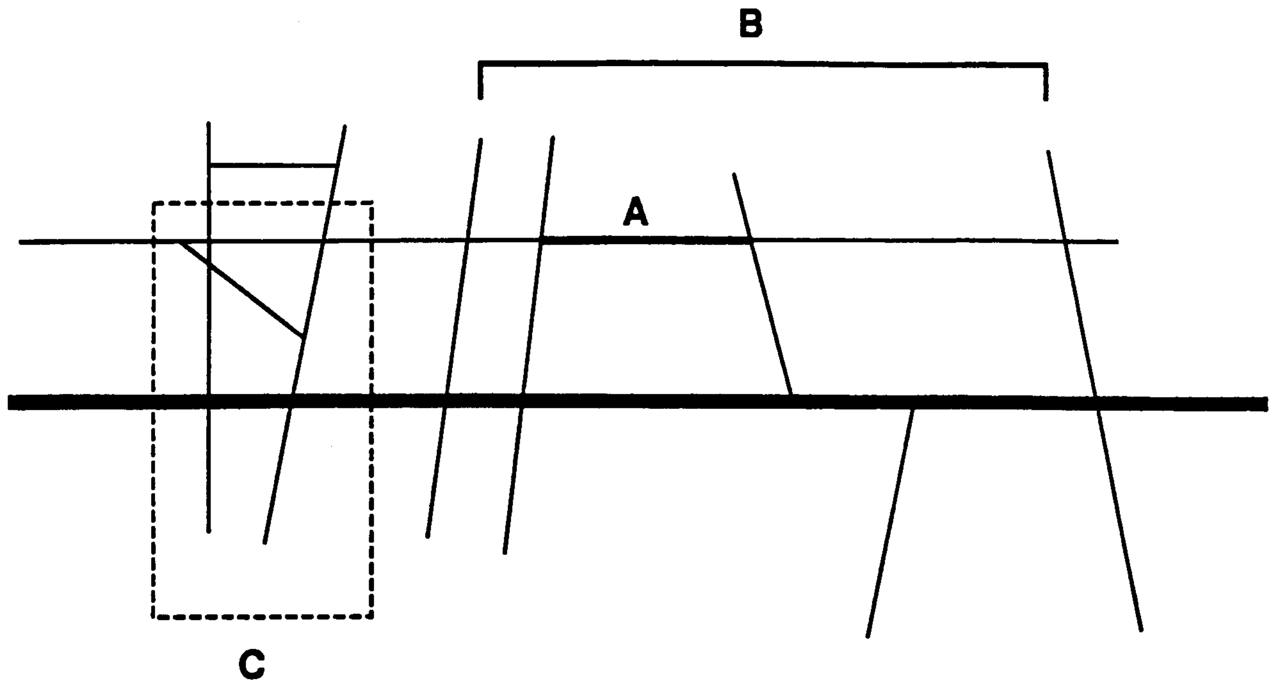
UI - User Interface

TUI - Textual User Interface

GUI - Graphical User Interface

MSG - Message

MUI - Motorist User interface



A -Link
B -Segment
C -Area

FIGURE 2-1 LINKS, SEGMENTS, AREAS

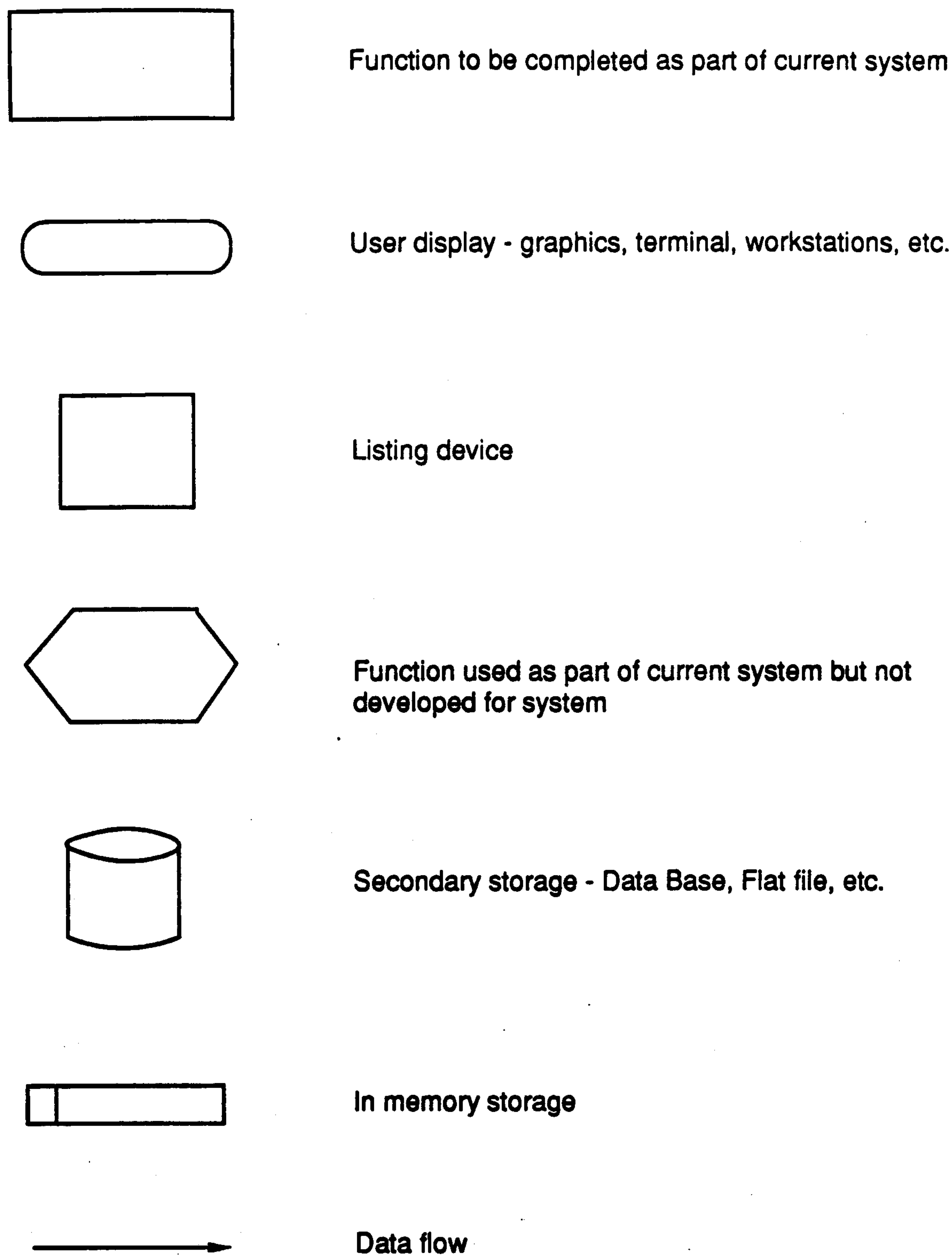


FIGURE 2-2 DIAGRAM SYMBOLS

act upon these data. The overall design is decomposed into finer and finer detail until specific functions can be identified.

The description that is presented is not of sufficient detail to be called a true design specification and it does deviate slightly from standard DFD techniques. The major deviation is in regard to the naming of data flows. In general, data flows should be unique units that describe one data object within the system. However, at the level of detail presented, such a policy is not possible, therefore, many flows will actually be a grouping of data composed of several basic data types. Such an approach would not be allowed in a final design. (Unique data flows will be provided whenever possible). The basic data composites are presented in table 2-2.

SPECIFIC CONCEPTS

Users

The concepts of user and user interface are central to the success of a system like Smart Corridor. User has been defined as any person that accesses information within the system. However, it is obvious that not all users should have equal access to the SC system. Therefore a refinement of user lever has been developed. At the very lowest level are those users that can only receive information from the system. This level would be filled by certain motorist. The next level would be those users that can request information from the system. This level is further divided into users with access to all information and those that have access to only certain aspects and presentations of the data. For example, certain Motorist Information functions allow the user to request specific information but the system would allow a restricted view of the system as compared to the access given to an agency at a report terminal. Such access could be controlled by hardware limitations of MI functions as well as a privilege scheme involving password mediated access. Finally, the highest level of user would be the group that can modify or make additions to the data base. This level could also be sub-divided to allow certain users modification access to only certain types of data (e.g. reporting, but not declaring, an incident).

Congestion

Another concept is that of congestion. For discussion and preliminary design purposes it has been assumed that a measure can be assigned to a link that will

TABLE 2-2

COMPOSITE DATA ITEMS

NAME	DESCRIPTION	EXAMPLE COMPONENTS
Textual Data	any text based data (elements can be entered and changed by users)	Incident Reports Response Plans Expert System Data Link Data Modeling Data
System Status	data that might be used to derive status of a system (elements may not be altered by users)	Measures of Congestion Incident Reports Active Response Plans Hardware Status Link Data (other) Text Data
Traffic Data	data describing traffic patterns and flows (elements not usually altered by users)	Measures of Congestion/ Detector Data Incident Report Hardware Statues
Link Data	traffic data on a link basis	Measure of Congestion Incident Reports Link Text Data
ES Data	data required for expert system modules	Rules Miscellaneous Data
Response Data	data required to request, execute and reply to a system condition	Response Response Plan Response Message Reply

describe the level of congestion on that link. The measure would be based on processed detector data and would provide a range of congestion. The measure would be used as part of the reporting mechanism and would be especially useful on graphics displays. Such a value would also be used to determine alternate plan selection. The actual form of the measures of congestion has yet to be established. It is recognized, however, that part of the Pathfinder In-Vehicle Navigation Field Trails project is to establish a measure of the level of congestion based on data from several different sources. It would be logical to assume the possibility of utilizing this work to establish an algorithm for the Measure of Congestion in the SC system. As a minimum this would provide for a degree of commonality between SC Central and Pathfinder Central data. Whatever the final algorithm, previous research on levels of service, of which there is a significant amount, would need to be taken into account in establishing a quantitative measure for congestion.

ALTERNATE RESPONSE PLANS

A final concept that requires some explanation is that of the Alternate Response Plan. The response plan has been conceived as a set of actions to be performed by local agencies based on information provided by some central processing software (that is, Smart Corridor Central). The RP will affect traffic flow for a relatively large area of the corridor. In current conception a Response Plan would be composed of one to several smaller units referred to as Responses. The Response at the central level would consist of a Response ID code and a description of actions that were expected at the local level. Part of the incident management process would be to combine these responses into a Response Plan that can be delivered to the local agencies for appropriate actions. The request that is delivered to the local agency would be a message consisting of a list of response codes. The local agency would be responsible for maintaining the actions required to perform each response. For example, ATSAC agrees that if a certain section of the freeway becomes blocked than it will enact timing plans that favor an east to west flow for given sections of the parallel arterials. When such an incident is reported by CALTRANS, the SC system would send the message to ATSAC that the condition had occurred. Once the local agency agreed to enact the response plan the Local Smart Corridor software would aid in executing the plan.

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3 - SYSTEM DESCRIPTION

This section presents a high level description of a Smart Corridor system using three different components. The first component consists of diagrams loosely conforming to Data Flow Diagramming practices. (See discussion above relating to DFD standards). The second component will provide text descriptions of functions presented in the data flows. The final component will present descriptions of data objects that have been relatively well identified by the other two components.

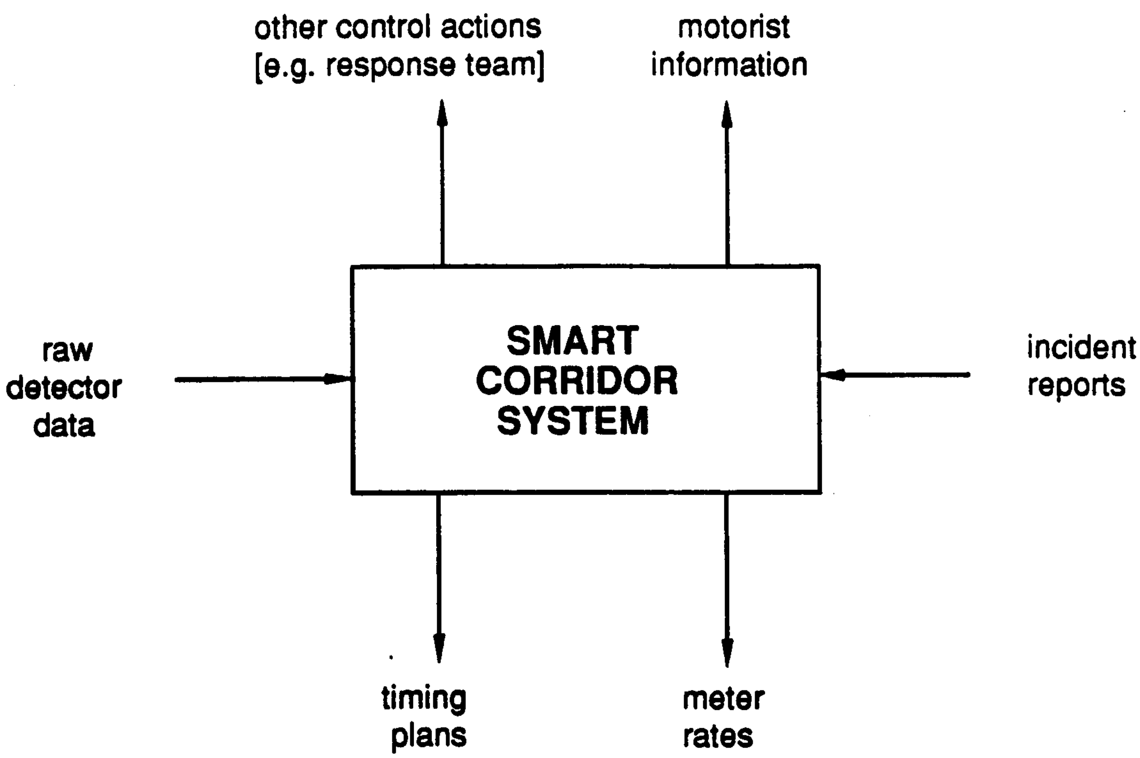
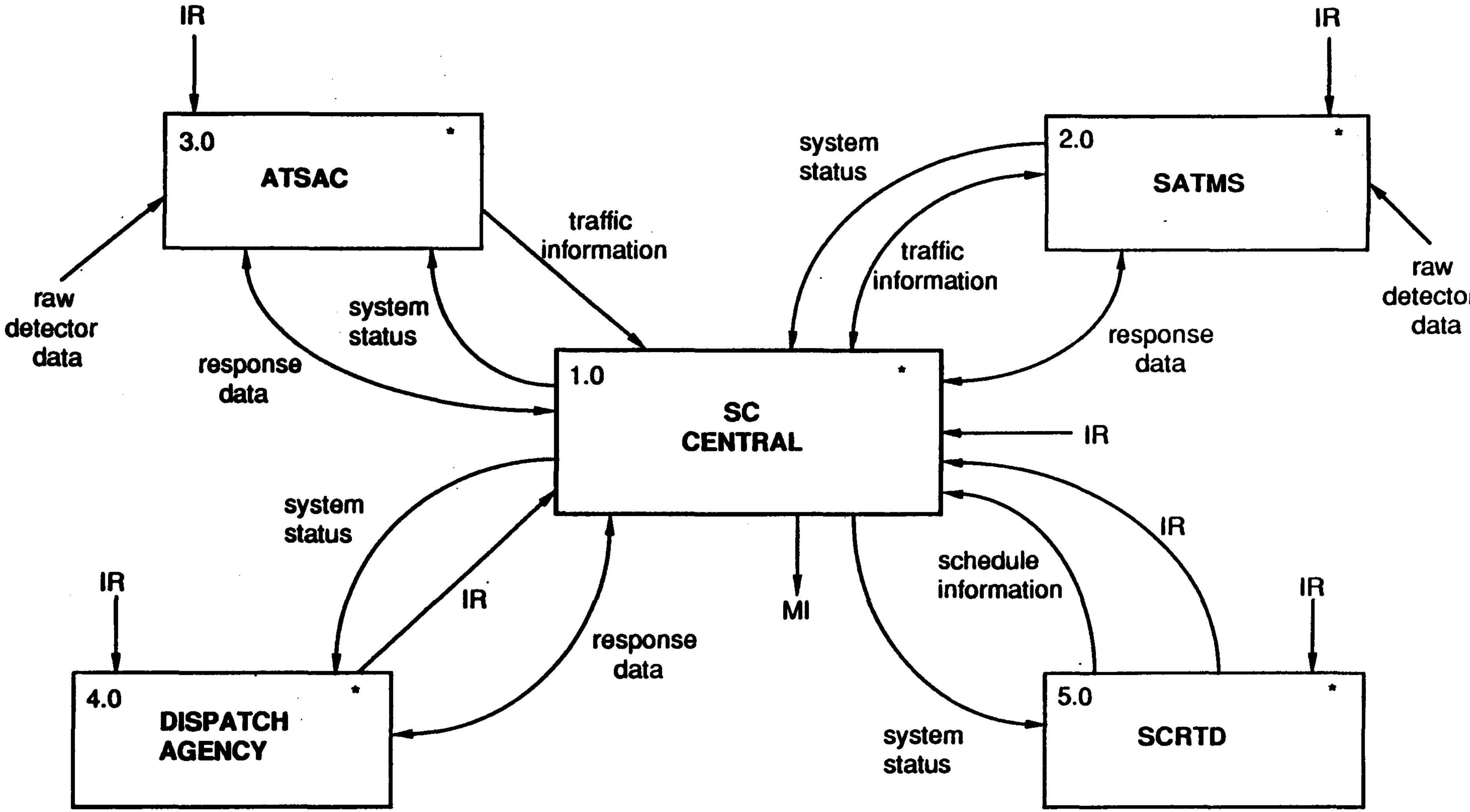


FIGURE 3-1 CONTEXT DIAGRAM

SMART CORRIDOR CONTEXT

Figure 3-1 presents the context diagram for the SC system. At this level Smart Corridor can be viewed as a single function whose inputs consist of raw detector data and incident reports provided from a variety of different sources (including participating agency analysis, motorist input, officer reports, etc.). The system outputs consist of timing plans, meter rates, other control actions (such as incident response team intervention) and motorist information.



* More detail provided

FIGURE 3-2 INITIAL DETAIL

Initial Detail

Figure 3-1 can be expanded into (slightly more) detail as presented in Figure 3-2. This figure presents the major participants in the Smart Corridor project, along with refinement as to the data that they might exchange. From this diagram the participants are: ATSAC, SATMS (CALTRANS), dispatch agencies (CHP, LAPD, LADOT parking control) and SCRTD. In general each participant provides traffic information (congestion, incident reports, etc.) to SC Central and in return receives response plans from the same source. Each agency also has access to a group of data items that can be used to describe the system status. (Note: The term Smart Corridor Central refers to central high level functions, the device performing the processing may or may not be at a central site).

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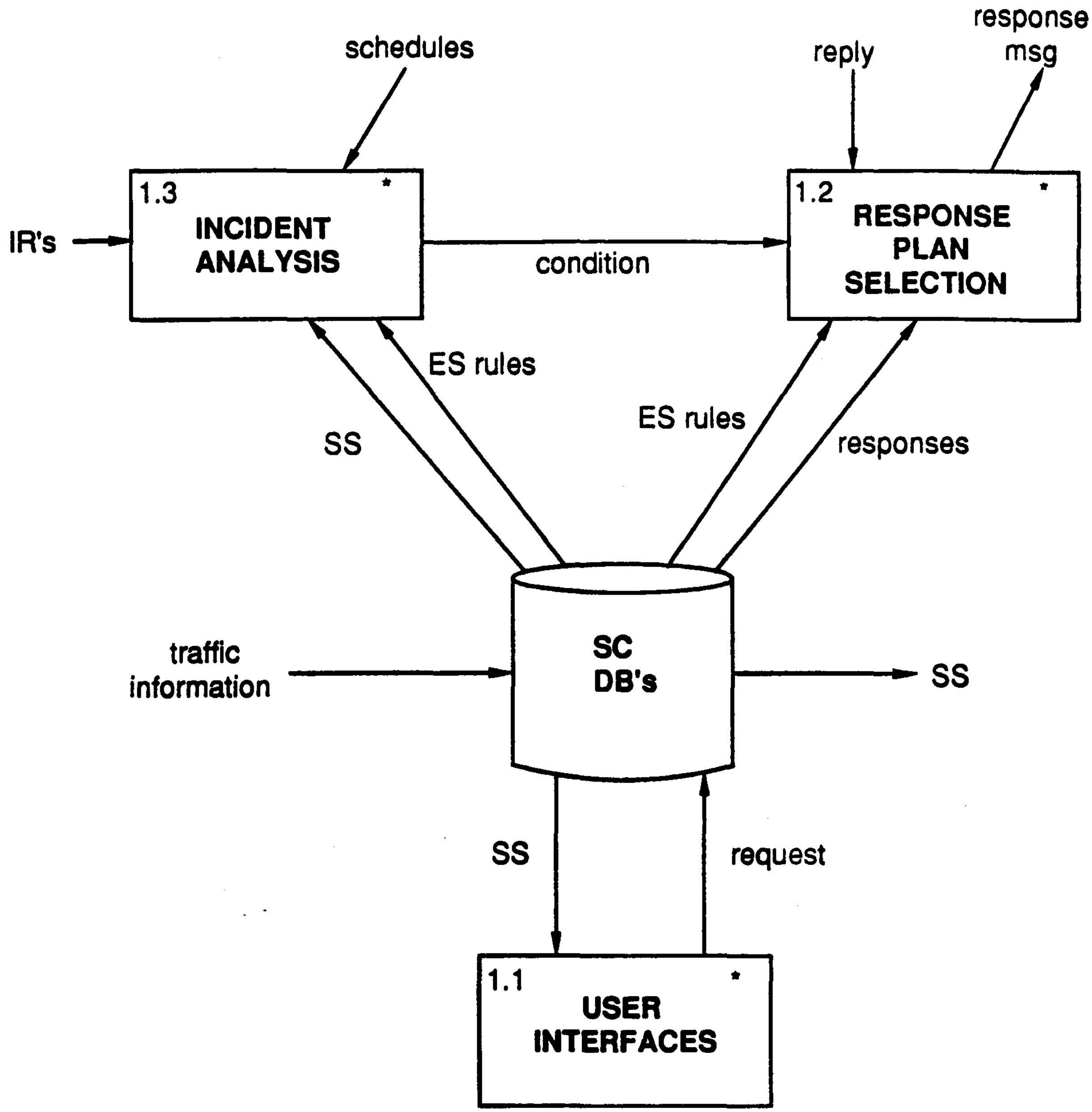

FIGURE 3-3.a SMART CORRIDOR CENTRAL

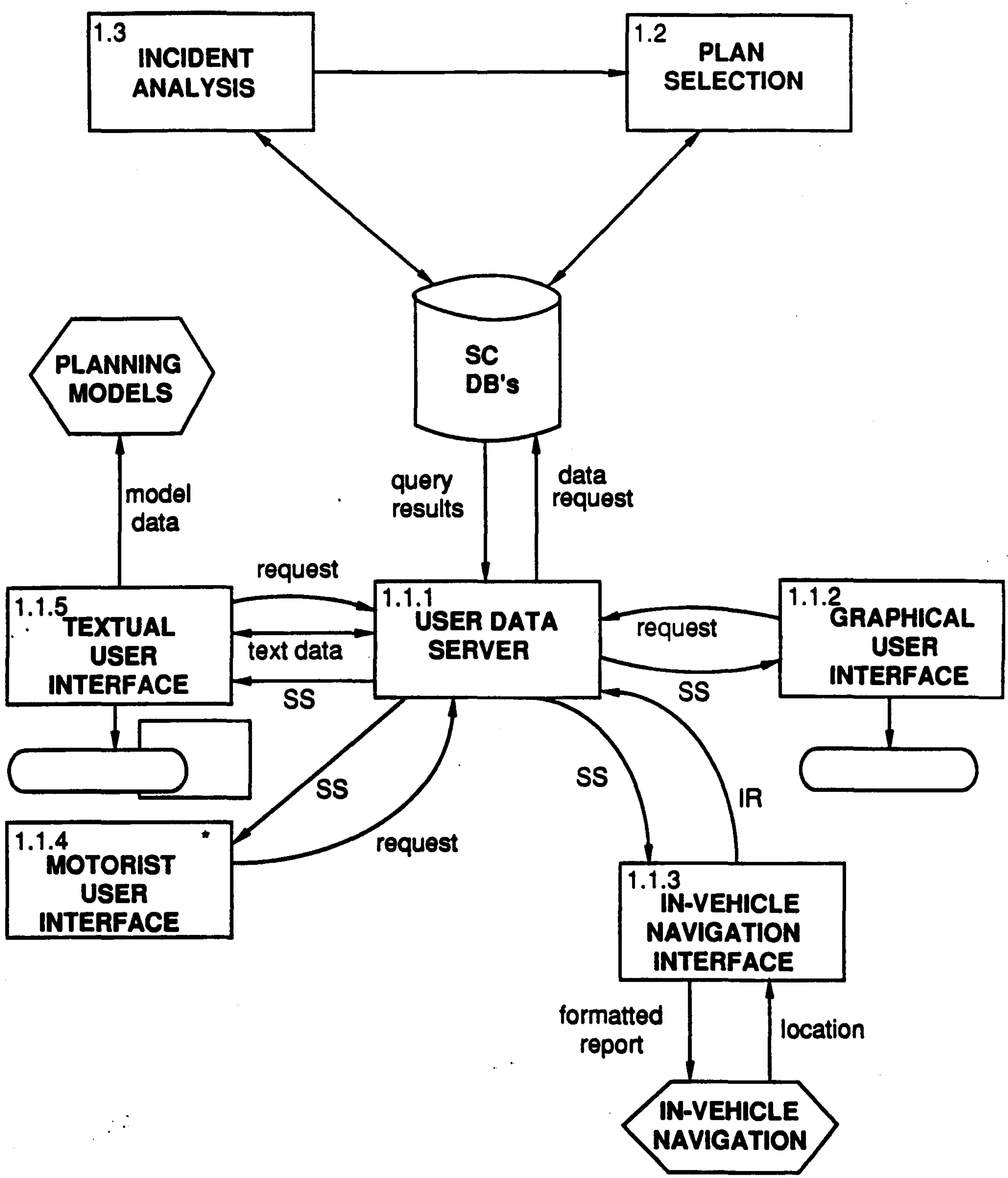

FIGURE 3-3.b SMART CORRIDOR CENTRAL - USER INTERFACES

SMART CORRIDOR CENTRAL: USER INTERFACES

Figure 3-3.a presents the major components of Smart Corridor Central: Incident Analysis, Response Plan Selection and User Interfaces. This diagram is further decomposed in figures 3-3.c and 3-3.d. Figure 3-3.b presents an exploded view of the SC user interfaces. Based on earlier discussions, all access to the system is through one of the three basic user interfaces. The Textual User Interface provides access to all text based data objects within the system. Objects may be entered or altered, reports generated and queries issued based on the level of access for the given user. The Graphical User Interface provides exactly the same type of interaction for all graphics based objects in the data base. (For most users the emphasis will be on display --however the GUI will also be used for locating incidents within the roadway system). One very important aspect of this diagram is the Data Server task. This task is the common (high level) mechanism by which all user interfaces access the data base. This mechanism is responsible for providing the levels of user access described above.

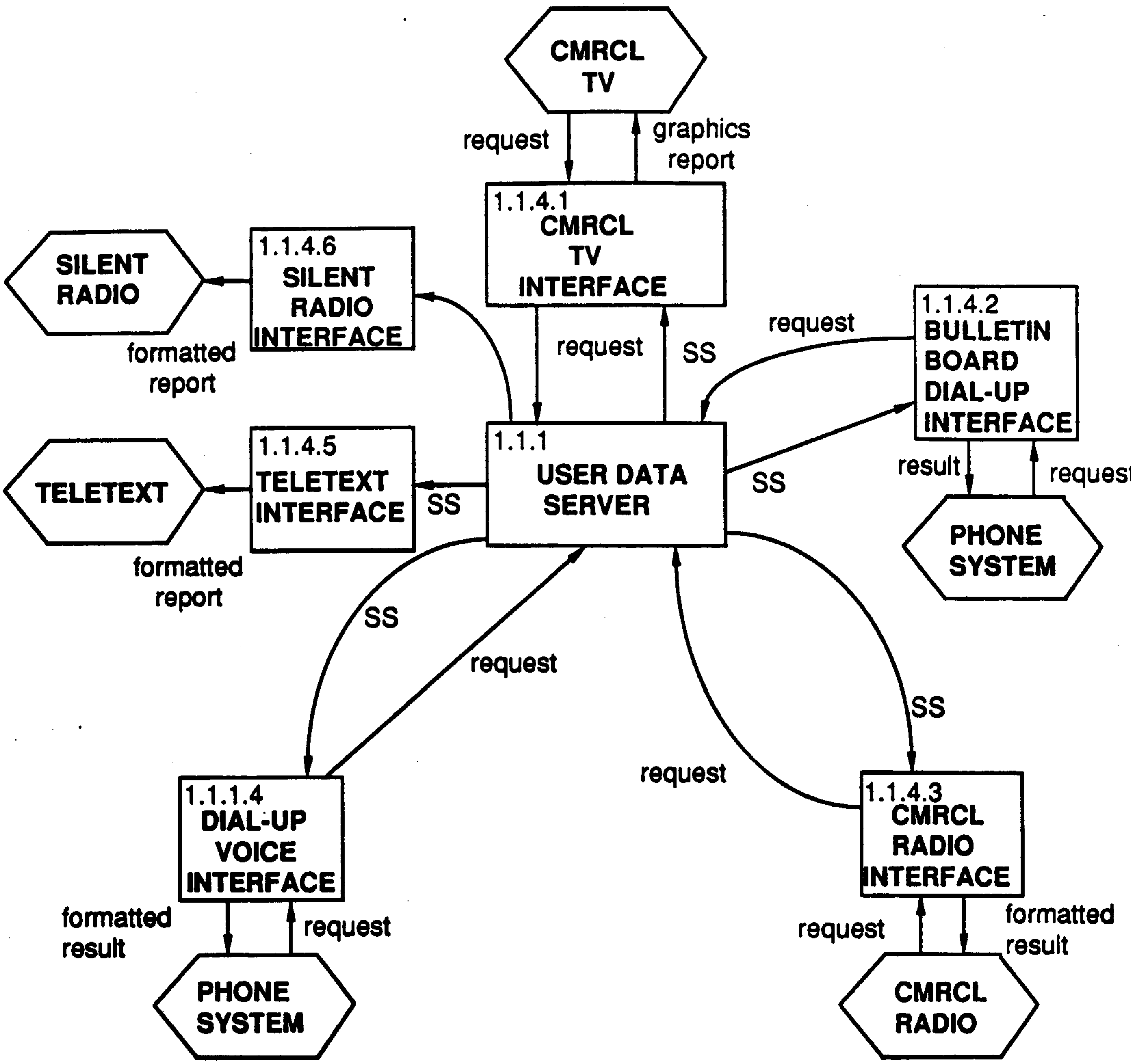

FIGURE 3-3.c SMART CORRIDOR CENTRAL MOTORIST USER INTERFACE

SMART CORRIDOR CENTRAL: MOTORIST USER INTERFACE

The Motorist User Interface can be further decomposed and is presented in Figure 3-3.c. Each of the MI functions can be characterized as a special case of the same basic operation. A request (either implicit as in the case of silent radio or explicit as in the case of dial-up voice access) will be made against the data base. The data grouping of System Status will be returned to the specific interface and formatted for the specific method of presentation.

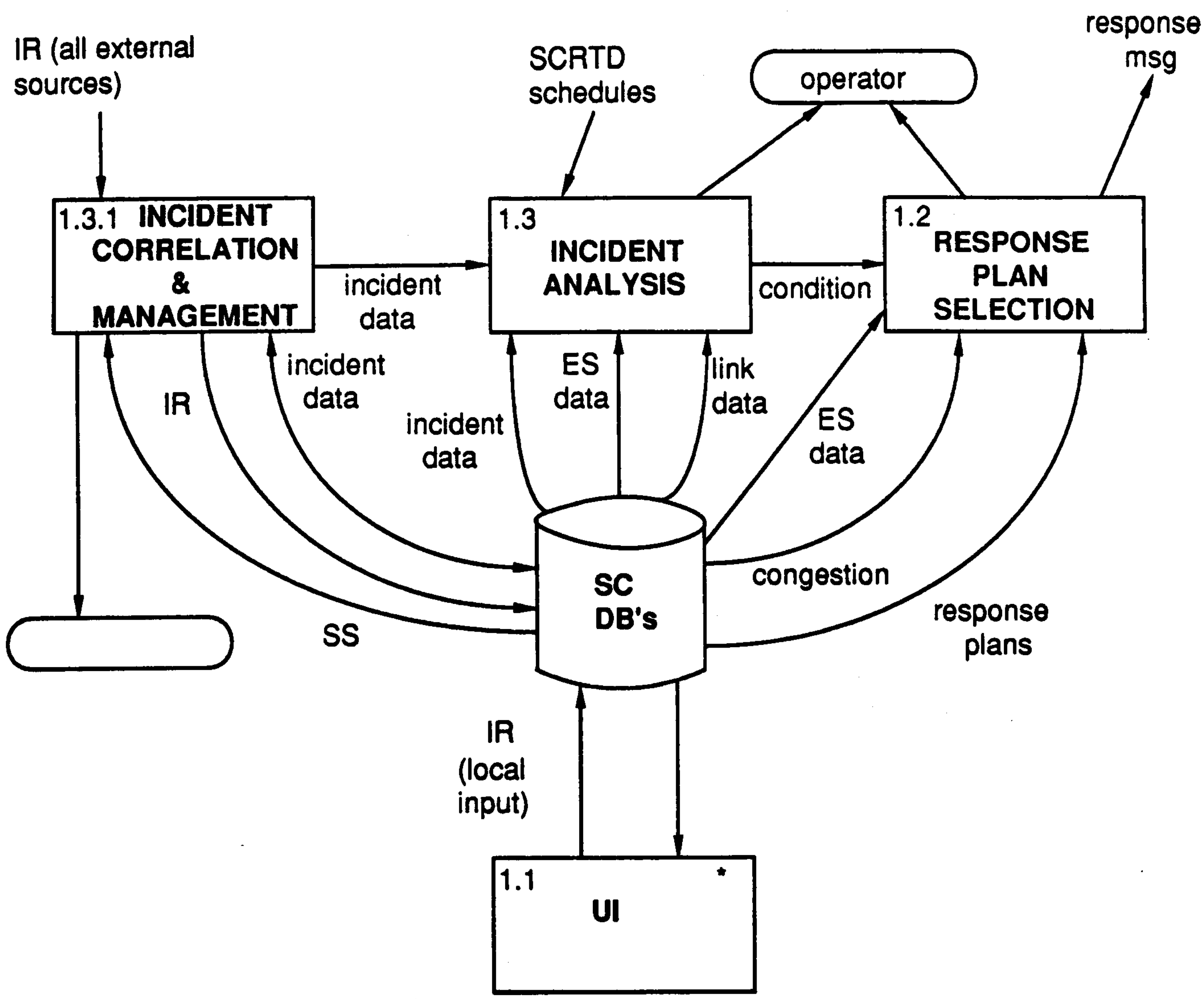

FIGURE 3- 3.d SMART CORRIDOR INCIDENT ANALYSIS & PLAN SELECTION

SC CENTRAL: INCIDENT ANALYSIS AND RESPONSE PLAN SELECTION

Figure 3-3.d provides greater detail for the SC Central incident detection and response plan selection. The function, Incident Correlation and Management, is responsible for producing one "actual" incident record in the data base for incident reports provided to SC. The Incident Analysis function is an expert system based module that will make use of various data objects (link status data, expert rules, etc.) to determine which incidents will require Smart Corridor action. Once the Incident Analysis function has determined that an action is warranted, the Response Plan Selection function selects which of numerous response plans will be issued. This function will make use of expert system rules, current traffic conditions and hardware status to make its decisions.

One of the major inputs to this process comes from the data base's knowledge of "future incidents" or events. These are planned incidents such as road closures for construction or demonstrations, the details or which are manually input into the system data base. In this way the system can provide for the tracking of such events and take their existence into account when analysing a report or assessing response plans.

A user will be able to plot the location of events graphically and with respect to time (i.e. current, future between given dates) and be able to access the data on that event through the graphical user interfaces (GUI's).

A further use of the facilities provided by a GUI is in the identification of a response plan. Each response plan will have associated with it a "signature" which is an indication of the base function of the plan (e.g. East to West preference, off-peak). It will be possible to define an icon for each response plan which pictorially defines the plan signature and which would be used to indicate which response plans were in action as well as providing an easy means for operator assessment and manual selection of the plan.

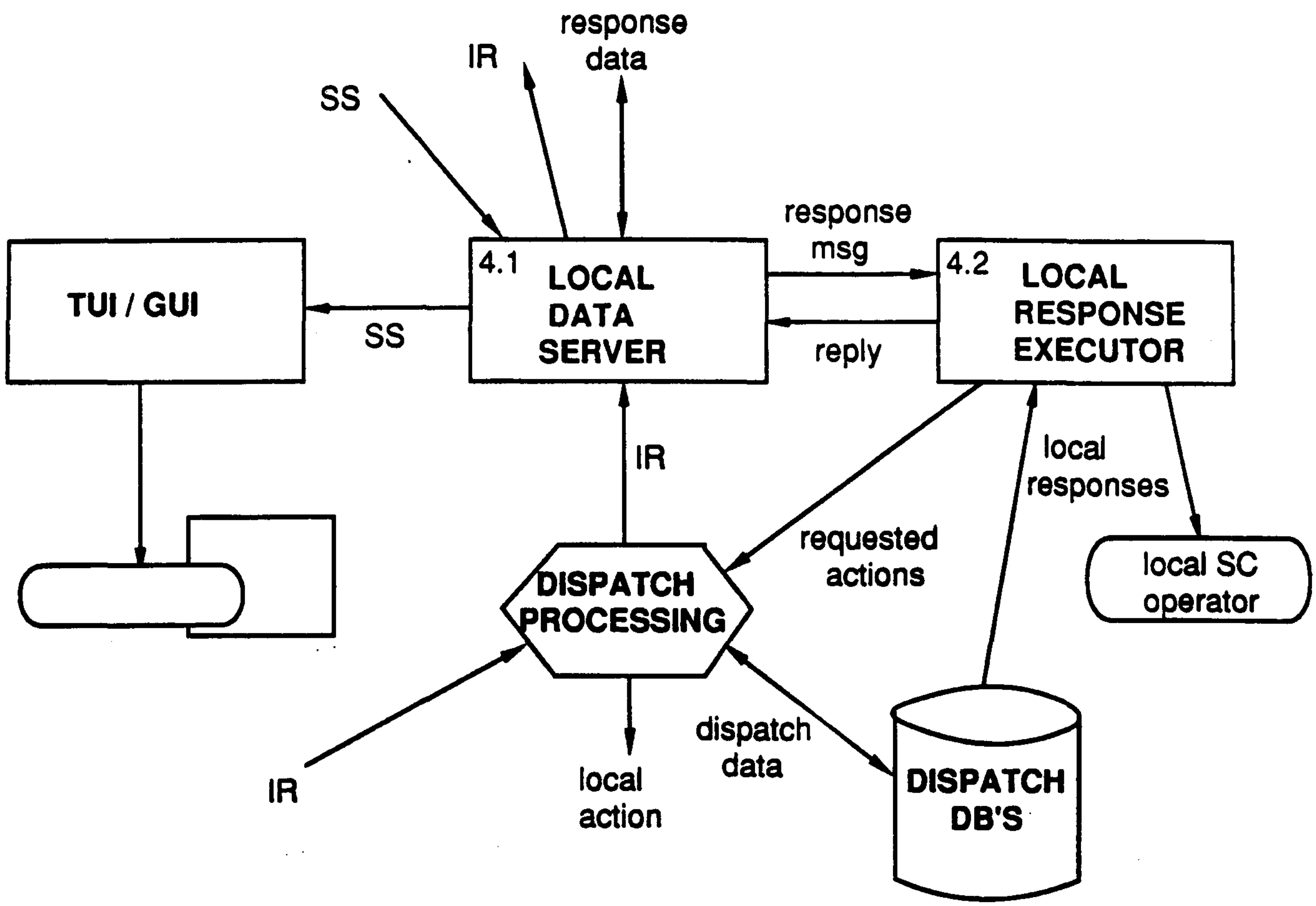

FIGURE 3-4 SMART CORRIDOR - DISPATCH AGENCY

SC LOCAL: DISPATCH AGENCIES

Figure 3-4 provides detail for Smart Corridor processing at a dispatch agency (CHP, LAPD, LADOT parking). A Local Data Server, similar to the user interface data server, mediates all data accesses between SC central and the agency. The server also has the added responsibility of extracting Incident Reports from the local agency and sending them to SC central. The local response executor processes response messages received from SC central and "expands" them into meaningful actions that the agency can perform. The Response Executor is also responsible for querying the local agency as whether it will comply with the response plan and relaying this reply to SC central. The TUI/GUI interface will be the same basic interface available at SC central.

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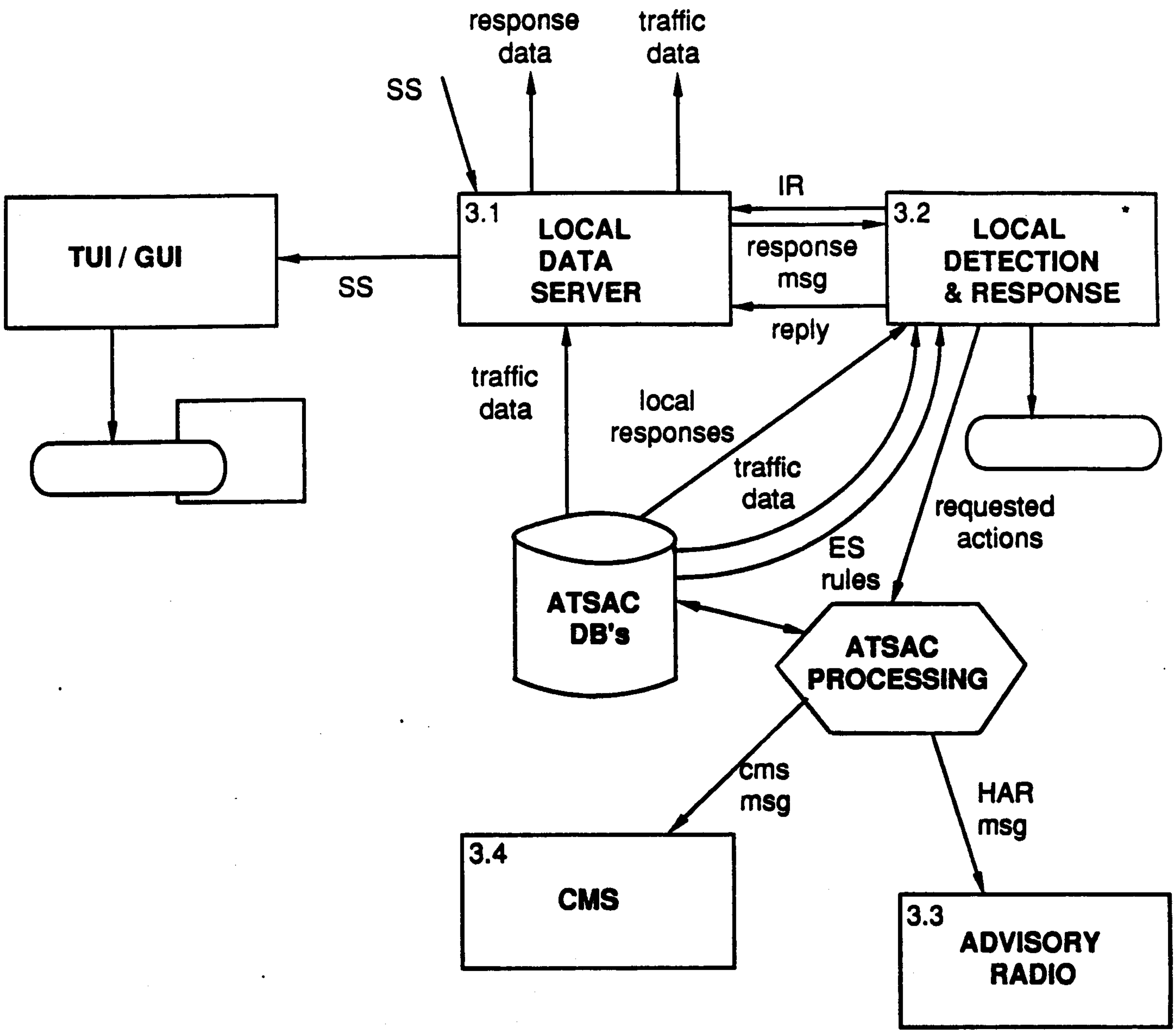

FIGURE 3-5.a SMART CORRIDOR - ATSAC

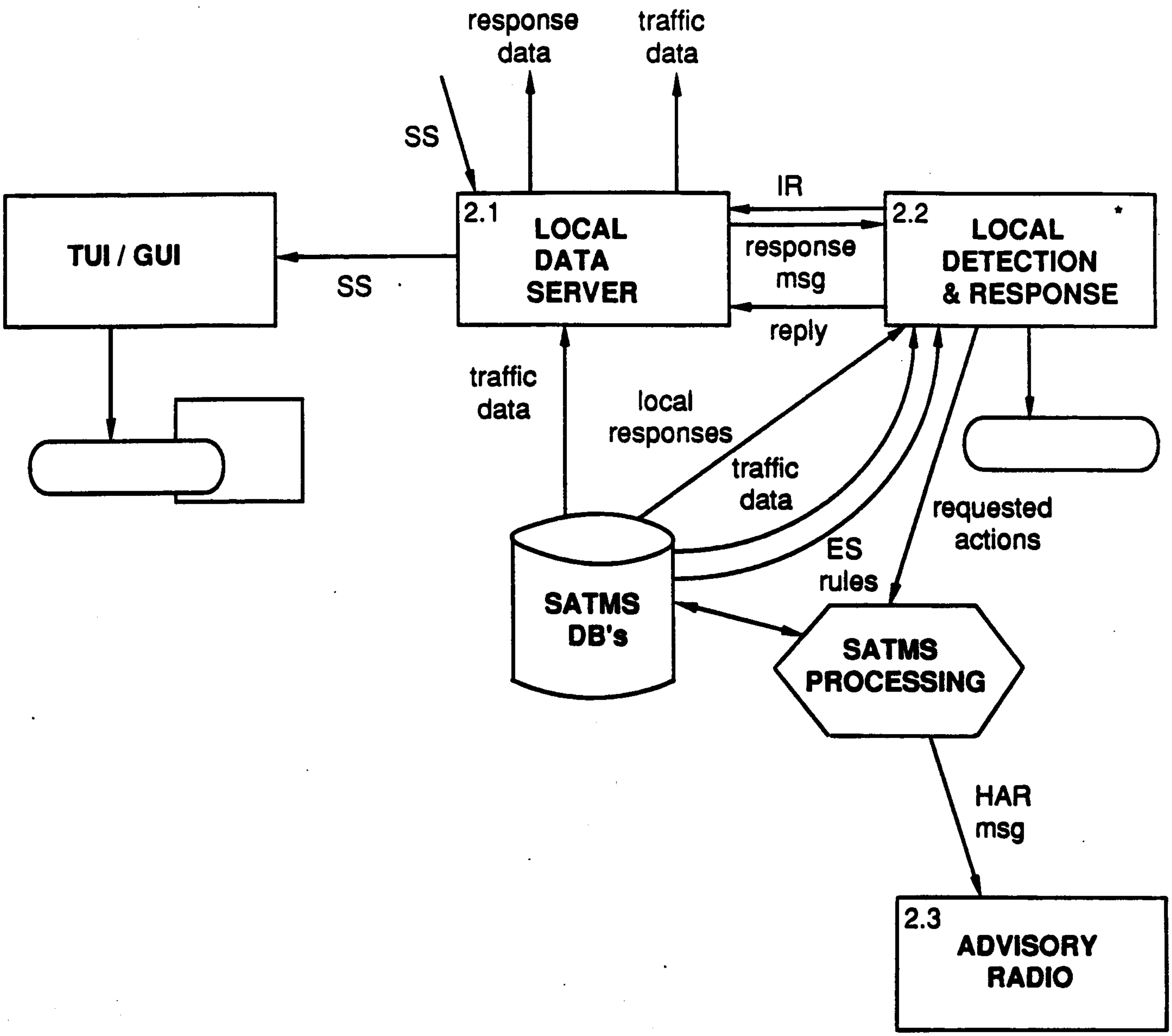

FIGURE 3-5.b SMART CORRIDOR - SATMS

SC LOCAL: ATSAC/SATMS

Figures 3-5.a and 3-5.b provide detail for SC processing at ATSAC and SATMS, respectively. The processing is conceptually similar, therefore, both are presented here. A Local Data Server provides access to data residing at SC central. A TUI/GUI interface is provided that is identical to the one available at SC Central. The detection function of Local Detection and Response receives traffic information and Exert System rules from the local data bases and identifies local incidents that are reported to SC Central. The Local Detection and Response function identifies incidents, expands response messages from SC Central and issues a response reply based local action.

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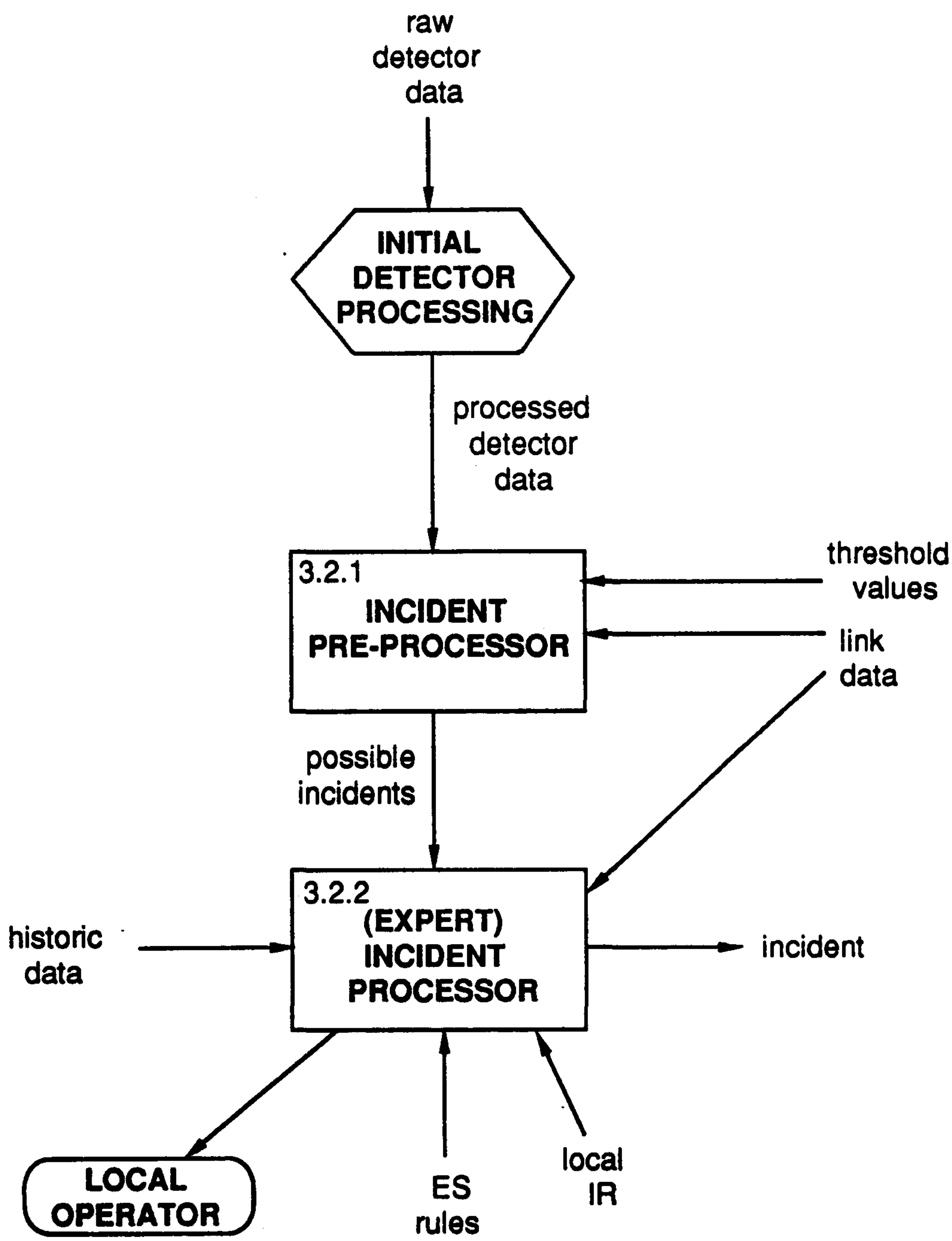

FIGURE 3-5.c SMART CORRIDOR - LOCAL INCIDENT DETECTION

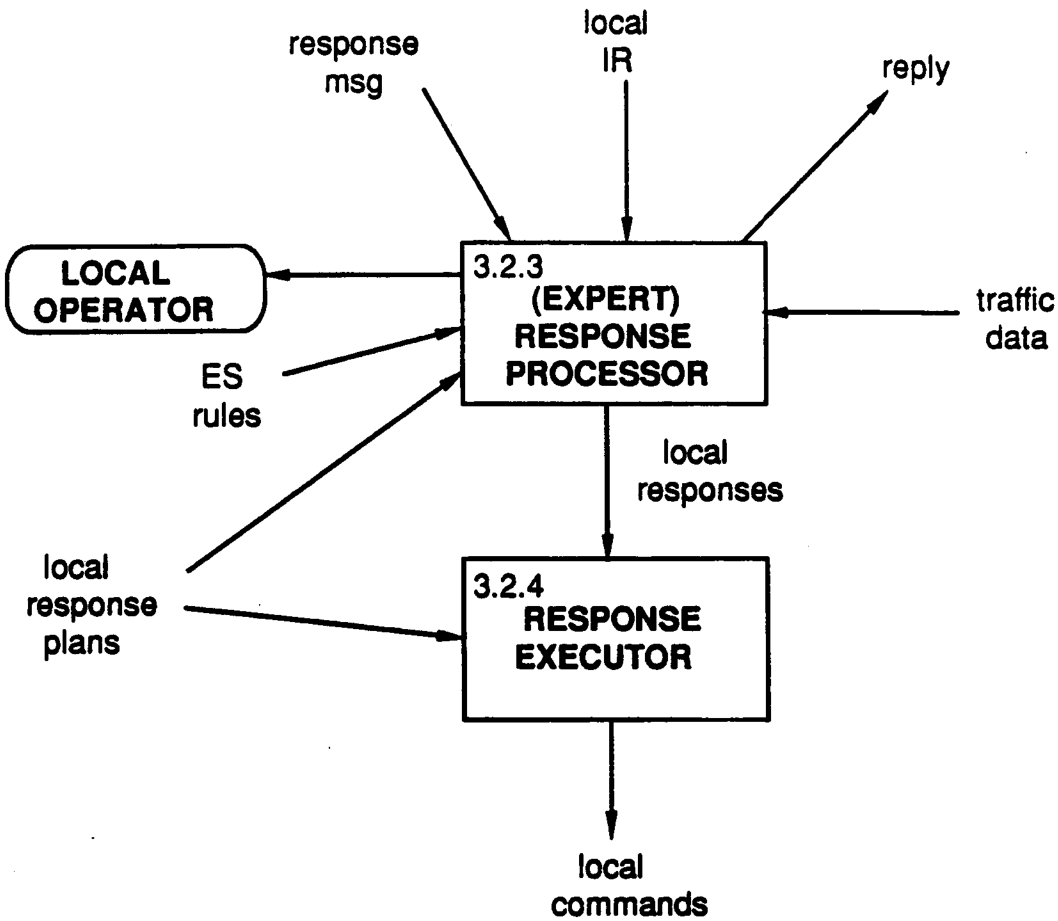

FIGURE 3-5.d SMART CORRIDOR - LOCAL RESPONSE

LOCAL INCIDENT DETECTION

Figures 3-5.c and 3-5.d provide further decomposition of the detection and response functions. From the diagrams, local detector data is processed by the software existing at each agency. The processed data is then passed to an algorithmic Incident Pre-processor. (Such software exists at SATMS). The Incident Pre-processor uses threshold values and link data to identify possible incidents within the system. Possible incidents are passed to the Expert Incident Processor. This function makes use of expert system rules, link data, historical traffic data, existing incident reports, and operator input to identify actual system incidents. The response function uses locally stored response plans expert system rules, traffic data and operator input to expand the SC Central generated response message and issue a reply as to the agency's actions. The response executor, in particular, once approved by the operator, will issue the local commands to enact the response plan.

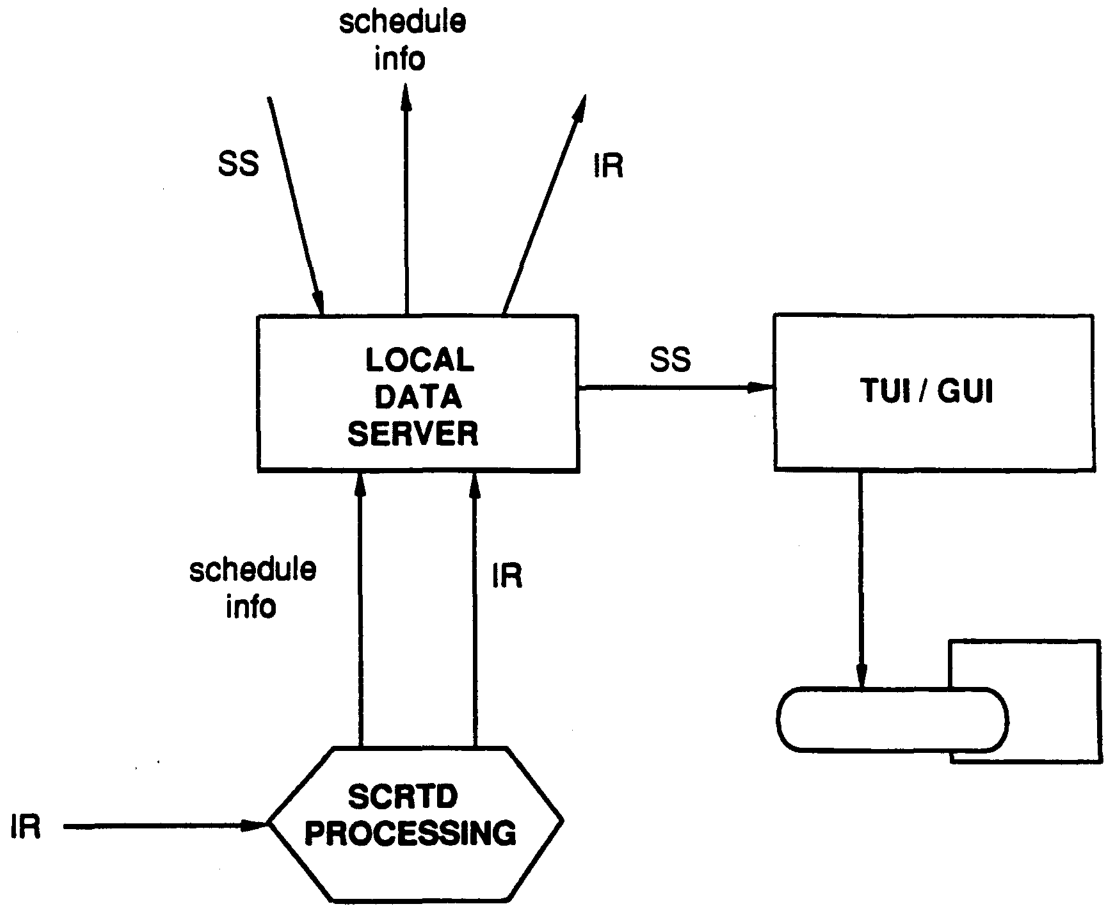

FIGURE 3-6 SMART CORRIDOR - SCRTD

SCRTD

Figure 3-6 presents the local SC functionality for SCRTD. The local Data server provides access to bus schedules and allows local operators to access SC Central data through TUI/GUI.

SYSTEM PROCESSES

In order to establish software, hardware and system communication requirements, it is necessary to take the data flow diagram analysis as presented above and produce a detailed definition of the various processes involved. This further breakdown of functions is presented in this section. The process/function descriptions are presented in a set format for ease of use later in this document when software, hardware and communications requirements are derived.

SYSTEM PROCESSES

Data Management

Designation - Part of data base software

Data In - All data base data

Data Out - All data base data

Description - Data Management is the set of functions responsible for maintaining the basic data of the SC system. In particular, the Data Manager allows data to be stored and accessed in such a way as to accurately represent (model) the "structure" of the real world data. Such a representation aids in both design and implementation. The Data Manager is also responsible for providing a safe, efficient, and consistent access mechanism for all higher level processes which is transparent to these processes. The majority of the functions will be supplied by the Data Base Management software with specific interfaces developed on an as needed basis (see User Server).

Notes -

Components -

1. provide data integrity
   a. data locking
   b. system failure

2. manage secondary storage
   a. file access
   b. storage optimization
   c. create storage allocations
   d. manage access indexes, hash tables, etc.
   e. archive data

3. access data
   a. order data
   b. select data
   c. aggregate different data types
   d. read from storage
   e. write to storage

SYSTEM PROCESSES

User Data Server

Designation - 1.1.1

Data In - Data requests from user interface tasks

Data Out - Data returned from data base: text data, system status

Description - The User Data Server is responsible for providing a consistent interface to the data base for all user processes. The Data Server will provide user access management (see User Access), and all high level functionality with regard to data access. In general, most data accesses will be of a similar nature and appearance. The User Data Server will provide the mechanism to manage the requests for data and the transfer of the data from the data base interface back to the requesting task. The Data Base Server will also be responsible for assuring that input data is of the proper form for data entry.

Notes -

1. As with any real time system, much of the system data will have a time critical nature -- one design strategy is to maintain this data in memory rather than on disk. The User Data Server will be responsible for managing this dual storage approach.

Components -

1. User Access control

2. request data
   a. build request
   b. issue request
   c. error checking and recovery

3. buffer returned data

4. pre-format data interface
   a. package data
   b. send data
   c. error checking and recovery

SYSTEM PROCESSES

Local Data Server

Designation - 2.1, 3.1, 4.1

Data In - user requests, local data

Data Out - request results, accumulated local data, incident reports, system status

Description - The Local Data Server is responsible for providing a specialized data interface to all agency processes. A large portion of the Local Data Server functionality will be identical to the User Data Server -- data request processing, user access, etc. The Local Data Server will also be responsible for extracting local data (particularly ATSAC and SATMS) on a periodic basis, formatting and converting it to a common measure, and shipping large blocks to the central data area.

Notes -

Components -

1. User Access control

2. request data
   a. build request
   b. issue request

3. buffer returned data

4. pre-format data interface
   a. package data
   b. send data
   c. error checking

5. extract local data

6. convert and format for central use

7. transfer data

8. error checking and recovery

SYSTEM PROCESSES

User Access Manager

Designation - Part of 1.1.1

Data In - User passwords, user authorizations

Data Out - Authorization, audit trail entry

Description - The User Access Function will manage the various types of users that will have access to the SC system. Users can be broadly classified into three groups - those that receive information, those that can request information, and those that can modify information. (In this context information is data stored at any place within the SC system). Receive only access will be hardware controlled and include silent radio, teletext, etc. Request access will be both hardware and password controlled -- for example the dial-up voice interface will be a hardware control and TV will have access only to a subset of all SC information. Modify access will be strictly controlled by password access. (See access matrix below).

Notes -

1. An initial matrix of users and possible access is provided:

User	Cruise Central (CC)	C ATSAC (CA)	C SATMS (CS)
CC_operator	M	M	M
CA_operator	I	M	R-1
CS_operator	I	R-1	M
ATSAC_operator	I	I	R
SATMS_operator	I	R	I
Disp_operator	M-1	-	-
SCRTD_operator	I	-	-
Radio/TV	I	-	-
Bulletin board	I	-	-
Teletext/SL	R	-	-
Driver	R	-	-
Dial-up voice	I	-	-

M - Modify, I - Interrogate, R - Receive (R-1 = optional) (Access level is hierarchial in that Modify implies Interrogate and Interrogate implies Receive).

Components -

1. get user's level of access
2. compare user's level against required level for operation
3. issue error messages
4. trap illegal usages
5. update authorization audit trail
6. update authorization lists

SYSTEM PROCESSES

Textual User Interface (TUI)

Designation - 1.1.5

Data In - System status, text data

Data Out - Text data, reports, data request

Description - The Textual User Interface will allow users access to text based items within the data base. All SC data (with the exception of background graphics displays) will have some text component. Users (depending on level of access) will be able to:

1. enter new data
2. edit existing data
3. build queries to select objects from the data base
4. issue report requests
5. export results to the Graphics User Interface for display

Notes -

1. items that can be entered/edited include:
   a. incidents
   b. response plans
   c. link data
   d. expert system rules
   e. model data
   f. user access parameters (passwords)
   g. filter values

2. a Query-By-Example (QBE) approach will be taken for most data selection activities. With QBE, a screen based "form" is provided that presents a basic template of a data base record type (or types). The user fills in selected fields, the system builds an appropriate query, and returns the results into the same screen that was used for the query input.

Components -

1. query manager
   a. standard queries (output is report)
   b. ad hoc queries (output is table)

2. report generator

3. data editor

4. mail server

SYSTEM PROCESSES

Graphics User Interface (GUI)

Designation - 1.1.2

Data In - System status

Data Out - Data requests

Description - The Graphics User Interface will provide users with a basic graphics interface including facilities to build and maintain a pictorial description of the smart corridor roadway system, locate and monitor the occurrence of incidents/levels of congestion and monitor the response plans that have been initiated by the SC system. The interface will also be enhanced to provide additional data access functionality. A mechanism similar to Query-By-Example in the TUI will allow GUI to query the data base from a graphics screen. The GUI will also possess a close functional tie with the TUI that will allow operation of both functions with the same data thus providing the facility to view the result of a text query from the graphics display as well as requesting greater detail within the text interface from within the graphics interface.

Notes -

Components -

1. display
   a. high resolution
   b. low resolution

2. query manager (more limited than TUI)
   a. standard (output is display and printed report)
   b. ad hoc (output is table presented as display)

3. data editor

4. graphics editor

SYSTEM PROCESSES

Motorist User Interface (MUI)

Designation - 1.1.3, 1.1.4

Data In - Data request

Data Out - System status

Description - The Motorist User Interface is a suite of interfaces that are specific to each of the various MI methods. MI presentations can be either text or graphics based and can be thought of as special cases of TUI and GUI. Each MUI will form data requests from user input (as in dial-up voice) or based on a set of standard report requests (as in silent radio). The form of the output, text or display, will be simplified versions of those available from TUI and GUI formatted for the specific media/presentation.

Notes -

Components -

1. manage user request

2. request data

3. format for:
   a. commercial TV (graphical)
   b. bulletin board dial-up (graphical)
   c. commercial radio (text)
   d. dial-up voice (text)
   e. teletext (both)
   f. silent radio (text)

SYSTEM PROCESSES

Incident Correlation and Management

Designation - 1.3.1

Data In - Incident reports, incident data, system status

Data Out - Incident data

Description - The Incident Correlation and Management Function is responsible for the reduction of Incident Reports from multiple sources into a single Incident Record. An Incident of even a modest size might be reported by the detector based reporting mechanism, by a police officer and by several motorists. This function would assure a single incident record within the system and update the record for each additional report that is received. Once an incident has been established this function would also monitor the system status with regard to the incident and "retire" the record when it becomes cleared, request further information when the estimated time to clearing has elapsed, etc. Special cases such as events and recurring congestion will also be monitored by this task.

Notes -

1. There will be a response mechanism to deactivate a given response plan once the incident has cleared

Components -

1. receive incoming IR
2. check data base for co-responding IR
3. create/update Incident record
4. monitor system status and Incident records for cleared incidents
5. create historical record, delete Incident record, delete IR's
6. query operator for additional information

SYSTEM PROCESSES

SCC Incident Analysis

Designation - 1.3

Data In -

1. incident reports - data include location, capacity reduction, type, expected duration and quality; report sources:
   a. automatically detected by control agencies
   b. incident reports from CAD type agencies

2. SCC operator input

3. knowledge

4. link data - geographical location information

Data Out - Validated incidents. Location, capacity reduction and quality

Description - Reports from various sources are correlated to determine which correspond to the same actual events. Correlation is performed on the basis of time and geographic location. The quality of the reports are accumulated to verify an incident.

Notes -

Components -

1. incident preprocessor - collects incident reports and places them in the incident data base.

2. central incident expert - correlates and quantifies the quality of reports

SYSTEM PROCESSES

Response Plan Selection

Designation - 1.2

Data In -

1. validated incidents
2. operator confirmations
3. link data - connectivity, capacity and congestion
4. alternate routing data base - identifies "parallel" routes
5. response plans - keyed by effect on flow; a response plan may refer to one or more responses; the actual actions performed are part of each control agencies data base
6. knowledge
7. control agency "replies"

Data Out - Response plan selections

Description - The Response Plan Selection Function is responsible for selecting a response plan once a condition exists that requires a response. This function is an expert system based module that will make use of ES rules, traffic status and system incident data to produce recommendations for actions to improve system performance.

Notes -

Components -

1. congestion analysis - determines problem areas and level of congestion

2. response expert - searches the response plan data base for combinations of responses that improve the situation as measured by congestion analysis

3. response implementor - communicates response requests and replies to and from the affected agencies

SYSTEM PROCESSES

Local Incident Detection (LID)

Designation - 3.2.1, 3.2.2

Data In -

1. detector data collected over a period of 30 seconds, 1 minute or by intersection cycle - data include volume, occupancy and speed

2. historical detector data

3. link data
   a. expected MOE values by time period
   b. capacity
   c. detectors - location, percent contribution
   d. input and output links and percentage in/out by time period
   e. location

4. detector static data - associated link and location

5. knowledge

Data Out - Actual incidents. Data include location, link capacity reduction

Description - The Local Incident Detection process is responsible for identifying and reporting local incidents. Algorithms that are currently part of SATMS and would have to be installed at ATSAC process detector data to identify possible local incidents. The possible incidents are reviewed by an expert system module that can make use of Expert System rules, link data, and operator input to provide a high level of accuracy. The algorithmic processes would be "tuned" to produce a bias in the direction of false positive.

Notes -

Components -

1. Incident preprocessor - determines possible incidents

2. local incident expert - uses link data to perform input/output analysis of each affected link

SYSTEM PROCESSES

Local Response Plan Executor

Designation - 4.2, 3.2.3, 3.2.4

Data In -

1. local incidents - location, link and capacity reduction

2. operator - explicit incident reports, incident confirmations and overrides

3. central incidents - location, link and capacity reduction

4. response plan requests

5. response plans - keyed by flow affect, incident on link, central event and time of day; data include affected entities and actions; actions include CIC on/off, specific plans or meter rates, plan or meter rate adjustments, operator instructions, log messages, CMS updates and HAR messages

6. knowledge

Data Out - Control actions

Description - The Local Response Plan Executor is responsible for aiding local operators in performing those actions required to enact a Response Plan. Based on local responses, operator input, link data and Expert System rules this function will expand the Response Message sent from SC Central into commands that can be processed by existing local software. The Local Response Plan Executor will also send a reply to SC Central describing the actions that were taken by the local agency.

Notes -

1. types of actions that might be initiated by the local ES software:
   a. change timing plans
   b. change meter rates
   c. change splits/offsets
   d. request human intervention -- eg response team
   e. change CIC mode
   f. request Changeable Message Sign message
   g. request Highway Advisory Radio message

Components -

1. response expert - accepts events and determines actions

2. response executor - carries out the actions

DATA BASE DEFINITION

The final component to be provided in the system description is a presentation of actual data base objects that would be required in a system such as Smart Corridor. Table 3-2 provides a list of the basic data objects with storage estimates and Figure 3-7 presents the relationship between the various objects. In Figure 3-7, the following relationships are presented:

one-to-one: for every parent record there is one child record

one-to-many: for every parent record there is at least one but there may be many child records

zero, one-to-many: for every parent record there may be zero, one, or many child records

many-to-many: for every parent record there is at least one but there may be many child records and every child record may has more than one parent

TABLE 3-2

SC DATA OBJECTS

Incident, Actual	- One record in data base per occurrence that requires some action by SC processes
ID	- Unique identifier, automatically generated by system
Location	- Link on which incident occurred
Start	- Time incident first reported/started
Est_ending	- Estimated time incident will end
Severity	- Measure of reduction in traffic flow
Type	- Type of incident code, selected from category list
Validity	- Measure as to the validity/quality of report
Response	- ID of the response plan(s) invoked by system
Incident Report	- Data that is reported for each incident, there may be several reports for a given incident
ID	- Unique identifier, automatically generated by system
Location	- Link on which incident occurred
Start	- Time incident first reported/started
Est_ending	- Estimated time incident will end
Severity	- Measure of reduction in traffic flow
Type	- Type of incident code, selected from category list
Validity	- Measure as to the validity/quality of report
Description	- Text description, primarily from dispatch reports
Source	- Source of report
Historic Incident Record	- Once an incident has been cleared the incident record becomes historical in nature, there will be one for each actual incident record
ID	- Unique identifier, automatically generated by system
Location	- Link on which incident occurred
Start	- Time incident first reported/started
Est_ending	- Estimated time incident will end
Severity	- Measure of reduction in traffic flow
Type	- Type of incident code, selected from category list
Validity	- Measure as to the validity/quality of report
Description	- Text description, primarily from dispatch reports
Source	- Source of report
Actual_end	- Actual time incident cleared
Event	- "Future" incident
Unexplained_congestion	- Special case of Incident
Recurring_congestion	- Special case of Incident

TABLE 3-2
(Continued)

SC DATA OBJECTS

Link	- Roadway segment in roadway network typically arterial, freeway, or ramp
ID	- Unique identifier
Name	- Link name, reference to name list
Owner	- Reference to jurisdictional ownership list
Location	- Location information used as part of display mechanism
Direction	- Directionality indication
Current_MOC	- Current measure of congestion
Hstry_MOC	- Historical measures of congestion
Nom_cpcty	- Nominal capacity for the link
Cur_cpcty	- Current capacity for link as function of nominal capacity
Input_links	- List of associated links that can provide traffic
Input_flow	- Volumes by time of day
Output_links	- List of associated links that can receive traffic
Output_flow	- Volumes by time of day (turning movements)
Hardware	- Inventory of field hardware: controller, detector, camera
Type	- Type code selected from category list
Status	- Current status selected from category list
Location	- Link ID
Associations	- List of associated hardware (eg upstream detectors)
Response	- description of some unique action to be performed at the local level
ID	- Unique Identifier for response
Intensity	- Degree to which response should be invoked
Description	- Human readable description
Links	- List of affected links
Affect	- Indication of how links would be affected
Display	- Icon data to be used to display action that will be take (signature)
Response _Plan	- Grouping of responses that should be treated as a unit
ID	- Unique identifier code
Responses	- List of Response that make up plan
Response_Message	- message that is sent to participating agency to invoke local responses
ID	- Unique Identifier for response
Description	- Description of action to be taken
Time	- Time response message was issued

TABLE 3-2
(Continued)

SC DATA OBJECTS

Local_Response	- Response that will be invoked at the local level
ID	- Unique Identifier for response
Description	- Description of of local actions that will be performed
Commands	- List of system commands to invoke desired response
Active_Response_Plan	- Mechanism to track response plans that have been invoked and are currently active
ID	- Unique Identifier of response plan
Congestion	- Cross reference to the incident, event, etc. responded to
Response_ID	- Response plan ID code
Start	- Time response plan message was issued
End	- Time response plan was no longer in effect
Reply	
ID	- Unique Identifier of response plan
Description	- Text description of action to be taken
Status	- Action that local agency will take to select from list

TABLE 3-2
(Continued)

DATA STORAGE ESTIMATES PER OBJECT TYPE

Object Type	Storage in Bytes
Incident	20
Incident Report	100
Historic	20
Link	300
Hardware	80
Response	400
Response_Plan	90
Response_Message	90
Local_Response	500
Active_Response	50
Reply	90

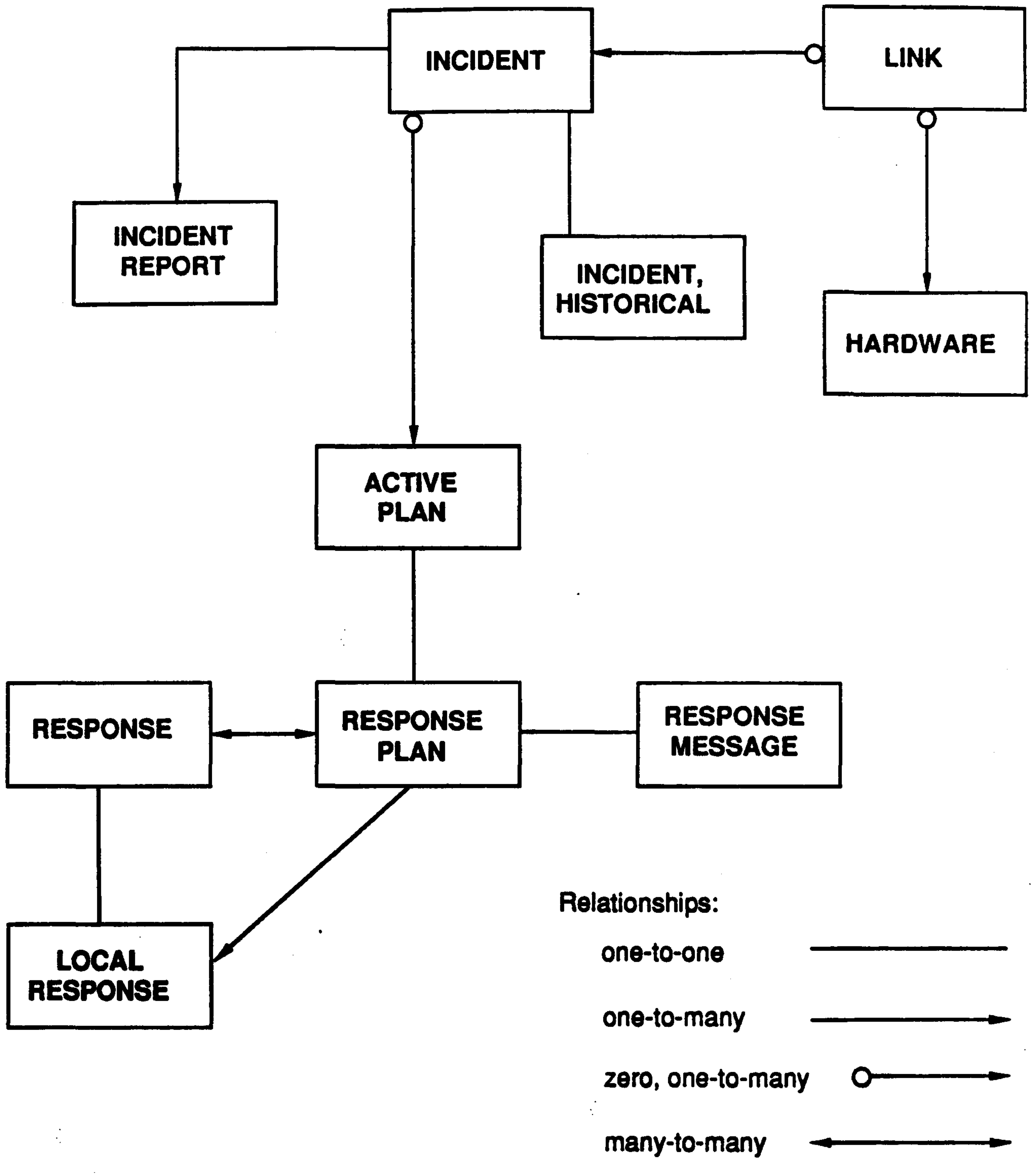

FIGURE 3-7 SMART CORRIDOR - DATA RELATIONSHIPS

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4 - HARDWARE CONFIGURATION ALTERNATIVES

INTRODUCTION

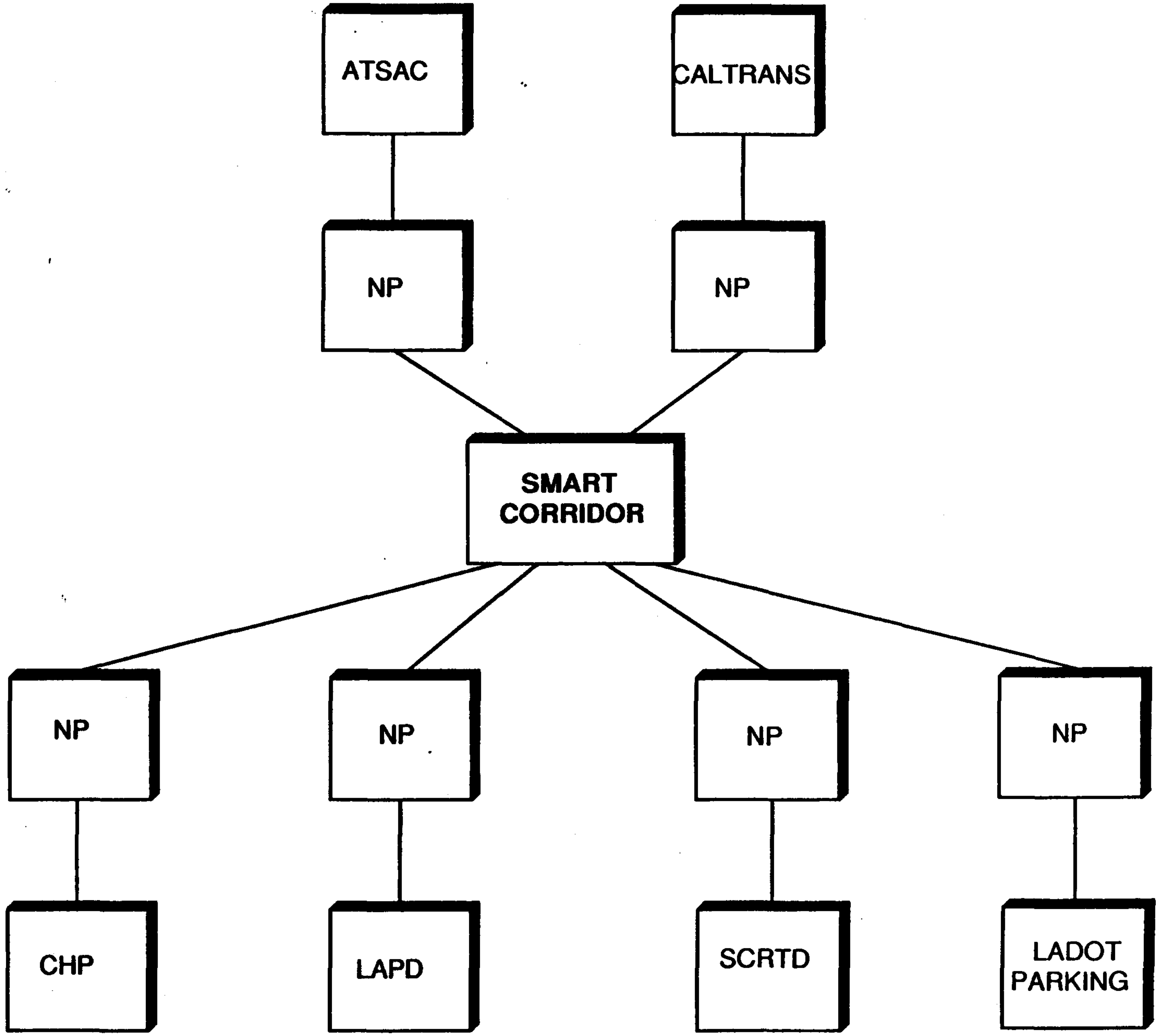
The previous discussion paper ("Central Data Base System") presented a base system configuration which is represented in Figure 4-1. This defines the SC system as being made up of two basic components, a central and node processors serving as interfaces to the other systems. In translating this basic concept to a tangible system architecture and eventually actual hardware (and software) as number of different approaches may be taken. These approaches vary as to the degree of processing or intelligence which is allocated to the node processor, the extremes being a highly centralized system (low-capability) node processors, and no central intelligence (all the SC functions being at the node processor).

This section presents candidate system configurations and to support the preceding system description. A set of criteria has been developed to aid in the evaluation process. Table 4-1 presents the list of criteria items, a brief description of each item and a weighing factor assigned to the criteria item. The weighting factors represent the relative importance that is assigned to the item. The values reflect the need for a functioning reliable system than can be delivered given current technology and a relatively short time frame.

Figure 4-2 presents the range of possible hardware configurations for the Smart Corridor system. In this figure rectangular boxes represent computing hardware with the size of the box reflecting the relative power/cost of the associated hardware. Solid lines represent data flows. The symbol 'T' represents some type of terminal user interface device. (The actual type of device will be further discussed below).

