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CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
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Smart Corridor Evaluation Plan: Conceptual Design

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California PATH Research Paper

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February 1994

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SMART CORRIDOR EVALUATION PLAN: CONCEPTUAL DESIGN

FINAL REPORT

prepared for the

Santa Monica Freeway Smart Corridor Technical Committee/Caltrans

prepared by the

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1. INTRODUCTION

This document is the final report for PATH MOU 98, "Design of Evaluation Plan for Smart Corridor, " performed by California PATH under contract to Caltrans. This report presents the Conceptual Design Plan for evaluating the effectiveness of the Smart Corridor Demonstration Project. Follow-up work is required to produce a completely specified and implementable evaluation plan and should focus on methods for data collection, reduction, and analysis, the schedule, budget, and deliverables. The evaluation project is one of approximately thirty components of the entire Smart Corridor Demonstration Project.

The Smart Corridor Demonstration Project is funded by several governmental agencies, including the Federal Highway Administration (FHWA), Caltrans, California Highway Patrol (CHP), Los Angeles County Metropolitan Transportation Authority (LACMTA), Los Angeles Department of Transportation (LADOT), Culver City, Beverly Hills, and the Los Angeles Police Department (LAPD). Overall, the Smart Corridor is designed to obtain improved utilization of existing roadway facilities, both freeway and arterial, through the use of Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS), through improved inter-agency coordination, and through better use of conventional traffic management strategies.

1.1 STUDY OBJECTIVES

The purpose of this study is to develop a plan for the comprehensive evaluation of the Smart Corridor Demonstration Project. To assist in the fulfillment of this objective, several documents were reviewed, including a draft evaluation design plan produced as part of previous Smart Corridor-related work by JHK & Associates [1], and evaluation design plans for such related demonstration projects in the United States as Pathfinder (Farradyne Systems, Inc. and JHK & Associates [2]), TravTek (Farradyne Systems, Inc. and The Center for Applied Research [3]), INFORM (Peat, Marwick, Mitchell & Co. and JHK & Associates [4]), and FAME (Washington State Department of Transportation [5]). The specific objectives of this report are to

- develop a conceptual structure for the Smart Corridor evaluation,
- define evaluation data requirements and collection procedures, and
- select and/or develop data reduction and data analysis methodologies.

The evaluation project should be comprehensive and should include studies of network performance, traveler response, institutional effectiveness, system operational performance, and environmental impacts.

1.2 ORGANIZATION OF THE REPORT

This report consists of four major sections, this introduction being Section 1. Section 2 describes the overall conceptual framework for conducting the evaluation. Section 3 identifies general data requirements and collection methods to be used to develop a complete evaluation data base. The primary data sources to be used for the evaluation, consisting of surveillance systems, traveler surveys, agency records, and interviews are discussed, Section 4 outlines procedures for reducing and analyzing the data, and describes statistical significance tests applicable to the evaluation.

1.3 OVERVIEW OF THE SMART CORRIDOR DEMONSTRATION PROJECT

The Smart Corridor Demonstration Project is a multi-agency undertaking utilizing the combined weight of Advanced Traveler Information Systems and Advanced Traffic Management Systems, in addition to existing methods and services, to address all forms of traffic congestion on the Santa Monica freeway corridor. Geographically, the study area is approximately five miles wide and fourteen miles long, encompassing the region between Centinela Avenue on the west, Soto Street on the east, Olympic Boulevard on the north, and Adams and Washington Boulevards on the south (Figure 1). The principal roadway segment of the Smart Corridor is Interstate 10 (Santa Monica Freeway). Major parallel arterial roadways in the corridor are Olympic, Pico, Venice, Washington, and Adams Boulevards. The roadway configuration of the corridor is integral to its choice as the site for this demonstration project. The five major arterials parallel to and within a few miles of a major east-west freeway corridor (Interstate 10) offer an opportunity to alleviate the interlinked issues of traffic congestion, safety, and air quality.

The project's purpose is to address not only problems of mobility within the corridor, but also those of on-road mobile source emissions and energy usage. These issues will be addressed technologically through traveler information devices, signal control and incident response.

The Smart Corridor system will strive to address these problems by 1) continuous monitoring and controlling traffic flows, especially during conditions of recurring and non-recurring congestion, 2) managing accidents and other roadway incidents, 3) providing information to motorists, and 4) controlling traffic signals to dynamically improve traffic flow. Monitoring and control of traffic flows will be accomplished through the expanded use of existing systems for both freeway and arterial traffic, under the coordinated management of the Smart Corridor centralized computer system.

Caltrans currently monitors freeways via its Semi-Automated Traffic Management System (SATMS), which also controls freeway access with ramp metering. The Los Angeles Department of Transportation currently monitors and controls arterial traffic in several areas throughout the city, including the Los Angeles Central Business District (CBD), the Sports Arena/Coliseum area, Los Angeles International Airport, Westwood, and on Ventura

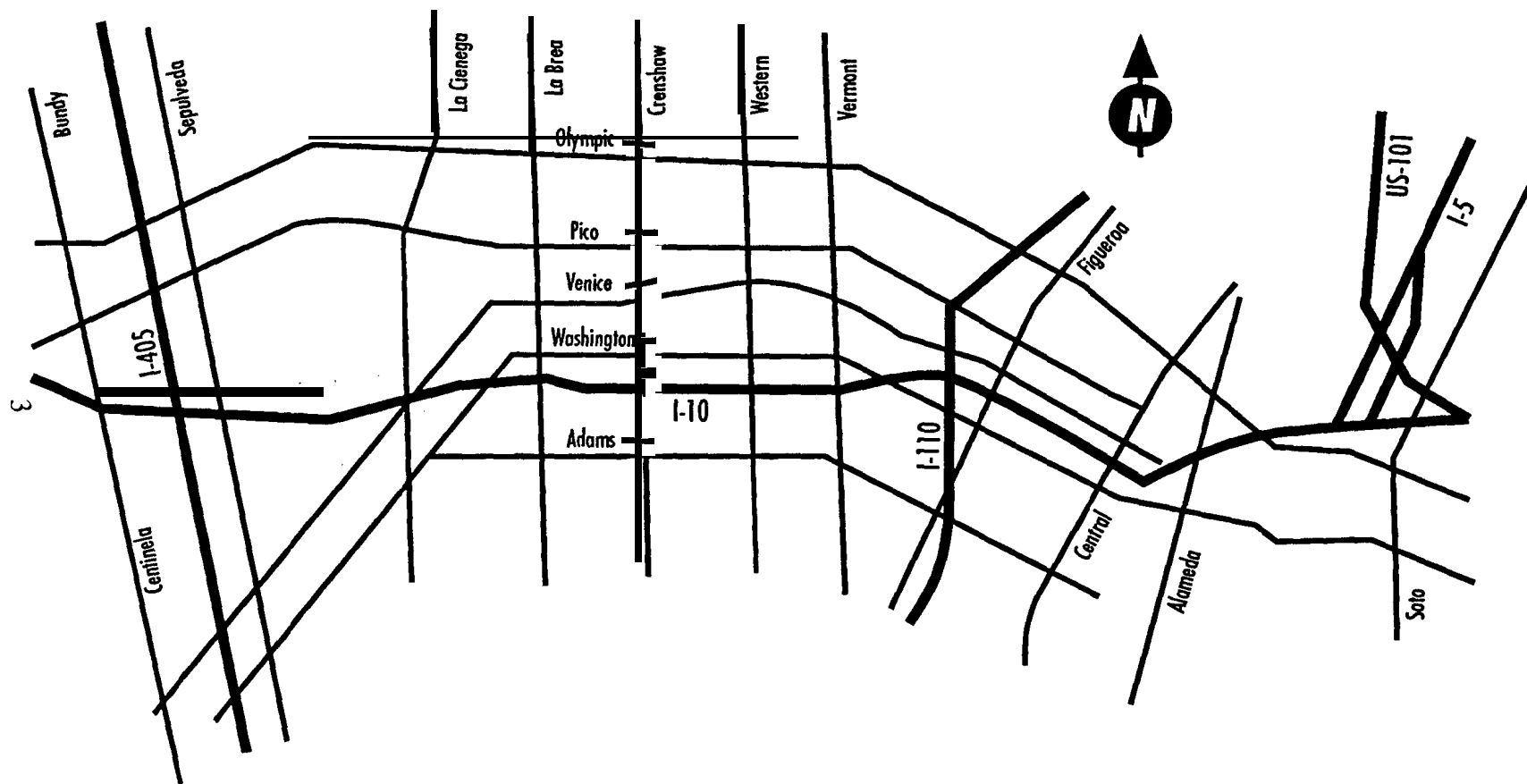


Figure 1: Smart Corridor Region

Boulevard in the San Fernando Valley between Lankershim and **Mulholland** Boulevards. This activity is carried out through the use of computerized arterial signal control, the Automated Traffic Surveillance and Control (ATSAC) system.

The monitoring of non-recurring incidents, such as accidents and vehicle breakdowns, will continue through the expanded use of Closed Circuit Television (CCTV) on the freeway and arterials, freeway call boxes, cellular phones, and Freeway Service Patrols (FSP). Motorist information will be provided through the expanded use of existing services and the introduction of new ones. Examples of these services are Changeable Message Signs (CMS) on freeways and arterials, Trailblazer (detour) signs on arterials, Highway Advisory Radio (HAR), and Highway Advisory Telephone (HAT). Most of the Smart Corridor's elements are being deployed in a phased implementation process over the course of approximately a year and a half.

In addition to these technological means of addressing the corridor's mobility problems, the project will strive to implement a heretofore unprecedented level of inter-agency cooperation and coordination. The blending of both the technological and institutional aspects will determine the level of success for the Smart Corridor Demonstration Project.

1.3.1 Smart Corridor Studies

Prior studies related to the Smart Corridor have used survey research, simulation, and field operational tests. A telephone survey described in Shirazi et al. [6] interviewed about 400 respondents and found that a significant number of drivers occasionally divert from their preferred route. About 40% of the commuters in Los Angeles diverted on their way to work, and 14% percent of the respondents diverted to alternate routes either "very often" or "often." Thirty percent of the drivers said that radio traffic reports helped them in their decision to divert.

Researchers at the University of California at Berkeley (Al-Deek et al. [7]) used simulation tools (FREQ and TRANSYT) to model incident scenarios in the Smart Corridor. They found a limited potential to save travel time by diverting drivers to alternate routes. This work is currently being extended by UC Berkeley researchers to a more realistic representation of the Smart Corridor network.

A recently completed evaluation of the Pathfinder Project by JHK & Associates found that actual benefits from in-vehicle traveler information systems were limited, although drivers reacted positively to the information given by the Pathfinder system, found it to be useful in many contexts, and had a high perceived benefit (JHK & Associates [8]). Pathfinder was the first IVHS operational field test in the United States. Its primary purpose was to provide motorists with in-vehicle real-time traffic information for route choice decisions. The system also provided traffic performance information to the Pathfinder control center from the field. The main benefit of Pathfinder to the motorist was expected to be improvement in travel time, made possible by an improved knowledge of real-time traffic

conditions.

1.3.2 Other IVHS Evaluation Projects

Several other IVHS evaluation projects in the United States--INFORM, FAME, TravTek, and TRANSCOM--were investigated with an eye to evaluation planning and, if applicable, deployment and operation.

INFORM (INformation FOR Motorists), formerly known as the IMIS (Integrated Motorist Information System), is a corridor traffic management system designed to improve utilization of existing highway facilities in a heavily congested 40-mile long highway corridor on Long Island, New York. The system includes integrated electronic traffic monitoring, variable message signing, ramp metering, and related strategies to optimize traffic flow. Both the evaluation plan and evaluation final report were reviewed. The evaluation, conducted using extensive field data, surveys, and surveillance system data, investigated the traffic surveillance and control system, the variable message signs, and the ramp metering subsystem. Users' perceptions of the system were also documented.

FAME (Freeway and Arterial Management Effort) is a series of separate but related projects conducted by the Washington State Department of Transportation in affiliation with the Washington State Transportation Center-University of Washington. Geographically, the projects encompass the greater metropolitan Puget Sound area. These projects are being pursued in parallel and will be integrated as they are completed. They cover a range of areas, including IVHS: (1) an integrated freeway and arterial control system, (2) forecasting freeway and ramp data for improved real-time control, (3) real-time motorist information, (4) incident detection and truck congestion alleviation demonstration, and (5) integrating arterial operations between jurisdictional and system boundaries. These individual tasks are at various stages of development from planning, design, and implementation to evaluation.

TravTek (Travel Technology) is a project conducted in the Orlando, Florida area whose main goal is to provide traffic congestion information, motorist services information, tourist information, and route guidance to operators of 100 test vehicles equipped with an in-vehicle TravTek device. Route guidance will reflect real-time traffic conditions in the TravTek traffic network. A Traffic Management Center will obtain traffic congestion information from various sources and provide this integrated information to the test vehicles and the sources. The Evaluation Plan for the TravTek project has been completed and the system has been implemented and is currently undergoing evaluation.

TRANSCOM (Transportation Operations Coordinating Committee) is a consortium of several transportation and public safety agencies in the New York and New Jersey area whose goal is to improve inter-agency response to traffic incidents. As part of this goal, 1000 commercial vehicles will be equipped with transponders, and readers will be placed at selected toll booths to automatically collect tolls for equipped vehicles. Readers will also be installed at other locations, allowing equipped vehicles to serve as traffic probes. The

evaluation will determine the effectiveness of using this data to determine real-time traffic information such as speed, travel time, and occurrence of incidents. The project has recently completed its Preliminary Design Feasibility Phase and will soon begin the final Design Phase, which will include development of an evaluation plan.

2. CONCEPTUAL STRUCTURE OF THE EVALUATION PLAN

This section presents an overall conceptual framework for the evaluation plan and lays the foundation on which the recommendation to conduct the evaluation study is based. Three major subsections are described:

- study goals and objectives,
- research design framework, and
- research framework for project components.

2.1 STUDY GOALS AND OBJECTIVES

The goal of the evaluation project is to assess the Smart Corridor's effectiveness in accomplishing its overall mission, namely to reduce delay, energy consumption, and pollution by: (1) dynamically balancing traffic loads across the network of freeways and arterials in the Smart Corridor, and (2) improving the performance of roadways through ramp and intersection control, incident response, and associated communications. Hence, the evaluation study's core questions should be:

- Does the Smart Corridor improve the dynamic distribution of traffic across the network in the case of both recurrent and non-recurrent congestion?
- Does the Smart Corridor improve the network's capability to serve large volumes of traffic with an acceptable level of service?
- How effective is the multi-agency configuration of Smart Corridor's response to both recurrent and non-recurrent congestion in achieving these goals?

