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CALIFORNIA PARTNERS FOR ADVANCED TRANSIT AND HIGHWAYS

INTERMODAL TRANSPORTATION OPERATION SYSTEM (ITOS) FOR THE STATE OF CALIFORNIA

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August 24, 1998

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ABSTRACT

Intermodal transportation entails the coordinated movement of different types of transportation (rail, truck, automobile, etc.) to serve the needs of travelers and shippers. The purpose of this report is to provide a vision for systems to coordinate intermodal operations in California in the future, and also to document the types of systems that are being used today in a range of transportation modes. An intermodal system could, conceivably, establish a center (or centers) that is responsible for the joint operation of multiple modes of transportation. This is not our preferred vision. Instead, we envision that these systems will retain their current organizational and modal identifies in the future. However, systems will be developed to provide interconnections when benefits are significant.

Keywords: Transportation Management Centers, Intermodal Transportation, System Architecture, Transportation Systems Management

EXECUTIVE SUMMARY

Intermodal transportation entails the coordinated movement of different types of transportation (rail, truck, automobile, etc.) to serve the needs of travelers and shippers. Most transportation organizations today have developed a "command and control" structure for coordinating their operations. Command and control is typically executed through a center that serves as the focal point for regulating the movement of vehicles, assigning employees to tasks, interfacing with customers, and collecting data on the state of the system. The center usually provides links for communicating data and voice, computers for processing data, and displays that provide center operators with decision support aids and "situational awareness." The center is configured in a manner that supports the distinct responsibilities of each operator (usually defined by a geographic area or function), and also provides for communication between operators where coordination is needed. This is the predominant model for a "modal" management system -- a system for managing the operations of a single mode.

Because of the state's diversity, it is clear that a single method of transportation cannot serve the needs of the entire state, and our structure for managing and operating transportation system must be flexible and adaptable to local needs. This need is reflected in the mission of the California Department of Transportation (Caltrans and CHP, 1997):

"In partnership with others, Caltrans: Provides the people of California with a safe, efficient, and effective intermodal transportation system…"

In the update to the California Transportation Plan (Caltrans, 1998a,b), intermodalism is receiving further emphasis in the area of goods movement:

"The vision is that the State's transportation system is a balanced, integrated, multimodal network. … The commitment is that Caltrans fosters the development of an integrated, multimodal goods movement transportation system that is safe, efficient and effective."

Caltrans' Advanced Transportation Systems Program Plan envisions Transportation Management Centers as the nerve centers for integrating new technologies, but states "Additional effort is needed to determine the best way to integrate a greater scope of … advanced intermodal functions into TMC operations. This has even greater priority as TMC activities extend to coordination of more functions, modes and agencies, through a mix of computer automation and operator involvement." (Caltrans, 1997).

The purpose of this report is to provide a vision for California's intermodal systems of the future. An intermodal management system could, conceivably, establish a center (or centers) that is responsible for the joint operation of multiple modes of transportation. This is not our preferred vision. Instead, we envision that these systems will retain their

current organizational and modal identities in the future. However, systems will be developed to provide interconnections when benefits are significant, examples of which follow:

- Minimize delays at city boundaries, where traffic control systems must be interfaced
- Maximize capacity within a corridor of roadways, especially in the event of incidents
- Reduce the time required to clear incidents and restore capacity, while ensuring safety
- Make quality information available to travelers and fleets to optimize their travel and goods movement decisions

We also envision that the operational functions of transportation management centers will become interconnected with the planning and regulatory functions, so that operational data can be applied to the design of transportation infrastructure and deployment of resources. This would include the existing Intermodal Transportation Management System (ITMS).

In our preferred vision, linkages are created between information systems when there are critical physical or operational interfaces. Incident systems and traffic systems are naturally connected, as they are jointly responsible for managing the infrastructure. Terminal and fleet systems are also naturally interconnected due to the role of terminals in processing vehicles. And though highways and streets are required for the operation of fleets, we do not show a strong connection between traffic and fleet systems. This is because we envision that mobile fleets will continue to obtain information through private sector consolidators, rather than directly from traffic agencies.

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1. INTRODUCTION

Intermodal transportation entails the coordinated movement of different modes of transportation (rail, truck, automobile, etc.) to serve the needs of travelers and shippers. Intermodalism is widely practiced in goods movement. Most imports entering the United States travel by a combination of ocean-going vessel and truck, and often by rail as well. Freight is often moved in the United States by a combination of truck and trailer-on-flatcar (rail), and urgent shipments are typically sent by a combination of airplane, package van and truck. In goods movement, intermodalism allows modes or companies to specialize in either local pickup-and-delivery or in longhaul transportation, providing for the most efficient combination of speed and cost.