CANDIDATE SYSTEMS

Alternative-A presents a configuration in which there is essentially only a single smart corridor computer communicating with each of the existing agency computers. the small devices positioned between existing and proposed hardware (labeled data extractor) are processors that would be used to capture and transfer relevant data from the local processors. (As has been previously noted, there is currently little



NP - Node Processor

FIGURE 4-1 HARDWARE

TABLE 4-1

EVALUATION CRITERIA, HARDWARE ALTERNATIVES

WEIGHING FACTOR	TITLE	DESCRIPTION
100	Technology Feasibility	degree to which alternative can be achieved given current (or near current) technology
90	Speed of Development	speed at which alternative can be developed
80	Agency Autonomy	degree to which alternative allows participating agencies to maintain control of their own operations
70	Ease of Development	degree of difficulty to develop alternative (development risk)
60	Expandability	degree to which alternative allows for future expansion in the areas and number of links that it oversees
50	Minimization of Data Transfer	degree to which alternative encourages minimal transfer of data -- especially real time data
40	Phased Implementation	degree to which system can be "phased in" over time
30	Reliability	measure of the resistance of system to failure
20	Extendibility	degree to which alternative allows for future expansion with regard to functionality
10	Adaptability	degree to which alternative might adapt to technological advancements within the traffic and computing industries

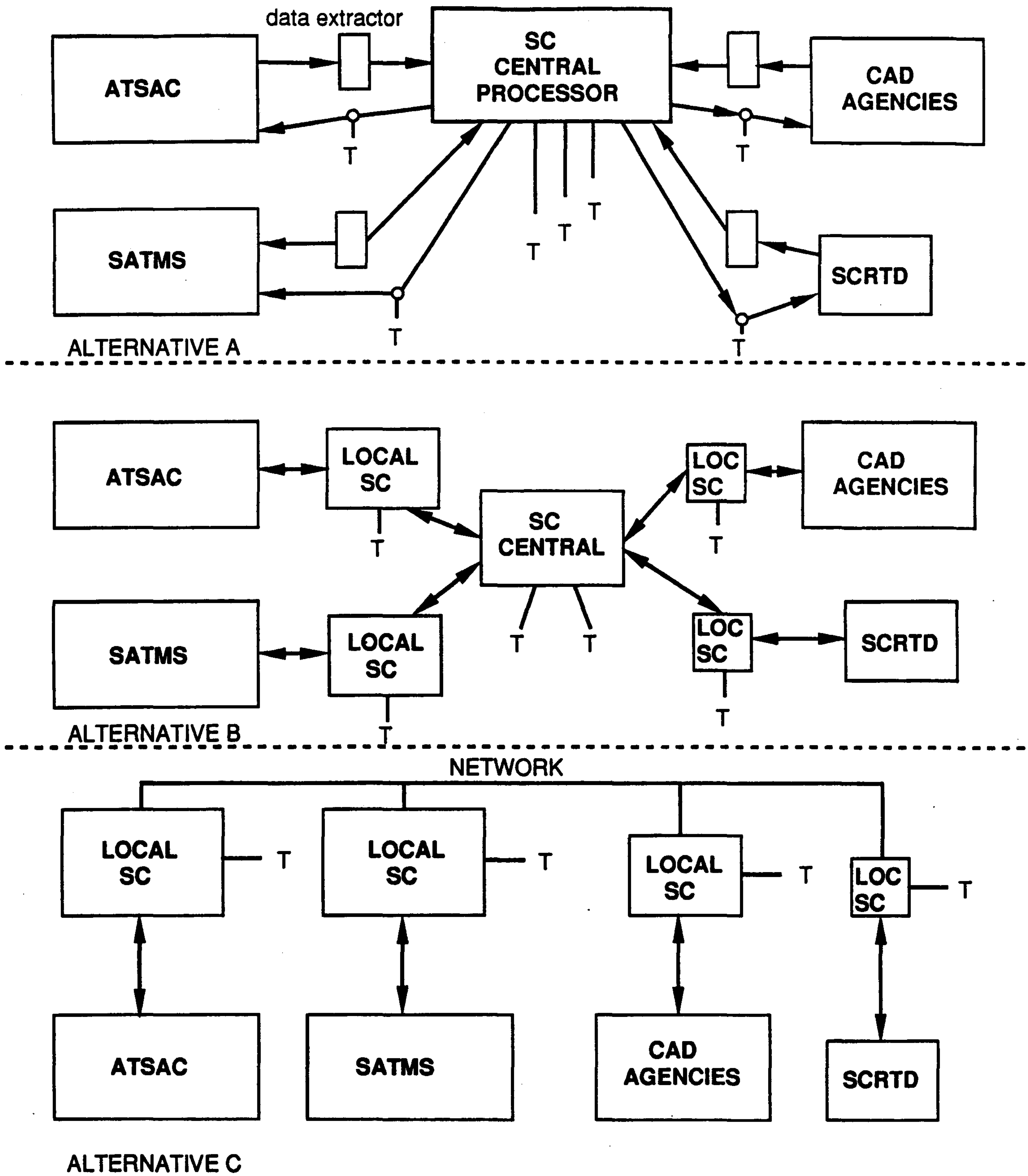


FIGURE 4-2 HARDWARE CONFIGURATIONS

spare processing power on many of the local machines). In this approach the Central SC machine performs all Smart Corridor activities -- including identification and/or validation of local incidents, incident analysis on a system basis, selection of response plans management of system responses and user access. The approach is appealing at several levels -- it is highly centralized, is conceptually simple and has relatively few connections.

Alternative-B presents a different approach. In this configuration a central machine still provides high level functionality but functions that are specific to a given agency or that are specifically local in nature have been moved to machines that would reside at the participating agency's facilities. These local machines are responsible for all local processing (including incident validation and response processing), data communications, and user access. The central computer, now responsible for incident analysis, response selection, and user interfaces, can be a substantially smaller machine. This approach allows a much much smaller central hardware investment, distributes much of the processing load, but involves increased inter-process control.

Alternative-C presents the next step in the evolution of the Smart Corridor hardware configuration. In this approach there is no central machine -- all functionality has been distributed to local machines across a sophisticated data network. Each machine is responsible for local processing (incident identification/validation, response processing and user accesses) as well as some portion of the central SC functionality -- therefore the computers will need to be somewhat more powerful than in Alternative-B. This approach has the advantages of not requiring a central machine but imposes some difficult control aspects.

EVALUATION PROCESS

The evaluation of the alternatives is presented in Table 4-2. In this table each alternative is given a score from one to ten (ten being best, one being worst) for each criteria item. The score is then multiplied by the weighing factor to provide a weighted item score and all weighed scores are summed to provide a aggregate alternative weighed score. notes are provided to explain certain score value assignments.

From Table 4-2, Alternative-B provides the best solution. Briefly, Alternative-B is a middle ground approach that will make use of current technology in the limited time frame of the Smart Corridor Project but manages to address the high profile policy issues involved in the Smart Corridor project.

TABLE 4-2 : EVALUATION OF SYSTEM CONFIGURATIONS

		Alternative 1 Score		Alternative 2 Score		Alternative 3 Score	
Item	*Weight*	*Raw*	*Weighted*	*Raw*	*Weighted*	*Raw*	*Weighted*
Technological Feasibility	100	9	900	9	900	2	200
Speed of Development	90	7	630	8	720	4	360
Agency Autonomy	80	1	80	8	640	9	720
Ease of Development	70	5	350	5	350	5	350
Expandibility	60	1	60	5	300	7	420
Minimize Data Transfer	50	2	100	6	300	8	400
Phased Implementation	40	4	160	6	240	9	360
Reliability	30	1	30	5	150	9	270
Extendability	20	5	100	5	100	9	180
Adaptibility	10	3	30	7	70	9	90
			2440		3770		3350

TERMINAL CONSIDERATIONS

The hardware configuration presented above can be further refined with regard to the type of user interactive device that will be employed. The first Alternative involves the use of "dumb" terminals as the only device for user access. Such an approach is conceptually simple but places a heavy processing burden on the host machine. A second approach is the use of workstations that are micro processor based devices. This approach while somewhat more complicated allows a distribution of the computing load. Table 4-3 provides a list of the criteria to be used to select between these two alternatives. Table 4-4 presents the evaluation. From this table the better Alternative is that of workstations. This approach allows for a very powerful user interface without impacting the processing load of the host machines -- in fact the host machines will likely be smaller in the workstation approach. Also, recent trends within the computing industry indicate that such an approach will become more and more common in the next few years thereby assuring hardware availability.

The Working Paper "Communications Issues and Alternatives" recommended the installation of sufficient communications capacity between the ATSAC and TOC facilities to allow the transfer of video images derived from the CCTV systems. There is commercially available hardware and software for Intel 80386-based personal computers using the IBM PC/AT system architecture which will receive video images and allow them to be displayed in a window superimposed on the screen. This facility is provided on a system add-in board which also supports various levels of graphics.

Such machines (80386-based PC's) are viable options for use as workstations; in addition, there is at least one manufacturer of workstations which also provides support of this feature which is known as video imaging. Video imaging is considered to have major potential in the control systems area as it permits the operator to view a CCTV image on the same screen as the command interface of the system. The camera control capability could also be accomplished from the same terminal.

The adoption of a workstation approach would permit the use of video imaging which would be precluded through using simpler terminals.

TABLE 4-3

EVALUATION CRITERIA, USER INTERFACE ALTERNATIVES

WEIGHING FACTOR	TITLE	DESCRIPTION
100	Technological Feasibility	degree to which alternative can be achieved given current (or near current) technology
90	System Performance	measure of speed of response to user input and real time operations
80	Speed of Development	speed at which alternative can be developed
70	Ease of Development	degree of difficulty to develop alternative (development risk)
65	Graphics/Report Oriented Interface	degree to which the system supports a user interface that is highly graphics display and report oriented
60	Consistency of Interface	degree to which system allows for a consistent user interfaces at all levels of operation and at all installations
55	Minimization of Data Transfer	degree to which alternative encourages minimal transfer of data -- especially real time data
50	Extendibility	degree to which alternative allows for future expansion with regard to functionality
40	Phased Implementation	degree to which system can be "phased in" over time
30	Reliability	measure of the resistance of system to failure

TABLE 4-3
(Continued)

EVALUATION CRITERIA, USER INTERFACE ALTERNATIVES

WEIGHING FACTOR	TITLE	DESCRIPTION
10	Expandability	degree to which alternative allows for future user interface connections
10	Adaptability	degree to which alternative might adapt to technological advancements within the traffic and computing industries

TABLE 4-4 : EVALUATION OF USER INTERFACE SUPPORT

		Terminals Score		Workstations Score	
Item	*Weight*	*Raw*	*Weighted*	*Raw*	*Weighted*
Technological Feasibility	100	10	1000	9	900
System Performance	90	5	450	8	720
Speed of Development	80	8	640	7	560
Ease of Development	70	8	560	6	420
Graphics/Report Oriented	65	4	260	9	585
Consistency of Interface	60	6	360	5	300
Minimize Data Transfer	55	4	220	7	385
Expandibility	50	7	350	4	200
Phased Implementation	40	5	200	7	280
Reliability	30	9	270	5	150
Extendability	20	2	40	7	140
Adaptibility	10	2	20	9	90
			4370		4730

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5 - SOFTWARE OPTIONS

In establishing software options to be used in the SC system, it is first necessary to relate the function to the system configuration. Figure 5-1 presents the most logical possible assignment. From this figure, all processing involved in local SC activities resides at the local level. Software on the central machine provides processing that requires information from all participating agencies to be complete.

During the course of the analysis of the system functions and processes, it has become apparent that the software to be used falls into four categories:

1. data base
2. expert system
3. user interface
4. applications (i.e. SC specific or custom)

For the first three categories there are two options for fulfilling the requirements:

1. make use of existing (commercially available) software
2. provide custom software

The following analysis looks at the implications of each of these options on the first three categories of software.

DATA BASE

The field of system data base design and development has developed into a highly specialized part of the software industry. There are numerous commercially available packages available for the two categories of data base which broadly define data base design i.e.:

1. those that follow the relational model
2. those that follow a CODASYL model

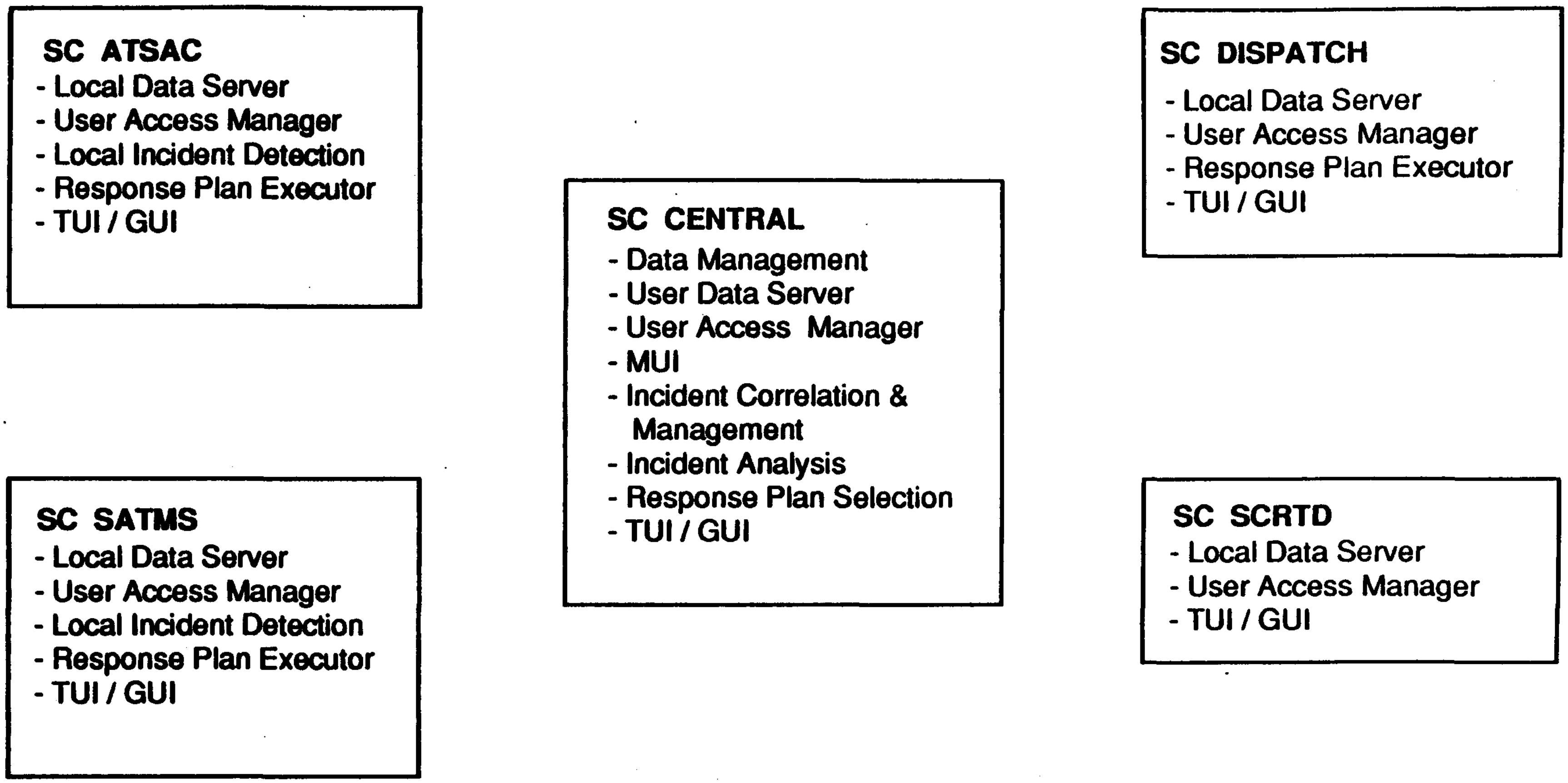


FIGURE 5-1 SOFTWARE

Briefly, the relational model views all data as residing in two dimensional tables. The CODASYL model views data as a network or tree structure. The relational model provides two big advantages. First, within the relational model relationships between data (see figure 3-7) are very dynamic -- that is, the manner in which the various tables can be accessed and associated is (for the most part) determined at the time of access. This aspect yields far greater flexibility in final system design and allows the developer to finalize the data base later in the design phase that with other types of data bases. Secondly, the current data base market is strongly focused on the relational model. Thus, providing many more software packages (with greater functionality) than for the CODASYL model.

In the past, there has been a justification for the development of custom data bases in real-time systems because of the performance constraints imposed by the then available hardware and software. This is no longer he case; the recommended approach is therefore to use a commercially available data base and develop applications software for its use in the SC system.

The data base manager software should provide certain basic functionality. The manager should possess a powerful data base "engine" that can respond to requests for data in a timely manner. It should provide tools that allow developers easy access to stored data. These tools would include a standard query language, screen management, report generators and communications networking support. It should provide methods that allow third party software, such as language compilers, expert system software and networking software, to have access to data base operations. Finally, it should run in a wide variety of hardware environments.

Two data base packages that would provide the above functionality are INGRES by Relational Technology, Inc. and ORACLE by Oracle, Inc. Both products provide a powerful data engine, sufficient tools for development and numerous third party software connections. INGRES has a slight edge with regard to the efficiency its data processing ability and ORACLE provides a greater number of third party vendor connections. While the power of the data engine is important, the specific number and types of interconnections will probably be the deciding factor for choice of a data base manager.

EXPERT SYSTEMS

The arena of Expert Systems is a relatively new field in software terms but one which is rapidly developing its own identity with the establishment of unique concepts and system design approaches. It is therefore similar to the data base field in that it requires specialized knowledge for efficient state-of-the-art design, but differs in that there is not such a degree of software readily available on the marker.

To date, only one real time commercially available expert system has surfaced -- G2 by Gensym. G2 exhibits numerous features that are necessary for an application such as Smart Corridor -- including: wide range of hardware environments, networking support, and data base interfaces. Currently, the only data base interface available that might be useful for Smart Corridor is ORACLE. Future discussions will assume application software built around G2 and ORACLE.

An approach in which expert system processes are custom developed has also been considered. Such an approach would entail development of software modules written in a language particularly suited to artificial software development (e.g. LISP), although a more common high level language such as C could be applicable.

There are two major development areas involved in the application of ES techniques to the Smart Corridor. They are:

1. Base ES software
2. Developing the "knowledge base" application

The time frame envisaged for this pilot precludes an attempt at developing custom ES software. The specialized nature of ES software dictates that it is more practical to choose an existing ES base and concentrate on the development of the application.

USER INTERFACE SUPPORT

The final software configuration issue involves the form of the user interfaces text and graphical user interfaces (TUI and GUI) that will be provided. The most logical presentation is that of a multi-tasking window environment, similar in appearance to the one employed by Apple for its MacIntosh computers. Many concepts of the GUI were originally developed at Xerox's Palo Alto Research Center (PARC) and first successfully brought to small computers with the Apple Macintosh. The GUI has come to be regarded as the state of the art in user interfaces and will probably be common on computers (both small and large) produced over much of the next decade.

Typically a GUI displays multiple programs in separate windows on the screen. Users can move these windows around, resize them, and easily switch among the programs. The programs have a consistent user interface that makes use of pull-down menus, dialog boxes, and graphical objects such as scroll bars, buttons and icons. This is commonly known as a WIMP interface (Windows, Icons, Menus and Pull-downs).

Programs running under a GUI use graphics for all screen output. This makes possible the display of text in different fonts and sizes, as well as the easy integration and manipulation of text and graphics. The use of graphics results in a richer and denser information content than is possible in character mode.

Graphical user interfaces commonly support a secondary user-input device, most often a mouse. The mouse provides an easy way for the user to switch among programs, manipulate windows, and indicate program options.

Users generally find a graphical user interface easy to learn. The GUI establishes a consistency in the user interface that allows knowledge of one application to carry over into the next. Ease of operation becomes increasingly more important as the use of PCs extends to less-sophisticated and more-casual users. Of course, power users also benefit. If the basic functions of a program are trivial to learn, more time can be spent on the more difficult features (such as macro languages). Proper implementation will allow windows to share data. For example, a user could have windows running both GUI and TUI at the same time. The result of a complicated query in the form of list, could be taken from the text window to the GUI window for display against current capacities of a segment of roadway.

Several industry collaboration efforts are in progress to establish multi-vendor standards, these include Presentation Manager (IBM and Microsoft) and X Windows (DEC, IBM, MIT, Sun); in addition, the Open Software Foundation is active in trying to establish industry wide standards.

Both Presentation Manager (running under the OS/2 operating system) and X. Windows (under UNIX) are viable options for the software to support user interfaces at the workstations. While it is not necessary to actually make a firm choice at this stage in the design, it must be realized that standardization of user interfaces is an essential element in the total system implementation. This may be compromised if a "mix" of user interface support software is not guarded against. The implication is that at the next stage of the system design, a clear decision will have to be taken as to the choice of user interface environment (i.e. software base).

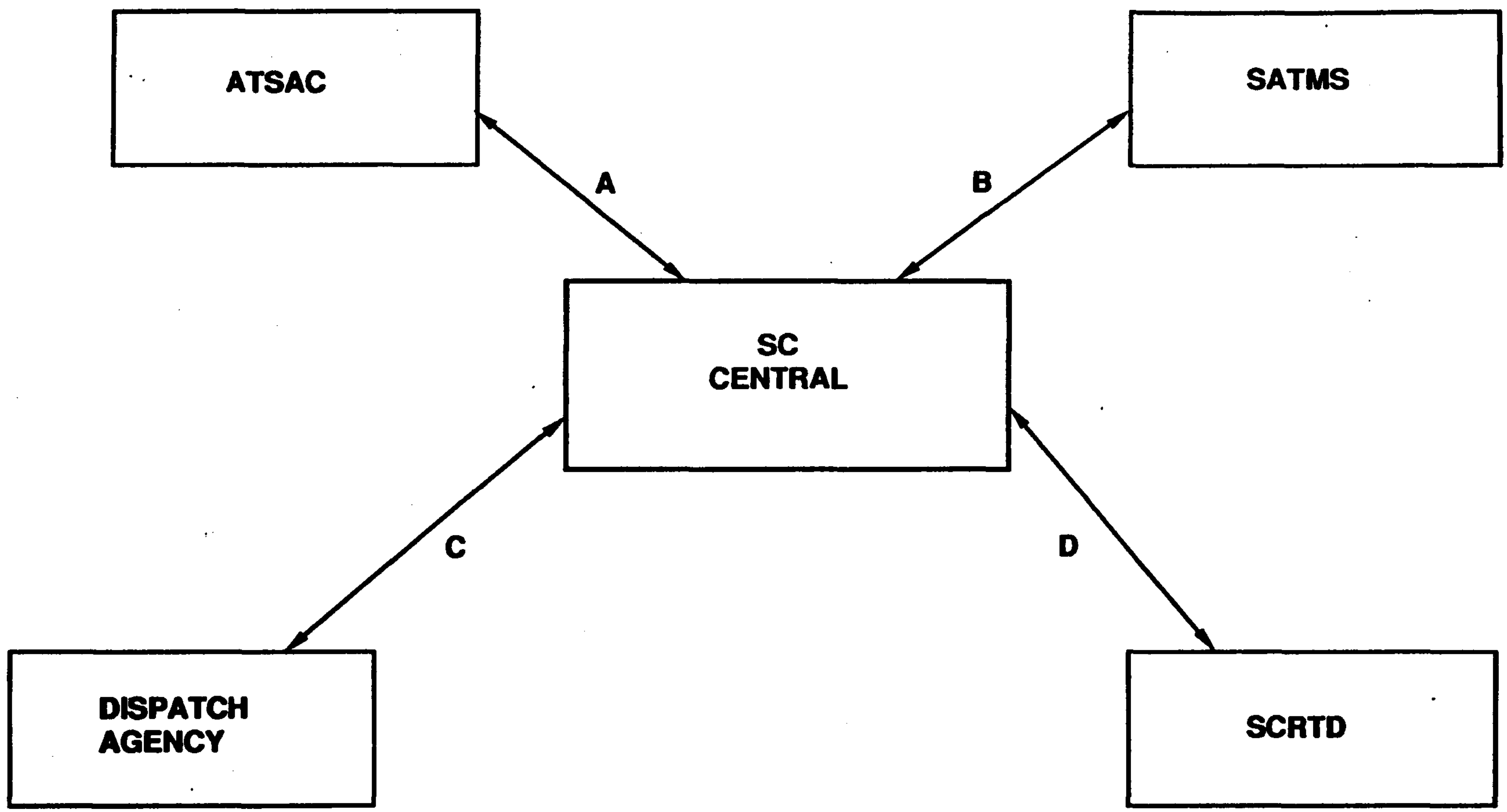


FIGURE 6-1 COMMUNICATION DETAIL

6 - SYSTEM CONFIGURATION

This section defines a system configuration in terms of hardware and software elements upon which the cost estimate presented in Section 7 is based. Previous sections defined the system architecture and the allocation of functions. This section examines the implications on the communication requirements and system components in order to arrive at a practically feasible system configuration.

COMMUNICATION REQUIREMENTS

Figure 6-1 provides a representation of the Smart Corridor System in terms of major data paths. As can be seen, four major links have been established:

Path A : ATSAC to Central

Path B : SATMS to Central

Path C : Dispatch Agency to Central

Path D : SCRTD to Central

Table 6-1 details the data to be transferred along these major paths and derives an estimate of the worst case data transfer rate in bytes per second. The worst case has been calculated by simply adding the individual requirements and yield the following results:

Path	Worst Case Bytes/sec	Transfer Rate kbits/sec	Design Rate kbits/sec
A	1773	19.5	39
B	1532	16.8	34
C	1468	16.1	33
D	1450	16.0	32

TABLE 6-1.1 : DATA COMMUNICATIONS ANALYSIS

Path	Data Item	Bytes/ Item	Items/ Transfer	Bytes/ Transfer	Transfer Frequency	Acceptable Transfer Time (Sec)	Transfer Rate Bytes/Sec
A.	Detector Data (Id, Status, Moc)	10	1,600	16,000	Once Per Minute	60	270
	Controller Data (Id, Status)	5	400	2,000	Once Per Minute	60	35
	Text Data (Report Data, Query Results)			2,000	As Needed, Avg. 15 Per Day	2	1000
	Static Display Data			50,000	As Needed, Avg. 2 Per Day	300	170
	Dynamic Display Data (Link Id, Moc, Ir)	16	1,000	16,000	Once Per Minute	60	270
	Response Data (Plan, Reply)	90	2	180	On Request, Avg. 15 Per Day For Each Agency	10	18
	Incident Reports	100	1	100	On Request, Avg. 200 Per Day	10	10
				Path A : Worst case Transfer rate :			1773

TABLE 6-1.2 : DATA COMMUNICATIONS ANALYSIS

Path	Data Item	Bytes/ Item	Items/ Transfer	Bytes/ Transfer	Transfer Frequency	Acceptable Transfer Time (Sec)	Transfer Rate Bytes/Sec
B.	Detector Data (Id, Status, Moc)	10	325	3250	Once Per Minute	60	55
	Controller Data (Id, Status)	5	100	500	Once Per Minute	60	9
	Text Data (Report Data, Query Results)			2,000	As Needed, Avg. 15 Per Day	2	1000
	Static Display Data			50,000	As Needed, Avg. 2 Per Day	300	170
	Dynamic Display Data (Link Id, Moc, Ir)	16	1,000	16,000	Once Per Minute	60	270
	Response Data (Plan, Reply)	90	2	180	On Request, Avg. 15 Per Day For Each Agency	10	18
	Incident Reports	100	1	100	On Request, Avg. 200 Per Day	10	10
				Path B : Worst case Transfer rate :			1532

TABLE 6-1.3 : DATA COMMUNICATIONS ANALYSIS

Path	Data Item	Bytes/ Item	Items/ Transfer	Bytes/ Transfer	Transfer Frequency	Acceptable Transfer Time (Sec)	Transfer Rate Bytes/Sec
C.	Text Data (Report Data, Query Results)			2,000	As Needed, Avg. 15 Per Day	2	1000
	Static Display Data			50,000	As Needed, Avg. 2 Per Day	300	170
	Dynamic Display Data (Link Id, Moc, Ir)	16	1,000	16,000	Once Per Minute	60	270
	Response Data (Plan, Reply)	90	2	180	On Request, Avg. 15 Per Day For Each Agency	10	18
	Incident Reports	100	1	100	On Request, Avg. 200 Per Day	10	10
				Path C : Worst case Transfer rate :			1468

TABLE 6-1.4 : DATA COMMUNICATIONS ANALYSIS

Path	Data Item	Bytes/ Item	Items/ Transfer	Bytes/ Transfer	Transfer Frequency	Acceptable Transfer Time (Sec)	Transfer Rate Bytes/Sec
D.	Text Data (Report Data, Query Results)			2,000	As Needed, Avg. 10 Per Day	2	1000
	Static Display Data			50,000	As Needed, Avg. 2 Per Day	300	170
	Dynamic Display Data (Link Id, Moc, Ir)	16	1,000	16,000	Once Per Minute	60	270
	Incident Reports	100	1	100	On Request, Avg. 200 Per Day	10	10

Path D : Worst case Transfer rate : 1450

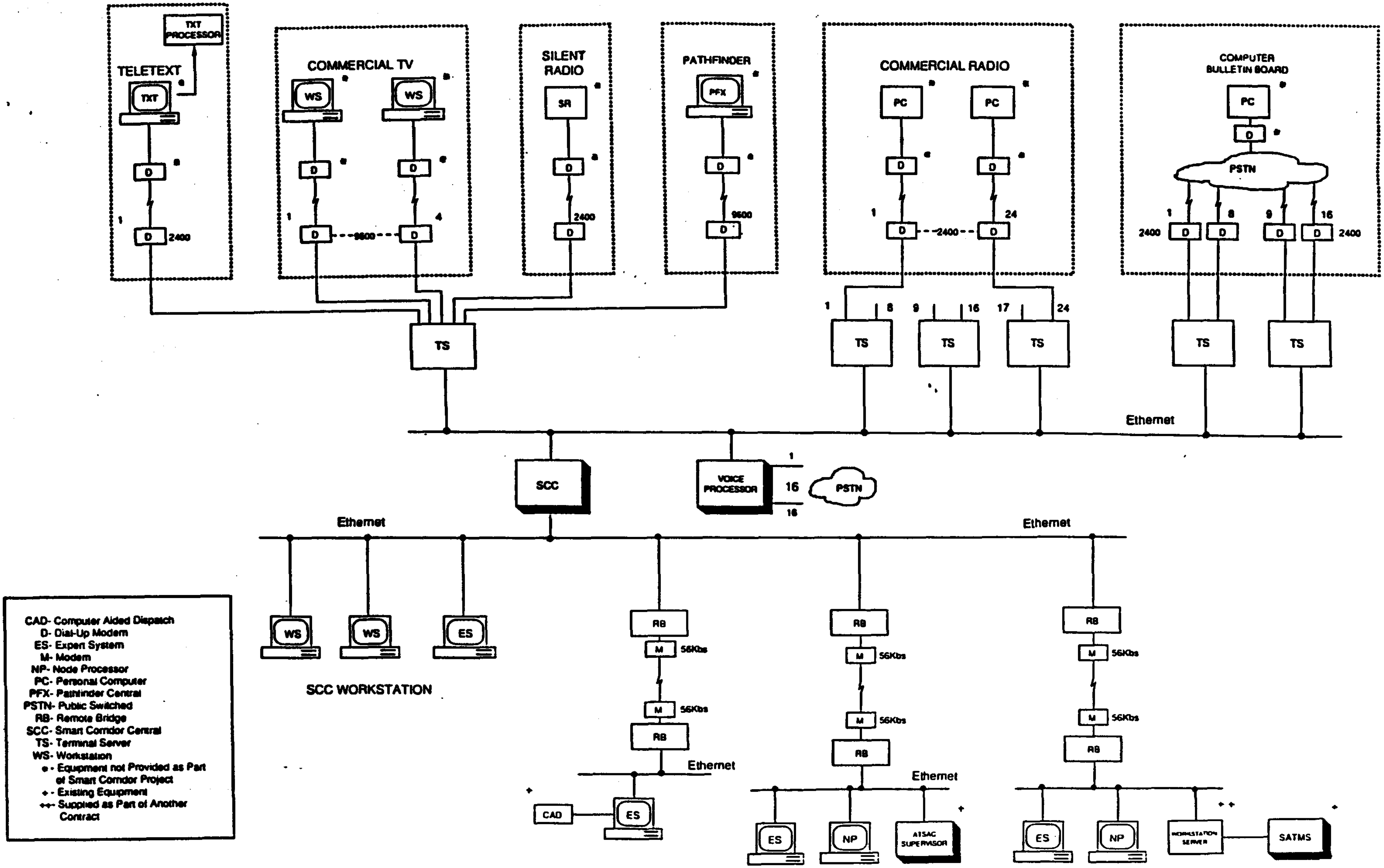


FIGURE 6-2 SMART CORRIDOR SYSTEM CONFIGURATION

The transfer rate in bits/sec is derived by multiplying the byte transfer rate by 11. The final column shows a recommended design rate which provides ample capacity for future system growth and provides an element of contingency when moving from this the conceptual design stage into the detailed design stage. In this case a 100% safety factor has been used. The indication is clearly that 56 kbs links are required for all paths.

SYSTEM COMPONENTS

The overall system configuration is shown in Figure 6-2. As can be seen, the architecture is designed around local and wide area networks (LAN's and WAN's) in order to comply with the architecture chosen in Section 4.

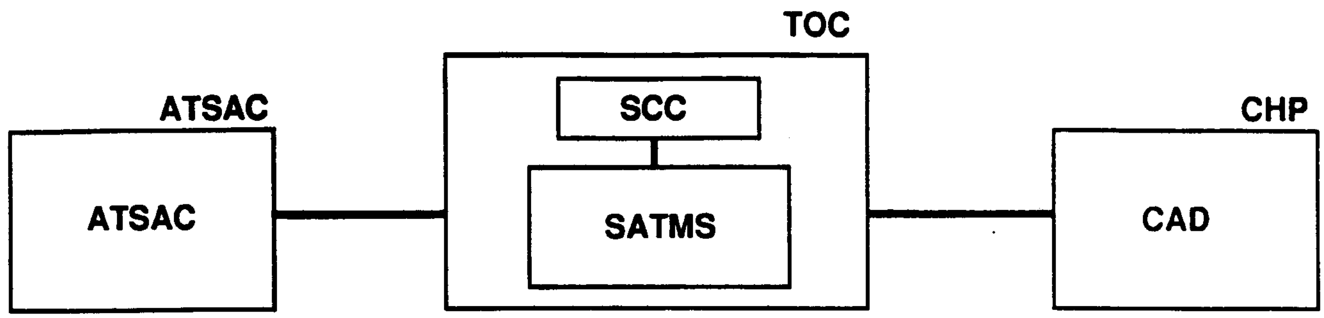
Topologically, the configuration chosen makes the network transparent to the individual system users. In addition, the LANs and WANs as proposed are comprised of commercially available products which shield the applications from the physical transmission media. This means that, taking levels of system security and permitted user access into account, the physical location of a terminal does not restrict access to any part of the Smart Corridor System which is connected directly to the LAN/WAN (i.e. this does not apply to the ATSAC Area computers or the existing SATMS computer as they are interfaced to the Smart Corridor system via interposing equipment.)

The following sections explain various aspects of the system design in more detail.

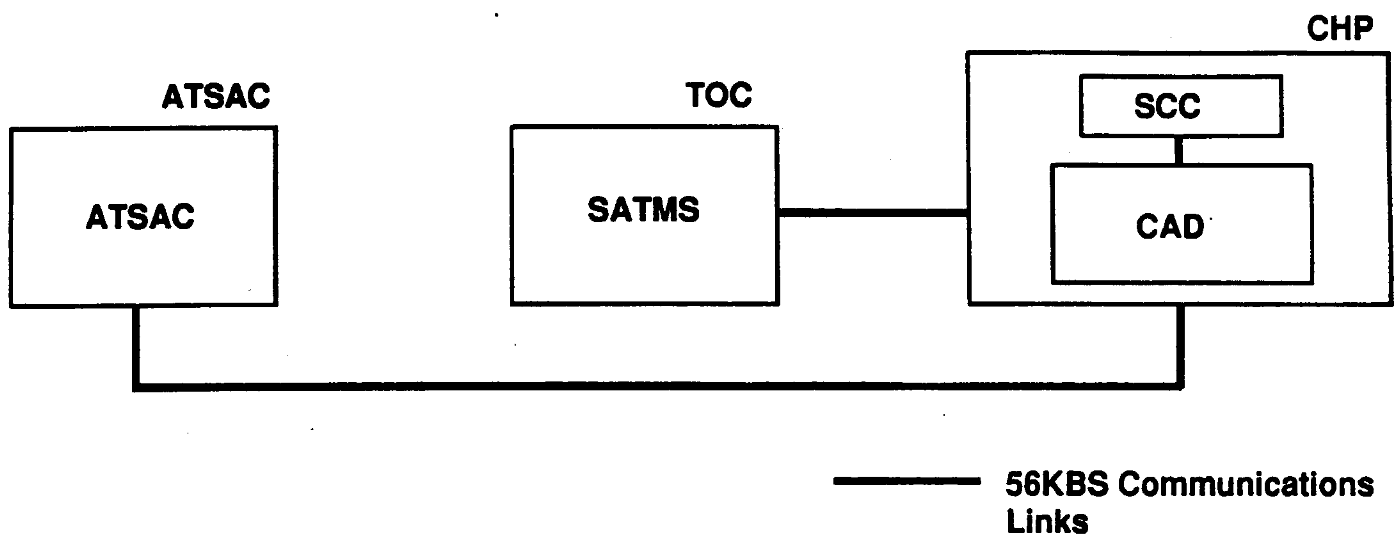
Location of Central

At the time of writing, there is no clear decision as to the location of the Smart Corridor Central. Viable candidates are the Caltrans TOC and the CHP control central. The imminent expansion of the CHP system and improved public information access systems make the latter a strong contender.

The system configuration does not influence the choice of location of the Central because of the flexibility afforded by the choice of LAN/WAN communications (see above). There may be a difference however in the physical communications media involved in locating the SCC at the CHP rather than at the TOC. This is illustrated in Figure 6-3.



6-3.a SCC at TOC



6-3.b SCC at CHP

FIGURE 6-3 EFFECT OF SC CENTRAL LOCATION ON COMMUNICATIONS LINKS

The TOC and ATSAC control rooms are located relatively close together (within two blocks of each other) and there has already been a recommendation for the establishment of high-capacity communications facilities between them (see the Discussion Paper "Communications Issues and Alternatives" page 25). The CHP control room is located some five miles distant from both control rooms. Thus, locating the SCC at the CHP control room would mean running or leasing a much longer length of communication media between the SCC and the ATSAC systems. (The SCC to SATMS link being needed in both scenarios.)

A further recommendation of the above mentioned Discussion Paper is the tying-in of the CHP to the ATSAC/SATMS communications network through use of a City-owned trunk cable (see page 26 of the Paper). Should this happen, then it is possible that this would remove any cost difference related to the choice of location of the central between the TOC and the CHP control room.

Inter-system Communications

The configuration uses LAN's (expanded to WAN's) employing the ETHERNET standard. Remote bridges are used to enable the ETHERNET to be extended to sites such as the Dispatch centers. These bridges convert the coaxial based LAN signals for serial transmission along 56kbs links.

ETHERNET is an industry standard communications facility well supported by all major computer companies. In terms of the International Organization for standards' (OSI) model for Open Systems Interconnection, ETHERNET specifies the two lowest layers, the Physical and Data Link Layers.

The applications controlling the data flow along the ETHERNET links are separated from the physical link by other layers which, among other tasks, define anticipates that more than one transmission protocol will be needed to serve the various equipment types. Inter-system, inter-workstation and system to workstation communications would be handled using an industry standard such as TCP/IP but there may be the necessity to use proprietary software in special cases (e.g. Digital Equipment Corporations's DECNet).

Smart Corridor Central Computer

The SCC is configured around a 3 mips processor configured to be able to operate at least two ETHERNET LAN's and with sufficient memory and secondary disk storage to handle the data base requirements as detailed in Section 3 of this paper and demanded by a suitable relational data base package. A typical machine would be a DEC Microvax 3500, configured with 16Mb of memory and two, 280 Mb fixed disk drives.

Expert Systems

The requirements for the expert system hardware are based upon discussions held with Gensym Corporation, the suppliers of the System G2 software. They recommend:

a. the ES runs on a dedicated processor

b. that a 3 mips/12Mb RAM are minimum machine requirements

The most cost effective equipment under these circumstances is the latest generation of workstations. These can either be Intel 386 or Motorola 68030 based. The configuration chosen uses a Motorola processor and is equipped with 16Mb of Ram, two, 100Mb fixed disks and a 3.5" floppy. The costs include an ETHERNET interface.

Node Processors

Having defined separate hardware for the ES functions, this reduced the demands on the node processors. This brings the equipment options into the area of workstations as well given that the local data base functions and I/O are less demanding than in the case of the SCC central. The node processors are configured the same as for the ES workstations.

Workstations

As well as the workstations which form the basis for the ES and node processors, there are several workstations which provide the various operator and user interfaces. These have been configured and costed as Intel 80386 processor-based machines with 8Mb of RAM, single 110Mb fixed disk, super VGA graphics and WIMP support and LAN support software.

The cost does not include video imaging capability. It is likely that this will only be required on specific workstations and so has been included as an option for the workstation in the SCC.

SATMS Developments

The existing SATMS is severely constrained by the limitations of the existing central equipment. There are insufficient memory and processing capacities to allow the addition of further software for interfacing directly to the SC system. The SC configuration proposes interfacing to the SATMS via a Workstation Server. This is a device which interfaces with the map display driver and receives the following conditioned information from the SATMS per detector zone:

Code	Condition
0	speed 35 mph or greater
1	speed between 20 and 35 mph
2	speed between 0 and 20 mph
3	incident detected

The Workstation Server will be supplied as part of a separate contract to be issued by Caltrans. The SC interface software for the Workstation Server would be developed under the Smart Corridor implementation contract.

There are plans to upgrade the SATMS in the future, but not within the timescale of the Smart Corridor Experimental system implementation. In the future, it is anticipated that the ES and local SC features could be incorporated on the upgraded SATMS central machine which would be interfaced directly to the SC system via the ETHERNET communications link.

Motorist Information Systems Interfaces

Teletext Services

It is envisioned that a dedicated teletext workstation (TXT/WS) would require be required to supply the teletext system with information from the SC in the form of character based screen graphics for direct transmission. The TXT/WS would store the base screens locally and update the dynamic data derived from the SC central.

Such a workstation would be configured around an Intel 80386-based PC. The cost of the TXT/WS and the local modem appear as options in the cost estimates.

Commercial TV

It is proposed that commercial TV stations (up to four in number) be allowed the capability of the full display of graphics screens and so would need workstations for this purpose.

The cost of the supply of the workstations and local modems appear as options in the cost estimates.

Silent Radio

It is proposed that the Silent Radio (SR) central is interfaced directly with the SC system via a serial data link. The SR system would be responsible for data reception, conversion and transmittal.

Pathfinder In-Vehicle Navigation System

In the Pathfinder field trials, the system receives data from both the SATMS and the ATSAC systems and derives a measure of congestion on a link basis. With the advent of the Smart Corridor system, these data links would be replaced by a single link to the SCC which would transmit the SC derived link data.

The costs of the Pathfinder central and local modems are not considered as they will be existing equipment. The cost of the update to the Pathfinder central equipment is estimated and appears as an option.

Commercial Radio

It is proposed that provision be made for the supply of data to twenty-four local radio stations via dedicated, leased lines. The terminal devices would be very basic PC's with minimal memory, monochrome displays and terminal emulation software. The costs of the PC's and the modems are not included in the cost estimates as it is expected that the stations will provide their own.

An optional approach would be for the lines to be part of the switched telephone network (PSTN) and to support a dial-in capability. This would not impact the estimated costs.

Computer Bulletin Board

The computer bulletin board facility would initially support up to 16 concurrent users dialling-in via the PSTN and using PC-based terminals. The cost for the instation modems and software support is included in the cost estimates.

The configuration shows dial-up voice support for 16 lines. This equipment is discussed in more detail in the Discussion Paper "Telephone Dial-in Services".

7 - COST ESTIMATES

This section presents an estimate of the costs associated with the hardware and the software associated with the implementation of a SC system according to the configuration as detailed in Section 6.

Table 7-1 summarizes the costs for the commercially available hardware and software. Table 7-2 estimates the costs associated with the development of software specifically for the SC application. These cost include application software and custom software.

TABLE 7-1 : SMART CORRIDOR BASE SYSTEM COSTS

Item	Qty	Sub-total	Total
Smart Corridor Central			
Central Computer			
3mips processor	1		
16Mb RAM/280Mb disk			
Ethernet i/f			
296Mb tape			
2nd 280Mb disk	1		
2nd Ethernet i/f	1		
Line Printer	1		
LAN Interconnect	2		
Console	3		
Operating System	1		
cables			
Sub-total Central hardware		$110,000	
Relational Dbase	1		
Sub-total Central software		$80,000	
Total Central			$190,000
Expert System			
3mips/8Mb RAM/Ethernet			
2x104Mb disks	1		
3.5" floppy	1		
Ethernet Trans. + cable	1		
8Mb RAM (2x4Mb)	2		
Sub-total ES hardware		$20,000	
Expert System (Dev Sys)	1		
Applications Interface	1		
Database Interface	1		
Communications Protocol	1		
Sub-total ES software		$64,000	
Total ES			$84,000

Item	*Qty*	*Sub-total*	*Total*
User Workstations			
Intel 80386 based			
Super VGA graphics			
110Mb disk			
3.5" floppy disk	1		
Ethernet interface	1		
8Mb RAM	1		
WIMP support software	1		
LAN software	1		
sub-total workstations		$20,000	
User Workstations	2		
Workstation Total			$40,000
Remote Communications			
Network Server			
Server (modem control)	2		
Server (non-modem control)	4		
Software	1		
Copies	3		
8 line EIA 232	2		
Sub-total Network Server		$27,000	
Modems 9600bd	5		
Modems 2400bd	27		
Cables			
Sub-total modems		$20,000	
Total Remote Communications			$47,000

	Item	*Qty*	*Sub-total*	*Total*
Dial-Up Voice				
	Turnkey System	1		
	Total Voice Response System			**$200,000**
Remote Systems				
	Remote Bridges	3		
	Modems 56kbd	4		
	Cables			
	Total Remote Systems			**$26,000**

	Item	Totals	Sub-total

ATSAC Related

Expert System

Item	Qty	Totals	Sub-total
3mips/8Mb RAM/Ethernet			
2x104Mb disks	1		
3.5" floppy	1		
Ethernet Trans. + cable	1		
8Mb RAM (2x4Mb)	2		
Sub-total ES hardware		$20,000	
Expert System (Run-time)	1		
Applications Interface	1		
Database Interface	1		
Communications Protocol	1		
Sub-total ES software		$46,000	
Total ES			$66,000

Node Processor

Item	Qty	Totals	Sub-total
3mips/8Mb RAM/Ethernet			
2x104Mb disks	1		
3.5" floppy	1		
Ethernet Trans. + cable	1		
8Mb RAM (2x4Mb)	2		
Sub-total ES hardware		$20,000	
Relational Dbase (Single User)	1		
Sub-total NP software		$11,000	
Total NP			$31,000

Item	*Qty*	*Sub-total*	*Total*
Smart Corridor System Link			
Remote Bridges	1		
Modems 56kbd	1		
Cables			
Total Remote Systems			**$9,000**

SATMS Related

Item	*Qty*	*Sub-total*	*Total*
Expert System			
3mips/8Mb RAM/Ethernet			
2x104Mb disks	1		
3.5" floppy	1		
Ethernet Trans. + cable	1		
8Mb RAM (2x4Mb)	2		
Sub-Total ES hardware		$20,000	
Expert System (Run-time)	1		
Applications Interface	1		
Database Interface	1		
Communications Protocol	1		
Sub-total ES software		$46,000	
Total ES			**$66,000**
Node Processor			
3mips/8Mb RAM/Ethernet			
2x104Mb disks	1		
3.5" floppy	1		
Ethernet Trans. + cable	1		
8Mb RAM (2x4Mb)	2		
Sub-total NP hardware		$20,000	
Relational Dbase	1		
Sub-total NP software		$11,000	
Total NP			**$31,000**

Item	*Qty*	*Sub-total*	*Total*
Smart Corridor System Link			
Remote Bridges	1		
Modems 56kbd	1		
Cables			
Total Remote Systems			**$9,000**

CAD Related

Workstations			
User Workstations	4		
Workstation Total			**$80,000**
Communications			
Remote Bridges	4		
Modems 56kbd	4		
Cables			
Total Remote Systems			**$35,000**
Total Base System			**$914,000**
			======

Item	*Qty*	Sub-total	*Total*

OPTIONS

SC Central

Workstations

Video Imaging Support	2		
Total SC Central Options :			**$18,000**

Motorist Information Systems

Teletext

TXT Workstation	1		
Modems 2400bd	1		

Commercial TV

Workstations	4		
Modems	4		
Total Motorist Information Options			**$97,000**

TABLE 7-2 : SC SPECIFIC SOFTWARE COST

Item	*Function*	*Labor (man-months)*
Smart Corridor System		
1	User Data Server	5
2	Local Data Server	6
3	User Access Manager	4
4	Textual User Interface	6
5	Graphics User Interface	12
6	Motorist User Interface	18
7	Incident Correlation and Management	6
8	Central Incident Analysis	4
9	Central Plan Selection	4
10	Local Incident Detection	4
11	Local Response Execution	5
12	Data Base Setup	2
13	Network Access	14
	Total SC Specific Software	**90**
	Value of a Man-Month	
	Average Monthly Labor Rate (cost of service/overhead/fee)	$10,000
	Cost of SC Specific Software	**$900,000**
	Direct Costs	$90,000
	Total Software Costs	**$990,000**
Options		
Motorist Information System		
	Pathfinder Modifications	3
	Cost of MIS Software Option	$30,000
	Direct Costs	$3,000
	Total Cost	**$33,000**

ACCIDENT INVESTIGATION SITES

BACKGROUND

Studies conducted by the Texas Transportation Institute (TTI) on accident investigation sites (AIS) indicate that they provide an effective means for reducing delay by encouraging the early removal of vehicles from an accident scene on a freeway. An additional benefit from the use of AISs is a reduction in secondary accidents.

The criteria recommended in the TTI study for the selection of a site and the design of an AIS include the following:

- easily accessible from the freeway - preferably downstream and within one block of the ramp exit
- well marked
- located near a high accident area
- paved
- illuminated
- at least 1000 sq.ft.
- equipped with telephone communications
- should not be visible from the freeway

It is also desirable to have the AIS accessible from both directions of travel on the freeway.

Possible sites include:

- land under the freeway
- other unused land adjacent to the freeway
- city streets (curb parking areas)

Assuming that public land is used for the AIS, the costs associated with the construction of a site include the paving, telephone communications, lighting, and signing. Other costs might be incurred in constructing guardrails and adding pavement markings. Typical costs for these items are as follows:

- grading and paving 1000 sq.ft. = $7-10K
- installation of new lighting = $6-8K
- signing (freeway) = $500-1000 per direction
- signing (streets and AIS) = $250-700 per site

In the Smart Corridor area, there are numerous areas adjacent to freeways in the Caltrans right-of-way which appear to be suitable as AIS. Leveling and grading of some areas may be required in order to make them usable. The worst case estimate is that it would cost approximately $20,000 to develop an accident investigation site on public right-of-way.

An alternative to the use of Caltrans right-of-way is the use of curb parking areas of surface streets. When appropriately signed and marked, these sites become viable AISs.

An additional benefit of implementing accident investigation sites is that they can also be used by the freeway service patrols as sites to which disabled vehicles can be moved from the freeway. The sites can double as locations where minor or interim repairs can be performed or where the vehicles can safely wait, out of the view of freeway motorists, for assistance.

ACCIDENT INVESTIGATION SITES FOR THE SANTA MONICA FREEWAY

On the Santa Monica Freeway, there are a total of 12 ramps westbound between the Harbor Freeway and the San Diego Freeway and 11 ramps eastbound. Most of the ramps on the east end of the corridor are at diamond interchanges where the ramps for each direction intersect at-grade with the cross street. The configurations of the remaining ramps varies, and one ramp exit may provide direct access to one or more major surface streets.

Ideally, access to an AIS should be provided at every exit ramp from the freeway with one site serving both directions of travel where possible. Locating a site which is accessible from both directions is easier to accomplish at standard diamond and cloverleaf interchanges than at some of the more unusual interchanges such as exist in the Smart Corridor at the Overland/National, Venice, and La Cienega exits. It is expected that one AIS can be developed to serve each of the interchanges at La Brea, Crenshaw, Arlington, Western, Normandie, and Vermont. Due to the proximity of the exit ramps, it is also expected that one AIS can serve the exits at Washington/Fairfax westbound and Fairfax eastbound. Based on the stated criteria, the following exit ramps are far enough away from other ramps to make the joint use of an AIS unsuitable:

- Overland westbound
- National westbound
- National/Overland eastbound
- Robertson eastbound
- Robertson westbound
- La Cienega eastbound
- Venice/La Cienega
- Hoover eastbound
- Hoover westbound

Therefore, the development of a total of 16 accident investigation sites could serve all exit ramps from the Santa Monica between the Harbor and San Diego freeways. The interchanges and ramps where AISs are proposed are illustrated in Exhibit 1.

COSTS

Based on the assumption that Caltrans right-of-way is utilized for the development of these AISs, it is estimated that the total cost will be $320,000. If on-street curb parking space sites are identified for AIS use, the costs will be appreciably less.

BENEFITS

Extrapolating from the information presented in the TTI study, it is estimated that 1.8 million hours of delay could be saved per year on weekdays alone by removing accidents to off-freeway investigation sites. At the figure of $6.35 per hour, the savings to the motoring public is estimated at $11.5 Million. Using an annual cost of $48,000 for the sites (10 year amortization with a 5% cost per year for physical maintenance), the estimated benefit/cost ratio is 240 to 1.

RECOMMENDATIONS

Based on the savings in delay to the motorist to be accrued from the rapid removal of accidents from the freeway, it is recommended that off-freeway accident investigation sites be developed by Caltrans at each of the 16 locations near exit ramps from the Santa Monica Freeway as previously identified.

PROPOSED ACCIDENT INVESTIGATION SITES

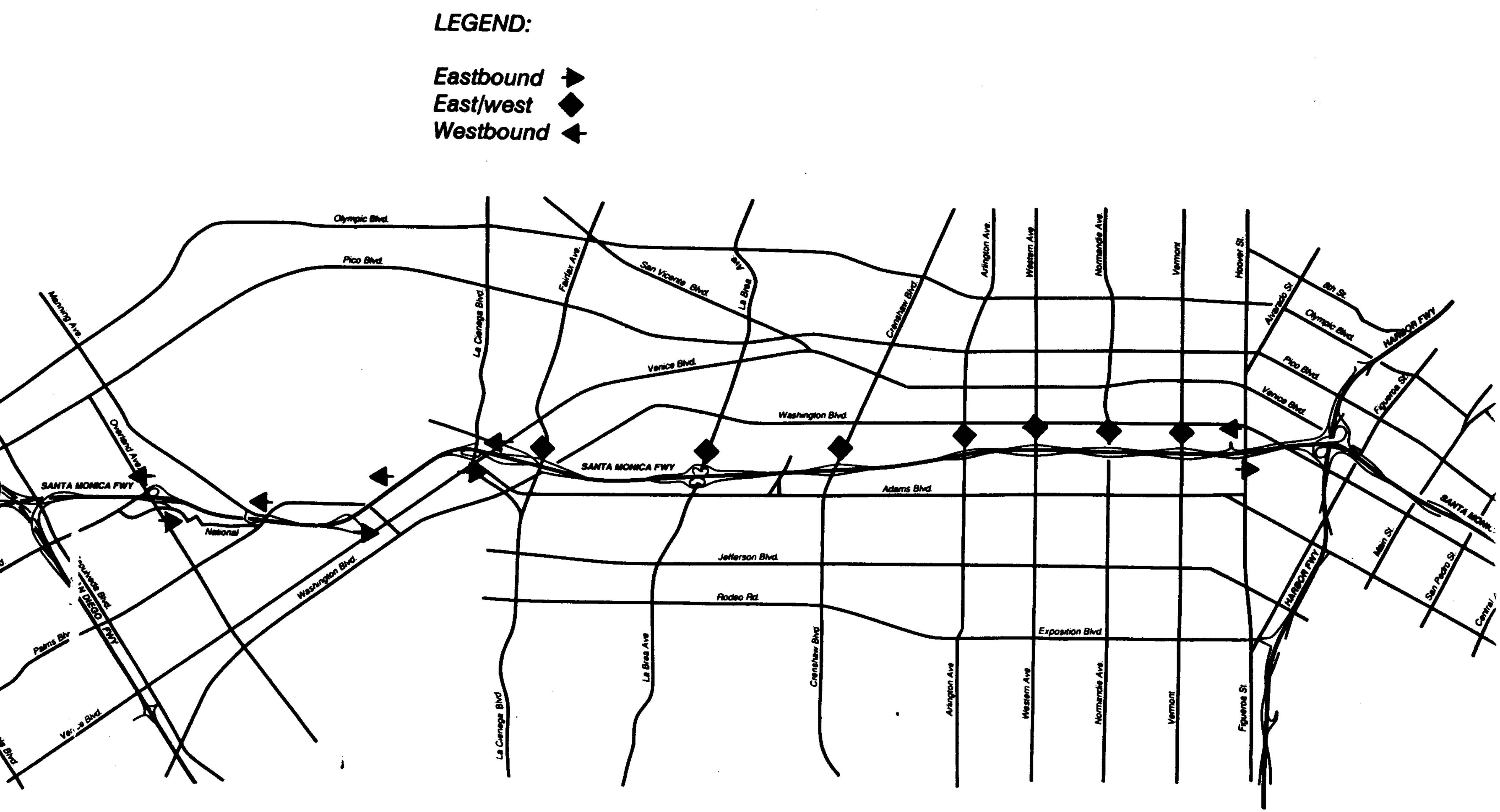


EXHIBIT 1

ATSAC PROGRAM

Expansion of the LADOT Automated Traffic Surveillance and Control system (ATSAC) to cover the entire Smart Corridor project area has been seen as a "given" as part of the Smart Corridor project. This system is the heart of the City's ability to provide the necessary traffic signal timing to provide coordinated control along the five surface street arterials and their north-south access routes. ATSAC exists in the eastern section of the corridor, having been implemented as part of the Coliseum and Central Business District (CBD) systems.

There are 312 signalized intersections in the project area which are under the control of the City of Los Angeles. A contract is being executed for the design of ATSAC for these locations and approximately 40 locations are to have interim improvements to coordinate with the Pathfinder project. The Smart Corridor budget includes funding for this design and construction. Field construction is to include both trunk and distribution components of the recommended City owned communications network which is covered under a separate working paper.

The project also requires furnishing and installing an additional area computer to handle the signals in the Smart Corridor area. This computer will be linked to the existing supervisory computer and directly integrated into the operation of ATSAC. The area computer will also require a new central communications processor and additional graphics workstations. The overall project is also to include an expansion of the control center to provide space for the increased computer and City owned communications equipment.

The project team has also strongly recommended that the signalized intersections in Culver City and Beverly Hills that are along Smart Corridor routes be included in the project and connected to the ATSAC system. This will allow coordination and surveillance across jurisdictional boundaries and provide an improved alternative route. It will also demonstrate the ability of agencies to cooperatively handle traffic at jurisdictional boundaries. This recommendation is discussed briefly in a separate working paper.

Operations and Maintenance

The addition of an area computer with 312 intersections plus the signals in Culver City and possibly Beverly Hills will require additional operating staff for the ATSAC center. Also, the fact that more complicated operating plans will be required to coordinate ATSAC, the Caltrans ramp metering system, and to provide coordinated diversion during incidents will add to the operating load at the center. It is recommended that 2 additional staff members be added to the center to handle day by day operations in ATSAC after the initial operating plans have been developed.

The City is well established to handle the normal signal maintenance. The 312 intersections do not represent totally "new" work in that signals and controllers are in place. The new controllers, Type 170's require increased skills over that of the electromechanical ones, however the City is already moving in that direction for all of its signals and has developed a maintenance capability for the controllers.

The communications trunk lines, the electronic equipment at the hubs and ATSAC center, and the fiber optic portion of the distribution network do, however, add very specific maintenance requirements to ATSAC. Testing and repair of the electronics equipment is the most demanding of the new requirements. Although the project team has recommended the use of standard telephone industry equipment for digital communications, the equipment is very complex.

Special training and skill levels will be needed for this equipment if it is to be maintained by City staff. The staff will have to be highest level electronics staff, preferably with electrical or electronic engineering degrees or strong electronics training. This staff will require skills, and therefore salary levels, significantly different than those associated with normal signal technicians. It is recommended that two staff positions be provided at this level to insure availability for emergency repairs and to handle all of the equipment at the two hubs and central. The staff can also be used to train signal technicians in fiber optics testing and splicing and handle the more complex problems with the cable network. Additional staff will be required when the network is expanded and new hubs are brought on line.

If the specially trained staff cannot be provided through the City, the available alternative is to use contract maintenance for the electronic equipment and the fiber optic trunk network. Resources are available in the Los Angeles basin for contract maintenance if that approach is selected by the City.

Costs

Costs for the ATSAC project, developed primarily by City staff are shown on Exhibit 1. The costs exclude the trunk communications system as recommended by the project team. As can be seen, the ATSAC project element represents the single largest component of the overall project. The ATSAC system has been found to reduce delays by 10 to 15%, reduce stops by approximately 35%, reduce emissions by approximately 10%, and have a benefit cost ratio of approximately 10 to 1, making it an easily warranted component of the program.

EXHIBIT 1

LADOT COST SUMMARY

ATSAC

Control Center Hardware	$ 3,171,000
Intersection Construction	$ 9,828,000
Caltrans/ATSAC Control Center Link	$ 500,000
Control Center Staff	$ 318,400
Additional Staff Costs for 24 hr/day	$ 300,000
Incident Management Team (Staff & Eqmt)	$ 233,000
Changeable Message Signs	$ 1,600,000
ATSAC Control Center Expansion	$ 125,000
Field Construction Staff (Eqmt)	$ 67,500
Highway Advisory Radio	$ 315,000
Construction/Incident Mgmt System	$ 320,000
CCTV	$ 1,000,000
Project Evaluation	$ 250,000
Total Costs	$ 18,027,900

ATSAC HOURS OF OPERATION

The ATSAC system control center is currently staffed between the hours of 6:30 a.m. and 6:30 p.m. during normal work days. The center is also staffed for scheduled special events such as major football games at the Coliseum, the Academy Awards at the Shrine Auditorium, and especially heavy sales days during the Christmas period. It is expected that the control center will be staffed for longer and longer periods as more intersections ar added to the system and as congestion continues to increase. When the system reaches its planned scale of approximately 3000 intersections, it is expected that the center will be staffed 24 hours a day, 7 days a week. The LADOT communications center is operated on a full time basis and their are signal technicians available at all times.

The Smart Corridor project will add a significant load to the center and increase the times when responses to incidents or unusual congestion is required. As has been discussed, many of the responses will be preplanned and will not require on-site staff. Many conditions will occur, however, for which pre-agreed plans or policies have not been set. This will require operator action so that ATSAC and other features of Smart Corridor are operated to fit the conditions.

Assuming a staff of two persons for the currently unmanned periods (approximately 20 to 25 person shifts), it would cost approximately $300,000 additional per year to provide the operating staff. The staff would be dealing with almost 1000 traffic signals by the time the Smart Corridor project is completed. Using figures developed from earlier evaluations of the ATSAC project, the system provides $60,000 in annual benefits per intersection. If this could be increased by even 1% by having staff available to respond to unusual conditions during the currently unattended period, the added staff would have a benefit cost ratio of over 2 to 1.

During the 12 hour period at night and the two weekend days, approximately 20% of the travel and accidents occur. Recognizing that the incidents have significantly lower congestion impacts because of the volume levels, it is still reasonable to expect that the staff could have a one percent impact over existing conditions. Further, the staff could be productively involved in developing new timing and operations plans, improving the expert system rules using off line data, and documenting system performance. The staff could also reduce the need for overtime or compensatory time use of existing staff to handle special events.

It is the project team's recommendation that ATSAC control center operations be extended to full time operation when the signals in the Smart Corridor project area come on line. If this is not acceptable to the City, it is recommended that a regular call out process be developed so that Caltrans and CHP staff have a mechanism for contacting an operator with decision making power on a 24 hour a day basis. the on call person would be equipped with a remote terminal so that ATSAC and other system features could be accessed quickly and appropriate responses implemented.

CLOSED CIRCUIT TELEVISION

Closed circuit television (CCTV) has been used extensively as part of freeway surveillance and control systems for purposes of identifying the cause of unusual delays or incidents. Generally CCTV is used to visually review conditions after they have been identified by another source, such as surveillance detectors. The Santa Monica Freeway has CCTV throughout the corridor and it has been used successfully for the purposes noted. The existing system uses 13 black and white cameras mounted on structures and overcrossings. One location is on a CHP radio tower. The cameras are controlled from the TOC using leased telephone lines. The video signal is transmitted over microwave. The microwave channel is to be lost at the end of 1991 and replacement communications will be required.

More limited use of CCTV has been made in conjunction with surface street signal control systems. ATSAC is using color CCTV to view a CBD area and additional sites are planned. Columbus, Ohio has made extensive use of CCTV in its downtown area and monitors it regularly to identify unusual congestion. Anaheim has recently awarded a contract to install 8 CCTV at critical intersections to provide visual surveillance of a congested area.

Future applications of CCTV are also expected to include image processing technology to collect traffic data directly from the video image. This is being extensively tested in the Minneapolis/St. Paul area and is the subject of a separate discussion paper.

SMART CORRIDOR APPLICATIONS

Several applications of CCTV are contemplated for the Smart Corridor project area. The existing locations on the freeway appear to provide useful information for operations decision making and more extensive use during the project is expected. The existing system, however, has limitations which should be reviewed. The existing black and white cameras, coupled with the microwave communications, provide relatively unclear or "fuzzy" images. Also, black and white images are less clear for observing traffic congestion and tracking individual vehicles. The existing camera mountings are also relatively low, resulting in reduced field of view and making it difficult to observe traffic at a distance from the camera. The existing system is also reaching an age where it is becoming more difficult to maintain, that is, the equipment is nearing the end of its useful life.

When the Santa Monica cameras were installed, black and white cameras were the logical choice. They provided greater clarity than color, were significantly less expensive to install and maintain, and were markedly superior during low light conditions. Also, the mounting height was reasonable given the concern for the reaction of residents in the area or motorists for the "big brother" aspect of CCTV. As one of the early California implementations, a conservative approach was warranted.

The majority of the reasons for the initial decisions do not apply today. Color cameras are very inexpensive and the new CMOS/CCD technology cameras offer excellent clarity, fading to shades of gray and black at night (instead of the shades of pink of early cameras). CCTV is also more broadly applied and it is not expected that adverse reactions would occur if the cameras were mounted at a greater height. Given the need to modify the video transmission for use with the proposed communications network, the expected life of the existing units, and the potential for improving the performance of the CCTV element, the project team conducted field review of several of the camera sites to determine if replacement was warranted.

Extensive application to the surface street network is also being considered to serve two primary purposes. First, CCTV is seen as the best way to insure that the street system has operating capacity before additional diversion is implemented and to monitor system performance as diversion occurs. This reflects the strong concern that the streets should not become overloaded so that motorist confidence in the alternate routes is gained and to avoid any diversion from backed-up intersections to the residential streets. The second use parallels that of the freeway; to provide visual confirmation of an accident or other condition that is causing unusual congestion.

TECHNICAL AND OPERATIONAL CONSIDERATIONS

Four sites along the freeway were selected for review. These sites were selected such that tests could be run without interfering with traffic. Videotapes were made from the existing cameras and then field tapes were made using a commercial color camera with lenses similar to the existing. The field tapes were made from a lift truck, generally parked on an overcrossing. Tapes were made showing the effect of a mounting height of approximately 45 feet above the level of the overcrossing. The field tests clearly show the improved field of view offered by the increased mounting height. The tests also provide a limited comparison of the black and white and color images. The overcrossings offer replacement sites for several of the existing cameras. Other locations can use extensions placed on sign structures. Exhibit 1 shows the locations where comparisons were made. Exhibit 2 depicts the existing Caltrans camera sites with proposed modifications.

For surface street application, CCTV placement guidelines were first developed and then sites selected for field review and test. The following criteria were used.

- o Located along a major diversion route (Venice, Olympic, Washington, Adams).
- o Critical intersection as defined by LADOT.
- o Intersection with greater than 20 accidents per 3 year period or an accident rate equal to or greater than 0.5 per million.
- o Intersection cross street serves as major collector arterial to the Santa Monica freeway.
- o The site is relatively unobstructed and either has, or can be provided with, enough height to offer excellent viewing.
- o Intersection is situated near one of the outer limits of the Smart Corridor diversion routes. This is to verify that starting points of suggested routes are clear prior to recommending their use.

Site Locations (ATSAC)

Thirty-seven potential camera sites, based on the above mentioned criteria, were identified to provide good coverage of the Smart Corridor. Video tapes were then made to simulate, as close as possible, the prospective camera range using a full zoom lens and a bucket truck capable of extending to a 40 foot visual reference height.

Data obtained from these tapes were then plotted onto a map of the Smart Corridor to define the range and overlaps provided at these initial sites. In conjunction with City personnel, 29 final locations were then defined (Exhibit 3) and plotted showing the expected CCTV camera coverage (Exhibit 4).

The primary concerns for extensive use of CCTV is its initial and maintenance cost and its impact on communications bandwidth. Costs are addressed later in this

Exhibit 1

CCTV VIDEO COMPARISONS

CALTRANS		JHK FILM LOCATIONS
EXISTING CCTV LOCATION	**CAMERA NUMBER**	
National Blvd.	#1	Overland Overpass
West Blvd.	#7	West Blvd. Overpass
10th Avenue	#7	10th Avenue Overpass
Arlington Ave.	#9	Arlington Avenue Overpass
Western Ave.	#10	Western Avenue Overpass

Exhibit 2

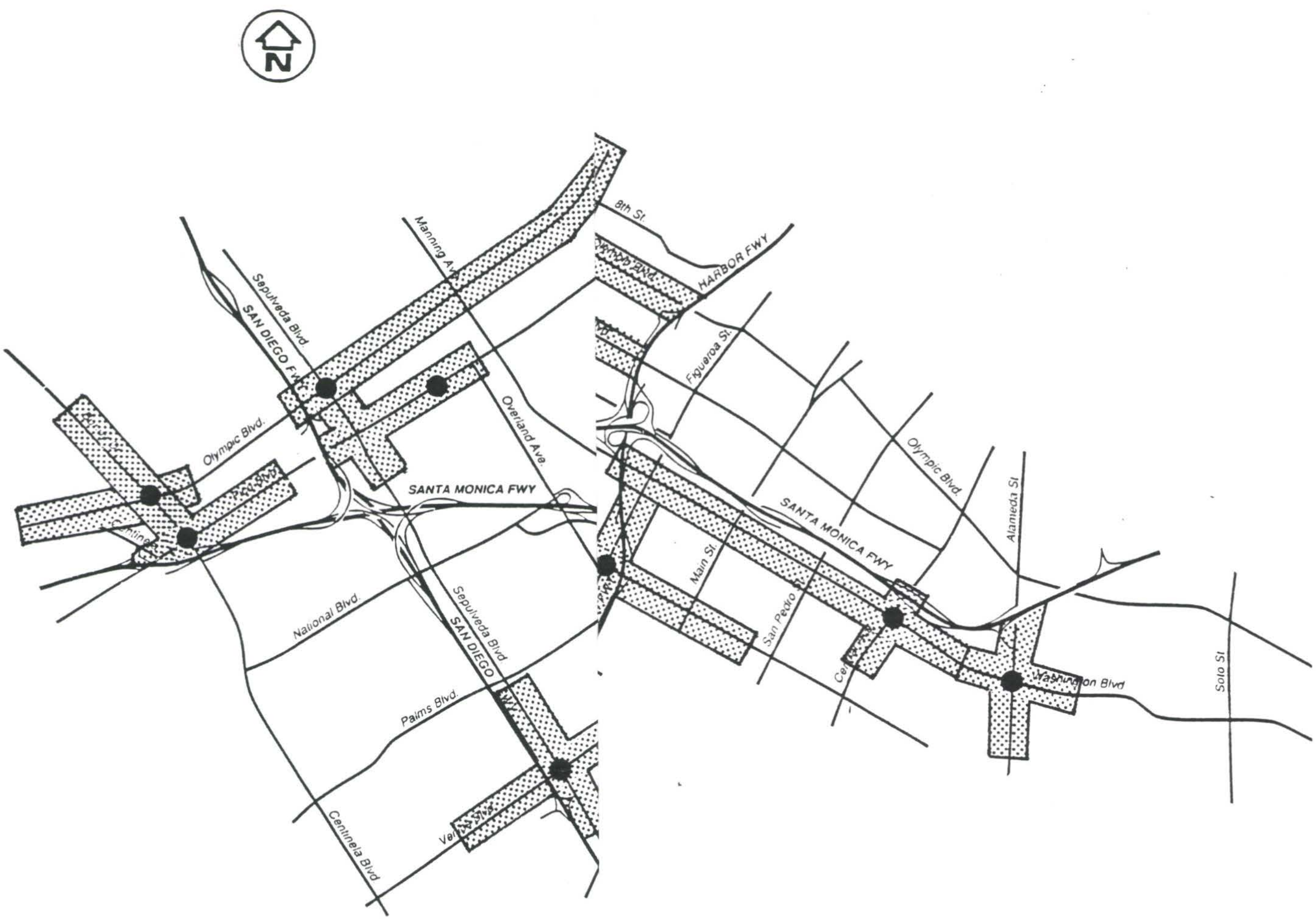
PROPOSED CALTRANS CCTV MODIFICATIONS

PROPOSED SANTA MONICA FREEWAY CAMERA LOCATIONS	REQUIRED STRUCTURE MODIFICATIONS
Centinella	Attach CCTV extension pole to existing freeway sign structure
SB 405 to EB 10 Connector Ramp (Centered over the 405/10 freeway)	Install new 45' CCTV pole
National	Leave on existing microwave structure
Manning	Attach CCTV pole to topside of overpass
Robertson	Attach CCTV extension pole to existing freeway sign structure
La Cienega	Attach CCTV extension pole to existing freeway sign structure
Fairfax	Attach CCTV extension pole to existing freeway sign structure
La Brea	Attach CCTV extension pole to existing freeway sign structure
West Blvd.	Attach CCTV pole to topside of overpass
10th Avenue	Attach CCTV pole to topside of overpass
Arlington	Attach CCTV pole to topside of overpass
Western	Attach CCTV pole to topside of overpass
Vermont	Attach CCTV pole to topside of overpass
10th/11th Street Interchange	Leave on existing FM radio tower

Exhibit 3

PROPOSED LADOT CAMERA LOCATIONS

Intersection	Total # of Accidents (3-yr Period)	Accident Rate (Per Million Vehicles)	Peak Hour Level of Service AM	Peak Hour Level of Service PM
Olympic/Alvarado	-	-	E	F
Olympic/Western	48	0.56	D	E
Olympic/Crenshaw	36	0.5	D	E
Olympic/La Brea	33	0.36	E	D
Olympic/Fairfax	19	0.28	B	D
Olympic/La Cienega	28	0.28	D	E
Olympic/Century Park East				
Olympic/Sepulveda	22	0.22	F	F
Olympic/Bundy	-	-	D	E
Pico/Alvarado	-	-	A	E
Pico/Westwood				
Pico/Bundy	19	0.23	A	B
Venice/Vermont	47	0.8	C	D
Venice/Western	44	0.77	B	D
Venice/Crenshaw	-	-		
Venice/La Brea	55	0.59	E	E
Venice/La Cienega	48	0.58	E	F
Venice/Sepulveda	22	0.26	E	F
Washington/Alameda	17	0.28	C	C
Washington/Central	52	0.9	D	F
Washington/Normandie	23	0.35	D	E
Washington/Arlington	29	0.51	C	C
Washington/Crenshaw	28	0.4	D	D
Washington/La Brea	35	0.38	E	F
Washington/La Cienega	2	-		
Adams/Figueroa	46	1.0	B	E
Adams/St. Andrews	26	0.49	C	D
Adams/10th Avenue				
Jefferson/La Cienega				



8th St.
HARBOR FWY
Manning Ave.
Sepulveda Blvd
SAN DIEGO FWY
Overland Ave.
Olympic Blvd.
SANTA MONICA FWY
National Blvd.
Sepulveda Blvd
SAN DIEGO
Palms Blvd.
Centinela Blvd
Figueroa St.
Olympic Blvd.
Alameda St.
SANTA MONICA FWY
Main St.
San Pedro St.
Soto St.

paper. Regarding communications requirements, there is no question that video transmission places the heaviest load on the network. As discussed under the Communications paper, it is impractical to convert full motion images to digital data for an application such as the Smart Corridor. This requires the use of dedicated fiber for the CCTV image and use of FM or AM modulation techniques to allow multiple images over a single fiber. If, however, a dedicated network is used as is recommended for the project, the costs of the extra fiber optic cable is negligible. Also, the multiplexing equipment is expected to add approximately $5,000 per camera (depending on the number of cameras actually connected to a trunk and the number of hubs or repeaters the signal passes through) and this can be considered directly.

A second method for dealing with the communications requirement is to use slow scan digitizing techniques. This technology involves converting the video image into a digital format, somewhat similar to FAX transmission. The problem that occurs is that traffic images involve major changes in a short time period. General use of the information would require 5 to 10 frames per second to be provided. This places a transmission load on the network similar to a T-1 telephone channel. Further the equipment needed for this conversion is more expensive on a per camera basis than the FM or AM modulation technique.

One firm, Universal Video Communication Corp. (UVC), is making great strides in the area of compacting data using X Delta Compression and Differencing techniques to remove the amount of image data needed for motion video. X Delta Compression is the deletion of every 2nd or 3rd line of pixels from the image prior to transmitting, thereby reducing the video data by 1/2 or 2/3 percent. The image is then reconstructed on the other end by computing the missing lines and inserting them back into the picture. Differencing on the other hand, is the process of comparing two frames in a picture sequence and then transmitting only this difference. At this time, differencing can only be utilized in applications where motion is limited and there is no panning or zooming of the camera lens.

EVALUATION AND RECOMMENDATION

Costs for the Caltrans and ATSAC implementation of CCTV—are shown on Exhibit 5. Using a ten year amortization of initial costs and a 10% per year maintenance cost, the Caltrans CCTV system replacement will cost approximately $95,000 per year.

Exhibit 5

SUMMARY OF CCTV COSTS

Caltrans CCTV

Cameras and Mounting	14 @ $10,000	$ 140,000
Installation	12 @ $15,000	180,000
	2 @ $5,000	10,000
Central Control & Monitors		30,000
Subtotal		$ 360,000
Contingencies @15%		55,000
Engineering & Inspection @ 15%		55,000
Total		$ 470,000
Use		$ 475,000

ATSAC CCTV

Cameras & Mounting	29 @ $10,000	$ 290,000
Installation	29 @ $15,000	435,000
Central Monitors & Control		50,000
Subtotal		$ 775,000
Contingencies @ 15%		115,000
Engineering & Inspection @ 15%		115,000
Total		$1,005,000
Use		$1,000,000

Note: Communications and Hub electronics costs are included with communications estimates.

The existing Caltrans CCTV system provides visual confirmation on freeway traffic conditions throughout the Smart Corridor. Identification and verification of incidents is also possible, however, to a lesser extent. Often the visual image provided by the existing cameras can be unclear making incident detection difficult. Modification of the current system to include higher camera mounts, high quality color cameras, and fiber optic transmission would greatly improve the systems ability to identify and verify freeway incidents. Once identified, the proper incident response teams would be alerted and if necessary, metering rates on nearby ramps could be adjusted until the incident had been cleared. Overall, incident response would be improved and the duration of the congestion causing incident reduced.

Preliminary results from a study of improved incident response with Freeway Service Patrols indicated that the average duration of incidents could be reduced by 50 percent. It is reasonable to assume that a modified Caltrans CCTV system would play a large role in reducing incident duration. Assuming that one-half of the benefits associated with improved incident detection and response could be attributed to CCTV, a minimum of 150,000 vehicle hours of delay would be saved annually.

Using a cost savings of $6.35 per hour, this results in a direct benefit of $950,000. When compared to costs, a benefit cost ratio of 2 to 1 results.

Implementation of CCTV on the surface street system within the Smart Corridor provides several potential benefits. Incidents, including both accidents and stalls, would be identified and appropriate response measures could be implemented to reduce the impacts on traffic flow. Depending upon the severity of the incident, appropriate response teams could be alerted in a timely manner, thus reducing the duration of the incident. For the more frequent minor incidents or stalls, with the aide of the visual image, signal timings could be adjusted to minimize the traffic impacts until the incident is cleared. Also, traffic control and parking control officers could be dispatched.

Another major benefit is simply the ability of CCTV to verify traffic conditions on the surface streets. This is especially important when freeway traffic is diverted to an alternate route during an incident, or when alternative routes are suggested during peak traffic conditions. Unusual roadway conditions, such as construction activities, could be identified and the information added to the database. Also, illegally parked cars could be spotted and officers dispatched.

Quantifying the benefits of CCTV on surface streets is difficult. Essentially, CCTV is considered to provide an important supportive function in the system. It is possible, however, to estimate the potential of CCTV to reduce the impacts of incidents on surface street traffic operations. Currently within the Smart Corridor, an average of 500 accidents per year are reported at those intersections where CCTV coverage is projected. This number only represents accidents which occur in or near major intersections and do not include mid-block accidents, unreported accidents, or other minor incidents. The total number of incidents which would occur within the area of CCTV coverage might be 5 to 10 times as high or 2500 to 5000 per year.

Based on estimates of intersection delay, the benefits associated with this particular function of CCTV would approximate 30,000 - 60,000 vehicle hours of travel time saved per year and a similar reduction in vehicle hours of delay. Fuel consumption and vehicle emissions would also improve slightly. These benefits are small when compared with other system components, however, they are significant. Assuming direct benefit of $6.35 per hour of time, a savings of $190,000 to $380,000 results. When compared to annual costs of approximately $200,000 (10% of capital costs and 10% maintenance per year), it may be expected that the surface street system will have a positive benefit/cost ratio. The indirect benefits associated with verification of on-street conditions are even more important than these direct benefits.

RECOMMENDATION

The project team recommends replacement of the existing Caltrans CCTV system to provide color cameras at improved mounting heights. The system should be installed in conjunction with the new communications network.

The project team also recommends installation of the complete ATSAC system as shown on Exhibits 3 and 4. This work should be scheduled for completion at approximately the same time that the ATSAC signal work and the trunk communications network is brought on line.

CELLULAR CALL-IN SERVICE

Current estimates indicate that there are approximately 200,000 cellular telephones operating in the Los Angeles basin with perhaps another 50,000 being used in the San Diego area. The density of telephones and their use is such that there are now periods in downtown Los Angeles where delays are experienced in getting an open line or "dial tone". The cellular telephones are popular in the area because significant time is spent in commuting or traveling between appointments in private automobiles and the telephone permits the travel time to be somewhat productive.

Given the large number of the units and the amount of travel being made, essentially all of the freeway network is covered by motorists in vehicles with cellular telephones. These motorists offer the potential for additional "real time" travel information and for early identification of traffic accidents or other incidents which may reduce the capacity of the freeways. This source is currently being tapped in Los Angeles by a private service (Metro Traffic) and a radio station (KNX). Metro Traffic receives approximately 2,000 calls per day on a dedicated number (*JAM) and generally has two operators handling the calls. The caller can get traffic advisory information or serve as a "traffic tipster". On receiving a tip, the reporters may use the information or more likely report it to an airborne observer for verification. The calls are provided free by LA Cellular as a promotional tool for their customers.

The radio station has found that several of the tipsters are very reliable and use their information regularly. Judgement is used in reporting the information from unknown tipsters. The report is personalized, such as "thanks to Ventura Fred", and this seems to appeal to the user. A similar format has been adopted by a sister station in the San Francisco Bay Area (KCBS). Both of the services are free to the user.

There are, however, reported problems with the cellular calls in identifying traffic conditions. Most notably, the callers often report the wrong location for the condition. This may be attributed to not knowing the cross streets along a route or to general directional confusion. It is clear that any "official" use of tipster information would require judgement, increased reliance on known informers, and verification where warranted. A parallel may be drawn with traffic detector information where limitations are recognized but the information is used to identify conditions which warrant further review. In the Smart Corridor system, for example, tipster information might be entered into the common database and used as one of the confirming data elements in an expert system. Even with the limitations inherent in the cellular telephone tipster element, it appears to warrant consideration for the project simply because of its coverage and potential.

Cellular telephones are currently being used to report accidents or incidents on an emergency basis. Any call on the emergency "911" number and made from a cellular telephone is automatically directed to the CHP. It is assumed that the majority of these calls involve automobile accidents and it was logical to route them to the responding agency, the CHP, rather than through the city police agencies, where they would just have to be forwarded. The CHP reports that many of the "911" calls are not true emergencies and this is resulting in an unnecessary loading of the system.

Since the CHP also handles the extensive call box system in Los Angeles County, they have an established system for gathering and acting on call-in information. The system is to be improved under a program to upgrade the call box system and additional equipment and staff positions are to be provided. Given this in-place system for cellular "911" and call boxes and a CAD based mechanism for entering the information into a database, it appears logical to include any cellular traffic information call in service to this operation. It is possible, but unproven, that a service for receiving standard traffic information calls might reduce the misuse of the "911" service. A priority response, where "911" is answered first, call boxes second, and tipster lines third, would allow the additional load to be responded to as conditions permitted, recognizing that a minimum level of service would have to be met. Some new staff would be required but the number would be reduced by integrating the service with the current operations.

System Requirements

If a cellular call-in service is to be provided, it must meet criteria similar to that used by Metro Traffic and the radio stations. Namely, the service must be easy to use by having a simple dial procedure; the service must be free to the user; and the response must be within a reasonable period, say less than two minutes. Also, if the data are to be used in a motorist information or expert system database, methods for insuring some level of accuracy must be maintained. This latter point argues for human operators collecting the information rather than a recorder so that secondary questions may be asked as appropriate. A separate number may also be made available to "regulars" with known ability to accurately report information.