To answer these core questions, the evaluation project would measure the Smart Corridor's success in meeting narrower goals and objectives (Table 1). The goals are areas of potential improvement within the Smart Corridor. The objectives further specify these goals by identifying specific changes which can result from the Smart Corridor. Goals 8 through 10 are more operational in nature than the others because they are measures of the means by which goals 1 through 7 will be achieved.

TABLE 1
GOALS AND OBJECTIVES

<u>GOALS</u>	<u>OBJECTIVES</u>
1) Improved throughput	Increase corridor throughput during peak periods
2) Decreased travel time	Decrease average travel time (during recurrent congestion conditions)
3) Predictable travel time	Reduce variability of average travel time
4) Improved response time for incidents	Reduce incident duration time
5) Improved traffic distribution	Increase use of facilities with excess capacity and decrease use of congested facilities
6) Improved air quality	Reduce CO, HC, and NO _x vehicle emissions
7) Reduced energy use	Reduce fuel consumption (gasoline, diesel)
8) Improved motorist information for pre-trip or en route decision making	Increase number of motorists given advisory information Reduce number of lost motorists Increase accuracy, specificity, timeliness, and relevance of information Increase influence of information systems on motorist/traveler choices
9) Improved management of roadway facilities	Increase effectiveness of corridor roadway system
10) Improved working relationships among organizations responsible for operations within the Smart Corridor	Increase communication, cooperation, and coordination in day-to-day operation and management of the corridor transportation system

It is recommended that the evaluation be divided into the following five major areas of investigation (Figure 2):

- roadway network performance,
- traveler response,
- emissions and energy impacts,
- operational performance of system components, and
- institutional issues.

The roadway network performance component of the evaluation would be oriented toward field measurement of broad changes in performance, with respect to delay, throughput and related factors. The network performance component would further support the emissions and energy evaluation, which would estimate these environmental impacts. Ultimately, the success of the Smart Corridor hinges on achievements in three inter-related areas: system operations, traveler response, and institutional effectiveness. These three areas define the remaining three components of the evaluation project.

2.2 RESEARCH DESIGN FRAMEWORK

This study's recommendations are designed to achieve maximum coordination across project elements. Traveler surveys should be administered in the same weeks that traffic data is collected on freeways and arterials. This would enable the evaluators to determine whether specific events, such as incidents, directly influence traveler perceptions and behavior. Several data collection "waves", e.g. three or four, should occur over the course of the study, spaced at approximately six-month intervals. These waves may be supplemented by additional data collections in the off-months.

Each data collection wave would focus on strategic screenlines spanning the corridor in the north-south direction. Data would be collected on the Santa Monica Freeway and all Smart Corridor arterials as they cross the screenlines, to assess the dynamic distribution of traffic and delay across the corridor. In the event of an incident, traffic would likely redistribute across the various Smart Corridor streets as illustrated in Figure 3. Traffic would be warned in advance, so that it could begin moving over to parallel arterials well ahead of the incident. After passing the incident, traffic could then return toward the freeway. Diversion could even begin at the time of departure. Figure 4, for instance, shows how an incident may affect the arterials' "drawing region" for a given destination (i.e., the set of origins for which it is fastest to reach the destination without using the freeway). When a freeway incident occurs, the arterial drawing region expands, meaning that the arterial routes become attractive for more origins and destinations. One important measure of the Smart

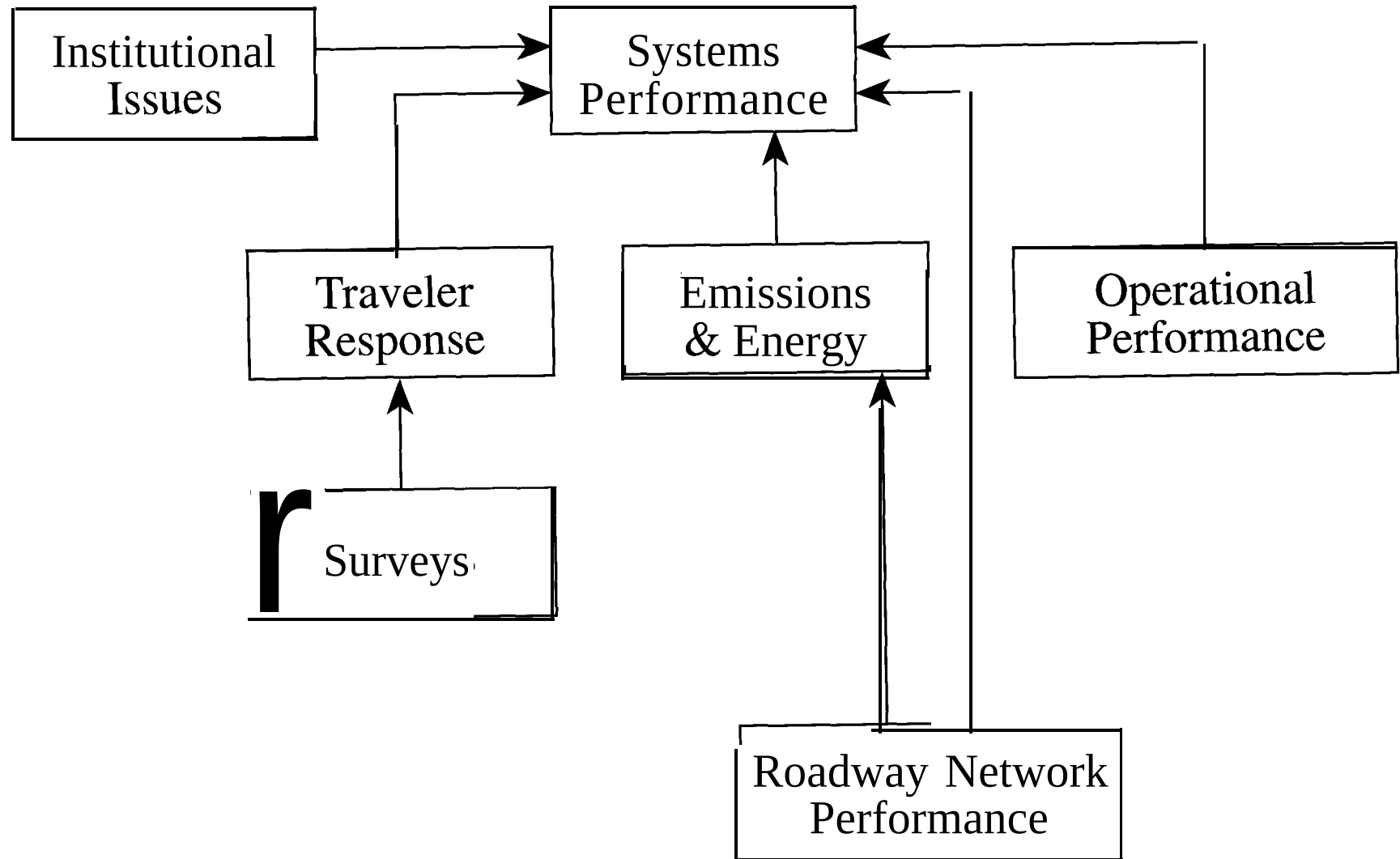


Figure 2: Flow of Research Information

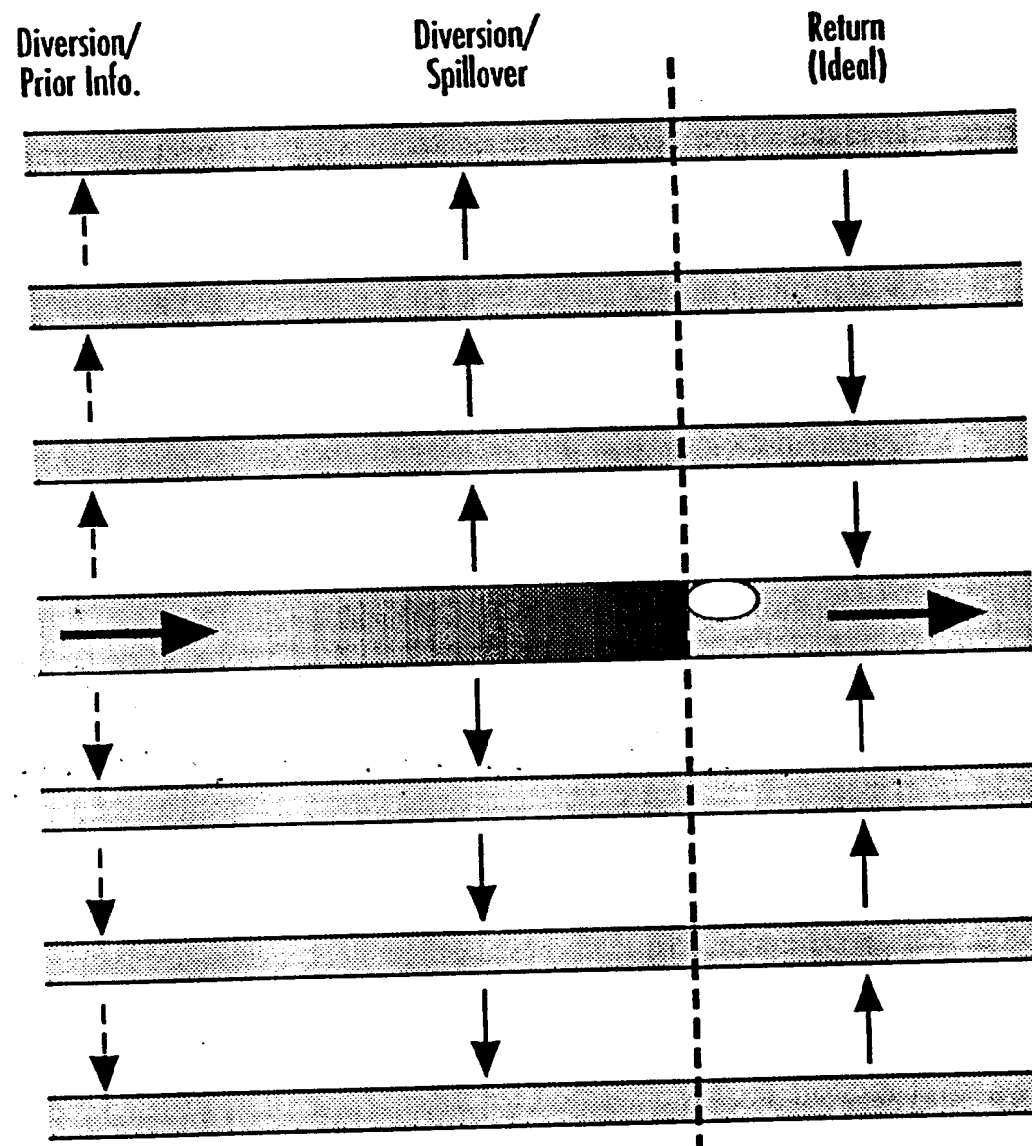


Figure 3: Traffic Diversion During an Incident

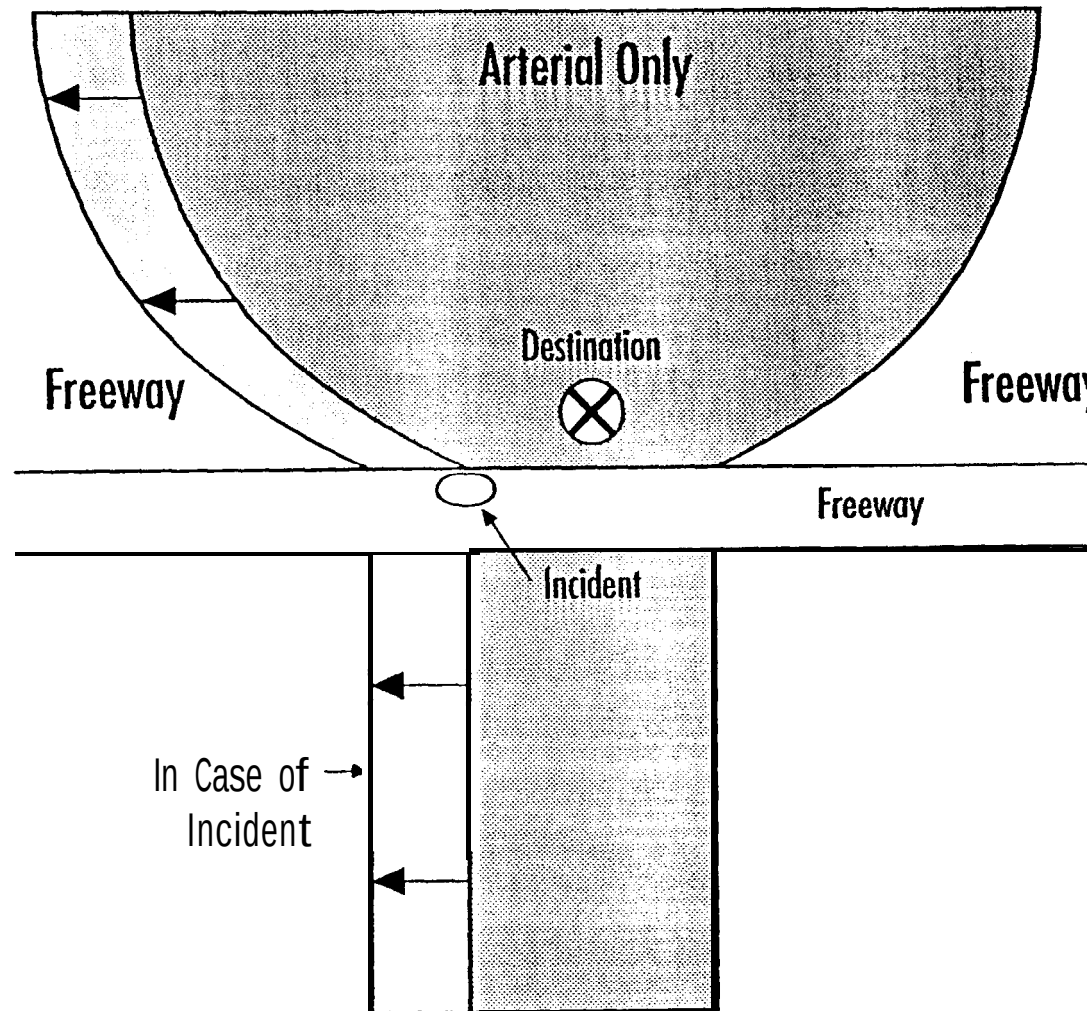


Figure 4: Drawing Region

Corridor's effectiveness is whether travelers would be provided with sufficient information to divert to alternate routes.

To further assess the Smart Corridor's effectiveness, traffic plots would be produced at each screenline, to show total traffic volume and relative traffic volume. If effective, the Smart Corridor would enable traffic to use the corridor's full capacity at and around any incident, by diverting traffic to parallel arterials (Figure 5). The end result should be reduced queueing and delay upstream from the incident. The Smart Corridor should also affect the shares of traffic traveling on the freeway and parallel arterials, as shown in Figure 6.