Passenger travel is less likely to be intermodal in the United States, as automobiles account for the vast majority of travel. Nevertheless, most automobile trips cross through multiple jurisdictions, including city street systems and state/national highway systems. So even though mode-to-mode coordination is usually not needed for travelers, coordination is still needed as traffic crosses from one jurisdiction to the next. Furthermore, bus and rail modes have a strong presence in many of the more congested corridors of the United States, making their efficiency crucial to minimizing delay.

In California, transit mode shares are largest on the corridors leading into Downtown San Francisco and Downtown Los Angeles, which are also the most congested locations in the State. Travel by transit is inherently intermodal, requiring a combination of transit and walking at a minimum, and often combinations of automobile and transit, or combinations of different transit modes.

Most transportation organizations today have developed a "command and control" structure for coordinating their operations. Command and control is typically executed through a center that serves as the focal point for regulating the movement of vehicles, assigning employees to tasks, interfacing with customers, and collecting data on the state of the system. The center usually provides links for communicating data and voice, computers for processing data, and displays that provide center operators with decision support aids and "situational awareness." The center is configured in a manner that supports the distinct responsibilities of each operator (usually defined by a geographic area or function), and also provides for communication between operators where coordination is needed. This is the predominant model for a "modal" management system -- a system for managing the operations of a single mode.

The purpose of this report is to provide a vision for California's intermodal systems of the future. We define intermodal transportation to be when different transportation systems interact with each other, either because shipments or travelers transfer between systems or because vehicles share a common guideway. Our specific focus is on ground

transportation, and the interactions between ground transportation and other forms of transportation. By this definition, we are concerned with not just changes in modes, but interactions between different systems operating the same mode (e.g., between one transit system and another). Examples of the interactions include:

Examples of System Transfers

- Ground transportation (passenger vehicle, shuttle van, taxi, etc.) access to airports
- Bus feeder service to rail and ferry systems and bus transfers at timed transfer terminals
- Rail/ship and rail/truck transfers at port terminals
- Truck/rail transfers at rail terminals
- Vehicles entering highways from local streets, or the reverse
- Vehicles crossing from one street jurisdiction to an adjacent jurisdiction

Examples of Common Guideway

- Truck, bus and passenger vehicle usage of streets and highways
- Shared usage of track right-of-way by Amtrak, commuter rail, and freight trains operated by different railroads

When these interactions exist, information exchange and control can be advantageous. It can help coordinate schedules, minimizing transfer delays, and it can assist shippers in tracking their shipments and planning their transportation from origin to destination. It can also minimize conflicting schedules among different types of vehicles that share a common guideway.

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In our preferred vision, linkages are created between information systems when there are critical physical or operational interfaces. Incident management and traffic systems have natural connections, as they are jointly responsible for operating the infrastructure. Terminal and fleet systems also have natural connections due to the role of terminals in processing vehicles. And though highways and streets are required for the operation of fleets, we do not see a strong connection between traffic and fleet systems. This is because we envision that mobile fleets will continue to obtain information through private sector information consolidators/providers, rather than directly from traffic agencies.

2. TRANSPORTATION IN CALIFORNIA

As the most populous state in the country, it is not surprising that California is home to some of the nation's largest transportation organizations. California's transportation infrastructure includes:

- 2,400 Interstate Highway miles and 12,900 additional miles of federal-aid highways, and 169,000 total road mileage.
- Transit agencies that serve several million trips per day
- The nation's largest container port complex in Los Angeles/Long Beach, and another major container port in Oakland, with more than 130 million tons in dry cargo handled in the state in 1995.
- 5,000 miles of Class I rail track
- More than 500 million tons of truck freight originating in the state.
- The 4th and 5th busiest airports in the country in Los Angeles and San Francisco
- A diverse set of transit modes, including buses operating on diesel and alternative fuels, electrified trolley buses, light-rail systems, cable cars and heavy-rail systems.
- 15 million registered passenger cars and 8 million registered trucks and buses, traveling 280 billion miles annually.