Discussion and Recommendation

Use of cellular call in services presents a dilemma for the Smart Corridor project. The potential for receiving good information exists, however the "good" information may be but a small portion of all of the information reported to the system. The question then becomes, is the useful information worth sorting through all of the other information and will too much bad information get into the database system because adequate filtering is not practical? To compound the problem, the question as to how to isolate the information to the Smart Corridor area so that the demonstration is on a limited basis must be addressed.

It is the project team's opinion that someone will have to tackle the issue head-on if the potential for use of cellular call in data are to be assessed. It is not felt that the experience of Metro Traffic and the radio stations will adequately cover the issue because of the different expectancies as to accuracy. A significant portion of traffic reporting is "entertainment" and the user performs his own filtering. If the information is provided from an official source, a different level of accuracy is expected.

Given that one of the goals of the Smart Corridor project is to demonstrate the use of new technologies and the fact that there will be surveillance information available in the Smart Corridor to assist in validating secondary information, it seems reasonable to include a demonstration as part of the project. This is further supported by the fact that the CHP is already handling significant call in services for the "911" and call box based calls and the cellular call in service would be an extension of the service rather than a totally new operation. The demonstration should include a request for a dedicated number that could be used throughout the Los Angeles basin (and perhaps the entire State) if the system proves effective.

At the same time, there are sufficient questions regarding the success of the demonstration that it should be limited. It is suggested that a one to two year demonstration be included in the project and that it be confined to the Smart Corridor area. This will require cooperation of the cellular companies to provide information to the users, to provide free calls, and to provide a dedicated number for the demonstration. The demonstration will also require significant public information to attempt to limit it to the corridor yet attract users - in essence the demonstration will compete for users with Metro Traffic and others who are covering the entire basin. Special signing will also be required to alert potential tipsters.

The cost of the demonstration will be for the added load to the CHP communications center. It is estimated that the load would be less than one additional operator for each peak period shift, reflecting a cost of approximately $100,000. Costs will also be included in the overall public information program and for fixed signs at approximately $25,000 (ten ground mounted signs at approximately $2,500 each). Telephone lines will also have to be added. A total budget of $150,000 is recommended for this element of the project.

HOURS OF OPERATION OF THE CALTRANS TRAFFIC OPERATIONS CENTER (TOC)

BACKGROUND

Since the beginning of construction work on the Harbor Freeway, the TOC has been operating for 24 hours per day, 5 days per week. Operations start at 5:00 AM on Monday morning and continue through 5:00 AM on Saturday. The TOC may also be operated during the week-end when special construction and maintenance projects indicate the need.

Under normal operations, the TOC is staffed by the following personnel:

- 1 supervisor on one shift
- 3 shifts of 3 assistant engineers

The assistants consist of two traffic engineers to operate the TOC and one programmer for computer operations.

There are no immediate plans to expand the operation of the TOC to 7 day per week operation.

EXPANDED RESPONSIBILITIES OF TOC WITH SMART CORRIDOR

The implementation of the recommendations being developed in this Smart Corridor project will increase the functions and activities being handled at the Caltrans TOC. The new and expanded responsibilities of the TOC operators will include the following:

- Operation of the Smart Corridor workstation
- Expansion of the operation of the freeway surveillance and control system in the Smart Corridor to include enhanced incident detection, operation of additional changeable message signs, enhancement of the application of centrally controlled ramp metering, connector metering, and the control of an additional CCTV camera.
- Enhanced motorist information including expanded operation of CHIN, operation of the HAR, and other motorist information elements.

The additional responsibilities will increase the workload of the existing TOC operators and will place added emphasis on the role they play in motorist information.

It is important as a function of providing traffic condition facts to the driving public that the information be as up to date and as accurate as possible. Otherwise, motorists become distrusting of the data being provided and decline to believe the information or take the advice being offered on alternate routes, etc. An adjunct to the importance of the accuracy and authenticity of the data is the need that new information always be available, and the driver not be subjected to listening to or viewing information from earlier in the day or yesterday. It is therefore important that the available information be constantly updated to reflect current conditions and to include data on abnormal traffic conditions, no matter what the time of day. It is therefore recommended that Caltrans personnel be available 24 hours per day, 7 days per week, to operate the TOC to ensure that up to date, reliable information is being communicated to the motorist. Also, the 7 day operation will allow more direct response to incidents which occur during the week-end.

Additional justification for 7 day per week operation is based simply on providing assurance that the traffic control elements of the TOC are operating correctly and effectively at all times. The automated elements of the system will be demonstrated and tested when the Smart Corridor is implemented; however, it would be overly optimistic to believe that completely automated operation will be totally operational and effective in controlling all the separate elements of the system.

Expanding to 7 day per week operation of the TOC would entail placing operators at the TOC during the week-end periods between 5 AM Saturday and 5 AM Monday. The level of traffic volumes in the corridor on week-ends is less than during the week-day peak periods, but congestion is still experienced on the freeway on week-ends and incidents still exacerbate the congestion. Seven day per week operation of the TOC would provide consistent coverage of the corridor on which the motorist could rely for incident management and motorist information.

Operators on duty during the weekends would be responsible for performing the traffic operations functions associated with the center but not the maintenance and planning functions which are carried out during the normal weekdays. It is anticipated therefore that two operators would be sufficient to handle the functions of the TOC during the week-end period.

COST

The cost in salaries to operate the TOC at its present level of five days per week, 24 hours per day, is approximately $386,100 annually. Based on the hourly wage of the assistant and associate engineers which currently staff the TOC, the manpower to expand the hours of operation to include coverage by one associate and one assistant engineer over the weekends would result in an increased salary cost of approximately $100,000 per year or an additional 26%.

RECOMMENDATION

Based on the above justifications, it is recommended that Caltrans implement 24 hour per day, 7 day per week staffing of the Traffic Operations Center (TOC).

EXPERT SYSTEMS

The operator tasks at the Caltrans and ATSAC control centers are complex, especially when unusual congestion occurs. The tasks will become more complex as project elements are added to the systems and as the control systems are expanded in area of coverage. The joint, coordinated responses planned as part of the Smart Corridor project will add an additional element of complexity and will require informed decision making. As experience is gained with all of the system elements, additional response plans will be prepared and a "fine" tuning of operations may be expected. Also, assuming success in the Smart Corridor, the concepts and control elements will be expanded to other freeways in Los Angeles and perhaps throughout the State.

The City of Los Angeles, working with the University of California at Berkeley, began reviewing the potential for "expert systems" to assist in day by day operation of their system. A paper was also prepared by the City's system manager outlining how expert systems might assist in identifying unusual traffic conditions, provide decision making support, and assist in implementing response plans. Work has continued on two fronts as part of the Smart Corridor work. UCB has continued development of a prototype of an expert system to analyze ATSAC detector data and identify "incidents". This subcontract is nearing completion and will result in a demonstratable PC based expert system for examining detector data. A limited real time test is also planned. The work will be documented separately.

The second thrust has been to review the overall expert system concepts to identify hardware and software that might be applicable to the Smart Corridor project. A paper summarizing the review by the project consultant for this is attached. The paper is complemented by the detailed configuration information included under the database "Conceptual Design Study - System Configuration" working paper included in the workbook. The working papers also relate to the basic operations recommendations included in the summary and overview.

SMART CORRIDOR CONSIDERATIONS

There are three potential applications of expert system technology for the Smart Corridor project. The Caltrans SATMS and the City's ATSAC system both offer opportunities, especially in the area of identifying and/or verifying the existence of "unusual congestion" or incidents. Work is being done to calibrate the Caltrans' incident detection algorithm, however it is expected that there will still be significant areas for improvement of this element. For example, comparing the incident detection to time of day, day of week, call box actuations, etc. Also, any expert system component developed for Caltrans for the project would have immediate application to the remainder of the SATMS area. There are limitations on the Caltrans potential, associated with the existing system, however the basis could be set and then refined when a new system is in place.

The potential in ATSAC applications appears even stronger, given the limitations with current threshold detection. Based on the initial results of the work by Professor May and Mr. Lee Han, there is strong evidence that procedures can be developed to discern between normal congestion and unusual conditions which might warrant operator action. As with the Caltrans' element, work done for the Smart Corridor will be immediately applicable to the full area under ATSAC control, extending the benefits which might be achieved.

The central database system offers further potential for expert system modules, especially associated with the complex decision matrix that will guide the coordination of the various agencies and the individual components under the control systems. The central database will contain information from all of the involved agencies and allow the expert system "if-then" comparisons to be made.

In all of the cases, significant work will be required to develop the actual rules and decision trees or matrices. Also, the modules will have to be "connected" to the existing systems to allow them to interrogate files as may be required. The expert system module will start as relatively straightforward applications programs, however it is expected that they will continue to undergo development throughout the life of the project and the SATMS and ATSAC systems.

It is also important for the expert system component to be able to take advantage of developments by other agencies and to be changed to reflect any host system changes, such as planned by Caltrans and the CHP. All of this argues for the expert system application to be made using stand-alone hardware and software, to the extent practical. The system must also recognize the unique character of real time control systems and operate in that environment.

RECOMMENDATION

There does appear to be significant potential for the use of expert systems as part of the Smart Corridor project and as direct adjuncts to the Caltrans' and City surveillance and control systems. There is little prior experience to draw on so the project team recommends an implementation that can be started relatively simply, but be easily modified and adapted as experience is gained. As stated in the attached paper and the system configuration paper, the best approach appears to be the use of dedicated workstations for the system modules and the use of a basic software package oriented toward real time control. The package identified for the project is called "G2" and will operate on the workstations recommended for the project. The software is also compatible with a relational database approach as is suggested for the project, allowing easier integration.

The costs for the various hardware and software elements are included with the overall central system configuration working paper.

SMART CORRIDOR DEMONSTRATION PROJECT: CONCEPTUAL DESIGN STUDY

Preliminary Design Of Real-Time Knowledge-Based Decision Support Systems

Stephen G. Ritchie

May 22, 1989

Working Paper SGR-WP-89-2

INTRODUCTION

This paper presents a preliminary design for the application of real-time knowledge-based expert systems (KBES) in the Smart Corridor, and discusses important technical issues related to system development. Real-time KBES will provide advanced decision support, principally to LADOT ATSAC and Caltrans TOC staff, and will facilitate timely, co-ordinated and systematic responses to non-recurrent congestion in the Smart Corridor. Decision support for control room staff is necessary to effectively detect, verify and develop response strategies for non-recurring congestion (incidents).

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 and construction activities and special events.

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 capture and emulate human problem-solving skills that involve specialized knowledge, judgement and experience.

Real-time KBES represent a complex and demanding application of KBES technology, and are appropriate where users suffer from cognitive overload in time-sensitive environments, or user productivity must be increased without increasing cognitive loads. This is expected to be the case for incident detection and response in the Smart Corridor. As yet, there are no known development efforts or applications of real-time KBES technology for integrated freeway and surface street traffic surveillance and control in the United States, other than for the Smart Corridor. Real-time KBES applications do exist in industrial and defense domains, however.

A basic premise of the recommendations developed in this paper is that there are significant opportunities for real-time KBES to provide decision support to control room staff, even in existing surveillance and control systems. Perhaps more importantly, however, as the breadth and scope of these systems is vastly expanded to embrace "Smart Streets" concepts for both freeway and surface street systems, it will be increasingly difficult if not impossible for human operators to detect and review all "problem" locations, verify incidents, and develop and implement appropriate response strategies in a timely manner. Real-time knowledge-based systems provide an automated approach to reduce the operator involvement needed to identify true problem locations, determine alternative and consistent courses of action by all relevant agencies, and implement response plans, thereby reducing traffic delays associated with non-recurrent congestion.

This paper first defines real-time KBES and identifies technical characteristics and issues important in system development. The application of real-time KBES to the Smart Corridor is then discussed in terms of preliminary design concepts. Hardware and software options are also discussed.

REAL-TIME KBES CHARACTERISTICS

Many definitions of "real-time" have been proposed, but a precise and generally accepted definition has proven elusive. A commonly perceived characteristic of a real-time system is its speed of operation, variously described as "fast," "faster than a human" or responding to data at a rate as fast or faster than it is arriving. More generally, for an arbitrary state of the system and arbitrary input, a response should always be available by the time it is needed (perhaps expressed by a fixed maximum time interval).

A real-time KBES must satisfy demands that do not exist in conventional domains where the inputs and conclusions are static and time-critical responses are not required. Also, the following features must often be incorporated into real-time systems, and tend to characterize the limitations and inappropriateness of conventional expert system development tools for real-time KBES development (this last issue is addressed in more detail later):

Nonmonotonic reasoning: because detector data, other inputs and deduced facts may decay in validity over time, or cease to be valid, previously established logical dependencies and conclusions must be able to be retracted or modified in light of new information. In a monotonic reasoning process all facts and conclusions remain true, and the amount of true information in the system grows steadily or monotonically. In the Smart Corridor, incident status and response status will change over time as incidents are verified, responded to and cleared. This issue is also referred to as truth maintenance in KBES terms.

Continuous operation: this must be possible, even with partial failures of the monitored system, or temporary loss of communication links. A "graceful" degradation of KBES performance should be ensured.

Asynchronous events: it should be possible for the system to be interrupted to process an unexpected or unscheduled event, or a more important event than those currently being processed.

External and sensor interface: conventional KBES are interactive and receive inputs from the operator; real-time systems typically gather data from sensors or database interfaces, as is expected to be the case in the Smart Corridor.

Uncertain or missing data: the system should be able to recognize and appropriately process such data, perhaps resulting from faulty or inoperative detectors.

High performance: very short response times are often required in the face of rapidly changing data (in the Smart Corridor, response times in the range of 30 seconds to several minutes will likely be required).

Temporal reasoning: this is the ability to reason about past, present and future events, as well as the sequence of events. Knowledge-base rules with time-dependent values and time-dependencies in the input data, will almost certainly need to be provided for.

Focus of attention: this is the ability of the system to focus its resources when a particularly significant event occurs, just as humans do, while maintaining peripheral awareness of the overall problem. Concurrent focus on several individual problems (e.g. incidents in the Corridor) may also be required.

Guaranteed response times: ideally, a response (preferably the "optimum"), should be guaranteed within a given duration.

Integration with conventional software: this should be readily achieved, including interfaces to conventional packages and code such as Fortran, Pascal and C.

OVERALL CONCEPT

The preliminary design of real-time KBES for the Smart Corridor is based on previously developed concepts illustrated in Figures 1.A and 1.B. Each agency is assumed to be supplied with a new local processing unit (node processor). This processor handles data extraction and communications. Real-time KBES would interface to database servers on the node processors at ATSAC, TOC and Smart Corridor Central, denoted henceforth as SCC (the physical location of which is yet to be determined). The ATSAC and TOC KBES would provide decision support pertaining to the LADOT and Caltrans traffic systems, respectively, while the SCC KBES would optimize corridor conditions and co-ordinate actions amongst all agencies.

This design envisions three networked real-time KBES running initially on separate 32-bit microprocessors attached to the node processors at ATSAC, TOC and SCC, with networked terminal displays at any or all of the CHP, LAPD, SCRTD and LADOT Central Communications, to permit viewing of various corridor status reports (and possibly to enable interactive data input to SCC). Communications between the SCC KBES and the ATSAC and TOC KBES would occur via the respective database servers in most cases.

A major component of the ATSAC and TOC KBES would be their user-friendly operator interface (the SCC KBES could probably be designed to run largely unattended). Initial user interfaces will utilize windowing techniques on dedicated monitors. Subsequent on-going development could integrate these interfaces into regular operator terminal displays, to result in one integrated display environment.

The ATSAC and TOC KBES would permit stand-alone independent operation with respect to the LADOT and Caltrans traffic systems. Although this concept involves some redundancy with the SCC KBES, it permits continued operation of the ATSAC and TOC KBES in the event of a communication loss to SCC. Furthermore, this capability is likely to be

The primary intent of this design is to provide decision support to ATSAC and TOC staff, and attempt to optimize corridor mobility, through five integrated modules:

- incident detection
- incident verification
- identification and evaluation of alternative responses
- implementation of selected responses(s)
- monitoring recovery

In addition, timely and useful information can be provided to CHP, SCRTD, and LAPD.

As currently envisioned, the incident detection modules would complement existing and developing algorithmic methods at ATSAC and TOC. This means that separate software could be used to identify potential incident conditions, and that the KBES would only be invoked after such conditions have been declared. This approach removes what would otherwise be an enormous processing burden from the KBES. However, in the case of the surface street system, considerable research is required to develop incident detection capabilities. A greater basic research effort integrating algorithmic and knowledge-based approaches may therefore be required in this case, than for the freeway system.

The incident verification module would guide operators in verification procedures for suspected incidents, This could include selecting and activating appropriate closed-circuit TV cameras, and obtaining and assessing other supporting or negating data e.g. calls from field personnel, nearby call-boxes or cellular telephones.

The module for identification and evaluation of alternative responses will be a major module, requiring not only identification of feasible responses, but possibly on-line traffic network modeling for evaluation and refinement of the alternatives. The conditions under which various responses should be considered will have to be identified, as will evaluation and selection procedures.

Current incident response methods are complex and involve considerable operator judgement as well as familiarity with extensive procedures. This situation will become more complex with the incorporation of additional Smart Corridor alternatives to the list of possible responses:

- activating the Caltrans major incident traffic management team
- dispatch of City traffic control officers and/or traffic signal maintenance crews
- initiating ramp metering changes
- locating and activating freeway mobile and ground-mounted changeable message signs
- co-ordination with other agencies and the media
- co-ordination of ramp meters and surface street traffic signal timing
- activating changeable message signs on surface streets, approaches to freeway access ramps, and in parking garages
- selecting and implementing signed traffic detours
- dispatch of tow trucks on both the freeway and surface street system
- highway advisory radio broadcasts
- telephone dial-in traffic reports
- cable TV traffic reports
- commercial radio/TV traffic reports

- in-vehicle navigation system traffic reports
- traffic condition reports and information displays in major buildings, fleet dispatch centers and computer bulletin boards.

The module for implementation of selected responses must therefore determine consistent courses of action by all relevant agencies, communicate these action plans to the agencies, and monitor confirmation of their implementation.

Finally, the module for monitoring recovery will attempt to assess the efficacy of the implemented response(s) by monitoring selected measures of effectiveness, presenting these to the operator through graphical displays, and assisting the operator to determine if further responses are required.

SMART CORRIDOR CENTRAL (SCC) KBES

The preliminary design of the SCC KBES is predicated on previously developed high-level representations of agency data flows within the Smart Corridor, and central database functions. These ideas are illustrated in Figures 2.A and 2.B, respectively.

As currently envisioned, the SCC KBES would be concerned primarily with incident conditions of corridor-wide significance, requiring co-ordinated responses by more than one agency, or modification of a specific agency's locally developed response plan.

Accordingly, the SCC KBES would continually receive and synthesize verified incident reports (and response plans) from all agencies, to identify existing (and possibly potential) problems of corridor significance. The system could request and process detector data from ATSAC and the TOC to facilitate this process. When such problems are determined, alternative responses are identified and evaluated, a preferred response plan is selected and individual agency actions identified. These actions may confirm or modify locally proposed agency actions, by either the ATSAC or TOC KBES. The SCC KBES then sends messages to each agency advising of incident status and required response actions. Confirmation or otherwise of agency actions is received and logged. Incident recovery is then monitored with a view to the need for additional or different agency responses. When incident conditions affect one agency only, the SCC KBES could largely hand-off to that agency, after approving response plans, and then continue to monitor corridor traffic conditions. In addition, as corridor traffic conditions change, the SCC KBES could be the entity to recommend activation of or changes to motorist information system messages ("system status" in Figure 2.B).

ATSAC AND TOC KBES

The LADOT ATSAC and Caltrans TOC KBES are similar in function, and so are discussed together. The operation of each is consistent with the five decision support modules that have already been discussed.

The operator would first receive a report of a suspected incident, stating the location and invoking conditions. The KBES would attempt to apply more refined tests employing heuristics and localized information to determine with greater certainty whether an incident exists or not. Guidance would be given to the operator on verification procedures, particularly involving closed-circuit TV cameras, where available. The operator, with the assistance of the system, would then indicate whether the incident is verified or not. At the local level, alternative responses would be identified and evaluated by the system, with specific operator actions presented for implementation of the selected response plan. The system would automatically send an incident report and proposed response plan to SCC, which in turn would authorize or suggest modifications to the response plan. Once the response actions have been implemented by the operator, confirmation would be sent to SCC. Through the incident recovery monitoring module, recommendations for further operator action may be made.

Several high-level window interfaces could be displayed to the operator in these KBES, including an incident status report for locally and SCC detected incidents (showing if local incidents are also verified or not), an incident verification window listing suspected incidents and what operator actions to take for verification, and a response status report listing response actions and whether they have been approved by SCC and implemented yet. An action box could also be displayed telling the operator what to do next. Underlying these windows, various menus, reports and graphical displays would be available to the operator.

HARDWARE AND SOFTWARE OPTIONS

An important element that has also been carefully considered in this preliminary design stage is the most appropriate KBES development and implementation environment.

Development tools to build expert systems can generally be divided into programming languages and knowledge engineering languages. Programming languages include conventional problem-oriented languages such as Fortran, Pascal and C, and symbol manipulation languages such as Lisp and Prolog. Symbol manipulation languages have been designed specially for AI applications, but require the expert system developer to essentially start from "scratch" with respect to programming knowledge representation and control methods. On the other hand, knowledge engineering languages usually offer one or more knowledge representation methods, and an inference engine for accessing the knowledge, as well as a more extensive support environment. Knowledge engineering languages range from a large number of shells (a complete expert system with an empty knowledge base, to be completed by the developer using the system's support tools) that are now available for powerful general-purpose workstations and microcomputers, to sophisticated packages for dedicated AI hardware. KBES shells usually offer a faster route to system prototyping and development, and with the recent advances in both computer hardware and KBES software, provide a particularly cost-effective environment for both development and implementation.

However, as discussed earlier in this paper, conventional KBES development tools do not typically support the advanced features necessary in a real-time KBES. This particularly includes high performance (response time), temporal reasoning, nonmonotonic reasoning or truth maintenance, external interfaces to databases, conventional software and sensors, asynchronous inputs, and focus of attention. In addition, this preliminary design calls for interacting, networked real-time KBES communicating via database servers or directly through the network, and to remote terminals. Substantial KBES expansion may also be required in the future (with further implementation of "Smart Streets" concepts), without degrading system performance.

Ideally, one would like a powerful, flexible, proven and easy-to-use real-time KBES tool, that would permit development and implementation on a variety of hardware platforms.

While there are a great many KBES development tools available, many of which claim a real-time capability, only one commercially available system has been identified to date that is designed specifically for real-time applications, and which provides many of the features referred to above. This tool is G2, from Gensym Corporation in Cambridge, Massachusetts.

G2 is a powerful "high-end" KBES development tool, capable of addressing large, networked real-time applications. The user-interface utilizes interactive graphics and natural english language to facilitate both development and implementation. G2 is Lisp-based, and currently runs on workstations from Sun, DEC, HP, TI, Symbolics, as well as Macintosh II and the Compaq 386. A version for the IBM PS/2 80 is due later this year. Version 2.0 of G2 is planned for release in September, 1989, at which time full integration with the ORACLE database management system proposed for use in the Smart Corridor will be provided (simple interfaces are currently said to be supported).

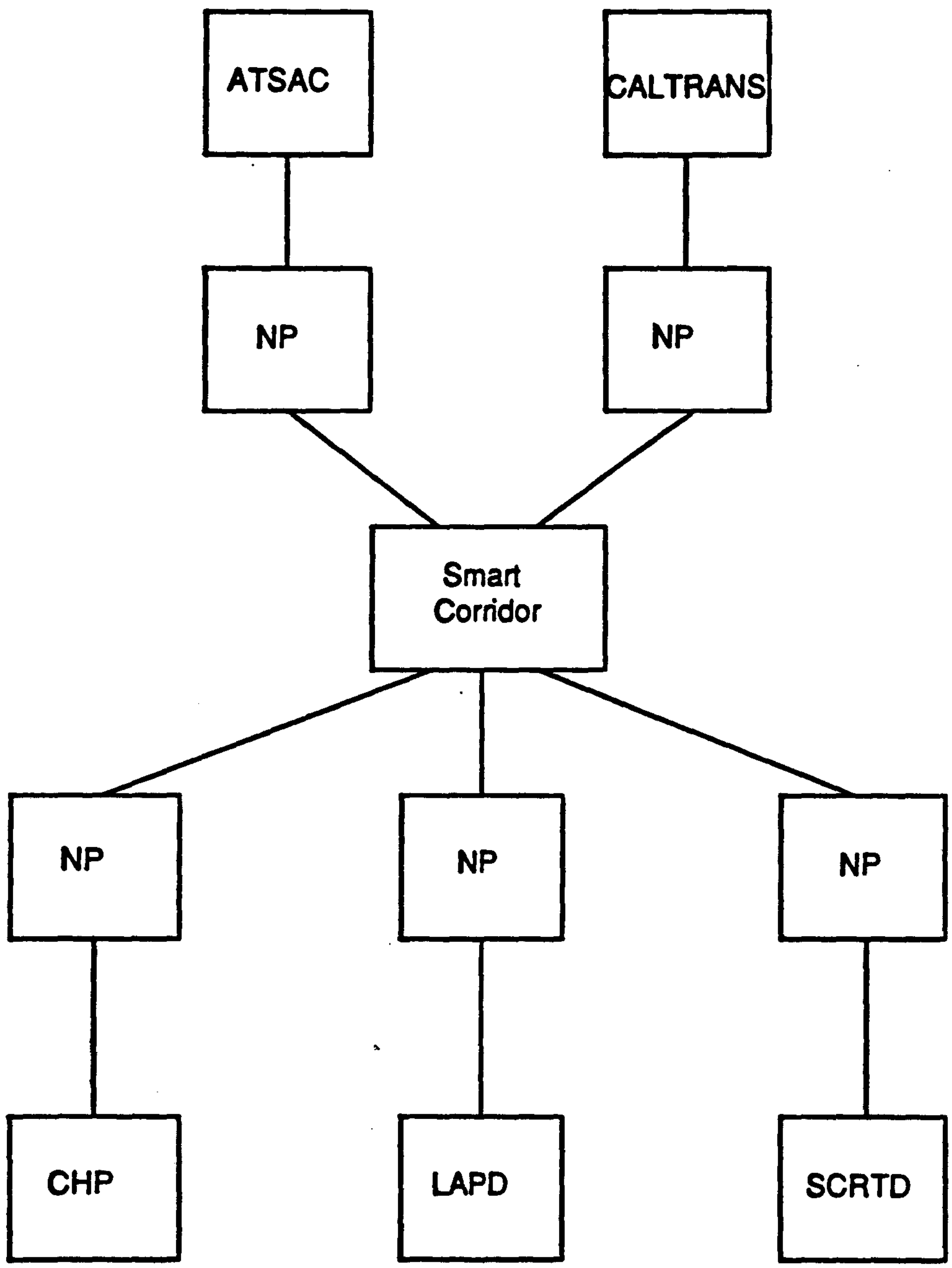
Assuming use of mid-range workstation platforms such as the DEC MicroVAX or Sun-3 (each with 16 MB of RAM), G2 software costs are currently as follows:

1 G2 development system (for SCC)	36,000
2 G2 run-time systems (for ATSAC and TOC) @ $18,000 each	36,000
3 Intelligent Communication Protocol systems (1 for each G2) @ $8,000 each	24,000
4 Telewindow systems (for remote G2 access at CHP, SCRTD, LAPD, and LADOT Central Communications) @ $6,000 each	24,000
	120,000
10% site license discount	-12,000
	108,000

First year maintenance @ 15%	16,200
	124,200
Sales tax @ 6%	7,452
TOTAL	$131,652

Gensym reports that this pricing is indicative only and is under review. In particular, run-time system prices may be reduced in the near future.

Further information about G2 is provided in Figure 3.

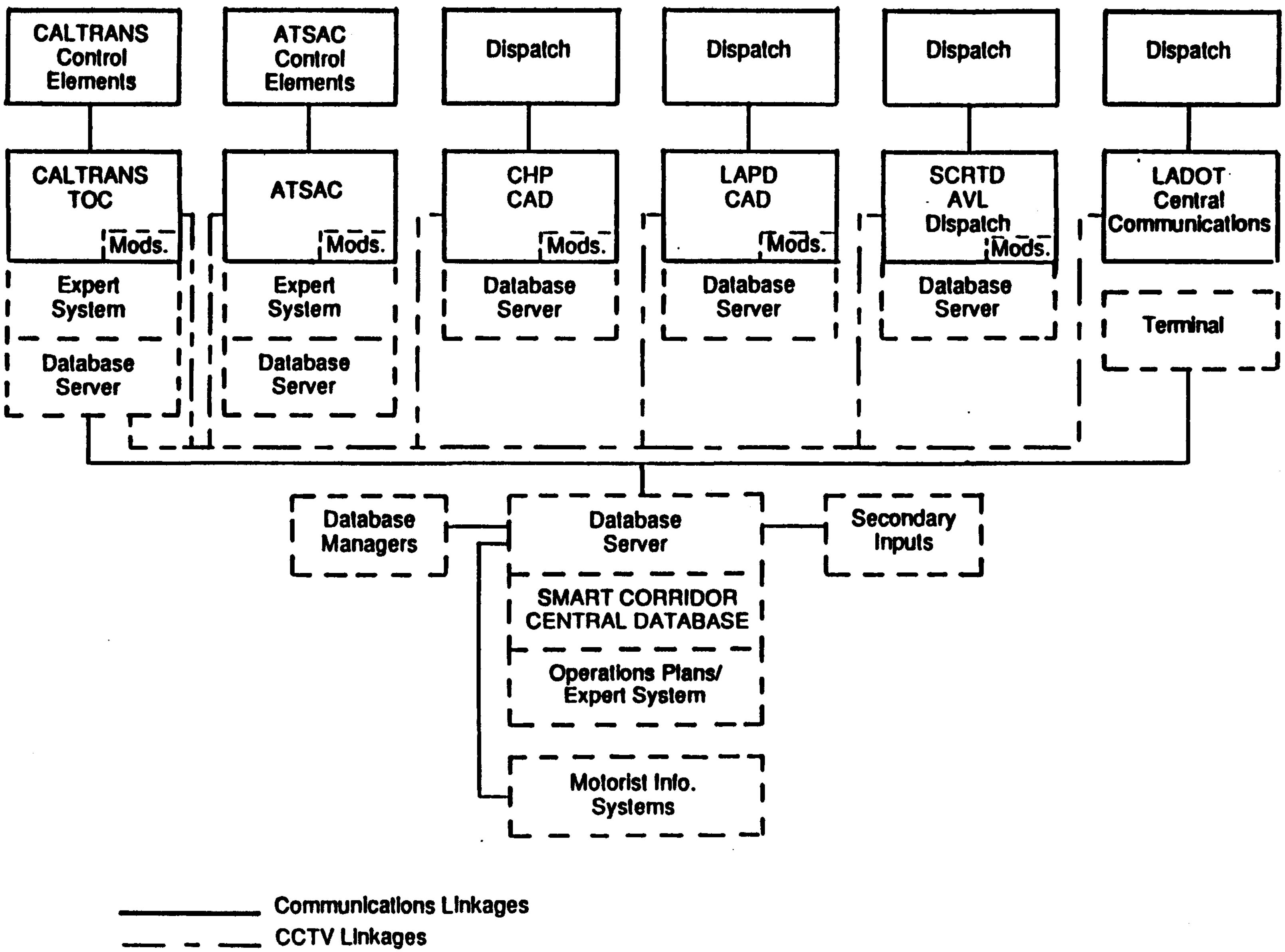


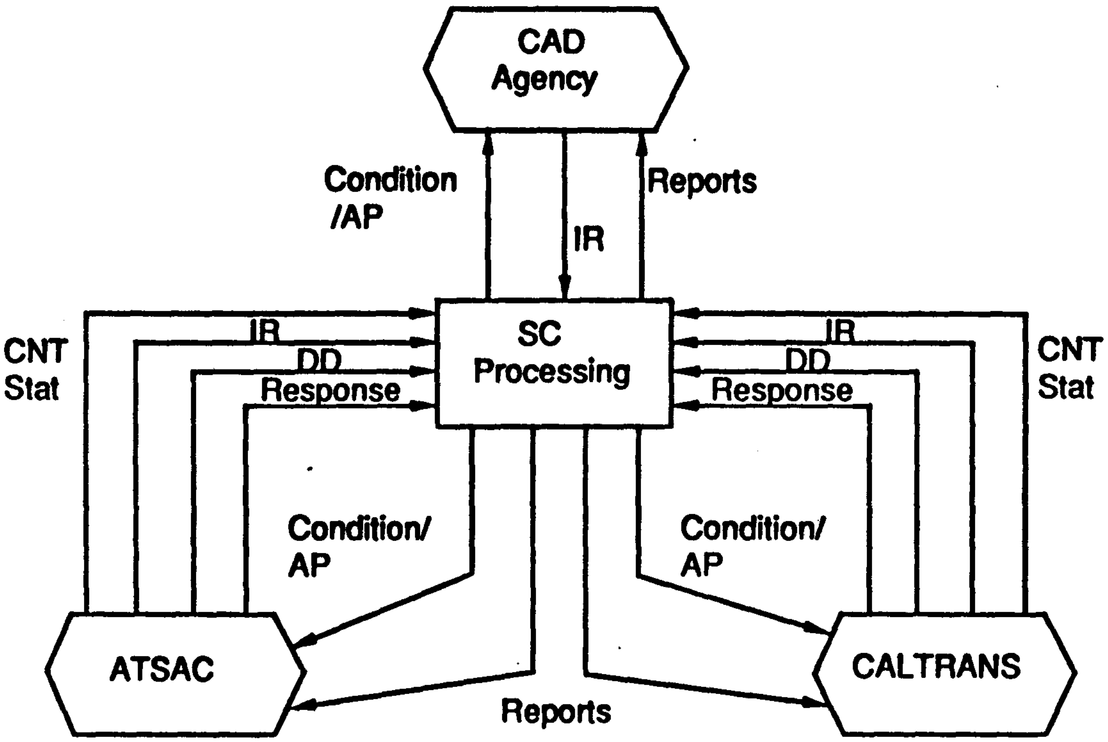
NP - Node Processor

FIGURE 1.A HARDWARE

FIGURE 1.B

OVERALL CONCEPT LAYOUT





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 :

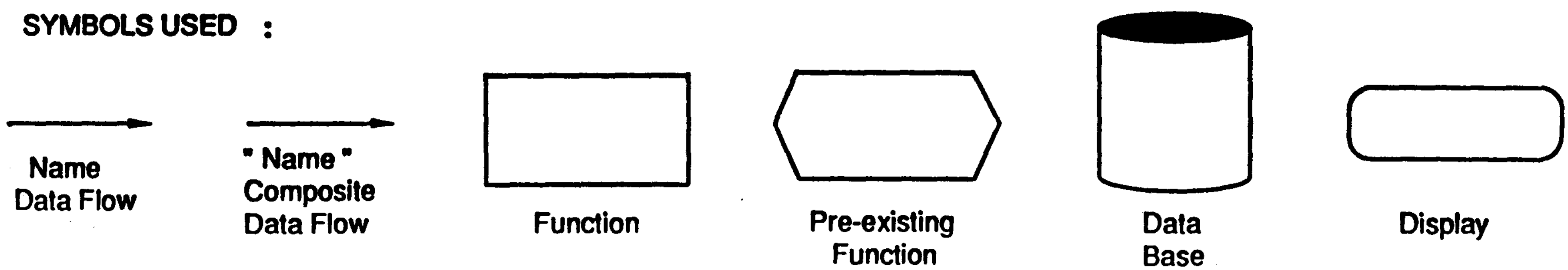


FIGURE 2.A - AGENCY INTERFACE

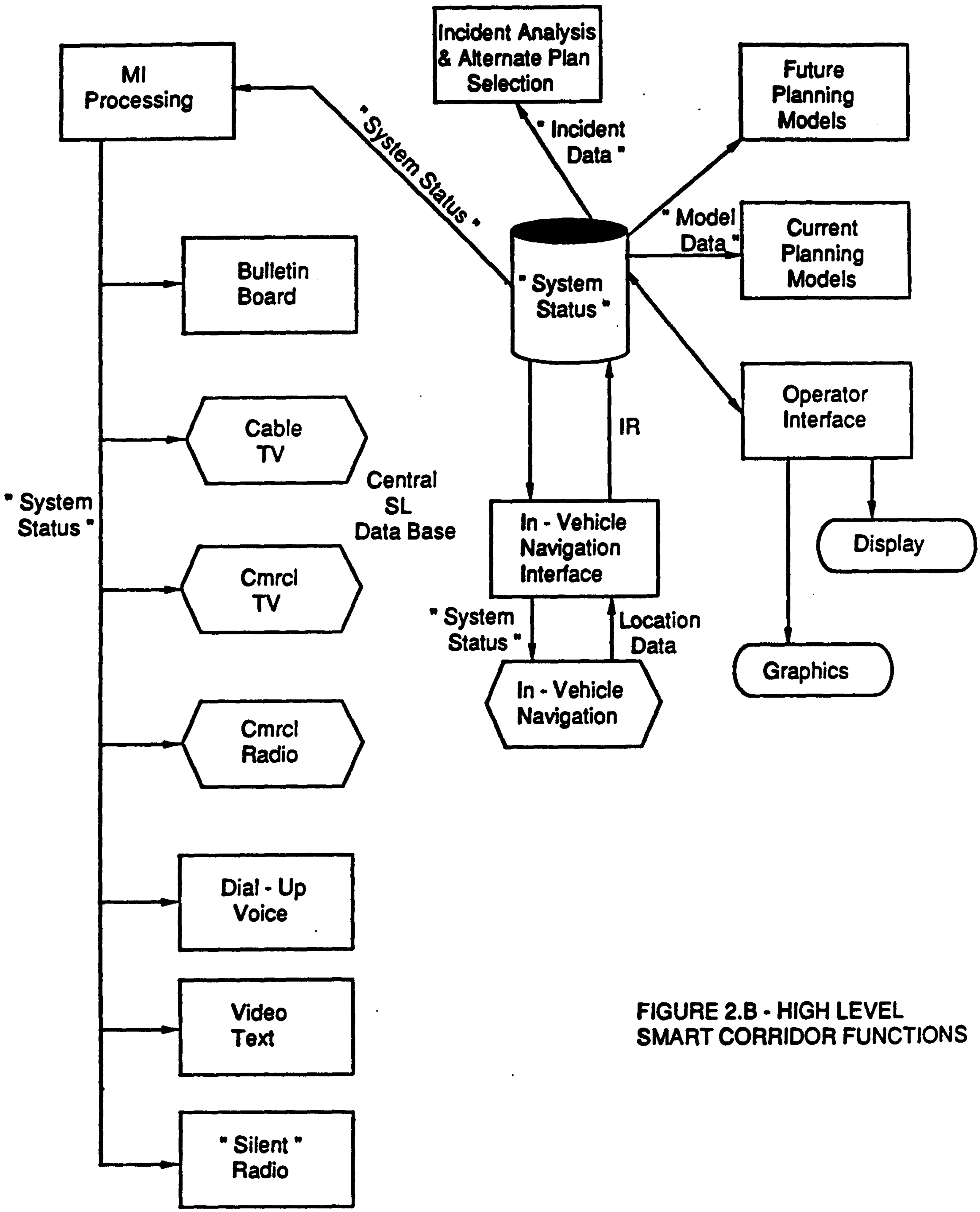


FIGURE 2.B - HIGH LEVEL SMART CORRIDOR FUNCTIONS

FIGURE 3 - INTRODUCTION TO G2, (PROVIDED BY GENSYM)

Gensym

An Introduction to G2

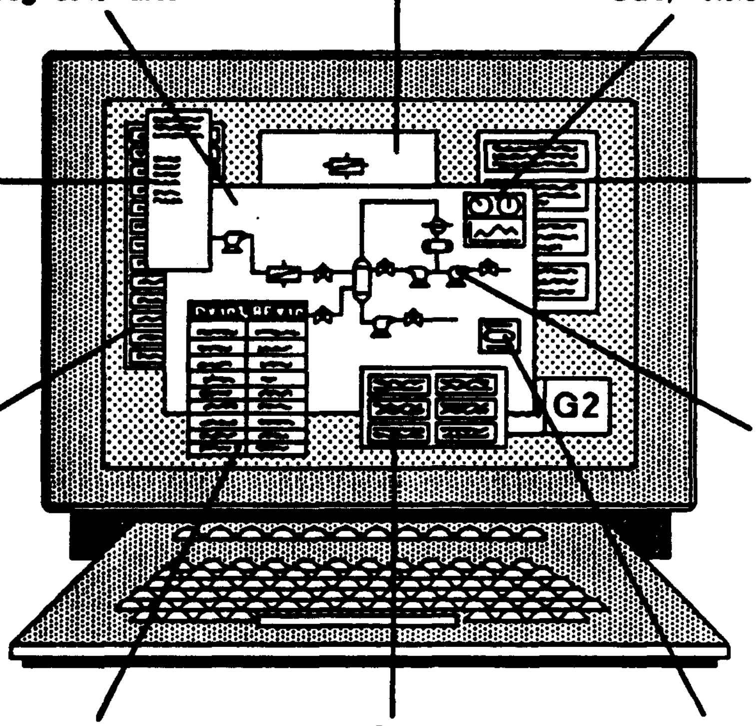
Workspaces
Allow the user to represent an application graphically through schematics.

Subworkspaces
Allow for organizing knowledge hierarchically.

Graphic Displays
Represent data in easy-to-understand forms, such as dials, meters, and graphs.

Editor Window
Guides the user in entering rules, statements, and values.

Operator Logbook
Maintains a chronology of events and operator actions.



Message Board
Posts important information to the operator concerning real-time events.

Dynamic Simulation
Models and simulates real-world applications, for testing knowledge bases and comparing actual and ideal behaviors.

Attribute Table
Allows the user to view and edit the information associated with objects.

Real-Time Generic Rules
Used to represent knowledge that can apply to any of a class of objects.

Animation
Provides the ability to move and rotate objects dynamically.

G2 User Interface

G2 displays information through a highly-organized, easy-to-understand windowing system that enables the user to easily work with knowledge and real-time data. These windows can contain schematics, animated graphs, rules, or tables. All windows are at the user's control: they can be viewed, hidden, moved, scaled and layered as desired.

G2 features an editor window and attribute tables to assist the user in editing rules and objects. This provides an easy-to-follow, uniform framework for either entering new data or editing existing information.

A built-in inspect utility enables users of large knowledge bases to search for, locate, and edit various types of knowledge.

USE OF PRIVATE SECTOR - DIGITAL BROADCAST OF MOTORIST INFORMATION

PURPOSE

This paper is to discuss an alternative for providing motorist information in a voice synthesized format. The alternative uses digital radio broadcast over an existing, privately operated FM Side Carrier Allocation (SCA) network.

DESCRIPTION

Commercial radio stations, operating in the FM range, have "space" between the frequencies that serve as buffers between stations. This space can be used to transmit control information, such as blanking out commercials for music in offices, or used to carry limited digital information. Stations that do not have a direct use of this capability lease the service to others as a way of partially offsetting operating costs. The most familiar use of the space is Muzak. The direct cost to the station is very limited so any derived income is beneficial to the station.

The project team has identified the largest user of leased FM SCA digital radio that has an existing network in 20 major cities in the United States, including two stations in the Los Angeles basin. This firm, Lotus Information Network Corporation, a subsidiary of Lotus Development Corporation, currently operates at 4800 baud to deliver stock quotations to over 9,000 subscribers. Two forms of device are offered, one which is hand-held and tracks a specific set of stocks and a second that attaches to a PC and can track essentially all stock transactions. The network is loaded during only a fraction of the day, generally when the New York Stock Exchange opens (6 a.m. Pacific Time). Other than for a few minutes at opening, data are generally provided within 3 seconds after it becomes available from the exchanges. Lotus Information is currently upgrading its system to transmit at 9600 baud and will have significant excess capacity.

USE FOR SMART CORRIDOR PROJECT

The project team considers FM SCA to offer opportunities for providing motorist information in a "broadcast" form, where significant data are transmitted recurringly over the airwaves and interpreted by an "intelligent" receiving device.

There are two specific potential uses of the technology. One is for information to be provided to an in-vehicle navigation device, such as the ETAK Navigator to be used as part of the Pathfinder project. In this case, the information could be used to update status information displayed on the screen and perhaps presented verbally to the driver. Note that information is one-way to the vehicle only and no information is returned from the vehicle. The in-vehicle device "listens" to all of the information being sent out and displays only that which is applicable to the vehicle's current trip.

A second form of possible use of FM SCA, and the alternative to be considered here, is to transmit traffic information zoned for the Smart Corridor over the digital channel and have it broadcast in the vehicle using voice synthesis techniques. The FM SCA is ideally suited for this application because it uses the exact same radio stations to transmit data which the average driver enjoys going to work. This ensures that the electronic engineered noise reduction, antenna replacement, etc., have been optimized for reception of the commercial FM signal, thus ensuring the reception of the FM SCA.

DESCRIPTION OF ALTERNATIVE

In this alternative, a special receiver would be installed in the vehicle and connected to the radio power and antenna. The receiver would be a stand-alone device with separate power supply, receiver, voice synthesizer, speaker, and controls. This would allow it to be used in parallel with normal operation of the radio. When the vehicle was started and the special radio enabled, all of the messages for the corridor would be given. Subsequently, only updated or new information would be given, unless a special priority was assigned to the information which caused periodic repeating. In either case, the message might be preceded by a tone to allow the user to turn down the standard radio, or the message might be repeated to insure that it was heard.

Use of the existing antenna is important because of the requirements for clear FM reception inside a vehicle and use of the radio power allows the receiver to work only when the ignition is on. The use of a stand-alone device allows the receiver to be installed and used without interference to the existing radio system. Use of a stand-alone device will also allow the system to be monitored by hand held units with antenna or by units in offices that were connected to free standing antenna.

For the Smart Corridor Demonstration Project, a working pilot test has been considered and is recommended. In this test, 200 receiver units will be manufactured and installed in vehicles that use the corridor. The vehicles could include employees of government agencies, private delivery services, limousine and shared van services, taxis oriented toward the airport, and individuals elected from volunteers from organizations such as the Southern California Automobile Club. The users would be provided with the receiver and be required to provide information back to the Smart Corridor project team.

Lotus Information would be provided with traffic data for the corridor from the motorist information database. Through negotiated agreement, they would broadcast the information over their network within an agreed time frame, say thirty seconds.

REQUIREMENTS FOR THE PILOT TEST

The pilot test would require design and development of the receiver, design and integration of the data with the Smart Corridor database and the Lotus Information database, manufacture of the receivers, selection of the users of the system for the pilot test, installation of the receivers, operation and monitoring of the test of a period such as one year, and evaluation and reporting of the results.

Discussions with Lotus Information have led to the initial agreement that the network could be provided at no cost during the pilot test. The project would be expected to pay for the development and manufacture of the receivers, installation, system integration, and monitoring. A working budget for the pilot test is as follows:

1.	Test Design and User Selection	$ 35,000
2.	Design of Receiver and Functionality of System	35,000
3.	System Integration	35,000
4.	Manufacture of 200 Receivers (@$400)	80,000
5.	Installation of Receivers	20,000
6.	Monitoring and Evaluation	60,000
	Total	$ 265,000

FUTURE POTENTIAL

A major component of the Smart Corridor Demonstration Project is improving the quality and timeliness of motorist information. Several technologies are being considered, including in-vehicle navigation devices, changeable message signs, low powered AM radio, teletext, telephone and computer based dial-in systems, and commercial radio and television. The use of FM SCA represents another form of these complementary efforts. Specifically, it provides a radio based system "dedicated" to traffic information without continual interference with commercial broadcast. The technology can be likened to the systems in Europe, but with the expectation that much more specific information would be provided.

If the pilot test proves the utility of the system, future applications would include a method for selecting the zone of interest. That is, the user would enable the system and indicate the class of information to be received. Information class could be geographically coded and could include roadway type or incident severity indexing. The receiver could remain as a stand-alone device, or be connected to the radio in the vehicle (including using the speakers and overriding the radio when a new message came in), or be totally integrated into new radios provided by manufacturers if the market potential was sufficiently large. The future broadcast medium could remain with a commercial venture, such as Lotus Information, or be funded as a public service by a government agency.

If it remained a private service, it is expected that a subscription fee would be charged by the server - say $3 - $7 per month. It would also be expected that the provider would pay for connection to the future Smart Corridor type system but not for the information received, however, this will be a matter of policy for the Smart Corridor policy committee. Note, a parallel issue will occur with information to be provided to commercial radio and television carriers.

SIDE CARRIER ALLOCATION IN LOS ANGELES

Many local FM radio stations have already committed, or are unwilling to lease their SCA bandwidth. A commonly cited reason for restricting the use of SCA is to retain the full clarity of their analog signal. SCA use does degrade the voice quality of a radio transmission at the lower powered stations, however in most instances this degradation is unnoticeable to the listeners.

Pirate Radio (100.3 FM) transmits from Mt. Wilson and has 3 bands of 5 kHz available for lease. Each band is available for a fee of $10,000 per month. KMAX radio (107.1), has 2 bands available for a fee of $7500 per month. They use an antennae located in Sierra Madre with an output of 3000 Watts. One of the leading development and manufacturing firms called SCA Data Systems, is located in Los Angeles. One of the options SCA Data has developed is page queing.

Alternative sources of SCA are available through companies such as Lotus. Three other such firms are Bonneville Data, MultiComm and Indice. The project is recommending a demonstration using Lotus. If Lotus is used, no special equipment will be required by the system. Dedicated leased lines and a standard hardwire interface will be required.

An AM based alternative, using phase shift keying, is begining to receive more attention as an alternative to the FM SCA data transmission. By the nature of the media, Amplitude Modulation is a slower form of transmission with current baud rates approaching 1200 bits/second. There are however, some benefits to this approach as phase shift keying reportedly has a lower error count, and there is significantly less interference to adjacient channel stations.

CALTRANS' INCIDENT MANAGEMENT TEAM

FOR THE SMART CORRIDOR

EXISTING TEAMS

Caltrans is currently operating an Incident Management Team of personnel who respond to freeway incidents which block 2 or more lanes for 2 or more hours. The 22 person team is made up of a combination of volunteers and a core group of regular incident response team members. All are Caltrans employees. The core group consists of employees whose job responsibilities include being a member of the team and responding to incidents during their duty hours. The volunteers are only called upon to assist in incidents during their off-duty hours. They are paid overtime at a rate based on their existing job classification and pay scale. The volunteers are assigned to a shift on a list which is published daily.

The job responsibilities of the core group members include other duties besides being assigned to an incident squad. When not responding to an incident, they work with related activities such as planned closures, data evaluation, etc.

There are 22 vehicles assigned to the response team, one for each member. There are a total of 11 sedans and 11 pick-up trucks. All of the trucks are equipped with changeable message signs.

The number of team members which are called upon to respond to an incident is dependent upon the severity of the accident. Typically, four persons are assigned to an incident with one person serving as team leader. Eleven members of the overall team have been trained to serve in this capacity and are the drivers of the sedans.

The Caltrans teams service the entire freeway system of District 7. There are approximately 3-4 incidents per week to which a team is requested to respond.

PREVIOUS ESTIMATES FOR SMART CORRIDOR INCIDENT MANAGEMENT TEAM

It has been proposed that a Caltrans Incident Management Team be formed for assignment to the Smart Corridor. Estimated costs for this team were developed by Caltrans in 1987 based on the

purchase of five vehicles and the assignment of 5 persons to all incidents in the corridor.
The estimated costs were as follows:

o 2 sedans including radio equipment and detour signs	$30,000
o 1 fabric message sign truck fully equipped	$25,000
o 2 two-line electronic bulb-matrix sign truck fully equipped	$124,000
	$179,000

Estimated personnel costs ($45,000) were based on an hourly rate of $45 and the assumption that a team would be required to respond to 100 incidents per year with an average duration of 2 hours. Allowing for inflation and additional miscellaneous expenses, the total estimated cost to operate an incident management team for one year was budgeted at $260,000.

EXPANDED CRITERIA FOR SUMMONING TEAMS

Presently, incident management teams are only called to the scene of what are defined by Caltrans as "major incidents": situations where it is estimated that there will be blockage of two or more lanes for two or more hours. A far greater number of incidents block one or more lanes for one or more hours. The increased levels of freeway surveillance, control, and motorist information which will be launched with the implementation of the Smart Corridor suggests that the level of response to incidents could also be improved. This improvement could be effected by redefining the criteria for a "major incident".

If this criteria were to be relaxed to encompass incidents of less severity, for example blocking "1 or more lanes for 1 or more hours", the teams would have the increased opportunity to respond to incidents thereby lessening the effects of any congestion resulting from the incident. It is estimated that the number of incidents in the "1 lane/1 hour" category is approximately 5 times the number of incidents which currently satisfy the major incident criteria. The incident management team for the Smart Corridor would therefore be responding to five times more incidents that the existing teams. These efforts would be complemented by the motorist information technology being applied in the Smart Corridor reducing the necessary team manpower resources per incident. The Smart Corridor technology thereby will assist the team efforts while the teams respond to a greater number of incidents.

PROPOSED SMART CORRIDOR INCIDENT MANAGEMENT TEAM

It is suggested that an incident management team allocated to the Smart Corridor operate under the same format as the current teams; i.e., core and volunteer staff. During normal daytime hours, the Smart Corridor staff would perform other duties related to planned closures, operations, etc., and would be on call to respond exclusively to incidents in the corridor. In the event that this team is busy covering one incident when another occurs within the corridor, another response team should be designated to back-up the dedicated team.

In order to provide a team which is dedicated exclusively to the Smart Corridor, one alternative is to hire a whole new team which would respond to incidents in this corridor alone. This solution is an costly one assuming that annual salaries of team members are approximately $50,000 not including benefits. Trying to provide comparable team coverage without hiring new personnel, one alternative is to give incident response on the Smart Corridor priority over other incidents. Another option is to hire only two or three new personnel to be assigned exclusively to the Smart Corridor, and supplement this team with existing team members. A hybrid solution would be to hire some additional employees, give priority to Smart Corridor incidents, and utilize existing employees to supplement the dedicated team. With this less costly approach, the same service would be provided as if a team of new employees were hired specifically for the corridor.

Further justification for retaining additional employees for this effort is derived from the extra workload for the regular employees which will result from the implementation of the Smart Corridor. They are currently occupied full time with planning and implementing planned closures and special events, and the added attention that will be devoted to Smart Corridor operations will put a strain on already busy personnel. When the new employees are not responding to incidents, they would perform the same function as existing team members, but with priority on Smart Corridor operations.

Also, additional resources would enable Caltrans to relax the criteria for the definition of a major incident in the Smart Corridor thereby permitting the teams to respond to more incidents.

The Smart Corridor team should have the capability of handling incidents without having to rely on back-up support team members. It is therefore recommended that the number of team members on the Smart Corridor team be five, one more than the number typically required to handle the average incident. This assignment might be accomplished by assigning regular team members to the Smart Corridor on a rotating basis. The same number (five) of volunteer team members should be on call during evenings and week-ends.

Regarding the volunteers who will be used to respond to incidents in off-duty hours, the ones selected for this duty should live within or in close proximity to the corridor to reduce their response time.

Two of the persons assigned to each shift should be trained team leaders. According to present criteria, these persons will be assigned sedan type vehicles.

The vehicles assigned to the remaining three team members should be trucks equipped with changeable message signs. Since this limited number of trucks must be capable of responding to all possible environmental and traffic conditions in the corridor (daylight, night, rain, fog, etc.), it is recommended that they be the most versatile available in terms of message visibility/presentation capabilities; i.e., bulb matrix or fiber optics signs. The cost of these trucks is greater than the one originally proposed fabric sign truck; however, the fabric sign is applicable only in good weather conditions, and its visibility is considerably less than that of the self illuminated signs.

COSTS

It is estimated that the number of incidents to which the Smart Corridor Incident Management Team would respond would be 5 per week. The annual cost to provide the recommended level of incident management team support is estimated to be:

o	Personnel -	
	- 2 new team members (salary only)	$100,000
	- 500 hours of volunteer response @ $50/hour	$225,000
o	Vehicles	
	- 1 sedan fully equipped	$20,000
	- 1 CMS truck fully equipped	$70,000
	Total =	$415,000

BENEFITS

It is estimated that each major incident of one hour duration results in 4200 hours of vehicle delay. At a rate of responding to 5 incidents per week that create a blockage for one hour, there will be a savings of $1.4 Million per year to the motoring public. This is a conservative estimate since the one hour of the blockage is the minimum incident duration to which the team would respond. This dollar savings results in a benefit/cost ratio of over 3 to 1 for the implementation of a dedicated freeway incident management team for the Smart Corridor.

RECOMMENDATION

It is recommended that a dedicated incident management team be designated by Caltrans for use in the Smart Corridor. The team would necessitate the addition of two new employees and the purchase of 2 new vehicles. As discussed above, the team should be composed of five members in total. This composition can be accomplished by assigning three present team members, and their vehicles, to the Smart Corridor team.

In order to provide service equivalent to that of a team dedicated exclusively to the Smart Corridor, it is recommended that top priority be given to incidents which occur in the corridor.

It is also recommended that, in the Smart Corridor, the criteria for the definition of a major incident be changed to "blockage of 1 or more lanes for 1 or more hours".

IN-VEHICLE NAVIGATION SYSTEMS

Caltrans, General Motors and the Federal Highway Administration (FHWA) are currently developing an in-vehicle navigation system based on the ETAK Navigator device. The work is being done under contract with Farradyne Systems, Inc. The ETAK devices uses a monochrome screen to display map data indicating the street network from the vehicle's current location to a selected destination. The ETAK system is to be modified and tested under a program known as the Pathfinder project. Twenty-five GM cars are to be equipped with a version of the device which is capable of receiving real time information over a dedicated radio link. Data are to be received from the vehicle on a time polling basis to allow location and travel information to be determined for each of the vehicles. The system is also to be equipped to provide verbal messages and updates to the real time traffic information.

The project is to use the Smart Corridor area as the demonstration site. Real time information is to be taken from the Caltrans TOC and the City of Los Angeles ATSAC system and automatically reported to the Pathfinder system and on to the equipped vehicles. Information is also to be entered manually into the Pathfinder computer to reflect the data developed from secondary sources, including the CHP's CAD system.

The project will use a dedicated radio frequency made available by Caltrans so that the information to and from the vehicles is reported on a regular basis each several seconds. The information is to be transmitted using a polling process where the central communicates with one vehicle at a time using a coded polling scheme. The number of vehicles is sufficiently small that direct radio communications is possible while maintaining a relatively short polling cycle.

The development and pilot testing of the Pathfinder system is to be completed in April, 1990. The evaluation contract is to begin in July, 1989, with major work completed by March, 1991. The evaluation is to include an analysis of the effectiveness of the in-vehicle system, its ability to accept real time information and provide real time information about traffic conditions. The question as to the clarity of the visual information and its usefulness will also be addressed, principally through user survey. The two way radio link is to be available for the duration of the project but is not permanently allocated for Pathfinder use.

SMART CORRIDOR PROJECT ELEMENTS

As noted, the Pathfinder project is to be conducted in the Smart Corridor project area. Data from the project will be available prior to the end of the implementation work for Smart Corridor. Also, the Smart Corridor central database component is expected to include information which is more complete than that to be available during the evaluation, with the result that future applications could be more effective than any found for the Pathfinder project. In the same time period, it is to be expected that additional ETAK devices will be sold in the Los Angeles basin and the Pathfinder work may encourage GM and others to accelerate marketing of in-vehicle navigation devices. Other U.S. and foreign firms may also be expected to increase marketing of in-vehicle navigation systems as the technology becomes more accepted.

The long term use of in-vehicle navigation systems by other than a small group of persons appears to be dependent on any usefulness beyond simply mapping the route from one location to another and on the cost of the devices. Hence, the provision of real time information would appear to be a critical element.

There are two major issues associated with continuing the Pathfinder project as part of the Smart Corridor project. The first issue is whether the system will be extended as a two way operation or if it will be used in only a broadcast mode, where the Pathfinder device receives information on traffic throughout the region and selects and displays that appropriate to the current trip.

If two way communications are assumed, the method for providing the communications is a major element - paralleling that required for a true motorist guidance system. The project could provide a major opportunity for this because of the high capacity trunk network that is being installed. Radio based transceivers could be located throughout the area, similar to cellular telephone or "sign posts", and the trunk network could be upgraded in speed to handle major data streams. This would require additional investment, however the backbone system would be in place.

The project team estimates that the likelihood that a large scale system will be in place near the beginning of operation of the Smart Corridor project is very low. With this in mind, the project should continue its communications design philosophy of high capacity trunks using standard telephone technology that can be expanded in capacity by added electronics. Also, the database structure should be sufficiently flexible to send data to, and accept information from, a two way in-vehicle navigation system.

The second issue, and the one felt more closely related to the current Smart Corridor project, is how would real time information be transmitted to the in-vehicle navigation systems if a one way broadcast alternative is assumed? As a first point, the Smart Corridor central database system will have the information needed to transmit to the field, since it combines all of the current sources into a single system. The requirement is to format the information and transmit it to the field.

The most obvious method for doing this is to use a form of digital radio, with the messages being interpreted by the in-vehicle device. This could be done over a dedicated channel or using the side carrier allocation (SCA) of an existing FM station. (See the working paper on "Use of Private Sector Digital Broadcast of Traffic Information".) Assuming that the private sector is the primary force behind the in-vehicle technology, one method of handling the issue is to simply provide them with the data and they would have the responsibility for formatting the information and sending it on to their users. This is parallel to the recommended demonstration test of FM/SCA in the paper referenced above.

A second method would be for a public agency to accept the responsibility for transmitting digitally coded traffic information over a radio frequency and allow any user to capture and display the data. This would require the agency to set the format for the information and then require the users to tailor their systems around the standard format. This has significant appeal and is the approach being taken in the European DRIVE project. A group is charged with establishing standards for the participating countries and they will all then conform to the standards. It is possible that the Smart Corridor project could undertake the role of establishing the standards for the Los Angeles basin with the possibility that it might then be applied elsewhere.

It is the project team's opinion, however, that the development of the standards is beyond the scope of the project. Instead it is suggested that an appropriate course is to provide the needed information and encourage the private sector to use the information in their systems. It is suggested that the recommended FM/SCA will go a long way toward proving the viability of the technology. If the initial Pathfinder project proves beneficial, those devices could be modified to receive the same information and included in the test. Once the test was completed, standard commercial units could also be modified to receive the information if determined to be warranted by the manufacturers.

RECOMMENDATION

It is recommended that the Smart Corridor project concentrate on developing the information needed to feed an in-vehicle navigation device, provide future communications capacity, and demonstrate the technology for digital radio broadcast of traffic information similar to that required by the devices.

MEDIA COMMUNICATIONS

The media serves as an important source of motorist information in present day Los Angeles. Traffic reporters from the majority of radio stations obtain accident and congestion information from Caltrans and the California Highway Patrol, and broadcast it to drivers. The public has learned to depend on these broadcasts as the only "almost" real time source of traffic information. It is envisioned that radio and TV broadcasts will continue to serve a major role in the Smart Corridor. The primary difference once the Smart Corridor system is implemented will be the accuracy and timeliness of the information to which the broadcasters will have access and will be able to broadcast.

The media currently is dependent upon two primary sources of traffic information: the Caltrans teletype and phone calls to a CHP information officer. The teletype information from Caltrans is input at the TOC based on traffic data and information obtained at that location. The majority of radio/TV stations have a teletype receiver at their studios and receive the messages as they are transmitted. Most of the information that is sent out in this manner pertains to planned freeway closures. Major incidents (SIGALERTS) are also sent out over this network. All other information on freeway congestion, incidents, and other problem situations on the freeways is obtained by calling CHP and speaking with the information officer. In addition to freeway information, CHP will also inform the media of surface street incidents and areas of congestion if they are informed of such by the jurisdiction.

The efficiency of the existing processes is not sufficient to ensure that accurate and timely information is always being broadcast by the media. The accuracy is dependent upon the length of time since the broadcaster's last verbal communication with CHP and the number of incidents that have occurred and/or been cleared during that period.

Seeking to provide the media with up-to-the-minute information more efficiently, the CHP has initiated an effort to develop a media communications interface which is hoped will be in place by the summer of 1989. The plan is to allow the media to have access to a dedicated system which will interface with CHP's CAD system and will be contain all of their traffic information. The information will be accessible by the media from PCs located at the their facilities over telephone lines to the interface system. The media will be able to access all accident and congestion information which is logged into the system. The information will be automatically made available to the interface system from the CHP main CAD system.

The media interface system is planned to be an integral part of CHP's interim and, possibly, future communications systems. It will make real time information available to the media upon inquiry. The expense to each radio or TV station will be the cost of a PC, modem, printer, and telephone connection. It is anticipated that many stations will opt for dial-up capability rather than the costs associated with using a dedicated line. The combination of inputs from Caltrans and the CHP should provide complete up to the minute freeway information and greatly improve the accuracy of the material broadcast by the media.

Regarding the application of CHP's media interface to the Smart Corridor, it appears that this means of providing information to the media will be efficient and effective when it becomes operational.

ISSUES AND RECOMMENDATIONS

The responsibility for the dissemination of information to the media is an issue which deserves considerable coordination between the agencies involved in the Smart Corridor. It is suggested that a policy/coordinating committee be established to address the issues and resolve the final configuration of the system which will source and distribute traffic information to the media.

In the interim, the CHP has the development of a media interface system underway, and it should be operational in early 1990. It is recommended that CHP continue in their current role providing motorist information to the media and coordinate with LADOT and Caltrans as significant sources of traffic information.

USE OF PUBLIC ACCESS TV

IN THE SMART CORRIDOR

BACKGROUND

The City of Los Angeles has recently created a new department, Communications, the goals of which are to provide information to the citizens on City activities, functions of the various departments, services, etc. The Department has developed plans to establish a City owned and operated cable television station. The current schedule call for the station to become operational in August of this year.

It is estimated that one third of a million households in the City of Los Angeles have cable hook-up and will be able to receive this channel free of charge. Many households do not subscribe because the signal strength of the major commercial stations is so powerful that CATV is not needed in order to receive these broadcasts.

The City's cable station will be #39 throughout the City of Los Angeles. All the cable companies which serve LA have agreed to allocate this channel to the City government. There is also a second cable channel which the City has dedicated to them for their future use. No plans presently exist for its implementation as a broadcast channel although it is available.

There has been no broadcast format firmly established for the planned channel; i.e., no specific programming has been defined yet. City council meetings will be broadcast on this channel, but the rest of the air time is still not reserved although there are tentative programming plans. The Communications Department plans on developing its own shows and videos for broadcast and will fill unscheduled time with public service bulletins.

The Department is building a complete production facility and broadcast studio in the mall by City Hall next to the bookstore. They are installing cameras in council chambers with a direct feed to the studios. There is the possibility of other direct feeds; e.g., from ATSAC.

USE OF THE CITY'S CATV STATION FOR THE SMART CORRIDOR

The Communications Department is willing to cooperate with LADOT regarding the broadcast of traffic information on this channel. In order for this type of telecast to be truly effective, continuous broadcast of traffic information during at least the peak hours is needed. The Communications Department however is scheduling its own programming for broadcast during the day including the peak traffic flow hours; however, there is the possibility of using a "crawl" message across the bottom of the screen containing traffic information or using interrupts for traffic reports as is done on commercial radio. There are also other options for broadcasting traffic information which should be explored more fully with the Communications Department as their plans for the station develop.

One problem in using the City's CATV station for the broadcast of Smart Corridor information at this time regards the area which will be capable of receiving the station. The City's cable television station will only be transmitted to cable subscribers within the city limits of Los Angeles leaving out adjacent areas such as Santa Monica, Beverly Hills, and Culver City. Therefore, some motorists living in the Smart Corridor area will be able to receive traffic reports broadcast by the City's station, but not all.

Additionally, motorists living in other parts of Los Angeles would be receiving traffic information for the corridor, but not traffic information for their own areas. If the broadcast of traffic information is initiated for the Smart Corridor project, the City should be cognizant of the desirability of providing more comprehensive traffic information to cover the entire Los Angeles basin including all of the freeways.

As mentioned above, there is a second cable station which is available to the City through the cable companies. The implementation of the channel however has not yet been funded, and there are no near term prospects to do so. This channel offers unlimited possibilities for traffic broadcasts however since no other plans have been made for its eventual use.

RECOMMENDATIONS

There are a number of drawbacks in attempting to use the City's own TV station for the broadcast of the traffic information for the Smart Corridor:

- cable TV only goes to a small percentage of the homes within the City of LA
- there is a lack of dedicated broadcast time available
- area of coverage (the whole City of LA would receive the Smart Corridor traffic information; however, some of the

Smart Corridor jurisdictions and other corridor users would not).

The use of the City's CATV station as a motorist information tool is one method by which to provide traffic condition information to drivers. It has some drawbacks for application in the Smart Corridor at this time, but it should not be overlooked as having considerable potential for future application and can be utilized to a limited degree now. It is therefore recommended that at the present time LADOT plan to make use of the "crawl feature" or interruptions for special traffic reports when the planned station is implemented; continue to monitor the activities of the Communications Department and their plans for cable TV; and consider the use of the second CATV channel to which the City has rights for possible future application as a traffic information station.

SILENT RADIO

OVERVIEW

Silent Radio (SR) is an information media using LED signs which display one or two lines of message. Messages are scrolled horizontally across the sign, and are capable of displaying graphics, logos, animation or simply moving and stationary text. The true SR is currently used as an entertainment and information media supported by advertisers, and holders of the signs (e.g., hotels, banks, airports, etc.). The displays are generally located in lobbies, waiting rooms, or other places with casual atmospheres and are effective in reducing the perceived waiting time for the viewer. SR offers several formats such as Newsline and Sportsline, but can be tailored around the subscriber. Silent Radio as the name implies has no audio output and the message content generally contains 80% editorial content and 20% advertising. The displayed news information is obtained from major wire services such as UPI and AP together with syndicated and local correspondents, and is prepared for delivery by SR news staff. Although changes are continuously being made, downloading of new material only occurs every 15 minutes. Each SR message sign receives its information directly from a local television or radio transmission signal, but each sign is capable of being individually addressed so that a mix of information based on locality or any other relevant factors can be displayed.

OPERATIONS

Silent Radio is willing to utilize the traffic information available from the Smart Corridor system as an additional news item. The information could either be formatted by SMART personnel and downloaded directly to the Silent Radio news room for input, or the accumulated information in the Smart Corridor system could be made available to the SR personnel as simply another input news source. The latter method would be totally free to the system as SR would provide the modem, and it is assumed that the data base containing the source of information would be established any way to be used by other news agencies such as radio and television. This latter method is probably the preferred direction to take since it is free and treats SR as simply another news announcer. Utilization of SR should only be considered as simply another news generator like the radio to disseminate information. This is because there is no control over the placement of the existing signs, and the amount and quality of information to be transmitted is of a very limited and generic quality. dedicating resources and manpower is not the preferred method.

DEDICATED SYSTEM

A second version of SR is in the form of a dedicated system. All of the equipment and software can be purchased by the Smart Corridor with all sign information being generated and formatted in-house. Data transmissions are similar to any other digitized information, and can utilize any of the standard transmission modes such as twisted pair or phone lines.

Purchasing and utilizing a network of signs and equipment is relatively inexpensive, especially if a subscriber network in local buildings could be established, but it does become more complicated than with the true SR concept since a maintenance issue comes into play as well as establishing the initial interconnect (e.g., phone, twisted pair, etc.). Each sign contains its own memory capabilities, so after a downloading is performed, no additional communications will be required. Consequently there is no limit on the number of signs which can be controlled.

Placement Criteria:

In analyzing the most effective placement of SR type signs, the following criteria and disadvantages and potential locations were considered.

Placement:

Must be located prior to a decision making point. For example, if a garage exits onto a 1 way street, the driver needs to be informed of traffic conditions before becoming committed to this exit.

Sign must be easily accessible to large numbers of freeway drivers.

Captive audiences are necessary, otherwise no one will take the time to read the message. On the other hand if the driver has nothing else to do, they will read each message if for no other reason than to pass the time.

Related to the previous criteria, pedestrian traffic on the way to their cars should be the targeted audience. This allows them to dwell as long as they like, and allows them time to evaluate alternative routes prior to moving their vehicle. Suggested sites might be near elevators that access a parking garage.

Disadvantages:

Locating signs for drivers (the intended audience of these signs), as a diversion tool, is generally to late as most drivers will have already committed themselves to their "default" route and may not make the extra effort to reroute.

Most commuter drivers will have a monthly pass, hence they will not need to stop at a toll booth. With the exception of special circumstances (i.e. airports) where everyone pays, this site option is not feasible.

Conversely, to direct the signs to pedestrian traffic may be misdirecting the message to the wrong audience, or even more likely will possibly be outdated by the time the viewer reaches their car.

Potential Sites:

Finding subscribers would be the most beneficial means of distributing and expanding the dedicated SR network. The audience of these signs will not be very large just by the nature of the system, and is of course dependant upon the occupant size within the building and convenience to the driver. Suggested locations based upon the above criteria might be as follows:

City Hall
- Walkway connecting CH and CH East.
- In elevators connecting CH to the parking garages.

LA TIMES building

Government Buildings (County & State buildings, Courthouse etc.)

The following costs are for a typical network setup and assumes a personal computer is available, and 20 single line signs are utilized.

Smart Corridor system:

Software (FACTS Program)		$ 795
Custom Keypad		$ 130
Test Sign		$ 1,635
Modem		$ 280

Field:

20 Single Line Signs @ $685 ea.		$13,700
20 Modems @ $280 ea.		$ 5,600
	Subtotal	$22,140
20% City discount		(4,428)
		$17,712
20 Phone drops @ $25/mo ($1500/5 yrs)		$30,000 / 5 yrs
	Approx.	$50,000 / 5 yrs

ADVANTAGES

SILENT RADIO

Free
Several signs currently in place
No additional personnel required to implement or operate

DEDICATED NETWORK

Complete control of message content by SMART Control Center
Sign content is 100 % traffic related

DISADVANTAGES

SILENT RADIO

Sign locations are generally not very beneficial to traffic application

Message will be superficial, short in duration & only updated at 15 minutes intervals.

DEDICATED NETWORK

System will require some attention from SMART Corridor personnel to manage.

Hardwire interconnect is required at each location.

System is not free.

Someone will need to serve in a liaison and promotional capacity to access, maintain and promote subscribers or volunteers to the network.

Most drivers will not take the time to read the message unless they are forced to wait. As such a captive audience of impending drivers is needed, and these locations are difficult to obtain.

For the same locations found for these message signs, a teletext monitor could be installed or incorporated onto an existing TV. Teletext would be able to provide more information, at a faster rate, and in a more appealing manner than can be obtained using the SR type signs. In addition, hardwire interconnects are not required with teletext.

RECOMMENDATION

The consultant team does not recommend that silent radio by pursued further at this time. The Teletext will be able to supply information in a comparable but less expensive manner to the same audience, an therefore it is Teletext that is recommended for implementation.

TELETEXT SERVICES

OVERVIEW

Obtaining timely information of current traffic conditions on a demand basis is currently only available with a telephone. One of the methods being proposed to supplement this media is through the use of television sets by using the Vertical Blanking Interval (VBI) of the video signal. The VBI is the black horizontal line located on the lower part of the TV screen, and can be seen when the TV vertical hold knob is adjusted.

Caltrans is currently evaluating this media in conjunction with the hardware manufacturer, Teletext Communications, and will be able to provide a great deal of information on its effectiveness. If incorporated into the Smart Corridor project, Teletext Communication will serve as an interface service between the Smart Corridor computer and local television and radio stations.

Technical and Operational Considerations

In the Los Angeles area, traffic information would be distributed via a section of the national information network (i.e., news, weather, sports etc.). This information would be generated and formatted by the Smart Corridor system and then transmitted to the public television station for general broadcast. Preliminary operations will require an operator to input and edit the database. The software needed to automate this process will be developed after Pathfinder's ETAK and prototype device have been built. After the ETAK protocol has been finalized, Teletext will then develop the automating software using the same database.

The information will be input into an IBM compatible PC equipped with a modem, and then transmitted via phone line to the local television station. Teletext Communication will provide, on either a lease or purchase basis, special teletext software and hardware for the PC. In addition they will equip the television network station with teletext inserters.

To view the transmitted information, observers must have a standard television equipped with a World System Teletext (WST) chip. This is the same device used to see the closed caption features available for the hearing impaired. Zenith is currently marketing TV's with the WST chip in the New York and Los Angeles area, and with less than one year of sales in the LA area, have sold over 300,000 of these units. Sony and Magnavox have plans to follow suit shortly with their products, and stand alone devices to adapt any television are currently available for under $200.

It is planned that the Caltrans TOC will be set up for transmitting to radio stations, TV news rooms or any other television receivers containing the WST receiver chip. Teletext pages will be transmitted over a phone line from the Caltrans office to the Teletext Inserter located at the TV station. Any updated page will then be inserted into the continuous loop of existing information. Within seconds, every receiving device within range of the TV station will be updated. For Lobbies, transit centers, malls etc. preset displays can be established such that only pertinent regional information will be displayed.

The current expense to Caltrans for their demonstration system is a $30,000 non-refundable deposit for installation and screen development, with an operating expense of $10,000 per month. Additional screen development, requiring the skills of an artist, will be provided on an as needed basis for the nominal cost of $35 per screen. To help defray some or all of these monthly operating expenses, advertising slots could be sold to related departments such as Rideshare or RTD thus promoting their use and benefitting all concerns.

Evaluation and Recommendation

Teletext is a promising media for providing visual and up-to-date information on demand to the motorist. It provides a relatively simple means of obtaining traffic information for trip planning purposes, thus, improving its changes for user acceptance. Since Caltrans is currently in the process of evaluating teletext, user acceptance and reliability reports will become available. Preliminary surveys of motorists, however, suggest that few drivers currently turn to television for traffic information, undoubtedly due to the infrequency and generality of reports. The same surveys also suggest that many drivers, approximately 10 percent, would like to obtain traffic information from television prior to beginning their trip. This desire for televised traffic information on demand strengthens the potential success of teletext.

Hardware requirements are minimal and generally employ readily available equipment (i.e., personal computers and home televisions sets). At this time, however, a relatively small percentage of televisions in use are equipped to receive teletext transmissions. The trend in the television manufacturing industry is to make teletext reception a standard function and as televisions are replaced, the potential audience for teletext will increase significantly over the next five years. This schedule is essentially on line with the expected implementation and start-up of the Santa Monica Smart Corridor system. As other Smart Corridor systems are added, the potential benefits of a teletext system in the Los Angeles area will increase significantly.

Based on the existing audience expected to use teletext for obtaining traffic information, operating costs are relatively high. Advertising can be used to partially or completely offset the operating costs. As the teletext audience increases, greater cost effectiveness will be realized.

Based on the ability of teletext to provide large amounts of traffic information to motorists on demand, the potentially large audience which could use teletext, and the anticipated acceptance of teletext by users, it is considered to be a worthwhile technology to include in the Smart Corridor.

TELEPHONE CALL-IN SERVICES

OVERVIEW

Telephone call-in services is a source of pre-trip motorist information. It is expected to be one of the most cost effective techniques proposed for the SMART Corridor, primarily because of the convenience of use of the telephone in our homes and offices.

Application of the telephone as a motorist information source in the Smart Corridor has been categorized into the following two sources:

Call-In Service -

A local number will initially be available with say 20 incoming lines. This number will directly access the SMART Control Center data base for a synthesized voice response on any of the monitored roadways. Generation of these messages will be discussed under the Automated Information System, but the content provided will detail information on any desired route.

Reporting line -

As an additional source of information to supplement or alert the SMART Center personnel of an incident, a cellular hot-line number will be established.

Currently telephone call-in services are available for a variety of information, including transit, weather, roadway construction and traveler information. One of the largest information centers in the United States is operated by SCRTD. With nearly 10,000 calls per day (3.1 million calls/year), as many as 90 operators may still be required to handle the system. Although certain functions in the SCRTD system are automated to reduce the operator workload, only 85% of the incoming calls are capable of being processed.

The system utilizes 140 telephone lines, and is currently experiencing an average call time of 5 minutes. This includes a queue waiting period of roughly 3 minutes for each caller. Current plans are to install a fully automated system which is expected to reduce this queue such that each call can be processed within 3-4 minutes. The automated system will require the caller to use their touch tone telephone as a scrolling device. The total capital investment in the SCRTD system is 6-8 million dollars with an annual operating cost of 3.5 million dollars.

A smaller system called the California Highway Information Network (CHIN), is operated by CALTRANS. Currently operating out of Sacramento, with 2 remote centers in San Francisco & LA, travelers are able to receive current construction activities or roadway conditions due to adverse weather. Operating with 20 phone lines in the LA region, 150-200 calls a day are received. This figure increases to nearly 5000 calls a day during poor weather conditions. Information pertaining to the freeway of interest for the caller is achieved simply by pressing the freeway designation number, followed by the # sign (i.e. "10#" for Interstate 10). Average listening time is less than 30 seconds for experienced users, which accounts for a busy signal being received less than 1% of the time.

Technical and Operational Considerations

Call In Service:

The following four criteria were used to evaluate the information call-in service, each one of which is considered to be essential for maintaining and promoting this service.

1) The call must be toll free

2) It should be an easy number to remember, and it should not change as one crosses into new area code boundaries.

3) The information received must be easily obtainable, and concise. Since it will be automated, potential users must not be scared away with a long and tedious menu selection.

4) Sufficient lines must be available to prevent the majority of users from receiving a busy signal or to be put into a long waiting queue.

Toll Free - Arranging for any number to become a local call to the user is a simple matter with PacBell through their Remote Call Forwarding (RCF) technology. Essentially what this does is to automatically transfer the locally dialed number to the SMART Control Center but retains the local call status for the user, thereby preventing a potential long distance fee.

Consistent numbers - Obtaining a single phone number for use throughout the Los Angeles basin (and even state-wide as the SMART corridors expand) is possible with PacBell, however it will require a little pressure from the City and State. More importantly however, is the commitment from these entities that there really is a need, and that the SMART concept will continue. Nonetheless, PacBell is a politically motivated company and they are very anxious to assist and contribute to this type of project.

Information Line - It is envisioned at this time that the same potential data base to be used by Teletext, HAR, Videotext and Pathfinders ETAK, will also be used to generate analog (voice) signals for the automated phone information service. Since this database contains detailed information on several of the surface streets and freeways, callers may designate their exact route of interest and receive the latest operating conditions and speeds. The initial message will necessarily begin with a voice menu selection, but for the frequent user, overrides will be provided to immediately access the route of interest. For instance, to obtain traffic reports on the Santa Monica corridor, callers familiar with the system could immediately press something like "SM" (76) on their phone touch buttons, and whatever was currently being broadcast would be preempted to output the existing conditions on the Santa Monica freeway. To avoid a tedious introduction, the menu selection should be short, concise and should avoid stepping the listener through several submenus. By establishing some obvious process such as "SM" for Santa Monica and "P" for the Pasadena freeway, many users will be able to comprehend the logic and direct the output to their needs with a minimum of effort.

Phone line capacity - The users of this information media will only be interested if it is simple, convenient and readily accessible. Many of these calls will be made at the last minute prior to leaving the home or office, and if the line is busy or they are put into a queue, chances are they will simply hang up. For the initial application assuming 20 incoming lines are established, and an average use of 2 minutes per call, this system will handle 600 calls per hour. However a 15 minute peak of 150 calls is a better measure since most calls can be directly correlated to the peak traffic conditions. Although the design is not expected to account for 100% of the incoming peak conditions, allowing for a sufficient queuing capacity with a message alerting the caller as to their status might be useful. In this manner the caller can make the determination as to whether or not the queue is worth holding for.

Reporting Line:

Cellular calls from motorists (tipsters) are currently used in the commercial business as a means of identifying or alerting private traffic reporters to the existence of some incident. One such service is a 4 digit, toll free cellular number (*JAM) which connects users to an operator at Metro Traffic. The caller is able to receive from Metro Traffic existing conditions for their general location with suggested alternate routes. Star-JAM can also be used by tipsters to report on incidents they see. This service is subsidized by LA Cellular as a promotional tool for their customers.

The 2 cellular companies in LA (PacBell Cellular & LA Cellular), are both interested in continuing, or starting as the case may be, with this type of service to their customers. Both entities have stated that they would be willing to negotiate a toll free, 3 or 4 digit number to link their customers with the SMART control center. It is recommended at this time that all incident reporting calls be directed to the CHP operations center. The CHP is currently handling the cellular 911 system, and has the infrastructure already setup. Although the "911" system is currently overburdened, it is expected that with an additional number, the formerly received traffic calls will be redirected to the new number such that a better structuring of the calls and answering hierarchy can be established.

Automated Information Technology

The key to ensuring driver participation with the telephone call in service or any other informational tool recommended for the SMART Corridor, is to ensure that the data provided is current and up to date. The preferred method for accomplishing this is to automate as much as possible the transmitted information. One such device for achieving this has been developed by Oracle Communications. Their system is capable of providing a variety of real-time traffic and transportation information, using "human quality" digital speech for transmission over both multiple telephone lines and low frequency HAR radio devices. The system is also capable of being enhanced to include automated video feed for broadcast TV stations and/or roadside tourist centers. System features include the ability to transmit traffic conditions, trip planning using real time information, public information (e.g. transit fares & schedules), operational and media information (e.g. alert police, news media, system operators, etc.), and voice mail and survey capabilities.