By comparing traffic plots, as in Figures 5 and 6, across data collection waves, the project would be able to assess whether the Smart Corridor achieves a more efficient distribution of traffic across the corridor, both on a non-recurrent and recurrent basis. By examining maximum traffic volumes, the effect of improvements on corridor traffic flow, on both a recurrent and non-recurrent basis, may be determined.

The design framework for the evaluation study is based on a "before-after" structure, relative to the implementation of components of the Smart Corridor system. Since a multitude of Smart Corridor elements will be deployed in clusters, sequentially over time, a more precise characterization of the structure might be "before-during-after". A successful evaluation will depend on closely coordinating evaluation tasks with the full deployment of all Smart Corridor components. This coordination of activities takes on great importance because there is neither a single project component, nor a single "treatment" event during which all Smart Corridor components are deployed.

Another complicating factor is that Smart Corridor elements differ with respect to geographical and functional deployment. The components may be categorized into the following five classes:

- never before deployed in the Smart Corridor, (e.g., HAT and the Smart Corridor Expert System),
- current limited functional deployment, with expanded coverage and upgrades during the project (e.g. CCTV),
- current limited geographic deployment, with wider geographic coverage during the project (e.g., ATSAC),
- widespread existing deployment, with upgrades planned (e.g., freeway ramp metering), and
- already deployed throughout the Smart Corridor, with no changes planned (e.g., FSP).

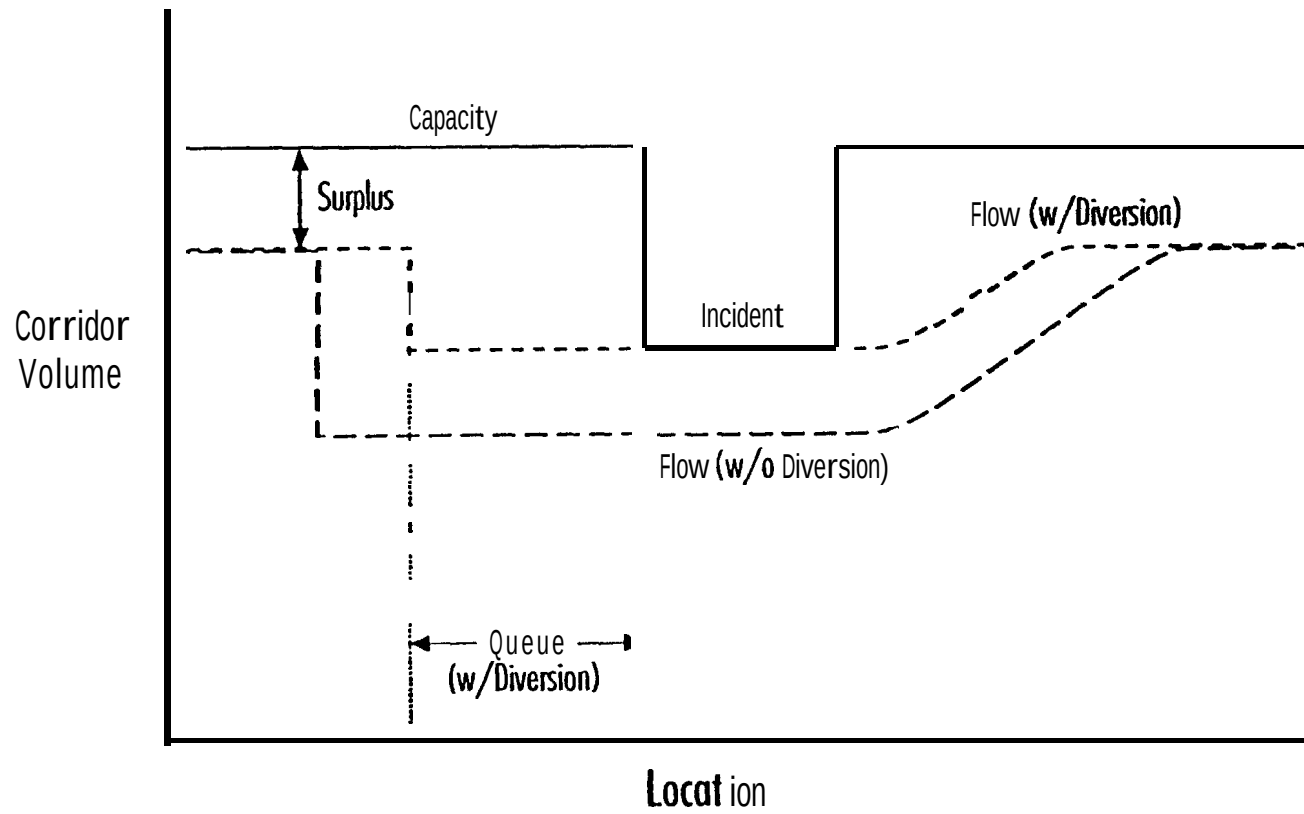


Figure 5: Corridor Volume During an Incident--With and Without Diversion

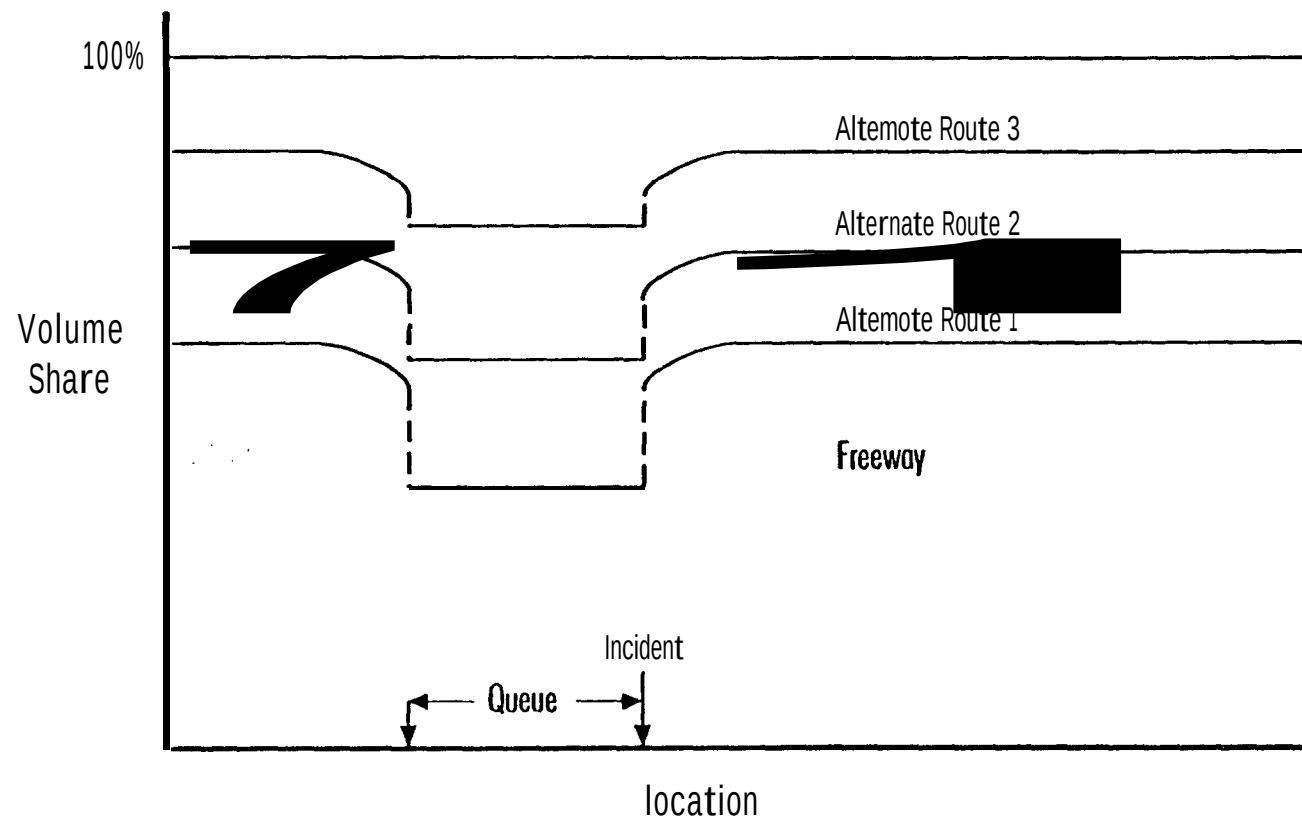


Figure 6: Traffic Volume Distribution During an Incident

Some overlap may exist across classifications because some elements, such as connector ramp metering, could be viewed either as completely new or as a geographical expansion of an existing technology. Two of the existing components, FSP and ATSAC, have been evaluated in previous studies ([9] and [10] respectively) and would not be reevaluated as part of this project. However, the study design should control for expanded ATSAC coverage and FSP, to ensure that only the effects of new Smart Corridor elements are measured.

2.3 RESEARCH FRAMEWORK FOR PROJECT COMPONENTS

2.3.1 Roadway Network Performance

The roadway network performance component of the study is aimed at measuring and evaluating actual changes in delay, throughput and speeds on the freeway and arterials in the Smart Corridor. Hence, the principal goal for this component of the evaluation is to see whether using Smart Corridor technologies results in measurable improvements in network performance. This would involve answering the following questions:

- How effective is the Smart Corridor in balancing the traffic load among the freeway and its neighboring parallel arterials?
- What is the change in average speed on the freeway, the arterials and the corridor as a whole aggregate under recurrent and nonrecurrent congestion?
- What is the change in average delay on the freeway, the arterials and the corridor as a whole aggregate under recurrent and nonrecurrent congestion?
- What is the change in traffic volume throughput on the freeway and arterials?
- To what extent may changes be attributed to either individual or groups of technologies?

For an improvement to occur, freeway and arterial speeds must increase for a given traffic volume, measured across the corridor as a whole. In addition, delays at signalized intersections must decrease. These improvements in the “state of the network” may come through redistribution of traffic, improvements in signal control that increase capacity, or improved incident response.

Even under conditions of fixed supply and demand for travel, the state of the network is a variable quantity. Consequently, the state of the Smart Corridor network is certain to vary with each cluster of project elements implemented for the Smart Corridor. The objective of evaluating network performance is to explain systematic variations in the most likely network states in terms of specific Smart Corridor project elements. If the resulting changes in performance exceed the variability in the corridor’s performance, then it would be

possible to estimate the magnitude of these changes and to attribute them to the implementation of the project elements.

Traffic patterns in the Smart Corridor network vary daily and hourly, and there are varying levels of recurrent congestion. Evaluation of network performance should account for these differences, which implies that the evaluation should be comprehensive across both time and space. Observations about network states must be controlled for seasonal, day-of-week, and time-of-day effects, as well as for any other factors, such as economic conditions, that may affect the volume of travel.

Hence, the network performance study would produce aggregate estimates of key performance measures of effectiveness (MOEs), including:

Throughput during: peak periods -Throughput, in terms of volume of vehicles per unit time, would be measured at selected north-south screenlines in the corridor.

Average travel time-Average travel time would not be directly measured. The average travel time for motorists to traverse a section of the corridor, as well as vehicle hours of travel (VHT) would be estimated under recurrent and nonrecurrent traffic conditions.

Variability of average travel time-By reducing the impact of both recurrent and non-recurrent incidents, the Smart Corridor should reduce the day-to-day variability of average travel time and thus increase the reliability of the system for motorists. The measure specified for this objective is the variance of VHT, calculated across days.

Incident duration time-Incident duration time would be measured for both the “before” and “after” time periods. Moreover, during the “after” period, with the Expert System Incident Management System in place, duration time would be further disaggregated into: time of correlation, confirmation, response plan generation, response plan approval, and response plan execution.

Usage of facilities with excess capacity-The measures specified for this objective are traffic volume and Vehicle Miles of Travel (VMT) across both the freeway and all five major parallel arterials, which should account for shifts in usage from congested facilities to those with excess capacity.

The network analysis will also support studies of environmental impacts, including the following performance measures:

CO, HC, and NO_x vehicle emissions -The measure of effectiveness specified for this objective is the amount of each of these three pollutants, expressed either in grams of pollutant per mile of travel, or total corridor pollutant level in tons, and would be estimated.

Fuel usage-The measure of gallons of gasoline and diesel fuel used by vehicles in the

corridor would be estimated.

Ideally, the evaluation would assess the effectiveness of each Smart Corridor project element with respect to these **MOEs**. However, a complete accounting of each element's contribution is not feasible, due to the extent and complexity of the Smart Corridor network, the number of different Smart Corridor project elements, the phased implementation of these elements, and the range of states with respect to current deployment. Repeated observations (data collections) would make it possible to assess the effectiveness of at least groups of Smart Corridor project elements undergoing a phased implementation, with a simultaneous implementation within each group. The timing of these observations is crucial: the best timing would be to bracket the greatest changes. If too much time were to elapse between observations, then external factors could confound them.

The network performance evaluation would produce a representative sample through selective data collection at screenlines cutting north-to-south across the Smart Corridor. The distribution of traffic and delay, would be analyzed across the parallel streets at each screenline. In addition, changes in speed and throughput would be estimated through weighted averages spanning the Smart Corridor as a whole. This would enable an in-depth statistical analysis of the impact of Smart Corridor project elements as they are implemented. The contributions made by smaller clusters of project elements would also be estimated to the extent that data and implementation schedules permit.

2.3.2 Traveler Response

The traveler response component of the study is aimed at measuring changes in individual travel patterns that result from the implementation of Smart Corridor technologies, as well as traveler acceptance and preferences for these innovations. Key questions are:

- What are the user benefits, both tangible and (to the extent they can be measured), intangible, from HAR, HAT, CMS and Trailblazers signs?
- What is the extent of change in motorist usage of these technologies over time?
- How can the effectiveness of **ATIS** and **ATMS** be improved?

The Smart Corridor may benefit users in terms of reduced travel time and reduced travel costs (e.g., vehicle operating costs, including wear and tear). These improvements can result from a decrease in excess travel to unfamiliar destinations. More important, benefits may result from changes in travel patterns under incident, adverse weather, or otherwise congested conditions. Additionally, regular travelers may change their normal travel patterns in response to recurrent congestion.

Other benefits that may result from the Smart Corridor include:

- Increased knowledge of travel options (e.g., **information** about alternate routes that may facilitate route choice).
- Reduced anxiety (even if travelers do not change their travel decisions).
- Reduced likelihood of getting lost.
- Increased reliability, particularly for arrival at destination.
- Enhanced ability to reschedule activities (especially through cellular telephones) when unexpected events occur.