California is also home to some of the most important transportation companies in the country, including:

- American Presidents Line (Oakland): ocean shipping
- Consolidated Freightways (Menlo Park): less-than-truckload carrier
- DHL Express (Redwood City) and Emery (Menlo Park): overnight package service
- Etak (Menlo Park) and Navigation Technologies (Sunnyvale): map databases
- QualComm (San Diego): wireless communication for the trucking industry
- Trimble Navigation (Santa Clara) and Magellan (San Dimas): global positioning systems
- Design shops for many of the major Japanese and American automobile manufacturers

The state's geography, demographics and climate also show tremendous diversity over its vast area. Temperatures range from the harsh winters of the Sierras to the extreme heat of inland summers, with the precipitation of a rain-forest in the north and the aridness of deserts in the south. Population density varies from sparsely populated Central Valley and mountain regions, to the urban concentrations of San Francisco and Los Angeles.

Because of the state's diversity, it is clear that a single method of transportation cannot serve the needs of the entire state, and our structure for managing and operating transportation system must be flexible and adaptable to local needs. This need is reflected in the mission of the California Department of Transportation (Caltrans and CHP, 1997):

"In partnership with others, Caltrans: Provides the people of California with a safe, efficient, and effective intermodal transportation system…"

A similar mission is stated in the California Transportation Plan (Caltrans, 1993):

"The State's fundamental objective is to create a comprehensive State transportation system that works as ONE SYSTEM as far as its users are concerned. The various parts of the system provide different modes or options of travel that satisfy different needs of the customer."

In the update to the California Transportation Plan (Caltrans, 1998a,b), intermodalism is receiving further emphasis in the area of goods movement:

"The vision is that the State's transportation system is a balanced, integrated, multimodal network. … The commitment is that Caltrans fosters the development of an integrated, multimodal goods movement transportation system that is safe, efficient and effective."

One aspect of realizing these visions is to deploy technology to operate, control, and coordinate transportation systems. The California Transportation Plan proposes the action to "Develop and deploy advanced transportation system management systems" as a means to achieve the objective to "Manage transportation networks as a seamless intermodal system." The 1998 update to the plan suggests a range of technological enhancements in the commercial vehicle area, as well as a comprehensive plan for monitoring transportation system performance.

Caltrans' Advanced Transportation Systems Program Plan envisions Transportation Management Centers as the nerve center for integrating these new technologies, but states "Additional effort is needed to determine the best way to integrate a greater scope of … advanced intermodal functions into TMC operations. This has even greater priority as TMC activities extend to coordination of more functions, modes and agencies, through a

mix of computer automation and operator involvement." (Caltrans, 1997). The document shows the TMC as being interconnected with freight operations, public transit, parking facilities, private vehicle and other types of systems.

The California Transportation Management Center plan states that a Transportation Management Center has five basic functions (Caltrans and CHP, 1997):

- Expedites the removal of major incidents to prevent secondary incidents and reduce delay
- Expedites the removal of any minor vehicular problems on the highway
- Provides weather warning systems (i.e., for or dust detection) in vital areas
- Controls traffic demands on the system
- Informs the public of transportation information

The Master Plan resulted from a Memorandum of Understanding between Caltrans and the California Highway Patrol to collate traffic operations centers, Caltrans Maintenance Communications Center and CHP Communications to provide a "more coordinated approach to transportation management." The Master Plan proposes a hierarchical structure, composed of regional TMCs (Bay, Area, Sacramento and Los Angeles), Urban TMCs and Satellite Operations Centers. Intermodalism is reflected as a long-range objective, by stating "further TMC development will provide interconnectivity with other transit agencies, information service providers, law enforcement and the media" and stating the goal to "enhance public and private partnerships that promote multimodal activities and services."

The first concerted effort at creating an intermodal transportation management center (IMTMC) is in the planning stages in San Diego. The goal of the IMTMC is to "optimize and coordinate freeway and surface street operations and private transportation systems, by the integration of intermodal transportation information, and intermodal transportation management systems," (Booz, Allen and Hamilton, 1998). The IMTMC is intended to include subgroups for transit, incident management, advanced traveler information systems, CVO/Borders, traffic systems, communications and InterCAD (connecting police agencies).

3. EXISTING TRANSPORTATION MANAGEMENT CENTERS

A great many transportation management centers already exist in California. In this section, we examine how these centers function today, along with the information they collect and how they use that information. These centers would form the backbone for any future intermodal transportation system. The following types of transportation management centers are covered:

- Airport ground traffic
- Port ground traffic
- Railroad train control
- Taxi dispatching
- Traffic control and surveillance
- Transit information and tracking
- Traveler information
- Trucking fleets

This section provides both an update of prior PATH work, and an expansion to include modes of transportation that were not previously covered. Refer to Hall et al (1994), Lo and Rybinski (1996), Hall and Chatterjee (1995), and Hickman and Day (1995) for further information. A detailed review of traffic management centers, as of 1992, can also be found in Loral AeroSys (1992).