Configuration

The following system hardware operates on commercially available "off-the-shelf" equipment, is programmed in "C" for portability between computers, and will operate under either DOS or UNIX operating systems:

- Micro-computer with a 386 processor, AT compatible bus, aboveboard memory, 7-15 full length expansion slots, and a large hard-drive

- Five phone/speech boards (each handling 4 phone lines)
- Terminal emulation and communication board with buffer (e.g. 3278 emulator, VAX emulator or serial ASCII port board)
- Medium-sized digitizing and plotting tables
- Cabling or a modem/phone connection to other computers
- Speaker, microphone and other digital recording equipment
- Dot matrix printer and bulk backup storage medium (e.g. tape or cassette backup).

Functions

The system will provide voice information over the public telephone system in response to incoming calls as follows:

- Simultaneously answer and handle multiple calls
- Make specified information available as a spoken menu from which callers can select using their touch tone keys
- Respond to the caller with the requested information using high quality digital speech
- Hang up, forward calls, or reset the line depending upon the menu logic
- Load and update HAR messages as needed
- Simultaneous incoming or outgoing calls to alert authorities on emergency conditions, with remaining lines continuing to respond to travellers inquiries
- Activate or change CMS messages
- Automatically update all information presented to the public (HAR, Call In service, CMS messages)

Digital Speech

The system will allow the recording, labeling, storage, concatenation and playing of high quality digital speech. The digital speech used by the system is of two types:

- Permanent vocabulary made up of words and phrases recorded directly on to the system. Most of the information spoken by the system will be concatenated from this vocabulary list.

- Temporary voice messages recorded onto the system and stored in their entirety without their text equivalent for unconcatenated play.

System Menus

The system is capable of operating several menus simultaneously, and is capable of automatically "cross-placing" certain messages in more than one menu. The management menu will operate on a separate phone number, and with a correct password can be used to manage or place messages onto the following system menus:

- Public call-in menu
- Radio feed to control the corridor HAR's
- Operations menu to control personnel call-outs, voice mail and other emergencies messages
- Media menu (call-in/out) available only to authorized agencies (e.g. TV, radio etc)

Video Capability

This system is also capable of providing several video features, but at a cost increase of more than 3 times, it is not recommended at this time.

Schedule and Cost

Oracle can install this system as a turnkey project in approximately 4 months from authorization to proceed. Costs are shown in Exhibit 1.

EXHIBIT 1

Automated Information System

Hardware:	
386 Computer	$ 8,000
Phone/voice handling boards (5)	$ 6,800
Terminal emulation board(s)	$ 2,000
Digitizing and plotting equipment	$ 7,500
Recording studio	$ 1,500
Printer and data backup	$ 4,000
Misc. cabling & equip	$ 1,000
Basic system software license (20 phone lines)	$ 32,200
	$ 63,000
Turnkey Basic System:	
Establish data communications (10 days)	$ 5,000
Develop menu and vocabulary (20 days)	$ 10,000
Develop roadway network (35 days)	$ 17,500
Input other data bases (15 days)	$ 7,500
Testing and system acceptance (20 days)	$ 10,000
	$ 50,000
Enhancements:	
Trip planning module	$ 25,000
	$138,000
Contingencies (15%)	$ 20,700
	$158,700
Use	$200,000

Benefits

Call-in services - Automated Telephone call-in services as a motorist information device have applications in the SMART Corridor project. Benefits from using this technology will improve dramatically as data input improves in quality and accuracy. These devices will even survey callers if desired to collect O/D information, and will keep track of valuable user information such as the number of calls and type of information received, and the time spent on each item.

Cellular - With approximately 250,000 cellular phones in Southern Calif. and over 5.5 million drivers in LA county alone, use of cellular phone will not have a significant impact.

Evaluation and Recommendation

This consultant recommends that a automating call-in system similar to that produced by Oracle Communication be installed to coordinate the various information resources (Phone, Har, CMS). It is also recommend that the a toll free incident reporting number be installed at the CHP office, but that due to the low impact no additional staff be added at this time.

VIDEO IMAGE DETECTION

The Smart Corridor project will rely heavily on the use of traffic surveillance information to make control decisions and provide motorist information. Specific use of detection will be made by the freeway surveillance and control system (including incident detection and ramp metering) and by ATSAC (for critical intersection control and system surveillance). Expert systems for both Caltrans and ATSAC will also rely on the surveillance information. These project elements are moving forward using inductive loop technology. This technology has recognized limitations and problems. As a partial mitigation of the loop limitations, CCTV is proposed to provide visual confirmation of critical situations.

VID POTENTIAL

Because of the known problems and limitations of loop detection, the project team included a review of an emerging technology using video image detection (VIDS) as a supplement to, or replacement of, loop detectors. An expert advisor to the team is heavily involved in developing this technology and has provided the team with information as the project progressed. Attached is an overall review of the technology as applicable to the project. The paper suggests that VIDS offers significant potential for both surface street and freeway use. The paper also indicates that VIDS is undergoing continuing development for the Minnesota Department of Transportation. Tests are currently being conducted and a full scale field test is scheduled for later this year. The paper also points out that this is an area of technology where the U.S. is more advanced than others working in traffic control. A second paper, presenting a state of the art review is also attached.

The paper raises questions which are applicable to application of the technology for the Smart Corridor. The questions are such that it is felt that VIDS must still be viewed as being in the research and development stage, especially for surface street applications. Given the on-going work by Minnesota DOT and others, it is the team's opinion that a workable product will become available within one or two years. The product is expected to include the necessary hardware and software for basic detection, but work is expected to remain on the applications software development and integration with control systems such as the Caltrans SATMS and LADOT'S ATSAC system.

As noted, the Smart Corridor project is proceeding with its surveillance and control elements using loop detectors. However, CCTV is included and the communications system is being developed with spare video and data capacity. The CCTV elements for both Caltrans and ATSAC are being designed to provide a 45 foot mounting height which provides excellent viewing for VIDS applications. Because the Smart Corridor project is heavily dependent on its surveillance component, a conservative approach to this element is prudent. Also, Caltrans is in the process of awarding a contract for the rehabilitation of detectors in the corridor, Los Angeles has negotiated a contract for the design of the ATSAC signals assuming loop detection, and plans are being prepared for early implementation of loop detectors at 40 intersections to provide data for the Pathfinder project.

RECOMMENDATION

It is recommended, then, that the primary detection portion of the project continue as planned. It is also recommended that the Smart Corridor project, working through Caltrans and ATSAC, develop a cooperative research and development program with FHWA to develop and test applications software using VIDS technology. The development should concentrate on use of VIDS for incident detection where significant problems currently exist, traffic performance measures which are essential to Smart Corridor type projects, and critical intersection control which has proved to be of major benefit to ATSAC and which requires extensive detectorization at the intersection. The project would appear to fit well with the current emphasis of FHWA and the cooperative program would enhance its support by FHWA. For program budgetting purposes, it is suggested that the Smart Corridor project include $300,000 with the expectation that it would be matched by FHWA. This will allow the Smart Corridor project to complement the work on Minnesota DOT in this challenging technology without duplicating that effort or placing the overall project at risk.

RECOMMENDED APPLICATIONS OF MACHINE VISION FOR THE SMART CORRIDOR PROJECT

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MACHINE VISION APPLICATIONS FOR THE SMART CORRIDOR PROJECT

1. INTRODUCTION

Vehicle detection appears to be the weakest link in traffic surveillance and control. Although detection equipment is available today for sensing vehicle presence on the roadway, it essentially employs technology of the late 50's, has limited capabilities, presents reliability problems and more often than not requires massive and expensive installation for truly traffic responsive control. The latter is particularly true in state of the art surveillance and control systems, which often involve large scale street or freeway corridor networks. With respect to reliability it is noted that most cities with mature systems in the U.S., report that at any time 25 to 30% of their detectors are not functional or operating properly at any time.

Perhaps the most important drawback of existing detectors is their limitation in measuring some important traffic parameters and accurately assessing traffic conditions. This is because the technology employed represents a "blind" type of detection, i.e., only the presence or absence of vehicles over the detectors can be assessed with high accuracy. Traffic parameters such as speed, traffic composition queue length, etc. must be derived from presence or passage and require multiple detection which increases cost and exacerbates the reliability problems mentioned earlier. Furthermore, common detectors (such as loops) do not have surveillance or sufficient vehicle recognition capabilities; most importantly, they are not flexible, i.e., they detect traffic only at fixed points. The latter is an important drawback for traffic control since the detection points should vary with speed, volume and control objective.

Despite the aforementioned problems, existing detectors (i.e., loops) cannot be casually dismissed as they represent proven technology which will continue to serve its purpose in the foreseeable future. However, recent advances in image processing and understanding, electronic cameras, special purpose computer architectures and microprocessor technology, have made the machine vision alternative for vehicle detection attractive, economical and promising. A machine vision system for vehicle detection consists of an electronic camera overlooking a long section of the roadway; from the images received by the camera, a microprocessor or a larger computer determines vehicle presence or passage and derives other traffic parameters preferably in real time. Vehicle detection can be obtained at specific points of the roadway while other traffic parameters can be derived by analyzing the images of the entire roadway scene.

The advantages of vehicle detection through image processing are many. To begin with, an imaging detection system (WADS, which stands for Wide Area Detection System or VIDS for Video Detection System) has multitasking capabilities, i.e., while performing its basic detection functions it could simultaneously derive traffic measurements locally (using a microprocessor) or at a central location, perform surveillance functions, act as a vehicle counting and classification station, detect incidents and alert a human operator, and recognize special vehicles (ambulances, fire trucks, buses, etc.). There are, of course, other secondary tasks that a VIDS system can perform; such tasks include collection and pre-processing of data that can be used in conjunction with existing traffic software packages, revealing the nature of an incident by transmitting images of the scene after the incident is detected, record data for accident analysis, reconstruction, etc. Finally, a VIDS system can be used as an evaluation device for measuring and assessing the quality of flow or for deriving measures of effectiveness for traffic studies.

An imaging detection system does not disturb the pavement and should, therefore, improve reliability, especially during reconstruction operations. Furthermore, it can detect traffic at multiple spots of the roadway within the field of the camera's view thereby becoming cost effective. For instance, in the feasibility study performed by the authors, it was estimated that in Minnesota the cost of fully instrumenting an intersection by a VIDS system (4 cameras, 1 microprocessor) is comparable or lower to that of loop detectors assuming that at least 3 loops per approach are required; furthermore, simultaneous detection at 30-40 points using one or multiple cameras is possible. It was also estimated that a VIDS system would save 35% of maintenance costs and reduce the man hours required for maintenance by about 70%. The savings can further increase if the same microprocessor also performs control functions (a viable alternative) thereby eliminating the need for a separate controller.

The flexible detection configuration of VIDS combined with its ability to extract traffic variables that cannot easily or accurately be obtained by conventional detection devices suggests that such a system should be particularly effective for automatic surveillance and control of saturated networks.

2. MINNESOTA SYSTEM STATUS

Because of these advantages there is worldwide interest in developing a cost effective system; to be sure, research on image processing for vehicle detection began to evolve during the mid 70's in the US, Europe and Japan. Research at the University of Minnesota started in 1984 through projects funded by the Minnesota Department of Transportation and later by the FHWA and University of Minnesota. As a result, a real-time multispot breadboard system was just completed installed and tested in several real situations. Placement of the detectors through a mouse can easily be accomplished by the user in minutes by placing detection lines on a television monitor in any desirable configuration. Once these "pseudo- detectors" are placed, the system generates presence and passage signals compatible to loops, measures speeds and generates essential traffic parameters such as volumes, headways, and occupancy. Furthermore, the system allows visual inspection of the detection results along with the actual traffic conditions for validation purposes and optimizing the detector placement. The latter can easily be changed as often as desired either manually or automatically. Special algorithms for treating artifacts such as rain, snow, shadows, pavement reflections, etc., were developed while the system can operate under both day and night conditions. Finally, any ordinary video camera used for surveillance purposes can be hooked to the breadboard system, i.e., no special purpose cameras are required, although it should be evident that better quality cameras without blooming or streaking characteristics improve the system's accuracy and effectiveness. Unlike other systems, which are essentially experimental, the one developed in Minnesota operates effectively under congested and adverse weather conditions as well as during rapid lighting changes and at night.

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 volume, 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 accepts inputs from a variety of cameras that are commonly installed in freeways and urban streets throughout the world. The system currently requires 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. Up to 4 cameras can be processed simultaneously with only one system. Currently the PC is being replaced with a "black box" that is easier to fabricate while being more compact and portable. The current version of the black box is designed for both office and field environments. In addition to the black box 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 system is installed at the freeway surveillance and control center of the Minnesota Department of Transportation in Minneapolis and tested against live data from several cameras. It was also demonstrated live in several cities in the U.S. and abroad. The results to this point are very encouraging and they suggest performance comparable to or exceeding that of loops. For this reason following additional testing which is currently underway, further improvements are expected so that the system can be confidently installed in other field applications and produced in quantities. This productization plan is expected to be completed in summer 1989.

3. POTENTIAL APPLICATIONS TO THE SMART CORRIDOR PROJECT

There are many practical applications of the video detection system described in this report. The primary advantage lies in the employment of cameras that permit definition of multiple wireless detection points which permits the system to operate as a wide area detection device. Therefore it should not be viewed simply as a replacement of loops, but rather as a device that leads to new potential applications which due to cost and complexity 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 ability to perform several functions simultaneously; for instance detection, control, surveillance, counting/classification, traffic parameter and MOE extraction functions can all be performed using the same device.

It is anticipated that the Smart Corridor project will have surveillance requirements that exceed those of either traditional signal or freeway surveillance and control systems. In the case of signal control, surveillance data has been traditionally used for timing plan selection (traffic responsive signal operation), and to provide a rough measure of overall system performance. The ATSAC system will also use this data for generation of signal timing plans (1 1/2 generation of control). However, the surveillance requirements for generation of signal plans can also be considered relatively modest, when compared with the corridor control requirements of the Smart Corridor, since this data can be averaged over long time periods and integrated with available manual count data. As a result, the data required for existing signal control systems has been tailored to the limited capabilities of the loop detector. The use of this data permits failures of large numbers of detectors, and is designed for measurement of through vehicle volumes and speeds. Large errors in the measurement of traffic characteristics are compensated for by smoothing intervals, manual reviews, and constraints on the timing plans that can be selected for traffic responsive operation.

The use of loop detector data for freeway surveillance and control has also been adapted to the capabilities of the detector. Freeway systems typically use this data as an overall indication of system performance, as well as for the support of incident detection. In limited cases, detector data is used for the selection of ramp metering rates. Freeway systems generally make more extensive use of closed circuit television (CCTV) than signal control systems. As a minimum, the CCTV is used to verify the presence of an incident identified by the loop detectors. In many systems, the CCTV is used as the primary source of incident information. However, in no case, are loop detectors relied on exclusively for incident diagnosis.

Thus, with the exception of traffic responsive operation, the traditional loop detector can generally be considered as a supplementary data source for surveillance and control applications. Its use is restricted both because of the detector's limited surveillance capabilities, and low reliability. Advances in traffic control technology within the United States has been seriously restricted by these problems. Corridor control systems have unique requirements that cannot be subjected to these restrictions. Although this technology is relatively new, its unique surveillance and control requirements can be identified in general terms to consist of:

* The requirements of existing signal and freeway surveillance and control systems.

* The need for accurate real-time information in adequate detail to permit informed decisions regarding diversion strategies and other major traffic control actions such as banning left turns, parking removal, etc.

* Detailed information to support major system changes such as signal retiming, ramp closures, modifications to metering rates, etc., that result from unanticipated changes in traffic flow patterns resulting from

diversion actions.

* Since, by their nature, Corridor control systems are intended for installation in congested corridors, the capability for providing signal and/or freeway control and monitoring under congested conditions must be provided.

* Reliable system status information to be used for public dissemination. This application might represent the most critical need for reliability because of the rapid loss of credibility associated with the broadcast of inaccurate traffic flow status to the general public.

Functions that are potentially applicable to the Smart Corridor project can be divided into two categories; (1) the use of machine vision for surface streets, and (2) the use of machine vision to support functions for freeways. Considerations related to the integration of these two applications are included in the discussions of each category, presented below.

In both cases, it must be recognized that the same equipment can be used to support both categories of functions. It should also be recognized, that if adequate communications capabilities are provided to support transmission of the video image to a control center, it will be possible to supplement the automated machine vision processing with the display of video images.

3.1 Applications for Surface Streets

Signal timing plans selected or calculated for major changes in traffic flow patters must be based on data from an adequate number of sample points to ensure the reliability of the signal timing process. Thus, it will be necessary to install loop detectors or video processing at all major intersections within the corridor.

In addition, since these plans must be sensitive to changes in flow patterns, it is critical that the system incorporate adequate levels of detection to measure changes in turning movements at critical points in the network. This detection capability can only be provided through instrumentation of exclusive turning lanes, or through the implementation of adequate logic to permit the direct measurement of turning vehicles from lanes with mixed flows of through and turning traffic. Traffic flow in exclusive turning lanes can be measured using traditional loop detectors - assuming queue lengths do not exceed the capacity of the turning bay. Turning flow from mixed lanes, can only be measured using machine vision, although it must be emphasized that new algorithm development is required to provide this capability.

As previously noted, control under congested conditions is an important element of a Corridor control system. This form of control leads to unique signal control requirements since algorithms must be developed with the capability to manage queue lengths in order to avoid spillback into upstream intersections. Loop detectors cannot be used for queue measurement, since they are essentially point detectors. Queue lengths require wide area detection that can be provided through the software controlled definition of detector locations that can be relocated to search for the upstream end of a queue. This is another capability that can only be provided through machine vision.

3.2 Applications for Freeways

The limitations of the loop detector are most evident for freeway control. Since the loop detector is a point detector, its capabilities are restricted to the measurement of volume occupancy and speed within its immediate location. Since incident detection technology must rely on this limited measurement to identify unusual traffic flow conditions, difficulties are frequently experienced in distinguishing between normal recurring congestion and incident conditions. The Smart Corridor, with its emphasis on incident response has a significant requirement for rapid, reliable, identification of incident conditions. For this reason, alternative forms of detection must be considered.

Machine vision, with its capabilities for software definition of multiple detectors, as well as its ability for relocation of detectors under software control offers the potential for enhancing existing incident detection processing. While it is important to measure traffic flow characteristics for the identification of congested conditions, reliable incident detection requires the identification of supplemental anomalies that can be used to differentiate between incident conditions and recurring congestion. Possible anomalies might include identification of the end of the freeway queue, measurement of vehicle travel on freeway shoulders, and measurement of ramp queues. As indicated in the previous section, queue measurement is more accurately performed using machine vision.

In addition to incident detection, ramp metering can also be more effectively performed using machine vision. Here again, queue measurement is important to minimize the effects of ramp spillback onto surface streets. Dynamic adjustment of ramp metering rates also relies on accurate of mainline freeway flows in individual lanes. This function can also be implemented using machine vision.

3.3 Additional Applications

In addition to the specific functions identified for signal and freeway control, there are a number of other applications for which machine vision is well suited including:

* The implementation of improved forms of critical intersection control such as the OPAC algorithm recently tested by the FHWA. This algorithm requires upstream detection which can be effectively provided by machine vision. Implementation using loop detectors is not practical because of the cost of installing loops to support this algorithm.

* Generation of areawide data for public dissemination through systems such as Pathfinder or Teletext.

* Monitoring of traffic flow characteristics such as travel time, delays, and stops which are required for evaluation of system benefits in terms of pollution and motorist cost savings.

* Studies of traffic flow characteristics for facilities within the corridor.

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 develop new, more effective traffic control solutions as we enter the 21st century, it becomes evident that deployment of new technology is unavoidable. However, new technology requires experimentation, patience and long term planning; as demonstrated by the activities of the Europeans and Japanese. Thus a long term view and objectives that can be reached in small steps is in order and machine vision is no exception. 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 become 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.

The literature search performed for the Smart Corridor Project has confirmed 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, 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.

APPLICATION OF VIDEO DETECTION IN THE SMART CORRIDOR PROJECT:

STATE OF THE ART LITERATURE REVIEW AND CRITIQUE

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May 1989

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TABLE OF CONTENTS

1 INTRODUCTION AND BACKGROUND

Research on image processing for vehicle detection began during the 1970's in the U.S., Europe, Japan and Australia. A recent survey of the technology was presented by Inigo [1]. In the U.S., research on this topic was initiated by the FHWA and was conducted by the Jet Propulsion Laboratory (JPL) [2],[3],[4]; although the major objective of this project was individual vehicle tracking, algorithms for vehicle detection and speed measurement were also developed. The original imaging system developed by the JPL, also called Wide Area Detection System (WADS), was evaluated by Sperry [5]. In this study recommendations were made for improving the hardware and software design of the WADS system. The technical problems and issues associated with the WADS system developed by the JPL and evaluated by Sperry are discussed in detail by the author [6]. Briefly, although the work performed by the JPL was pioneering, the WADS system developed was too primitive for practical application, something that might be expected at the initial stages of new technological developments, especially with respect to machine vision applications.

In Europe, several countries are currently funding research and development on this subject. Examples include: (1) the work in England on image processing applied to traffic begun at the University of Manchester Institute of Science and Technology (UMIST) [7] and continuing at Napier Polytechnic [8], the University of Sheffield [9],[10], the University College London [11],[12], University of Leeds and Wootton Jeffrys Consultants [13], and Computer Recognition Systems [14]; (2) a vehicle tracking system being developed in France by the National Research Institute for Transportation and Security (INRETS) [15],[16]; and (3) a real-time multispot detection system being developed in Belgium by Devlonics, Ltd. [17],[18]. Each of these efforts is briefly discussed below.

The UMIST project [7] utilized a solid state camera generating a 100x100 pixel per frame image at 8 frames per second. The camera was mounted at a height of 22.5 meters above a two-way highway and data was collected during a period in which illumination varied by a factor of four. The camera output was digitized and averaged. An image corresponding to road background in the absence of any vehicle was stored in the memory of the digital processor. During operation, the digitized image is subtracted from the reference image to generate the road background. In the absence of vehicles the two images should be similar and therefore their difference is due to noise and changes in illumination. A threshold then is used to compare it with the difference of the two images. The resulting binary image is compressed and stored on video cassette and processed in the laboratory. This system was not implemented in real-time and would only work in ideal conditions where the background did not change significantly and where there were no common artifacts such as shadows and reflections to cause false detections. Current work is focused on the combination of microcomputer based imaging processing hardware and neural-network pattern recognition techniques [8]. No details were available on performance in the presence of artifacts.

Currently the system being developed at the University of Sheffield [9] operates under the assumption that the roadway background does not change significantly over a period of 1 minute which is considered to represent ideal conditions. This approach is highly prone to errors due to illumination changes, shadows and reflections. More recently researchers at the University of Sheffield have concentrated on vehicle recognition based on vehicle outline template matching [10]. At the University College London [11], the focus is on implementing vehicle tracking on real-time parallel image processing computer architectures. This vehicle detection approach requires a background to be manually sampled, which is impractical in field situations. Work is underway to automate this background estimation. Once objects are separated from the background, features needed for vehicle tracking are extracted. The features being extracted would result in tracking not only vehicles but also common artifacts such as shadows and reflections which would generate a substantial number of detection false alarms. A more recent development [12] is a departure from this previous work. The thrust is to extract qualitative information from the traffic flow rather than quantitative. The system detects the formation of queues on the motorway. This system cannot count vehicles, it only gives queuing information. In addition, the system is yet very preliminary.

The University of Leeds has developed a system known as TULIP (Traffic analysis Using Low-cost Image-Processing) [13] based on off-shelf technology. The system can currently only process information from one lane of traffic with two detection spots placed by the operator. The operator must then select a method to detect the vehicles (determine the vehicles from the background) probably depending on the illumination available. The detection accuracy is claimed to be about 98 percent in non congested situation (no queues building up). This system has been combined with Wootton Jeffrys Consultants VISTA system to provide information in simple traffic situations (straight level roadways as constrasted to tracking vehicles at roundabouts). No information was available on performance in other types of artifact situations such as shadows, weather (rain, snow, fog, wind), or dawn/dusk transitions.

Computer Recognition Systems, Ltd. is advertising a vehicle detection product termed TAS (Traffic Analysis System) [14]. Not too much is known about this system except that it appears to be an offshoot product from their license plate reading systems. It is claimed to handle up to 3 lanes of traffic for calculating average occupancy and density for each lane, classification of vehicles into 3 classes and calculation of average speed. It is unclear if this system can detect traffic in more than three spots. No information is available concerning accuracies but from inquiries with CRS it was concluded that the system is not yet capable of running in the presence of artifacts such as rain, snow, fog, shadows, and dusk/dawn transitions and for proper operation it requires that the traffic be moving towards the camera.

In France, INRETS is also developing a real-time vehicle tracking system [15]. The system first automatically determines the roadway lane positions and then tracks vehicles down each lane through the entire camera field-of- view. The major problems with this system are that it can lock onto common artifacts such as vehicle shadows and reflections, as well as having problems tracking vehicles through various background changes (e.g. asphalt/cement boundaries, building shadows) and in congested situations where the tracking mechanism breaks down. Some observed test sequences indicated that dark shadow areas under vehicles were the primary objects being tracked and not the vehicle itself. Moreover, according to a recent paper [16], the geometrical shape of the shadow was relied upon for the detection process. This would present difficulty in adapting the system for different times of day and different types of cloud cover. In addition, completely separate approaches have been devised for detection during congestion and detection at night, which leaves open the question of the approach during congested transitional periods, i.e. wintertime rush-hours. INRETS is currently developing a dedicated processor with capability of handling 1 frame of video data every quarter of a second, which implies throughput of their system will be limited to 4/30ths of real-time speed.

Recently, Devlonics, Ltd. of Belgium has advertised a real-time system which can accommodate up to 4 detection spots, each covering a 10 meter lane area [18]. The approach taken, which originated in cooperation with the Catholic University Leuven [17], is to detect vehicles relative to an automatically determined reference background and track their movement through the 10 meter area so as to also determine vehicle speed. Little detailed information about the approach taken is available; however it was learned that vehicles must move through the 10 meter area in less than 2.5 seconds or they become part of the background signal. Furthermore, a microcomputer is needed to implement the detection for each spot, so the full 4 detection spot system requires 4 microcomputers. The system does not seem to operate in real-time but with a 5 second constant decision delay which is too long for critical intersection control applications. Once again, no detailed information is available about system performance in the presence of artifacts.

The Japanese government sponsored Institute of Industrial Science, University of Tokyo, research on measuring traffic flow using real time video processing [19],[20],[21],[22]. Of interest is the non-imaging sensor designed by Shigeta and Ooyama [23],[24]. The sensor is an array of photoelectric elements with geometry designed to match the perspective distortion produced by the camera installed at a specific height and angle of view. The photoelectric elements have a spectral response with a maximum of 930 nm. This response is thought to be optimum during the complete 24 hour day/night cycle. Detection is produced by difference of illumination which is detected by pairs of sensors. The distance between sensors in a pair is known and by measuring the time difference between detection by the first and the second element in a pair, the speed of the vehicle can be estimated.

This system was tested in Tokyo for two years. Finally, the Shigeta-Ooyama system which is the most cost effective, is not truly an imaging system and cannot be extended beyond simple detection as it requires fixed roadway placement geometries and has only fixed and discrete detection points in the field of view. Investigation is now underway in Japan to look at the application of image processing equipment to the vehicle detection problem [25].

The Australian Research Board has developed a real-time vehicle presence system [26]. The system allows placement of up to 16 detection spots at any position in the camera field-of-view via front panel thumbwheel switches. To determine the background level, an additional reference detector is required which must be placed in an area free of vehicles. This reference is compared with the outputs of each of the detection spots and when fixed thresholds are exceeded, a vehicle is detected. Each detection spot has a manual offset adjustment to compensate for the difference in road surfaces between the reference and detector areas. The approach works adequately for ideal situations but the system cannot distinguish the difference between vehicles and major artifacts such as vehicle shadows, reflections and building shadows. Also, since the detection algorithms are hard-wired, there is no flexibility to reprogram and improve the system. This system has been used to monitor the flow of vehicles at a single location on a "carriage-way", and as a tool for monitoring movement into and out of a parking lot [27].

Experience with machine vision over the past five years suggests that despite the impressions generated throughout the literature, a reliable, fieldable, cost effective, real-time multispot vehicle detection system operating under all weather and artifact conditions is still lacking. The major problems with the aforementioned research systems and products that have been addressed and resolved by the WADS system presented in this report are as follows:

1. Automatic adaptation to a wide variety of roadway backgrounds without reference marks.

   The inability of existing systems to automatically adapt to a wide variety of backgrounds prevents them from running reliably or autonomously. A unique approach to estimating the background at the detection spot was therefore developed; this allows automatic adjustment to any uniform or nonuniform road surface without any operator intervention at start-up or while running.

2. Operation in the presence of common artifacts such as shadows, illumination changes and reflections.

   Prior approaches have not really addressed common artifacts such as shadows, illumination changes and reflections. This has resulted in these systems having high false alarm rates under these conditions. In the system presented here, these problems were resolved using a vehicle signature based detection approach that can differentiate vehicles from these artifacts.

3. Operation in congested or stopped vehicle conditions.

   Congested traffic conditions and stopped vehicles have caused the loss of the vehicle and erroneous background estimation in prior approaches. The WADS system allows vehicles to stop for much longer periods of time without "blending" into the background.

4. Arbitrary placement of any type of detector in any configuration anywhere within the camera's field-of-view.

   Most existing systems only support a small number of fixed position detectors. In contrast, using the WADS system one is able to place any number, size and shape detection spots anywhere in the camera's field-of-view and can reposition these spots dynamically under software control. This is accomplished without requiring the camera to be placed at a fixed geometry (e.g., height or angle).

5. Cost effectiveness, real-time operation and programmability.

   Existing approaches to cost effective real-time implementations have resulted in oversimplification of the sensor, hard-wiring the detection processing or using cost prohibitive processors. Cost effectiveness was a major consideration in the development of the WADS detection system. The system can operate off of standard video cameras; no specialized sensors are needed. The approach taken in developing the WADS system allows operation in real-time while still being fully programmable. By using an IBM AT compatible personal computer for WADS rather than an expensive image processing platform, it is demonstrated that the final system implementation is cost effective.

2 Related Funding for Developing the Minnesota WADS System

The breadboard system developed to this point at the University of Minnesota under Mn/DOT, FHWA, and Center for Transportation Studies funding detects vehicle presence, passage, and speed in real-time with performance comparable to magnetic loop detectors. Advantages of this system over loops include the ability of a single system to simultaneously monitor multiple locations over a wide area of road, and the unique ability to reposition detection locations without disruption of traffic or cutting of pavement.

One application of this system will be preprocessing of video from traffic surveillance cameras in order to automatically alert surveillance operators of abnormal traffic conditions (incident detection). In addition, the system could be an important tool for transportation planners, allowing for the flexible collection of traffic data, i.e., vehicle counting and classification, derived from either live cameras in the field or videotape in the office.

As mentioned earlier, the WADS system developed so far at the University of Minnesota was initially funded by Mn/DOT and later by the FHWA and the Center for Transportation Studies (CTS). In what follows, a brief description of the work performed in related projects is presented for the benefit of the unfamiliar reader, as well as for historical purposes.

In 1984, an initial study was funded by Mn/DOT to determine the feasibility of detecting vehicles using video. During this phase (phase I) schemes for video-based detection of vehicles were surveyed to appraise interest of the traffic control community as well as to evaluate previous development attempts. Functional requirements of a video-based detection were then defined including derivable traffic data, accuracy of measurements, the environmental conditions under which detection must occur, expected reliability, compatibility with existing equipment, and range of operation. A data base of co-located visible and infrared video data was collected from nine different locations in the Minneapolis-St. Paul area, with day, night, and varied weather conditions represented. Preliminary algorithms for presence, passage, and speed estimation were then developed and evaluated on collected data. The result was an algorithm for detecting presence and passage based on a combination of temporal and spatial features. Performance limitations due to visibility, occlusion, and artifacts were studied. Finally, different potential sensor configurations were studied, and environmental constraints relative to the camera and processing electronics were estimated.

The findings of the Phase I study were very promising. Passage detection during daytime was 98% accurate with 1% false alarm rate, and 94% during nighttime with 6% false alarms. Speed was determined to be accurate within 15% at 60 mph and 7% at 30 mph. It was determined that a real-time video detection system could be built largely with existing technology, using off-the-shelf components. A visible detector was chosen as preferable to an infrared detector, based on both performance and cost (infrared detection was 70% daytime detection, 3% daytime false alarms, 92% nighttime detection, 1% nighttime false alarms).

It was concluded that night, rain, and snow did not present insurmountable difficulties for vehicle detection. Fog, however, could always be a problem, depending on the severity. However, in conditions where fog is severe enough to create a problem for video-based vehicle detection, drivers of vehicles would have such limited visibility of traffic lights and taillights of other vehicles that they would be best advised to pull off the road, wait it out, and not attempt to drive under such dangerous conditions. Traffic lights would operate in a pretimed mode in such a case.

The average installation cost per intersection was estimated to be 30% lower than loop detectors and maintenance cost was estimated to be 35% lower.

Following the successful completion of the feasibility study, a phase II contract, entitled "Breadboard Fabrication and Testing", was then awarded by Mn/DOT to the University of Minnesota. Work on this contract began in 1985, and was recently concluded in December 1988. The overall objective of this project was the design and implementation of a system capable of doing robust video-based vehicle detection in real-time, under fair weather conditions, i.e. without the presence of serious artifacts such as snow, headlight reflections, occlusion, camera motion, etc..

For the Mn/DOT Phase II contract the necessary set of software and hardware modules was developed in order to implement a real-time vehicle detection system, some of which were then reused to construct the necessary algorithm development facility for the FHWA project. Several ancillary tools were constructed for various support functions: a video disk interface for seeking and playing of sequences of frames on video disk under program control; a detector placement editor for set up and editing of arbitrary detector configurations; and a ground truth editor to facilitate entry of the manually-derived traffic parameters used to evaluate system performance.

A software module was devised to extract average image intensities under each element in a detector. This module, termed the software formatter, was not capable of operating in real-time (i.e. 30 frames per second) and instead single-stepped the video disk when ready for a new image. Subsequently, a hardware implementation of the software formatter was created, the hardware formatter, which allowed for the real-time extraction of detector intensity values. The real-time hardware formatter, developed along with its necessary attendant test and set up software, was integrated into a real-time control system that repeatedly applied the detection algorithms to frame after frame of video data.

In addition a result recorder was developed, which can be described as another real-time system, hosted on another PC separate from detection system, which monitors system performance and displays traffic measurements on a time-averaged basis, emulating the capability of a loop controller.

Further funding for the development of a video-based vehicle detection system has been supplied by the University of Minnesota's Center for Transportation Studies. These funds, appropriated by the U.S. Department of Energy, have been earmarked for the implementation of energy conservation technology, and have been invested in the WADS system in order to improve its ability to generate various indicators of energy efficiency with respect to traffic flow. To this end, at the time of preparation of this report a fieldable prototype was assembled that can be produced in quantities. This prototype is currently being installed at 3 Minneapolis freeway locations while an intersection installation will be initiated in the summer of 1989.

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FREEWAY SERVICE PATROLS

BACKGROUND

As early as 1971, Caltrans was seeking solutions to the removal of incidents on the State's freeways via the use of freeway service patrols. Caltrans first conducted service patrol studies in 1973 as part of the 42 mile loop project. Funding for the service patrols was provided through a grant program. The patrols were determined to be highly cost effective based on the dollar savings in delay time for the motorist.

A second service patrol study in 1973 was conducted by Caltrans in conjunction with CHP and the Auto Club of Southern California. In this study, the use of roving tow trucks was evaluated on selected portions of the Harbor Freeway. Two private tow truck companies provided the equipment and operators, and they charged for their service. The purpose of the study was to evaluate the effectiveness of roving tow services and to determine if privately owned companies could provide the service cost effectively.

During the conduct of the study, the tow companies determined that they were operating at a lose. Although it was not the intent that they make a profit, it was unrealistic to assume that they could continue the service while losing money. Under those conditions, the tow services became unreliable and unresponsive.

The conclusions of the study were that in order for a tow service be responsive to the needs of the public, it must be operated by a public agency. Also, it was determined that CHP was well equipped, from the communications and control points of view, to oversee the operation of the patrols and should therefore be responsible for providing the service. The reasoning for this conclusion is that CHP vehicles are already patrolling the freeways and are consequently in a better position to direct, monitor, and control the service patrols. Additionally, the CHP is the agency which receives all service requests from freeway call boxes and to which is directed all calls regarding incidents/accidents. They can immediately communicate with the tow trucks rather than go through an intermediary as would be the case if Caltrans or another department were the controlling agency.

Presently, tow truck services on the majority of freeways are provided by private tow companies which are called on a rotational basis by CHP dispatchers from an approved list developed by the CHP. In 1988, the CHP received a grant from the

State of California Office of Traffic Safety to "compare incident removal time using Department operated Freeway Service Patrols versus the existing rotational tow services system...". The CHP proposed to conduct this study with the cooperation of Caltrans on a 10-mile segment of the Santa Monica freeway. The site was selected based on its congestion characteristics and the fact that it is monitored by the Caltrans TOC.

EXISTING PROJECT

The study of freeway service patrols in the Santa Monica corridor conducted by the CHP began in September of 1988 and was originally funded as a one-year program. The grant provides funds for personnel to operate the tow trucks and to manage the operation and for all necessary equipment. Three tow trucks (two wheel-lift and one car carrier trucks) are being leased for the project. Other miscellaneous equipment is either purchased with grant funds or provided by CHP.

The roving tow service is provided between the hours of 6:30 A.M. and 10:30 P.M. Monday through Friday. Two shifts of two operators each patrol 5 mile segments at the east and west end of the Santa Monica freeway. The shifts correspond to the shifts of CHP officers on patrol. At this level of coverage, a roving tow truck would complete the patrol of his freeway segment approximately once every 15 minutes. During the midday and evening peak traffic hours from 10:30 A.M. to 7:00 P.M. a third tow truck operator is on duty driving the third vehicle.

It should be noted that during the service patrol study conducted by Caltrans as part of the 42 mile loop project, it was determined that the most efficient system was to have 2 vehicles patrolling freeway segments of approximately 4 miles in length for a total round-trip patrol of 8 miles. This plan closely replicates the CHP's current operation.

A CHP sergeant supervises the operation of the freeway service patrols from the West Los Angeles Area office of the CHP, and she is assisted part time by an office support staff person.

The tow vehicles are outfitted with CHP radios, public address systems, and amber warning lights. They are also equipped with such items as fire extinguishers, traffic cones, and shovels, and they carry gasoline for motorists out of fuel. The drivers wear uniforms identifying them as CHP personnel rather than private tow company emloyees. Mechanical repair service for the tow vehicles is provided by the CHP mechanics who service the Department's patrol cars.

During the last quarter in which study results were reported by the CHP (first quarter of calendar 1989), the freeway service patrol handled a total of 270 disablements, 37 of which were traffic collisions. The majority of disablements (194) were due to vehicle operational problems.

The tow trucks operators are instructed to remove the disabled vehicle from the freeway to a safe location where repairs can be made or a commercial tow service can pick up the vehicle. The intent is to remove the obstruction from the freeway as quickly as possible.

CHP STUDY RESULTS

The study results for the first two periods of operation indicate that there is a significant savings to motorists in reduced delay time due to the speedy removal of incidents from the Santa Monica freeway. The number of secondary accidents caused as a result of the congestion due to incidents is also estimated to have been reduced significantly. During the first reporting period of the study (month of September, 1989) the total cost of operation of the freeway service patrol was $63,813 which compares very favorably with the estimated time savings to motorists of $196,176. These figures result in a benefit cost ratio greater than 3. During the same period, congested related collisions were reduced by 24%.

During the six month period between October, 1988, and March, 1989, the study results yielded an estimated savings of $624,780 compared to operational costs of $101,570, and the number of congested related collisions was reduced by 10%. The resulting benefit cost ratio is calculated to be over 6.15 for this period. The comparatively high operational costs of the first reporting period can be attributed to one-time start-up costs. It is expected that the benefit cost ratio will continue at the latter level in the future given the same operation and conditions.

The California Highway Patrol is pleased with the operation of the freeway service patrol and the results being obtained. The one year grant program, as a result of the project's success, has been extended to provide funding through June of 1990.

DISCUSSION

The success of the existing study project suggests that the freeway service patrol should be continued in its present form and under its current operating agency. The expected future benefits also support the conclusion for the continued operation of the service. Because CHP patrols are continuously present on the freeways, because of CHP's role in freeway operations and in incident management, and because of its central communications and dispatch function, it is also suggested that the control of the operation of the service patrols be retained by the CHP.

The CHP feels that the present hours of operation are adequate and that service is being provided during the periods of the day which need it. It is also felt that the existing level of manpower and number of patrols is adequate to provide sufficient coverage of the 10 mile length of the freeway segment. The CHP had no suggestions for modifications or improvements in the operation of the patrols with regard to making them a permanent responsibility of the Department.

The present funding for the study project runs out in June, 1990. The CHP could continue the program without interruption at that time with the only significant difference being that the Department would purchase tow trucks before that time to replace the leased vehicles and be responsible for their maintenance under the new program.

PROJECTED COSTS

The costs associated with the continued operation of the freeway service patrols at their present level of coverage are presented in this section. The costs are divided into three categories: one-time capital expenditures, annual personnel costs, and annual operating cost.

Capital Expenditures

The following are the estimated costs for the purchase of three vehicles to be used in place of the vehicles which are currently being leased during the conduct of the study project.

VEHICLE	COST	EXTENSION
o 2 wheel-lift tow trucks fully equipped with CHP radios and warning lights	$ 32,000 ea	$ 64,000
o 1 car carrier tow truck fully equipped with CHP radios and warning lights	$ 34,000 ea	$ 32,000
	TOTAL	$ 96,000

Annual Personnel Costs

The personnel to be assigned to the freeway service patrol task include one supervisory sergeant, one clerk typist, and five operators. The personnel cost estimates for one year's operation are based on salary figures, including benefits, used in the original grant application. The salaries have been modified in accordance with the increased cost of living since the project was initiated in September of 1988.

Due to the sensitivity of the project and the level of responsilibility expected of the drivers, CHP established salaries for the operators at a relatively high level to attract a high quality of applicant. A comparable salary level is reflected in the following personnel cost estimates.

PERSONNEL	ANNUAL SALARY	EXTENSION
1 State Traffic Sergeant	$ 61,840	$ 61,840
1 Office Assistant II	$ 27,180	$ 27,180
5 Tow Truck Operators	$ 36,010	$180,050
	TOTAL	$269,070

The project staff is and would continue to work out of the West Los Angeles Area office of the CHP.

Annual Operational and Direct Expenses

Each of the tow trucks carries equipment such as shovels, fire extinguishers, and extra gasoline for stranded motorists. This section contains the annual cost estimates for these items as well as operating expenses covering fuel and vehicle maintenance.

The mileage driven per vehicle has been estimated by CHP to be approximately 100 miles per day. Vehicle maintance during the study project is the reponsibility of the leasing company and consequently there are no cost figures available. These costs have been estimated based on operating experience and are presented in Exhibit 1.

EXHIBIT 1

ESTIMATED ANNUAL OPERATING COSTS FOR FREEWAY SERVICE PATROLS

	COST ITEM	ANNUAL UNIT COST	EXTENSION
5	shovels, fire extinguishers, gas cans, brooms, etc.	$ 300	$1500
5	Gasoline for motorists/vehicle	$ 950	$4750
5	sets of uniforms	$100	$ 500
5	Vehicle insurance (comprehensive and collision)	$1100	$5500
5	Tow truck operating costs: 26,000 miles/truck @ $ .50/mi (incl. maintenance)	$13,000	$65,000
		TOTAL	$ 77,250

Summary of Costs

The major expense in the implementation of a program to provide continuing freeway service patrols on the Santa Monica freeway will be the purchase of the tow vehicles, estimated to cost approximately $96,000. Annual operating expenses are estimated at $346,320 with the major expense being the salaries of the operators. It is therefore estimated that the first year's cost will be approximately $450,000.

RECOMMENDATION

The project team recommends the continuation of the freeway patrol serviceas part of the Smart Corridor project. The project should continue to be monitored and the hours extended when conditions warrant.

System Component Evaluation

A preliminary assessment of the various system components and alternatives under consideration was performed in order to identify which components offer the greatest promise and should be implemented. A secondary objective of the evaluation was to assist in identifying appropriate locations at which system components should be implemented.

Based on the analysis performed, an evaluation matrix was developed in order to provide a comparison of the impacts, positive or negative, expected from each system component. This matrix is presented in Table 1. The information presented in the matrix was used to prepare appropriate recommendations for each system component. Some components, such as ramp metering, connector metering, the ATSAC system, and CCTV were evaluated quantitatively with existing analytical tools. The results of these analyses are presented and discussed later in this paper. The remaining components were evaluated qualitatively. A detailed description of each evaluation is not presented here, rather, is included in the individual component descriptions.

Table 1 is divided into three sections, freeway impacts, surface street impacts, and corridor impacts. The values listed represent potential annual impacts. The impacts associated with those components which were qualitatively evaluated are divided into three classes. Potential major impacts are denoted as "++" or "--". Impacts which are considered significant are denoted as "+" or "-". If no appreciable impact is expected, a "0" is listed. The remainder of this paper discusses the evaluation methods used, assumptions made, and results of various component analyses.

Evaluation Methods

Several methods were used to evaluate the various components of the Smart Corridor system, including identification of previous surveys, experience, and evaluation results, analytical techniques, and simulation models. Many of the components, such as connector ramp metering, the ATSAC system, freeway service patrols, and to a lesser extent CCTV, lent themselves well to quantitative evaluation. Quantifying the potential benefits of the driver informational components, including HAR, dial-in services, teletext, and CMS was not possible due to the limited amount of information available on previous applications. Rather, these components were evaluated qualitatively, based on technical and operational considerations, anticipated driver acceptance and response, and anticipated present and future availability.

Table 1
EVALUATION MATRIX

Potential Annual Freeway Impacts

Component/Alternative	Freeway Travel Time (veh-hrs) (millions)	Ramp Delay (veh-hrs) (millions)	Total Travel Time (veh-hrs) (millions)	Fuel (gals) (millions)	HC (kgs) (millions)	Emissions CO (kgs) (millions)	NOx (kgs) (millions)
Existing Conditions	16.30	0.95	17.30	3.30	1.90	9.80	1.60
Optimize Ramp Metering W/O Diversion	-0.90	+0.75	-0.15	+1.40	+0.03	+0.18	+0.03
Optimize Ramp Metering W/ Diversion (Desired Speed > 50 mph)	-2.40	+0.39	-2.00	+1.60	+0.03	-0.51	+0.60
Optimize Ramp Metering W/ Diversion (Desired Speed > 40 mph)	-1.40	+0.63	-0.72	+1.40	+0.03	+0.18	+0.60
Optimize Ramp and Connector Metering I-405, NB & SB (4-lanes)	-2.40	+0.27	-2.10	+1.30	-0.03	-0.45	+0.06
Optimize Ramp and Connector Metering R-110, NB	-2.40	+0.21	-2.10	+1.30	-0.03	-0.45	+0.06
Optimize Ramp and Connector Metering I-405,NB & SB; R-110,NB	-2.40	+0.09	-2.20	+1.00	-0.03	-0.45	+0.06
ATSAC System	+	+	+	+	+	+	+
Intersection Signal/ Ramp Meter Coordination	+	+	+	+	+	+	+
CCTV on Surface Streets	o	o	o	o	o	o	o
Highway Advisory Radio	++	++	++	++	++	++	++
CMS (freeway)	++	++	++	++	++	++	++
CMS (surface streets)	++	++	++	++	++	++	++
In-Vehicle Navigation	+	+	+	+	+	+	+
Cellular Telephone	o	o	o	o	o	o	o
Dial-In Services	+	+	+	+	+	+	+

Table 1
EVALUATION MATRIX

Potential Annual Freeway Impacts

Component/Alternative	Freeway Travel Time (veh-hrs) (millions)	Ramp Delay (veh-hrs) (millions)	Total Travel Time (veh-hrs) (millions)	Fuel (gals) (millions)	HC (kgs) (millions)	Emissions CO (kgs) (millions)	NOx (kgs) (millions)
CMS (garage or building) (Silent Radio)	o	o	o	o	o	o	o
Computer Bulletin Boards	o	o	o	o	o	o	o
Commercial Radio	++	++	++	++	++	++	++
Commercial TV	o	o	o	o	o	o	o
Cable TV	+	+	+	+	+	+	+
Teletext	+	+	+	+	+	+	+
Videotext	o	o	o	o	o	o	o
Control System Improvements	+	+	+	+	+	+	+
Expert System	+	+	+	+	+	+	+
Freeway Service Patrol	-0.3	+	-0.3	+	+	+	+
Freeway Incident Management Team	+	+	+	+	+	+	+
Surface Street Incident Management Team	+	+	+	+	+	+	+

Table 1
EVALUATION MATRIX

Potential Annual Surface Street Impacts

Component/Alternative	Total Travel Time (veh-hrs) (millions)	Total Delay (veh-hrs) (millions)	Number of Stops (veh-hrs) (millions)	Fuel (gals) (millions)	Emissions HC (kgs) (millions)	Emissions CO (kgs) (millions)	Emissions NOx (kgs) (millions)
Existing Conditions	17.77	8.1	693.8	21.98	1.95	16.90	0.75
Optimize Ramp Metering W/O Diversion	o	o	o	o	o	o	o
Optimize Ramp Metering W/ Diversion (Desired Speed > 50 mph)	+0.08	+0.05	+2.40	+	+	+	+
Optimize Ramp Metering W/ Diversion (Desired Speed > 40 mph)	+0.04	+0.03	+1.30	+	+	+	+
Optimize Ramp and Connector Metering I-405, NB & SB (4-lanes)	+0.04	+0.03	+1.30	+	+	+	+
Optimize Ramp and Connector Metering R-110, NB	+0.04	+0.03	+1.30	+	+	+	+
Optimize Ramp and Connector Metering I-405,NB & SB; R-110,NB	+0.08	+0.06	+2.60	+	+	+	+
ATSAC System	-3.15	-1.98	-293.04	-2.70	-0.27	-3.60	-0.05
Intersection Signal/ Ramp Meter Coordination	-	-	-	-	-	-	-
CCTV on Surface Streets	-0.07	-0.07	-0.25	-	-	-	-
Highway Advisory Radio	++	++	++	++	++	++	++
CMS (freeway)	-	-	-	-	-	-	-
CMS (surface streets)	++	++	++	++	++	++	++
In-Vehicle Navigation	+	+	+	+	+	+	+
Cellular Telephone	o	o	o	o	o	o	o
Dial-In Services	+	+	+	+	+	+	+

Table 1
EVALUATION MATRIX

Potential Annual Surface Street Impacts

Component/Alternative	Total Travel Time (veh-hrs) (millions)	Total Delay (veh-hrs) (millions)	Number of Stops (veh-hrs) (millions)	Fuel (gals) (millions)	Emissions HC (kgs) (millions)	Emissions CO (kgs) (millions)	Emissions NOx (kgs) (millions)
CMS (garage or building) (Silent Radio)	o	o	o	o	o	o	o
Computer Bulletin Boards	o	o	o	o	o	o	o
Commercial Radio	-	-	-	-	-	-	-
Commercial TV	o	o	o	o	o	o	o
Cable TV	+	+	+	+	+	+	+
Teletext	+	+	+	+	+	+	+
Videotext	o	o	o	o	o	o	o
Control System Improvements	+	+	+	+	+	+	+
Expert System	+	+	+	+	+	+	+
Freeway Service Patrol	o	o	o	o	o	o	o
Freeway Incident Management Team	o	o	o	o	o	o	o
Surface Street Incident Management Team	+	+	+	+	+	+	+

Table 1
EVALUATION MATRIX

Potential Annual Corridor Impacts

Component/Alternative	Total Travel Time (veh-hrs) (millions)	Fuel (gals) (millions)	Emissions HC (kgs) (millions)	CO (kgs) (millions)	NOx (kgs) (millions)
Existing Conditions	34.07	25.28	3.85	26.70	2.41
Optimize Ramp Metering W/O Diversion	-0.90	+0.14	+0.03	+0.51	+0.60
Optimize Ramp Metering W/ Diversion (Desired Speed > 50 mph)	-1.92	+1.60	+0.03	+0.51	+0.06
Optimize Ramp Metering W/ Diversion (Desired Speed > 40 mph)	-0.68	+1.40	0.03	0.18	+0.06
Optimize Ramp and Connector Metering I-405, NB & SB (4-lanes)	-2.06	+1.30	-0.03	-0.45	+0.06
Optimize Ramp and Connector Metering R-110, NB	-2.06	+1.30	-0.03	-0.45	+0.06
Optimize Ramp and Connector Metering I-405,NB & SB; R-110,NB	-2.36	+1.30	-0.03	-0.45	+0.06
ATSAC System	-3.15	-2.70	-0.27	-3.60	-0.05
Intersection Signal/ Ramp Meter Coordination	+	+	+	+	+
CCTV on Surface Streets	-0.07	-	-	-	-
Highway Advisory Radio	++	++	++	++	++
CMS (freeway)	++	++	++	++	++
CMS (surface streets)	++	++	++	++	++
In-Vehicle Navigation	+	+	+	+	+
Cellular Telephone	o	o	o	o	o
Dial-In Services	+	+	+	+	+

Table 1
EVALUATION MATRIX

Potential Annual Corridor Impacts

Component/Alternative	Total Travel Time (veh-hrs) (millions)	Fuel (gals) (millions)	Emissions HC (kgs) (millions)	Emissions CO (kgs) (millions)	Emissions NOx (kgs) (millions)
CMS (garage or building) (Silent Radio)	o	o	o	o	o
Computer Bulletin Boards	o	o	o	o	o
Commercial Radio	+	+	+	+	+
Commercial TV	o	o	o	o	o
Cable TV	+	+	+	+	+
Teletext	+	+	+	+	+
Videotext	o	o	o	o	o
Control System Improvements	+	+	+	+	+
Expert System	+	+	+	+	+
Freeway Service Patrol	+	+	+	+	+
Freeway Incident Management Team	+	+	+	+	+
Surface Street Incident Management Team	+	+	+	+	+

Two simulation models were used for the evaluation. The FREQ model, a freeway corridor model, was used to test the potential impacts of modifying existing ramp metering, and freeway connector ramp metering. Due to the limited time available for the evaluation task, an existing FREQ model, developed and calibrated at UC-Berkeley was used. This model included that section of the Santa Monica freeway extending rom the San Diego freeway (I-405), to the Harbor Freeway (R-110). The model included both eastbound and westbound freeway directions, however, only the morning peak period, 6-10 am, was calibrated. Since the off-peak and evening peak period models were not available, the morning peak period results were used as a basis from which potential daily and annual benefits were estimated.

Table 2 provides a comparison of am peak, pm peak, and off-peak period volumes on the Santa Monica freeway at selected locations. The data indicates that freeway demand remains high throughout the day. In fact, the average hourly volumes in each period are generally consistent. Therefore, the impacts of each system component during the off-peak and pm peak periods were considered equal to the am peak period. Impacts during nighttime traffic conditions were considered to be negligible due to the presence of much lower traffic volumes. Annual benefits were calculated assuming 300 traffic days per year.

TRANSYT was used to simulate traffic conditions on the surface street network. Similar to the FREQ model, the surface street network within the Smart Corridor had previously been coded and calibrated in a previous study performed by UC-Berkeley. TRANSYT runs were made for the am peak period. The existing TRANSYT model included Adams Blvd., Venice Blvd, and Washington Blvd. as well as all major north/south arterials. Based on existing peak period traffic volumes on Olympic Blvd. and Pico Blvd., the impacts on the entire corridor were estimated to be 50 percent greater than the model predictions. It was assumed that based on traffic volumes occurring throughout the day, similar impacts would occur during the pm peak period, while the benefits during the off-peak period were estimated at 50 percent of the peak period. No benefits were assumed for all other time periods.

Evaluation of the various driver information components under consideration in the Smart Corridor was performed qualitatively based on the results obtained from similar applications, technical and operational considerations, and anticipated driver acceptance and response. An initial indication of potential benefits of certain traffic information technologies was provided by a recent driver survey conducted by the Washington State Department of Transportation. The preliminary survey results suggested that the majority of drivers (75 percent) preferred to receive traffic information from commercial radio and in fact find the traffic information provided to be very useful. Only 10 percent of those surveyed preferred commercial television.

TABLE 2

Comparison of Santa Monica Freeway Traffic Volumes During AM, PM, and Off-Peak Periods

	AM Peak (6-10 am)		Off-Peak (10 am-3 pm)		PM Peak (3-7 pm)	
Location	EB	WB	EB	WB	EB	WB
Overland	30,100	32,800	38,900	38,500	34,100	32,800
National	28,100	—	35,900	—	32,100	—
La Cienega	30,200	31,100	35,900	37,300	29,500	30,800
Washington	28,900	—	38,500	—	32,900	—
La Brea	30,500	—	38,400	—	31,100	—
Western	31,400	28,300	38,300	40,900	28,700	34,200
Vermont	32,800	20,800	39,500	24,100	28,300	20,200

The drivers surveyed overwhelmingly accepted the idea of a dedicated traffic information radio station. Little preference was given to computer bulletin boards, dedicated cable TV, or dial-in services. Although it is not reasonable to predict the success of various driver information technologies based on the results of a single survey, several general conclusions were evident. Namely, drivers are more likely to use and accept technologies which are simple to use and do not add delay to the commute. In addition, drivers desire technologies which are capable of providing on-demand traffic information. The survey also suggested that two types of drivers exist. Those drivers that will change their normal route while on the road in response to traffic congestion and those drivers that will plan or alter their routes prior to departing, but will not deviate once on their selected route.

ATSAC System

Implementation of the ATSAC system in the Smart Corridor is expected to have a significant impact on the reduction of congestion resulting from recurring and non-recurring traffic conditions. Evaluation of the expected benefits was performed using the TRANSYT model to estimate existing traffic conditions, i.e. recurring congestion, and project future conditions once the system has been implemented. The results of this analysis provided an indication of the expected benefits due to the reduction in congestion caused by recurring traffic conditions. The benefits associated with the expected reduction in non-recurring congestion were difficult to evaluate, however, they can be expected to be equal to, if not greater than, those estimated for recurring congestion. Recent studies indicate that presently, non-recurring congestion is at least equal to recurring congestion. As traffic volumes continue to increase, this factor is also expected to rise.

Table 3 provides a summary of the TRANSYT model results for existing conditions in the Smart Corridor, and after the signal system has been optimized. The percent change between the TRANSYT results, along with those observed in the existing ATSAC system are provided for comparative purposes. Except for intersection delay and number stops, the benefits estimated using the TRANSYT model are close to those estimated from the before and after study of the initial ATSAC system. The TRANSYT model predicted a 32.4 percent reduction in intersection delay, as compared to a 20.3 percent reduction based on the ATSAC evaluation. These results were considered to be higher than previous experience in signal optimization had shown. A more appropriate reduction in intersection delay would range from 10-20 percent. Conversely, the projected reduction in the number of stops by the TRANSYT model was considered to be low. Typically, a large reduction in the number of stops is expected with a fairly large decrease in intersection delay.

TABLE 3

Summary of TRANSYT Results[1]
(AM Peak Period)

Measure of Effectiveness	Unit	Existing	Optimized	Estimated Percent Change	ATSAC[2] SYSTEM Observed Percent Change
Travel Time	veh-hrs	23,700	20,200	-14.8%	-13.2%
Intersection Delay	veh-hrs	10,800	7,300	-32.4%	-20.3%
Number of Stops		925,000	838,000	- 9.4%	-35.2%
Average Speed	mph	19.6	21.8	+11.2%	+14.8%
Fuel Consumption	gals	29,300	26,300	-10.2%	-12.5%
Vehicle Emissions	Kgs				
HC		2,600	2,300	-11.5%	-10.2%
CO		22,500	18,500	-17.8%	-10.3%
NO_x		1,000	950	- 5%	—

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[1] Includes all parallel arterials (Adams Blvd., Washington Blvd., Venice Blvd., Olympic Blvd., Pico Blvd.) within the Smart Corridor.

[2] Results from the ATSAC Evaluation Study performed by LADOT, July, 1987.

Based on the estimated benefits from the TRANSYT model for the am peak period, daily and annual savings were calculated. The anticipated savings in delay and number of stops were based on percent reductions observed in the ATSAC evaluation. Table 4 presents the estimated potential savings from implementation of the ATSAC system in the Smart Corridor. These values represent the potential impacts of the ATSAC system on recurring congestion only. Considering the analytical tools available and the lack of data from previous evaluations, quantification of the impacts on non-recurring congestion was not performed in this evaluation. As stated previously, however, benefits similar to those listed in Table 4 are reasonable to expect. In fact, the greatest benefits from the ATSAC system may be realized in reducing the negative effects of incidents on traffic flow.

Undoubtedly, not only will implementation of ATSAC in the Smart Corridor improve traffic flow, it will also provide an impetus for increased traffic demand. This increase in traffic demand would be in addition to natural increases expected from further development within the corridor, particularly in the downtown CBD and Century City.

Freeway Service Patrols

Freeway service patrols are currently being tested on the Santa Monica Freeway and interim results have been reported by the California Highway Patrol (CHP). Results during the first three months of the field tests indicated the following.

- Of 333 lane-blocking incidents which were detected and removed by the Freeway Service Patrols, the average incident duration was estimated to have been reduced by 50 percent (24 minutes to 12 minutes). This savings was based on a comparison between the average incident duration on the Santa Monica Freeway on which the field testing was performed and the Harbor Freeway which was considered a control.

- The majority of incidents which were responded to were non-accidents or stalls. Only 9 percent of the incidents were traffic collisions.

- Based on a comparison between 1987 and 1988 traffic accident data, it was estimated that the number of congestion related traffic accidents decreased by nearly 10 percent as a result of the Freeway Service Patrols.

Based on the initial results of the field tests, it is expected that under the current operating schedule (Monday-Friday, 6:00 am-7:30 pm), the Freeway Service Patrol would respond to nearly 1350 incidents per year. Based on a delay formula developed by

TABLE 4

Potential Impacts of ATSAC System on Recurring Congestion in the Smart Corridor[3]

Measure of Effectiveness	Unit	Daily Savings	Annual Savings
Travel Time	veh-hrs	10,500	3.15×10^6
Intersection Delay[4]	veh-hrs	6,600	1.98×10^6
Number of Stops[4]		976,800	293.04×10^6
Fuel Consumption	gals	9,000	2.70×10^6
Vehicle Emissions	Kgs		
HC		900	270,000
CO		12,000	3.60×10^6
NO_x		150	45,000

[3] Daily Savings are based on typical traffic conditions between 6:00 AM and 7:00 PM. Annual impacts are based on 300 traffic days per year.

[4] Reductions in intersection delay and number of stops are based on results obtained from the initial ATSAC Evaluation which are considered more reasonable than the TRANSYT results.

Caltrans, it was estimated that the average reduction in delay was 230 vehicle hours per incident. Therefore, the potential annual delay savings would be over 300,000 vehicle-hours. This estimate is considered to be quite conservative since recent accident data on the portion of the Santa Monica Freeway within the Smart Corridor indicates that over 1400 traffic collisions alone occur each year. Therefore, it is anticipated that the potential benefits of the Freeway Service Patrol on the Smart Corridor may be 2 to 3 times the delay savings indicated by the initial field tests.

CCTV on Surface Streets

The potential benefits associated with CCTV on the surface street network within the Smart Corridor include the ability to visually monitor traffic conditions and identify and verify incidents, resulting in improved traffic control response. Quantifying these benefits is difficult, however, the potential of CCTV in reducing non-recurring congestion was roughly estimated using TRANSYT.

Initially it was assumed that the average incident duration was approximately 20 minutes. Using TRANSYT, an incident, causing blockage to one thru lane, was simulated at the intersection of Washington Blvd. and La Brea Ave. The simulated incident occurred during the am peak hour (7-8 am). Normally, the intersection of Washington Blvd. and La Brea Ave. operates in LOS E (V/C = 0.94) during the am peak period. Therefore, the impacts of an incident at this intersection are probably greater than at those operating at LOS C or D, however, this intersection represents a more likely location for CCTV. The lane blockage was simulated in both the eastbound and southbound approaches, the latter of which had the highest approach volumes during the am peak period.

Due to the requirements of TRANSYT, the incident, or lane blockage was actually simulated over an entire 1-hour period. The impacts of the incident for shorter time intervals were estimated based on a straight-line interpolation between the impacts over an hour and normal non-incident traffic conditions. In the simulation results, the saturation flow rate of the total intersection reached 105 percent of available capacity. Based on previous experience with TRANSYT, the results are considered reasonable at this percent saturation.

The results of the incident simulation are presented in Table 5. These results show the estimated benefits of CCTV assuming the average incident duration is reduced from 20 minutes to 10 minutes. Currently, within the Smart Corridor, an average of 500 accidents per year are reported at those intersections where CCTV coverage is planned. This number only represents those accidents occurring in or near major intersections and do not include mid-block accidents, unreported accidents, or other minor incidents

TABLE 5

Summary of Incident Simulation Results

Measure of Effectiveness	Unit	Incident 20 Mins.	Duration 10 Mins.	Estimated Percent Change
Travel Time	veh-hrs	168	155	- 8%
Intersection Delay	veh-hrs	72	58	-19%
Number of Stops		4940	4890	- 1%
Fuel Consumption	gals	190	185	- 3%
Vehicle Emissions	kgs			
HC		—	—	—
CO		—	—	—
NO_x		—	—	—

such as stalls. Thus, the total number of incidents occurring within the area of CCTV coverage could be 5 to 10 times as high or 2500 to 5000 per year. The benefits listed in Table 6 reflect this higher number of incidents.

Ramp Metering

Several ramp metering strategies, including modification of existing metering rates and freeway connector ramp metering were evaluated using FREQ and TRANSYT. The FREQ model was used to estimate the impacts of ramp metering on freeway operation and the number of vehicles which are expected to divert to parallel routes. The TRANSYT model was used to determine the impacts of diversion on traffic conditions on the surface street network.

Initially, the FREQ output for the existing freeway conditions were analyzed in order to identify the primary causes of congestion in the Smart Corridor and potential mitigation measures which would improve freeway operation. The results of the analysis showed that several bottlenecks exist in both the eastbound and westbound directions. In the eastbound direction, the bottlenecks are located at La Brea Ave., Western Ave., and the southbound Harbor Freeway connector. Bottlenecks in the westbound direction are present at Western Ave., La Brea Ave., La Cienega Ave., Robertson Ave., and Overland Ave. Further analysis indicated that operational improvements to the freeway, i.e. improved normal and priority ramp metering, and connector metering offered greater potential benefits then physical improvements. It should be noted, however, that further study of the bottleneck conditions could identify spot physical improvements which could be cost effective.

Several metering strategies requiring modification of existing metering rates were evaluated. The FREQ results are presented in Table 7. The results represent the expected impacts of each metering strategy on both the eastbound and westbound directions of travel. The expected amount of diversion which would occur as a result of each metering strategy were estimated based on available ramp storage capacity. It was assumed that queues would not exceed ramp storage capacity and all excess vehicles would divert to an alternate route on the surface streets.

One metering strategy which was tested was to optimize the existing ramp meters at rates which would not allow ramp queues to exceed the available ramp storage capacity. Also tested were metering strategies which would improve freeway operation to free-flow conditions (>50 mph) and to a lesser degree (>40 mph).

In addition to testing modifications to the existing metering rates, metering at the I-405 and R-110 connectors were also evaluated. The FREQ results are presented in Tables 8 and 9. In addition to the results generated from the various FREQ runs in this evaluation, results from a recent study performed at UC-

TABLE 6

Potential Impacts of CCTV on Non-Recurring Congestion In The Smart Corridor

Measure of Effectiveness	Unit	Annual[5] Savings
Travel Time	veh-hrs	65,000
Intersection Delay	veh-hrs	70,000
Number of Stops		250,000
Fuel Consumption	gals	25,000
Vehicle Emissions	kgs	
HC		
CO		
NO_x		

[5] Based on an 5000 incidents per year within the areas of planned CCTV coverage.

TABLE 7

Summary of FREQ Results
Normal Ramp Metering Strategies

(AM Peak Period, Eastbound and Westbound)

Measure of Effectiveness	Unit	Existing Conditions	W/O Diversion Existing Storage	W/Diversion Desired Speed >50 mph	W/Diversion Desired Speed >40 mph
Freeway Travel Time	veh-hrs	18,100	16,600	14,050	15,800
Ramp Delay	veh-hrs	1,050	2,300	1,700	2,100
Total Travel Time	veh-hrs	19,200	19,000	15,800	18,000
Average Speed	mph	15-35	20-40	50-55	40-48
Fuel Consumption	gals	36,750	39,050	41,800	39,050
Vehicle Emissions	kgs				
HC		2,200	2,250	2,150	2,250
CO		10,850	11,550	10,000	11,150
NO_x		1,800	1,850	2,000	1,900
Expected Diversion	vph	---	0	1,700	500

TABLE 8

Summary of FREQ Results
Freeway Connector Metering Strategies
I-405 Connectors
(AM Peak Period, Eastbound Only)

Measure of Effectiveness	Unit	Optimize Ramp and Connector Metering			
		Existing Conditions	Optimize Ramp Meters Only	Meter 3-Lanes	Meter 4-Lanes[7]
Freeway Travel Time	veh-hrs	10,850	8,400	9,600	8,400
Ramp Delay	veh-hrs	750	1,100	1,500	1,900
Total Travel Time	veh-hrs	11,600	9,500	9,600	9,300
Average Speed	mph	15-35	53-56	52-55	53-56
Fuel Consumption	gals	22,250	25,450	25,200	25,000
Vehicle Emissions	kgs				
HC		1,350	1,300	1,310	1,300
CO		6,600	6,000	6,250	6,100
NO_x		1,100	1,230	1,200	1,200
Expected Diversion	vph	---	1,000	1,200	900

[7] Results of recent FREQ analysis of Santa Monica Freeway performed at UC-Berkeley were used to estimate impacts of 4-lane connector metering from I-405 to I-10. Report entitled Santa Monica Freeway Operation Improvement Study, by Sirous Alavi, Alex Tanco, and Edward Chung, May, 1989.

TABLE 9

Summary of FREQ Results
Freeway Connector Metering Strategies
R-110 Connectors
(AM Peak Period, Westbound Only)

Measure of Effectiveness	Unit	Existing Conditions	Optimize Ramp Meters Only	Optimize Ramp Meters & NB to WB Connector[8]
Freeway Travel Time	veh-hrs	7,300	5,700	5,700
Ramp Delay	veh-hrs	300	600	300
Total Travel Time	veh-hrs	7,600	6,300	6,000
Average Speed	mph	15-35	50-53	50-55
Fuel Consumption	/gals	14,500	16,350	16,350
Vehicle Emissions	kgs			
HC		850	850	850
CO		4,200	4,000	4,100
NO_x		700	800	800
Expected Diversion	vph	---	700	500

8 Implementation of connector metering on southbound to westbound R-110 connector resulted in long ramp queues. Existing connector storage was not sufficient to handle the anticipated queued vehicles.

Berkeley are also presented. The UC-Berkeley results are based on evaluation of the addition of a lane to the NB to EB I-405 connector. The overall annual freeway impacts of each ramp metering strategy tested are provided in Table 11. Annual savings are based on the impacts of each metering strategy during the am and pm peak periods only. The off-peak periods were not considered since it is expected that ramp metering would not be in effect.

Analysis of connector ramp metering at the I-405 connectors indicated that if all three lanes (1 NB to EB, 2 SB to EB) are metered at the maximum metering rate of 900 vph, the total queue on both connectors will exceed 1500 vehicles. The excessive ramp delays associated with this metering strategy would cause the overall travel time on the freeway to increase significantly and would severely impact traffic conditions on the I-405 freeway. Although diversion would occur as a result of the lengthy queues, it is unreasonable to expect nearly 450 vph to divert to an alternate route. Therefore, under the current conditions, ramp metering on the I-405 connectors is not feasible.

An alternative connector metering strategy would be to add a lane to the NB to EB I-405 connector, thus increasing the number of metered lanes from 3 to 4. By increasing the number of vehicles which are metered, the anticipated ramp storage on both connectors would be capable of handling the queuing which would occur. A preliminary review of the existing geometrics on the NB to EB connector indicated that an additional lane could be added by restriping. It was estimated that in addition to optimizing the ramp meters, connector ramp metering at the I-405 would result in an additional annual travel time savings of 100,000 vehicle-hours. Ramp delays would also decrease, thereby reducing the amount of potential diversion to surface streets.

The R-110 connectors were also analyzed for possible metering. The FREQ runs showed that metering the NB to WB connector storage was feasible and would not generate lengthy queues. Metering of the SB to WB connector, however, would create extremely large queues, in excess of 2900 vehicles. Therefore, metering of the NB to WB R-110 connectors is possible, however, the high volumes on the SB to WB connector makes metering improbable. It was estimated that metering on the NB to WB connector would result in an annual travel time savings of 100,000 vehicle-hours per year. Overall ramp delays would also be reduced, however, due to the low demand, the metering rates which would be refined on the NB to WB connector would have to be low in order to realize any benefits.

The annual impacts on the surface street network are provided in Table 11 based on results from TRANSYT runs. Based on the hourly diversion which is expected to occur due to the various metering strategies, an overall increase in surface street traffic was assumed. Using the growth factor available in TRANSYT, surface street traffic volumes were increased 1 to 5 percent. For

TABLE 10

Potential Impacts of Ramp Metering on Surface Streets in the Smart Corridor[9]

Measures of Effectiveness	Unit	Percent Diversion 1	2	3	5
Travel Time	veh-hrs	+40,000	+82,000	+130,000	+225,000
Intersection Delay	veh-hrs	+25,000	+52,000	+ 85,000	+150,000
Number of Stops		$+1.3 \times 10^6$	$+2.4 \times 10^6$	$+3.8 \times 10^6$	$+6.7 \times 10^6$
Vehicle Emissions	kgs				
HC		---	---	---	---
CO		---	---	---	---
NO_x		---	---	---	---

[9] Assumes that ATSAC system is implemented, allowing for signal optimization.

instance, a diversion of 1700 vph would reflect a 2 percent increase in surface street traffic demand. Similarly a diversion of 500 vph would equate to less than a 1 percent increase. The effects of the diversion are considered to include only the surface streets within relatively close freeway proximity during the peak periods when metering would be in effect. Therefore, only impacts on Venice Blvd., Adams Blvd., and Washington Blvd. are included in the estimated surface street impacts. These impacts are based on the assumption that the ATSAC system will likely be installed in the Smart Corridor. As Table 11 shows, even if the traffic demand on the surface street network increases by 5 percent due to more restructive ramp metering, the expected total travel time on the surface street system would increase by 225,000 vehicle hours per year, or approximately 0.1 percent. This is not to say that impacts on certain critical intersections may not be significant, however, it does indicate that more restructive ramp metering in the Smart Corridor could be handled by the surface network.

TABLE 11

Potential Annual Impacts of Ramp Metering Modifications
On Recurring Congestion on the Santa Monica Freeway
(Eastbound and Westbound Directions)

Measure of Effectiveness	Unit	Optimize Ramp Metering: Existing Storage	Optimize Ramp Metering: Desired Speed >50 mph	Optimize Ramp Metering: Desired Speed >40 mph	Optimize Ramp and Connector Metering (Desired Speed > 50 mph): I-405 4-Lanes	Optimize Ramp and Connector Metering (Desired Speed > 50 mph): R-110 NB to WB	Optimize Ramp and Connector Metering (Desired Speed > 50 mph): Both I-405 and R-110 Connectors
Freeway Travel Time	veh-hrs	-900,000	-2.4×10^6	-1.4×10^6	-2.4×10^6	-2.4×10^6	-2.4×10^6
Ramp Delay	veh-hrs	+750,000	+390,000	+630,000	+270,000	+210,000	+ 90,000
Total Travel Time	veh-hrs	-150,000	-2.0×10^6	-720,000	-2.1×10^6	-2.1×10^6	-2.2×10^6
Fuel Consumption	gals	$+1.4 \times 10^6$	$+1.6 \times 10^6$	+1.4 x 106	$+1.3 \times 10^6$	$+1.3 \times 10^6$	$+1.0 \times 10^6$
Vehicle Emissions	kgs						
HC		+ 30,000	- 30,000	+ 30,000	- 30,000	- 30,000	- 30,000
CO		+180,000	-510,000	+180,000	-450,000	-450,000	-450,000
NO_x		+ 30,000	+ 60,000	+ 60,000	+ 60,000	+ 60,000	+ 60,000

RAMP AND CONNECTOR METERING STRATEGIES

OVERVIEW

Presently, all on-ramps on the Santa Monica Freeway between the San Diego Freeway (I-405) and the Harbor Freeway (R-110) are metered. The meters currently operate during both the morning and evening peak periods. The meters are controlled by local Type 170 controllers. Metering rates are pre-set by time of day according to individual metering plans. All of the on-ramps between the San Diego and Harbor Freeways are currently metered. Several of the westbound on ramps east of the Harbor Freeway are currently unmetered. A full description on the ramp meters within the Smart Corridor is provided in the paper on traffic conditions contained in this report. Approximately one-half of the ramp meters are traffic responsive, adjusting their metering rates based on traffic volumes upstream of the ramp. Caltrans plans to make all meters within this freeway section traffic responsive in the near future. Many of the on-ramps have both normal and priority entry. Priority entry, or HOV, lanes are not metered. All ramp meter controllers within this freeway section are interconnected and can be centrally controlled from the Caltrans TOC, however, metering rates are normally not adjusted.

The current metering rates have been set to minimize the impacts of ramp queues on nearby surface streets. During the morning peak hour when metering rates are typically the lowest, average ramp delays range between 1.5 and 2 minutes per vehicle. Meter violations are generally low, however, a large number single occupancy vehicles do violate the HOV lanes. Increased enforcement has done little to reduce the violations, partially due to the absence of appropriate enforcement areas.

Ramp Metering Strategies

One of the primary goals of the Smart Corridor is to improve traffic flow on the Santa Monica Freeway. Analysis of the existing traffic conditions during the morning peak period indicate that improved control of freeway demand would have the greatest effect on reducing recurrent freeway congestion. Currently, speeds on the Santa Monica Freeway range from 15 to 35 mph in both directions during the morning and evening peak periods. Stop-and-go conditions are typical during both peak periods.

Several alternative metering strategies were analyzed to determine what impacts could be expected on both the freeway and the surrounding surface street system. These impacts are briefly discussed below.

- A slight improvement in freeway operation would result from modification of the existing meters in order to optimize entry control. Metering rates would be set so that resulting queues would not exceed the existing ramp storage capacities. It is estimated that the total freeway travel time would be reduced by approximately 150,000 vehicle-hours per year. Average freeway operating speeds during the peak periods would increase by approximately 5 mph, however, stop-and-go conditions would remain at certain critical freeway locations. It is anticipated that minimal modifications to the existing metering plan would have negligible impacts on the surrounding surface street system.

- In order to significantly improve freeway operation in the Smart Corridor, metering rates must be significantly reduced during peak traffic periods. Free-flow conditions, i.e. average speeds exceeding 50 mph, can be achieved with significant modifications to the existing metering plans. Travel time on the freeway would be reduced by at least 2 million vehicle-hours annually. The metering plan required to achieve free-flow conditions would result in queueing in excess of the existing ramp storage capacities. It is estimated that due to the longer ramp queues and added delay, approximately 2 percent of the current ramp demand would divert to nearby parallel routes. Ramp delays would be expected to range from 3 to 4 minutes. Most drivers, especially those making longer trips, would probably accept these added delays knowing that once they entered the freeway they would travel at relatively high speeds. In order to mitigate the adverse queuing, additional ramp storage capacity could be obtained at certain ramps. It is difficult to estimate the impacts of the anticipated diversion on surface streets, however, review of the excess capacity on the major parallel routes suggests that the added demand could be adequately handled. Impacts at specific intersections, especially near the freeway, could cause significant added surface street congestion.

- In order to balance the traffic conditions within the Smart Corridor, the ramp metering strategies chosen must provide equitable results on both the freeway and the surface streets. The optimal metering strategy would result in an increased average freeway speed above 40 mph, while only causing a relatively small amount of drivers to divert to alternate routes on the surface streets. Under such a metering strategy, it is estimated that less than 1 percent of the ramp demand would divert. The impacts on the surface streets would be minimal, however, an annual savings of 720,000 vehicle-hours of travel time would be realized on the freeways. Average ramp delays would range from 2 to 3 minutes.

Connector Metering

Another means of providing better entry control in the project area is through freeway connector metering. Connector metering also provides for better distribution of the impacts associated with more restrictive metering strategies. An equitable metering strategy in the Smart Corridor would require that all vehicles entering the corridor share in the penalties and benefits associated with metering. Previous experience in the San Diego area indicates that significant benefits can be achieved with connector metering under the appropriate conditions. Several opportunities currently exist for connector metering in the Smart Corridor. The connectors which were considered include the NB to EB and SB to EB at the San Diego Freeway and the NB to WB and SB to WB at the Harbor Freeway.

Analysis of the San Diego Freeway connectors indicated that with the current number of lanes and the available storage, metering of the SB to EB connector was possible, however, unreasonably long queues would result on the NB to EB connector. Current flow rates on the NB to EB connector range from 1200 to 1500 vph during the peak period, while the SB to EB connector typically has 1800 to 2200 vph during the peak period. Connector metering is feasible, however, with the addition of a second lane on the NB to EB connector. This added lane would serve to double the possible metering rate and provide additional storage for queueing. A preliminary review of the existing connector geometrics indicates that sufficient width is available and a second lane could be added by restriping. Delays on the metered connectors would be expected to range from 2 to 3 minutes, slightly higher then existing delays during peak periods. Analysis of metering four lanes on the San Diego Freeway connectors suggests that a reduction of 100,000 vehicle hours in overall travel time could be expected in addition to the benefits estimated for improved ramp metering.

Metering of the Harbor Freeway connectors was determined to be more difficult than the San Diego Freeway Connectors. The NB to WB connector lends itself well to metering since it has relatively low peak period flowrates (900 to 1000 vph) and two lanes which can be metered. Also, there is sufficient storage for approximately 200 vehicles. Due to the relatively low flowrates on the NB to WB connector, metering rates would have to be low in order to achieve any significant benefits on the freeway. If metered, however, it is expected that in addition to the benefits realized through improved ramp metering, an additional 100,000 vehicle-hours of travel time could be saved annually. Metering of the SB to NB connector would result in extremely long queues in excess of 2000 vehicles and would require the addition of a third or fourth lane in order to achieve the necessary metering rates and provide sufficient storage capacity. Currently, volumes on the SB to WB connector range from 2500 to 3200 vehicles during the peak hour. Addition of a lane would require major redesign and construction and could be difficult to tie into the existing CD road network.

Recommendations

It is recommended that the current metering strategies in the Smart Corridor be modified in order to make freeway entry more restrictive so as to improve freeway operations. Additionally, entry control should be expanded over the entire corridor. Current metering rates should be optimized with the objectives of increasing the average freeway speed to at least 40-45 mph and reducing the amount of stop-and-go conditions. Optimization of metering rates to provide free-flow conditions on the freeway is not considered appropriate at this time due to the negative impacts which might result on the surrounding surface streets. Once the entire Smart Corridor system is in place and the resulting travel patterns have been set, further modification of the metering rates could be implemented in order to further improve freeway conditions. In order to help mitigate any queueing problems which might occur with more restrictive metering rates, additional ramp storage capacity should be acquired. A preliminary review of existing ramp facilities indicated several opportunities to obtain added storage. Table 1 lists the ramps at which restriping or relocation of the meter might provide additional capacity.

The current ramp metering system should also be expanded to include both eastbound San Diego Freeway connectors and any ramps which are currently not metered. The NB to EB connectors should be restriped in order to add a fourth metering lane and provide additional ramp storage. Advanced "meter on" signs should be installed in order to alert freeway drivers of upcoming queues. It is anticipated that metering of the San Diego connectors will serve as a pilot test for the Los Angeles area and demonstrate its potential impacts on freeway operation. Although metering could also be implemented on the NB to WB Harbor Freeway connector and might provide some benefits to freeway conditions, it should not be installed at this time due to the relatively low volumes which are present. Further study of the feasibility of metering the Harbor Freeway connectors should be undertaken based on the results of the San Diego freeway pilot test. Consideration should be given to metering those ramps in the Smart Corridor which are currently not controlled. These would include the westbound ramps at Grand, Maple, Central, Alameda, and Santa Fe.

TABLE 1

Possible Added Ramp Storage[1]

Intersection	Eastbound On-Ramps Existing Storage	Eastbound On-Ramps Added Storage	Eastbound On-Ramps Ramp Improvement	Westbound On-Ramps Existing Storage	Westbound On-Ramps Added Storage	Westbound On-Ramps Ramp Improvement
Centinella	43	—		13	23	RT
Bundy	23	—		—	—	
I-405 SB	167	84	RT	40	40	RT
I-405 NB	50	50	RT	147	—	
Overland	33	20	RT/RM	23	20	RT/RM
Manning	30	—		—	—	
Robertson	—	—		27	33	RT/RM
National	23	30	RT/RM	—	—	
La Cienega	23	20	RT/RM/WST	34	13	RT/RM
Venice	12	33	RT/RM	—	—	
Fairfax	—	—		50	—	
Washington	33	—		—	—	
La Brea SB	12	5	RT/RM	33	—	
La Brea NB	33	10	RT/RM	12	12	RT
Crenshaw	40	—		21	—	
Arlington	30	10	RT/RM	20	13	RT/RM
Western	13	13	RT/RM	18	13	RT/RM
Normandie	17	13	RT/RM	21	12	RT/RM
Vermont	30	—		37	—	
Hoover	12	12	RT	33	—	
110 FWY SB	67	—		80	—	
110 FWY NB	40	—		200	—	
Flower	11	—		—	—	
Grand	—	—		27	—	
Los Angeles	50	—		—	—	
Maple	—	—		30	10	RT
San Pedro	43	—		—	—	
Central	47	—		18	—	
Alameda	50	—		30	—	
Olympic	23	—		—	—	
Sante Fe	33	—		23	—	

RT = Restripe for additional lane
RM = Relocate ramp meter
WST = Widen Surface Street to provide right-turn lane.