The evaluation project should investigate traveler responses (such as route diversion and departure time changes) that result from the Smart Corridor. A unique feature of the Smart Corridor is the availability of information to the general public and not just to a select group of individuals. In this regard it is important to understand how various factors impact traveler behavior over time; *changes* in traveler behavior are an important component in determining the degree of success of the Smart Corridor.

Traveler decisions are influenced by information received from various sources, including direct observation and traveler information systems (Figure 7). In addition, traffic control (e.g., **ATSAC**) will influence system performance (traffic flows), which can in turn influence individual behavior. To analyze traveler response, data needs to be collected on traveler behavior, transportation system performance and information system performance. These data would be processed to evaluate behavioral changes due to the information system. The analysis would allow for the evaluation of the impacts of advanced information and management systems on travel decisions, providing an assessment of the benefits and insights into **ATIS** and **ATMS** design and implementation.

To evaluate the effectiveness of these advanced technologies, the factors which influence traveler behavior--particularly, the effect of information on behavior (Figure 8) -- need to be understood. Individuals' choices are influenced by attributes of the alternatives, their personal characteristics (socioeconomic and personality) and the information acquired through direct and indirect contact with the environment. Individuals' perceptions regarding system characteristics, their preferences among alternatives and situational factors, such as work related constraints, determine individual choices.

Because of the project's emphasis on infrastructure improvements, the **ATIS** and **ATMS** technologies tested in the Smart Corridor would largely influence en route decisions, which include destination choice, route diversion and return choice, trip chaining, and rescheduling of activities (Figure 9). Smart Corridor elements such as Dial-Up, Media Interface, HAT, and to a limited extent HAR may influence pre-trip decisions which include destination, departure time, route, trip chaining decisions, and rescheduling of activities (mode change is out of the scope of this study).

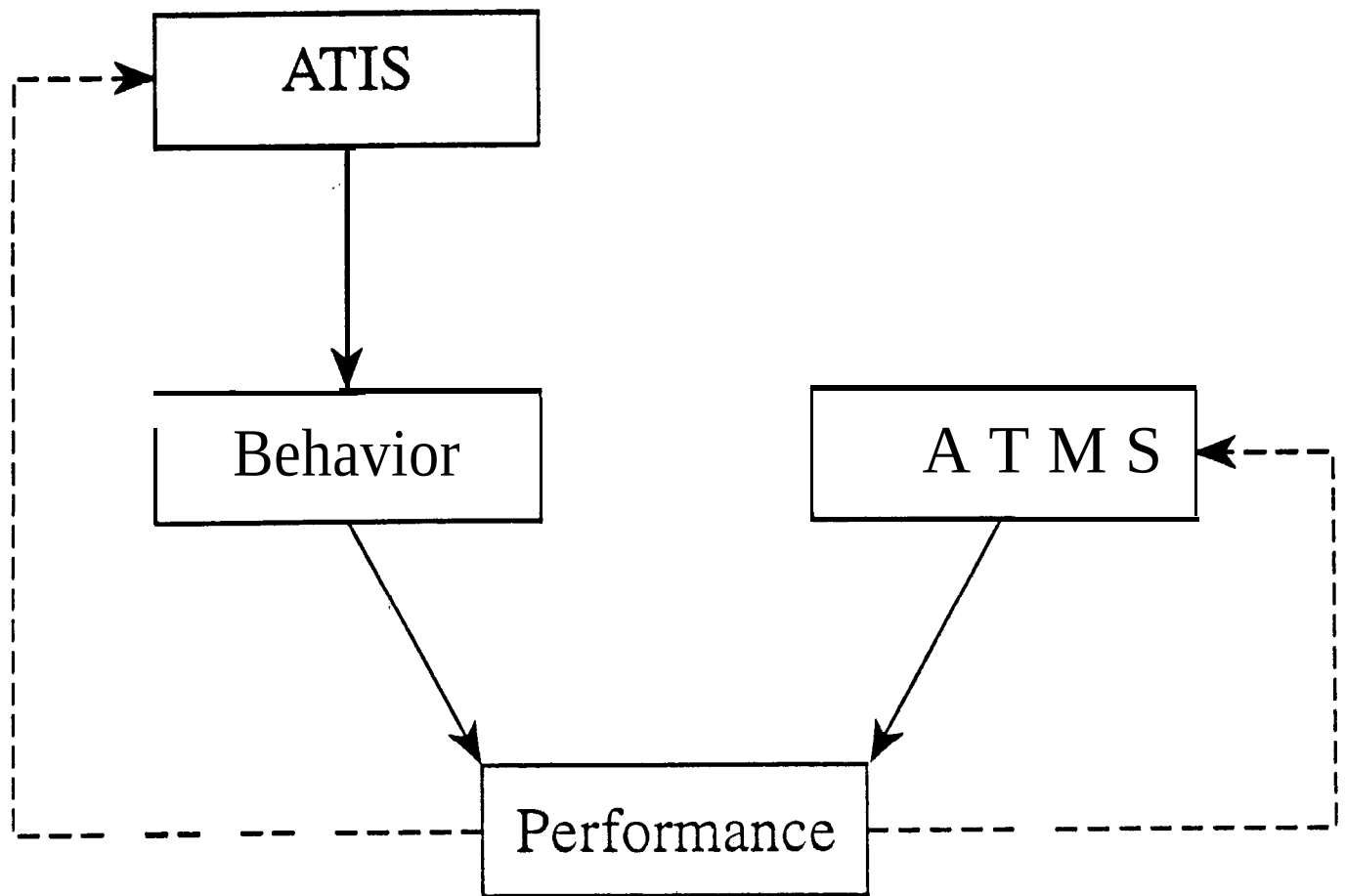


Figure 7: Real-World Dynamics of Traveler Behavior

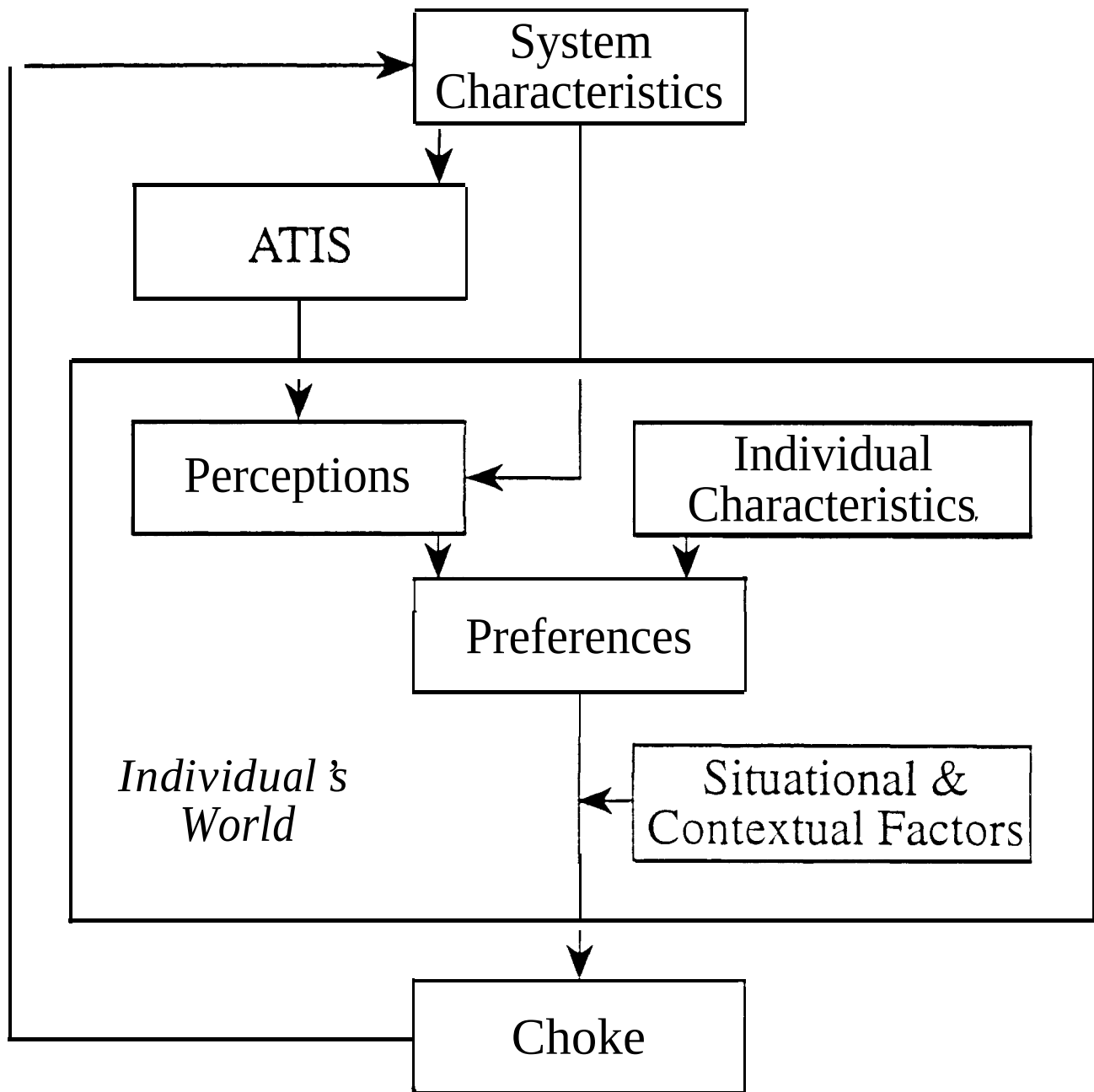


Figure 8: Traveler Decision Making Process

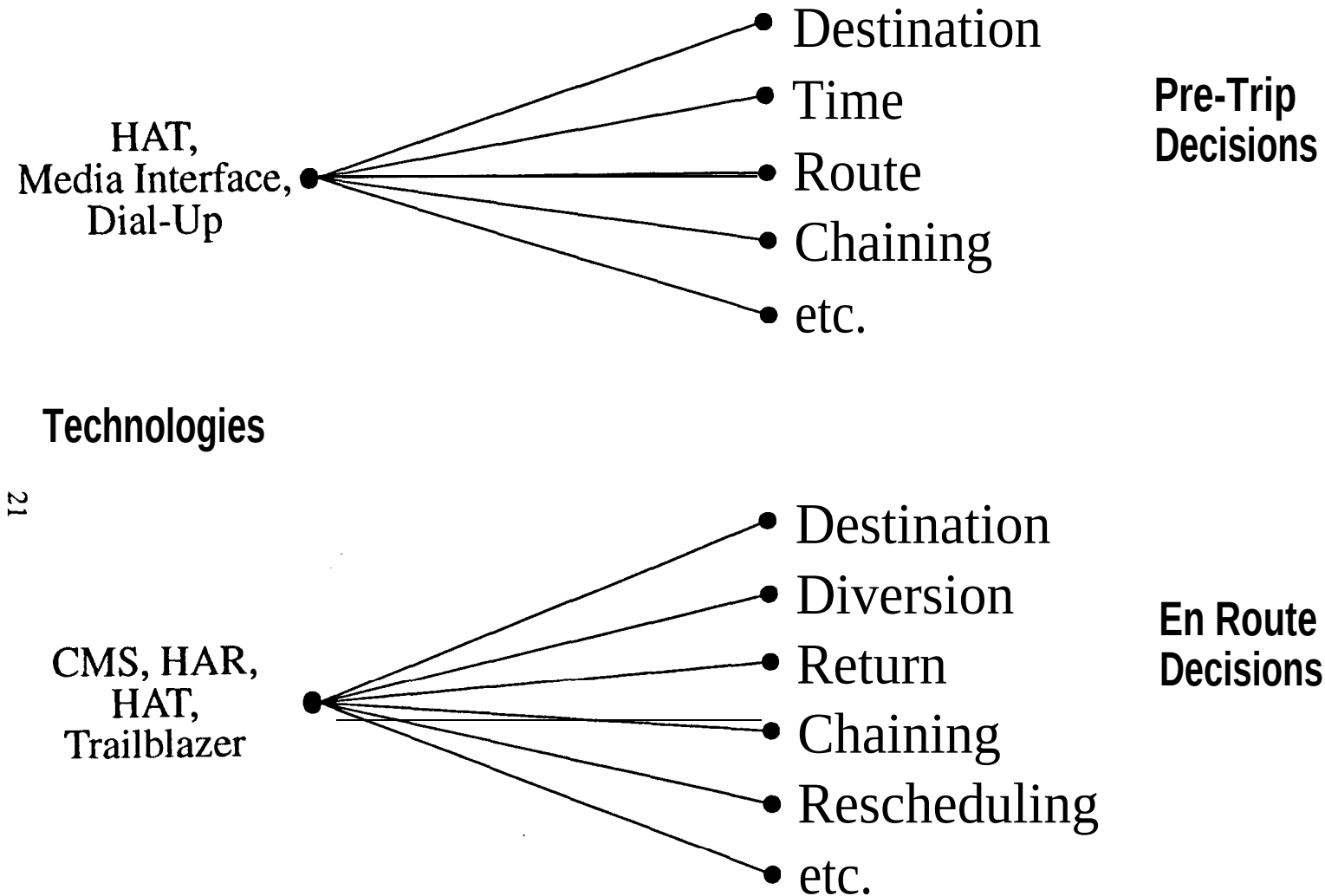


Figure 9: Influence of Various Technologies on Individual's Decisions

2.3.2.1 Role of Information in Traveler Decision Making

Information is a critically important aspect of decision making and in this regard information processing theories have been proposed (Bettman [11]). The main elements of such research (partly based on work of other researchers) are that individuals make decisions to achieve certain objectives. During the process of decision making, the person may acquire information (either actively or passively) from various sources, such as radio or newspaper, and use his/her memory (past experiences) to evaluate alternatives. Due to limited information processing capacity, individuals may use heuristics (simple decision rules such as choose the minimum distance route) to make their decisions. The consequences of a person's choice, after it is made, then provide feedback (learning) and may influence similar decisions in the future.

Individuals receive and process useful information from the environment and disregard irrelevant information. Travelers who perceive the information received positively are more likely to rely on the information. Specifically, travelers rely more on (and desire) relevant, accurate, timely, credible and reliable information. Important aspects of information that may influence behavior are:

- ***Content or meaning of information.*** The content of information is critically important for supporting travel decisions, For example, information about a freeway incident may support en route diversion and travel time information about alternate (arterial) routes may support return (to the freeway) decisions.
- ***Format or presentation style of information.*** Some presentation styles may be more effective than others. For example, terse messages may be preferred compared with conversational style or some people may find map-based information as may be found in in-vehicle information systems more useful than others.
- ***Nature of information.*** Whether the information is static or dynamic may have a significant influence on decisions. For example, static information about long-term road maintenance operations may induce fewer behavioral changes compared with real-time information about unexpected events.
- ***Type of information.*** The effect of qualitative information (non-numerical) and quantitative (numerical) information may differ: qualitative descriptions of congestion such as “jammed” and “operation at posted speed limits, ” may have less influence on route choice than quantitative estimates of travel times in minutes.
- ***Prescriptive information.*** The Smart Corridor information system may provide prescriptive information (e.g. ,advice on best alternate routes) in addition to

descriptive information. Behavioral responses to prescriptive and descriptive information may vary with the context and traveler attributes. For example, when a traveler is unfamiliar with the surroundings, he or she may be more willing to use prescriptive information, whereas in familiar areas a traveler may prefer descriptive information to make his or her route choices.