[1] Only non-priority lanes were considered for added ramp storage. Ramp storage capacity based on a special requirement of 30 feet per vehicle.

Estimated Costs

Provided below are preliminary cost estimates for modification of the existing ramp metering strategy in the Smart Corridor.

Item	Cost/Unit	Unit	Total Cost
Added Ramp Storage	$10,000	22	$220,000
Connector Meters (Both I-405 Connectors)	$100,000	2	$200,000
Connector Improvements (Restripe NB to WB to add 1 storage lane)			$20,000
Install Meters at additional ramps	$50,000	5	$250,000

SMART CORRIDOR DEMONSTRATION PROJECT

ISSUE PAPER ON EXISTING TRAFFIC CONDITIONS

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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; number of travel lanes for the Santa Monica Freeway; and number of lanes and estimated storage capacities for on-ramps to 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.

- Operational Analysis (Levels of Service, Capacities, Speeds) - Peak hour levels of service for surface street intersections, ramp intersections and freeway mainline segments. Evaluation of excess capacity on surface streets. Average travel speeds along the major east-west 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 within the construction zone.

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 typically provides four to five travel lanes in each direction, depending upon location. Auxiliary lanes are provided in the following areas:

- vicinity of the La Cienega and Venice Boulevard interchanges (eastbound)
- vicinity of the La Brea Avenue interchange (both directions)
- from the Arlington Avenue interchange east to the Harbor Freeway (both directions)
- between the Central Avenue and San Pedro Street ramps (westbound)
- vicinity of the East LA interchange (both directions)

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.

Exhibit 8 provides a description of the existing on-ramps to the Santa Monica Freeway in the study area. The exhibit indicates the number of both carpool and non-preferential lanes on each on-ramp, whether or not the non-preferential lanes are metered, and the approximate length and storage capacity of the on-ramp (prior to the ramp meter, if one exists).

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 9a and 9b illustrate the available 24-hour one-way approach volumes on the major surface streets in the corridor. Exhibits 10a and 10b illustrate the AM peak hour approach volumes for the surface streets, while Exhibits 11a and 11b 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 (at Alameda Street) 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. Surface street volumes during the AM peak hour are typically (but not always) 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 12 illustrates average annual daily traffic (AADT) volumes on the freeway mainline in 1987, as obtained from the Caltrans document entitled <u>1987 Traffic Volumes on California State Highways</u>. Exhibit 13 indicates daily volumes on most of the on- and off-ramps. Exhibits 14 and 15 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 eastbound on-ramp from Washington Boulevard (18,880 vehicles per day), the westbound off-ramp to Venice Boulevard (17,270 vpd), the eastbound on-ramp from Crenshaw Boulevard (16,370 vpd), and the westbound off-ramp to Crenshaw Boulevard (15,100 vpd).

<u>Screenlines</u>

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 16 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 17 presents the same data for the westbound direction. Exhibits 18, 19, 20 and 21 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 screenline does 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.

OPERATIONAL ANALYSIS

Surface Street Intersection Levels of Service

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 selected for analysis, 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. However, only 61 of the 70 intersections have actually been included in the analysis, due to either a lack of available traffic count data or the current light rail construction activity along a portion of Washington Boulevard (which skews the existing data). The 61 surface street/surface street intersections included in the analysis are shown on Exhibit 22.

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 23.

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 24. 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.

AM and PM peak hour levels of service were calculated using the intersection turning movement count data obtained from LADOT. In addition, an off-peak analysis was conducted using turning movements as estimated for the mid-day period through the application of factors derived from the available LADOT 24-hour approach counts and PM peak hour turning percentages.

Exhibits 25 and 26 list the existing V/C ratios and levels of service at the analyzed surface street and ramp intersections, respectively. Exhibits 27 and 28 display the AM peak hour operating conditions by LOS category for the surface street and ramp intersections, respectively. Exhibits 29 and 30 illustrate similar results for the off-peak (mid-day) peak hour, while Exhibits 31 and 32 illustrate the LOS results for the PM peak hour.

Three of the 61 analyzed surface street intersections currently operate at an overloaded LOS F during the morning peak hour, 13 at a poor LOS E, and 45 at a good LOS of D or better. Overall conditions are worse during the afternoon peak hour, with 11 of the 61 surface street intersections operating at LOS F, 16 at

LOS E, and 34 at LOS D or better. The off-peak analysis indicates that conditions during the mid-day period are generally better than during either of the peak periods, with 3 of the analyzed surface street intersections operating at LOS F, 4 at LOS E, and 54 at LOS D or better.

Santa Monica Freeway Levels of Service

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 33 summarizes the process used to calculate the V/C ratios, while the results are plotted on Exhibits 34 and 35. 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.

Surface Street 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

- o Western Avenue
- o Vermont Avenue
- o Hoover Street
- o Figueroa Street
- o Main Street
- o Central Avenue
- o Alameda Street
- o 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 each direction along the east-west street. This method assumes that the traffic signal at the intersection can be timed such that 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.

Exhibits 36a and 36b graphically display the estimated existing excess capacity along each of the five major parallel streets during the AM peak hour for the eastbound and westbound directions, respectively. Exhibits 37a and 37b display similar information for the off-peak (mid-day) peak hour, while Exhibits 38a and 38b illustrate the estimated excess capacity during the PM peak hour.

<u>Surface Street Speeds</u>

Speed and delay data was collected by the LADOT along the five major east-west surface streets in the corridor during both the morning and afternoon peak periods in 1987 and 1988. Exhibits 39a and 39b respectively display the eastbound and westbound average speeds summarized by segment for the AM peak period, while Exhibits 40a and 40b display similar data for the PM peak period.

In general, the average speeds are in the 20 to 30 mile per hour range during both peak hours in both directions throughout much of the corridor. Major exceptions to this include: the downtown Los Angeles area in both directions during both peaks (with average speeds in the 10 to 20 mph range, but as low as 6 mph on certain street segments in the PM peak hour); Pico Boulevard in both directions during the PM peak hour (with average speeds on many segments in the 15 to 20 mph range); and Venice Boulevard in the eastbound direction during both peaks (also with average speeds on many segments in the 15 to 20 mph range).

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 41, 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 42 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 43 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 44, 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. Exhibit 45 summarizes the total reported number of intersection accidents and the accident rate per million vehicles for the three-year period at the major surface street and ramp intersections evaluated in this document. Exhibit 46 presents the same information with the intersections ranked in order of the total number of accidents, while Exhibit 47 ranks the intersections by the accident rate.

As can be seen in Exhibits 46 and 47, the intersection of Pico Boulevard/Vermont Avenue tops both rankings, with both the highest number of reported accidents in the three-year period (59, or an average of about 20 per year) and the highest accident rate (1.01 accidents per million vehicles). The Pico Boulevard/Western Avenue intersection ranks second on both lists, with 57 reported accidents and a rate of 1.00 accidents per million vehicles. The Olympic Boulevard/Vermont Avenue intersection shares the second-place ranking for number of accidents (with 57 reported accidents), although the accident rate at this location was only 0.67. The Adams Boulevard/Figueroa Street intersection shares the second-place ranking for accident rate, although the number of accidents reported for this location ranks it as seventh in the latter category.

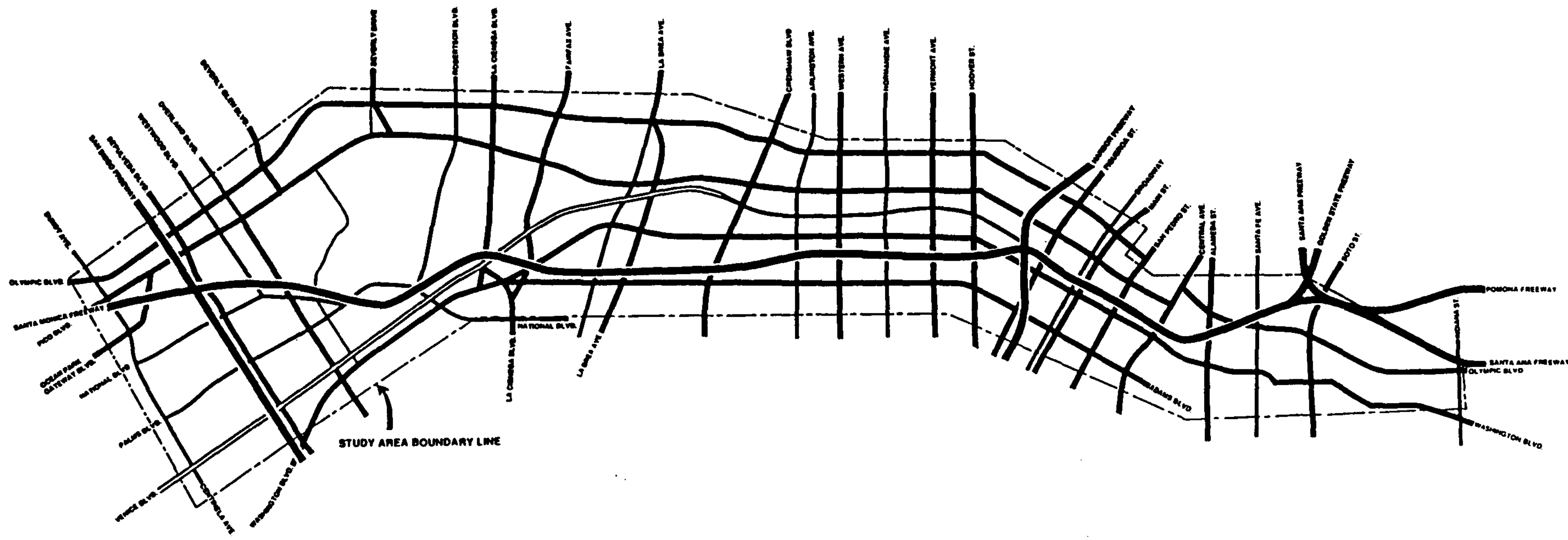
Santa Monica Freeway

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 48 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 49 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 DL ONSTRATION PROJECT



SMART CORRIDOR STUDY AREA

LEGEND:

FREEWAY
MAJOR HIGHWAY
MINOR HIGHWAY

N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 1

SMART CORRIDOR DEMONSTRATION PROJECT

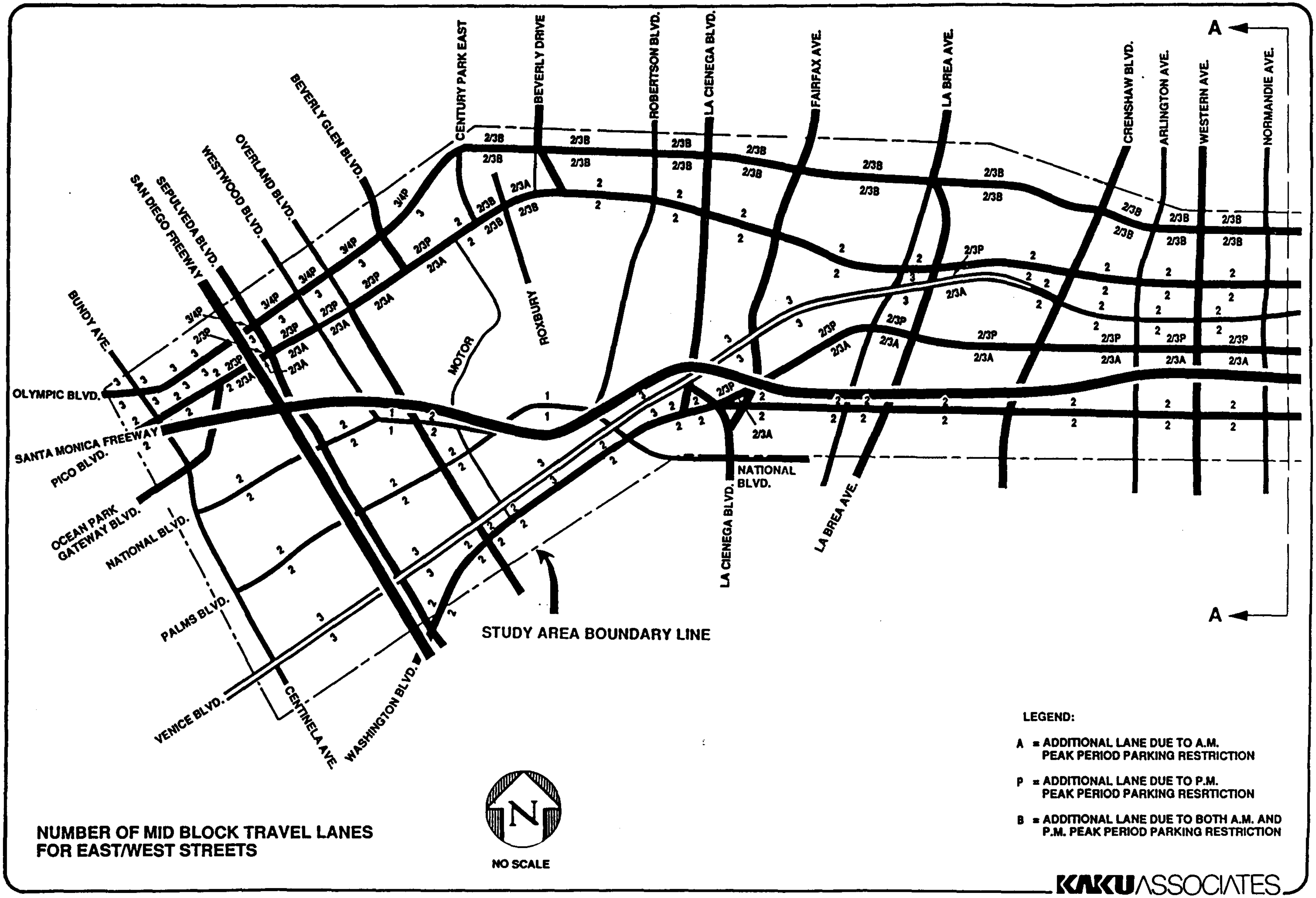


EXHIBIT 2A

SMART CORRIDOR D NSTRATION PROJECT

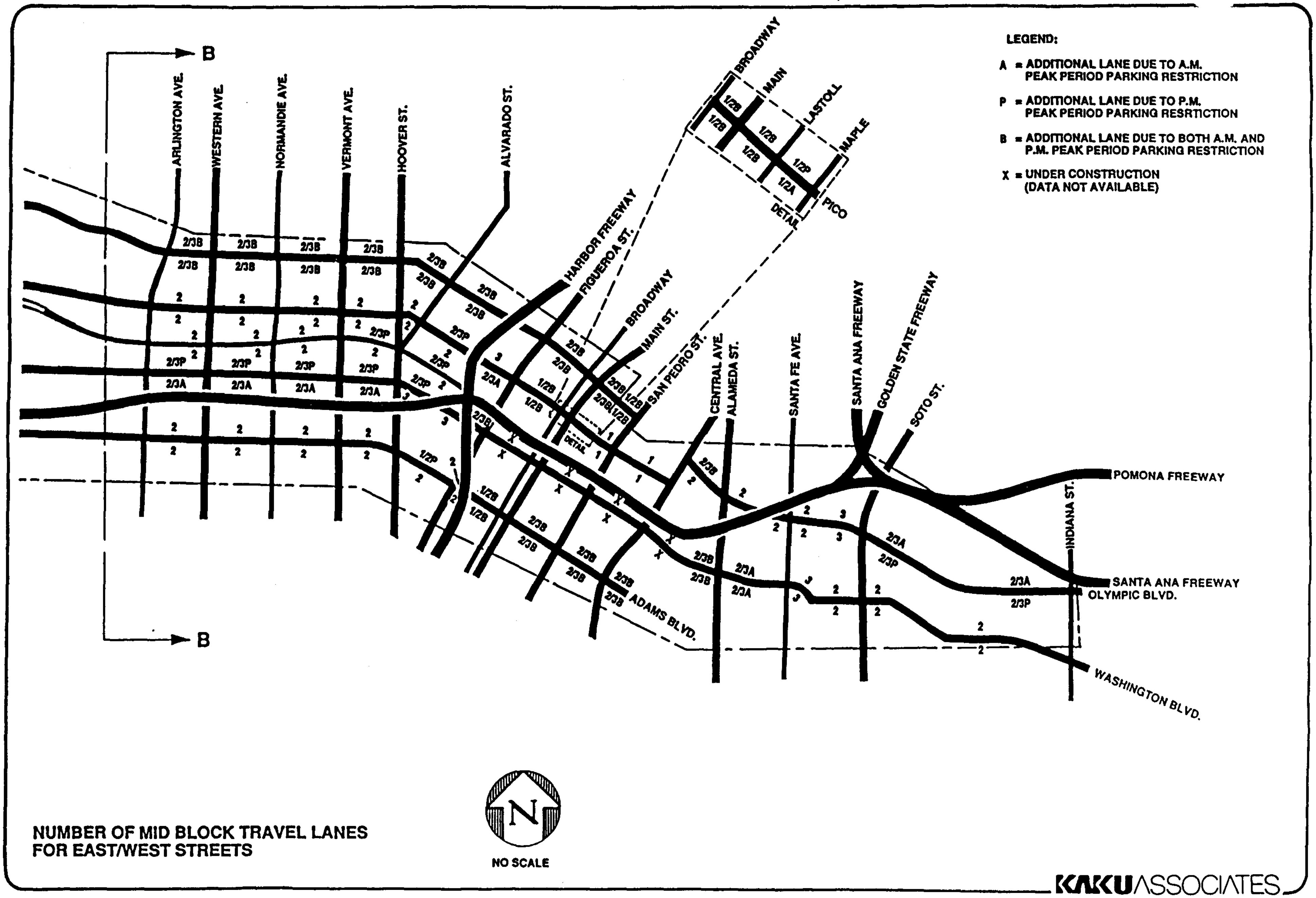


EXHIBIT 2B

SMART CORRIDOR D[illegible]ISTRATION PROJECT

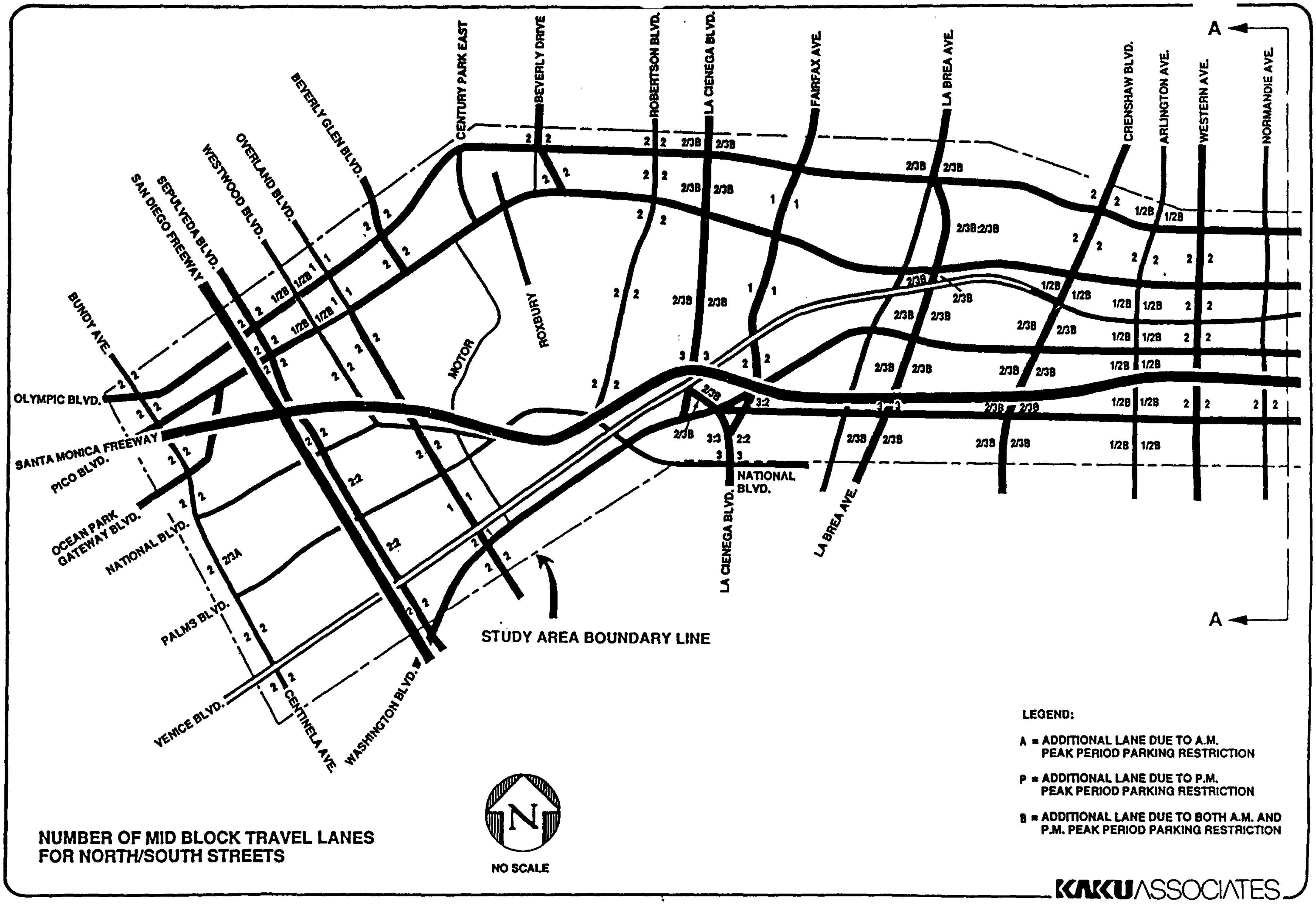
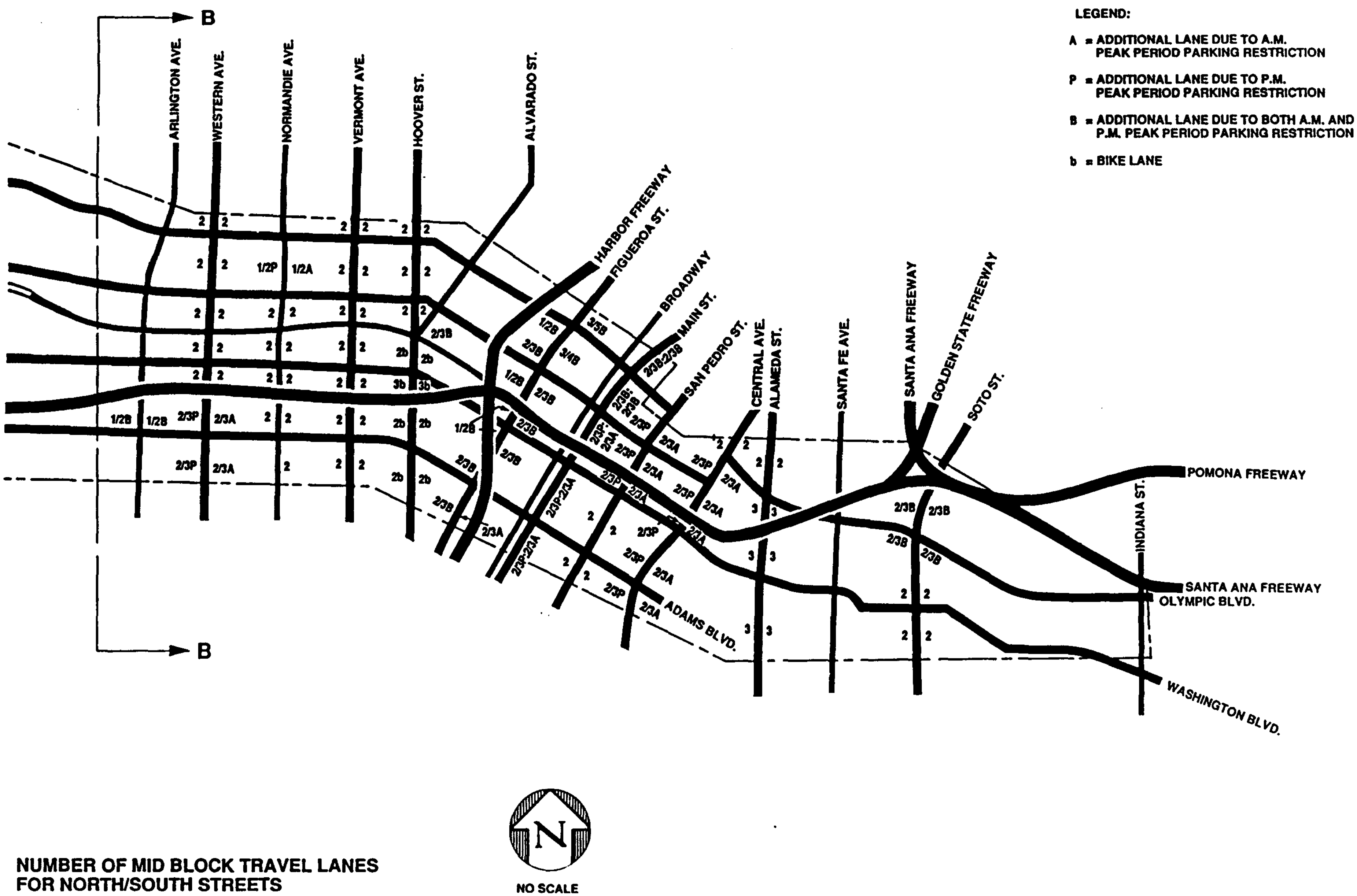


EXHIBIT 3A

SMART CORRIDOR DEMONSTRATION PROJECT

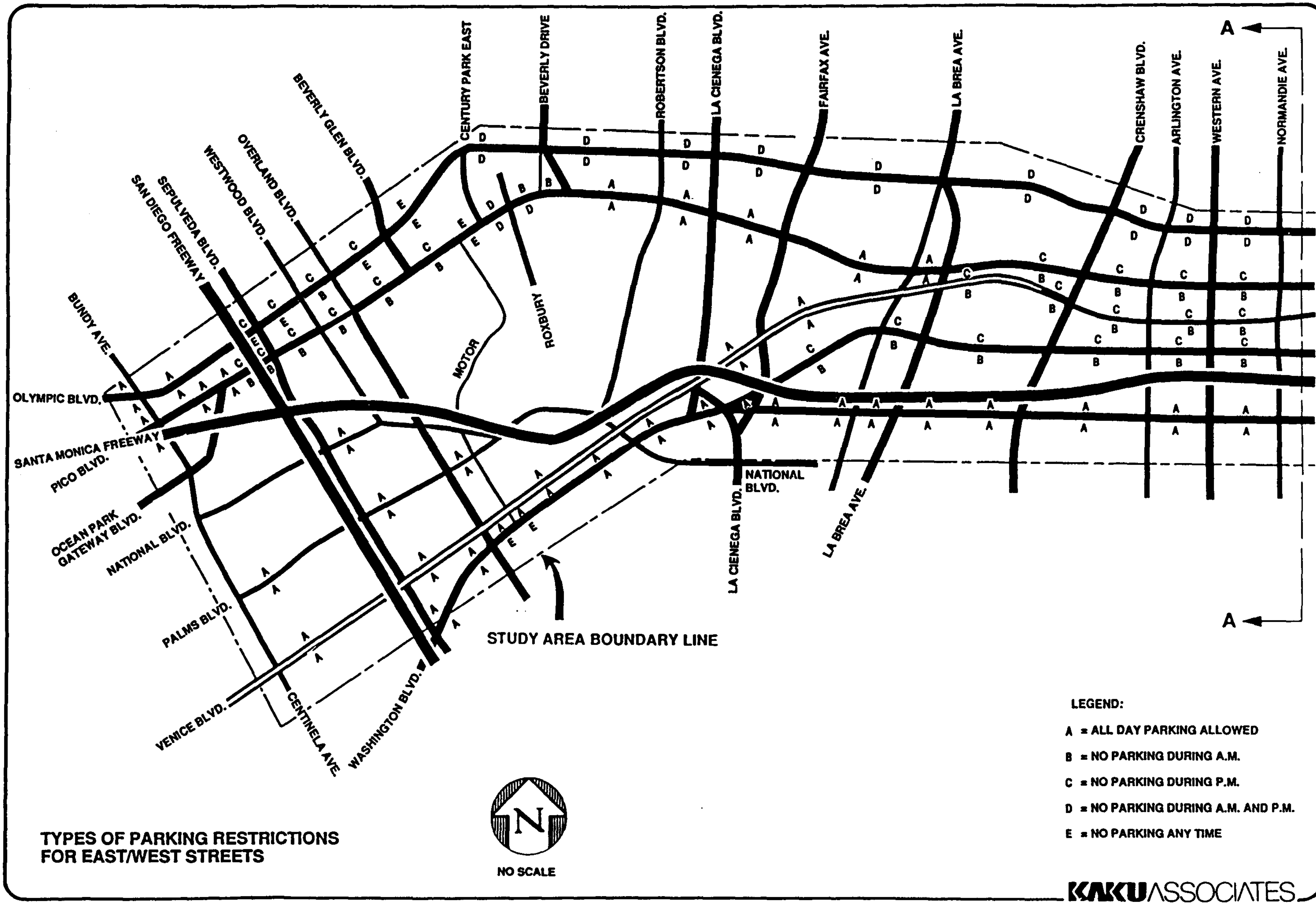


NUMBER OF MID BLOCK TRAVEL LANES FOR NORTH/SOUTH STREETS

KAKU ASSOCIATES

EXHIBIT 3B

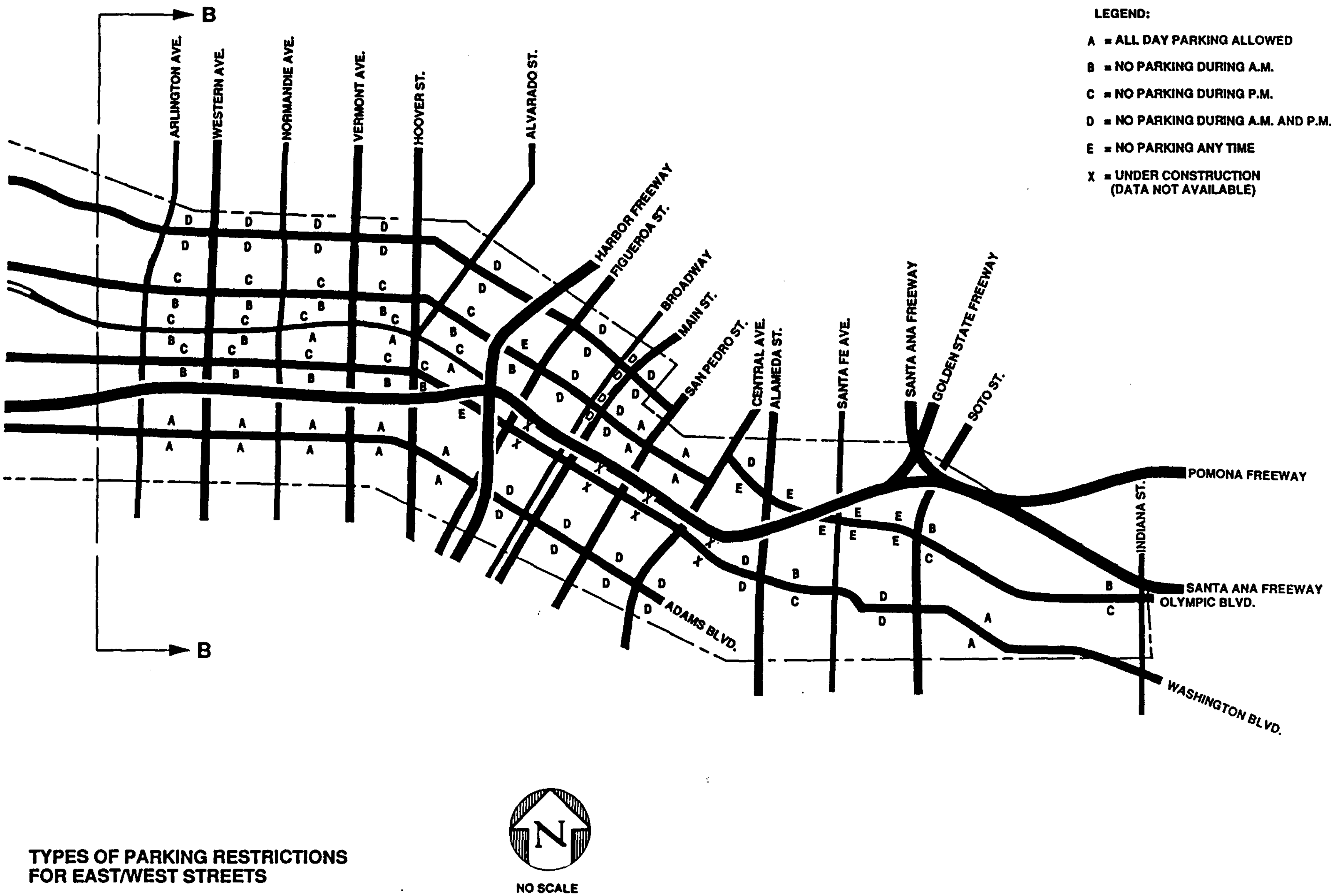
SMART CORRIDOR DEMONSTRATION PROJECT



TYPES OF PARKING RESTRICTIONS FOR EAST/WEST STREETS

EXHIBIT 4A

SMART CORRIDOR DEMONSTRATION PROJECT



TYPES OF PARKING RESTRICTIONS FOR EAST/WEST STREETS

KAKU ASSOCIATES

EXHIBIT 4B

SMART CORRIDOR DEMONSTRATION PROJECT

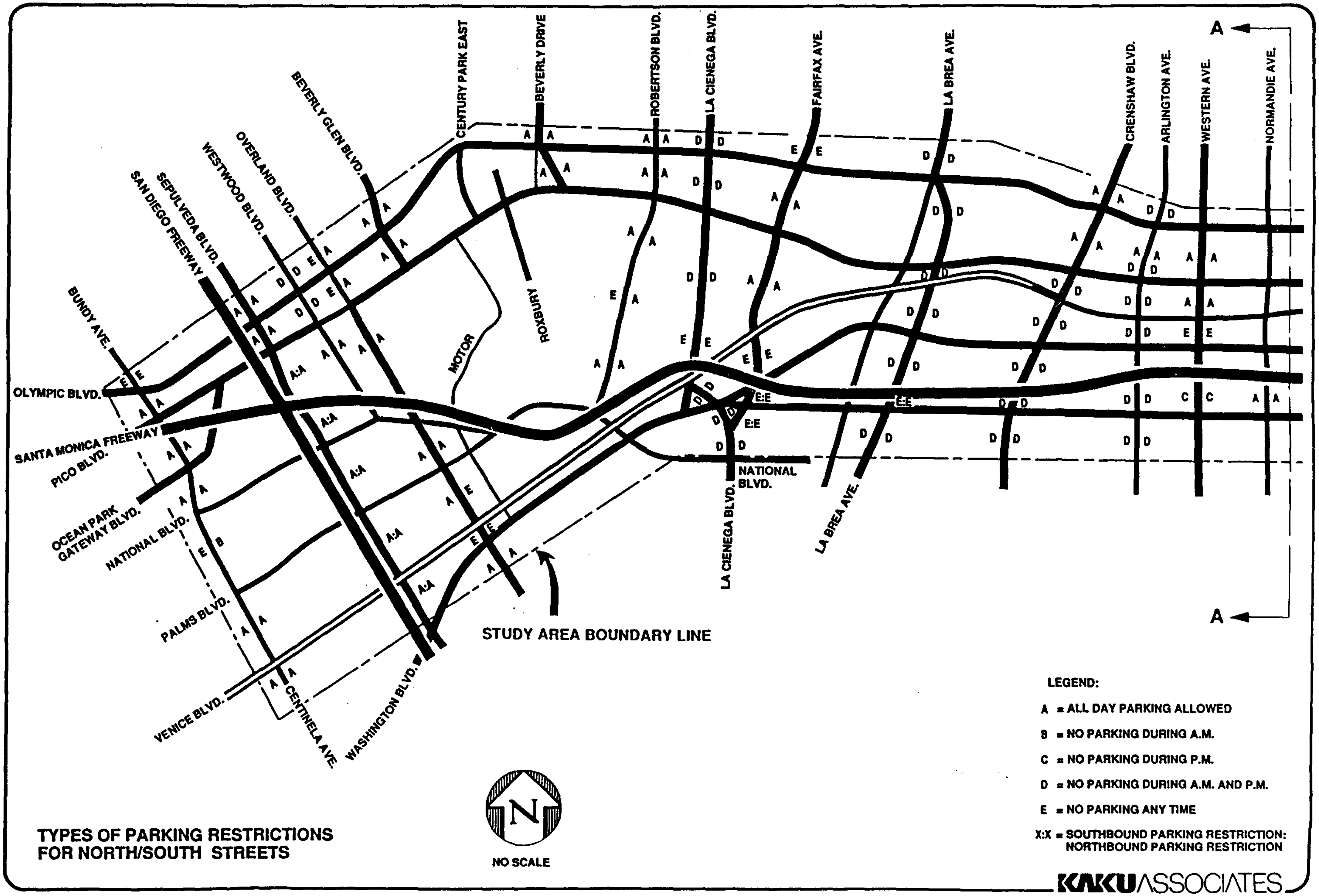
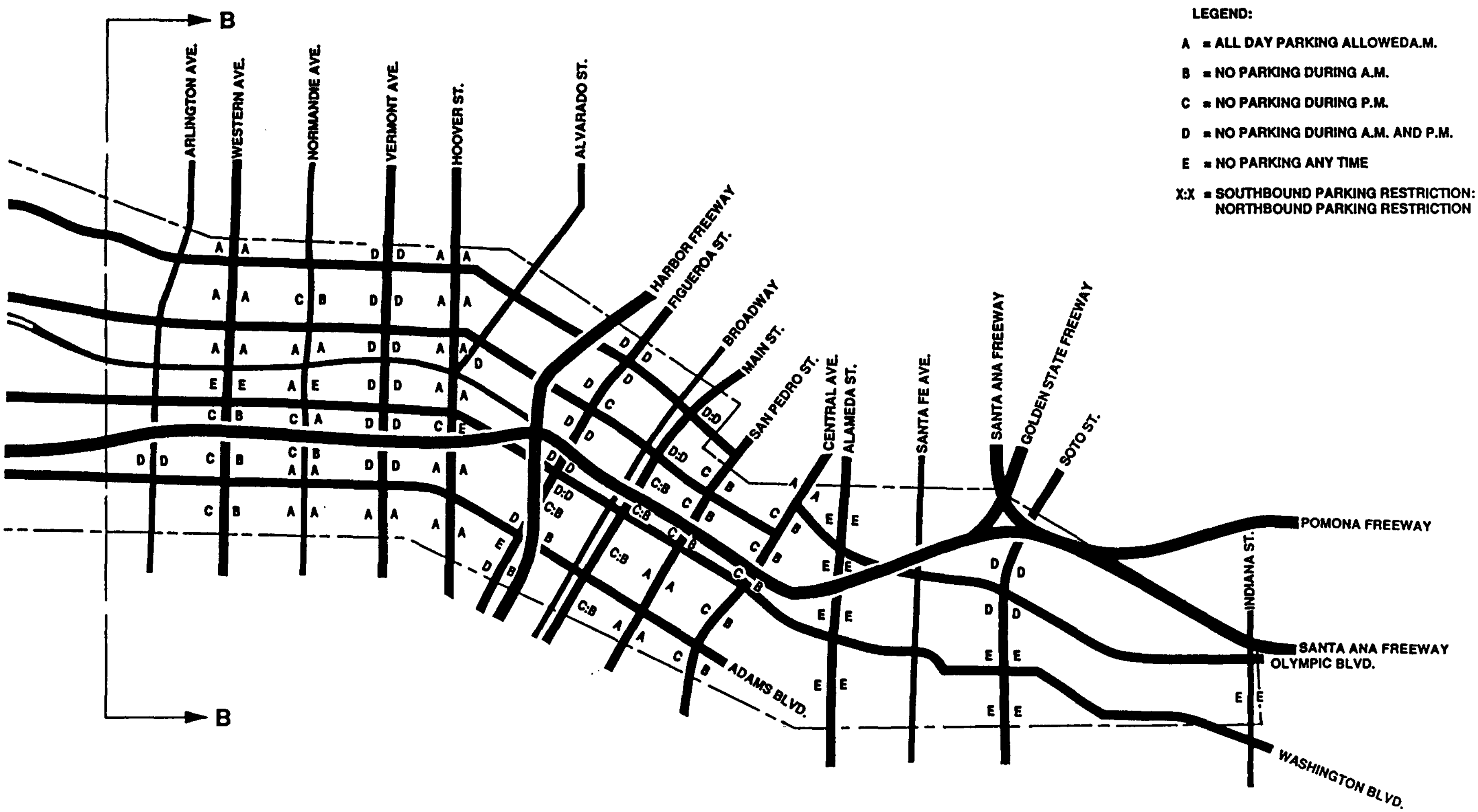


EXHIBIT 5A

SMART CORRIDOR DEMONSTRATION PROJECT



N

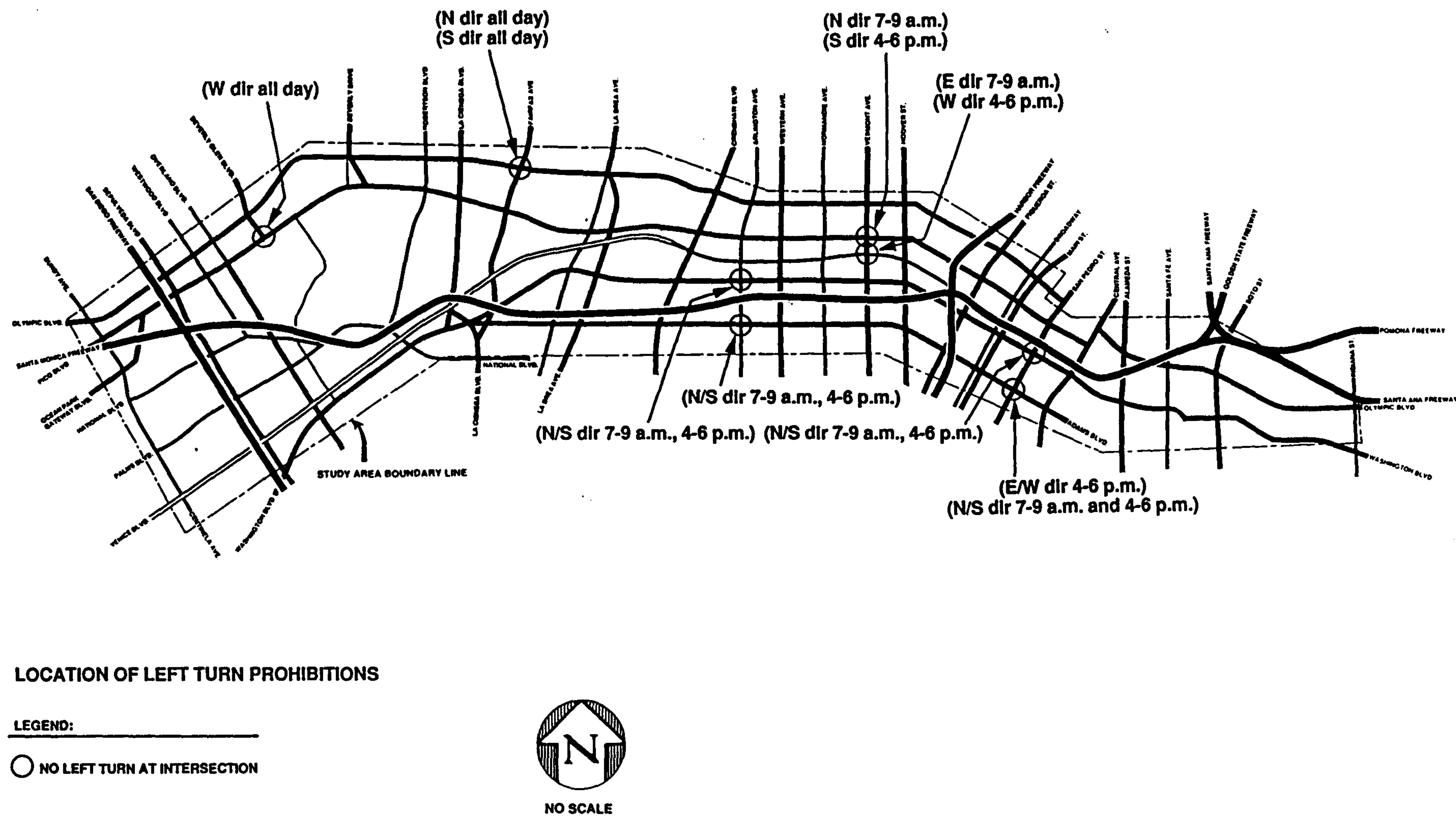
NO SCALE

TYPES OF PARKING RESTRICTIONS FOR NORTH/SOUTH STREETS

KAKU ASSOCIATES

EXHIBIT 5B

SMART CORRIDOR DEMONSTRATION PROJECT



LOCATION OF LEFT TURN PROHIBITIONS

LEGEND:

○ NO LEFT TURN AT INTERSECTION

KAKU ASSOCIATES

EXHIBIT 6

SMART CORRIDOR DE...NSTRATION PROJECT

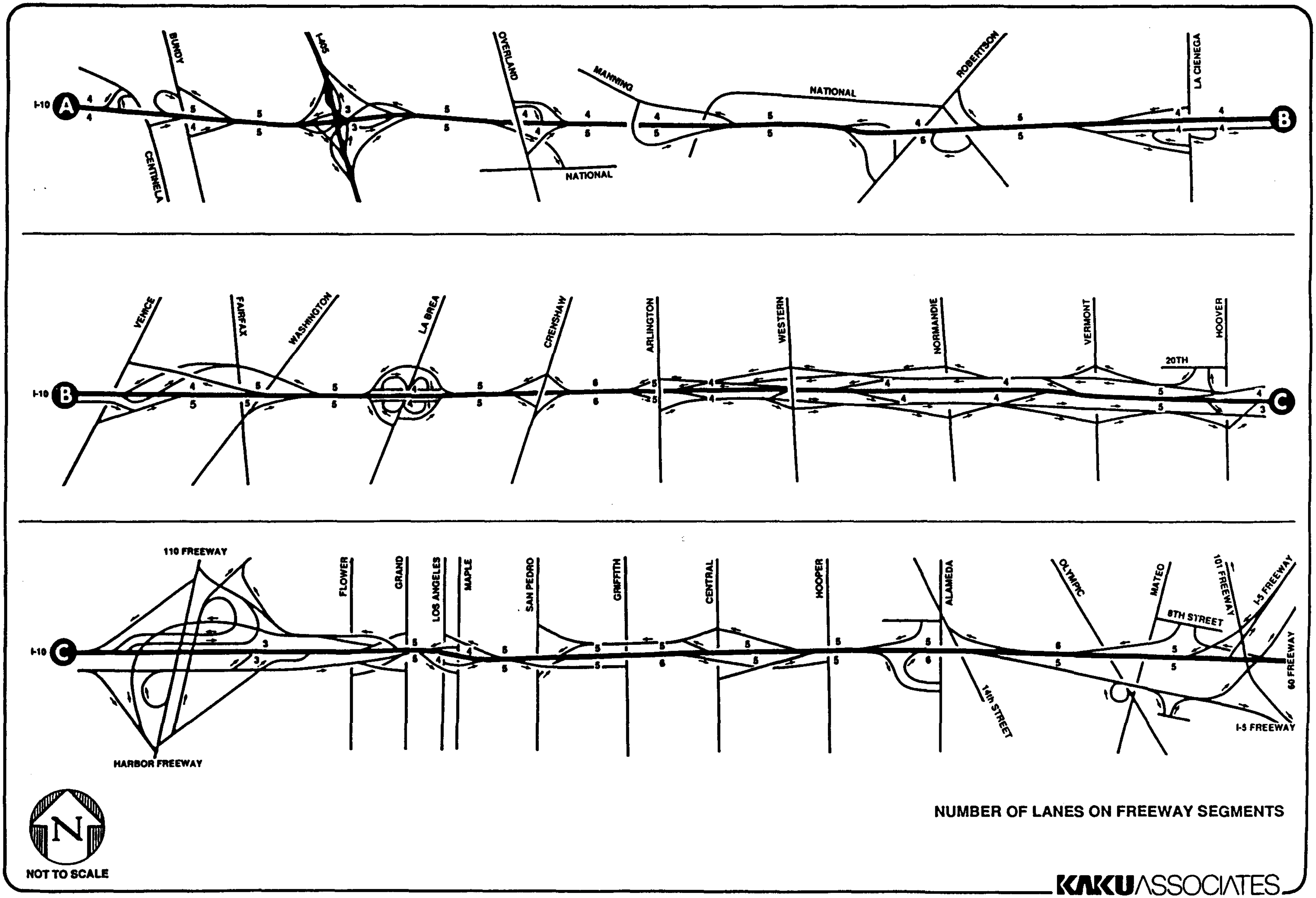


EXHIBIT 7

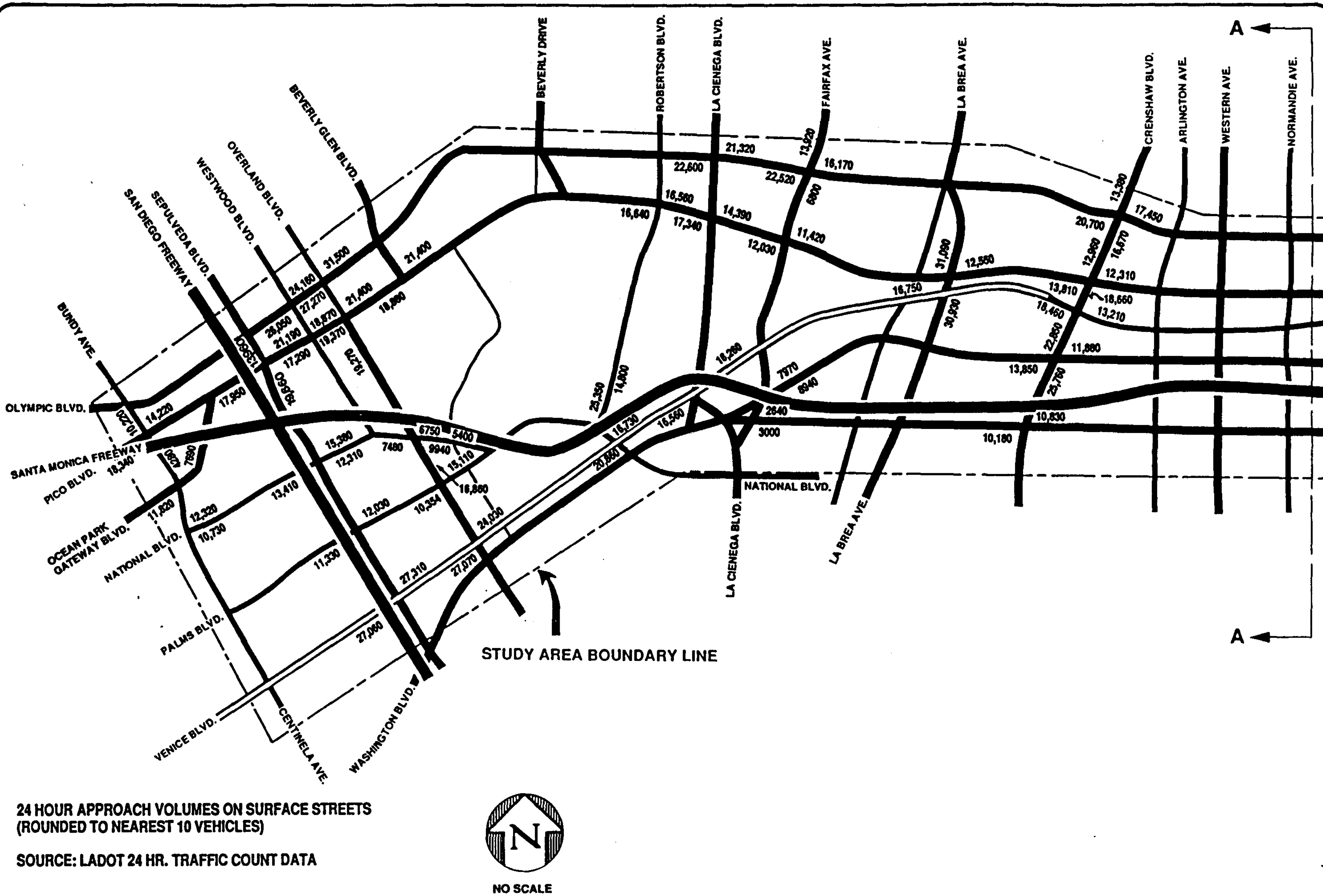
SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 8
PHYSICAL DESCRIPTION OF SANTA MONICA FREEWAY ON-RAMPS

	Eastbound On-Ramps				Westbound On-Ramps			
	# of Lanes		Approx.	Storage Capacity	# of Lanes		Approx.	Storage Capacity
Interchange	Car-pool	Non-Pref.	Length (feet)	(# of veh.)	Car-pool	Non-Pref.	Length (feet)	(# of veh.)
CENTINELA		1 *	650	22		2	200	13
BUNDY	1	1 *	700	47		--	--	--
I-405 SB		2	2,500	167		1	1,200	40
I-405 NB		1	1,500	50		2	2,200	147
OVERLAND		2 *	500	33		2 *	350	23
MANNING	1	1 *	900	60		--	--	--
ROBERTSON		--	--	--		2 *	400	27
NATIONAL	1	1 *	350	23		--	--	--
LA CIENEGA		2 *	350	23		2 +	400	27
						1 *	200	7
VENICE	1	1 *	350	23		--	--	--
FAIRFAX		--	--	--	1	1 *	750	50
WASHINGTON	1	1 *	500	33		--	--	--
LA BREA SB		1 *	350	12		2 *	500	33
LA BREA NB		2 *	500	33		1 *	350	12
CRENSHAW		2 *	600	40	1	1 *	650	43
ARLINGTON		2 *	450	30		2 *	300	20
WESTERN	1	1 *	400	27	1	1 *	550	37
NORMANDIE		2 +	150	10		2 +	200	13
		1 *	200	7		1 *	250	8
VERMONT	1	1 *	450	30		2 *	550	37
HOOVER		1 *	350	12		2 *	500	33
110 FWY SB		2	1,000	67		2	1,200	80
110 FWY NB		1	1,200	40		2	3,000	200
FLOWER	1	1 *	350	23		--	--	--
GRAND		--	--	--		1	800	27
LOS ANGELES		2 *	750	50		--	--	--
MAPLE		--	--	--		2 +	300	20
						1	300	10
SAN PEDRO		2 *	650	43		--	--	--
CENTRAL		2 *	700	47		2 +	150	10
						1	250	8
ALAMEDA		2 +	350	23		2 +	250	17
		1 +	500	17		1	400	13
		2 *	150	10				
OLYMPIC		1	700	23		--	--	--
SANTA FE		2 +	150	10		2 +	150	10
		1	700	23		1	400	13

o "Non-Pref." = non-preferential lanes.
o Ramp length estimated from aerial photographs.
o Storage capacity estimated assuming 30 feet per vehicle.
o Table does not include auxiliary lanes.
* Indicates non-preferential lane or lanes are metered.
+ Indicates description of ramp continues on following line.

SMART CORRIDOR DEMONSTRATION PROJECT



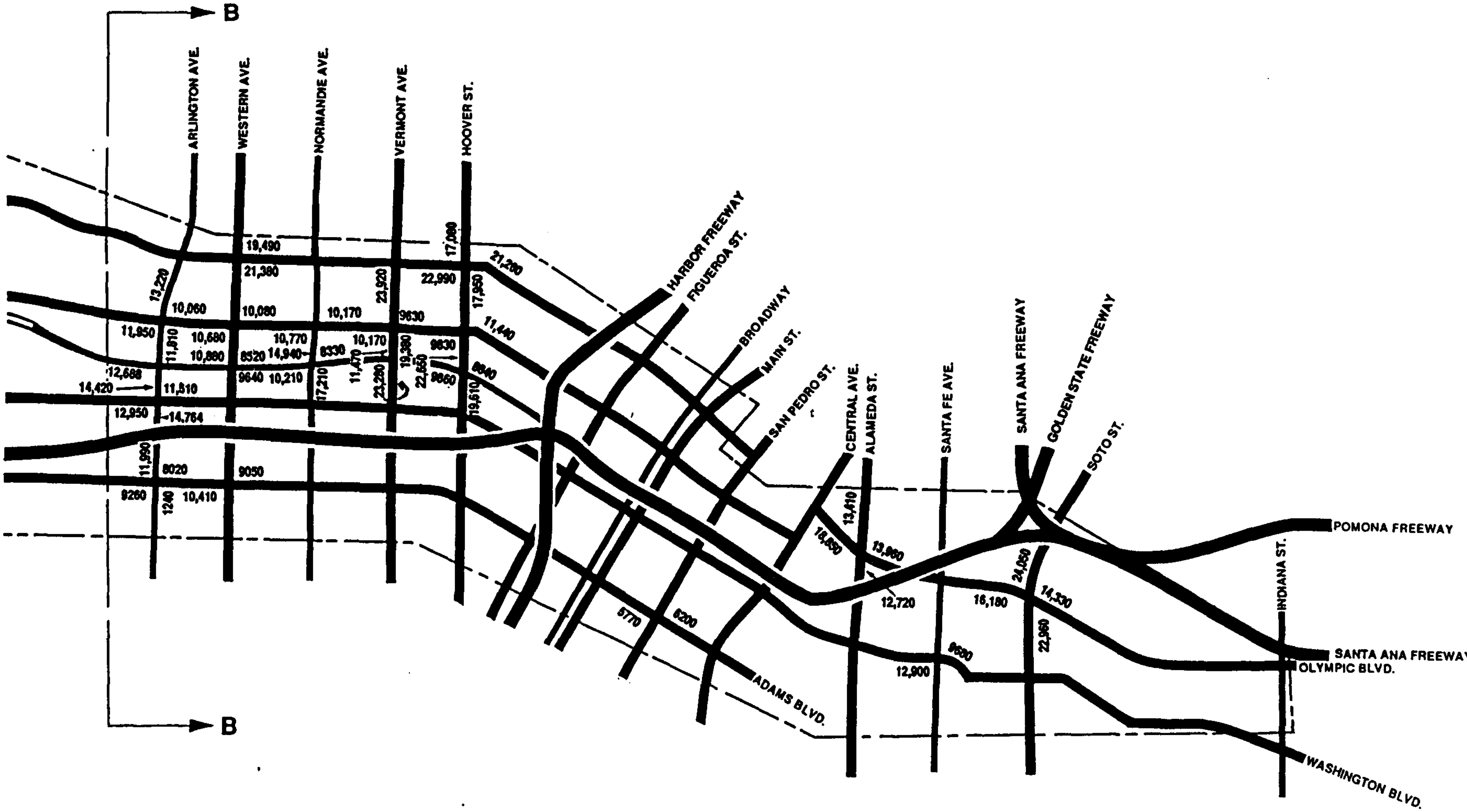
24 HOUR APPROACH VOLUMES ON SURFACE STREETS
(ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

KAKU ASSOCIATES

EXHIBIT 9A

SMART CORRIDOR DEMONSTRATION PROJECT



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

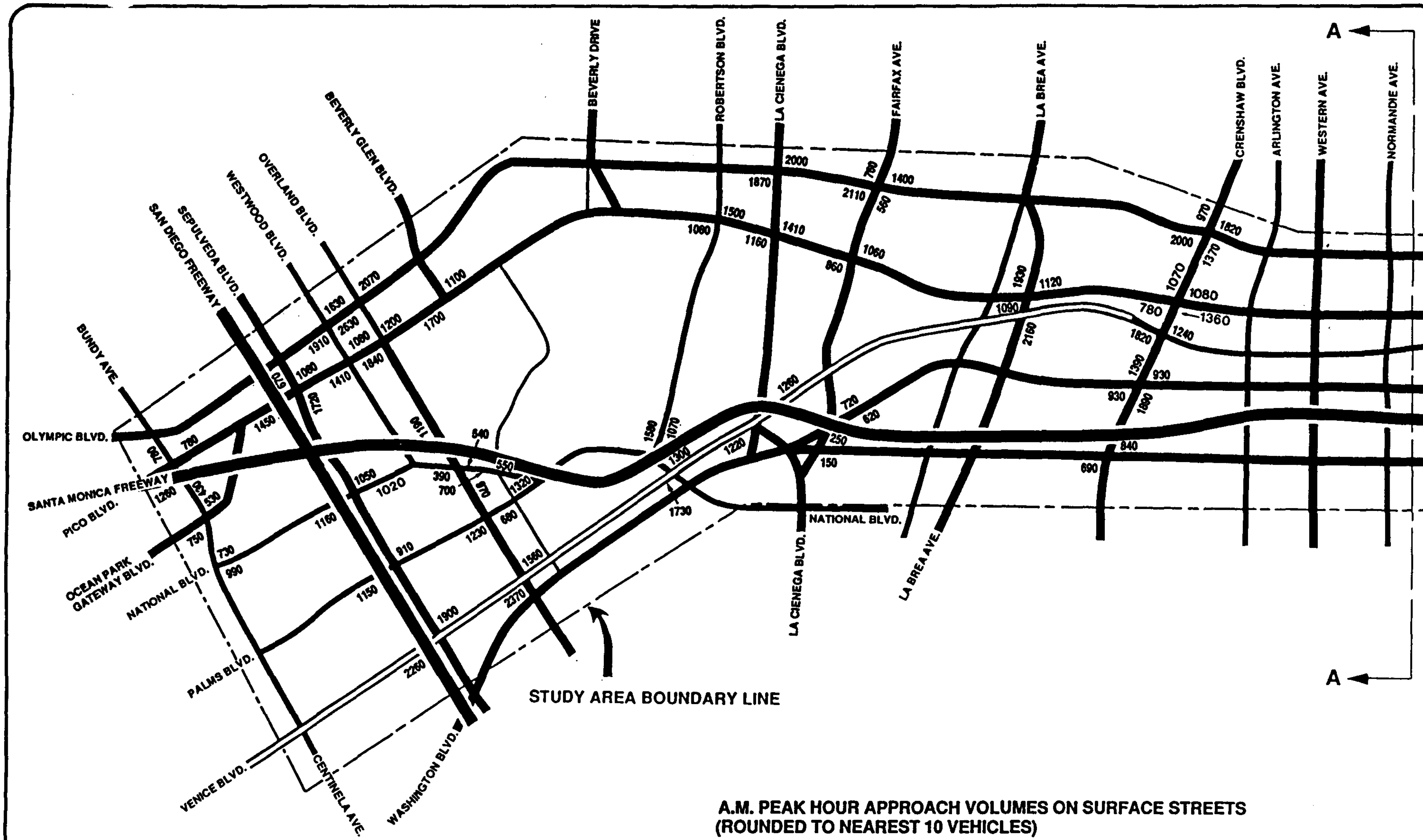
SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA.

NO SCALE

KAKU ASSOCIATES

EXHIBIT 9B

SMART CORRIDOR DE STRATION PROJECT



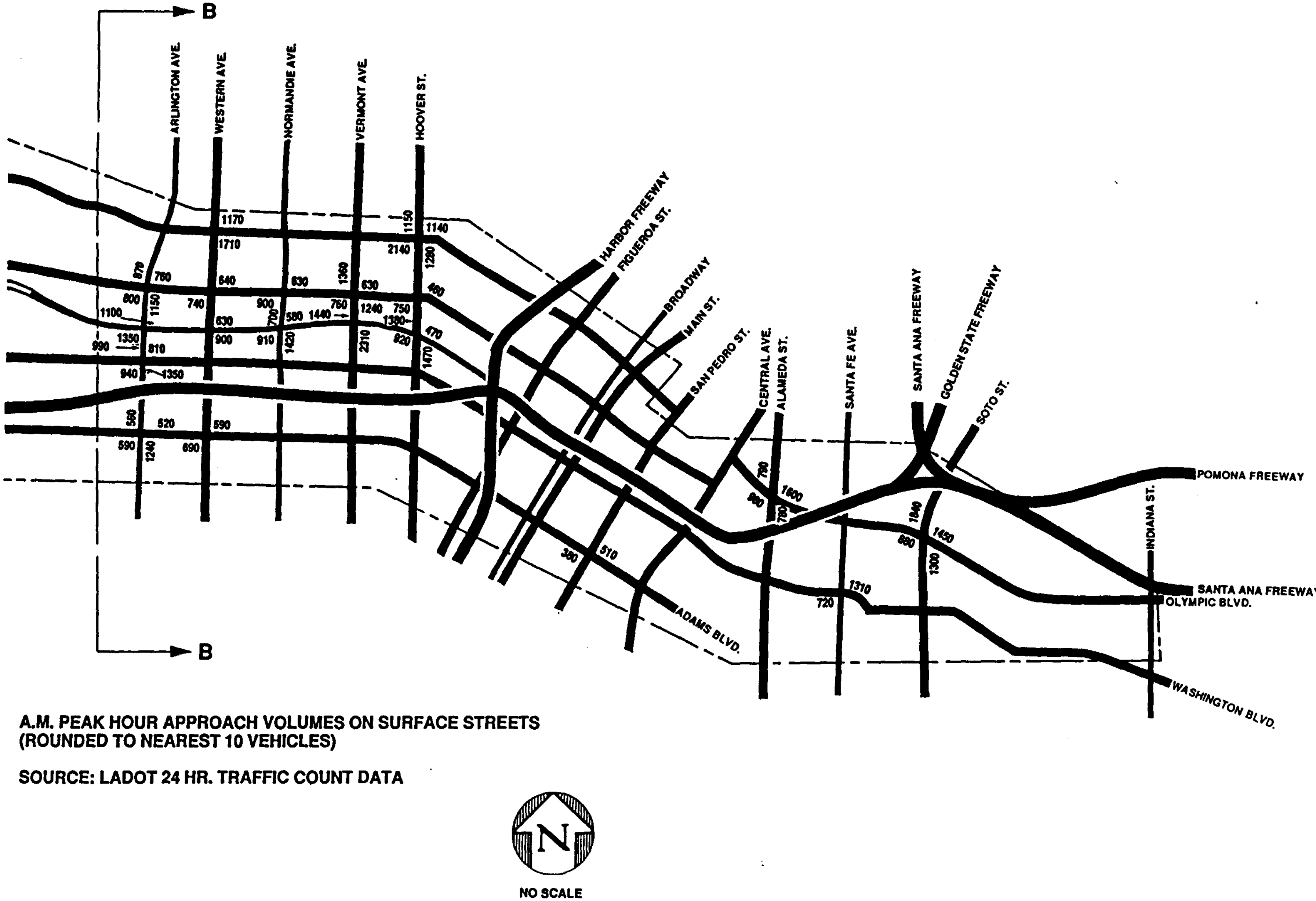
A.M. PEAK HOUR APPROACH VOLUMES ON SURFACE STREETS (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

NO SCALE

KAKU ASSOCIATES

EXHIBIT 10A



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

SOURCE: LADOT 24 HR. TRAFFIC COUNT DATA

KAKU ASSOCIATES

EXHIBIT 10B

SMART CORRIDOR DE STRATION PROJECT

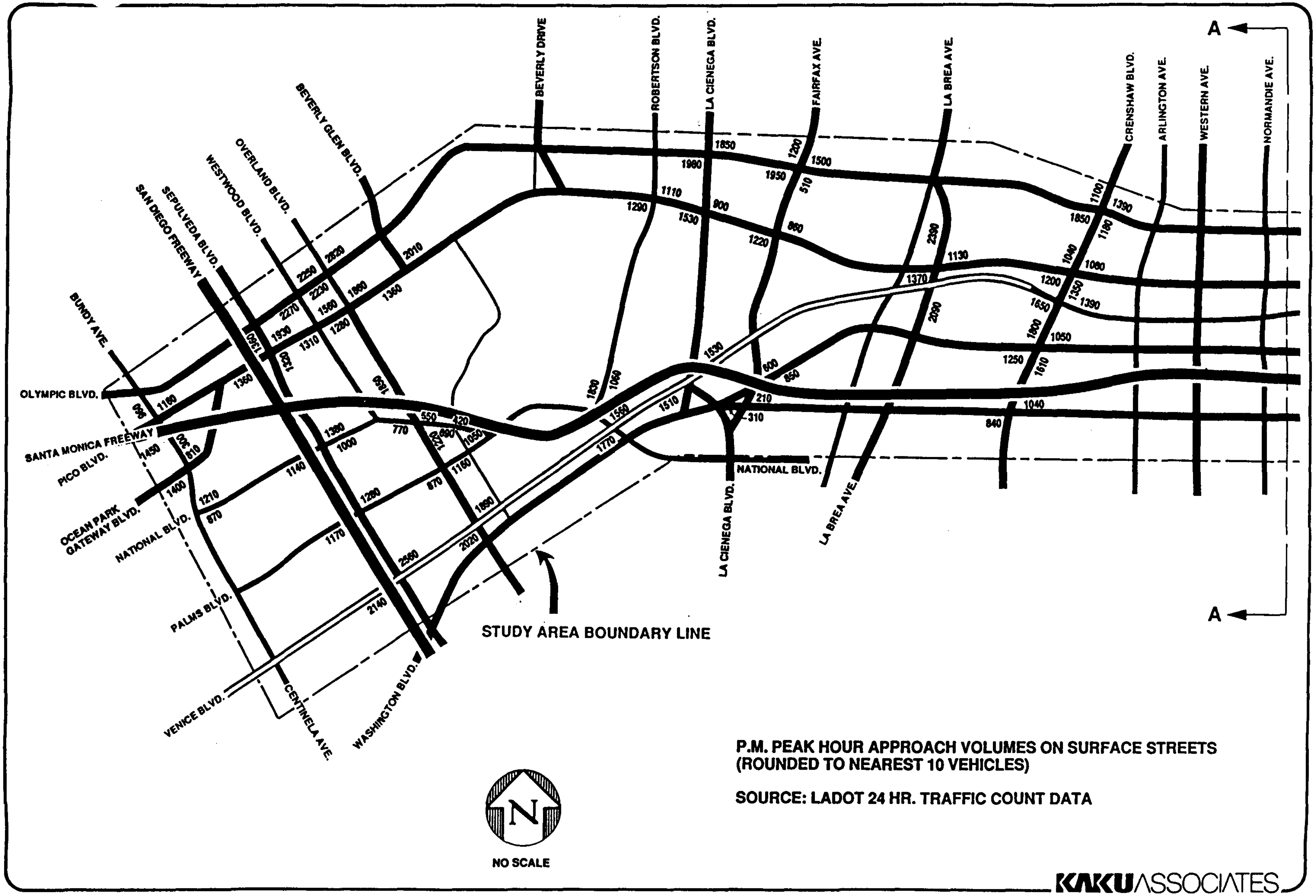
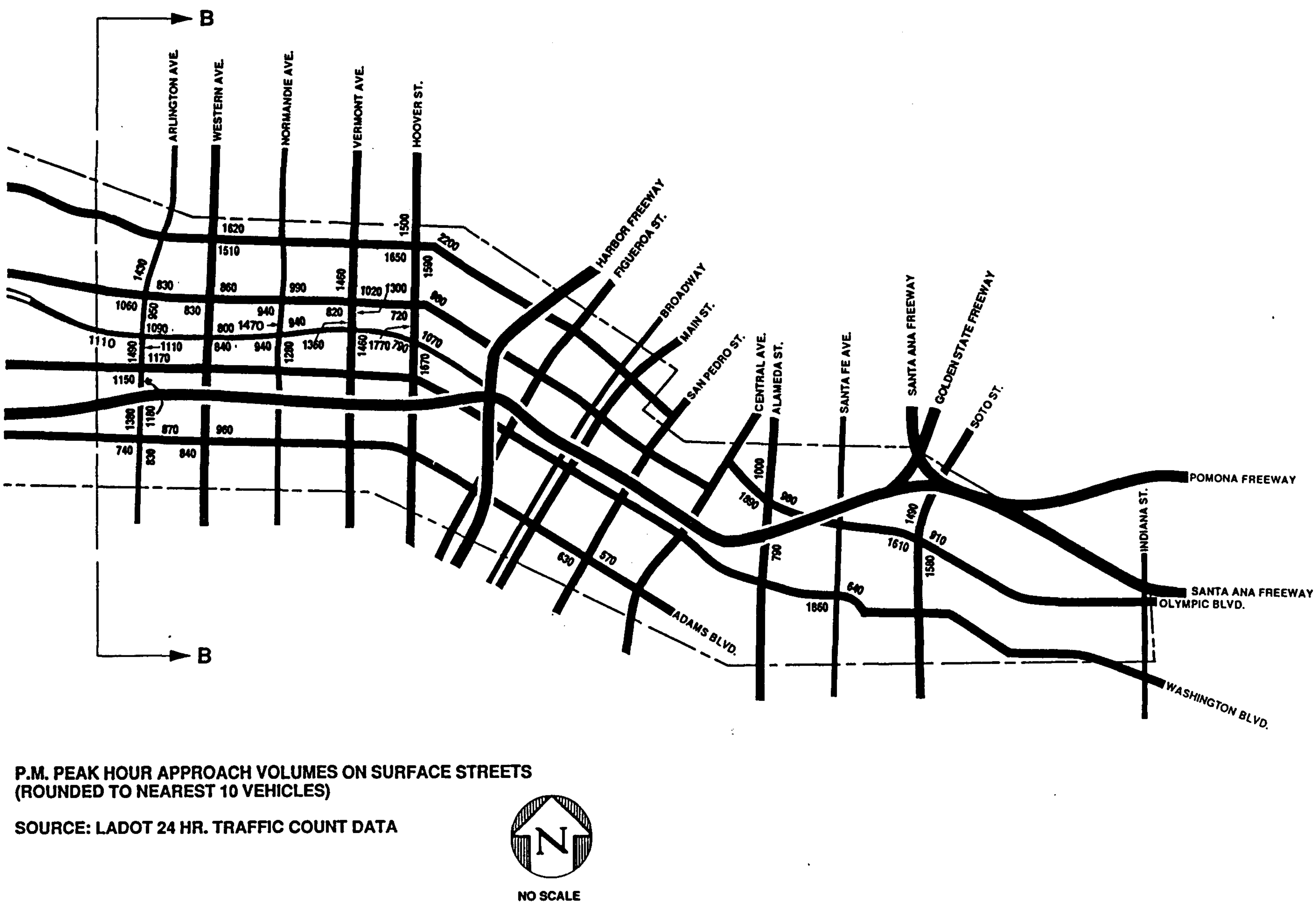


EXHIBIT 11A

SMART CORRIDOR DE. STRATION 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 11B

SMART CORRIDOR DE. .STRATION PROJECT

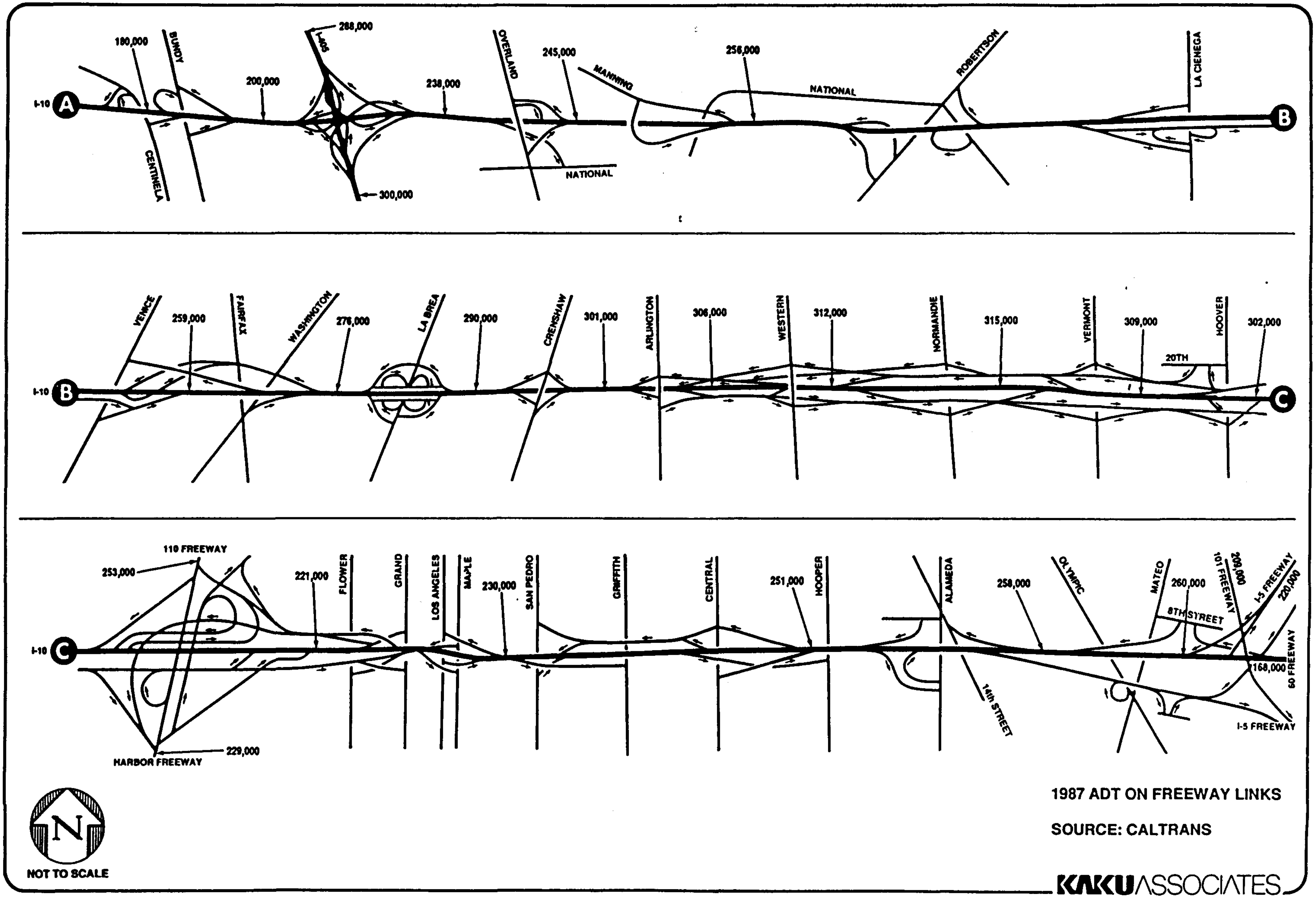


EXHIBIT 12

SMART CORRIDOR DE[illegible]STRATION PROJECT

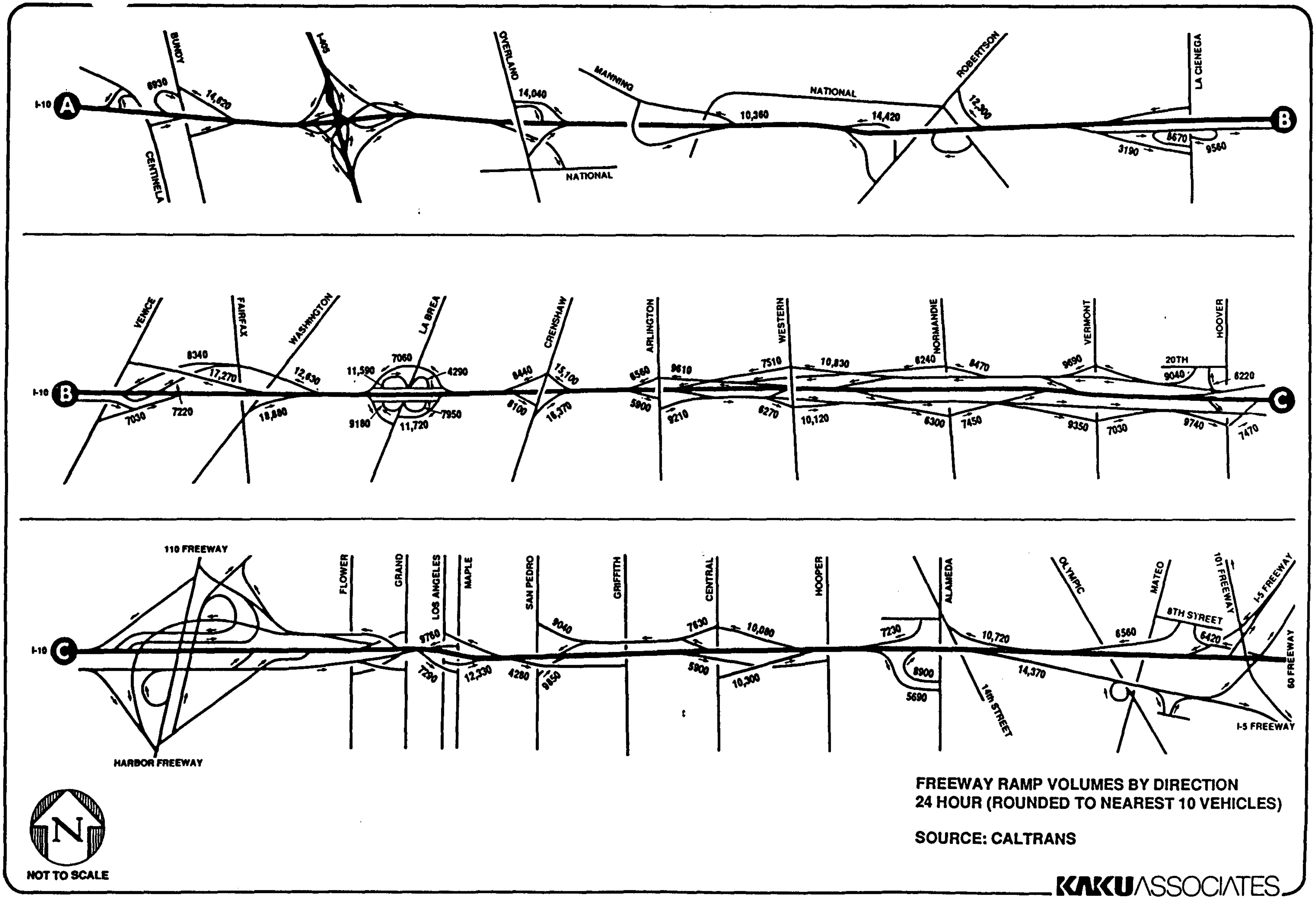
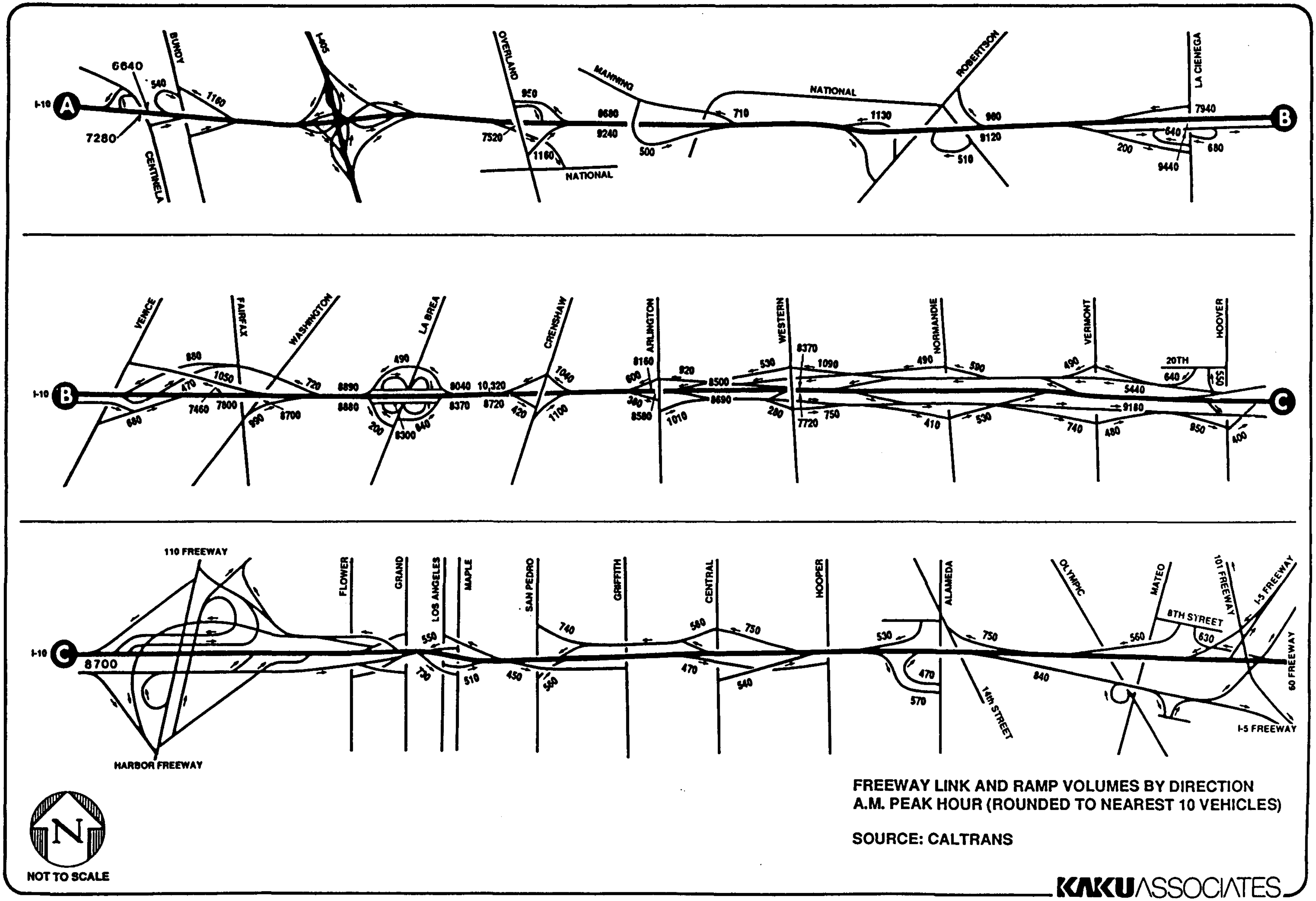


EXHIBIT 13

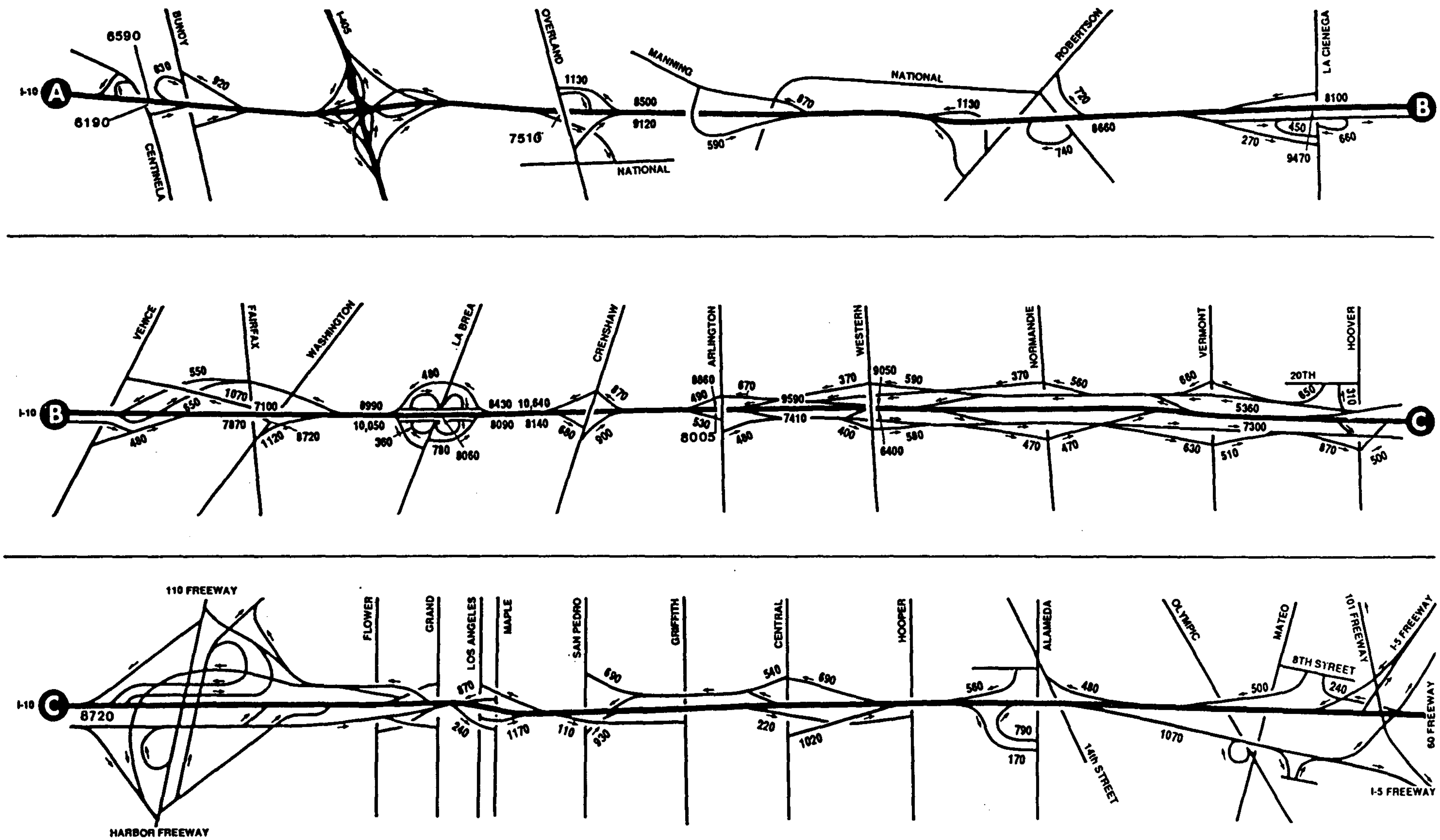


FREEWAY LINK AND RAMP VOLUMES BY DIRECTION
A.M. PEAK HOUR (ROUNDED TO NEAREST 10 VEHICLES)

SOURCE: CALTRANS

EXHIBIT 14

SMART CORRIDOR DE[illegible]STRATION PROJECT



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

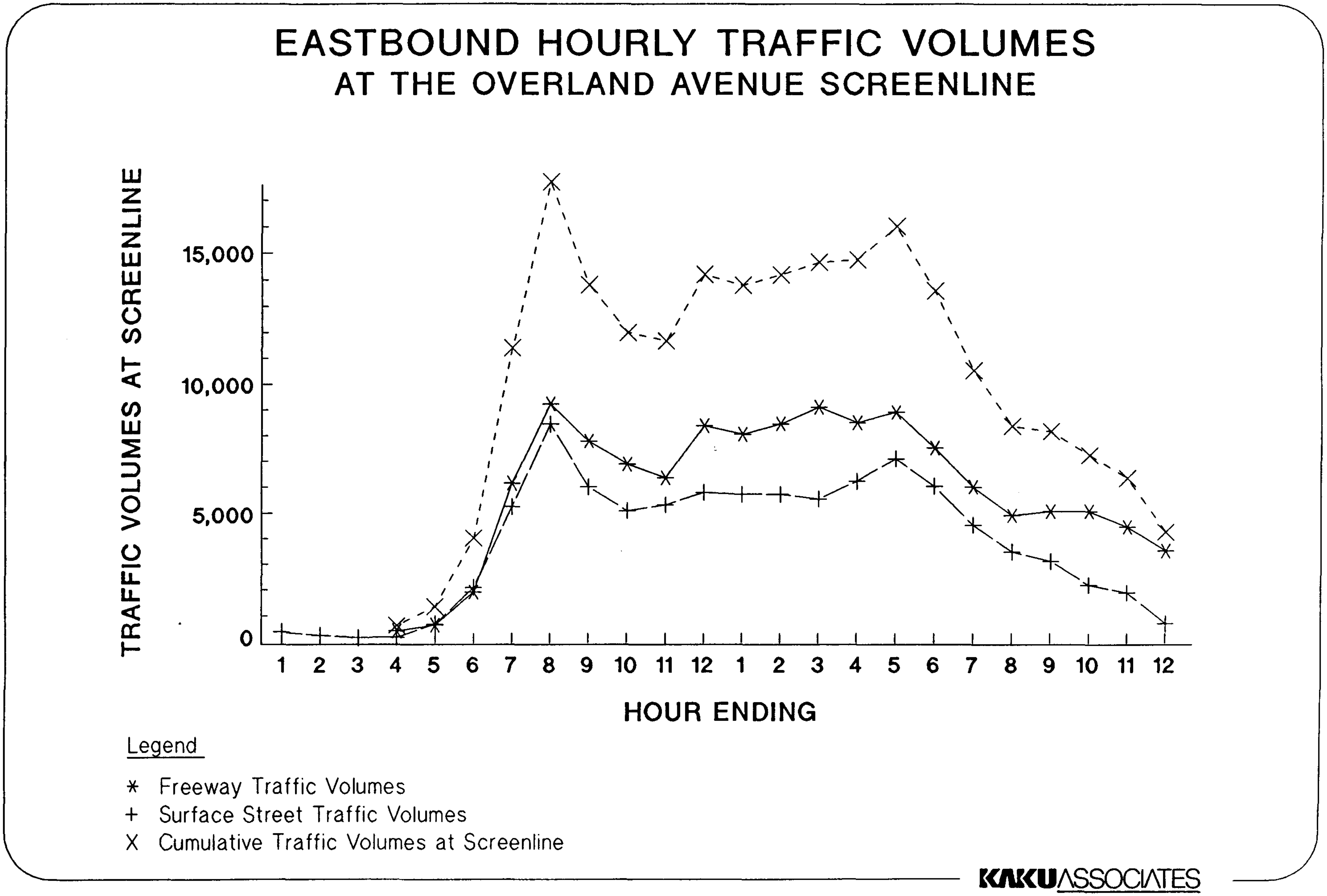
SOURCE: CALTRANS

N

NOT TO SCALE

KAKU ASSOCIATES

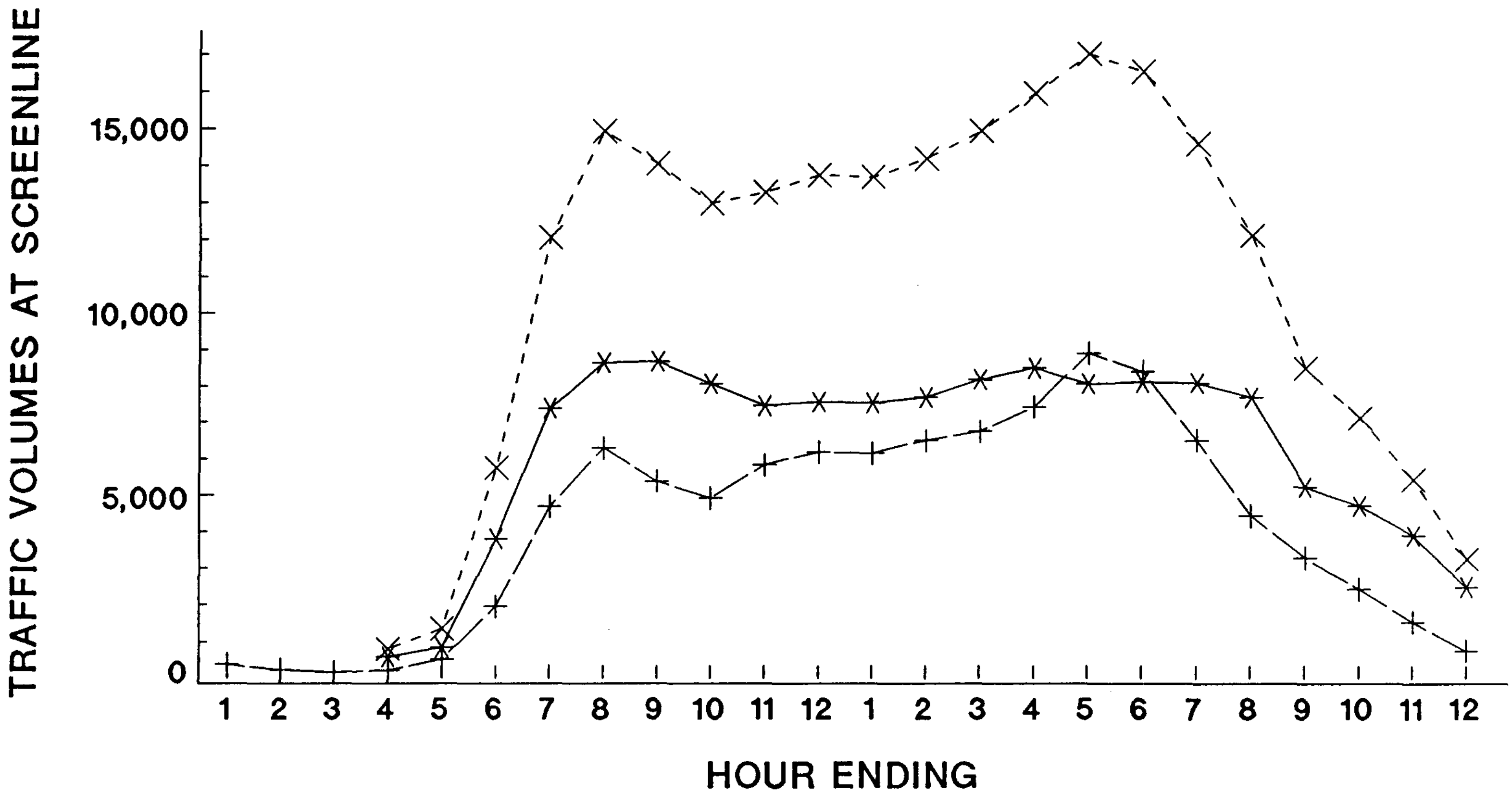
EXHIBIT 15



EASTBOUND HOURLY TRAFFIC VOLUMES
AT THE OVERLAND AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
15,000
10,000
5,000
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
Legend
* Freeway Traffic Volumes
+ Surface Street Traffic Volumes
X Cumulative Traffic Volumes at Screenline
KAKU ASSOCIATES

EXHIBIT 16

WESTBOUND HOURLY TRAFFIC VOLUMES
AT THE OVERLAND AVENUE SCREENLINE



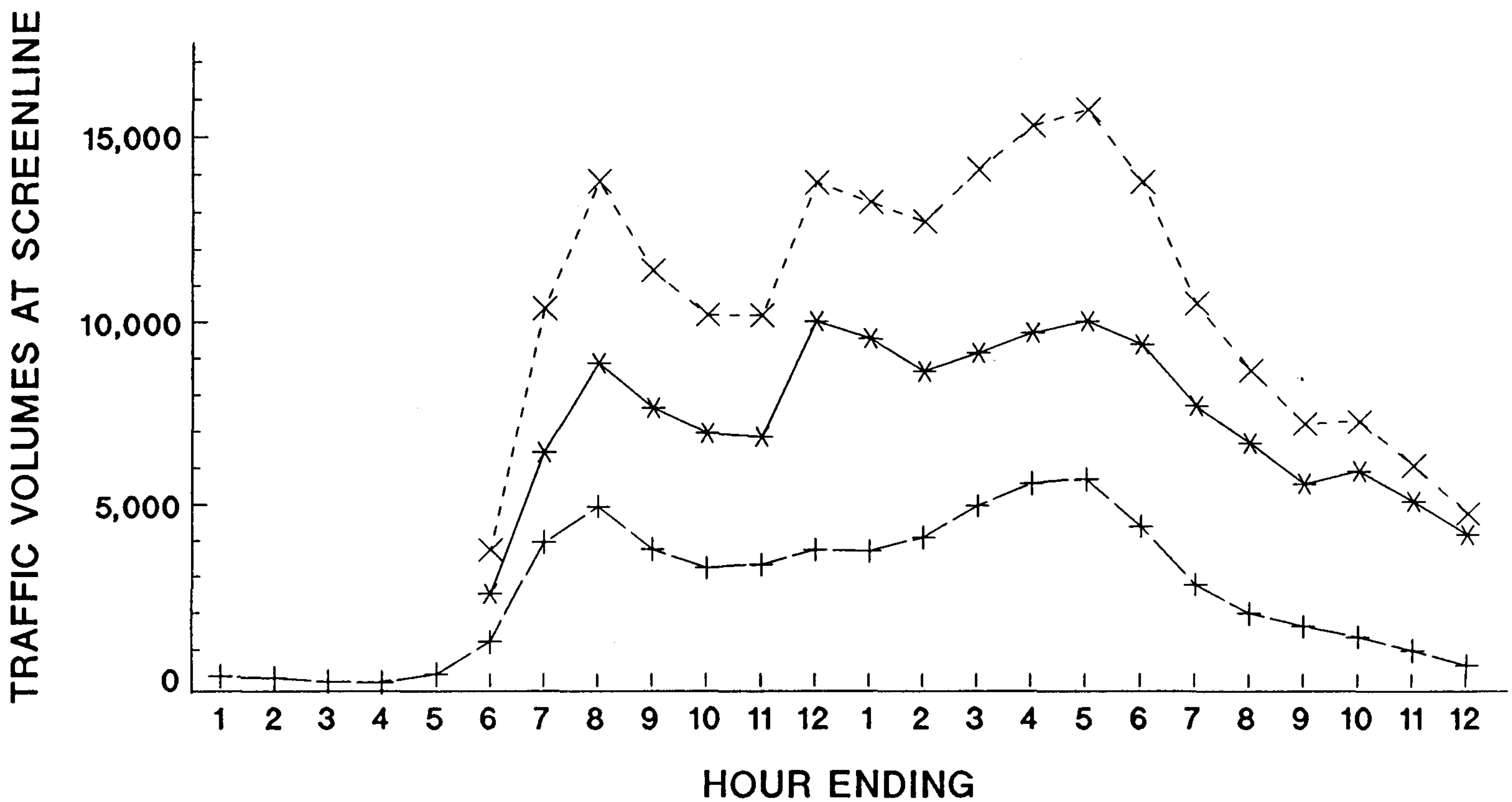
Legend

* Freeway Traffic Volumes
+ Surface Street Traffic Volumes
X Cumulative Traffic Volumes at Screenline

KAKU ASSOCIATES

EXHIBIT 17

EASTBOUND HOURLY TRAFFIC VOLUMES
AT THE FAIRFAX AVENUE SCREENLINE

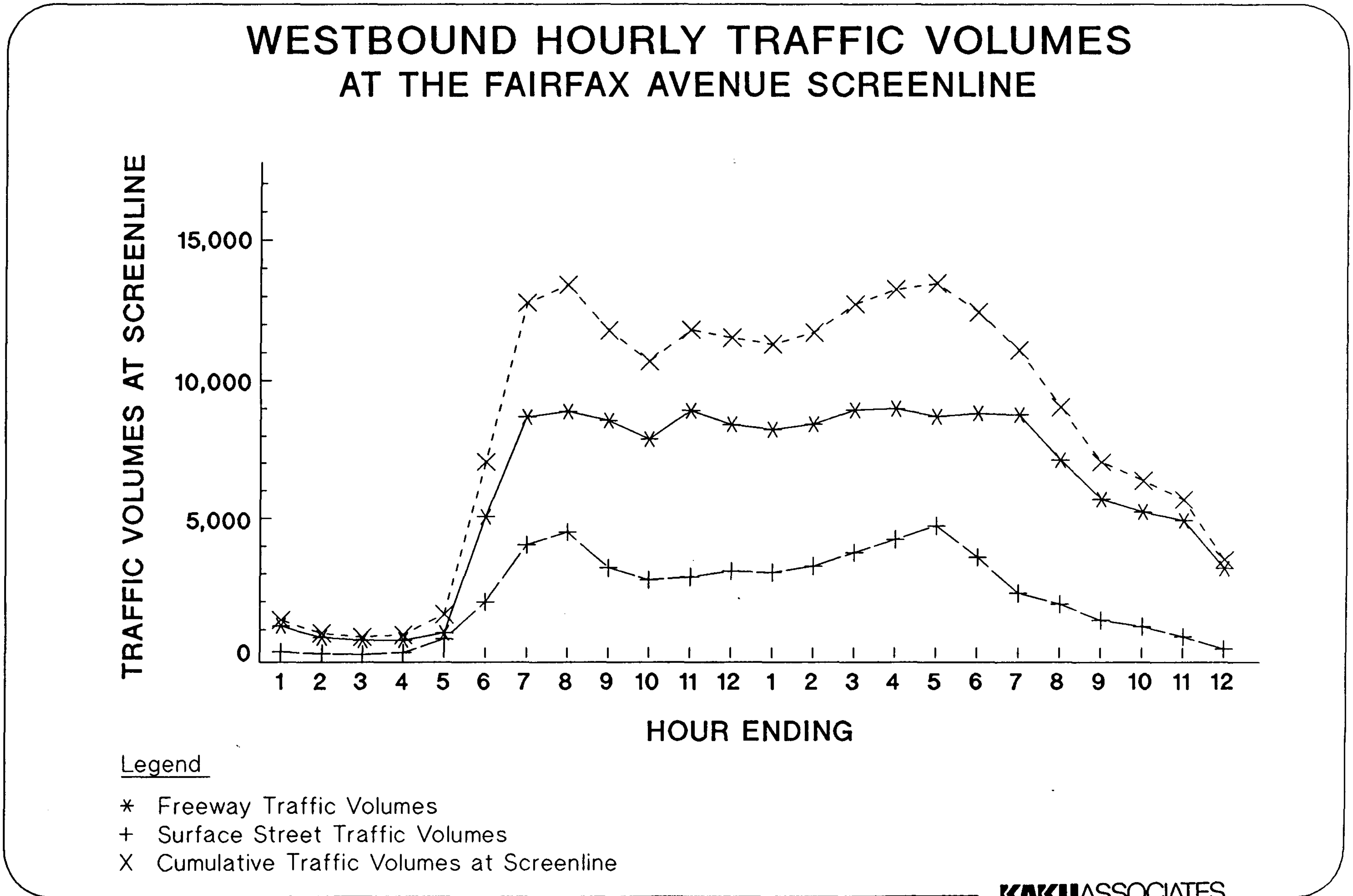


Legend

* Freeway Traffic Volumes
\+ Surface Street Traffic Volumes
X Cumulative Traffic Volumes at Screenline

KAKU ASSOCIATES

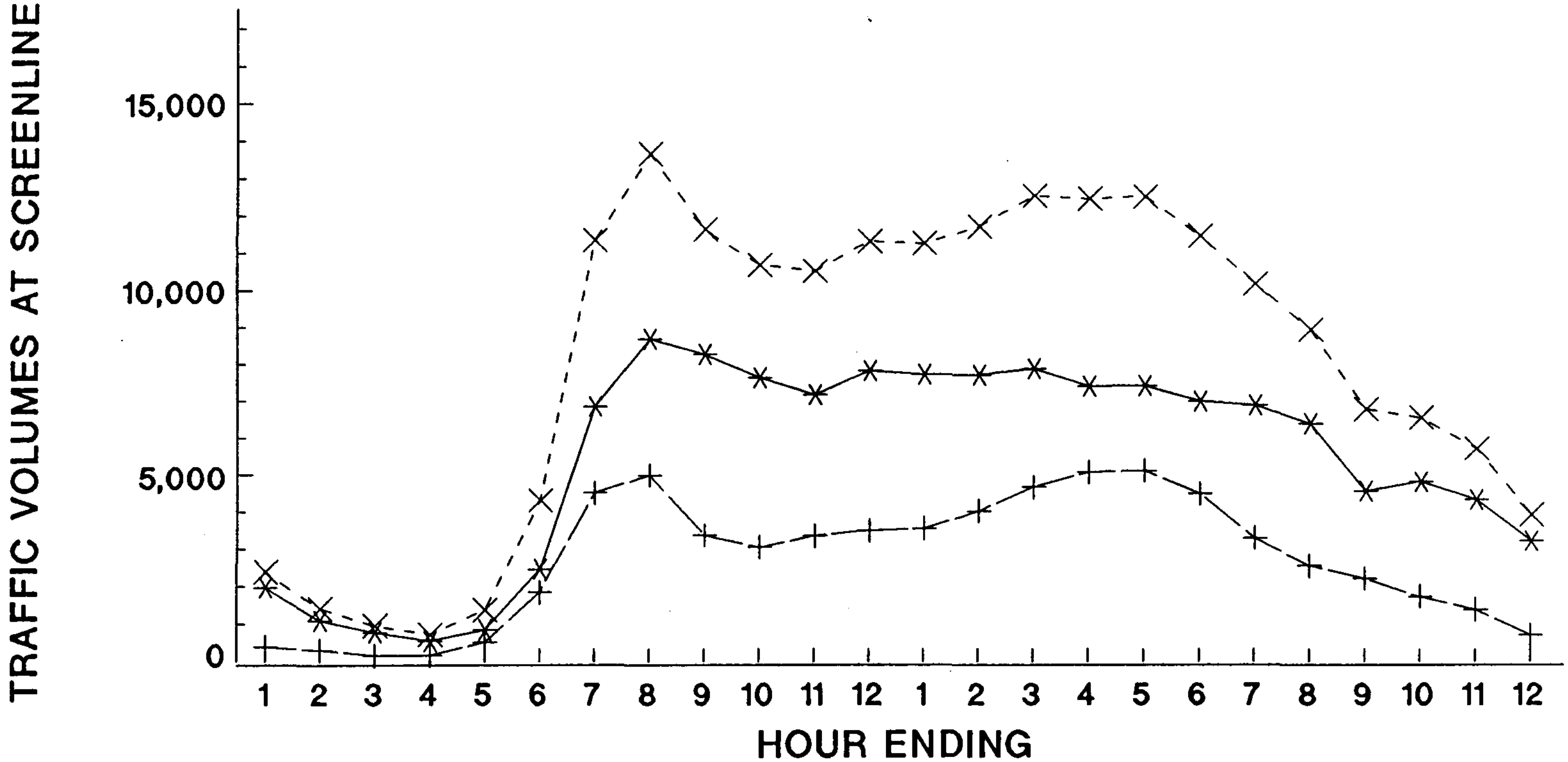
EXHIBIT 18



WESTBOUND HOURLY TRAFFIC VOLUMES
AT THE FAIRFAX AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
15,000
10,000
5,000
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
Legend
* Freeway Traffic Volumes
+ Surface Street Traffic Volumes
X Cumulative Traffic Volumes at Screenline
KAKU ASSOCIATES

EXHIBIT 19

EASTBOUND HOURLY TRAFFIC VOLUMES
AT THE WESTERN AVENUE SCREENLINE



Legend

- * Freeway Traffic Volumes
- \+ Surface Street Traffic Volumes
- X Cumulative Traffic Volumes at Screenline

KAKU ASSOCIATES

EXHIBIT 20

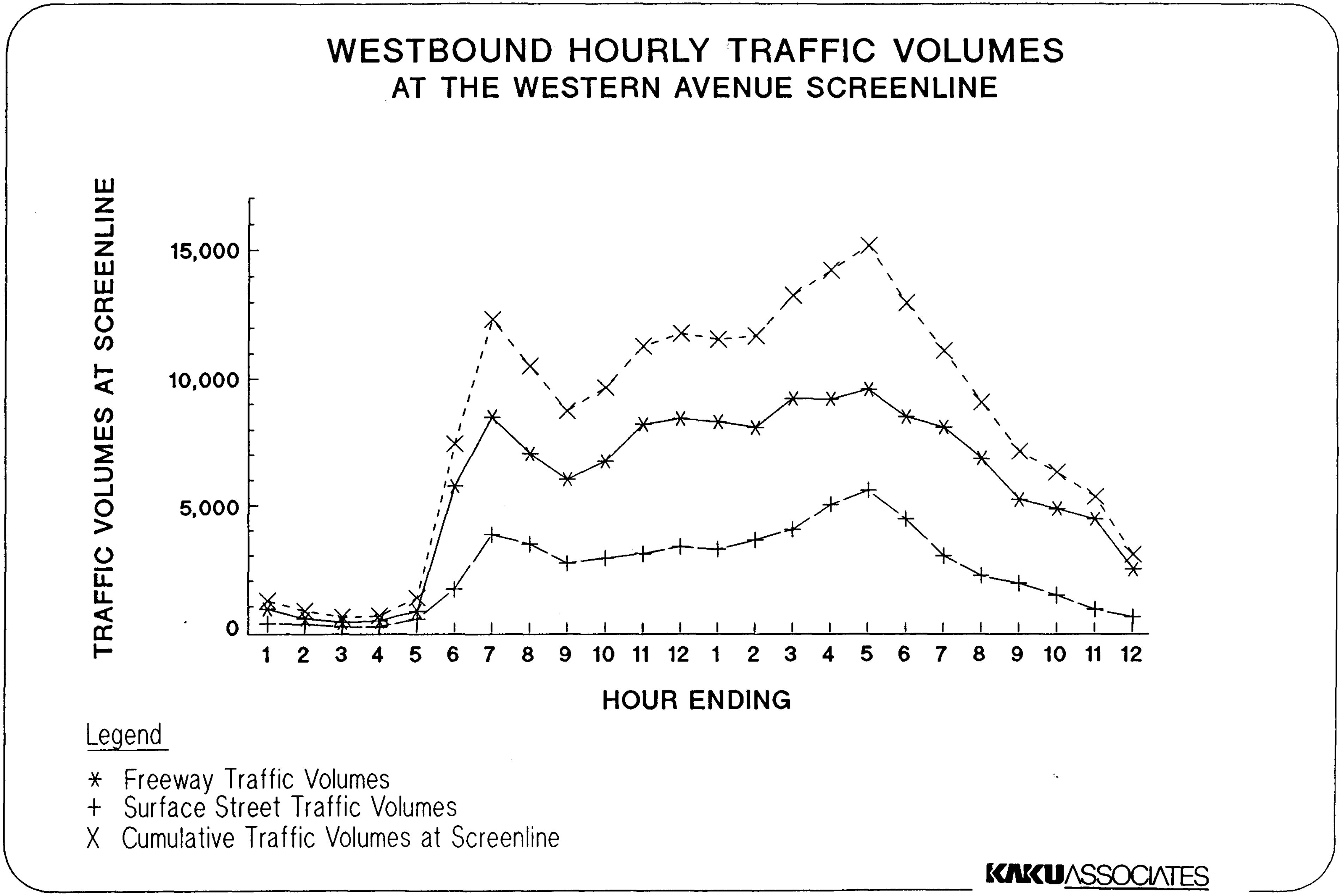
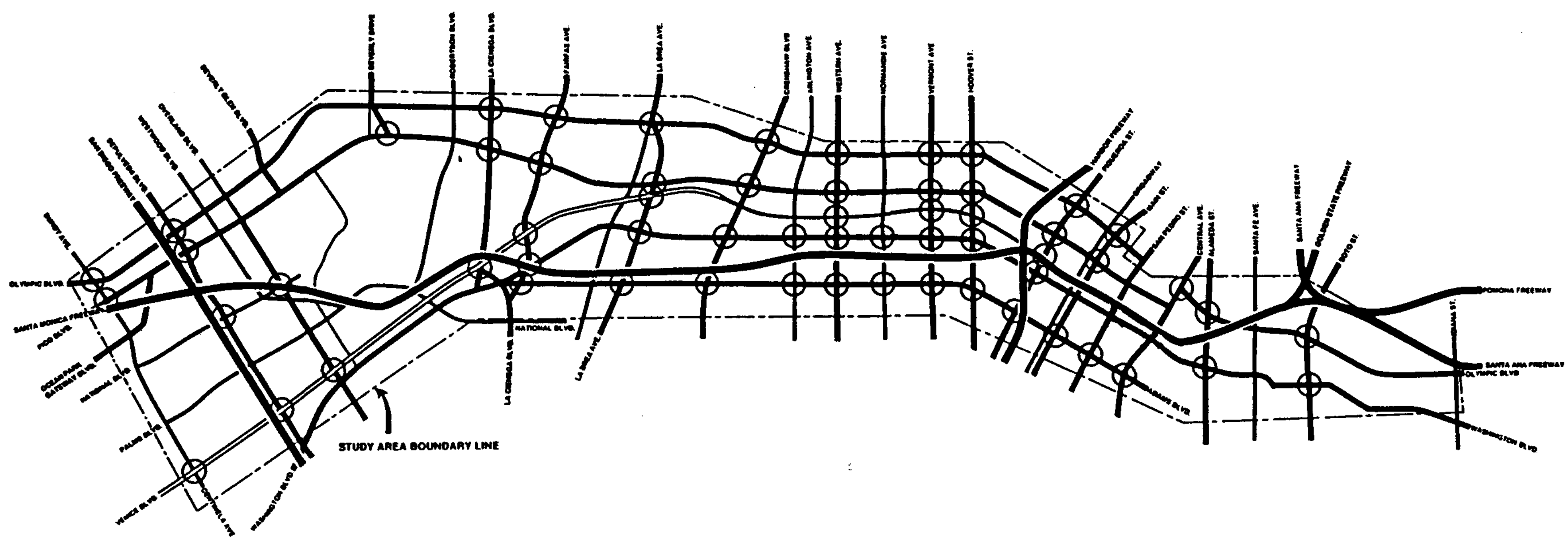

WESTBOUND HOURLY TRAFFIC VOLUMES
AT THE WESTERN AVENUE SCREENLINE
TRAFFIC VOLUMES AT SCREENLINE
15,000
10,000
5,000
0
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
HOUR ENDING
Legend
* Freeway Traffic Volumes
+ Surface Street Traffic Volumes
X Cumulative Traffic Volumes at Screenline
KAKU ASSOCIATES

EXHIBIT 21

SMART CORRIDOR DEMONSTRATION PROJECT



ANALYZED SURFACE STREET INTERSECTIONS

LEGEND:

○ ANALYZED INTERSECTION

N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 22

SMART CORRIDOR DEI STRATION PROJECT

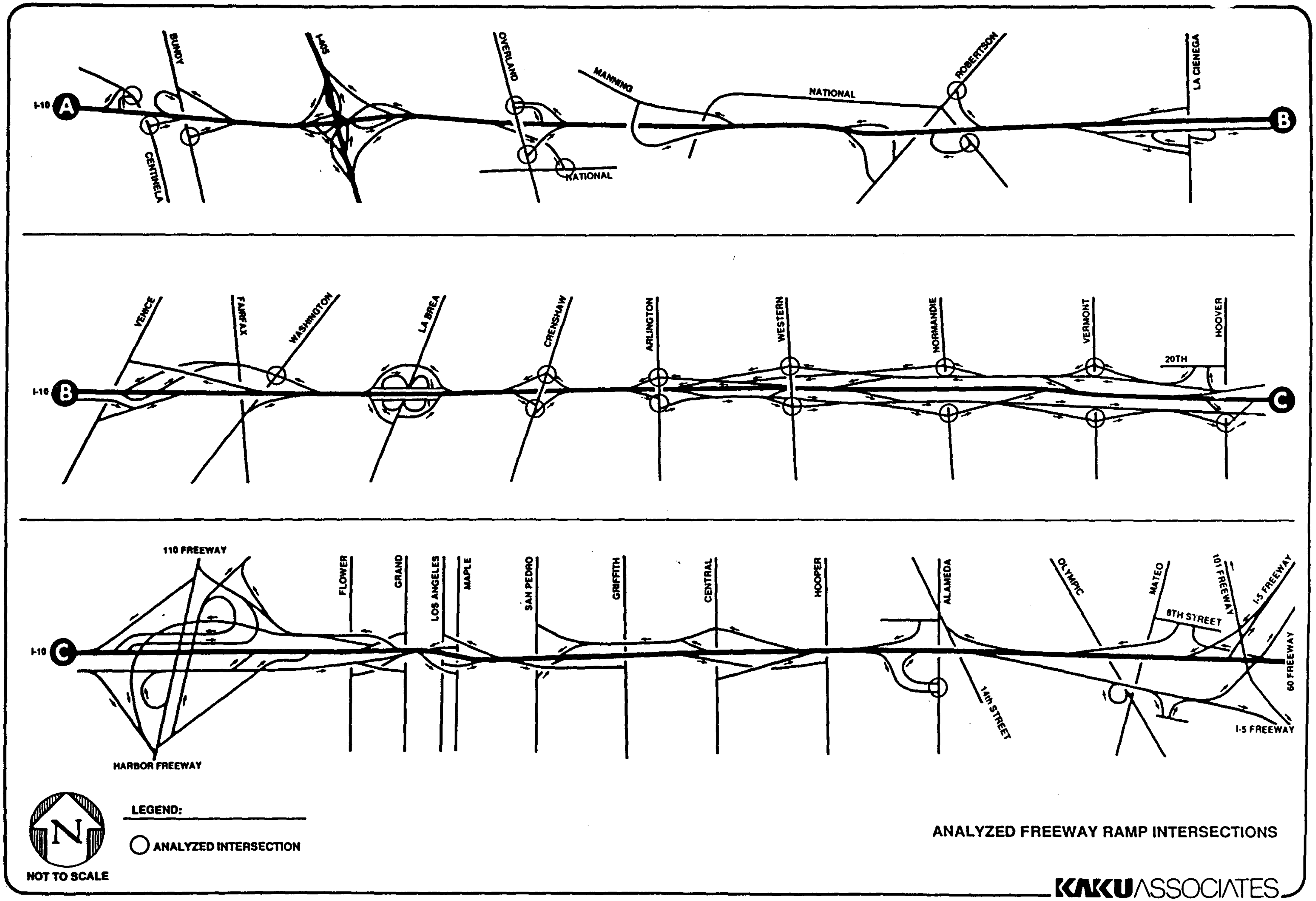


EXHIBIT 23

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 24
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 25
LEVEL OF SERVICE ANALYSIS - SURFACE STREET INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	AM Peak Hour V/C Ratio	AM Peak Hour LOS	Off-Peak Hour V/C Ratio	Off-Peak Hour LOS	PM Peak Hour V/C Ratio	PM Peak Hour LOS
1	319	OLYMPIC & BUNDY	0.90	D	0.77	C	0.96	E
2	274	OLYMPIC & SEPULVEDA	1.06	F	0.96	E	1.04	F
3	3	OLYMPIC & LA CIENEGA	0.88	D	0.96	E	0.99	E
4	7	OLYMPIC & FAIRFAX	0.65	B	0.77	C	0.82	D
5	14	OLYMPIC & LA BREA	0.92	E	0.85	D	0.87	D
6	20	OLYMPIC & CRENSHAW	0.89	D	0.74	C	0.92	E
7	25	OLYMPIC & WESTERN	0.85	D	0.88	D	0.97	E
8	30	OLYMPIC & VERMONT	0.95	E	0.94	E	1.01	F
9	33	OLYMPIC & HOOVER	0.97	E	0.88	D	1.07	F
10	*	OLYMPIC & FIGUEROA	0.55	A	0.67	B	0.76	C
11	*	OLYMPIC & MAIN	0.41	A	0.46	A	0.54	A
12	*	OLYMPIC & SAN PEDRO	n/a		n/a		n/a	
13	*	OLYMPIC & CENTRAL	0.68	B	0.76	C	0.86	D
14	236	OLYMPIC & ALAMEDA	0.70	B	0.77	C	0.89	D
15	241	OLYMPIC & SOTO	0.72	C	0.78	C	0.76	C
16	*	OLYMPIC & INDIANA	n/a		n/a		n/a	
17	325	PICO & BUNDY	0.47	A	0.50	A	0.61	B
18	297	PICO & SEPULVEDA	0.88	D	0.86	D	0.91	E
19	295	PICO & BEVERLY GLEN	n/a		n/a		n/a	
20	63	PICO & BEVERLY	0.97	E	0.75	C	0.87	D
21	70	PICO & LA CIENEGA	0.88	D	0.95	E	0.89	D
22	72	PICO & FAIRFAX	0.53	A	0.57	A	0.73	C
23	78	PICO & LA BREA	0.92	E	0.89	D	0.94	E
24	83	PICO & CRENSHAW	0.81	D	0.83	D	0.89	D
25	88	PICO & WESTERN	0.68	B	0.57	A	0.78	C
26	93	PICO & VERMONT	0.67	B	0.78	C	0.88	D
27	96	PICO & HOOVER	0.59	A	0.70	B	0.93	E
28	*	PICO & FIGUEROA	0.37	A	0.53	A	0.58	A
29	*	PICO & MAIN	0.41	A	0.56	A	0.55	A
30	106	NATIONAL & SEPULVEDA	0.87	D	0.82	D	1.02	F
31	302	NATIONAL/OVERLAND/WB RAMPS	1.10	F	0.81	D	1.01	F
32	346	VENICE & CENTINELA	0.83	D	0.67	B	0.95	E
33	146	VENICE & SEPULVEDA	0.96	E	0.80	C	1.14	F
34	148	VENICE & OVERLAND	1.09	F	0.85	D	1.05	F
35	*	VENICE & CULVER	n/a		n/a		n/a	
36	156	VENICE & LA CIENEGA	0.96	E	1.01	F	1.07	F
37	158	VENICE & FAIRFAX	0.93	E	0.79	C	1.05	F
38	163	VENICE & LA BREA	0.98	E	0.84	D	0.94	E
39	172	VENICE & WESTERN	0.65	B	0.57	A	0.82	D
40	177	VENICE & VERMONT	0.74	C	0.69	B	0.83	D
41	180	VENICE & HOOVER	0.81	D	0.69	B	0.99	E
42	*	VENICE & FIGUEROA	0.36	A	0.69	B	0.55	A

EXHIBIT 25 (continued)
LEVEL OF SERVICE ANALYSIS - SURFACE STREET INTERSECTIONS

	ATSAC		AM Peak Hour		Off-Peak Hour		PM Peak Hour	
Study Num	Smart Num	Intersection	V/C Ratio	LOS	V/C Ratio	LOS	V/C Ratio	LOS
43	*	WASHINGTON & LA CIENEGA	n/a		n/a		n/a	
44	185	WASHINGTON & FAIRFAX	0.79	C	0.81	D	0.84	D
45	190	WASHINGTON & LA BREA	0.94	E	1.08	F	1.08	F
46	194	WASHINGTON & CRENSHAW	0.90	D	0.80	C	0.86	D
47	198	WASHINGTON & ARLINGTON	0.75	C	0.84	D	0.79	C
48	201	WASHINGTON & WESTERN	0.75	C	0.70	B	0.85	D
49	203	WASHINGTON & NORMANDIE	0.83	D	0.63	B	0.92	E
50	205	WASHINGTON & VERMONT	0.74	C	0.84	D	0.88	D
51	*	WASHINGTON & HOOVER	0.79	C	0.78	C	0.97	E
52	*	WASHINGTON & FIGUEROA	0.76	C	1.13	F	0.97	E
53	*	WASHINGTON & MAIN	**		**		**	
54	*	WASHINGTON & SAN PEDRO	**		**		**	
55	*	WASHINGTON & CENTRAL	**		**		**	
56	*	WASHINGTON & ALAMEDA	0.72	C	0.76	C	0.77	C
57	*	WASHINGTON & SOTO	0.94	E	0.74	C	0.83	D
58	*	WASHINGTON & INDIANA	n/a		n/a		n/a	
59	207	ADAMS & FAIRFAX	0.71	C	0.69	B	0.81	D
60	213	ADAMS & LA BREA	0.95	E	0.79	C	1.01	F
61	218	ADAMS & CRENSHAW	0.92	E	0.82	D	0.91	E
62	223	ADAMS & ARLINGTON	0.57	A	0.75	C	0.81	D
63	228	ADAMS & WESTERN	0.73	C	0.65	B	0.86	D
64	*	ADAMS & NORMANDIE	0.70	B	0.61	B	0.93	E
65	*	ADAMS & VERMONT	0.74	C	0.69	B	0.85	D
66	*	ADAMS & HOOVER	0.48	A	0.51	A	0.62	B
67	*	ADAMS & FIGUEROA	0.69	B	0.67	B	0.93	E
68	*	ADAMS & MAIN	0.36	A	0.54	A	0.49	A
69	268	ADAMS & SAN PEDRO	0.46	A	0.66	B	0.67	B
70	270	ADAMS & CENTRAL	0.55	A	0.75	C	0.71	C

- o "AM Peak Hour" is peak hour of traffic between 7 & 10 AM; "Off-Peak Hour" is peak hour of traffic between 11 AM & 2 PM; "PM Peak Hour" is peak hour of traffic between 3 & 6 PM.
- 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.
- ** Long Beach-Los Angeles light rail line currently under construction along this section of Washington.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 26

LEVEL OF SERVICE ANALYSIS - RAMP INTERSECTIONS

Study Num	ATSAC Smart Num	Intersection	AM Peak Hour V/C Ratio	AM Peak Hour LOS	Off-Peak Hour V/C Ratio	Off-Peak Hour LOS	PM Peak Hour V/C Ratio	PM Peak Hour LOS
71	323	CENTINELA & WB RAMPS	0.86	D	0.59	A	0.98	E
72	328	CENTINELA & EB ON-RAMP	0.32	A	0.23	A	0.39	A
73	329	BUNDY & EB ON-RAMP	0.62	B	0.55	A	0.67	B
74	302	NATIONAL/OVERLAND/WB RAMPS	1.10	F	0.81	D	1.01	F
75	303	OVERLAND & EB ON-RAMP	0.71	C	0.39	A	0.66	B
76	305	NATIONAL & EB OFF-RAMP	0.70	B	0.41	A	0.69	B
77	136	NATIONAL & WB OFF-RAMP/MANNING	n/a		n/a		n/a	
78	139	ROBERTSON & WB OFF-RAMP/KINCARDINE	0.80	C	0.91	E	0.91	E
79	141	NATIONAL & EB ON-RAMP	0.38	A	0.24	A	0.39	A
80	143	LA CIENEGA & WB ON-RAMP/DAVID	n/a		n/a		n/a	
81	157	VENICE & WB OFF-RAMP/CADILLAC	n/a		n/a		n/a	
82	184	FAIRFAX & EB OFF/WB ON/APPLE	n/a		n/a		n/a	
83	186	WASHINGTON & WB OFF-RAMP	0.50	A	0.53	A	0.54	A
84	216	CRENSHAW & WB RAMPS	0.66	B	0.74	C	0.64	B
85	217	CRENSHAW & EB RAMPS	0.69	B	0.53	A	0.69	B
86	221	ARLINGTON & WB RAMPS	0.73	C	0.67	B	0.90	D
87	222	ARLINGTON & EB RAMPS	0.92	E	0.85	D	0.72	C
88	226	WESTERN & WB RAMPS	0.66	B	0.65	B	0.61	B
89	227	WESTERN & EB RAMPS	0.71	C	0.83	D	0.78	C
90	*	NORMANDIE & WB RAMPS	0.61	B	0.85	D	0.86	D
91	*	NORMANDIE & EB RAMPS	0.74	C	0.66	B	0.80	C
92	*	VERMONT & WB RAMPS	0.56	A	0.56	A	0.63	B
93	*	VERMONT & EB RAMPS	0.73	C	0.78	C	0.83	D
94	*	20TH & WB RAMPS	n/a		n/a		n/a	
95	*	HOOVER & EB RAMPS	0.55	A	0.55	A	0.68	B
96	*	GRAND & WB ON-RAMP/17TH	n/a		n/a		n/a	
97	*	GRAND & EB OFF-RAMP/18TH	n/a		n/a		n/a	
98	*	LOS ANGELES & WB OFF-RAMP/17TH	n/a		n/a		n/a	
99	*	LOS ANGELES & EB ON-RAMP	n/a		n/a		n/a	
100	*	MAPLE & WB ON-RAMP	n/a		n/a		n/a	
101	244	MAPLE & EB OFF-RAMP/18TH	n/a		n/a		n/a	
102	245	SAN PEDRO & WB OFF-RAMP/16TH	n/a		n/a		n/a	
103	247	CENTRAL & WB RAMPS/16TH	n/a		n/a		n/a	
104	251	ALAMEDA & EB RAMPS	0.50	A	0.80	C	0.76	C

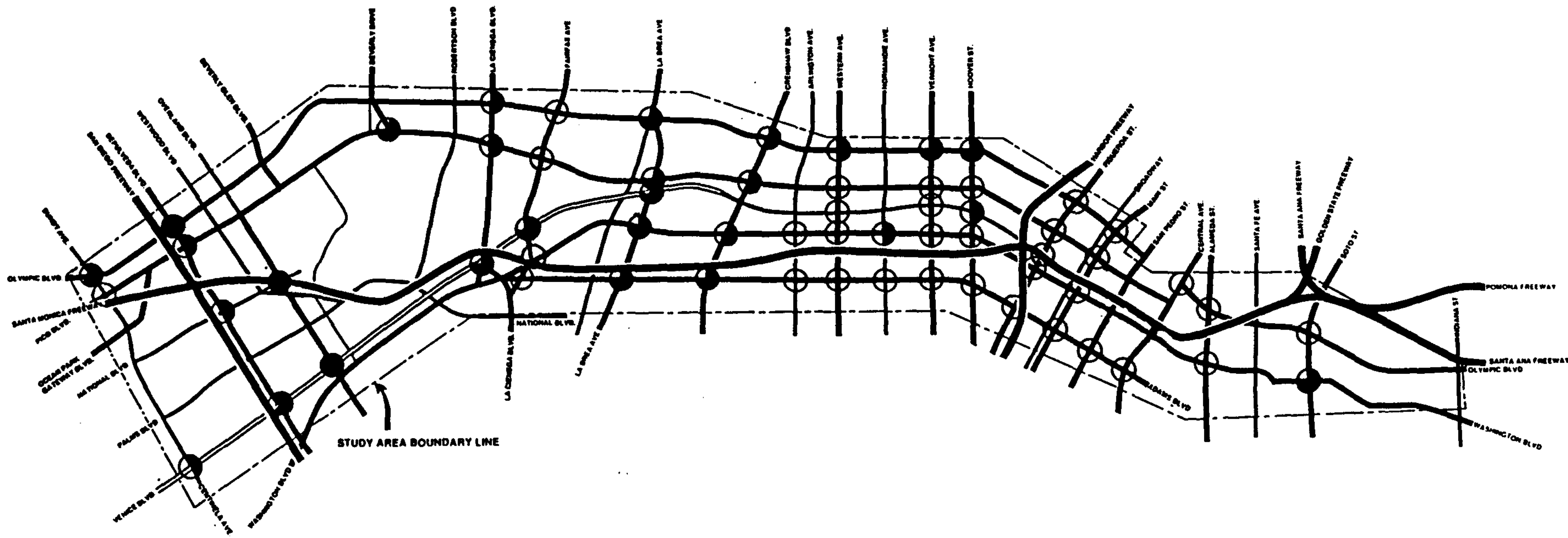
o "AM Peak Hour" is peak hour of traffic between 7 & 10 AM; "Off-Peak Hour" is peak hour of traffic between 11 AM & 2 PM; "PM Peak Hour" is peak hour of traffic between 3 & 6 PM.

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



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

A,B,C ○ D ◑

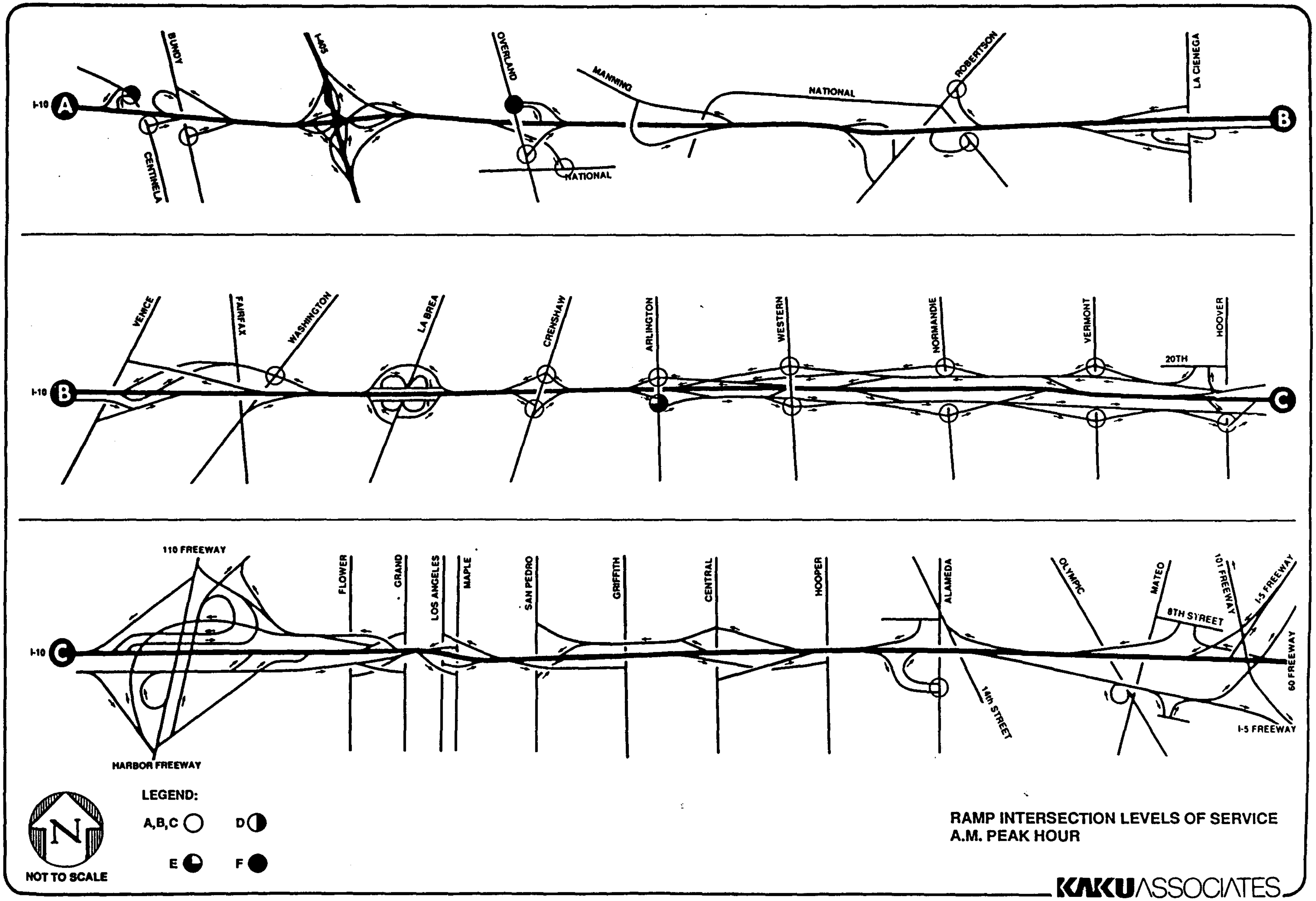
E ◕ F ●

NO SCALE

KAKU ASSOCIATES

EXHIBIT 27

SMART CORRIDOR DE... NSTRATION PROJECT

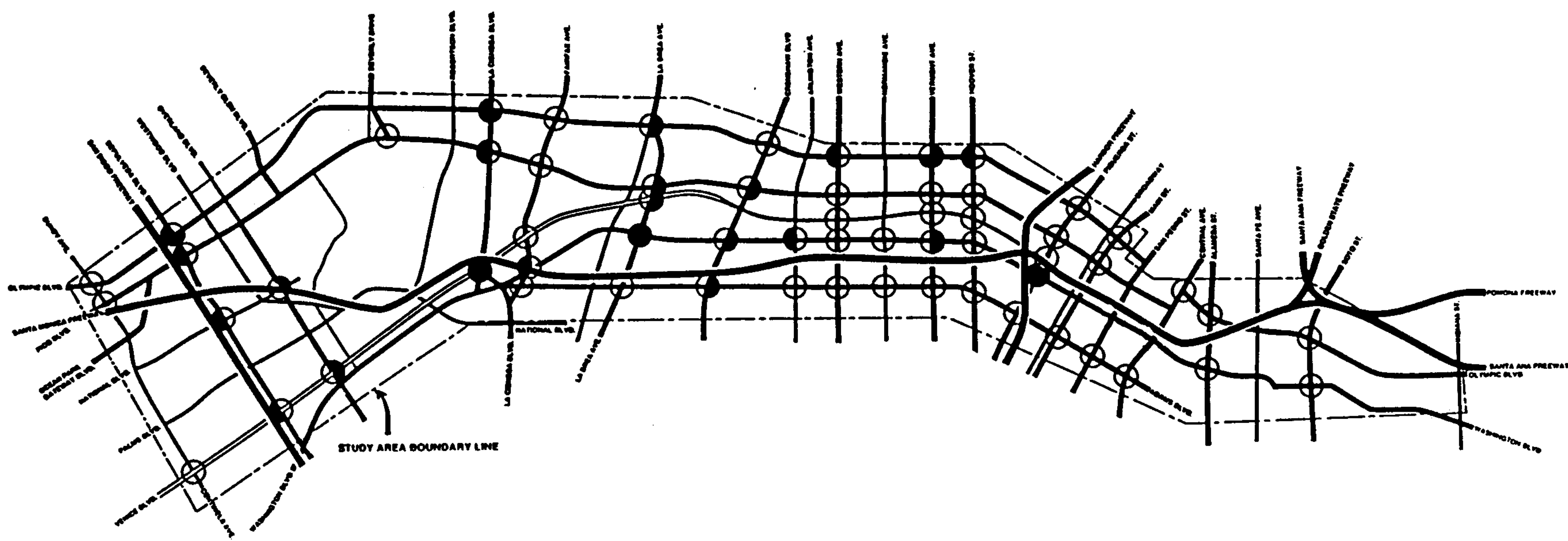


RAMP INTERSECTION LEVELS OF SERVICE
A.M. PEAK HOUR

KAKU ASSOCIATES

EXHIBIT 28

SMART CORRIDOR DEMONSTRATION PROJECT



OFF PEAK HOUR LEVEL OF SERVICE AT SURFACE STREET INTERSECTIONS

A,B,C ○ D ◑

E ◕ F ●

NO SCALE

KAKU ASSOCIATES

EXHIBIT 29

SMART CORRIDOR DEI.. .STRATION PROJECT

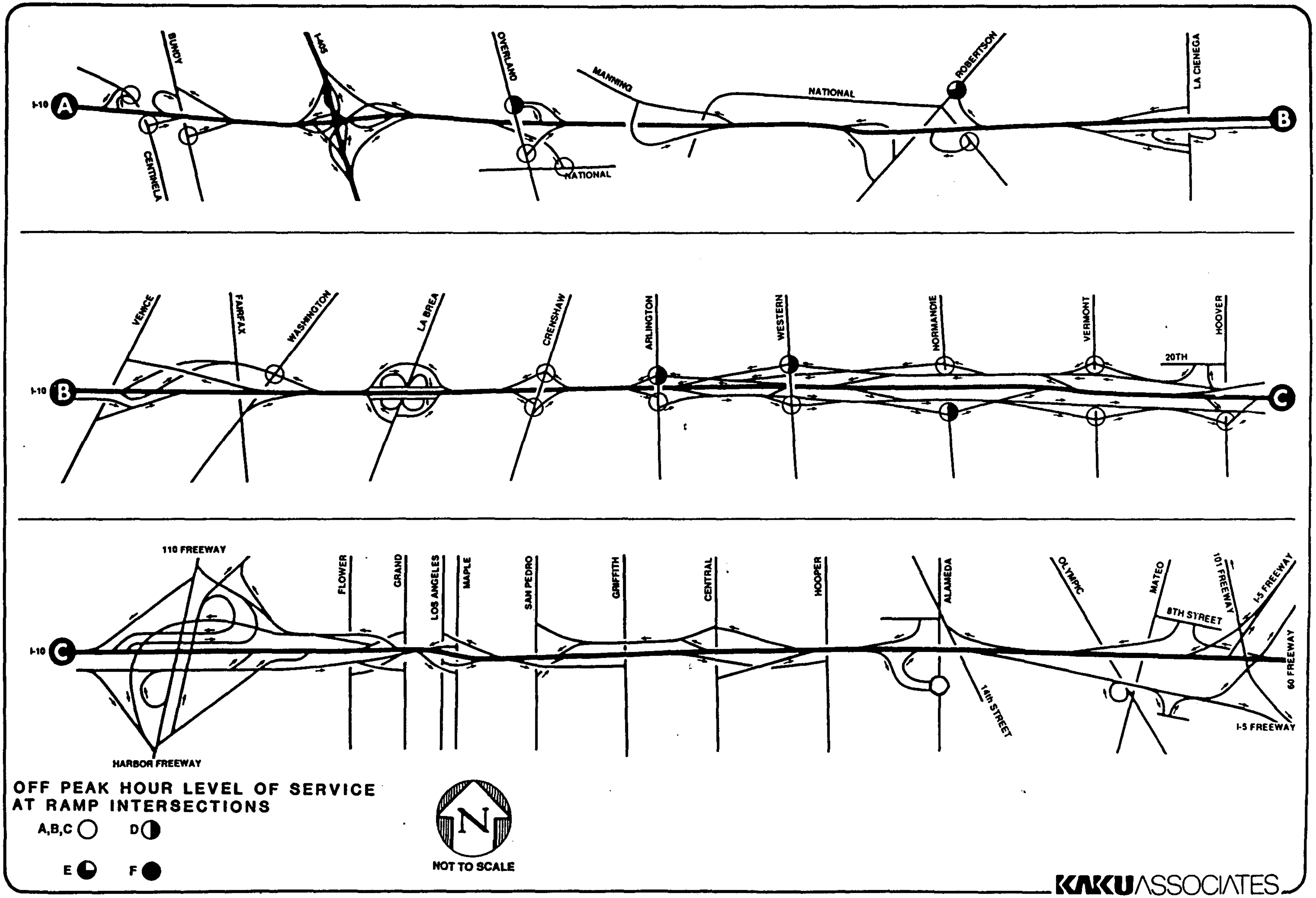
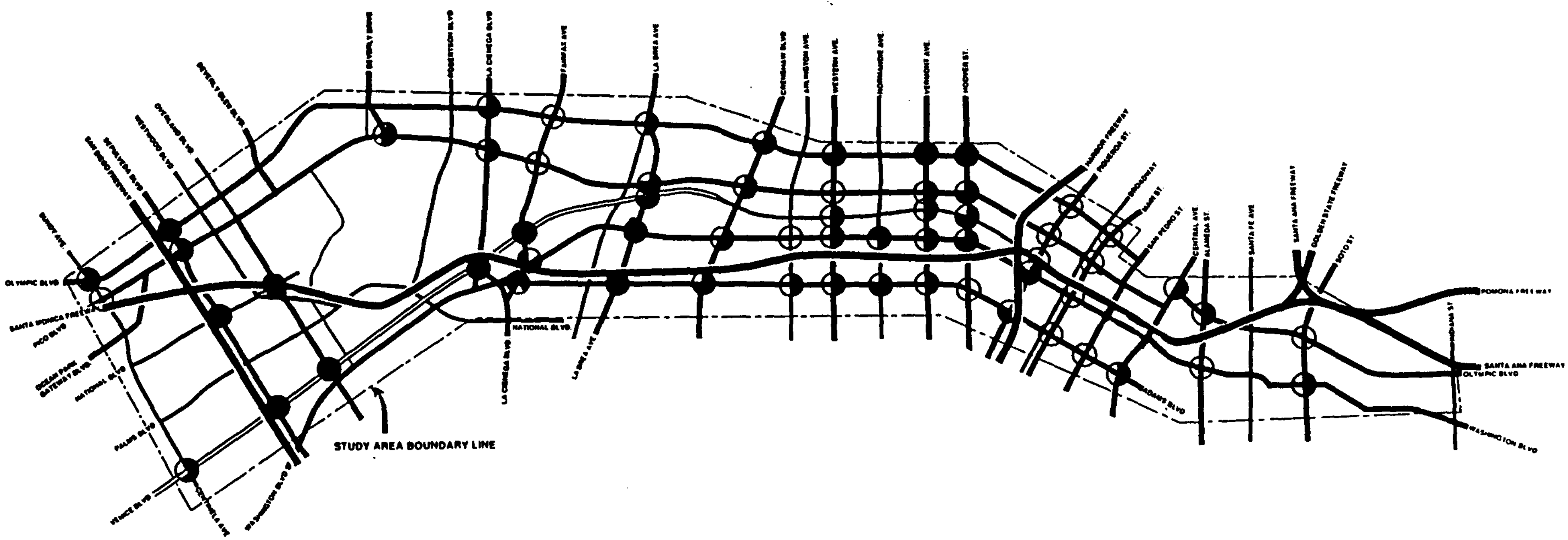


EXHIBIT 30



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

A,B,C ○ D ◑

E ◕ F ●

N

NO SCALE

KAKU ASSOCIATES

EXHIBIT 31

SMART CORRIDOR DEMONSTRATION PROJECT

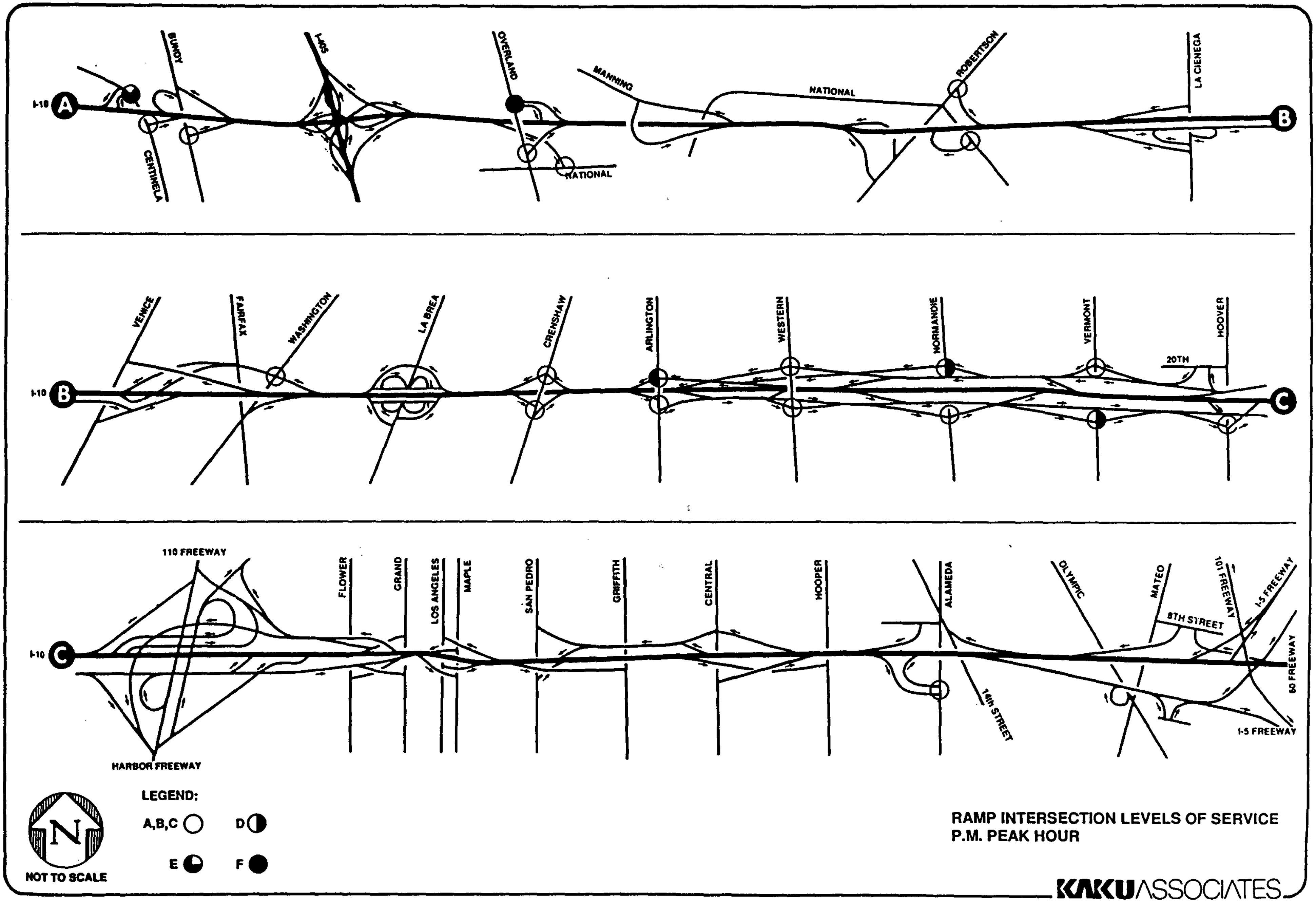


EXHIBIT 32

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 33
LEVEL OF SERVICE ANALYSIS - SANTA MONICA FREEWAY MAINLINE SEGMENTS

			AM Peak Hour			PM Peak Hour		
Location	# of Lanes	Capacity	Volume	V/C Ratio	LOS	Volume	V/C Ratio	LOS
EASTBOUND								
CENTINELA	4	7,000	7,280	1.04	F	6,190	0.88	D
OVERLAND	4	7,000	7,520	1.07	F	7,510	1.07	F
MANNING	5	8,750	9,240	1.06	F	9,120	1.04	F
NATIONAL	5	8,750	9,120	1.04	F	8,660	0.99	E
LA CIENEGA	4	7,000	9,440	1.35	F	9,470	1.35	F
FAIRFAX	5	8,750	7,800	0.89	D	7,870	0.90	D
HAUSER	5	8,750	8,880	1.01	F	10,050	1.15	F
LA BREA	4	7,000	8,300	1.19	F	8,060	1.15	F
HARCOURT	5	8,750	8,370	0.96	E	8,090	0.92	D
WEST	5	8,750	8,720	1.00	E	8,140	0.93	D
ARLINGTON	5	8,750	8,580	0.98	E	8,005	0.91	D
GRAMERCY	4	7,000	8,690	1.24	F	7,410	1.06	F
WESTERN	4	7,000	7,720	1.10	F	6,400	0.91	D
VERMONT	5	8,750	9,180	1.05	F	7,300	0.83	D
WASHINGTON	3	5,250	8,700	1.66	F	8,720	1.66	F
WESTBOUND								
CENTINELA	4	7,000	6,640	0.95	E	6,590	0.94	E
MANNING	4	7,000	8,680	1.24	F	8,500	1.21	F
LA CIENEGA	4	7,000	7,940	1.13	F	8,100	1.16	F
FAIRFAX	4	7,000	7,460	1.07	F	7,100	1.01	F
HAUSER	5	8,750	8,890	1.02	F	8,990	1.03	F
HARCOURT	5	8,750	8,040	0.92	D	8,430	0.96	E
WEST	5	8,750	10,320	1.18	F	10,640	1.22	F
ARLINGTON	5	8,750	8,160	0.93	D	8,860	1.01	F
GRAMERCY	4	7,000	8,500	1.21	F	9,590	1.37	F
WESTERN	4	7,000	8,370	1.20	F	9,050	1.29	F
VERMONT	5	8,750	5,440	0.62	C	5,360	0.61	C

- Segment capacity based on assumed theoretical lane capacity of 1,750 vehicles per hour per lane.
- Number of lanes from Exhibit 7.
- Volumes from Exhibits 14 and 15.
- Relation of LOS to V/C ratio for freeway segments from 1985 "Highway Capacity Manual," as follows: LOS A, 0.00-0.35; LOS B, 0.36-0.54; LOS C, 0.55-0.77; LOS D, 0.78-0.93; LOS E, 0.94-1.00; LOS F, >1.00.

SMART CORRIDOR DEMONSTRATION PROJECT

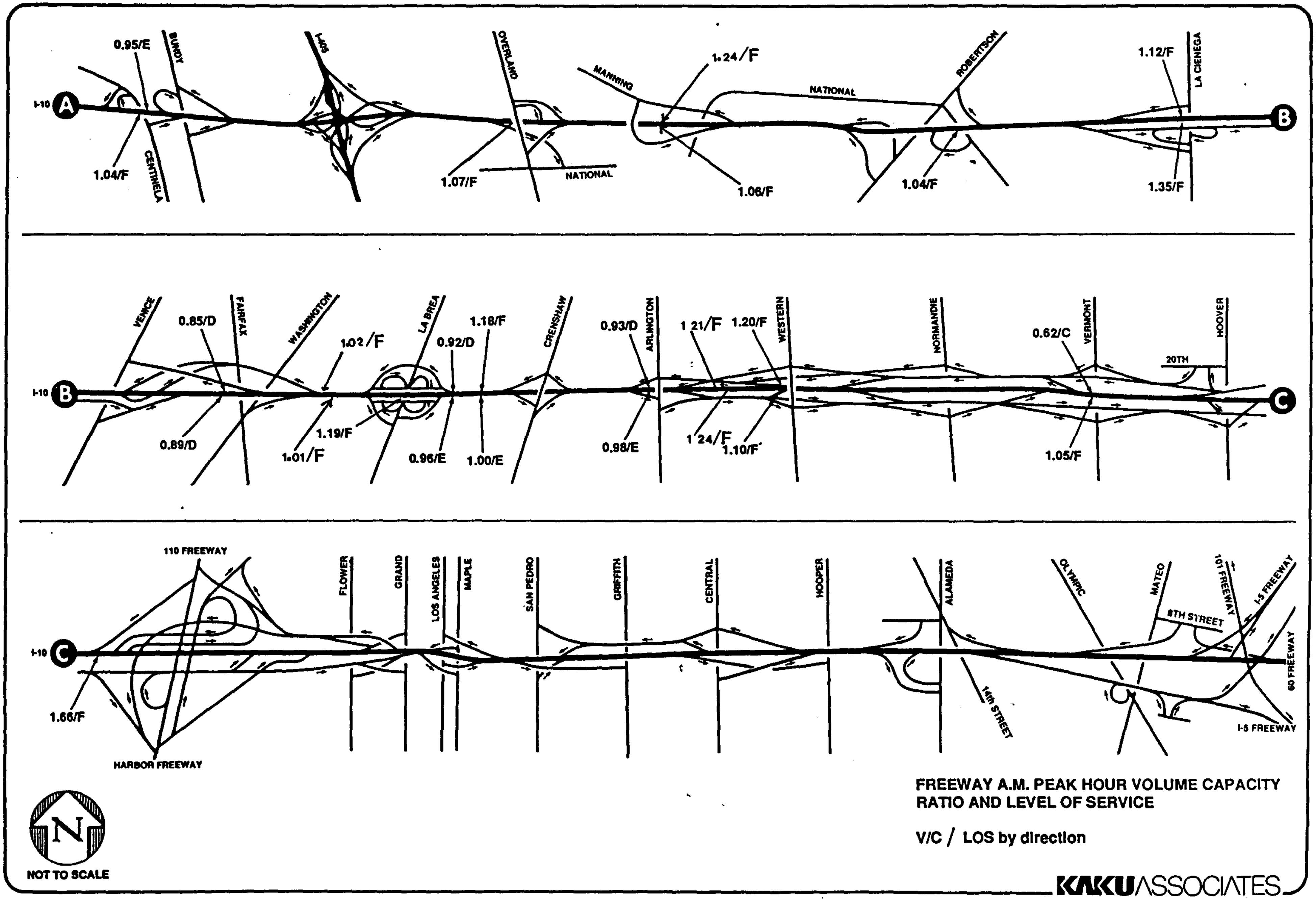
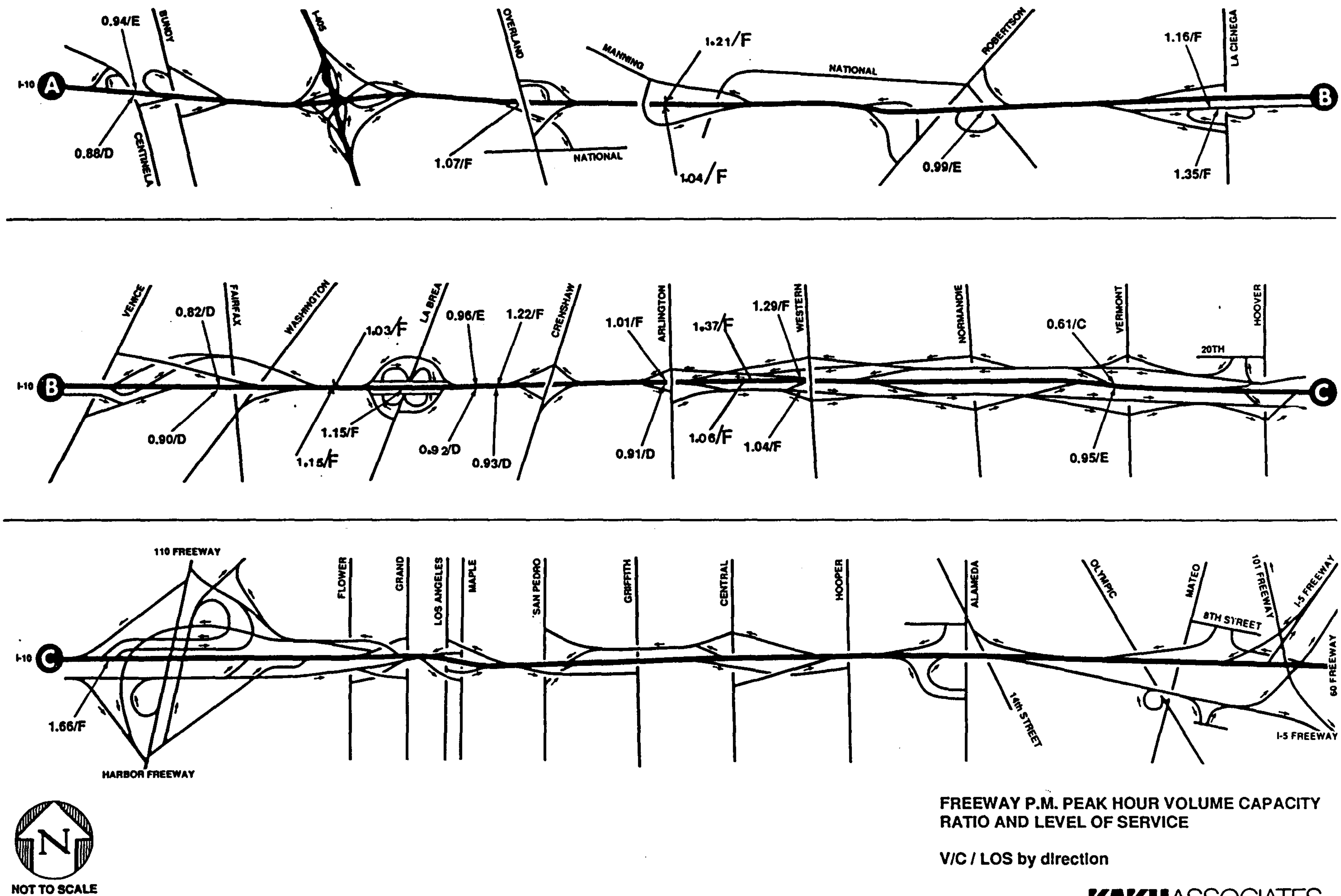


EXHIBIT 34



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

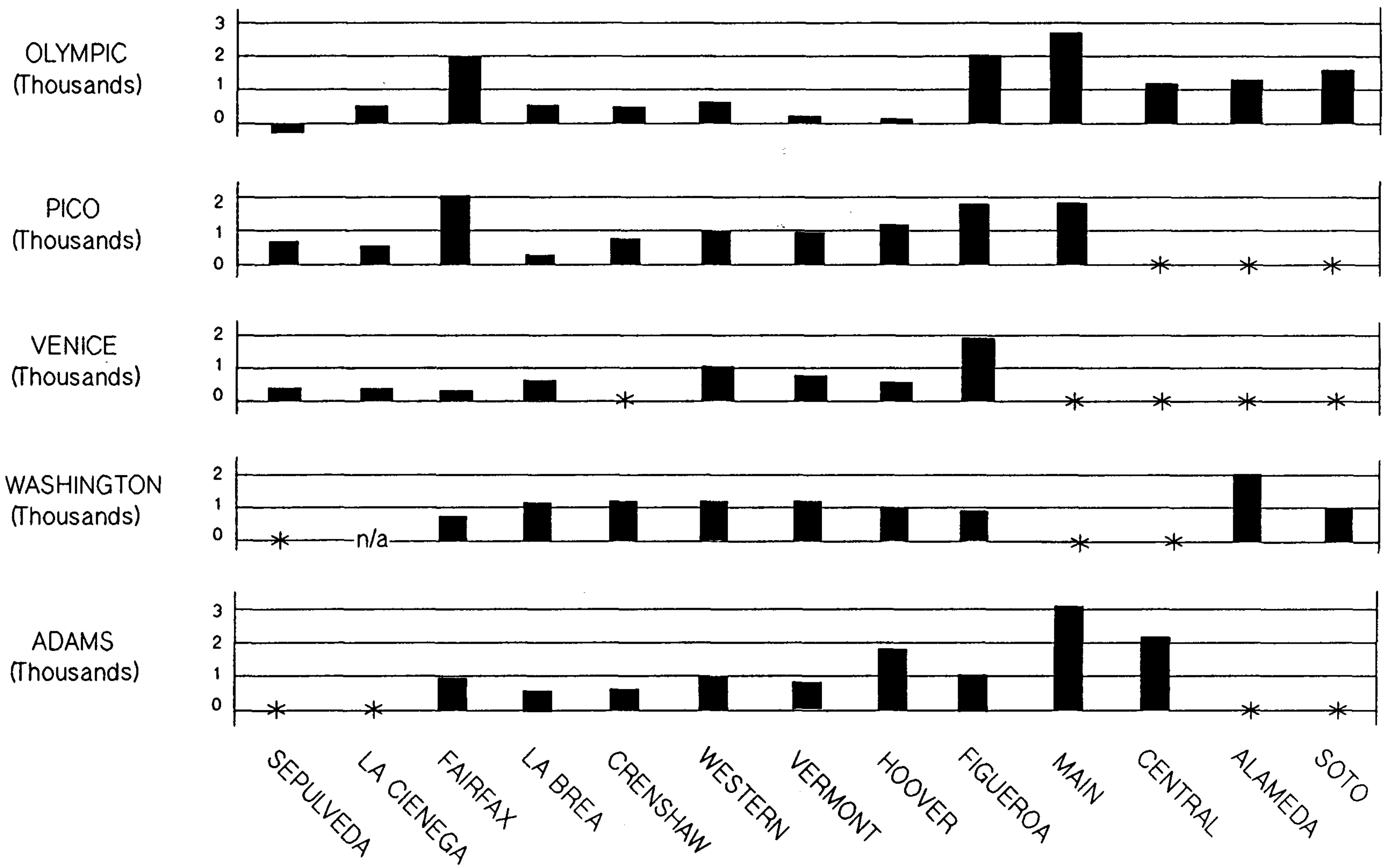
V/C / LOS by direction

KAKU ASSOCIATES

EXHIBIT 35

SURFACE STREET EXCESS CAPACITY ANALYSIS

A.M. PEAK HOUR EASTBOUND



*: Intersection does not exist or is not analyzed

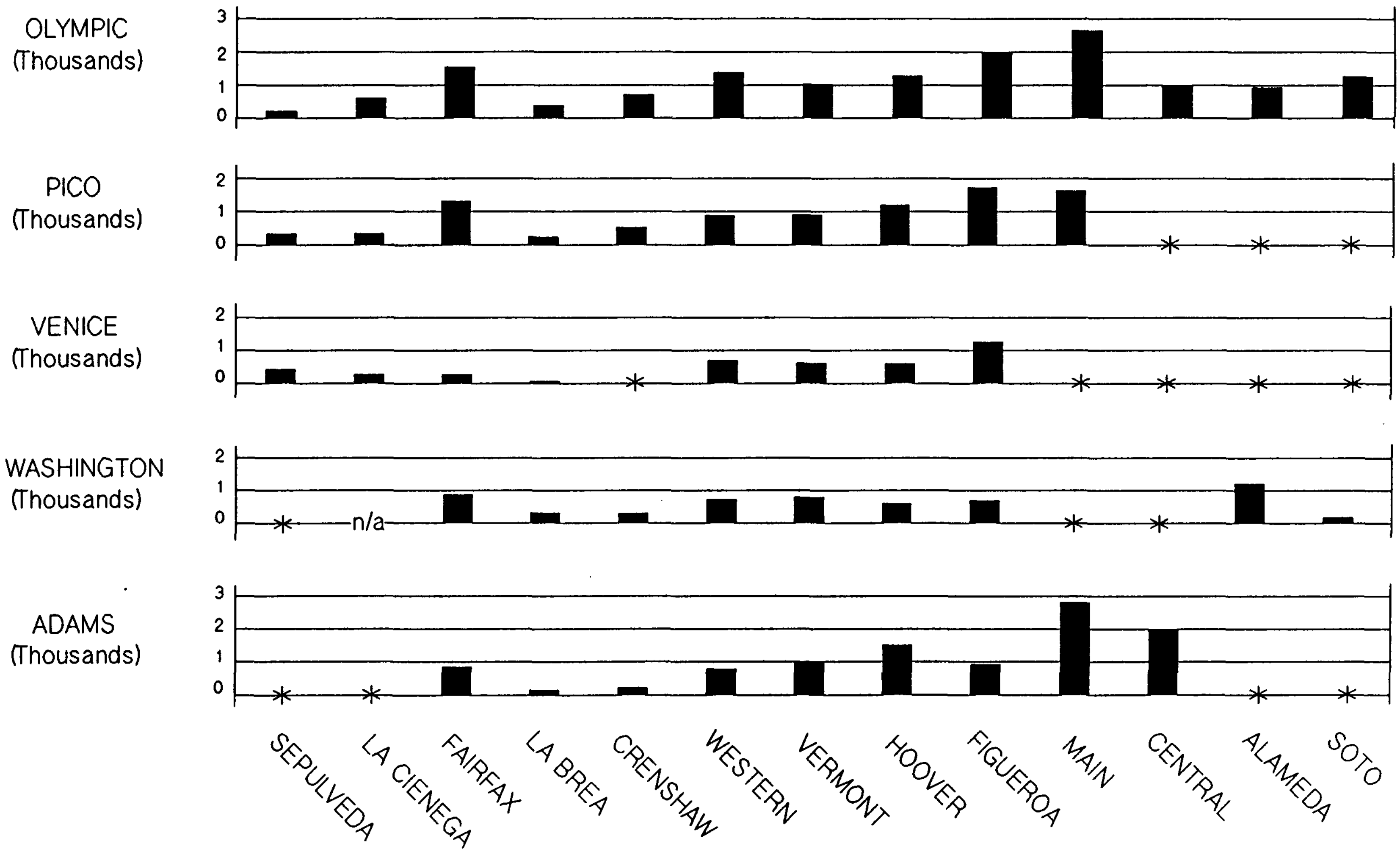
n/a: Traffic count data not available

KAKU ASSOCIATES

EXHIBIT 36A

SURFACE STREET EXCESS CAPACITY ANALYSIS

A.M. PEAK HOUR WESTBOUND



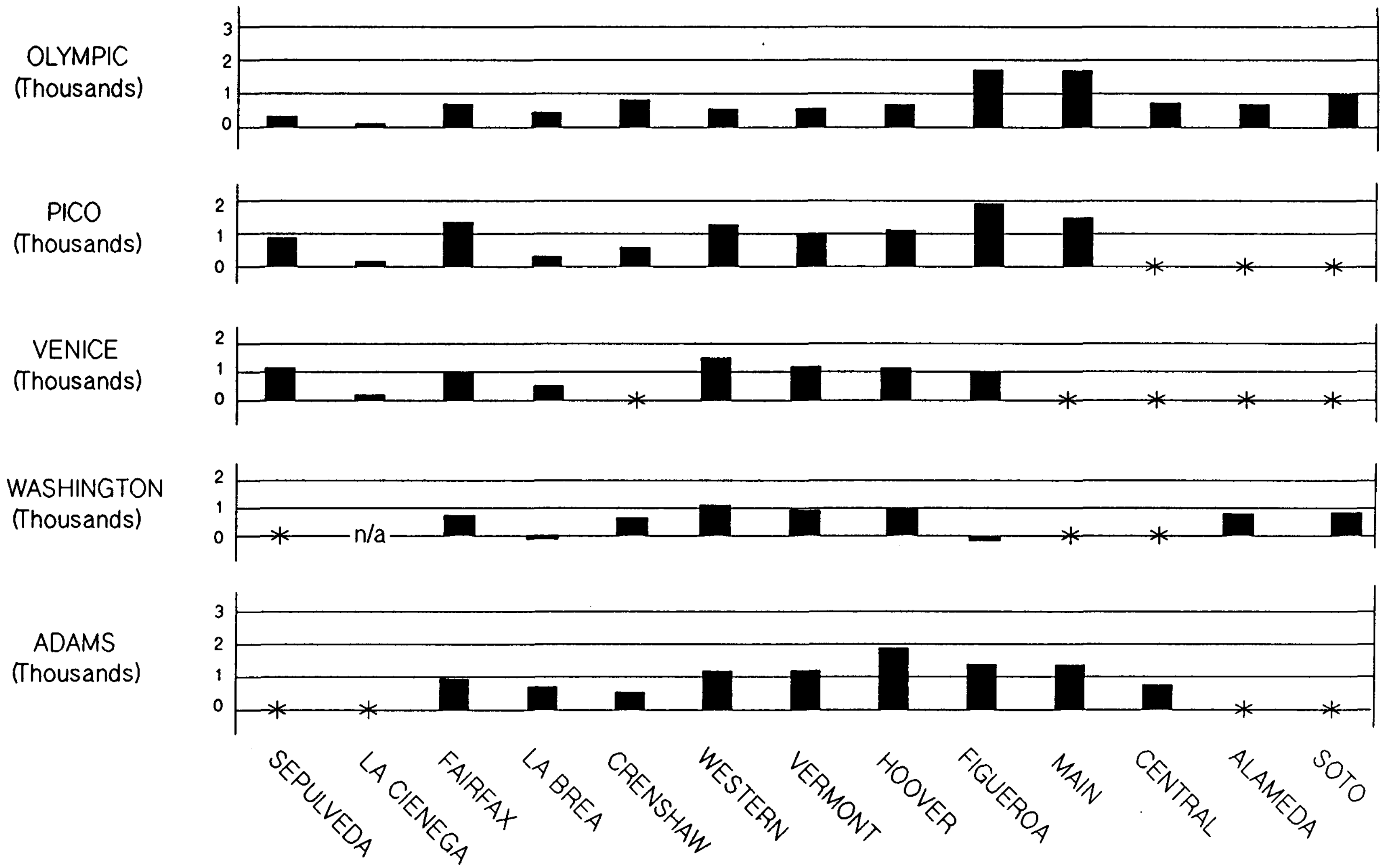
*: Intersection does not exist or is not analyzed
n/a: Traffic count data not available