- ***Specificity of information.*** Information may be spatially or temporally specific. Information such as “accident at exit ramp” is more spatially specific compared with “accident ahead” or “accident on S. I. freeway.” Similarly, information such as “incident will clear in X minutes” is more temporally specific compared with “incident will clear soon.” It is expected that individuals prefer more specific information.
- ***Level of information detail.*** In certain contexts higher levels of information detail can support decision making. For example, when an incident occurs, individuals may require not only travel time and delay information, but also information on the nature of the incident (number of vehicles involved, injuries), exact location of the incident, and actions taken to clear it (e.g., responses by patrol vehicles, emergency medical services, and the fire department).
- ***Consistency with which information is disseminated.*** Individuals may not respond to information which varies significantly across similar events or conditions. For example, when describing two similar incidents, highly detailed information may be provided in one case and not in the other. Travelers are likely to prefer consistent information.
- ***Future validity of information.*** Real-time information becomes “old,” with time, however, in many instances it may be as much as 15 minutes old by the time it is disseminated. Reduction in data processing time and short-term prediction of recurring and incident congestion (if done properly) may improve future validity.
- ***Timeliness of information.*** Information should be made available whenever it is needed by the traveler, i.e., by providing data on demand rather than regularly.
- ***Relevance of information to decisions (completeness).*** Ideally, information presented to individuals should support their travel and activity decisions. Providing information about travel conditions on options that are infeasible for a particular traveler is undesirable.

To understand the effectiveness of Smart Corridor technologies, traveler behavior could be analyzed within this framework. Repeated observations would then be taken to fully

understand traveler responses to Smart Corridor technologies with respect to each of the above elements.

2.3.3 Institutional Evaluation

The Smart Corridor Demonstration Project is dependent upon the cooperation and coordination of many organizations and agencies. The institutional component of the evaluation project will study the effectiveness of inter-organizational arrangements and procedures which have arisen in the course of planning, implementing, managing, and operating the Smart Corridor project. The purpose will be to document and analyze the organizational arrangements which constituted obstacles to the implementation of the project, and those which emerged as necessary to facilitate progress of the project. This would entail answering questions, a sample of which is provided below:

- What are the critical issues on which the success of the project depends?
- What differences, if any, are there between the formal working agreements and obligations among participating agencies and organizations, and more informal working relationships that will develop over the course of the project?
- How are conflicts among participating agencies and organizations resolved, and to what degree are the lessons of each conflict learned and used to settle subsequent issues of disagreement more expeditiously?

The Smart Corridor Project has been undertaken with the cooperation and participation of the following agencies and municipalities: The City of Los Angeles, Caltrans District 7, LACMTA, CHP, City of Beverly Hills, Culver City, and FHWA. While this list is extensive, it actually underestimates the organizational complexity of the project. Participants from the City of Los Angeles, for example, include a number of organizations which generally function somewhat autonomously: the Los Angeles Department of Transportation, the Los Angeles Police Department, offices of several members of the City Council, and others have all been involved. While these several offices are all part of the City of Los Angeles, they have different missions, goals, objectives, and operating procedures. It will be important to study inter-organizational cooperation, conflicts and resolutions of those conflicts, and changes in institutional arrangements which emerged in the course of the evolution of the project. In particular, one important organization which has been centrally involved in the project, the Smart Corridor Technical Committee, will be an important focus of the **inter-**organizational analysis, and the evaluation should include an evaluation of its work.

The benefits of all of the technological features of the Smart Corridor Project are critically dependent on the ability of these many agencies to cooperate with one another and to coordinate their activities, and such benefits may not be fully realized unless institutional barriers are overcome through coordination. The complexity of such coordination is

accentuated by the high public visibility of a project affecting traffic congestion, and the likely interest in it of many citizens' organizations, from the Automobile Club of Southern California to various homeowners' groups and Chambers of Commerce.

2.3.4 Emissions and Energy Impacts Assessment

The emissions and energy impacts assessment component of the study is aimed at measuring aggregate changes in emissions and energy usage as a secondary impact of Smart Corridor usage. These impacts would result from changes in delay, throughput, and speeds on the freeway and arterials. The goal is to see whether Smart Corridor technologies eventually translate into measurable improvements in air quality and reductions in energy usage. This would involve answering the following questions:

- What are the overall changes in pollutant levels for carbon monoxide, hydrocarbons, and nitrogen oxides as a result of motorist usage of the Smart Corridor?
- What are the overall changes in gasoline and diesel fuel consumption as a result of motorist use of the Smart Corridor?

2.3.5 Smart Corridor Operational Performance

The Smart Corridor operational performance component of the evaluation project is directed at quantifying the extent to which the Smart Corridor's elements are used from an operational perspective. The foundation for this part of the evaluation is based on preliminary work performed in [1]. The purpose is to determine how well the individual system elements operated from the perspective of the public agencies involved. Primary questions to be answered would be the following:

- What is the working state of the individual system components?
- Does each system component operate as intended?
- What is the association of the operation of each system component with other aspects of the evaluation analysis results?

The complete list of eleven system elements consists of the following:

- Accident Investigation Sites
- Incident Management Teams
- Ramp and Freeway Connector Metering

- ATIS
- Closed Circuit Television
- Media Interface
- Full-Matrix Changeable Message Signs
- Trailblazer Changeable Message Signs
- Highway Advisory Telephone
- Highway Advisory Radio
- Smart Corridor Computer Network (Expert System)

The working state for each of the system components is generally expressed in terms of its usage or usage rate (number of uses per given time period) as well as by other measures of effectiveness characteristic of an individual system element.

3. DATA REQUIREMENTS AND COLLECTION METHODS

This section describes general data requirements and collection methods recommended for the evaluation. Evaluation data will be needed from four basic sources:

- Smart Corridor surveillance systems (to support network performance evaluation)
- traveler surveys (to support traveler response evaluation)
- agency records (to support institutional, emissions and energy impacts and non-recurrent incident evaluations)
- logs and staff interviews from Smart Corridor agencies (to support operational performance and non-recurrent incident evaluations).

3.1 SURVEILLANCE

The Smart Corridor surveillance system will provide much of the data required to conduct the network performance portion of the evaluation. This database will include data for estimating MOEs, such as average speed and travel time, for assisting in the analysis and interpretation of the performance results, and for assessing the MOEs' potential usefulness

for evaluation studies. The three major data items provided by the Smart Corridor surveillance system are:

- loop detector traffic volume data
- loop detector percent occupancy data
- signal control data

3.1.1 Traffic Volume and Occupancy Detector Data

The system's loop detectors collect traffic volume and percent occupancy measurements from mainline lanes, on-ramps, and collector roadway portions of the freeway, and from both through traffic lanes and signal-controlled turn lanes at major signalized arterial intersections. This data is drawn from Caltrans' SATMS and LADOT's ATSAC system, respectively. All freeway-related SATMS volume and occupancy data is originally collected in thirty second time slices. All arterial volume data is collected every second. The volume database will be used to estimate MOEs such as VMT and VHT. The level of data aggregation across both time slices and traffic lanes for both the freeway and arterials is discussed in the next section on Data Reduction and Analysis Methodologies.

LADOT's ATSAC system calculates other vital information that will be used in the network performance evaluation, consisting of delay, number of vehicles stopped, and number of vehicles in queue.

3.1.2 Signal Control Data

The system will record the implementation of traffic flow control strategies on freeway on-ramps, as well as all signalized arterial intersections. This information, which will include ramp metering rates and arterial signal timing plans, will assist in the analysis and interpretation of the performance results.

3.1.3 Data Samples

Data reduction begins with determining the exact location and time for the data sample. Surveillance data should be sampled over several time intervals to capture as much of the phased deployment of the Smart Corridor elements as possible. Each time interval would likely be one or two weeks in duration. During each day of data collection, time periods under investigation would include AM peak, PM peak, and the afternoon off-peak periods. Data would be collected at numerous north-south screenline locations, representing the entire length of the corridor.

Two levels of aggregation parameters need to be considered, namely, across time slices and across traffic lanes. The level of aggregation presents a tradeoff between providing

sufficient detail in the data and producing a manageable data file to analyze. The time slice length should be in the range of five to fifteen minutes. The scope of the analysis across both freeway and arterial lanes would determine whether data will be aggregated across lanes.

On the freeway, derived measures of effectiveness include VMT, VHT, average speed, and travel time. Because exact measurements of these variables will not be possible, they must be estimated. A general approach would be to first derive average speeds at loop detector stations, and second estimate travel time between points from the speeds and delays. VMT may be estimated from average volume counts at each point, the distance between each point, and estimates for intermediate arrivals and departures.

As a result of collecting and analyzing network data over time, comparisons may be made relative to changes in these MOE's across the freeway and the five major parallel arterials. Changes in the distribution of traffic should also be noted, as the improved balancing of traffic across the corridor is one of the primary goals of the project.

3.2 TRAVELER SURVEYS

A survey of motorists traveling through the Smart Corridor should be made to assess their awareness of, and response to, the Smart Corridor system and individual system elements. While the emphasis would be on motorists' assessment of ATIS (such as CMS, HAR, HAT, and Trailblazer signs), motorists' judgment of ATMS (such as ramp metering and arterial signal control) should also be examined in the surveys. Travel decisions are generally not made autonomously, but in a certain context. Interdependencies exist among decisions of various members of the same household. Moreover, there are interdependencies among various decisions of the same person. For example, return (to the original route) decisions would be made conditional on diversion decisions. Travel and activity patterns and the factors which influence them may change over time. However, insufficient work has been conducted to fully understand the dynamics of behavior. There could be day-to-day variability in travel patterns as well as substantive behavioral changes over longer time periods. Furthermore, the effects of the Smart Corridor ATIS and ATMS technologies may not be instantaneous but rather become more visible over time. Alternatively, these effects may diminish over time because the "novelty" effect tapers off. The surveys will provide the means by which these behavior dynamics may be better understood.

It is recommended that two types of surveys be used in the evaluation: a broad survey, administered to a large sample of motorists in two waves, one year apart, and a panel survey, administered repeatedly to a smaller group. The former would provide a sufficiently large sample for making statistical inferences regarding Smart Corridor effectiveness. The latter would facilitate in depth analysis over time, through structured telephone interviews. Figure 10 shows the design structure for these traveler response surveys.

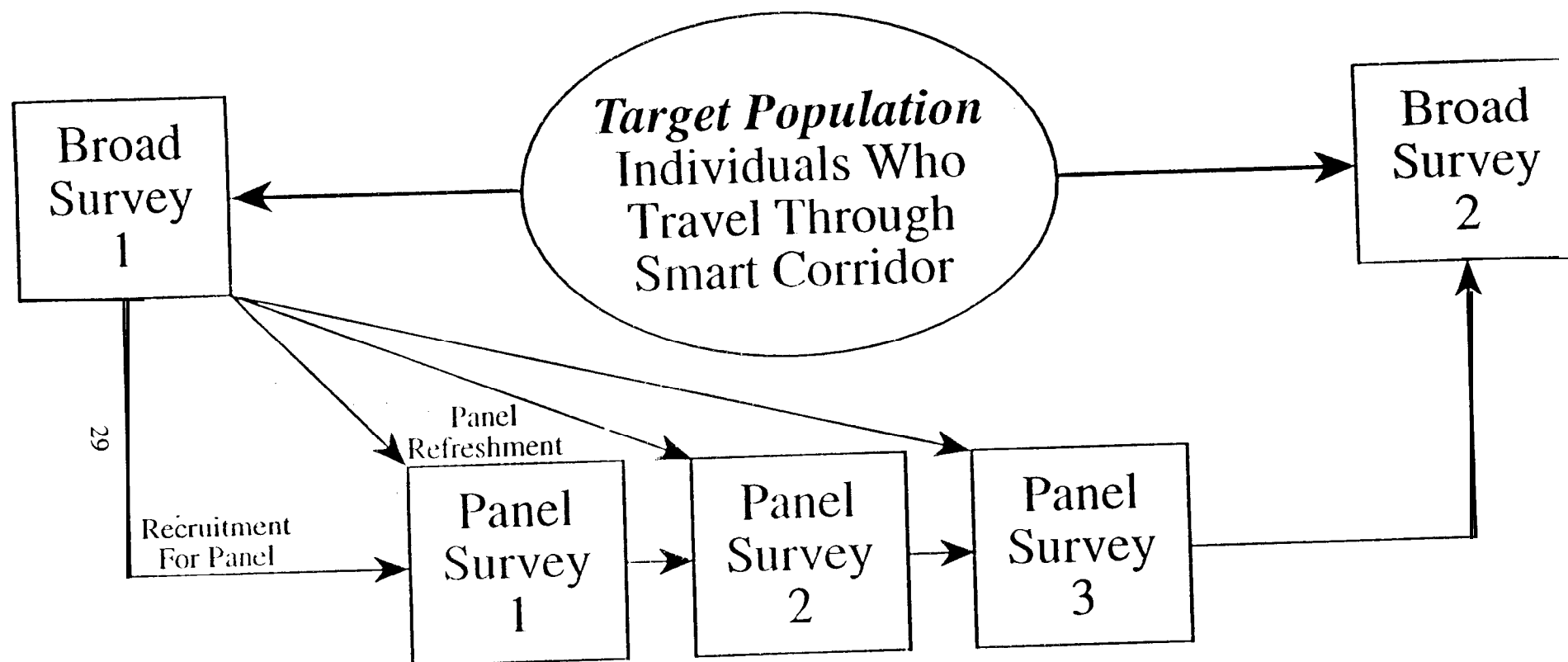


Figure 10: Design of Traveler Behavior Surveys

3.2.1 Survey Timing

A “before-and-after” study design would be used to understand motorist response. Initially, two large “broad” surveys would be conducted, one before and the other after full Smart Corridor implementation. While the first survey would be conducted prior to full implementation, it may not be distributed before the first element is implemented because of (1) the phased implementation of Smart Corridor elements, (2) necessary planning and initial data collection required prior to survey distribution, (3) desired coordination of the survey distribution with data collection for the network performance portion of the evaluation, and (4) timing recommendations on survey data and network performance data collections.