KAKU ASSOCIATES

EXHIBIT 36B

SURFACE STREET EXCESS CAPACITY ANALYSIS

OFF PEAK EASTBOUND



*: Intersection does not exist or is not analyzed

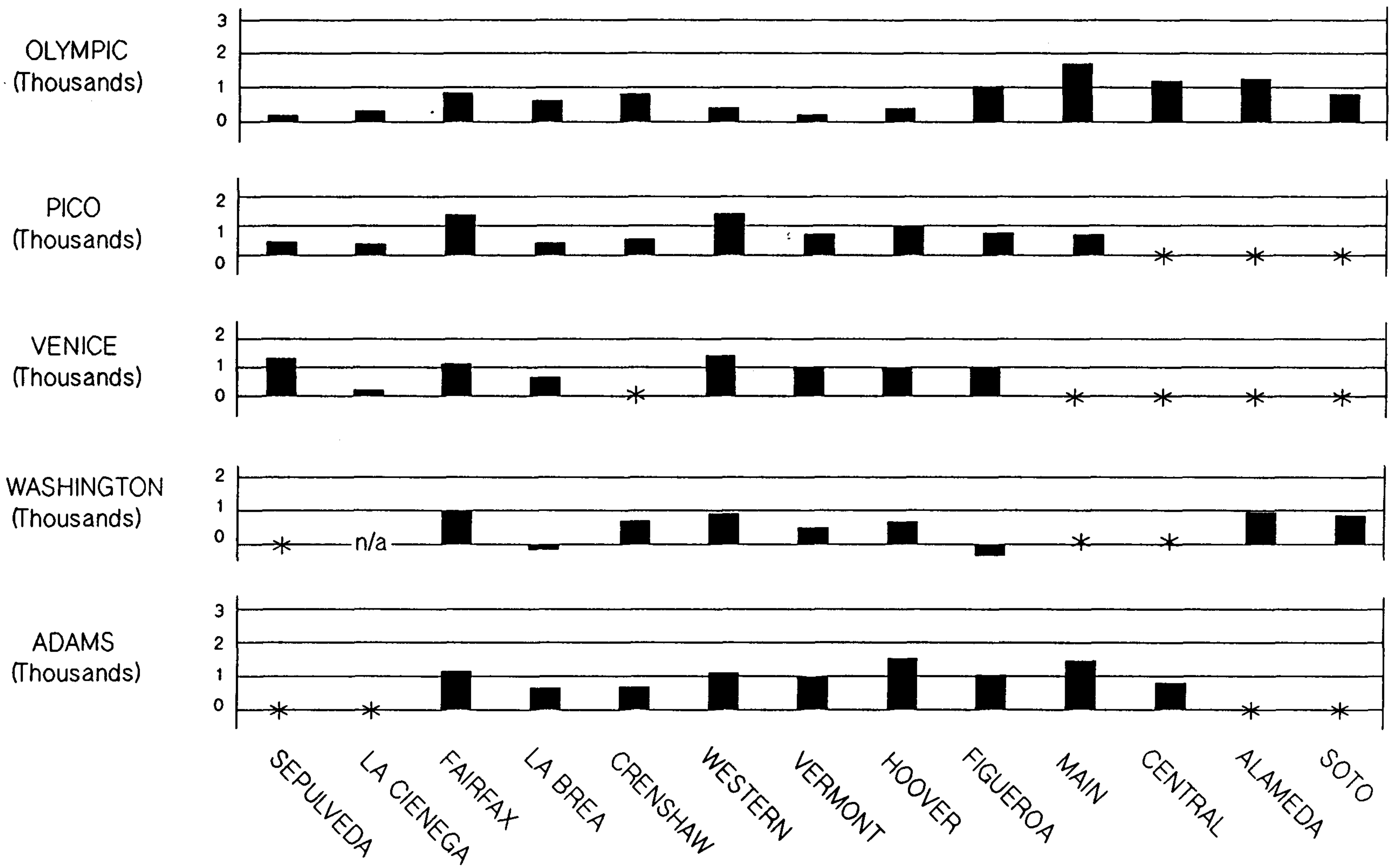
n/a: Traffic count data not available

KAKU ASSOCIATES

EXHIBIT 37A

SURFACE STREET EXCESS CAPACITY ANALYSIS

OFF PEAK WESTBOUND



*: Intersection does not exist or is not analyzed
n/a: Traffic count data not available

KAKU ASSOCIATES

EXHIBIT 37B

SURFACE STREET EXCESS CAPACITY ANALYSIS

P.M. PEAK HOUR EASTBOUND

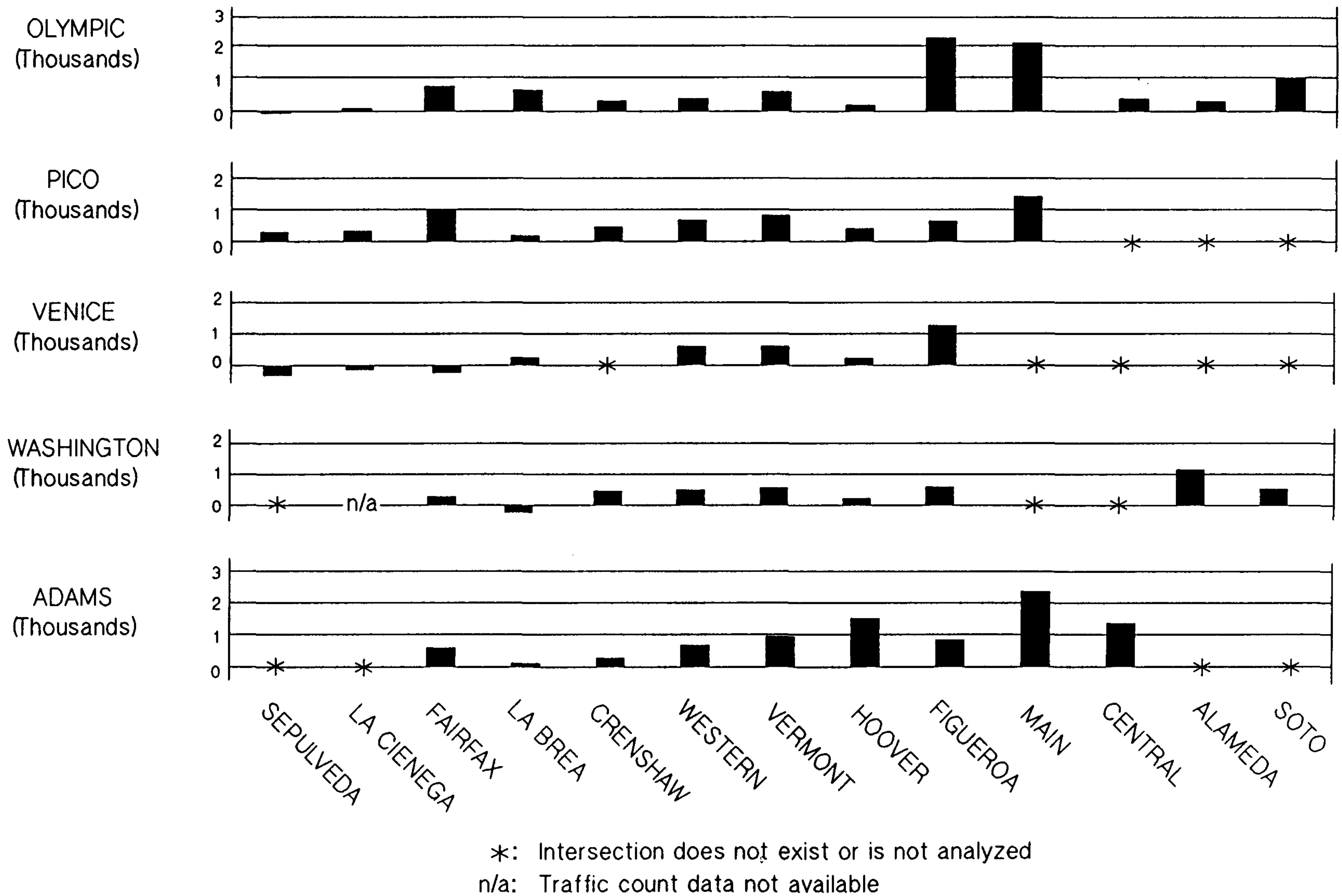
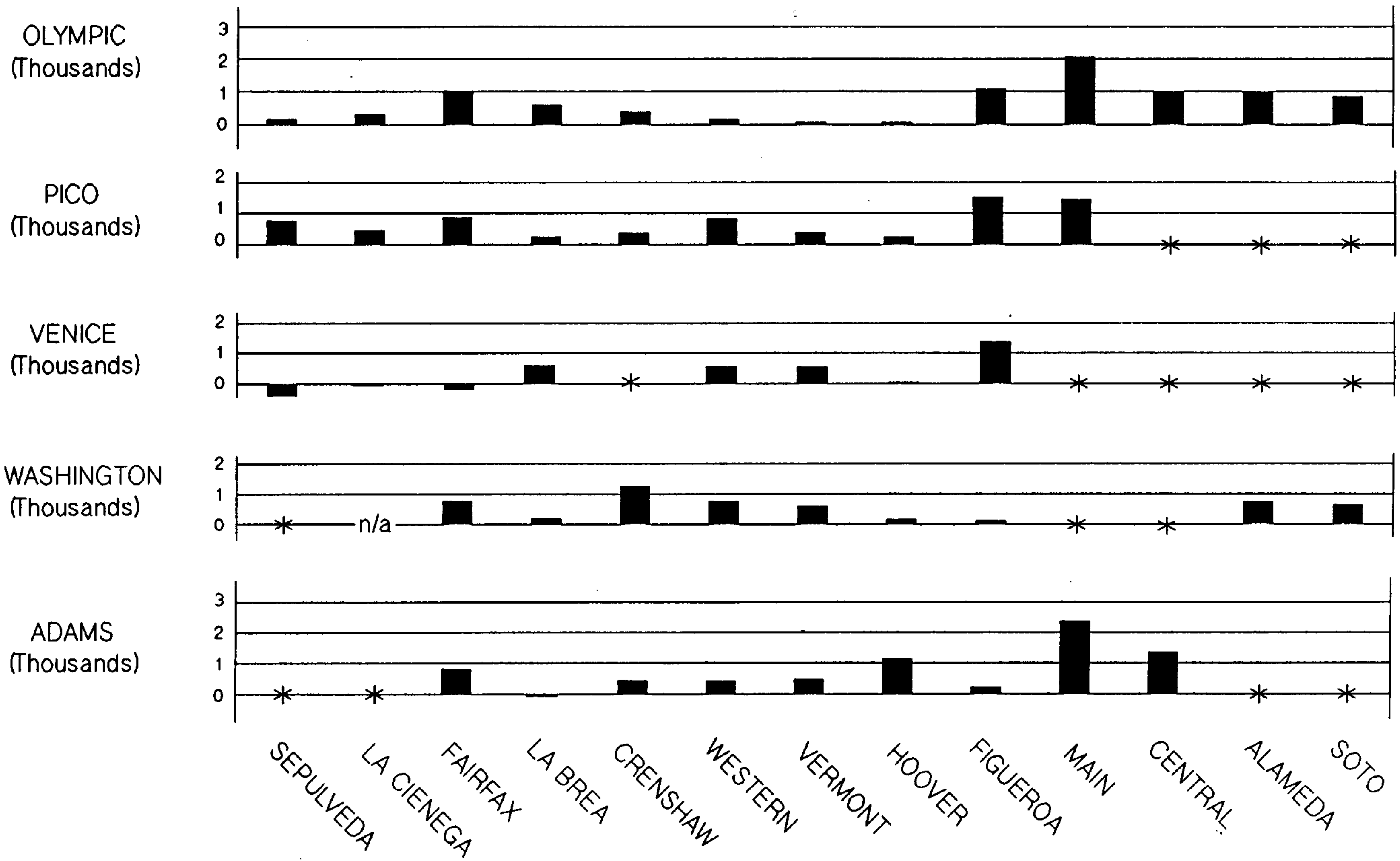


EXHIBIT 38A

SURFACE STREET EXCESS CAPACITY ANALYSIS

P.M. PEAK HOUR WESTBOUND



*: Intersection does not exist or is not analyzed
n/a: Traffic count data not available

KAKU ASSOCIATES

EXHIBIT 38B

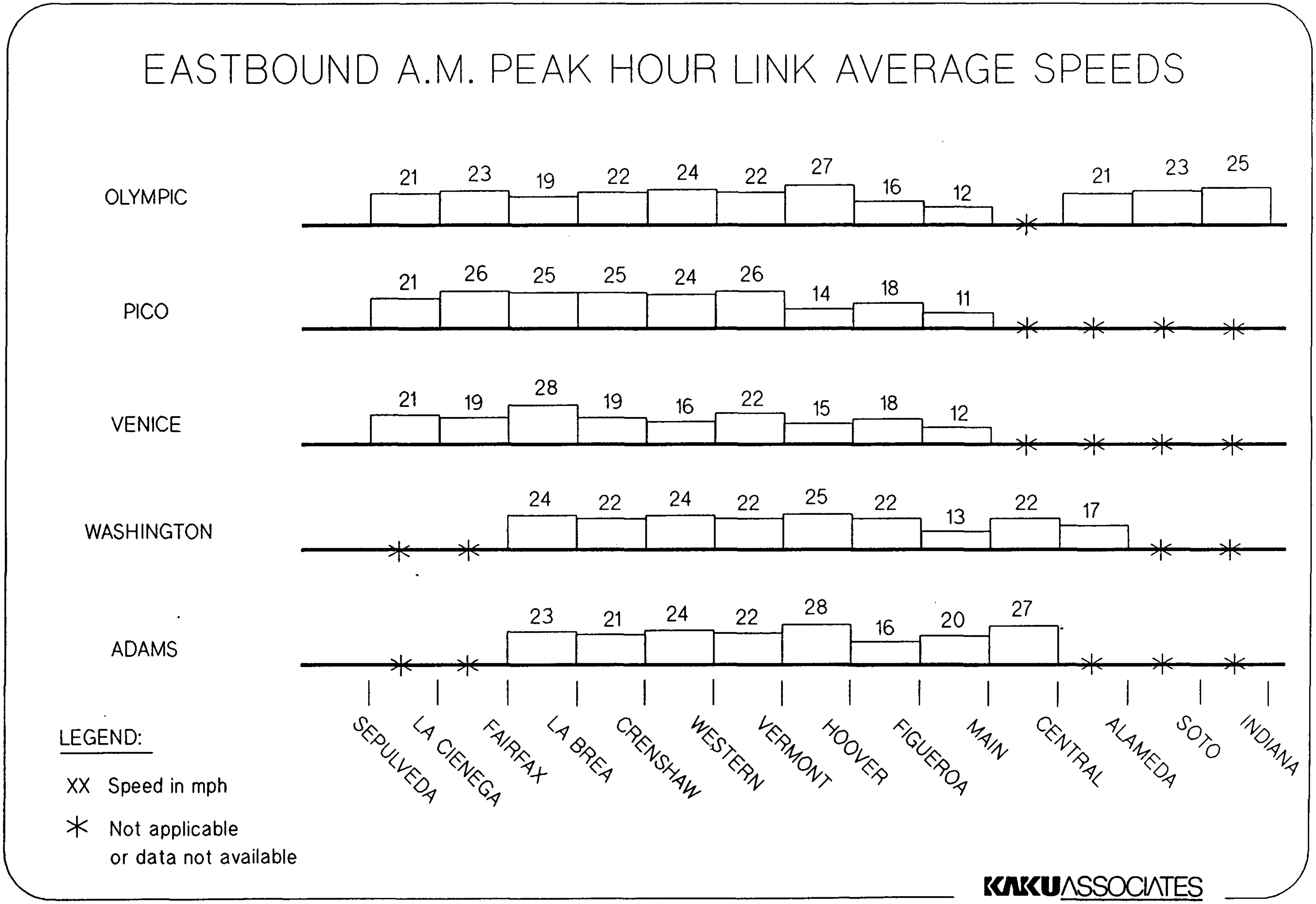

EASTBOUND A.M. PEAK HOUR LINK AVERAGE SPEEDS
OLYMPIC
21 23 19 22 24 22 27 16 12 21 23 25
PICO
21 26 25 25 24 26 14 18 11
VENICE
21 19 28 19 16 22 15 18 12
WASHINGTON
24 22 24 22 25 22 13 22 17
ADAMS
23 21 24 22 28 16 20 27
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
INDIANA
LEGEND:
XX Speed in mph
Not applicable or data not available
KAKU ASSOCIATES

Figure 39A

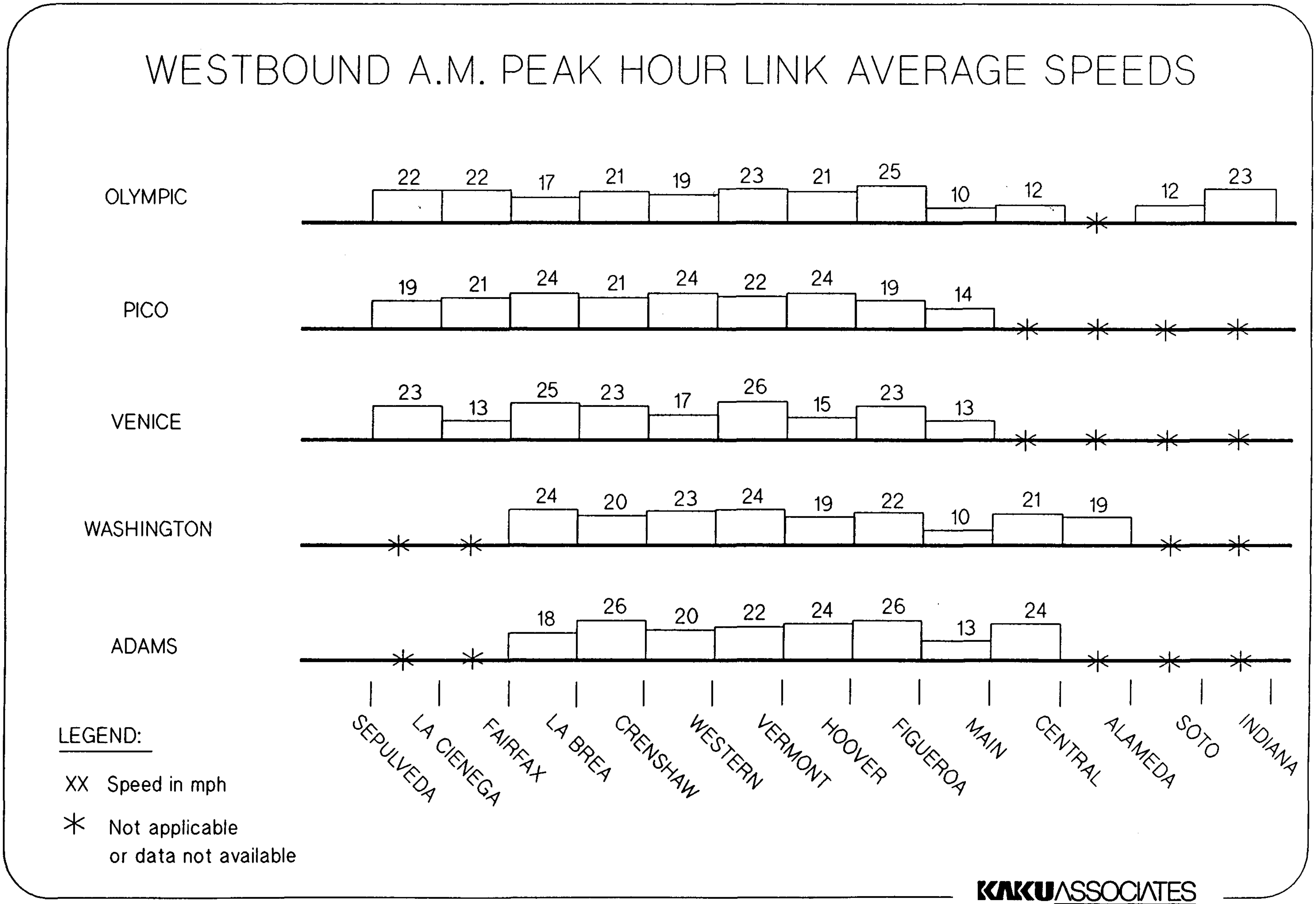

WESTBOUND A.M. PEAK HOUR LINK AVERAGE SPEEDS
OLYMPIC
22 22 17 21 19 23 21 25 10 12 12 23
PICO
19 21 24 21 24 22 24 19 14
VENICE
23 13 25 23 17 26 15 23 13
WASHINGTON
24 20 23 24 19 22 10 21 19
ADAMS
18 26 20 22 24 26 13 24
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
INDIANA
LEGEND:
XX Speed in mph
Not applicable
or data not available
KAKU ASSOCIATES

Figure 39B

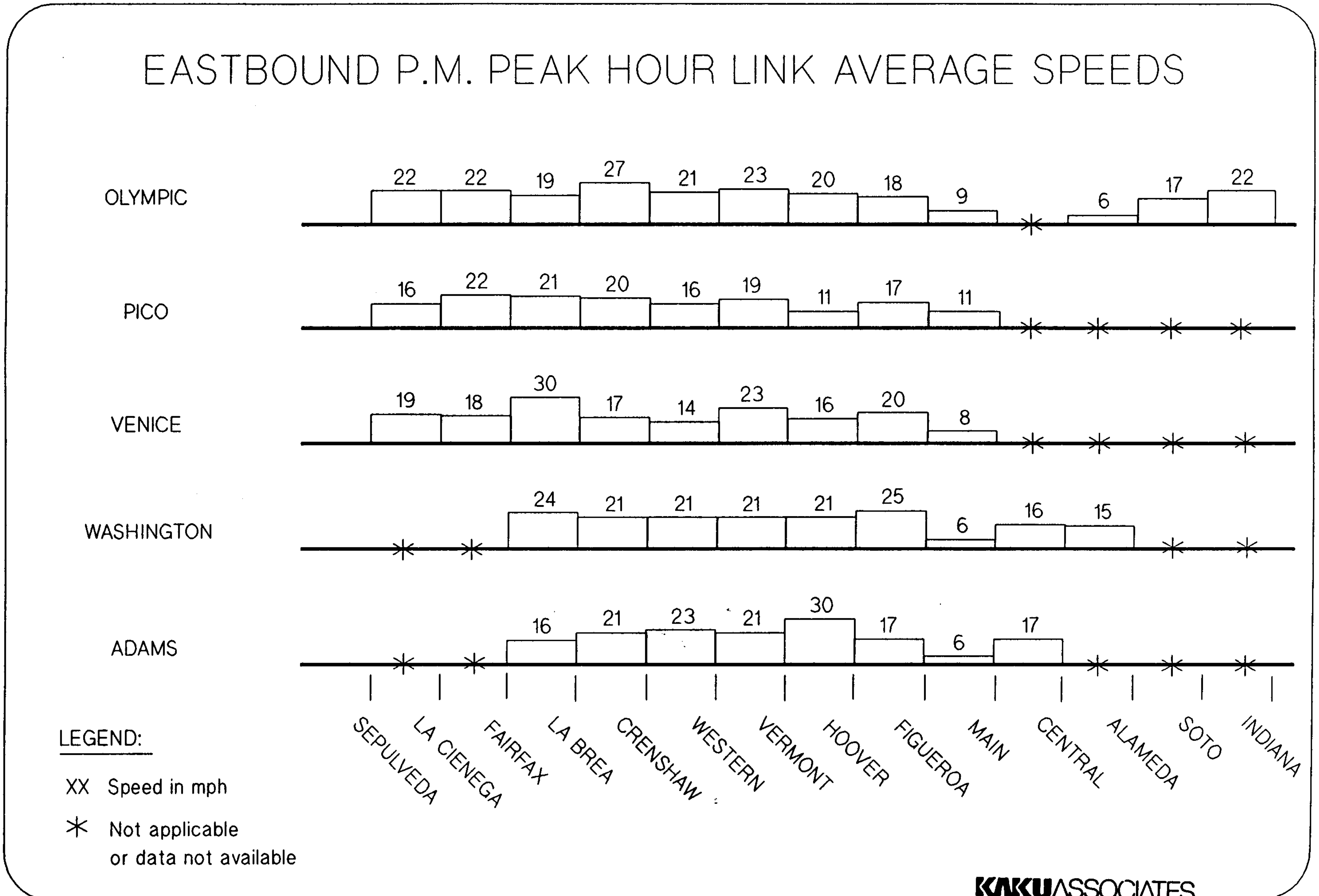

EASTBOUND P.M. PEAK HOUR LINK AVERAGE SPEEDS
OLYMPIC
22 22 19 27 21 23 20 18 9 6 17 22
PICO
16 22 21 20 16 19 11 17 11
VENICE
19 18 30 17 14 23 16 20 8
WASHINGTON
24 21 21 21 21 25 6 16 15
ADAMS
16 21 23 21 30 17 6 17
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
INDIANA
LEGEND:
XX Speed in mph
* Not applicable or data not available
KAKU ASSOCIATES

Figure 40A

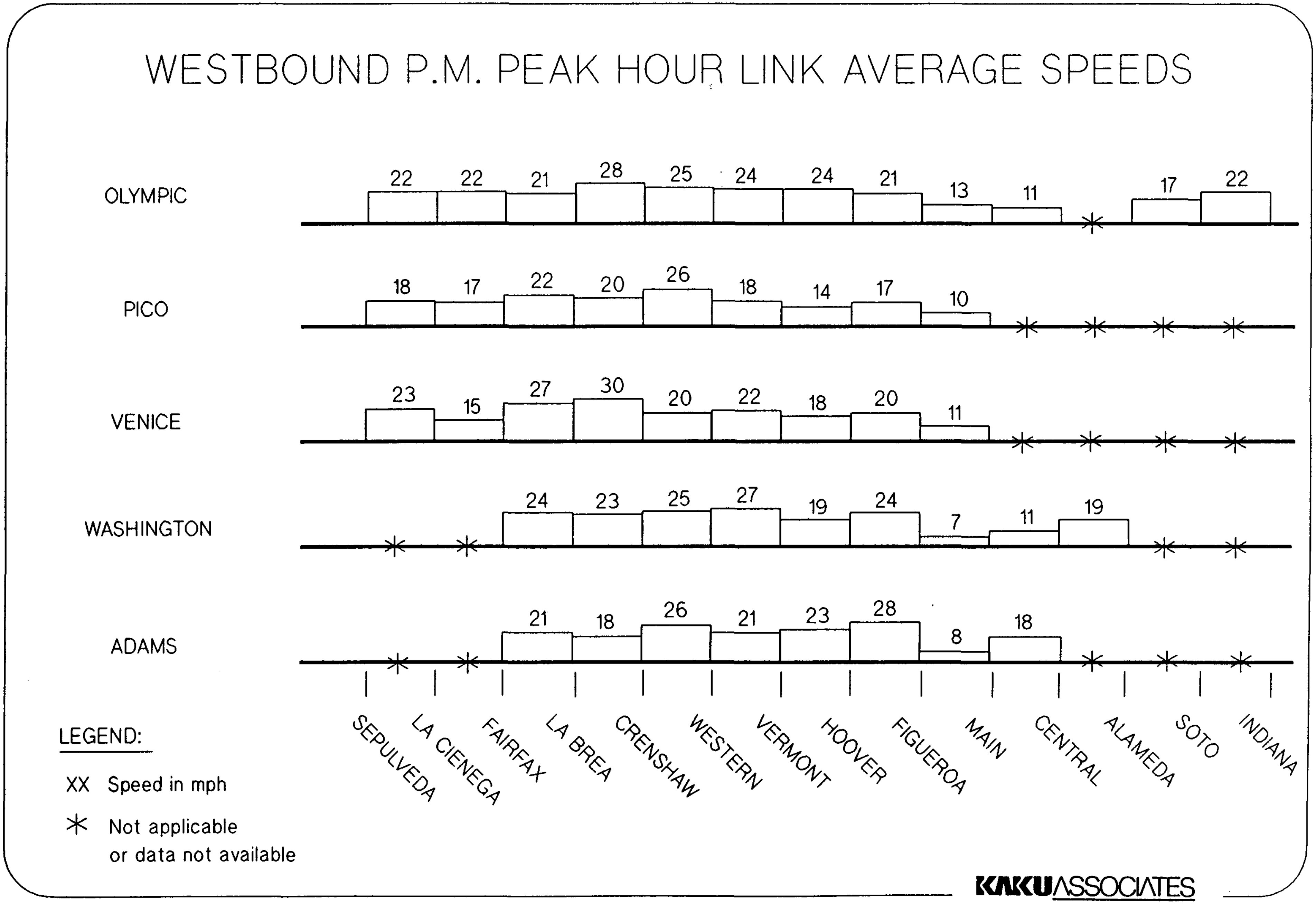

WESTBOUND P.M. PEAK HOUR LINK AVERAGE SPEEDS
OLYMPIC
22 22 21 28 25 24 24 21 13 11 17 22
PICO
18 17 22 20 26 18 14 17 10
VENICE
23 15 27 30 20 22 18 20 11
WASHINGTON
24 23 25 27 19 24 7 11 19
ADAMS
21 18 26 21 23 28 8 18
SEPULVEDA
LA CIENEGA
FAIRFAX
LA BREA
CRENSHAW
WESTERN
VERMONT
HOOVER
FIGUEROA
MAIN
CENTRAL
ALAMEDA
SOTO
INDIANA
LEGEND:
XX Speed in mph
Not applicable
or data not available
KAKU ASSOCIATES

Figure 40B

SMART CORRIDOR DEMONSTRATION PROJECT

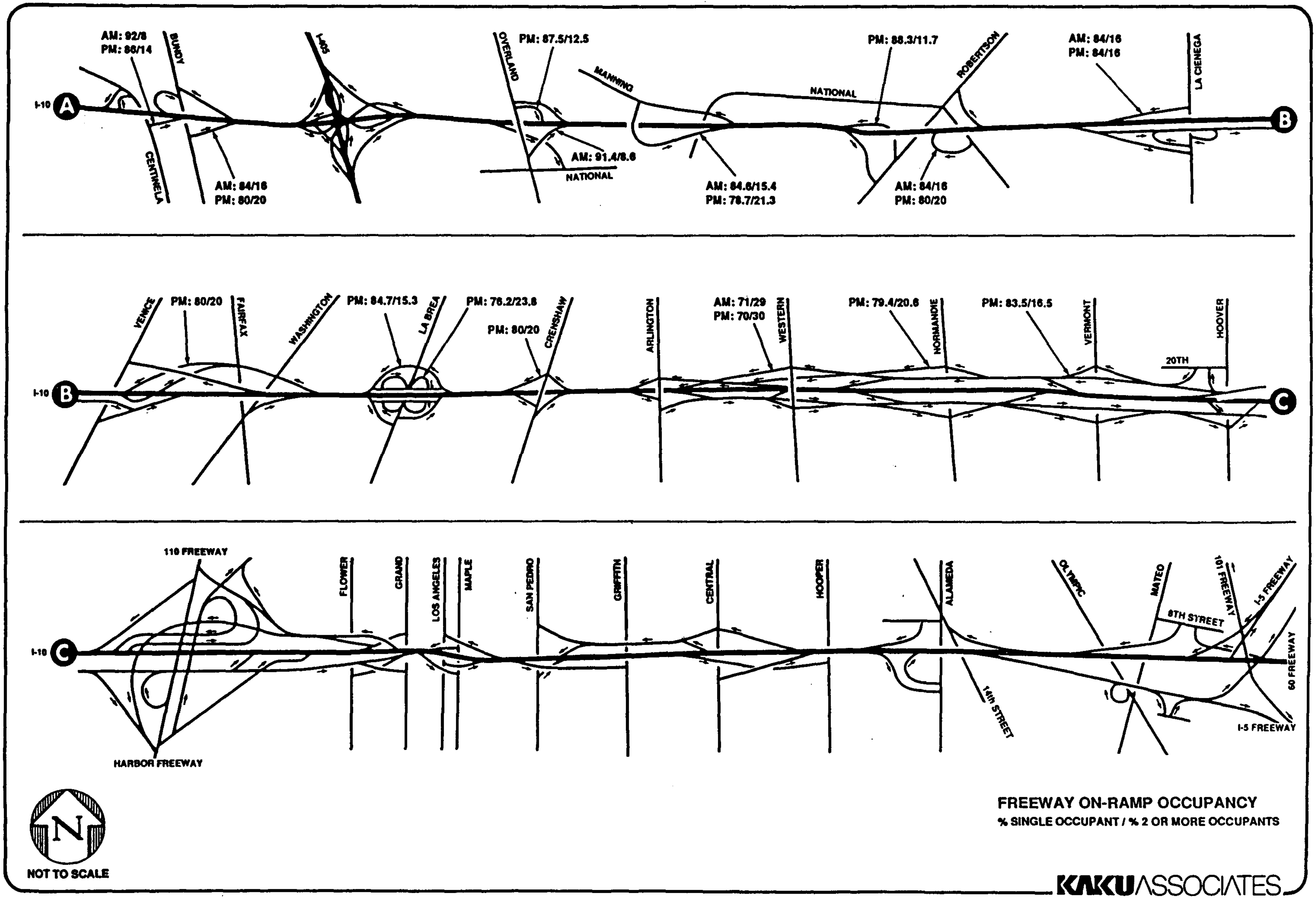


EXHIBIT 41

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 42
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 42 (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 Truck defined as three or more axles.
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 43
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 43 (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 Definition of bus includes public, private and school buses.
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 44
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%

o Truck defined as three or more axles.

Source: Caltrans.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 45
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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	57	0.67
9	33	OLYMPIC & HOOVER	36	0.41
10	*	OLYMPIC & FIGUEROA	27	n/a
11	*	OLYMPIC & MAIN	20	n/a
12	*	OLYMPIC & SAN PEDRO	n/a	n/a
13	*	OLYMPIC & CENTRAL	22	0.49
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	19	0.23
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	9	0.17
23	78	PICO & LA BREA	40	0.50
24	83	PICO & CRENSHAW	33	0.53
25	88	PICO & WESTERN	57	1.00
26	93	PICO & VERMONT	59	1.01
27	96	PICO & HOOVER	33	0.63
28	*	PICO & FIGUEROA	22	0.56
29	*	PICO & MAIN	6	0.20
30	106	NATIONAL & SEPULVEDA	19	0.30
31	302	NATIONAL/OVERLAND/WB RAMPS	20	0.29
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	23	0.29
38	163	VENICE & LA BREA	55	0.59
39	172	VENICE & WESTERN	44	0.77
40	177	VENICE & VERMONT	47	0.80
41	180	VENICE & HOOVER	n/a	n/a
42	*	VENICE & FIGUEROA	20	0.55

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 45 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP INTERSECTIONS
(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	2	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
50	205	WASHINGTON & VERMONT	n/a	n/a
51	*	WASHINGTON & HOOVER	47	0.64
52	*	WASHINGTON & FIGUEROA	46	0.70
53	*	WASHINGTON & MAIN	17	0.35
54	*	WASHINGTON & SAN PEDRO	45	0.70
55	*	WASHINGTON & CENTRAL	52	0.90
56	*	WASHINGTON & ALAMEDA	17	0.28
57	*	WASHINGTON & SOTO	20	0.33
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	32	0.76
65	*	ADAMS & VERMONT	28	0.58
66	*	ADAMS & HOOVER	26	0.51
67	*	ADAMS & FIGUEROA	46	1.00
68	*	ADAMS & MAIN	33	0.92
69	268	ADAMS & SAN PEDRO	31	0.71
70	270	ADAMS & CENTRAL	27	0.62
71	323	CENTINELA & WB RAMPS	0	0.00
72	328	CENTINELA & EB ON-RAMP	1	n/a
73	329	BUNDY & EB ON-RAMP	0	0.00
74	302	NATIONAL/OVERLAND/WB RAMPS	20	0.29
75	303	OVERLAND & EB ON-RAMP	9	0.15
76	305	NATIONAL & EB OFF-RAMP	1	n/a
77	136	NATIONAL & WB OFF/MANNING	0	0.00
78	139	ROBERTSON & WB OFF/KINCARDINE	2	n/a
79	141	NATIONAL & EB ON-RAMP	2	n/a
80	143	LA CIENEGA & WB ON/DAVID	21	0.27
81	157	VENICE & WB OFF/CADILLAC	10	0.15
82	184	FAIRFAX & EB OFF/WB ON/APPLE	7	0.18
83	186	WASHINGTON & WB OFF-RAMP	5	0.16
84	216	CRENSHAW & WB RAMPS	14	0.08

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 45 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP INTERSECTIONS
(June 1, 1985 to June 1, 1988)

Study Num	ATSAC Smart Num	Intersection	Total Number of Accidents	Accident Rate (per million vehicles)
85	217	CRENSHAW & EB RAMPS	9	0.09
86	221	ARLINGTON & WB RAMPS	6	0.12
87	222	ARLINGTON & EB RAMPS	9	0.10
88	226	WESTERN & WB RAMPS	6	0.08
89	227	WESTERN & EB RAMPS	4	n/a
90	*	NORMANDIE & WB RAMPS	2	0.04
91	*	NORMANDIE & EB RAMPS	8	0.19
92	*	VERMONT & WB RAMPS	5	0.06
93	*	VERMONT & EB RAMPS	3	n/a
94	*	20TH & WB RAMPS	1	n/a
95	*	HOOVER & EB RAMPS	3	0.04
96	*	GRAND & WB ON-RAMP/17TH	8	0.43
97	*	GRAND & EB OFF-RAMP/18TH	5	0.24
98	*	LOS ANGELES & WB OFF/17TH	22	0.92
99	*	LOS ANGELES & EB ON-RAMP	0	0.00
100	*	MAPLE & WB ON-RAMP	0	0.00
101	244	MAPLE & EB OFF-RAMP/18TH	1	n/a
102	245	SAN PEDRO & WB OFF/16TH	15	0.36
103	247	CENTRAL & WB RAMPS/16TH	6	0.22
104	251	ALAMEDA & EB RAMPS	0	0.00

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o Intersection accidents defined as all accidents occurring within crosswalk lines, and rear end and side swipe approach accidents within 200 feet of intersection.
o Intersection #31 (National/Overland/WB Ramps) is same as intersection #74 in ramp intersection analysis.
* Indicates intersection not in Smart Corridor ATSAC system.

Source: LADOT, Traffic Accident Reports, August 1988 & March 1989.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 46
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
26	93	PICO & VERMONT	59	1.01	1
25	88	PICO & WESTERN	57	1.00	2
8	30	OLYMPIC & VERMONT	57	0.67	2
38	163	VENICE & LA BREA	55	0.59	3
55	*	WASHINGTON & CENTRAL	52	0.90	4
36	156	VENICE & LA CIENEGA	48	0.58	5
7	25	OLYMPIC & WESTERN	48	0.56	5
40	177	VENICE & VERMONT	47	0.80	6
51	*	WASHINGTON & HOOVER	47	0.64	6
67	*	ADAMS & FIGUEROA	46	1.00	7
52	*	WASHINGTON & FIGUEROA	46	0.70	7
61	218	ADAMS & CRENSHAW	46	0.61	7
54	*	WASHINGTON & SAN PEDRO	45	0.70	8
39	172	VENICE & WESTERN	44	0.77	9
60	213	ADAMS & LA BREA	43	0.52	10
23	78	PICO & LA BREA	40	0.50	11
15	241	OLYMPIC & SOTO	37	0.54	12
6	20	OLYMPIC & CRENSHAW	36	0.50	13
9	33	OLYMPIC & HOOVER	36	0.41	13
48	201	WASHINGTON & WESTERN	35	0.55	14
45	190	WASHINGTON & LA BREA	35	0.38	14
32	346	VENICE & CENTINELA	34	0.49	15
68	*	ADAMS & MAIN	33	0.92	16
27	96	PICO & HOOVER	33	0.63	16
24	83	PICO & CRENSHAW	33	0.53	16
5	14	OLYMPIC & LA BREA	33	0.36	16
64	*	ADAMS & NORMANDIE	32	0.76	17
14	236	OLYMPIC & ALAMEDA	32	0.70	17
69	268	ADAMS & SAN PEDRO	31	0.71	18
34	148	VENICE & OVERLAND	31	0.39	18
47	198	WASHINGTON & ARLINGTON	29	0.51	19
65	*	ADAMS & VERMONT	28	0.58	20
46	194	WASHINGTON & CRENSHAW	28	0.40	20
3	3	OLYMPIC & LA CIENEGA	28	0.28	20
70	270	ADAMS & CENTRAL	27	0.62	21
21	70	PICO & LA CIENEGA	27	0.32	21
10	*	OLYMPIC & FIGUEROA	27	n/a	21
62	223	ADAMS & ARLINGTON	26	0.69	22
66	*	ADAMS & HOOVER	26	0.51	22
63	228	ADAMS & WESTERN	26	0.49	22
49	203	WASHINGTON & NORMANDIE	23	0.35	23
18	297	PICO & SEPULVEDA	23	0.33	23

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 46 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
37	158	VENICE & FAIRFAX	23	0.29	23
98	*	LOS ANGELES & WB OFF/17TH	22	0.92	24
28	*	PICO & FIGUEROA	22	0.56	24
13	*	OLYMPIC & CENTRAL	22	0.49	24
33	146	VENICE & SEPULVEDA	22	0.26	24
2	274	OLYMPIC & SEPULVEDA	22	0.22	24
80	143	LA CIENEGA & WB ON/DAVID	21	0.27	25
42	*	VENICE & FIGUEROA	20	0.55	26
57	*	WASHINGTON & SOTO	20	0.33	26
31/74	302	NATIONAL/OVERLAND/WB RAMPS	20	0.29	26
11	*	OLYMPIC & MAIN	20	n/a	26
30	106	NATIONAL & SEPULVEDA	19	0.30	27
4	7	OLYMPIC & FAIRFAX	19	0.28	27
17	325	PICO & BUNDY	19	0.23	27
53	*	WASHINGTON & MAIN	17	0.35	28
56	*	WASHINGTON & ALAMEDA	17	0.28	28
59	207	ADAMS & FAIRFAX	16	0.38	29
102	245	SAN PEDRO & WB OFF/16TH	15	0.36	30
44	185	WASHINGTON & FAIRFAX	14	0.24	31
84	216	CRENSHAW & WB RAMPS	14	0.08	31
81	157	VENICE & WB OFF/CADILLAC	10	0.15	32
22	72	PICO & FAIRFAX	9	0.17	33
20	63	PICO & BEVERLY	9	0.17	33
75	303	OVERLAND & EB ON-RAMP	9	0.15	33
87	222	ARLINGTON & EB RAMPS	9	0.10	33
85	217	CRENSHAW & EB RAMPS	9	0.09	33
96	*	GRAND & WB ON-RAMP/17TH	8	0.43	34
91	*	NORMANDIE & EB RAMPS	8	0.19	34
82	184	FAIRFAX & EB OFF/WB ON/APPLE	7	0.18	35
103	247	CENTRAL & WB RAMPS/16TH	6	0.22	36
29	*	PICO & MAIN	6	0.20	36
86	221	ARLINGTON & WB RAMPS	6	0.12	36
88	226	WESTERN & WB RAMPS	6	0.08	36
97	*	GRAND & EB OFF-RAMP/18TH	5	0.24	37
83	186	WASHINGTON & WB OFF-RAMP	5	0.16	37
35	*	VENICE & CULVER	5	0.08	37
92	*	VERMONT & WB RAMPS	5	0.06	37
89	227	WESTERN & EB RAMPS	4	n/a	38
95	*	HOOVER & EB RAMPS	3	0.04	39
93	*	VERMONT & EB RAMPS	3	n/a	39
90	*	NORMANDIE & WB RAMPS	2	0.04	40
19	295	PICO & BEVERLY GLEN	2	0.03	40

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 46 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
43	*	WASHINGTON & LA CIENEGA	2	n/a	40
78	139	ROBERTSON & WB OFF/KINCARDINE	2	n/a	40
79	141	NATIONAL & EB ON-RAMP	2	n/a	40
72	328	CENTINELA & EB ON-RAMP	1	n/a	41
76	305	NATIONAL & EB OFF-RAMP	1	n/a	41
94	*	20TH & WB RAMPS	1	n/a	41
101	244	MAPLE & EB OFF-RAMP/18TH	1	n/a	41
71	323	CENTINELA & WB RAMPS	0	0.00	42
73	329	BUNDY & EB ON-RAMP	0	0.00	42
77	136	NATIONAL & WB OFF/MANNING	0	0.00	42
99	*	LOS ANGELES & EB ON-RAMP	0	0.00	42
100	*	MAPLE & WB ON-RAMP	0	0.00	42
104	251	ALAMEDA & EB RAMPS	0	0.00	42
1	319	OLYMPIC & BUNDY	n/a	n/a	n/a
12	*	OLYMPIC & SAN PEDRO	n/a	n/a	n/a
16	*	OLYMPIC & INDIANA	n/a	n/a	n/a
41	180	VENICE & HOOVER	n/a	n/a	n/a
50	205	WASHINGTON & VERMONT	n/a	n/a	n/a
58	*	WASHINGTON & INDIANA	n/a	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.
- o Intersection #31 (National/Overland/WB Ramps) is same as intersection #74 in ramp intersection analysis.
- * Indicates intersection not in Smart Corridor ATSAC system.

Source: LADOT, Traffic Accident Reports, August 1988 & March 1989.

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 47
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
26	93	PICO & VERMONT	59	1.01	1
25	88	PICO & WESTERN	57	1.00	2
67	*	ADAMS & FIGUEROA	46	1.00	2
68	*	ADAMS & MAIN	33	0.92	3
98	*	LOS ANGELES & WB OFF/17TH	22	0.92	3
55	*	WASHINGTON & CENTRAL	52	0.90	4
40	177	VENICE & VERMONT	47	0.80	5
39	172	VENICE & WESTERN	44	0.77	6
64	*	ADAMS & NORMANDIE	32	0.76	7
69	268	ADAMS & SAN PEDRO	31	0.71	8
52	*	WASHINGTON & FIGUEROA	46	0.70	9
54	*	WASHINGTON & SAN PEDRO	45	0.70	9
14	236	OLYMPIC & ALAMEDA	32	0.70	9
62	223	ADAMS & ARLINGTON	26	0.69	10
8	30	OLYMPIC & VERMONT	57	0.67	11
51	*	WASHINGTON & HOOVER	47	0.64	12
27	96	PICO & HOOVER	33	0.63	13
70	270	ADAMS & CENTRAL	27	0.62	14
61	218	ADAMS & CRENSHAW	46	0.61	15
38	163	VENICE & LA BREA	55	0.59	16
36	156	VENICE & LA CIENEGA	48	0.58	17
65	*	ADAMS & VERMONT	28	0.58	17
7	25	OLYMPIC & WESTERN	48	0.56	18
28	*	PICO & FIGUEROA	22	0.56	18
48	201	WASHINGTON & WESTERN	35	0.55	19
42	*	VENICE & FIGUEROA	20	0.55	19
15	241	OLYMPIC & SOTO	37	0.54	20
24	83	PICO & CRENSHAW	33	0.53	21
60	213	ADAMS & LA BREA	43	0.52	22
47	198	WASHINGTON & ARLINGTON	29	0.51	23
66	*	ADAMS & HOOVER	26	0.51	23
23	78	PICO & LA BREA	40	0.50	24
6	20	OLYMPIC & CRENSHAW	36	0.50	24
32	346	VENICE & CENTINELA	34	0.49	25
63	228	ADAMS & WESTERN	26	0.49	25
13	*	OLYMPIC & CENTRAL	22	0.49	25
96	*	GRAND & WB ON-RAMP/17TH	8	0.43	26
9	33	OLYMPIC & HOOVER	36	0.41	27
46	194	WASHINGTON & CRENSHAW	28	0.40	28
34	148	VENICE & OVERLAND	31	0.39	29
45	190	WASHINGTON & LA BREA	35	0.38	30
59	207	ADAMS & FAIRFAX	16	0.38	30

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 47 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
5	14	OLYMPIC & LA BREA	33	0.36	31
102	245	SAN PEDRO & WB OFF/16TH	15	0.36	31
49	203	WASHINGTON & NORMANDIE	23	0.35	32
53	*	WASHINGTON & MAIN	17	0.35	32
18	297	PICO & SEPULVEDA	23	0.33	33
57	*	WASHINGTON & SOTO	20	0.33	33
21	70	PICO & LA CIENEGA	27	0.32	34
30	106	NATIONAL & SEPULVEDA	19	0.30	35
37	158	VENICE & FAIRFAX	23	0.29	36
31/74	302	NATIONAL/OVERLAND/WB RAMPS	20	0.29	36
3	3	OLYMPIC & LA CIENEGA	28	0.28	37
4	7	OLYMPIC & FAIRFAX	19	0.28	37
56	*	WASHINGTON & ALAMEDA	17	0.28	37
80	143	LA CIENEGA & WB ON/DAVID	21	0.27	38
33	146	VENICE & SEPULVEDA	22	0.26	39
44	185	WASHINGTON & FAIRFAX	14	0.24	40
97	*	GRAND & EB OFF-RAMP/18TH	5	0.24	40
17	325	PICO & BUNDY	19	0.23	41
2	274	OLYMPIC & SEPULVEDA	22	0.22	42
103	247	CENTRAL & WB RAMPS/16TH	6	0.22	42
29	*	PICO & MAIN	6	0.20	43
91	*	NORMANDIE & EB RAMPS	8	0.19	44
82	184	FAIRFAX & EB OFF/WB ON/APPLE	7	0.18	45
22	72	PICO & FAIRFAX	9	0.17	46
20	63	PICO & BEVERLY	9	0.17	46
83	186	WASHINGTON & WB OFF-RAMP	5	0.16	47
81	157	VENICE & WB OFF/CADILLAC	10	0.15	48
75	303	OVERLAND & EB ON-RAMP	9	0.15	48
86	221	ARLINGTON & WB RAMPS	6	0.12	49
87	222	ARLINGTON & EB RAMPS	9	0.10	50
85	217	CRENSHAW & EB RAMPS	9	0.09	51
84	216	CRENSHAW & WB RAMPS	14	0.08	52
88	226	WESTERN & WB RAMPS	6	0.08	52
35	*	VENICE & CULVER	5	0.08	52
92	*	VERMONT & WB RAMPS	5	0.06	53
95	*	HOOVER & EB RAMPS	3	0.04	54
90	*	NORMANDIE & WB RAMPS	2	0.04	54
19	295	PICO & BEVERLY GLEN	2	0.03	55
71	323	CENTINELA & WB RAMPS	0	0.00	56
73	329	BUNDY & EB ON-RAMP	0	0.00	56
77	136	NATIONAL & WB OFF/MANNING	0	0.00	56
99	*	LOS ANGELES & EB ON-RAMP	0	0.00	56

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 47 (continued)
3-YEAR ACCIDENT SUMMARY FOR SURFACE STREET & RAMP 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)	Rank
100	*	MAPLE & WB ON-RAMP	0	0.00	56
104	251	ALAMEDA & EB RAMPS	0	0.00	56
10	*	OLYMPIC & FIGUEROA	27	n/a	n/a
11	*	OLYMPIC & MAIN	20	n/a	n/a
89	227	WESTERN & EB RAMPS	4	n/a	n/a
93	*	VERMONT & EB RAMPS	3	n/a	n/a
43	*	WASHINGTON & LA CIENEGA	2	n/a	n/a
78	139	ROBERTSON & WB OFF/KINCARDINE	2	n/a	n/a
79	141	NATIONAL & EB ON-RAMP	2	n/a	n/a
72	328	CENTINELA & EB ON-RAMP	1	n/a	n/a
76	305	NATIONAL & EB OFF-RAMP	1	n/a	n/a
94	*	20TH & WB RAMPS	1	n/a	n/a
101	244	MAPLE & EB OFF-RAMP/18TH	1	n/a	n/a
1	319	OLYMPIC & BUNDY	n/a	n/a	n/a
12	*	OLYMPIC & SAN PEDRO	n/a	n/a	n/a
16	*	OLYMPIC & INDIANA	n/a	n/a	n/a
41	180	VENICE & HOOVER	n/a	n/a	n/a
50	205	WASHINGTON & VERMONT	n/a	n/a	n/a
58	*	WASHINGTON & INDIANA	n/a	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.
o Intersection #31 (National/Overland/WB Ramps) is same as intersection #74 in ramp intersection analysis.
* Indicates intersection not in Smart Corridor ATSAC system.

Source: LADOT, Traffic Accident Reports, August 1988 & March 1989.

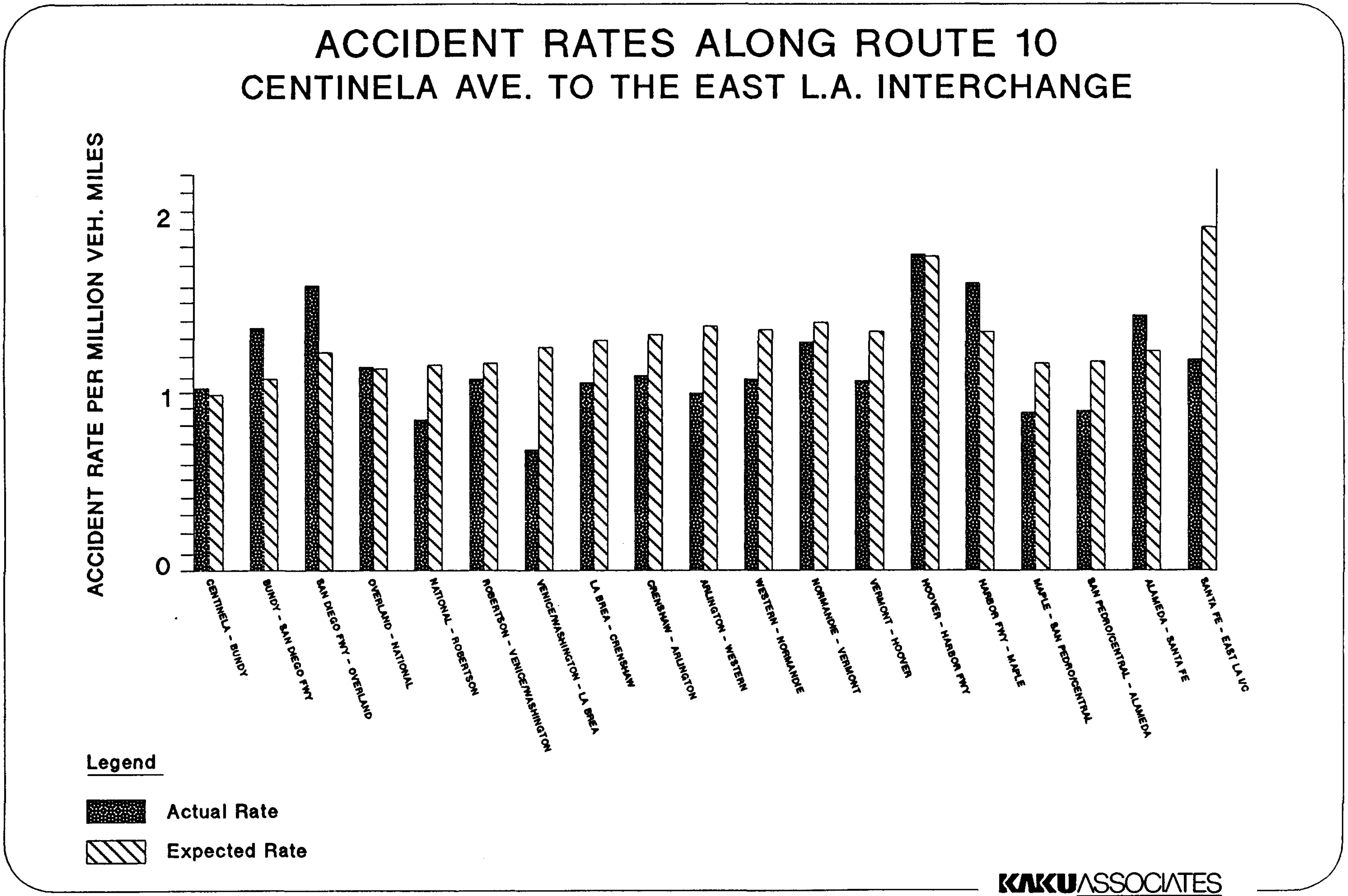
SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 48
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
CENTINELA AVE. TO THE EAST L.A. INTERCHANGE
ACCIDENT RATE PER MILLION VEH. MILES
2
1
0
CENTINELA - BUNDY
BUNDY - SAN DIEGO FWY
SAN DIEGO FWY - OVERLAND
OVERLAND - NATIONAL
NATIONAL - ROBERTSON
ROBERTSON - VENICE/WASHINGTON
VENICE/WASHINGTON - LA BREA
LA BREA - CRENSHAW
CRENSHAW - ARLINGTON
ARLINGTON - WESTERN
WESTERN - NORMANDIE
NORMANDIE - VERMONT
VERMONT - HOOVER
HOOVER - HARBOR FWY
HARBOR FWY - MAPLE
MAPLE - SAN PEDRO/CENTRAL
SAN PEDRO/CENTRAL - ALAMEDA
ALAMEDA - SANTA FE
SANTA FE - EAST LA I/C
Legend
Actual Rate
Expected Rate
KAKU ASSOCIATES

EXHIBIT 49

CHANGEABLE MESSAGE SIGNS

OVERVIEW

Changeable Message Signs (CMS) on surface streets in the SMART Corridor are designed primarily as guide signs or "trailblazers" whose function is to:

a) Give drivers the opportunity to divert by informing them of existing conditions within the corridor

b) Advise the motorist on ways to obtain additional information through HAR's

c) Suggest alternate routes to avoid freeway congestion

d) Reassure drivers on unfamiliar alternate routes

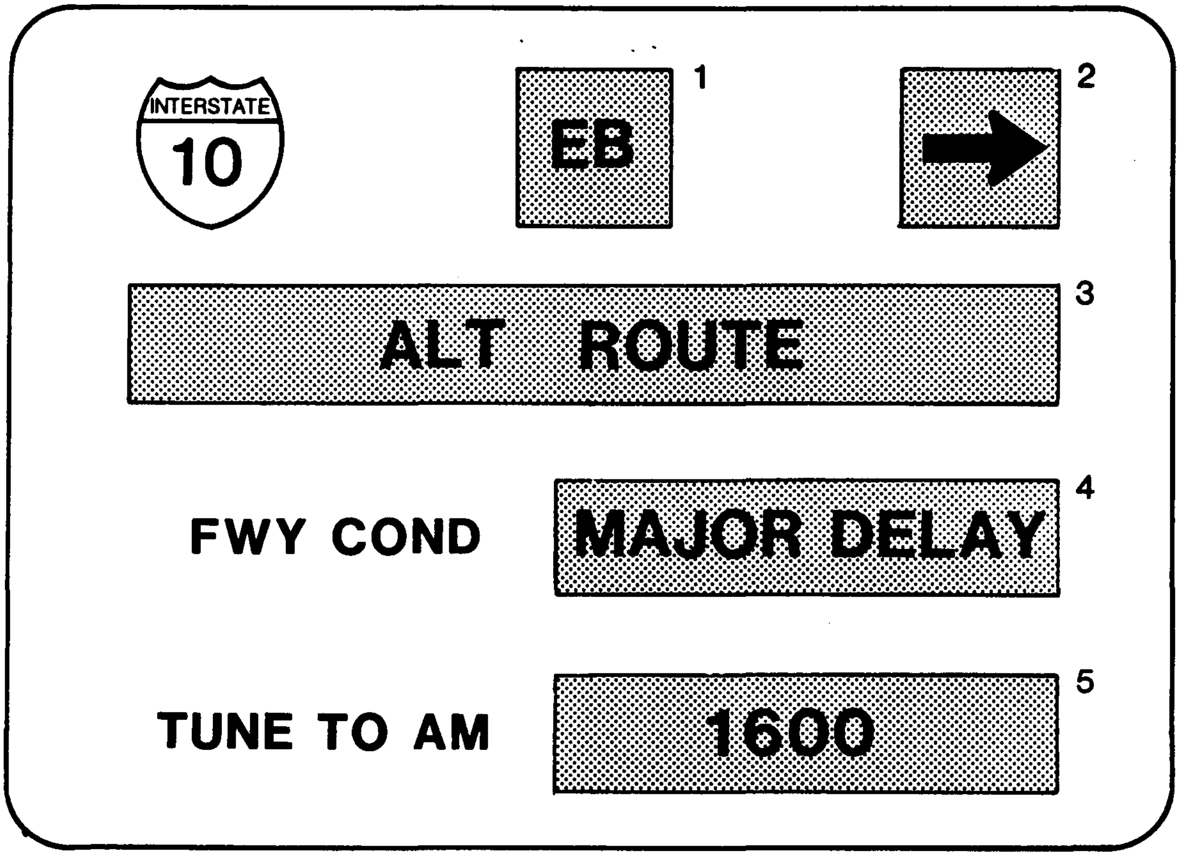
e) Redirect drivers back to the freeway

The message content of these real-time displays should be limited to no more than 2 unique ideas and 4 units of information (providing 1 of these units does not require any retention by the driver to be acted on). It is also important for the message to be legible at a distance sufficient to allow the driver to comprehend the message and take appropriate action where necessary, without creating any new driving hazards or bottlenecks.

Signs must be situated such that the motorist is able to attend to the normal driving duties and still have ample time to merge or change lanes safely. This distance is generally dictated by the purpose of the sign, its informational content, and roadway geometrics. The signs should be placed approximately 100 feet upstream from a diversion point.

MESSAGE CONTENT

To accomplish the above mentioned objectives, two (2) sign types were chosen for use within the corridor. The first, a trailblazer, will be used extensively and might resemble the sign depicted in Exhibit 1. The sign consists of a static portion (the Interstate symbol, the freeway condition statement, and the directions to tune in the HAR) and three sections which contain changeable messages. The changeable portion of this sign will indicate that a diversion route is in effect by suggesting an "alternate route". This alternate will then be indicated to the driver by use of one of three possible directional arrows. Existing freeway conditions



Dynamic Indications (Letter Size = 4")

1. EB, WB, or Blank
2. →, ←, ↑
3. ALT ROUTE or Blank
4. NO DELAY, MINOR DELAY, MAJOR DELAY
5. Any 4 Digit Number Range 530-1710

Exhibit 1
Typical Trailblazer

and HAR frequency advisories will also be illuminated to provide drivers with additional roadway and diversion information. During off peak periods when the freeway is the preferred route, the status and arrow indicating the direction to the freeway may be the only portion active.

For ready identification of these signs from a distance as special "Smart Corridor" signs, a unique trailblazer logo and the freeway corridor to which it applies, should be displayed. It is intended that drivers will learn that these signs will alert them to an impending diversion or to a guide sign prior to it being legible.

The second type of sign being proposed for installation is a full matrix LED. These signs are more sophisticated than the first type and will convey more detailed information to the motorist. Larger than the trailblazer (13 ft. X 5 ft.), each pixel of the 32 inch x 96 inch matrix sign face will be individually addressable. This addressability can be used advantageously to test different message formats and to display logos and other unique illustrations for special events (e.g., coliseum events).

Application of this sign will require software modifications at ATSAC to provide the interface with the signs and to permit their integration into the supervisory and area computers.

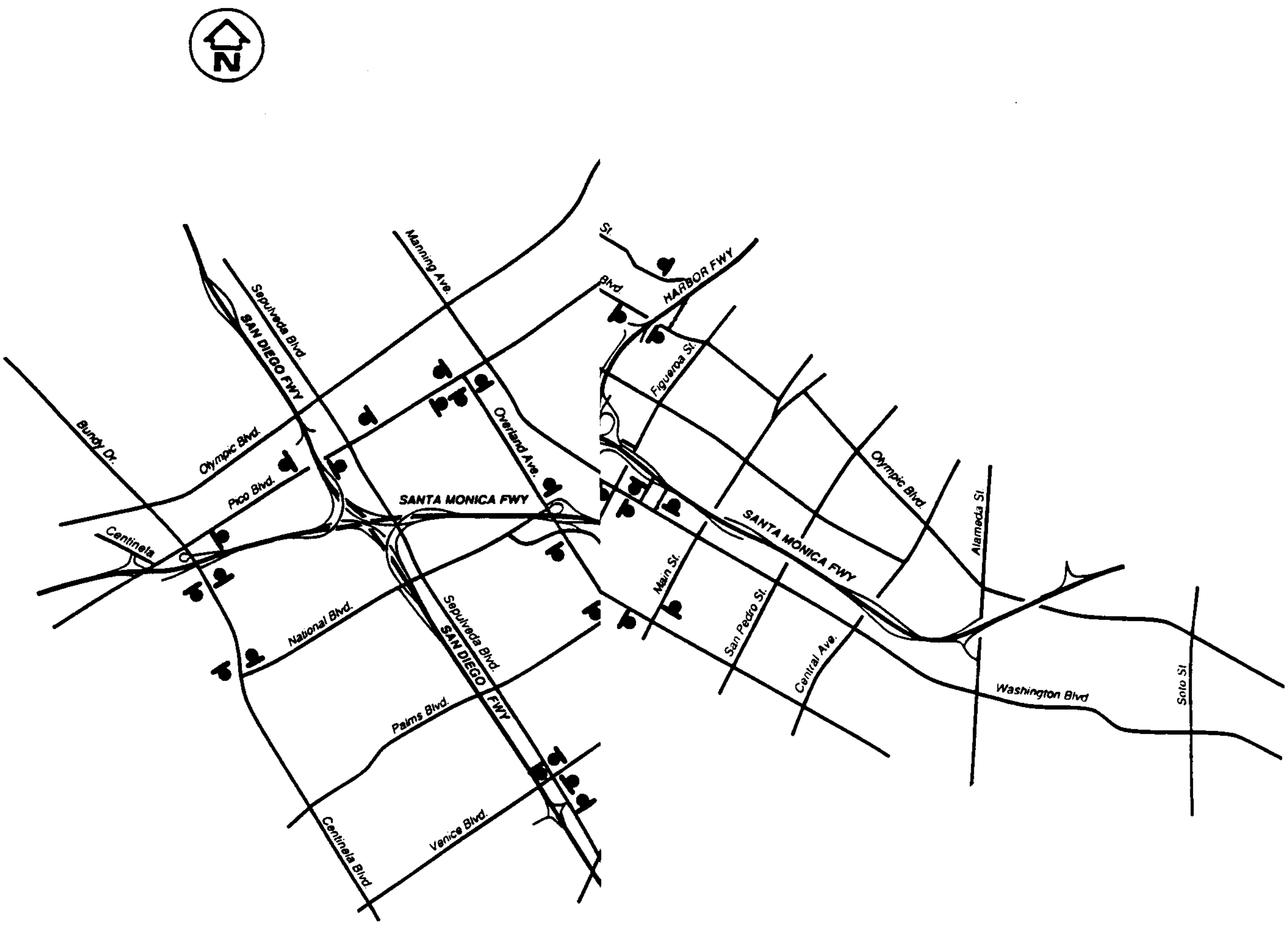
SIGN PLACEMENTS

The trailblazer signs can be placed 1 to 1 1/2 miles apart; however, within the LADOT corridor, the proposed sites of most of the signs has been dictated by roadway geometrics and the need for giving the driver positive guidance throughout the route. Consequently, it is recommended that a sign be placed on the approach to every signalized intersection along the primary and secondary diversion routes. These signs should be positioned approximately 100 feet from the intersection. This distance allows the driver sufficient advance notice to maneuver if necessary, and yet keeps the cost of interconnecting the sign to the intersection at a reasonable level.

In addition to the advance signing, supplemental trailblazer signs are recommended on the departure side of these intersections to reassure the motorist that the proper turn or through movement was made. These signs should be placed at a consistent distance downstream from the intersections, and, if possible, in areas where the driver is not overburdened by other sign messages. Consistent placement of signs creates a pattern for the driver and serves to alert the motorist quickly if an incorrect turn was made.

Using the above guidelines and criteria, 170 locations for the installation of surface street changeable message signs were identified. These locations are depicted in Exhibit 3.

It is proposed that use of the full matrix type sign be limited



jhk & associates

within the corridor to areas having high special event uses or important primary diversion functions. The following criteria was used for developing the recommendations for the placement of the matrix signs:

- Roadway serves as a major collector to the freeway and diversion routes
- Area undergoes high special event usage (e.g., coliseum)
- Upstream from a primary or secondary diversion route

Using these criteria, 25 locations were identified and are shown in Exhibit 4. Due to the high cost of these signs, only five locations are being recommended at this time for implementation. After their effectiveness in the Smart Corridor has been evaluated, it will be determined whether more signs of this type should be installed at other locations.

The five locations being recommended for implementation at this time are:

1. South of Adams on La Brea
2. Washington; west of La Cienega
3. North of Venice on La Cienega
4. South of Adams on Vermont
5. West of La Cienega on Venice

An additional location outside of the corridor should be considered on La Cienega; south of Rodeo. This location is excellent to study the diversion patterns of drivers when they are informed of freeway conditions well in advance of entering the corridor.

The remaining 20 sites identified for potential use of full matrix signs are important locations and should have Trailblazers installed at this stage of the project. The evaluation which will be conducted on the effectiveness of the first 5 signs will define whether the Trailblazers at these locations should be replaced with the full matrix signs.

COSTS

Costs for the LADOT CMS project are shown in Exhibit 5. Estimates for building a trailblazer using the same LED pixels as in the full matrix type are as high as $15,000 apiece, however by using the simpler flip disk or bulb type displays, more reasonable costs in the neighborhood of $3000 can be obtained. Hence the cost differential between a full matrix sign and a Trailblazer is on the order of 30 to 1.

BENEFITS

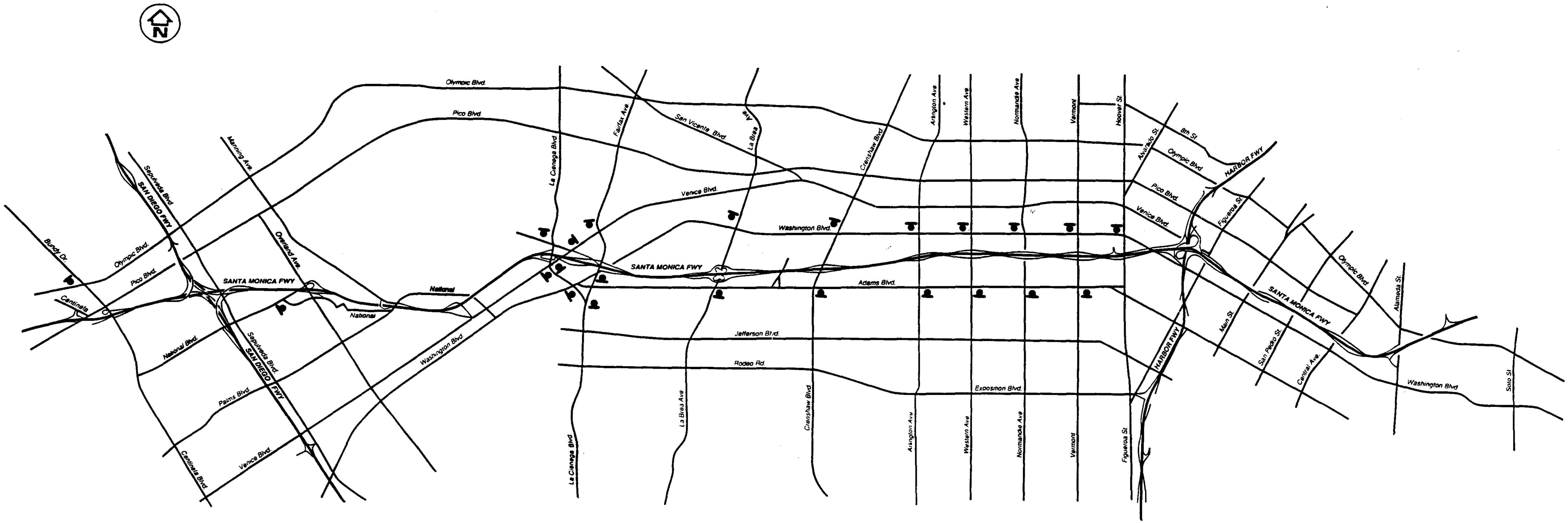


Exhibit 4

Changeable Message Signs
Full Matrix LED
(Type II)

jhk & associates

Changeable message signs as a motorist information device have application for traffic conditions of both recurrent and non-recurrent congestion. Regarding the former, benefits from the use of CMS in the corridor will arise as a result of balancing the traffic flow within the network between the freeway and alternate routes thus effecting an overall savings in time to all motorists.

In situations where incidents are the cause of congestion, CMS will provide information to inform the driver of viable alternate routes thus again benefitting motorists by saving them time and consequent dollars.

CMS are one of many motorist information devices which will be used in the Smart Corridor. It is not possible at this time to quantify the portion of savings that will be directly attributable to CMS alone. It is planned however that the evaluation of the Smart Corridor project will seek to quantify the direct benefit of the use of CMS.

RECOMMENDATIONS

The consultant team recommends that the two types of surface street changeable message signs be implemented in the locations as proposed and that the evaluation of the Smart Corridor project seek to analyze the impacts of the various motorist information devices and to identify that which is directly attributable to CMS.

EXHIBIT 5

SUMMARY OF CMS COSTS - LADOT

Type I - Trailblazer:			
170 @ $3,000		= $	510,000
Type II - Full Matrix LED			
Phase I -			
5 @ $93,000		= $	465,000
20 Temporary Trailblazers @ $ 3,000		= $	60,000
Installation - 190 TB @ $3,000		= $	570,000
5 Full Matrix @ $3,000		= $	15,000
	Subtotal	$	1,620,000
Local Control & Software Development		= $	60,000
Contingencies - 15%		= $	243,000
Engineering & Inspection - 15%		= $	243,000
	Total	$	2,166,000
			=========
	USE	$	2,200,000

HIGHWAY ADVISORY RADIO

OVERVIEW

Highway Advisory Radio (HAR) is considered by the consultant team to be an important key to successfully diverting drivers within the Santa Monica Corridor. The importance of HAR can be attributed to the fact that it is the primary media mode for communicating with drivers after they have committed themselves to the roadways and other conventional means of receiving information are no longer available. The exception to this statement is cellular phone, but the number of users is, and always will be, small in comparison with radio.

USE OF 10 WATT TRANSMISSION

Although the use of HAR is very appealing for the Smart Corridor, there were some difficulties which needed to be overcome regarding its operation. The greatest difficulties involve the frequencies and the power at which HAR is normally broadcast.

The FCC has designated two frequencies specifically for HAR applications. These frequencies are 530 and 1610 KHz, and they are intended to be broadcast at a power input level of 10 Watts. The FCC will make the latter frequency available for commercial broadcasting in 1991. The agency is also in the process of expanding the AM frequency spectrum of 530 KHz to 1610 KHz, to a new high end of 1710 KHz. This change means that as 1610 KHz becomes licensed for commercial high power use, the HAR application will be preempted and phased out. At this time, the FCC has not designated a high end HAR replacement frequency, but it is generally accepted that 1710 KHz will become available. The use of this new frequency will not however be of immediate benefit to the Smart Corridor since there are very few AM radios are capable of receiving anything above 1610 KHz. Manufacturers are only now modifying their equipment, and it will be several years before 1710 KHz becomes a common and acceptable HAR frequency. There consequently is no frequency at the high end of the AM band which is viable for use in the Smart Corridor.

Additionally, 530 KHz cannot be used in the corridor since it is already an overburdened channel. For example, it is not uncommon to receive the LAX airport transmission on 530 KHz within the corridor even though their transmission at this frequency is only 10 watts.

The consequence of not being able to use either the low end or the high end AM HAR frequencies is that alternatives needed to be found. Since the FCC does not regulate broadcasts at power inputs less than 10 watts, it is possible to broadcast on frequencies other than those designated by the FCC for HAR usage as long as the power is lower than the 10 watt threshold. The investigations of the consultant team found that there is an HAR configuration that uses transmitters with a power input less than 10 watts. The configuration is applicable to the requirements of the Smart Corridor and is presented below.

LOW POWER AM TRANSMITTERS

The alternative to the 10 Watt HAR operation is a series of low power, 100 milliwatt transmitters, each of which are interconnected and synchronized to the other to form a zone. The FCC has only recently approved this type of operation, and consequently, very little research has been performed on this technology, and there have been few applications. The major advantage with this concept is the ability to use frequencies other than 530 and 1610 KHz. Other than a concept approval, the FCC does not regulate AM transmitter's of 100 milliwatts or less. This means that HAR can be broadcast on any unused commercial frequency. An additional advantage is that transmitters are arranged in a zonal configuration, and different messages can be broadcast in each zone. Since this HAR concept is at such a low power level, several zones can be established, and each can transmit a unique messages over the same frequency.

Since this concept has only recently been approved by the FCC, there are as yet no installations of this type HAR available for evaluation of its operation. Laboratory and field tests conducted my the manufacturer, and additional field tests conducted by the consultant team, indicate that this type of HAR configuration performs well and is very applicable to the special needs of the Smart Corridor.

In the field test conducted by the consultant, the HAR antenna was mounted at a height of approximately 30 feet on a power pole. This is the height that will be used in the implementation of the HAR; however, it is expected that the antenna will be mounted on signal standards. The field test indicated that the strongest radio signal is produced by using the highest broadcast frequency possible. The best results were obtained at frequencies of 1610 and 1490 KHz. The tests also indicate that the broadcast coverage is achieved with a transmitter spacing of approximately 1200 ft. The manufacturer of the HAR indicates that improvements in transmission and reception may be achieved with the introduction of their forthcoming helix antenna which is currently undergoing testing.

The primary factors which affect the signal strength and reception of the signal are the following:

Ground: Other than using the highest frequency available, establishing an extensive ground system is the most critical factor for transmitting over any great distance. Recommended grounding systems are dependent upon the soil conductivity and vary with geographical location. The poorer the soil conductivity, the greater the number of ground rods required. Recommended grounding systems for extended coverage or to compensate for poor soil conditions, involves installation of 4 foot copper rods at the end of 100 foot #6 bare wire leads, radially extending from the transmitter (Fig. 1). Up to 18 such leads could be required for worst case situations. This of course could become quite cost prohibitive, so it was of great interest to establish the suitability of the existing intersection ground. As a comparison, an earlier test at Venice and La Brea using only a 4 foot ground rod produced a range of 50 feet at 1610 KHz. It therefore appears that the signal controller ground or a nearby water line will be adequate, bearing in mind that reception at greater distances can be achieved with more extensive ground systems.

Line of sight - HAR, being low power AM, is best received when there is a direct line of sight between the transmitter and the receiver. These conditions are prevalent along the freeway in the corridor.

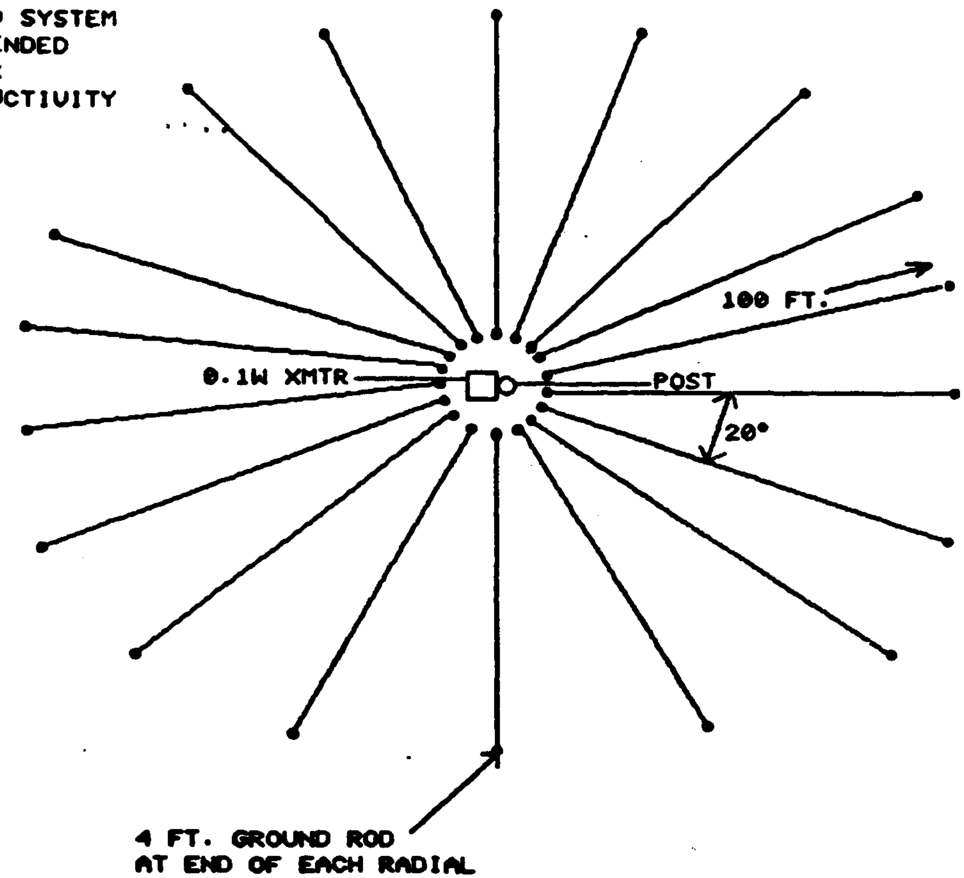
Spacing - The design of the HAR configuration calls for up to ten transmitters to be broadcasting the identical message simultaneously. There is consequently a need to synchronize the signal so that there will not be any echoes. The transmitters must therefore be spaced on the half or full wavelength. The consequence of this is that the frequency must be assigned for each group of ten transmitters within the corridor prior to construction. This does not eliminate the possibility of assigning another frequency to this group in the future; however, the receiving range will be reduced in proportion to the difference in wave length from the design value.

Reception - An advantage of the system in application to the Smart Corridor is the rapid loss of signal on the outer edges. The signal strength/loss is asymptotic and quickly disappears once it starts to fade. This is advantageous in that two adjacent groups will not be as likely to interfere with each other.

Placement Criteria - Exhibit 2 shows the proposed surface street transmitter locations and groupings. Exhibit 3 shows the same information for the freeway coverage. At this time, only approximate locations have been defined for comments. More precise locations will be made during the design stage after results of the helix antenna are received, and a final transmitting frequency is selected. The following criteria

0.1W AM TRANSMITTER

PROPOSED GROUND SYSTEM
TO PROVIDE EXTENDED
COVERAGE OR FOR
POOR SOIL CONDUCTIVITY



18 GROUND RADIALS
#6 OR #8 BARE COPPER WIRE
BURIED 6 TO 12 INCHES BELOW GRADE

GROUND SYSTEM

EXHIBIT 1

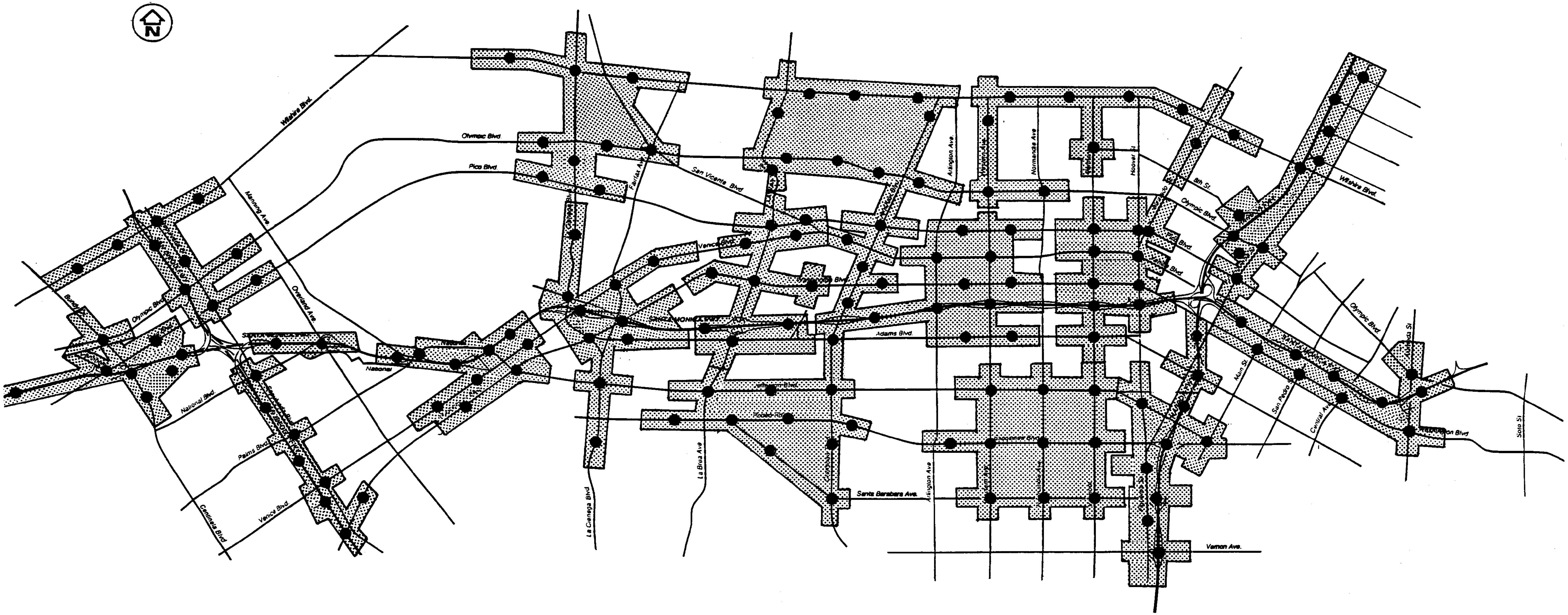


Exhibit 2

Low Power Highway Advisory Radio (HAR) Transmitter Sites
Surface Streets

jhk & associates

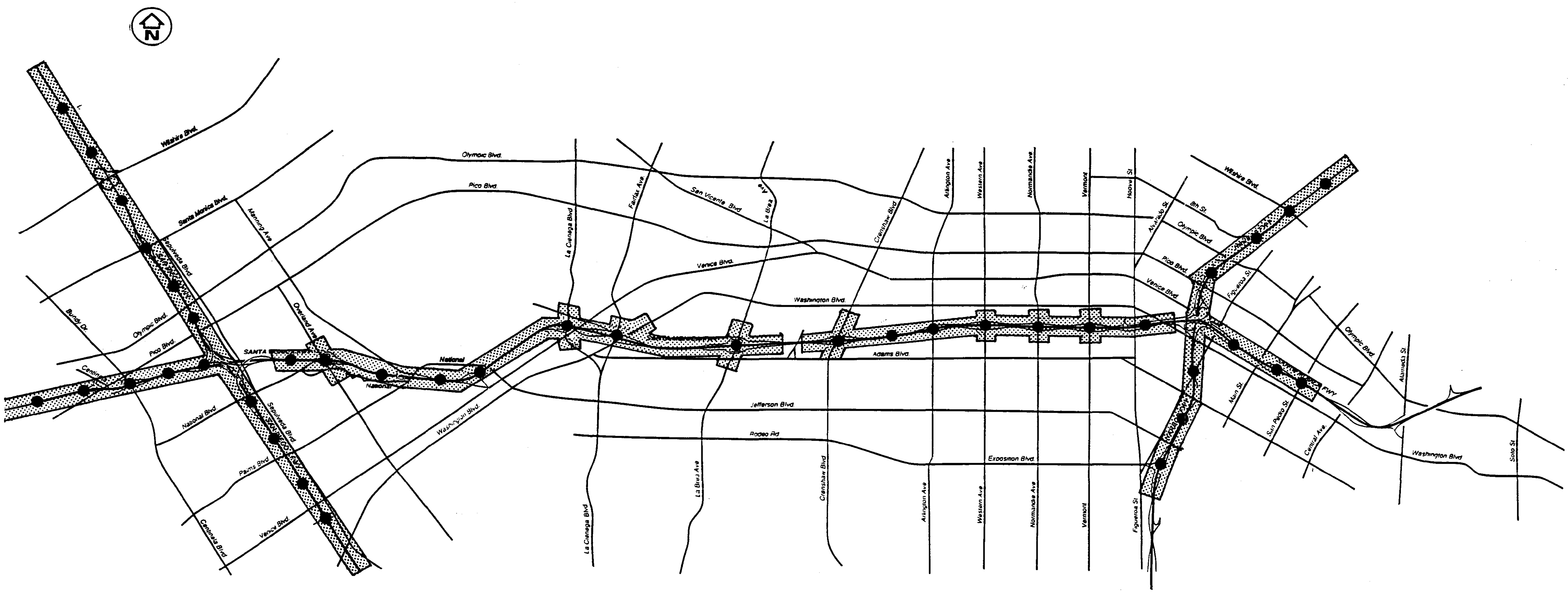


Exhibit 3
Low Power Highway Advisory Radio (HAR) Transmitter Sites
Freeways

jhk & associates

were used as a guide in determining the suggested placements.

- o With the preliminary field test results, it is safe to assume that a clear transmission can be obtained with group transmitters located every 1200 feet.
- o Groups should be defined such that the radio reception will be audible well in advance of potential diversion exits.
- o Groups should be located such that as much of the freeway segment as possible will be covered.
- o All major interchanges within the surface street network must receive coverage to allow for diversion and freeway status information.
- o All major arterials and freeway collector streets must receive sufficient coverage to provide ample time for route selection.
- o Freeway and surface streets should be assigned different frequencies. The 1610 KHz frequency is tentatively suggested for the surface street HAR due to its ability to cover a larger area. Broadcasts at 1490 KHz and 1000 KHz are suggested for the freeway since there are fewer site obstructions, and placements on overpasses will provide excellent vantage points, thus overcoming some of the range handicaps associated with the lower frequency transmissions.
- o Distances between groups must be sufficient (say approximately 2000 feet) to prevent overlapping of messages.

SUMMARY

HAR is considered an important technology for the dissemination of information to drivers. Of the available HAR devices, use of the 100 milliwatt, DC input transmitters with zone capabilities is considered the most promising. The advantages of this configuration are as follows:

- FCC license not required
- Any available frequency may be used
- Zonal grouping consisting of ten transmitters available
- Each group capable of broadcasting like or separate messages
- Low power can be advantageous when two zonal groups using the same frequency are in close proximity to each other.
- AM modulation experiences a rapid loss in reception once the receiver is out of range

- Adequate grounding sources are prevalent throughout the City and freeway corridor to eliminate the need for installing expensive grounding networks.

Disadvantages of the low power HAR are as follows:

- Untested technology
- AM modulation fluctuates with atmospheric conditions with the consequences not being realized until after the system has been installed
- Frequencies must be selected prior to installation of the transmitters

RECOMMENDATIONS

It is recommended that the project include 17 zones of HAR on surface streets and 5 for freeway application. Costs for this are estimated at:

LADOT	$ 315,000
Caltrans	$ 100,000

A build-up of the costs is shown on Exhibit 4.

Because the technology is new, it is recommended that one zone be installed as an early state of implementation. The zone covering the ATSAC served Coliseum area is used to coordinate the transmitters. The cost for the test zone is estimated at $20,000 and is included in the above costs for LADOT. As a note, it is fully expected that the technology will prove workable and can be assumed to be a critical part of the project. The test will allow design problems to be resolved early in the project so that future implementation problems are minimized.

EXHIBIT 4

Summary of HAR Costs

LADOT HAR

Equipment	17	@	$13,500	=	$ 229,500
Phone Interface	1	@	1,000	=	1,000
Installation	17	@	500	=	8,500
		Sub Total		=	$ 239,000
Contingencies @ 15%				=	35,850
Engineering & Inspection @ 15%				=	35,850
		Total		=	$ 310,700
		Use		=	$ 315,000

CALTRANS HAR

Equipment	5	@	$13,500	=	$ 67,500
Phone Interface	1	@	1,000	=	1,000
Installation	5	@	500	=	2,500
		Sub Total		=	$ 71,000
Contingencies @ 15%				=	10,650
Engineering & Inspection @ 15%				=	10,650
		Total		=	92,300
		Use		=	$ 100,000

SURFACE STREET INCIDENT MANAGEMENT TEAMS

BACKGROUND

The LADOT currently has a surface street incident management team which responds to the very severe incidents within the City limits. The team members come from the LADOT group (Special Event Traffic Management) which handles the traffic control for planned closures and major events such as the Academy Awards and the Los Angeles Marathon. The group is made up of three persons which have the responsibility for both planning and implementing the traffic control plans. The group currently has three radio equipped pick-up trucks which are used to transport their equipment (signs, barricades, etc.) to the field. They call on the services of other LADOT employees when additional staff is needed to manage and implement the traffic control plans for large events.

Although LADOT's traffic management team does not presently respond to incidents other than the most severe, it is suggested that there would be benefit to using the team to coordinate with Caltrans during responses to major freeway incidents when there is significant diversion from the freeways and during other incidents on surface streets in the Smart Corridor which cause a serious disruption to traffic flow. This paper presents the recommendations of the Smart Corridor consultant team regarding a surface street incident management team.

DISCUSSION

The LADOT traffic management team is currently used almost exclusively for special event traffic control rather than incident management. The staff is used to plan and develop the traffic control plans for scheduled events as well as to implement them. If traffic management in response to incidents were to be added to the responsibilities of the present group, supplementary staff would have to be assigned or hired for the team. Additionally, the equipment and supplies required to perform these duties would need to be purchased to support these activities.

According to information available from LADOT and Caltrans, an incident response team should consist of three to five members depending upon the severity of the incident. The existing LADOT

group consists of three persons. It is therefore suggested that, in order to provide an adequate level of response to all incidents, LADOT add two additional positions to the present group and form a dedicated Smart Corridor surface street incident management team. As is the case currently, these persons would be on call 24 hours per day. The duties of the team would be to respond to major incidents in the Smart Corridor and, during their normal work hours when not responding to an incident, they would perform the same duties as are presently undertaken by the group with special attention to activities which affect flow in the Corridor.

It is recognized that the 24 hour per day on-call status of the team could be overly burdensome and that adjustments may be needed to achieve a satisfactory working arrangement. Alternatives to this scheme include employing a plan similar to that used by Caltrans which calls on volunteers during off duty hours. It is suggested that the dedicated team plan be implemented for a demonstration period during which an evaluation of the program be conducted. The evaluation should analyze the effectiveness of the team as well as permit adjustments to be made to the team's structure or a new plan developed.

COSTS

The following identifies the needs of the existing traffic management group in order to expand and handle the additional duties associated with incident response.

ITEM		COST
Personnel		
- 1 T.E. associate		$51,000
- 1 T.E. assistant		$42,000
- Overhead (108%)		$100,000
Vehicles		
- 2 pick-up trucks fully equipped		$40,000
	Total	$233,000

The vehicles would be amortized over five years resulting in an annual cost (including vehicle maintenance) of $203,000.

RECOMMENDATION

The Smart Corridor consultant team recommends that a surface street incident management team be established by LADOT to coordinate with Caltrans in the Smart Corridor during major freeway incidents and to handle surface street incidents in the corridor which create a serious disruption to traffic flow.

CULVER CITY/BEVERLY HILLS

BACKGROUND

The boundaries of the Smart Corridor project encompass small areas of two cities toward the west end of the Santa Monica Freeway. These cities, Beverly Hills and Culver City, have had only limited involvement 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 Boulevard. Smart Corridor monies have been budgeted to bring these signals under the control of ATSAC 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.

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 on an arterial which would serve as an alternate route for traffic travelling south on the I-405 to the I-10 to points east, and vice versa.

Monies in the amount of $576,000 has been designated in the Smart Corridor budget for the task of placing the signals in Beverly Hills on the ATSAC system. The City did not apply for the funds prior to the deadline and their have been no decisions yet on further action.

Culver City

An extensive section of Washington Avenue, containing 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 applied, and been approved, for the funding ($1,472,000) to accomplish this task.

Recommendations

To achieve the desired coordination of signals on Washington Avenue within Culver City, it is recommended that the City proceed as planned with placing the signals under the coordination by ATSAC. The next step for LADOT is to develop an agreement with Culver City on the operation of the signals within the City's jurisdiction which will take effect when they are placed under the ATSAC system.

It is recommended that the same agreement be pursued with the City of Beverly Hills to obtain their cooperation in placing their signals on Olympic Boulevard on the ATSAC system. The issue of the funding still needs to be resolved, but is recommended as a continuing project budget item.

VIDEOTEXT

Overview

New attempts to bring products and services directly into the home via the personal computer using videotext technology, have recently been initiated through a joint venture between IBM and Sears. Their product is called Prodigy. Promoted for the "busy professional" yet geared for the computer illiterate, Prodigy combines text and graphics to produce and access information services such as news, weather, entertainment, financial reports, and magazine excerpts. Other interactive services such as grocery shopping, banking, E-mail, or purchasing theater tickets are available in some areas. Prodigy is available in the Los Angeles basin.

Other attempts in the videotext market have been tried (e.g. Viewtron, Gateway and Keyfax Interactive Information Service). For a variety of reasons, they have never succeeded. Prodigy claims to have solved the problem by offering this service for a low flat fee of $10 per month. In addition they are reportedly spending over $35 million to help promote and attract users of the estimated 8 million compatible devices currently in the U.S. market. With future growth rates and upgrades to install modems, Prodigy predicts the number of eligible devices will increase by 30% a year.

Technical and Operational Considerations

If Prodigy is successful in capturing a large audience, displaying traffic information might well prove to be beneficial, since the only requirements placed on the Smart Corridor project will be to provide access to the database source. Provision of this type of service (not to mention the existing transit information RTD currently maintains) is extremely inviting to Prodigy since it offers a daily use to their customers. Consequently, it is expected that all development and integration costs such as the graphics and text format would be borne by Prodigy.

Evaluation and Recommendation

Videotext is essentially a variation of the dial-in or bulletin board information services, with its use somewhat limited by the availability of personal computers. While most businesses have personal computers, only a small percentage of homes

are currently equipped with the necessary computer and modem. There is also a question as to the capacity of a videotext service since it is accessed by telephone lines.

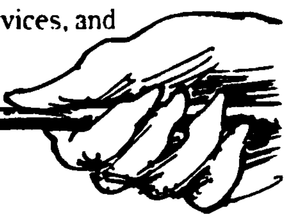
In addition, although the number of available computers is expected to grow significantly in the near future, and with it the potential use of videotext services, it is still unclear whether drivers will use such services to obtain traffic information for pre-trip planning. Recent surveys suggest that only a limited number would, presumably due to the complexity of the task.

Even with this concern, use of videotext is a "no cost" alternative in terms of Smart Corridor project outlay. It is recommended that videotext be treated as a "computer bulletin board" and be given access to the Smart Corridor public information database. Reformatting of data required to serve Prodigy would be at the cost of the service provider. A description of the Prodigy system is included for reference.

THE PRODIGY PROMISE

BY
MICHAEL
ANTONOFF

Videotex, the perennial stage flop of information services in the mid-1980s, is back, and this time it's come to town with some big-name backing. Sears, the nation's largest retailer, and IBM, the world's biggest computer company, have put their marketing and technology muscle behind an on-line electronic mall of information and shopping services called Prodigy. In true videotex fashion, Prodigy combines text and graphics in lively displays to bring news and weather, shopping, entertainment, education, travel, financial services, and magazine excerpts into your home or office through your PC.



SEARS AND IBM HAVE BROUGHT VIDEOTEX A LONG WAY, BUT NOT FAR ENOUGH.

Currently, Prodigy is available only in the regional markets of Connecticut, Atlanta, Detroit, Boston, Baltimore, Washington D.C., and most of California. But it's coming to your neighborhood: By the early 1990s, Prodigy will be available nationwide. And Prodigy is pulling out all the stops to make you a customer. According to Gary Arlen, publisher of the *Interactivity Report* videotex newsletter, $2 billion has been invested in videotex in the past eight to 10 years—Prodigy accounts for fully a quarter of that. This year alone, the company plans to spend $20 million in direct mail, newspaper, and television advertising.

But earlier videotex systems had their out-of-town tryouts and never achieved the bright lights, big city success of mass-market penetration. Is the world ready for another fling with videotex? More important, is Prodigy ready for the world?

In the past, the public has responded to videotex with a re-

VIDEOTEX DEJA VU

Prodigy isn't the first videotex service to try to capture a mass audience. Earlier services' displays and features are strikingly similar to Prodigy's, but their high connect-time charges, slow response time, and expensive dedicated terminals accounted for low subscribership. That brought on their untimely deaths, despite the backing of millions of dollars by large corporations. Four of the major information services of the early and mid-1980s are pictured at right.

Knight-Ridder offered Viewtron in south Florida in 1982. The service was shut down in 1986 after a $50 million loss.

sounding "No." From 1980 to 1986, services with futuristic names like Viewtron, Gateway, and Keyfax Interactive Information Service sprang up across the country: Knight-Ridder offered Viewtron in Miami; the Los Angeles *Times* had Gateway; and Honeywell, Centel Corp., and Field Enterprises offered Keyfax in Illinois. Britain, meanwhile, had a Prestel-based system.

Like Prodigy, they all boasted colorful screens that delivered information and shopping services to your home or office. But despite millions of dollars invested, not one of these services attracted anywhere close to the number of subscribers needed to break even, let alone turn a profit.

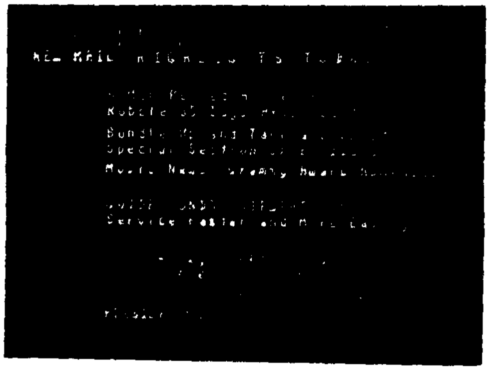
So why try to sell videotex to a reluctant public again? Because this time, perhaps, Prodigy is addressing a much larger audience than the one that existed five years ago. According to Mike Darcy, a Prodigy communications specialist, 8 million computers in the United States can receive Prodigy, and that base is growing at a rate of 30 percent a year. "The big advantage over earlier services is the significant difference in the number of addressable machines," Darcy says. "We're not trying to create machines out there. They already exist."

Prodigy also cites the growing sector of busy, two-income families for whom an all-in-one-box information system is, if not yet a necessity, at least a convenience.

Strategically, Prodigy has made some good moves. It has solved one of the biggest problems of earlier videotex services: high connect-time charges. Taking a lesson from the pages of *Life* magazine, Prodigy uses advertising revenue to absorb the bulk of the service's cost, significantly reducing the tab to consumers. Prodigy will pour an interactive avalanche of information, shopping, and entertainment services onto your computer screen for a flat fee of $9.95 per month. (Some banks charge extra for optional home banking services.) Declares Richard Adler, director of the teleservices program at Institute for the Future in Menlo Park, Calif.: "Prodigy's most attractive aspect is the flat-rate pricing. That's unique, and it's a breakthrough." Quips the *Interactivity Report*'s Arlen, "It's $10 for all you can eat."

The Prodigy Start-up Kit, which includes software, a sign-on ID, and free access to the first three months of service, costs a reasonable $49.95. (The same kit with a 1,200-baud Hayes modem that plugs into your computer's serial port and hangs from a wall outlet costs $149.95.) And one Prodigy subscription lets up to six family members sign on with individual IDs, putting its service within easy reach of potential customers.

Prodigy also works on low-common-denominator PCs: IBM-compatible computers with at least 512K of RAM, a graphics adapter, one disk drive, and a 1,200-baud Hayes-compatible modem. (Versions for the Apple IIGS and Macintosh are promised this year.) So you're not required to buy a terminal, as was the case with earlier services. (Viewtron belatedly added personal computer support).



Prodigy's opening menu displays news highlights and alerts you to E-mail, but you can't enter a selection until the "Working" message vanishes. The lower part of the Prodigy display contains advertising and a navigational menu.

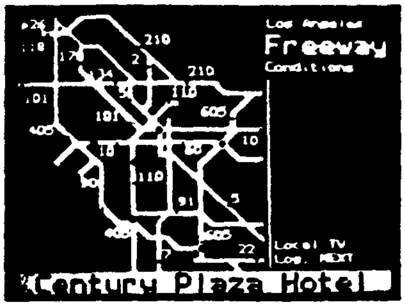
But all that given, the question remains: Does Prodigy succeed where others have failed, and does it offer something people genuinely want and need?

In a word, no. Prodigy displays too many of the same shortcomings that quashed earlier services, including slow response time and shallow information. Despite Arlen's all-you-can-eat analogy, using Prodigy is like seeing a buffet table stacked with food, then realizing, on closer inspection, that your options are pretty much cottage cheese and peaches. It leaves you wanting more.

Prodigy is organized like a shopping mall with six "buildings": Information, LifeStyles, Shopping I and II, Finance, and Travel. Within each building, various "floors" offer different services. For example, the Informa-

■ The L. A. *Times* launched Gateway in 1980 and pulled the plug in 1985. Users decided that paying a premium for an electronic newspaper with poor resolution wasn't worth it.

■ Honeywell, Centel Corp., and Field Enterprises offered Keyfax in Chicago from 1984 to 1986. Its dedicated keyboard-and-terminal unit was too expensive for most users.



■ While not true videotex, CBS provided a teletext service (one-way TV-band transmission) called Extravision in L.A. from 1980 to 1982. It used a decoder box and offered a limited array of information.

tion building provides floors for national news, business news, sports, weather, and *Consumer Reports* excerpts.

Like all videotex, Prodigy's forte is ease-of-use. The buildings and floors take the form of pop-down menus. Highlighting and entering a menu choice brings up a deeper set of selections in a menu to the right.

Prodigy uses a double-height, 40-column character display, meaning you can read the screen from across the room, but you'll get less than half the text you'd see on a typical word processing screen.

The near-bottom quarter of the screen contains Prodigy's advertising, which usually includes a "Look" option. Choosing this option provides full-screen details and submenus that often offer a way to place an order. The very bottom of the screen lists your navigational options. Highlighting and entering "Menu" (or pressing the F9 key) displays pull-down menus with Prodigy's topics.

If you habitually look at the same topics—for example, you hop from stocks to astrology to Sylvia Porter—you can create a personal path to cycle through the same areas of Prodigy each time you log on. If you decline the personal path, the default path takes you to a *USA Today*-type color weather map.

When you first log on, an opening screen displays three news headlines (you can elect to view these news stories, which are about two screens in length) as well as a flashing "New Mail" alert if you have a message in your electronic mailbox.

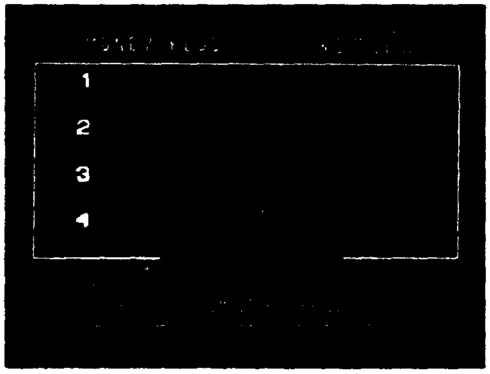
Prodigy's news section doesn't attempt to compete with your local newspaper. This is a national-based service which, for now, has little local content. (You can get a smattering of news for the areas served that any subscribers can view.) Unlike earlier videotex services, you can't find out what's playing at the local cinema. Instead, you can read a few screens of celebrity gossip or check out which popular movies are being released on videocassette that month.

If any newspaper can best serve as a description of Prodigy's news, it's *USA Today*. Even then, you'd have to call Prodigy a capsule of a newspaper that already is a summary. You get capsules of the three top national or world stories of the day. The colorful weather map is right off the paper's back page. The advice columns on food, money, and health could just as easily be clipped from the paper, though Prodigy shortens them. Forget high school sports scores.

For financial news, Prodigy provides free gateways to Dow Jones News/Retrieval. You get 15-minute delayed stock quotations, and you can store portfolios to automatically check given stocks. Unlike such other gateways as CompuServe, MCI Mail, and Lotus Express or Lotus Signal, you can't download the stock prices into a spreadsheet to automatically calculate their net worth. You can print them, but you'll still have to type the numbers into another program for any analysis.

Perhaps Prodigy's most utilitarian feature—for both business and personal use—is Eaasy Sabre, an on-line flight information system that lets you review flight schedules and costs, as well as book reservations. You can even see what type of aircraft you're flying in and check a given flight's on-time performance percentages.

Owned by American Airlines, Eaasy Sabre lets you store your credit card number and a seating preference and can designate a travel agent to write tickets for reservations you make. (The same flight information is available through CompuServe, but you're paying an hourly rate in that case. However, CompuServe's service also enables you to reserve hotel rooms and rental cars, while Prodigy's does not.)



You navigate Prodigy's electronic mall using its "buildings" and "floors," or nested menus. Each building offers multiple services. You select a service by moving the highlight cursor with either the tab or arrow keys, and pressing the Enter key.

You can also order goods from such on-line department stores as Sears and J.C. Penny's. An electronic order blank lets you type in items you might see in a Sears catalog or circular, though the complete Sears catalog and illustrations are not available. (The screen might direct you to see a particular VCR "on page 681 of the 1988 Fall General Catalog.")

Grocery shopping is available in San Francisco and Atlanta. Though Prodigy envisions the day when you can maneuver a shopping cart icon through "aisles," for now shopping is text-based. You browse through lists of items, divided into categories, and type in the quantity of each you want to order. Though you can't read the ingredients on the canned soup or squeeze the tomatoes, you can indicate ripeness or how thick you'd like your freshly sliced deli meats under "special instructions" you type in with your order. In San Francisco, for example, Grocery Express brings the groceries to your door for a $4.25 delivery charge three to five hours after the order is placed—if you order by their deadlines. (If you just can't wait for that pint of Ben & Jerry's Cherry Garcia, delivery is guaranteed within 60 minutes for a $20 charge.) But in addition to the

PRODIGY AT A GLANCE

BANKING	**Gateways into Manufacturers Hanover, Key Bank, Citizens and Southern National, and Great Western home banking services. Avoids lines and lets you shop around for best rates. May incur additional charges.**
BUSINESS NEWS	**General business and market news; columns on computers, taxes, investments, real estate, and money; media and aviation news. Items are current. Not much story depth or variety, nor is there a way to search for specific information.**
***CONSUMER REPORTS* EXCERPTS**	**Electronic version of magazine. Library displays evaluative summaries of varied product categories. Provides abbreviated product evaluations only; doesn't offer printing option.**
DOW JONES NEWS/ RETRIEVAL	**Stock, corporate bond, mutual, and money-market fund tracking. Prints 15-minute-updated quotes; you can type in stock abbreviation or company name; stores two portfolios with up to 15 entries each for batch tracking. Doesn't provide historical stock data, download any data for analysis, or provide DJ/NR stories.**
EAASY SABRE	**Flight reservations. Prints comprehensive flight schedules and fares; stores personal travel profile; agent you designate writes ticket. Doesn't handle hotel and car reservations.**
ELECTRONIC MAIL	**Private and public message center. Members can send and print unlimited messages to each other or post questions in special-interest forums (for example, PC Club, Money Talk, Food and Wine, Healthy Living); long-distance charges are bypassed. Only Prodigy's markets are served, limiting your communications access; forum themes are limited by Prodigy; you can't upload files or store text to disk.**
ENTERTAINMENT	**Movie, TV, video, music, and book information. Capsules of current national film releases, top box office receipts, and coming attractions; capsules about a few programs on TV that night, Nielsen ratings, soap opera summaries; new video releases; music news and *Billboard* magazine charts; book news and sales chart. Depending on subject, information is updated daily or weekly. Coverage is extremely limited; lacks local movie and TV listings.**
GAMES	**CEO, business simulation; Eureka Project and Carmen San Diego, adventure serials; Boxes, geometry strategy; jokes; contests; art gallery. Games appeal to adults and children; whole family can get involved. Can keep phone tied up for hours.**
HEADLINE NEWS	**National and world news. Displays news highlights when you enter system. Offers about three stories that occupy only a few screens each; teases rather than satisfies.**
SHOPPING	**On-line ordering from Sears, J.C. Penny, local groceries, and other stores. Shop-at-home convenience saves time and gasoline; avoids lines. Product pictures you'd find in a catalog are missing; grocery shopping restricted to a few cities; premium prices are charged.**
WEATHER	**National map; local and travelers' forecasts. Comprehensive for areas served and for a few major cities. Ignores international weather and smaller U.S. cities.**

delivery charge and optional tip, you are paying a premium for most items. Don't expect to find generic bargains. The least expensive four-roll pack of toilet paper, for example, is $1.79 and one pear will run you 69 cents. Your order is kept on file so that the next time you log on, you may only have to change the quantities. Grocery Express, incidentally, predates Prodigy. The "all-delivery market" also takes orders by phone and fax.

While this sampling of Prodigy services gives you an idea of what's available, two specific areas have been particularly popular, according to Prodigy's manager of press relations, Brian Ek. The first is electronic mail. Subscribers realize that they can trade bicoastal messages for the price of a local call. The service isn't as flexible as MCI Mail or CompuServe, though. Since you can't temporarily store prepared files on Prodigy's mainframe or capture text to disk from Prodigy, you must type each screen one at a time or retype printouts. When we checked *Consumer Reports* to study used and new car prices, we had to write out the information longhand, since this service had no print option.

Besides sending messages, you can play a business simula-

PRODIGY USERS SPEAK UP

■ An electronic bulletin board is an efficient way to conduct passive research. We sent a message marked for "All" Prodigy users, soliciting feedback about Prodigy's merits and flaws, and logged on again 48 hours later to find several dozen opinions. Now, that's response.

Users' reviews ranged from glowing to glowering. A few people were favorably impressed by the service, many were not, and most thought Prodigy was improving.

On the positive side, a couple in Stamford, Conn., called it "The best thing since sliced bread." They do their banking with it, reserve flights with Eaasy Sabre, look at *Consumer Reports* for product evaluations, and buy items. Said the husband, "I have used at least six or seven of the [column] experts for advice. They reply in a timely manner."

Another user declared: "The designers have provided a little something for everyone at a very appealing price. I've ordered several items from Prodigy businesses without any problem." He says that the service is "almost idiot-proof."

The last comment is a point of contention for experienced users of online services. One such user would like to see "an expert mode" and an 80-character display. The screen is used so inefficiently, he says, that with 40 characters across and nine lines down, "it takes so little time to read this small amount of information my perception is that I am always waiting for Prodigy to do its thing.

"As for the news messages," he continued, "they are too short to be of much use. I can do better with (free) radio news, and far better reading the newspaper. Because of the small text window and speed problems, Prodigy is far more of a hassle than picking up a newspaper."

Echoing this perception, a San Diegoan said, "Slowness is at the center of all my complaints."

Another user says he's changed his opinion during the four months he's been using the service. "My initial reaction was that it was juvenile, intended for users who had no computer experience or expertise but who must own a fairly expensive computer to reach Prodigy at all. Significant changes have been made since then. I find it a useful tool as well as an entertaining diversion."

The PC Club Bulletin Board is a major attraction for this user, who is retired. It's "as entertaining a forum as you can find. Members are widely disparate in age, experience, interest, geographic location, and volatility, which makes for a lively exchange of ideas." It was through reading the bulletin board, for example, that we learned that users had successfully used mice with Prodigy, though the Prodigy manual makes no mention of this. In fact, you are told you may experience trouble with RAM-resident utilities like mouse drivers. (We weren't able to test a mouse because our external modem is plugged into the serial port.) We also successfully ran a RAM-resident screen capture utility in our 640K machine, though people with 512K may run into problems.

Users want to see more special-interest bulletin boards and localized information. A Los Angeles resident suggested "a philosophy/religion board so people can get into some 'deep' talks." He'd also like to see tickets for concerts, plays, and sports events that can be ordered on-line.

In the weeks before Valentine's Day, Prodigy did in fact carry a special-interest bulletin board in which users pontificated on the nature of love and solicited advice. In one message addressed to "All," a woman who had been dating someone for a couple of months said that it drove her crazy whenever they parted because he never said anything like "I'll call you." She asked, "Is it unreasonable to ask for more continuity? Is there some way I might discuss it with him without sounding too demanding? Feedback and suggestions are welcome." In the new world of Prodigy, everyone can be Dear Abby.

The prices of goods sold on Prodigy also invoked comments. "There is an interesting selection of merchants on Prodigy," said one user, "but their prices seem pretty noncompetitive. It's as if they think people who use on-line shopping are such computer nerds that we don't get out in the real world."

Other suggestions had to do with more printing options and the ability to download data. Currently, you can print out only messages, flight schedules, stock prices, and transaction records. You can't issue a print screen command through your computer because Prodigy is delivered in a graphics mode, and your system prints only screens that have ASCII content underneath. There is no way to download a file. One user would like to be able to upload paint screens into an on-line gallery. Prodigy does offer an art gallery that you can peruse, but the Prodigy staff creates the art.

Another enhancement might be the addition of sound to what is currently a silent medium. The only thing you hear now is a beep when you select an option that isn't available. —*M. A.*

tion game called CEO, which according to Ek, "has taken on a life of its own." You head up a company making beer, chocolate, automobiles, soda, toys, or computers, and compete against other players. Each game lasts 15 days, and you make daily decisions on production and advertising and whether to issue stock, borrow money, or increase the plant size.

In spite of its limitations, Prodigy *has* improved on the videotex theme. In addition to the flat-rate fee, it has enhanced videotex technology. Early videotex services held hostage the two most popular appliances in the household—the telephone and the television. (As an alternative to using a personal computer, the services sold or rented a dedicated keyboard that sat between your phone jack and TV.) Prodigy doesn't monopolize the TV since it works only with a personal computer, though it hasn't solved the problem of tying up your phone.

Unlike software you take home, software bugs can be corrected at the source—or, if they're discovered but not yet fixed—Prodigy can tell you about them on-line.

Another lesson Prodigy learned is to distribute processing as much as possible to the personal computer or regionally located minicomputer so that all data doesn't have to come from the mainframe in White Plains, N.Y. For example, Prodigy stores the weather map on the program disk in your computer. It transmits only the current readings over the phone so it can overlay them on the map graphic. If Prodigy wants to send a circle, it sends two points—the center and the radius—and lets the software in your computer do the rest.

But for all the improvements Prodigy has made, some problems linger. Our major gripe is waiting for Prodigy to retrieve and display information—an idle time of 8 seconds every time you change screens is not unusual. This wait will seem significant to people who have little experience with computers, and annoying to experienced users who expect Prodigy to immediately execute commands. Imagine staring at the wall and counting "One Mississippi, two Mississippi, etc." between each paragraph you read in this magazine. Even if your reading speed is average, you'll spend more time staring at the "Working" message than digesting the large-character content that follows. For serious use, we wouldn't recommend anything less than a 2,400-baud modem—Prodigy's maximum—but even that performance level really isn't good enough.

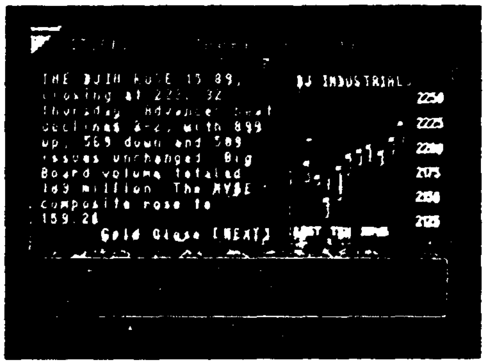
The Institute for the Future's Adler, who also subscribed to Viewtron, thinks that Prodigy's response rate is slower than Viewtron, and suspects that despite the local nodes (including one a mile from his office) and personal computer, the system still takes its cue from the mainframe 3,000 miles away.

"Absolutely not," responds David Wacks, Prodigy's director of technology. "We couldn't afford to sell the service for $10 a month if it was organized in the classical mainframe way. There is a heavy price to pay for host processing and communications." What you see is always coming from one of three places, in this order, says Wacks: the disk in your computer, a mini-computer node located in your area of the country, or the mainframe in White Plains.

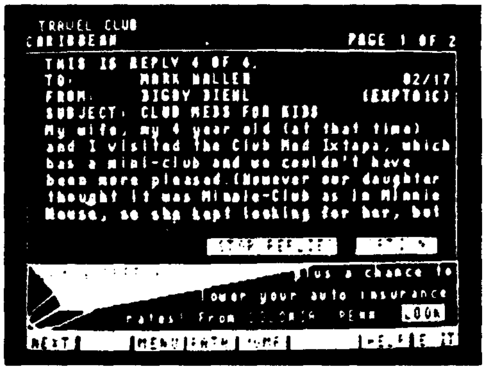
Wacks blames the slow response on the phone lines. "A PC AT can process 100,000 bytes a second," he says. "A phone line with a 2,400-baud modem processes 240 bytes a second. That's a 400-to-one disparity. There's precious little that we can do about it."

We also experienced problems as late-night users. The first time our screen simply froze. The second night, our session was interrupted and we were left staring at a cryptic message about a communications error. It even suggested we redial. There was no answer. We later found out that the service operates from 7 a.m. to 1 a.m. on the East Coast, and from 6 a.m. to midnight everywhere else. At day's end, the system simply cuts off without warning. At the very least, there should be a message at 10 minutes to the hour telling you that you should plan your remaining minutes accordingly. Ek says Prodigy plans to add an alert feature. In any case, it's a pity that Prodigy turns into a pumpkin at midnight because it's about that time that you're not so concerned about tying up the phone. Ek says the system needs to be off-line so it can be refreshed.

If you have call waiting, an incoming call will knock you off



Prodigy's business building offers brief market updates. Its portal into Dow Jones News/Retrieval lets you maintain two sets of stock portfolios.



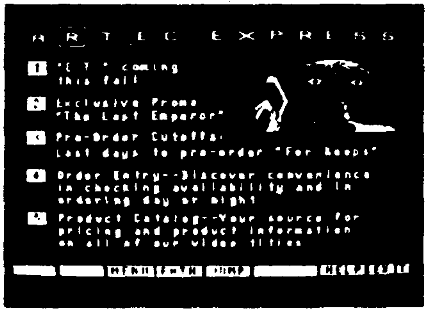
Electronic mail is one of Prodigy's most popular features. You can send messages privately, post them publicly, or query your favorite columnist.

DOING BUSINESS WITH VIDEOTEX

■ While videotex is being pushed for the home, it may begin to shine in business-to-business settings. Artec, Inc., a distributor of prerecorded video cassettes in the Northeast, uses a customized Prodigy network to present its catalog to video stores and take orders from them.

Since many video stores already have personal computers installed (they may do double duty as cash registers and inventory managers), they can, with the addition of a modem, tie into a distributor's warehouse. The advantage to retailers is quick ordering. The advantage to distributors is that they can cover a lot more ground electronically than with a traveling sales force. And such a system also improves service to the customer: Answers to inquiries from dealers trying to locate vintage titles or check a home video release date for a current box office hit can now be stored in the system, thus reducing the number of telemarketing representatives need to handle routine inquires.

At press time, Artec, Shelburne, Vt., was set to go on-line to its retailers on March 31st with a service called Artec Express. Prodigy serves as the graphics shell and gateway between the retail stores and Artec.



Artec lets video stores place orders, check new releases.

Artec Express will display movie synopses to video store employees, check video release dates, find out it if the cassettes are available, and order titles. The retailer hits "Action" to order. (The service will not be available to Prodigy's general users.)

Retailers' system requirements are the same as those for Prodigy users, except that 640K of memory is needed instead of 512K to improve response time. According to Michael Greenbaum, director of marketing for Prodigy, "We do what is called staging, which is to put more code in the personal computer for better response time. We're sensitive to the fact that in a business environment, waiting is not something you like to do."

Because Prodigy is graphics-based, computer novices can quickly learn to use the service. Greg Casto, Artec's vice president of information systems, says video store employees can operate the system without formal training. "It's a one-figure operation," he says.

As in the Prodigy consumer service, advertising helps defray the costs of the network. In Artec's case, movie studios are being solicited to promote their new cassette releases. However, according to Casto, none of the studios had signed up as of mid-February. The ads appearing at the bottom of the screen will be, at least in the beginning, designed to promote Artec's dealer specials. —*M.A.*

Prodigy unless the phone company provides a way to temporarily turn off the feature. In certain prefixes of the 415 area code, for example, you can dial "*70," listen for the dial tone, and dial out.

Even if these technological problems were solved, there's still the problem of information density. The lean news section results from Prodigy's study of past systems. While Viewtron and Gateway used a local newspaper as their paradigm for local and national information, Prodigy learned that consumers are unwilling to pay $5 an hour for the privilege of seeing on-screen what they'd normally pay a quarter to see in print. Referring to the unsuccessful earlier services owned by newspapers, Ek says, "We saw what happened there, and we didn't want to go into a market and replicate a newspaper.

"There's not a lot of value that we can add to the newspaper. We're not doing local movie listings. As far as local news, that's something that could be done, but we'd have to consider the cost factor and whether there is added value there."

Distributing information that remains static around the country may make for a less labor-intensive operation, but it's like replacing local radio announcers with satellite-fed Muzak. Adler remembers an experimental teletext service where you could check local traffic conditions on maps before leaving for work. You *can* access local weather through Prodigy, but otherwise it seems far removed from the local community. We'd like to see local news and entertainment listings. Perhaps that would violate Prodigy's strategy against reproducing the local paper, but we find the present editorial mix ultimately unneighborly. As for using Prodigy as a news substitute for other media, forget it. News junkies will starve.

The things we'd most like to buy with Prodigy—tickets for plays (although you can order Broadway tickets through one of Prodigy's advertisers), concerts, and sports events in our city—was possible with earlier services like Viewtron (which even gave you access to seating plans), but is unavailable with Prodigy. Prodigy would be an ideal way to avoid long ticket lines or to order municipal transit passes or pay parking tickets. Ordering groceries by computer is a start, but that's not available in all locales served by Prodigy. Prodigy does let you check winning lottery tickets, and that's certainly convenient, but it would be even more convenient to buy them there, too.

Most important, Prodigy has to expand the scope and substance of its content. Serious research for anyone—from a business person gathering statistics to a high school student writing a report—isn't possible in Prodigy's current incarnation. Even the most basic reference tools like a dictionary, almanac, atlas, zip code directory, and encyclopedia are missing. If you're serious about researching back issues of magazines, you're bound to be disappointed unless subsets of *Consumer Reports* and *Home Office Computing* are sufficient. (CompuServe, the ASCII-based on-line service, serves as a gateway into Information Access Corp.'s hefty library of abstracts and complete text retrieval for many computing magazines. But you'll pay time and per article charges that can quickly dwarf Prodigy's paltry $9.95 a month.)

Prodigy also needs to dramatically speed up its information-

MINITEL: THE FRENCH CONNECTION

■ While videotex in the United States remains a technology in search of a market, it's very much part of everyday communications in France. Some 4 million terminals in French homes and businesses pick up France's Minitel service, and about 500,000 more users access Minitel from PCs.

"In France, videotex is a mass medium," says Richard Adler, director of the teleservices program at Institute for the Future in Menlo Park, Calif. "Everyone does it, but it was a massive countrywide effort to get it installed."

Indeed, the French government itself subsidized the effort by giving away terminals. "The trigger was that you got a terminal instead of the white pages [of the telephone book]. Think of all the trees you were going to save," says Adler.

Besides, with the paper directory, 20 percent of the listings were out-of-date, so an on-line directory had more appeal. Also, the on-line directory is more efficient since users can scan listings by location and service descriptions as well as by name.

Beyond telephone listings, Minitel hosts about 8,000 service providers that offer everything from car parts to dinner recipes. A profitable message service that initially gave Minitel a boost was sexually oriented, though home banking and mail order shopping are areas now growing more rapidly.

Aline, Minitel's U.S. counterpart, offers a real-time chat mode.

Unlike Prodigy, which has tens of thousands of users and is still limited in its variety of services, Minitel has millions of users and many services. The French service has the substance and scope that Prodigy only promises.

Users of IBM-compatible and Macintosh computers in the U.S. can go online with Minitel via MinitelNet in New York (1-800-822-MNET). Terminal emulation software is available for both systems. The connect charge is $25 per hour.

An alternative way to interface with Minitel is via Aline, a New York-based service from Newcom Link, Inc. Americans can practice their French (or the French can practice their English) via live chat lines and classified ads. The classifieds are like the personal columns you might find in print, with people looking for everything from a relationship to an apartment swap. You can set up a mailbox to receive messages.

Aline also affords you a direct line into the Paris phone directory. So, if you're taking the Concorde over to Paris for dinner, you can make your restaurant reservations before leaving your office. Aline also offers financial news, Paris Stock Exchange quotes, BBC news, weather conditions in France, and plane reservations.

According to Caroline Camougis, Aline's marketing and administrative director, the chat aspects of Aline are much different from Prodigy because Prodigy is run more like an advice column while Aline is "like meeting someone at a party. You get an immediate reaction to what he or she is like." She says people have gotten job opportunities and developed relationships through Aline, and one couple has even gotten married. (Prodigy doesn't permit personal ads on its bulletin boards, and there is no live chat line.)

Aline charges a flat 30 cents a minute in New York or 20 cents a minute outside of New York via Infonet. Questions about the Miniterm emulator (personal computer software that enables you to reach Aline) and access to Infonet can be answered by calling 1-800-272-8737 or 212-832-8311.—*M.A.*

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handling options. Uploading message files, capturing data to disk, and printing any text on the screen are functions people will intuitively expect. More attention should be paid to subscribers with monochrome displays and mouse support, although a Prodigy spokesman responds that once a Macintosh version is available, mouse and monochrome enhancements are inevitable.

Prodigy officials retort, just give us time, you haven't seen anything yet. Their argument really comes down to a promise. Prodigy needs a critical mass of users to make its subscriber base attractive to advertisers and service providers; users need many more information options to make Prodigy compelling enough to join. Neither side is being satisfied yet.

Though Prodigy is still in only a handful of markets, returns are coming in. While the company won't release subscriber or renewal figures, as of February, users numbered "in the tens of thousands," and renewals were "slightly ahead" of what was expected, according to a spokesman. Arlen estimates that during Prodigy's first seven months of service, between 30,000 and 40,000 users joined, though about 10,000 of those were freebies. Out of that last group, "roughly half started paying for it" after their three free months were up, he says.

Egghead Discount Software, a 180-store chain, ranked the Prodigy Start-up Kit 10th in sales in the IBM Business Category during the month of January. That's the same category that includes such packages as WordPerfect and First Publisher. What's noteworthy about the ranking is that unlike the other packages, less than half of Egghead's outlets were selling the kit at the time.

In its best light, Prodigy suggests the shape of things to come. For now, checking airline schedules and stock prices or *Consumer Reports*' car recommendations may be useful for some but not critical for many. As it stands now, Prodigy does not offer the depth and breadth of information you can get from other sources such as the daily newspaper, library, or other remote services.

The Prodigy mall is full of promise, the price of entry is clearly low enough to invite the casual stroller, and while there's a novelty about visiting it once in a while, the mall is just too hollow right now to make frequent visits compelling.■

DIVERSION ANALYSIS

An important part of this study is to define the primary surface street diversion routes for drivers who divert from the freeway, due to either recurring or nonrecurring congestion conditions. The purpose of this paper is to discuss the criteria and methodologies used to identify these routes. Two separate diversion scenarios were analyzed. The first scenario was diversion of drivers from the freeway during an incident or peak traffic periods. The second, and perhaps more difficult to analyze is the diversion of drivers to an alternate route on the surface streets before the driver reaches the freeway. Based on the analysis of each scenario, appropriate diversion routes were identified.

Scenario 1 - Diversion From the Freeway

A primary objective of the Smart Corridor is to divert drivers from the freeway during an incident. The goal of this type of diversion is to re-route freeway traffic around an incident, returning them to the freeway as soon as possible. This action is based on the premise that most drivers are freeway biased, especially drivers who are already on the freeway. Previous research on driver behavior supports this premise, generally concluding that drivers on a freeway are very difficult to divert from the freeway, even in the case of an incident. Recent observations on the Santa Monica Freeway bear this out. In one instance an incident was observed involving a large tractor-trailer. Two freeway lanes were blocked creating severe congestion and queueing, however, few drivers were observed to divert to one of the parallel surface streets, Adams Blvd. or Washington Blvd., which at that time had very little traffic. In order to facilitate freeway diversion during an incident, it is necessary to define specific routes by which drivers can leave the freeway, bypass an incident, and return to the freeway. These particular routes would be identified by both static and changeable message signs.

The criteria which were used to define the incident diversion routes are described below.

o The diversion trip should be as short as possible, i.e. the parallel route should be a minimum distance from the freeway.

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The criteria which were used to define the incident diversion routes are described below.

o The diversion trip should be as short as possible, i.e. the parallel route should be a minimum distance from the freeway.

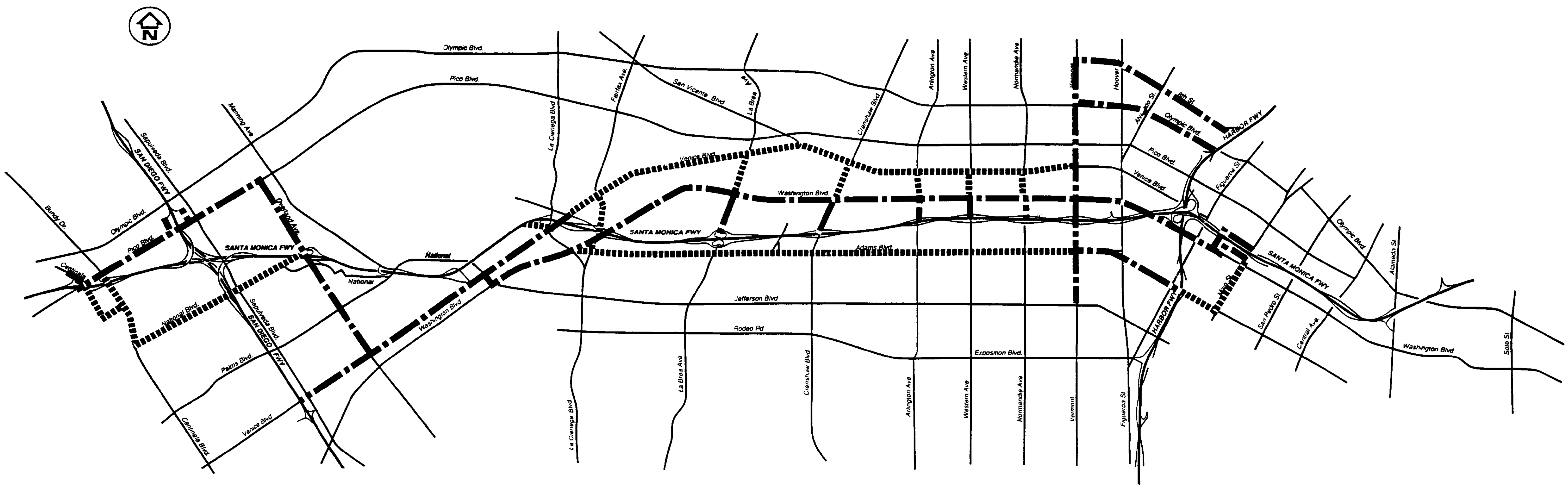
- o The diversion route must have sufficient capacity to accomodate the vehicles which divert.
- o Access to the parallel route should be at least one-half mile spacings if possible.
- o The diversion route must maintain operational integrity along its entire length.
- o The diversion route should have a high profile in order to provide drivers with a greater feeling of comfort. Well known routes, preferably with commercial activity are preferred.
- o Diversion through residential areas must be avoided.
- o The connectors linking the freeway and parallel routes should be smooth flowing requiring a minimal amount of navigation.
- o Ramp capacity should be sufficient to accomodate the diversion demand.

Based on these criteria, preliminary diversion routes were identified for the Smart Corridor. These routes are diagramed in Exhibit 1. Washington Blvd. was defined as the primary parallel route east of La Cienega Blvd. West of La Cienega Blvd., Venice Blvd. was identified as the primary route. Adams Blvd. and Venice Blvd. east of La Cienega Blvd. were identified as secondary diversion routes. It is anticipated these secondary routes would only be used if primary route was unable to handle the diversion demand. Exhibits 2 thru 7 illustrate the existing excess capacity which was estimated for each of the parallel routes in the Smart Corridor. Keep in mind that these exhibits illustrate the existing excess capacity and not the potential excess capacity. Analysis of potential mitigation measures which would increase the capacity a certain key intersections is continuing and will be documented in the final report.

Scenario 2 - Diversion Prior to the Freeway

POTENTIAL FOR RECURRENT DIVERSION

The purpose of this section of the report is to discuss the potential for diversion of trips from the Santa Monica Freeway to parallel surface streets as a result of recurrent congestion on the freeway. Potential diversion routes are discussed first, followed by an estimation of the level of diversion which could potentially be achieved, and an evaluation of whether this estimated level of diversion could be accommodated by the surface streets.



LEGEND

- Primary
- Secondary

Exhibit 1

Diversion Routes

jhk & associates

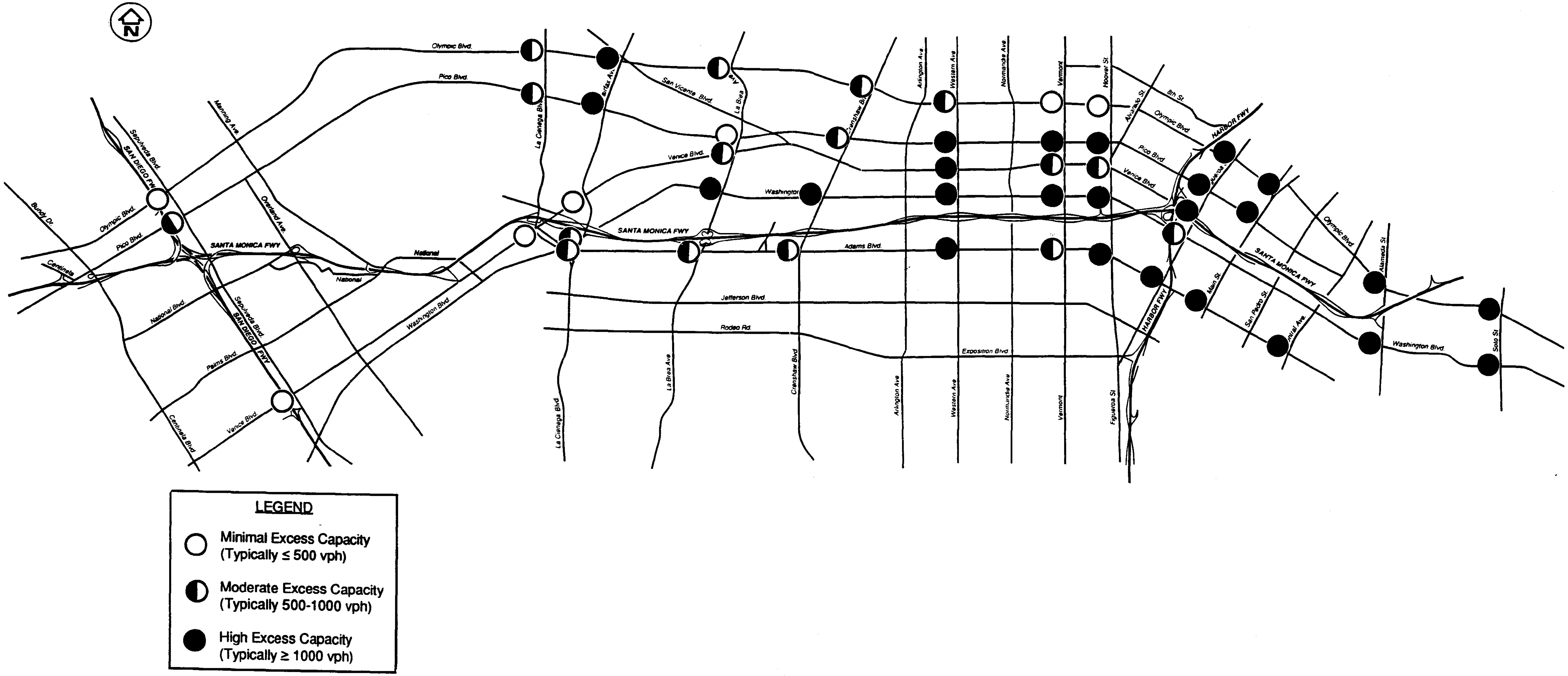


Exhibit 2

Existing Excess Capacity Analysis: AM Peak Hour (7-8 AM)
East Bound

jhk & associates

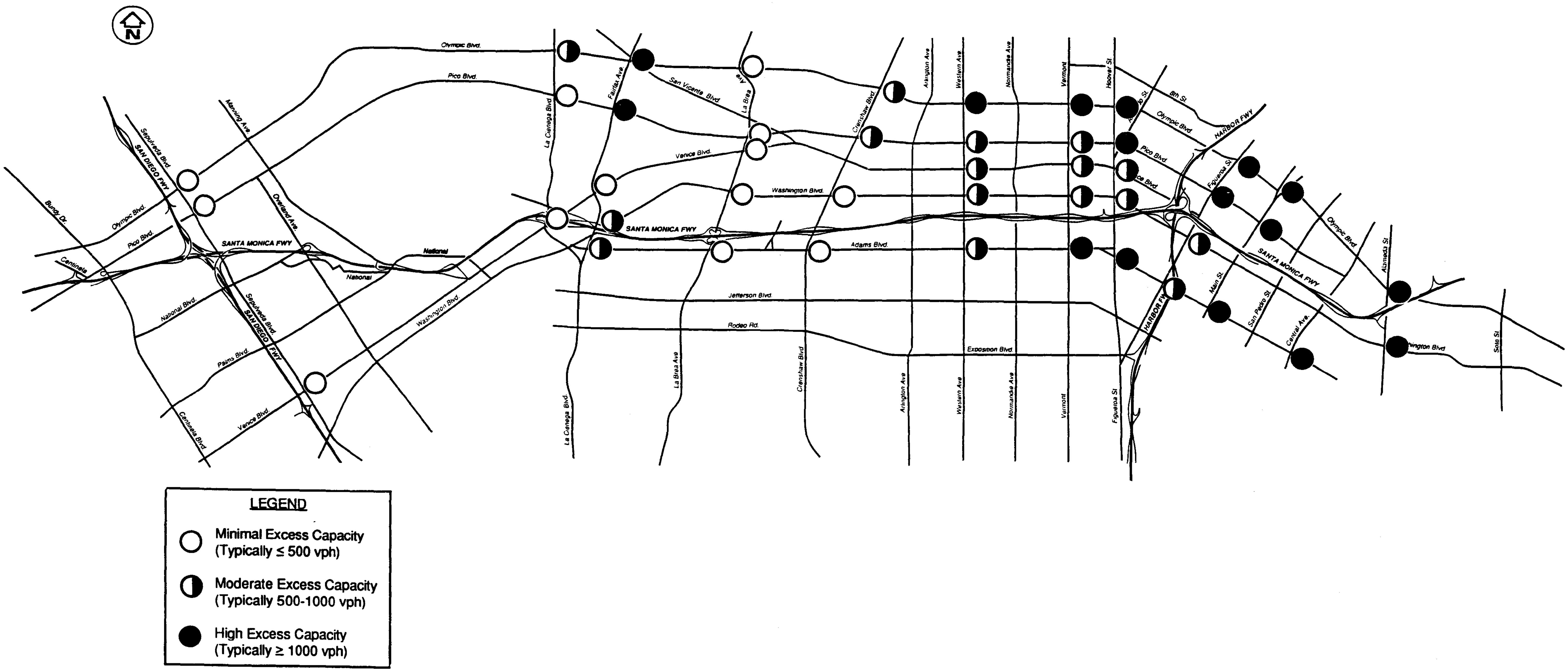


Exhibit 3

Existing Excess Capacity Analysis: AM Peak Hour (7-8 AM)
West Bound

jhk & associates

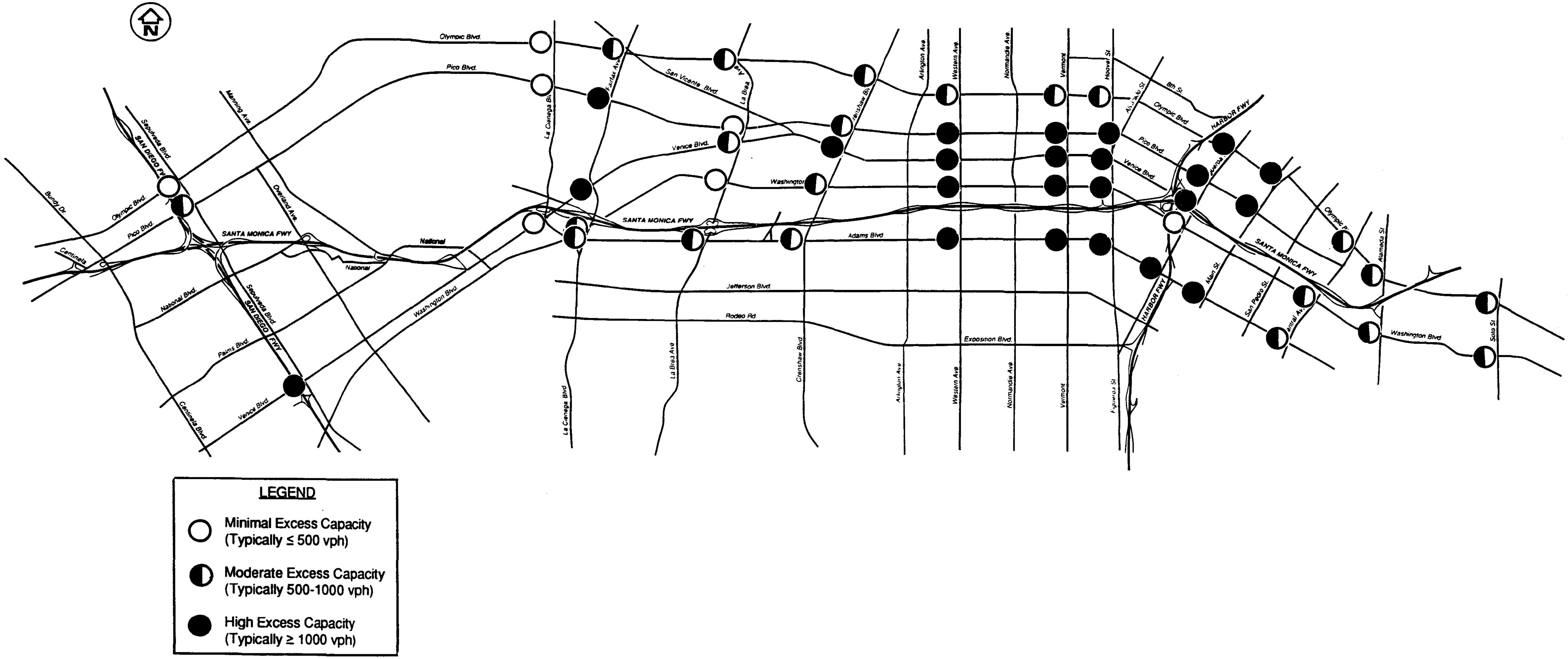


Exhibit 4

Existing Excess Capacity Analysis: Off-Peak Hour (12-1 PM)
East Bound

jhk & associates

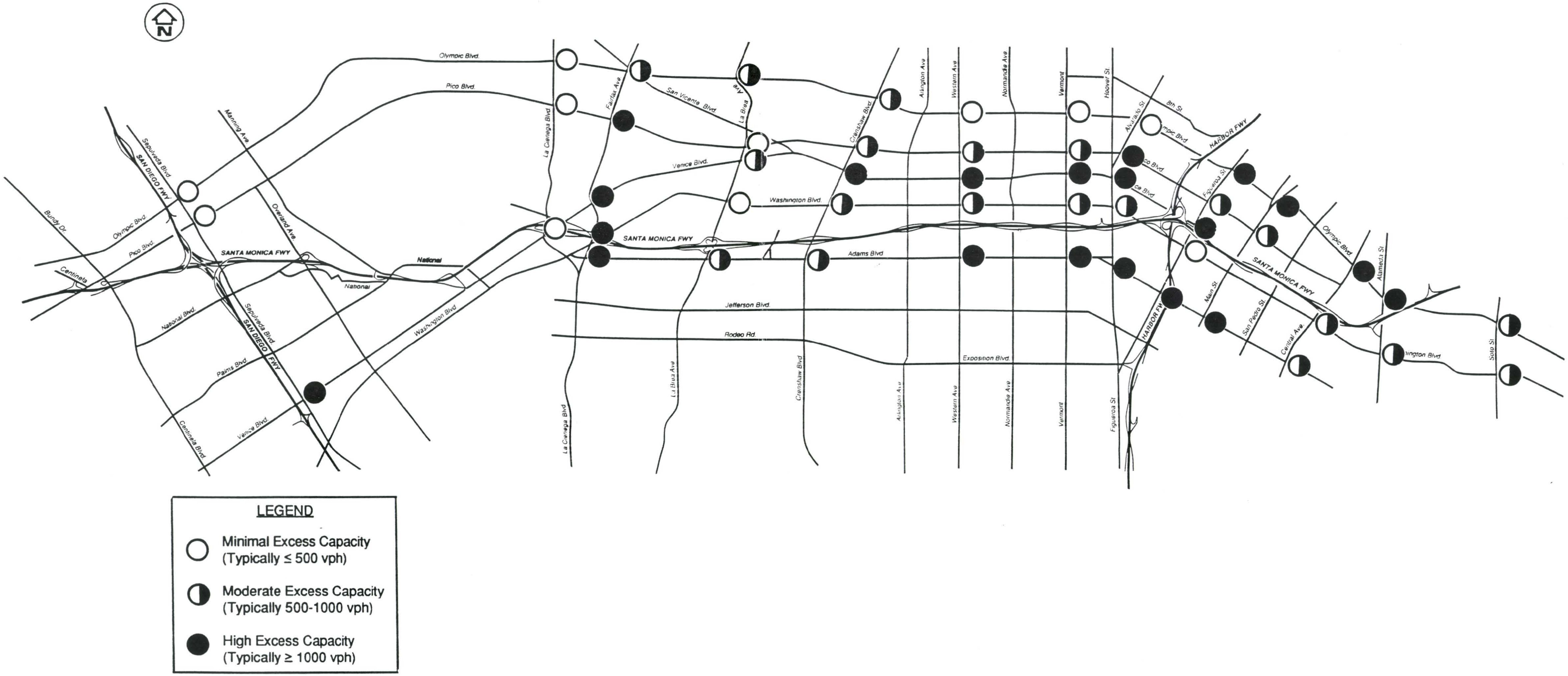


Exhibit 5

Existing Excess Capacity Analysis: Off-Peak Hour (12-1 PM)
West Bound

jhk & associates

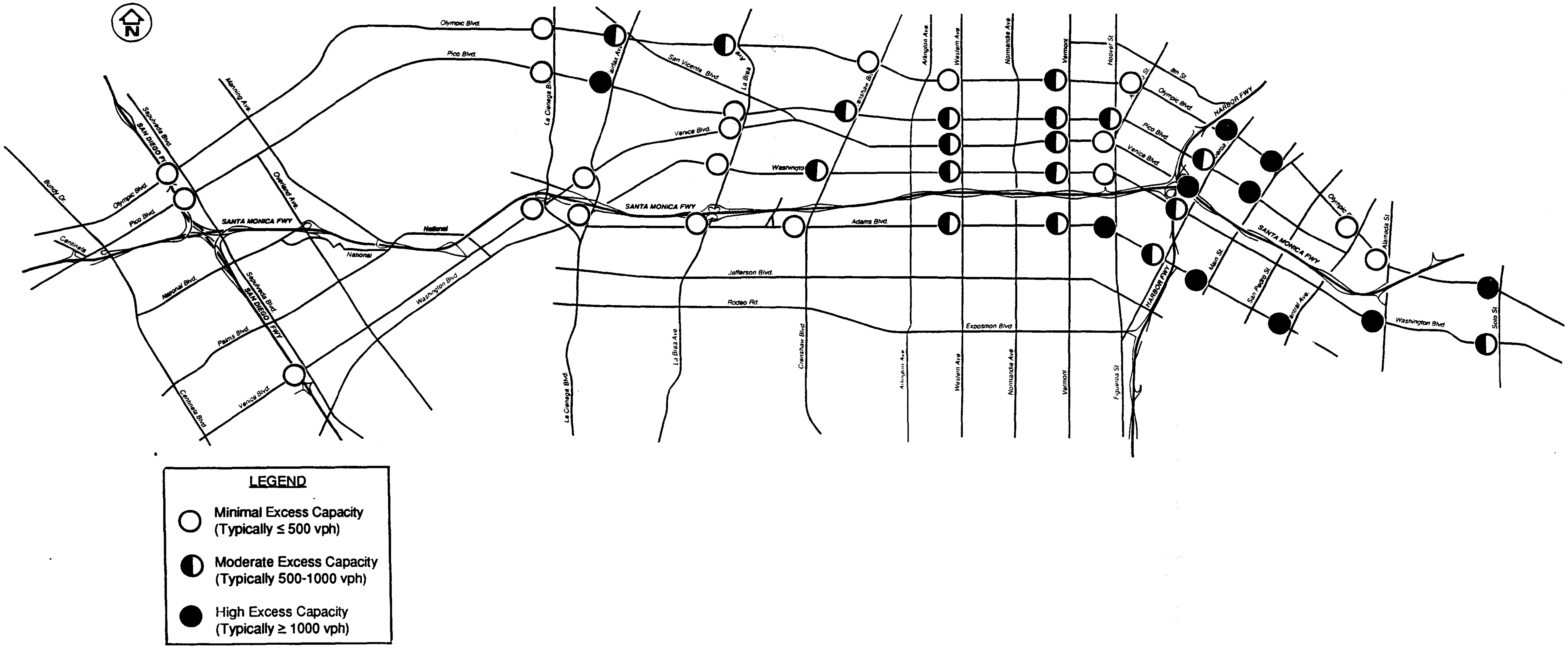


Exhibit 6

Existing Excess Capacity Analysis: PM Peak Hour (5-6 PM)
East Bound

jhk & associates

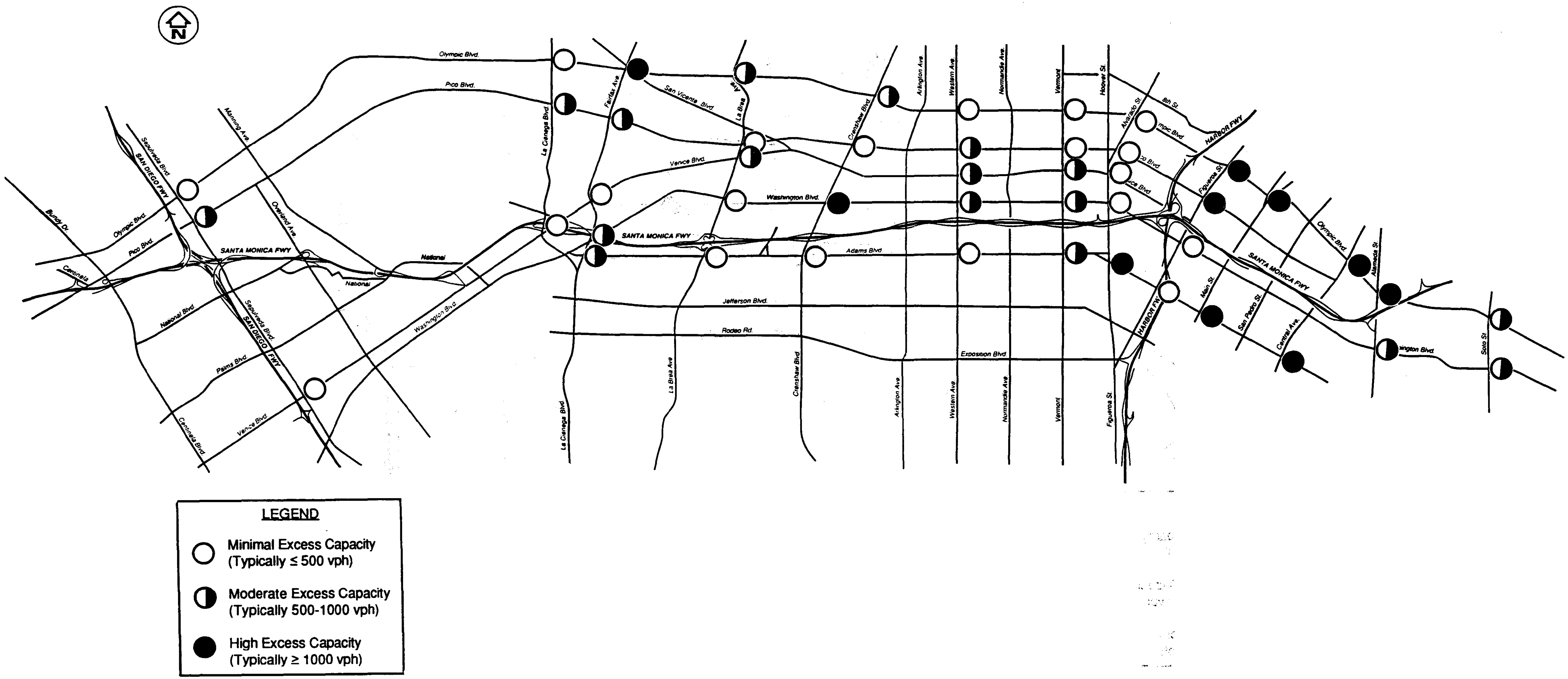


Exhibit 7

Existing Excess Capacity Analysis: PM Peak Hour (5-6 PM)
West Bound

jhk & associates

Potential Routes

Unlike non-recurring or incident-based diversion (in which the parallel streets closest to the freeway would be the most likely candidates for diversion routes), diversion in reaction to recurrent congestion could be expected to utilize any of the major parallel streets. The actual route which would be used by a given diverted trip would depend upon three primary factors: (1) the precise origin and destination of the individual trip which is diverted; (2) the degree of familiarity of the individual motorist with the local street system; and (3) the amount of motorist information relative to the availability of parallel routes which is available to the motorist both prior to and during the trip. As such, any of the five major parallel arterials within the corridor (i.e., Olympic Boulevard, Pico Boulevard, Venice Boulevard, Washington Boulevard or Adams Boulevard) could potentially be used as diversion routes, as could lesser streets such as National Boulevard in the western portion of the corridor.

Magnitude of Potential Diverted Trips

In order to estimate the magnitude of trips which could potentially divert as a result of recurrent congestion on the freeway, information was obtained from the regional travel demand model maintained by the Southern California Association of Governments (SCAG). SCAG provided "select link" analyses for a number of sections along the Santa Monica Freeway based on the 1984 calibrated model (representing existing travel conditions), for both the morning and evening peak hours. With this information, estimates of the amount of trips on various segments of freeway which were between various zones within the corridor, versus regional traffic travelling through the corridor, could be developed.

The portion of trips currently travelling on the freeway which could have the potential to divert to surface streets in reaction to recurrent congestion was estimated from the SCAG data using a number of key assumptions. The primary assumptions include:

- Generally, trips from zones within approximately one mile on either side of the freeway to destination zones within the corridor could potentially divert from the freeway to remain on surface streets if their total travel distance along the corridor is five miles or less.

- All trips from zones between approximately one and two miles from the freeway to destination zones within the corridor could divert from the freeway to remain on surface streets. This results from the assumption that, the further the travel distance required to access the freeway, the greater the distance along

surface streets motorists would be willing to divert from the freeway.

- o Trips from zones within the corridor to destinations outside of the corridor (i.e., regionally-bound trips) would remain on the freeway, and would not be likely to divert to surface streets in reaction to recurrent congestion.

- o Regional trips passing through the corridor (with both origins and destinations outside of the corridor) would remain on the freeway, and would not divert to surface streets in reaction to recurrent congestion.

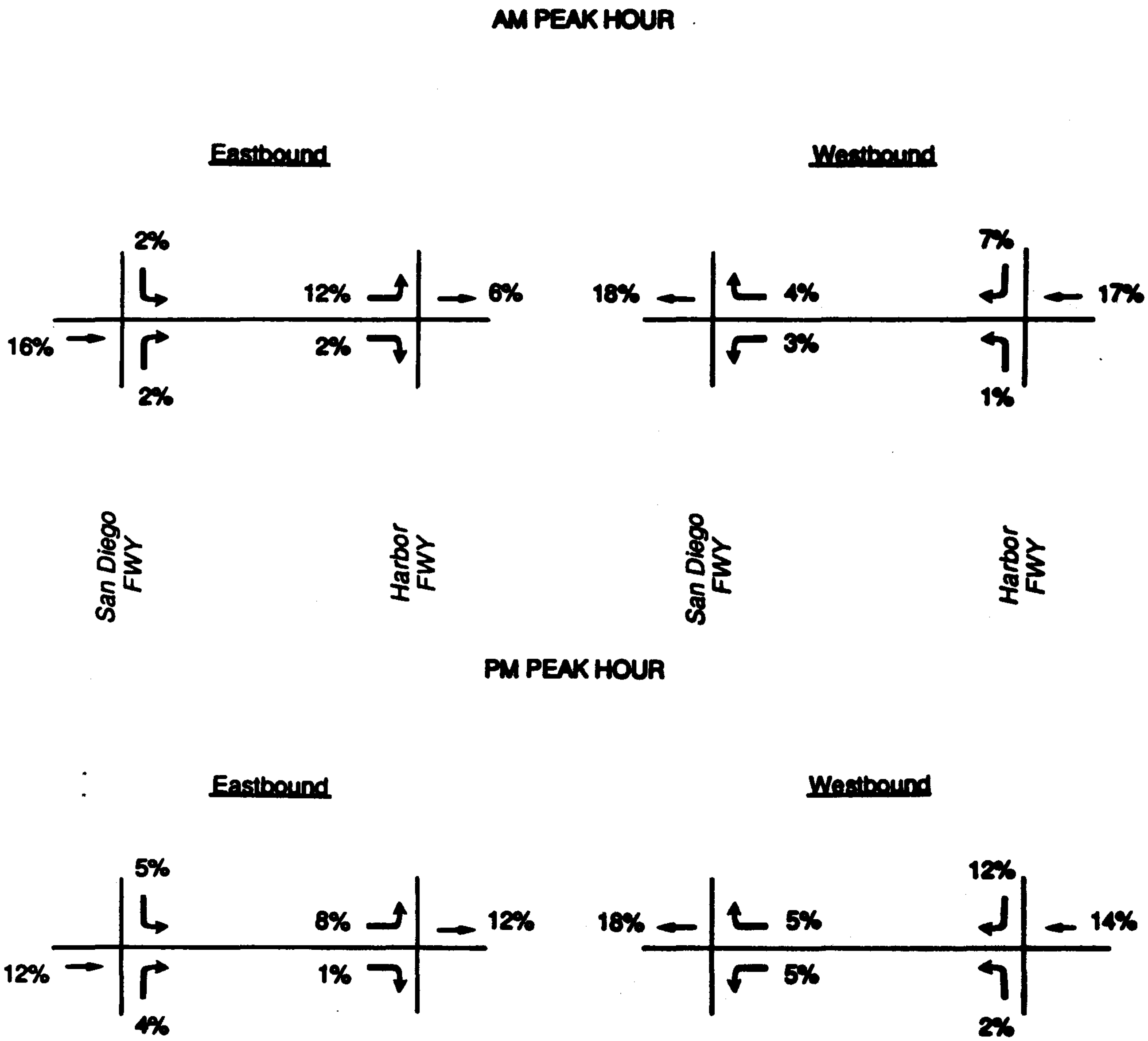
Exhibit 8 summarizes the number of thru trips through the corridor and which are considered to be non-divertable. Thru trips are defined as those trips with origins and destinations outside of the corridor. Exhibit 8 shows that roughly 20 percent of all trips using the Santa Monica Freeway in the Smart Corridor are thru trips. Exhibit 9 summarizes the estimated number of trips during both the morning and evening peak hours currently travelling on the freeway which could have the potential to divert, at a number of locations along the corridor. It should be recognized that these estimates represent the upper bound of the potential for recurrent diversion, as not all of the trips with the potential for diverting could in reality be expected to divert.

As indicated in the exhibit, the estimate potential for diversion is generally greater in the pm peak than in the am peak (both eastbound and westbound). The potential for diversion is also generally greater eastbound than westbound, during either peak period. It is estimated that between about 1,200 and 2,100 vehicle trips could have the potential to divert from the freeway to parallel surface streets eastbound during the am peak hour, depending upon location. Westbound during the pm peak hour, the estimated potential for diversion ranges from approximately 300 to 1,700 trips.

Comparison to Surface Street Excess Capacity

In order to provide an indication of the degree to which the parallel streets may be able to accommodate diverted traffic flows, existing excess capacity was estimated at major intersections along the five parallel surface streets in the report entitled Smart Corridor Demonstration Project, Issue Paper on Existing Traffic Conditions (May 1989 revision). Exhibits 36a through 38b of the issue paper graphically display the estimated existing excess capacities by street for both the eastbound and westbound directions during various peak periods.

Exhibit 8



1. Thru freeway trips are considered to have origins and destinations outside of the Smart Corridor.

Thru Freeway Trips [1] as a Percentage of Total Smart Corridor Freeway Trips

jhk & associates

SMART CORRIDOR DEMONSTRATION PROJECT

EXHIBIT 9
COMPARISON OF RECURRENT DIVERSION POTENTIAL TO SURFACE STREET EXCESS CAPACITY
(BY CORRIDOR SEGMENT)

Corridor Segment	AM Peak Hour: Potential # of Diverted Trips	AM Peak Hour: Excess Capacity	AM Peak Hour: Capacity Exceed Diversion?	PM Peak Hour: Potential # of Diverted Trips	PM Peak Hour: Excess Capacity	PM Peak Hour: Capacity Exceed Diversion?
EASTBOUND						
OVERLAND/LA CIENEGA	1,190 - 1,460	2,220	yes	1,500 - 1,840	550	no
FAIRFAX/LA BREA	1,730 - 2,110	3,230	yes	2,510 - 3,070	1,160	no
LA BREA/CRENSHAW	1,380 - 1,690	3,680	yes	2,390 - 2,920	1,720	no
WESTERN/VERMONT	1,650 - 2,020	3,930	yes	3,350 - 4,100	2,860	no
WESTBOUND						
VERMONT/WESTERN	190 - 230	4,760	yes	300 - 370	1,830	yes
CRENSHAW/LA BREA	290 - 350	1,850	yes	520 - 630	2,900	yes
LA BREA/FAIRFAX	720 - 880	1,140	yes	1,350 - 1,650	1,550	no
LA CIENEGA/OVERLAND	560 - 690	2,260	yes	1,080 - 1,320	1,410	yes

- Potential number of diverted trips estimated as described in text.
- Excess capacity estimates are total for north/south screenline with lowest aggregate excess capacity within given corridor segment.

The estimated existing capacity was summed across the five parallel arterials for various north-south screenlines. For each of the corridor segments included in the diversion analysis, the excess capacity for those screenlines with the lowest overall excess capacity was determined and is also shown in Exhibit 9. This presents a "worst case" evaluation of the surface street excess capacity, since the excess capacity at various locations along the corridor can vary proportional to the existing operating conditions at various intersections.

As can be seen on the exhibit, on a corridor-wide screenline basis, the estimated existing excess capacity is sufficient to accommodate the entire potential for diverted trips in both the eastbound and westbound directions during the am peak hour. During the pm peak hour, on the other hand, the excess capacity is not sufficient to accommodate all of the potential diversion in the eastbound direction and at certain locations in the westbound direction. However, it is important to note that, while it may not be possible to accommodate the entire potential diversion, a significant portion of the potential could be handled. Furthermore, as noted previously, it is not realistic to expect that all of the trips which may have a potential for diverting would actually do so.

In addition to the screenline analysis presented in Exhibit 9 the diversion estimates were compared to the existing excess capacity estimates on a street-by-street basis. The results of this comparison generally matched those of the screenline analysis above, with each of the streets generally able to accommodate a portion of the estimated potential for diversion both eastbound and westbound during the am peak hour. During the pm peak hour, poor operating conditions at a number of intersections restrict the number of diverted trips which could be accommodated by the parallel street, particularly along portions of Olympic Boulevard, Venice Boulevard and Washington Boulevard. A review of Exhibits through indicates that, although many of the intersections currently have a significant amount of excess capacity (500 vehicles per hour or more, particularly during the morning peak hour), there are numerous remaining locations which could create bottlenecks to diversion (particularly during the pm peak hour).

However, it should be noted that the excess capacity analysis as presented herein represents estimated excess capacities for existing traffic conditions at the major intersections. As such, it does not address the potential for additional excess capacity which could result from implementation of capacity improvements at the intersections or along street segments. Identification of operational and/or minor physical improvements which could potentially be implemented to improve operating conditions (and thus increase available excess capacity) is the subject of a separate evaluation currently underway.