Summer and winter months contain strong seasonal variability and other confounding factors in travel patterns, and these months are not recommended for survey distribution for the same reasons. Since the data collection for network performance and motorist response should be coordinated, the best times for data collection would be the Spring and Fall, specifically May and October. Because of ATSAC’s data collection capabilities, and because ATSAC is considered a precursor to the Smart Corridor, it is highly desirable that the first wave of data collection occur after full deployment of ATSAC.

Three smaller panel surveys should be administered between the two broad surveys, at 3-4 month intervals, to be coordinated with network performance data collection. The “before” study will be used to establish base travel conditions and to recruit individuals for the panel, which is a set of individuals who will be surveyed for repeated questioning.

The panel surveys are intended to study changes in behavior over time. It would, for example, allow for the development of a fundamental understanding of how travel decisions, such as route selection, change over time in response to real-time travel information. Only by following individuals’ responses over time can the impact of information (and to some degree control) on travel decisions be understood in depth.

Panel surveys present many advantages over repeated cross-sectional surveys. One advantage is that changes in travelers’ behavior are better captured in panels since such changes are observed over longer time intervals than for cross-sectional studies. While long-term changes such as route selection are important, observing individuals’ travel patterns over several consecutive days is equally significant and offers insight into activity scheduling and travel planning, i.e. short-term changes, (Kitamura et al. [13]). For example, the ability to identify the loyal transit user, or an experimenter of new modes would be crucial for successful transit marketing or car pool promotion. Panel data facilitates the identification of both long and short-term changes. Secondly, panel analysis is the most effective, sometimes the only means, through which dynamic aspects of travel behavior can be investigated. For example, traveler responses to a change in policy, i.e. the availability of new transportation information systems, is dynamic and may involve time lags to fully realize the impacts of such changes. Behavioral responses to new policies and attitudes may

change, not spontaneously, but gradually. An evaluation of a new system or system improvements may be imprecise or even erroneous if it is not based on an understanding of time lags involved in individuals' responses. Panel surveys allow for the examination of aspects of travel behavior dynamics, such as habit formation and persistence, learning or anticipation of changing circumstances. Finally, panel surveys present an additional advantage because sampling errors of net change may be lower than in repeated cross-sectional surveys which could lead to reduced sample size requirements (Meurs et al. [14]).

There are, however, problems associated with panel surveys which could bias the results if not properly addressed. Attrition is the problem of respondents dropping-out from participating in all surveys, (Golob et al. [15]). Such drop-out individuals are likely to come from households of older, single, or low-income individuals. Another potential problem is known as panel conditioning, and refers to the change in response that occurs because the respondent has had previous interviews and might attempt to appear consistent across survey responses. Thus, responses in later surveys could be influenced by panel participation and earlier survey responses. However, research by Water-ton et al. [16] suggests that conditioning may not be a major problem, and could even have beneficial effects, such as respondents becoming less likely to answer "do not know". Panel fatigue is another potential problem to panel surveys resulting in decreasing response rates. An important reason for this problem is the loss of motivation after answering similar questionnaires over time. Another disadvantage to panel surveys arises from the long-term commitment requirement they place on respondents. Common practice is to "recruit" respondents, rather than to randomly sample the population at large resulting in reduced sample representativeness. Another problem associated with panel surveys is that locating the same set of respondents in subsequent panels is not a trivial task and a considerable part of the "loss of information" due to attrition is further attributed to difficulties in locating the respondents.

There are, nevertheless, countermeasures to address these problems or at least reduce their impact. These methods may be grouped into those administered prior to or after the survey is conducted. A priori methods include improvements in survey administrative procedures. The following a priori measures should be considered to maximize participation and response:

- **Methods of contact:** It is recommended that telephone surveys be used since they yield high response rates and allow more detailed information to be collected about the respondents.
- **Questionnaire length:** Possible bias from non-response or response inaccuracy may be attributable to excessive questionnaire length. The survey should be kept short, with short and clear questions.
- **Instructions:** Preliminary notification, personalization, follow-up letters, and instruction sheets can yield positive impacts and should be seriously considered. In addition to letters of preliminary notification, instruction

sheets to help guide respondents should be provided.

- **Incentives:** Monetary incentives have been shown to have a very strong positive effect on the quality of the response. This option should be considered as a means to increase the number of participants and the quality of their responses.

Even after these efforts, it is possible that the resulting data would still contain deficiencies. One method to address this problem is through survey pretesting prior to its general distribution. Pretesting has yielded benefits to both the respondents and the survey administrators. Increasing the sample size may also be applied, however, this strategy is usually one of last resort and only in cases of extreme need. It is questionable if this approach would solve the problem when systematic tendencies exist in non-response. Attrition may be minimized by improving the cover letter and instruction sheet, tightening survey administration and possibly by revising the questionnaire itself. While the effects of these measures on attrition are not well known, recent research by Goulias et al. [17] suggests that survey administration is the most critical element in decreasing attrition. However, since administration is the most expensive part of the survey procedure, consideration should also be given to other remedies as well. It is thus recommended that letters of persuasion, assurances of anonymity, and the use of monetary (or other) incentives be considered to reduce losses from attrition. It is also desirable to recontact and trace nonrespondents. If this proves unfeasible or expensive, however, the sample could be weighted to account for attrition or nonresponse bias. A probabilistic model of attrition developed using the earlier panel surveys can be used to formulate these weights. Panel conditioning, as previously mentioned, is a major source of nonsampling error in panel surveys. In practice, however, it is difficult to separate the effects of conditioning from those of other changes between panels, especially attrition (Kasprzyk et al. [18]). The result of panel conditioning are not necessarily negative, as previously discussed (Water-ton et al. [16]). Because of attrition as well as other causes such as residential relocation and household dissolution, the number of panel respondents declines over time. Concurrently, new members enter the study population through birth, marriage, and migration. These changes necessitate constant updating of the panel composition or sample refreshment. The effort spent in this process can be substantially reduced if the panel is refreshed by replacing drop-outs with new respondents, selected according to prespecified and observable attributes.

It is suggested that a combination of “true panel” (participants are asked the same question repeatedly) and “omnibus panel” (participants are asked different questions in successive waves) be used. Trip pattern and socioeconomic characteristic questions would be repeated on each survey, whereas questions about impacts of various technologies would vary.

3.2.2 Target Population

The target population should consist of travelers who use the Smart Corridor during both

peak and off-peak periods. Commuters and non-commuters should be included in the sampling population. The non-commuters include shoppers, people running errands, and recreational travelers. It is important to include these travelers because alternate routes are less congested during the off-peak, possibly providing significant potential for diverting traffic to alternate routes when necessary such as during incident conditions. This result is based on an analysis of 1989 Smart Corridor data compiled by Kaku & Associates for JHK & Associates [19]. Details of this analysis are provided in Appendix A.

After examining several alternatives, it is recommended that the chosen sampling method be the mail-out/mail-back method for the two broad surveys, and telephone interviews for the three panel surveys. License plate tracing may be used to obtain the survey mailing lists. Individuals would be sampled by recording the license plate numbers of their vehicles as they enter or exit the Smart Corridor both during the peak and off-peak periods, on both the freeway and some, if not all, the five major parallel arterials. The two broad surveys would be distributed under the auspices of Caltrans and the Department of Motor Vehicles (DMV) to guarantee confidentiality to the individuals whose names and addresses will be obtained in this manner.

The major advantage of license plate tracking over other sampling methods is sample representativeness, since all Smart Corridor travelers have an equal probability of being selected. However, one source of potential bias is that with any leased and/or company owned vehicle, the driver would be almost impossible to survey. Alternative methods of data collection, i.e. videotaping and/or manual methods should be investigated. It is recommended that a mixture of videotaping and manual methods not be used for reasons of consistency. Moreover, manually collected data cannot be verified if required to correct for possible errors.

The following steps describe the principal means of recruitment for the panel surveys: At the end of the first broad survey, respondents would be asked if they would be willing to voluntarily participate in a few follow-up telephone surveys to obtain more information about their reaction to the Smart Corridor technologies. To allow volunteers to be called by some organization other than Caltrans, and to ensure the confidentiality of all survey recipients, all respondents should be told about the evaluator, who is funding it to do the evaluation, and any professional service hired by the evaluators to conduct the survey. People who volunteer to take part in the follow-up surveys would so indicate by signing a statement that relinquishes confidentiality. The main advantage of using a telephone survey is that it facilitates the implementation of a complex questionnaire design by allowing easy skips built into the survey structure.

The sample sizes required for both the two large surveys and the three panel surveys are based primarily on prior experience, best professional judgment, and budgetary constraints. Approximately 10,000 surveys should be distributed in the broad survey, with an expectation of 2,000 valid responses (a 20% response rate), which would be sufficient for statistical purposes. All respondents would be invited to participate in the panel survey, with an

expectation of 800 respondents agreeing. Of these, approximately 400 would be included in the initial panel, with the remainder available for panel replenishment, should there be drop-outs. Sample size determination procedures for both the two broad surveys and the follow-up telephone panel surveys are described in Appendix B.

3.2.3 Questionnaire Format

The surveys are intended to measure stated and revealed preferences. Revealed preferences indicate how motorists responded to actual driving situations, whereas stated preferences demonstrate how motorists may respond under different driving circumstances. Though stated preferences are not exact representations of actual traveler behavior, their use allows for a deeper and more comprehensive examination of motorists' responses to driving in the Smart Corridor than possible through revealed preferences alone. Motorists' responses to actual Smart Corridor driving conditions, while essential for the evaluation, cannot provide the depth of understanding about motorist behavior since revealed preferences cannot include all situations motorists are likely to encounter. Thus, analysis of survey results and subsequent conclusions based solely on revealed preferences cannot provide a complete and accurate evaluation of motorists' response to the Smart Corridor. Moreover, stated preference type questions would provide insights into what specific improvements, if any, in Smart Corridor technologies could be most useful and beneficial to motorists.

The reasons why motorists did or did not divert as a result of a particular type of message, e.g. CMS or HAR, inquiring into message accuracy, specificity, timeliness, and other message attributes should also be examined.

The general structure of the broad survey is described below and example questions are given in Appendix C.

- Normal travel patterns.
- Perceptions of usual and alternate route attributes, such as reliability and neighborhood character.
- Changes in travel patterns, such as route diversion and destination change, due to information about expected and unexpected delays.
- Expected benefits from changing travel decisions.
- Attitude toward information and stated preferences.
- Socioeconomic attributes and personality.

The panel survey would include a one-day "information" diary that focuses on what

information the individual received and when (s)he received it, from various sources and their effect. An inquiry into the content of information, its format, nature, type, specificity, level of detail, future validity, timeliness, and relevance is recommended. Further, questions about route, departure and arrival time, trip purpose at destination, and trip origin and destination (i.e. home or office), would also be asked in the panel questionnaire. These questions would allow for the assessment of the impact of information received before and during trips. A sample of questions for the panel survey is provided in Appendix D.

3.3 AGENCY RECORDS

Agency records and documentation would support the institutional issues evaluation. They would also supply some of the data required to conduct the emissions and energy impacts assessment, as well as the portion of the network performance evaluation dealing with the investigation of nonrecurrent incidents.

3.3.1 Emissions and Energy Impacts Assessment

The emissions and energy impacts assessment analysis would rely on agency records and reports to supply part of the data required for analysis. Examples of such agencies include the Southern California Association of Governments (SCAG), the California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD).

Carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x) are the pollutants to be considered. Pollutant sources consist of: emissions dependent on amount of driving (such as running evaporative and exhaust emissions), cold and hot start emissions, and diurnal emissions which result from the warming and cooling cycle the vehicle experiences during the course of the day. The required data consists of (1) the vehicle fleet mix traveling the Smart Corridor, e.g. light-duty vehicles (autos and vans), medium-duty trucks, and heavy-duty trucks; (2) the age distribution for vehicles traveling the Smart Corridor by vehicle type; (3) speed profile data for freeway and arterial operating conditions in the Smart Corridor; (4) emission factors (grams/mile) distributed by vehicle type, vehicle age, pollutant, source, and speed profile; (5) fuel efficiency factors (miles/gallon) distributed by vehicle type, vehicle age, and speed profile.

Other information necessary to complete the data requirements for this task include estimates of vehicle miles of travel (VMT) and average speeds. These measures of effectiveness may be estimated from network travel data collected from the Smart Corridor surveillance systems. Assuming that the sample of motorists who respond to the broad surveys are representative of all Smart Corridor travelers, vehicle fleet mix and vehicle age distribution information may be obtained from the surveys to corroborate and/or update other sources of this information.

3.3.2 Non-recurrent Incidents

The network performance evaluation would also include an analysis of non-recurrent incidents to determine the impact on traffic conditions, such as throughput and delay, resulting from the use of the Smart Corridor Incident Management Subsystem. The work would rely partly on agency records and reports to supply needed data. The data required include the following:

- time of incident occurrence
- incident type
- incident location
- lanes affected
- estimated verification time
- duration or clearance time of incident
- resources used for incident response
- estimated area of influence
- estimated traffic recovery time

The source of data would be agency logs, such as the CHP computer aided dispatch (CAD) system, Caltrans' Modcomp system, and records from Freeway Service Patrol reports.

3.3.3 Institutional Issues

By its nature, the evaluation's institutional issues component has data requirements that are substantively qualitative rather than quantitative in nature. Data would be informational in format, from direct observation, interviews, project-related documentation, and relevant published literature, as follows:

- ***Direct observation.*** From attendance at project meetings such as the Smart Corridor Technical Committee.
- ***Interviews.*** Participating agencies' personnel should be interviewed about their formal and informal working relationships.
- ***Project-related documentation.*** Meeting minutes and memoranda.
- ***Otherpublished material.*** Information on complex interactions among agencies in the transportation sector and in government generally. Information on organizational structures in transportation.
- ***Interviews/project-related documentation.*** Information on roles and positions of project organizations, agencies, and individuals, forms of inter-organizational communication, and forms of organizational structure.

Members of the evaluator team should (1) attend and observe selected meetings, (2) interview appropriate individuals, with assistance from specific agencies to help arrange the interviews, (3) search the literature for relevant published material, and (4) obtain all relevant project-related documentation through all appropriate project agencies.

3.4 SMART CORRIDOR SYSTEM LOGS

Smart Corridor system record logs would be the primary source of data to conduct the Smart Corridor operational performance evaluation. They would also supply data needed for that portion of the network performance evaluation dealing with the investigation of nonrecurrent incidents. Additionally, interviews with agency operator staff should be arranged as required to supplement the log data for the system operational performance evaluation.

3.4.1 Smart Corridor Operational Performance

The information required to evaluate Smart Corridor operational performance would be obtained via a special data collection effort during the “after” period, as all Smart Corridor elements are deployed and operational. The data required would be drawn primarily from logs documenting the use and performance of the system and its individual elements (listed in Section 2.3.5). Examples of typical information that could be obtained follow:

Smart Corridor Expert System

- percentage of incidents correctly identified.
- response time between incident detection and response plan execution, including all intermediate response times.
- average time to generate an incident response plan by the Expert System for a confirmed incident.

Highway Advisory Radio

- number of messages broadcast during both recurrent and non-recurrent congestion conditions.

Accident Investigation Sites

- number of uses per month by incident type as well as average duration for each use.

3.4.2 Non-recurrent Incidents

The Incident Management (IM) subsystem of the Smart Corridor system will generate an incident report and a response plan for each confirmed incident. Information from these

sources would be used to evaluate the impact on non-recurrent incidents. Data contained in the incident reports would be consistent with data obtained from agency records (Section 3.3.2).

4. METHODS FOR DATA REDUCTION AND ANALYSIS

This section discusses the data reduction and analysis procedures that could be used to conduct the evaluation study, beginning with converting the data into evaluation measures.

4.1 ROADWAY NETWORK PERFORMANCE

To understand the sources of changes in network travel performance (i.e. quantifying effects of either individual or clusters of Smart Corridor project elements), Multivariate Analysis of Variance (**MANOVA**) is a viable methodological approach to be considered. This approach offers a number of advantages, including:

- a well understood set of procedures that can be subjected to numerous extensions.
- a minimal number of parametric assumptions. At the extreme, entirely nonparametric **MANOVA** procedures are available.
- opportunity to incorporate a variety of measures for treatment effects. These include intersection delays, intersection queue lengths, intersection stops, ramp delays, and ramp queue lengths.
- means to proceed even if data sources are sharply curtailed.
- a flexible data gathering approach that does not depend in any critical way on the planned or actual schedule for implementing the various Smart Corridor strategies.
- means to identify systematic changes in the network state produced by scheduled or unscheduled external events, such as construction, and means to separate these effects from the improvements resulting from Smart Corridor project elements.
- means to control for non-recurrent congestion effects that would otherwise confound efforts to track improvements resulting from the mitigation of recurrent congestion.

For illustration, consider an example of an ideal three-way layout for analysis of variance.

In a **MANOVA** context, Smart Corridor project elements constitute treatments. The entity being treated is the transportation network. The treatments may or may not produce changes in the state of the network. In this example, the set of treatments includes three project elements, HAR, CMS, and HAT. Given complete control over how these treatments are applied, one very useful approach would be to apply the treatments both individually, in pairs, and simultaneously, and to compare the state of the network observed under each possible combination. In this case, there would be eight such configurations, as follows:

- none of the three technologies applied
- HAR applied with no CMS and no HAT
- CMS applied with no HAR and no HAT
- HAT applied with no CMS and no HAR
- HAR and CMS applied with no HAT
- HAR and HAT applied with no CMS
- CMS and HAT applied with no HAR
- HAR, HAT, and CMS applied

The context of this three-way layout is summarized in Figure 11. Each combination of treatments provides a separate sample. In this example, link volumes define the state. The collection of links for which volume data are available defines the objects in the sample. The same analysis can and should be executed for other link measures, such as occupancy and speed. Collectively, these multiple **ANOVA** procedures constitute a **MANOVA** procedure. The objective of the **MANOVA** is to determine if applying the HAR, HAT, and CMS treatments account for a statistically significant portion of the variance in network performance relative to the untreated case.

Variance within each of the eight samples is due to systematic variations in demand across the network and to unsystematic noise in traffic conditions. If the HAR, HAT, and CMS treatments induce changes in the central tendency of the network state, then this will tend to increase the variance in states observed relative to the baseline condition. The three treatments may be more or less effective if applied in combinations than if applied separately. By applying all three elements in all their combinations, interaction effects among the elements can be tested.

Such multi-way layouts are best case procedures that presume all treatments will be applied to large representative samples in all possible combinations. Moreover, even in the depicted case with only three Smart Corridor elements, the situation is complex. In fact, the implementation schedule for the Smart Corridor project elements does not support this idealized situation. Evaluating the treatments defined by these project elements therefore presents some special complications. The first complication is that data collection constraints make it difficult to undertake a fully randomized design, thus resulting in a nonrandom block design.

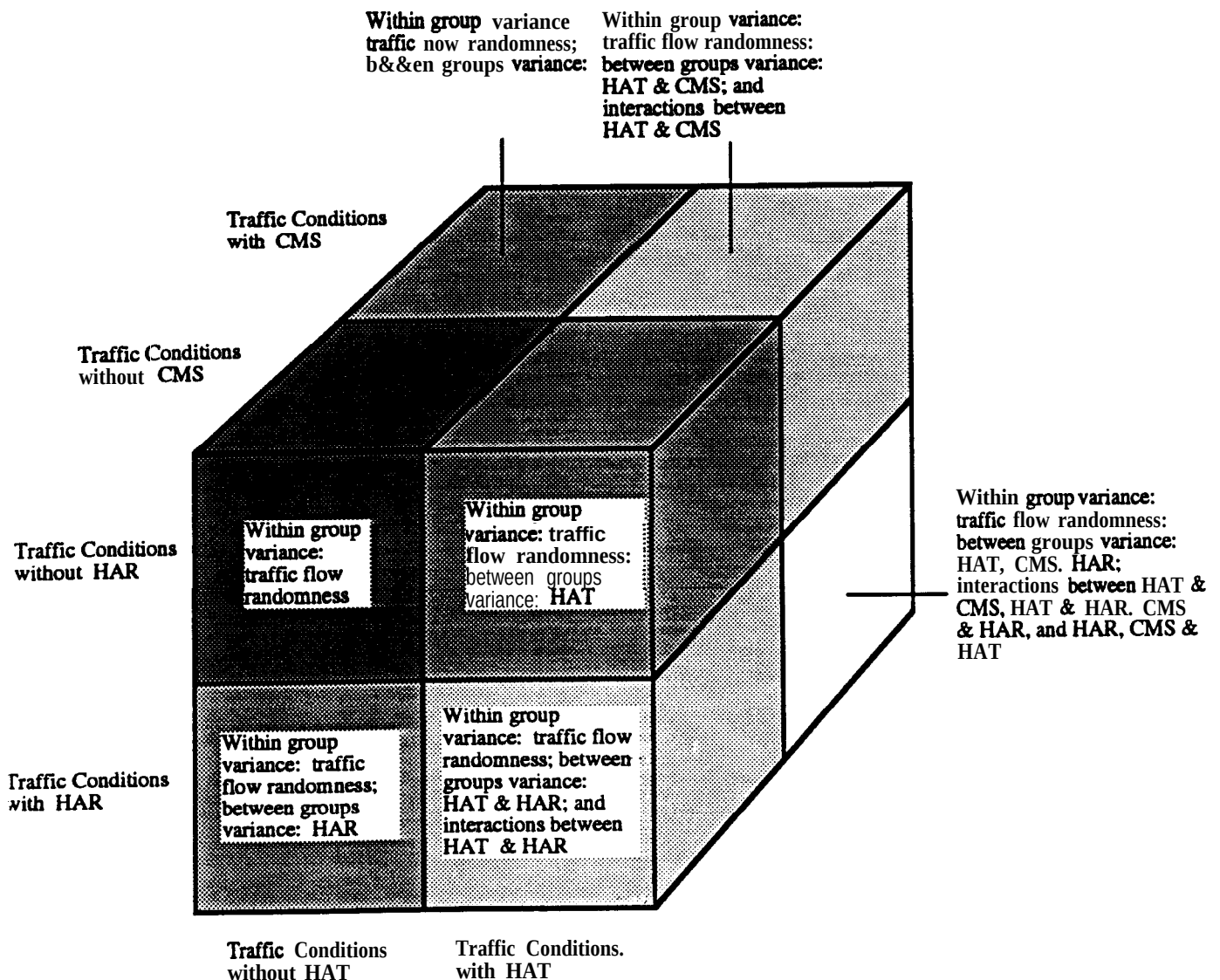


Figure 11: Three-way Layout for Analysis of Variance (ANOVA)¹

¹ The cell for which within group variance is due to traffic flow randomness and the between groups variance is due to CMS, HAR, and interactions between CMS and HAR is hidden from view.

The second complication is similar, but more problematic. Smart Corridor project elements are applied sequentially, and are not scheduled to be removed after their deployment. Further, network data would likely be collected in waves as resources permit. It would not be possible to collect a full inventory of network data prior to and following the application of each project element, nor would it be possible to guarantee that the current deployment schedule for all elements remain unchanged. Consequently, each wave of data would be associated with a cluster of technologies. If any cluster of project elements improves the state of the network, there would be no definitive way to know which technologies in the cluster are responsible for the outcome, though it may be possible to answer such questions qualitatively rather than statistically. There would also be a potential for interaction effects between project elements, both within clusters and across clusters.

4.2 TRAVELER RESPONSE

Survey data and transportation system performance data would be used to relate traveler response to attributes of alternatives, individuals, and information. It is recommended that initially, simple univariate statistical techniques, such as frequency analysis and cross tabulations, be used to analyze the data and test hypotheses. This first stage analysis would consist of deriving MOEs, such as the frequency of motorist usage of HAR, HAT, Teletext Services, Full-matrix CMS, and Trailblazer CMS, as well as the degree of information usefulness, accuracy, timeliness, and reliability. Motorist usage of such Smart Corridor elements would consist of both inquiring (listening, viewing) and implementing its recommendations. Multivariate models of behavior (i.e. diversion propensity) would be estimated to explore the effects of several variables simultaneously. The multivariate approach is superior to the examination of variables independently, as it compensates for interdependencies among explanatory variables and allows exploration of interaction effects. Two such methodologies are discrete choice analysis and structural equations which could be used to quantify the effect of information and other factors on traveler response.

Discrete choice analysis could be used to quantify the effect of information and other factors on traveler response. For example, the effect of several variables on the diversion decisions would be examined by estimating diversion choice models, i.e. the probability of diverting based on survey respondents' reported experience of a recent delay. The choice to divert or not is based on values of variables that explain traveler response. Such explanatory variables include attributes of usual and alternate routes, such as congestion, reliability, neighborhood safety, and traffic stops; attributes of individuals such as socioeconomic characteristics and personality (measured through self-assessment statements) and attitude toward diversion (measured through stated preference questions).

To analyze the smaller panel data set, a technique called structural equations could be used. This approach can connect more than one dependent variable (e.g. diversion from and return to the original route). Furthermore, this method allows the linking of variables at two or more distinct points in time. Therefore, dynamic effects may be explored. In the context of the Smart Corridor, it would allow the derivation of both short-term (immediately

after implementation) and long-term effects (e.g. after six months) of Smart Corridor elements on traveler response.

By the approaches outlined above, the effect of both individual and combined Smart Corridor technologies would be assessed, to the maximum extent possible given the constraints of the deployment schedule. In addition, tangible and intangible benefits would be evaluated under incident and recurring congestion conditions.

4.3 EMISSIONS AND ENERGY IMPACTS ASSESSMENT

The basic methodology recommended for use to derive emissions and energy impacts would be an indirect approach, relying on results from the network performance evaluation. This means that no direct measurements would be taken of pollutant levels or energy consumption. In addition, energy impacts would be restricted to an assessment of gasoline and diesel fuel consumption by Smart Corridor travelers.

It is recommended that analytical regression models be used to derive estimates for both pollutant levels and fuel efficiency. Both linear and nonlinear regression models should be considered. The pollutant and energy models would likely be a function of some or all of the following explanatory variables: (1) average speed; (2) travel time; (3) number of stops (arterial traffic); (4) total stopped time (freeway travel); (5) total distance traveled. Several models should be tested to determine which provides the best predictive power. Basic statistical techniques would also be employed in this work, including estimation of t-statistics, F-statistics, and R^2 values. The t-statistics would be used to test the statistical significance of regression equation coefficients. F-statistics would be used to test the statistical significance of the regression model as a whole. The value of R^2 qualitatively describes the proportion of the variance in the dependent variable of the regression equation which is attributable to the independent variables in the model.

Examples of commonly used analytically specified models for derivation of fuel consumption include the following (Lindley [20]):

Model 1: $FCR = A + B/v + (Cv^2)$, where

FCR = Fuel consumption rate (gallons/mile)

v = Average travel speed (miles/hour)

A = Constant related to the vehicle's rolling resistance

B = Constant related to the vehicle's idling fuel consumption rate

C = Constant related to the vehicle's air resistance

Model 2: $FE = A + (Bv) + (Cv^2)$, where

FE = Fuel economy (miles/gallon)

v = Average travel speed (miles/hour)

A, B, C = Constants

Models developed by the Environmental Protection Agency and the California Air Resources Board should also be investigated for use to derive the impacts on emissions.

4.4 SMART CORRIDOR OPERATIONAL PERFORMANCE

The basic methodology to be used to analyze the use of each Smart Corridor element would primarily be cross tabulations and, where appropriate, “before/after” statistical comparisons. For example, in the case of the Smart Corridor Expert System, although no system performance specifications have been developed and thus there is actually no system benchmark to use for comparative purposes, its performance will be evaluated by tracking over time its ability to perform its functions effectively, accurately, and speedily. With respect to the IM subsystem, comparisons with the state of incident management may be made since truly “before” data on incident characteristics will be collected by the System Manager as part of its Operations Planning element of the Smart Corridor. The potential improvement in the IM subsystem over time, the maturation effect, should also be considered in the analysis.

4.5 INSTITUTIONAL ISSUES

To place the analysis of institutional factors in perspective, it is recommended that the evaluator first review the literature describing complex interactions among agencies within the transportation sector, and in government generally, looking for formal and informal models of cooperation, conflict, and coordination which can be used to frame the study of the Smart Corridor, and which can give rise to hypotheses about organizational effectiveness to be tested in the case of the Smart Corridor. Previous evaluations of specific projects involving several jurisdictions would be reviewed, such as the ongoing evaluation of the TravTek program in Orlando, and the recently completed signal timing program along Katella Avenue in Orange County, to determine what was learned about the significance of institutional and organizational issues affecting those projects. In addition, the more general literature about organizational structures in transportation should also be analyzed for their relevance to the Smart Corridor project.

In order to produce the analytical institutional and organizational account of the evolution of the Smart Corridor, i.e. the details of what brought the project to its current state, the evaluator should review documentary evidence of the evolution of the project in the form of minutes of meetings and memoranda prepared by the many participating agencies. Based upon content analysis of these reports and minutes hypotheses would then be formulated regarding key barriers to and opportunities for cooperation and coordination in the management of the project. Aware that a significant component of the essence of the inter-organizational relationships would likely be found in previously held telephone conversations among agency staff that eventually produced such written documents, the meeting minutes and memoranda would be supplemented by interviews with specifically targeted agency staff

to help capture more of the core of the inter-organizational issues, including the problems encountered and methods used to resolve them. It may be desirable to interview additional individuals based upon their roles in the project, as well as investigate other issues. Interviews would be conducted using semi-structured open-ended interviewing techniques.

It is recommended that meetings of the Smart Corridor Technical Committee, as well as other project committees be attended noting the critical issues which emerge at the meetings which affect and are affected by different organizational perspectives and operating procedures.

The roles, positions, and perspectives of the many organizations involved in the project, including formal and informal working relationships which characterize the management of the project should be documented. The particular roles played by individuals and agencies would be defined, reviewed and traced over the life of the project. Critical issues on which the success of the project depended would be identified (e.g. equipment purchased by one agency and used by another agency) and the ways in which those critical issues were resolved would be described. It is likely that the several participating agencies hold different expectations regarding the Smart Corridor, and would define the costs and benefits of the project differently.

To the extent that they do, these findings would be critical to an understanding of the institutional context of the project. In addition, in all probability the personnel of the several participating agencies will develop informal working relationships which may differ to some extent from the formal working agreements and contractual obligations. The discovery and analysis of such differences will constitute an important part of the study. It would also be important to observe the ways in which relationships between the participants differ during the planning phase of the project and after the initiation of the operating phase.

Particular difficulties and successes would be noted, and conflicts which have arisen among participating agencies would be described and analyzed. From this institutional history and analysis, both recommendations for maximizing the effectiveness of future working relationships within the Smart Corridor project, and conclusions which may be useful for others organizing similar complex projects should be extracted. If appropriate, guidelines could be drafted which might help facilitate institutional cooperation and coordination in the future.

Also noted would be features of the organizational arrangement which were frequently seen as potential stumbling blocks, as well as organizational alternatives to avoid these problems. Ways in which choices of organizational structure give rise to particular outcomes, and whether inter-organizational communications can be streamlined without threat to the accomplishment of the project's mission should also be defined. Forms of organization adopted by this project would be compared with others identified in the literature review, and with evaluations of the effectiveness of those alternative models of organization in

previous studies of a similar nature.

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APPENDIX A

POTENTIAL FOR DIVERSION TO ARTERIAL STREETS

To assess the potential for diversion from the freeway to arterial streets, the primary measure of traffic congestion examined was the volume to capacity ratio (V/C) for all roadway facilities (freeway, ramps, and major parallel arterials). Data were available from the previous Smart Corridor study conducted by Kaku Associates [19]. Initially, volume data had been collected in 1987 and 1988 along Interstate 10 (Santa Monica Freeway) and the major parallel arterial streets consisting of Venice, Washington, Pico, Olympic, and Adams Boulevards, during the AM peak period (7:00 - 10:00 AM), the PM peak period (3:00 - 6:00 PM) and the Off-peak (11:00 AM - 2:00 PM) from which volume to capacity ratios were derived based on an hourly lane capacity of 1,750 vehicles.

Based on these data, a linear regression model was estimated to determine the potential for diversion to alternate routes during various times of day. The dependent variable was V/C, and the set of independent variables describing roadway type and time-of-day used, consisted of dummy variables, i.e. variables taking on the values 1 or 0 indicating the presence or absence of a particular characteristic, respectively. For variables indicating type of roadway use or non-use, initially two variables were specified, FREEWAYDUMMY and RAMPDUMMY, followed by variables describing the specific arterial used, namely VDUMMY, WDUMMY, PDUMMY, and ODUMMY. These arterial-specific variables refer to the use or non-use of Venice, Washington, Pico, and Olympic Boulevards, respectively, and were created to understand the V/C ratio differences among arterials. There was no need to specify a variable for Adams Boulevard since its use or non-use is inferred from the values of the other four variables. In general, to differentiate among the five different arterials, only four dummy variables representing any four of the arterials suffice. Another group of independent variables depict time of day usage, PMDUMMY and AMDUMMY. These time-of-day variables are specific to the arterials, i.e. PMDUMMY (AMDUMMY) has value 1 for PM (AM) peak travel on arterials, 0 otherwise. As in the case for roadway type variables, there was no need to specify a variable for the third time period (Off-peak) as driving or not driving during the Off-peak is inferred from values of the two other time-of-day variables.² The model specification used to estimate volume-to-capacity ratios is given by Equation 1. The results of the model estimation--both estimates for the values of the model coefficients and t-statistics (level of statistical significance)--are provided in Table 2.

²Originally, similar time-of-day variables specific to freeways were included in the model. However, it was determined that no statistically significant difference existed between freeway traffic during the PM and AM peak periods, so this variable was omitted in the final model specification.

$$\begin{aligned} \text{Equation 1: } V/C = & \beta_0 + \beta_1 \text{FREEWAYDUMMY} + \beta_2 \text{RAMPDUMMY} + \beta_3 \text{VDUMMY} \\ & + \beta_4 \text{WDUMMY} + \beta_5 \text{PDUMMY} + \beta_6 \text{ODUMMY} + \beta_7 \text{PMDUMMY} \\ & + \beta_8 \text{AMDUMMY} \end{aligned}$$

TABLE 2

REGRESSION MODEL ESTIMATION RESULTS FOR V/C RATIOS
IN THE SMART CORRIDOR

Variable Name	Coefficient	t-statistic
Constant	0.701	23.356
ROADWAY TYPE		
FREEWAYDUMMY(= 1 for freeway, 0 otherwise)	0.369	9.729
RAMPDUMMY(= 1 for ramps, 0 otherwise)	-0.072	-2.150
ARTERIAL STREETS		
VDUMMY(= 1 for Venice, 0 otherwise)	0.100	2.503
WDUMMY(= 1 for Washington, 0 otherwise)	0.082	2.104
PDUMMY (= 1 for Pico, 0 otherwise)	-0.014	-0.361
ODUMMY (= 1 for Olympic, 0 otherwise)	0.084	2.312
TIME OF DAY		
PMDUMMY (= 1 for PM peak on arterials, 0 otherwise)	0.107	4.080
AMDUMMY(= 1 for AM peak on arterials, 0 otherwise)	0.018	0.687
Summary statistics:	$R^2 = 0.417$, N = 297 data points	

The sign, plus or minus, of each parameter coefficient indicates an increase or decrease in V/C ratio, relative to the constant, whereas the magnitude of parameters indicates the size of the contribution associated with the dummy variable. The summary statistics show that the model explains 41.7 % of the variability in the data.

The **FREEWAYDUMMY** variable shows that the freeway operates at a relatively high V/C ratio ($0.701 + 0.369 = 1.07$), whereas the ramp intersections (**RAMPDUMMY**) operate at a relatively low ratio ($0.701 - 0.072 = 0.629$). Further, there is a significant surplus capacity on the arterials ($V/C = 0.701$) and at the ramp intersections and therefore a significant potential for diverting traffic during times when excess capacity is needed on alternate routes, e . g . during incidents. The parameter values indicate that Adams and Pico Boulevards may have greater capacity than Venice, Washington, and Olympic Boulevards. The relative magnitudes indicate that Venice and Olympic have the least

surplus capacity.

The time of day variables show that the potential to divert individuals to alternate routes is greater during the Off-peak and the **AM peak** periods than during the PM peak period. These results represent overall trends only. It is certainly possible that the AM peak period contains times in which the potential for diversion is no greater (or in fact even worse) than during the PM peak period. This occurs because of the possibly higher concentration of commuter traffic during a relatively short time period in the AM peak.

Overall, there seems to be significant surplus capacity on the arterial streets, which is more likely to be available during the Off-peak and AM peak periods. Based on this result, it is important to consider Off-peak travelers. Thus, the target population is chosen to consist of Smart Corridor travelers during the Off-peak (largely non-work trips) as well as during the peak periods (primarily work trips).

APPENDIX B

DETERMINATION OF SAMPLE SIZE

In computing a sample size, the analyst is often interested in measuring changes. An important dimension in sample design then, is the rate of behavioral change in respective population subgroups. Stratified sampling schemes may be developed to account for the rate of change in the target measure. In general, however, sample size requirements for a panel survey can be derived from the available sampling theory.

The sample size is also based on considerations of budgetary constraints, historical evidence, i.e. what researchers have used for analysis, professional judgment, and rules of thumb. All these factors will be taken into account to determine the final survey sample size.

From sampling theory, the basic question that needs to be answered is: How large must the sample size, "n", be to guarantee with a probability or level of confidence of $1 - \alpha$ that the answer to a particular survey question differs from the views of the population at large by no more than a certain tolerance level, "d"? Since costs are an important factor in the analysis, the smallest possible "n" is desired to satisfy the above requirements. Commonly used values for both parameters are, $\alpha = 5\%$ and $d = 5\%$. The larger the confidence level or the smaller the tolerance level, the larger "n" must be. The value of "n" may be estimated by the following formula as derived in Larson et al. [21]:

Equation 2: $n = (z_{\alpha/2}/2d)^2$, where $z_{\alpha/2}$ is the value for the standard normal random variable, Z, such that the probability is $1 - \alpha$ that Z lies between $-z_{\alpha/2}$ and $z_{\alpha/2}$.

Using equation 2 to estimate the panel sample size for a 95% confidence level, the sample size would be approximately 384, which is rounded up to 400 panel participants. Based on this estimate for the panel sample size (400), the next step is to estimate the total number of broad surveys that need to be mailed out.

Since we are dealing with a panel survey, it is expected that a number of people who would return the initial mail-out (broad) survey might not be willing to participate in the panel survey. Moreover, the potential loss of panel participants through attrition and fatigue would have to be addressed. This loss would necessitate panel refreshment.

A literature search was used to gain an understanding from historical evidence of the typical size of losses through attrition. Work reported in Giuliano et al. [22] report a 22% loss between the original sample, i.e. those people who agreed to participate, and the first

panel, a further 5 % loss between the first and second panels, and another 5% loss between the second and third waves. In another study (Golob and van Wissen [23]), of the total households originally contacted, 47.1% expressed a willingness to participate in the panel survey. The reported attrition between the first and second panels was approximately 32 %. Finally, in Waterton and Lievesley [16], an attrition rate of approximately 30%, 20%, and 5% are reported for the first, second, and third panels, respectively.

Using conservative estimates based on this previous research, the following attrition rates were assumed: 30% attrition rate for the first panel, 25 % for the second panel, and 20% for the third and final panel. Thus, to maintain a sample size of 400, it would be necessary to have an initial number of willing participants of approximately 805. This estimate was calculated using the following formula:

$$\text{Equation 3: } N_p = N_s * [1 + (W_1/(1-W_1)) + (W_2/(1-W_2)) + (W_3/(1-W_3))]$$

Where:

N_p = Total pool size of participants required for maintaining a 400 panel sample size.

N_s = Required panel sample size (400).

W_1 = Percent of attrition in the first panel (30%).

W_2 = Percent of attrition in the second panel (25 %).

W_3 = Percent of attrition in the third panel (20%).

Finally, assuming a typical response rate of 20% to the initial mail-back broad survey sent out, and an estimated 50% of respondents to the initial mail-back survey agreeing to participate, the total number of mail-back surveys that need to be sent out (N) is estimated to be:

$$\text{Equation 4: } N = 805 / (0.5 * 0.2) = 8,050$$

Based on this number of mail-out broad surveys, a conservative estimate of 10,000 mail-out broad surveys is made.

APPENDIX C

SAMPLE QUESTIONS FOR BROAD SURVEY

Category: Normal travel patterns

In a typical week how often do you (i) drive alone to work by car, (ii) go to work in a car pool, (iii) travel for work-related purposes, (iv) go grocery shopping.

Which of the following best describes your work schedule? (a) I am rewired to s t a r t w o r k a t (b) the time I begin work is flexible and normally I prefer to arrive at e (c) my work shift changes ~~from day-to-day~~, week-to-week, o weeks, or less frequently.

Category: Perceptions of usual and alternate route attributes such as reliability and neighborhood character

Excluding intermediate stops, how long does your usual route normally take from: (i) home to work? (ii) work to home?

Under normal conditions (no accidents or bad weather), how congested is your usual route traveling from home to work? (i) not congested, (ii) stop-and-go.

How long does your best alternate route normally take from home to work?

Under normal conditions (no accidents or bad weather), how congested is your best alternate route traveling from home to work? (i) not congested, (ii) stop-and-go*

Category: Changes in travel patterns, such as route diversion and destination change, due to information about expected and unexpected delays.

Due to regular delays, how often do you change your normal travel plans in the following ways?

D e p a r t minutes earlier, departminutes later, use public transportation, take alternate route(s), add intermediate stop(s), e.g. to run errands.

Due to unexpected congestion, how often do you: Take your alternate route, use public transportation, add unintended intermediate stop(s), e.g. stop at a store.

If you take an alternate route, do you normally return to your originally planned (usual) route? Yes, no (continued on alternate route to the final destination).

Category: Expected benefits from changing travel decisions

Due to route diversion, how many minutes did you save or lose?

Category: Attitude toward information and stated preferences

Please indicate your level of agreement or disagreement with the following statements:

- (i) I frequently listen to radio traffic reports (strongly disagree . . . strongly agree),***
- (ii) I like discovering new routes to get someplace (strongly disagree . . .strongly agree)***

Category: Socioeconomic attributes and personality

Gender: male or female

Age: under 18 years, 18-29 years, 30-39 years, 40-49 years, 50-64 years, 65 and over.

What is the highest level of education you have completed? High school or less, some college, vocational or technical training, graduated college, post graduate work (master's or doctoral degree)

What best describes your occupation? Clerical/secretary, executive/managerial, retired, professional/technical, service, student, salesperson/buyer, construction, production/manufacturing, ...

How long have you (i) lived at your present home location? (ii) worked at your present job location?

How many motorized vehicles (cars, vans, trucks, two wheelers) does your household have?

How many persons, including yourself, live in your household?

How many persons in your household, including yourself are employed full-time?

APPENDIX D

SAMPLE QUESTIONNAIRE FOR PANEL SURVEY (SHORT MAIL OUT VERSION)

Day of the week _____

Trip o.	Trip Location		Purpose at destination			Mode used		Departure Time	Arrival Time	Route(s) Used	Before starting trip			During trip			
	Location trip started	Location trip ended	To work or commute	Shopping/errands	Other (specify)	Car/van	Bus/rail				Other (specify)	Travel info received from:			Travel info received from:		
												Observation	Radio/TV	Other	Radio	Telephone	Other
1	Home								AM PM	AM PM							
2									AM PM	AM PM							
3									AM PM	AM PM							
4									AM PM	AM PM							
5									AM PM	AM PM							
6									AM PM	AM PM							
7									AM PM	AM PM							
8									AM PM	AM PM							
9									AM PM	AM PM							
10									AM PM	AM PM							