Airports

Los Angeles International and San Francisco International are the 3rd and 6th busiest airports in the country, in terms of boardings. Both serve as major hubs for international traffic throughout the pacific region, as well as the primary airports for their regions. Other major airports are located in San Diego, San Jose, Orange County, Oakland, Ontario, Sacramento and Burbank. These airports not only generate large numbers of private automobile trips, but van, bus and taxi trips as well (especially to serve out-of-town visitors). They also serve substantial amounts of freight traffic for the overnight delivery industry, though not nearly as much traffic as ports and intermodal rail terminals.

Information Collected and Monitored

Various airports have installed transponder based systems (radio frequency tags) for tracking the movement of buses, shuttles, taxis and limousines in and out of the terminal areas. Los Angeles International and Ontario airports (both operated by the Los Angeles Bureau of airports) use an Amtech system. The system's primary use is for billing. Commercial vehicles are charged for each loop made through the terminal. A database is also maintained on the number of vehicles entering the terminal area by type. Airports have not used tags for other types of commercial vehicles, such as cargo trucks.

Most major airports have installed informational kiosks throughout their terminal areas. These provide information on ground transportation services (service area, price, phone number), maps of the terminal area, and access to flight information. They are not used for providing real-time information, such as schedule delays, which is displayed through each airline's flight monitors instead.

Air traffic is monitored by the FAA from the standpoint of flight control (for safety and capacity allocation purposes) and by the individual airlines for scheduling purposes. Airports do not track flight schedules or delays, making it impossible to get information on all flights out of a single airport from a single source. The FAA also controls the movement of planes from runways to gates as part of their ground control responsibility. Individual airlines provide real-time schedule information to the public through telephone information lines (often automated) and in some cases web sites (such as San Jose) provide access to flight schedules. FAA flight data can be obtained through a private web site, which obtains the data from the Volpe Center in Massachusetts. This provides an alternative means for estimating flight arrival times. In some cases, these data can be more current than airline data, though they do not account for anticipated changes in the flight plan that might only be known to the airline.

Currently, air traffic and surface traffic are not coordinated in any substantive way. Though airlines do coordinate transfers from aircraft to aircraft, they do not coordinate transfers from aircraft to surface transportation.

Relevance of Information to Other Organizations

Airports have the potential for tracking ground traffic delays within the terminal area, and for counting queues of taxis and vans. They also have the potential for tracking parking lot occupancy. This information could be useful to travelers in planning their trips to and from the airport. Information could be accessed directly via a web page or by an automated phone service. It could also be disseminated through an information service provider to provide in-vehicle access to information. Taxi and van companies may need to access a web site that provides information on taxi/van queues, and make this information available to their drivers.

Some interconnection may be needed between traffic control systems on the airport property and those of surrounding cities and Caltrans, to manage traffic flowing through the facility. This will provide synchronization of signals, and improved management of queues in the terminal area.

Incident Responders

Incident responders include emergency agencies (California Highway Patrol, Police, Fire, Ambulance), tow and clearance companies, and hazardous materials teams. California Highway Patrol (CHP) is the primary law-enforcement agency on California state highways, and is therefore constantly engaged in serving incidents. CHP acts as the overall scene commander for incidents on highways. It functions to safely remove people and vehicles as quickly as possible, to control the movement of incident responders in and out of the scene and to control the incident scene to prevent follow-on incidents. The CHP also serves as the communication hub through use of its Computer Aided Dispatch

system, and through its role as the Public Service Answering Point (PSAP) for cellular 911 phone calls.   The CHP communication center is also used for dispatching Freeway Service Patrol (FSP) vehicles to minor highway incidents.

CHP patrol cars are equipped with 2-way radio and (sometimes) a laptop computer connected to a cellular modem. The laptop computer allows officers to receive and send text messages regarding incidents. Officers also carry portable radios, which allows them to communicate with their dispatcher when within a limited range of their car.

CHP's specific roles in incident management are as follows:

Incident Detection Incident detection is handled by CHP most of the time. The phone calls made by the public or from call boxes are all processed by the CHP communication center and then routed to the appropriate agency. CHP officers in the field are constantly patrolling the highways and, therefore, they are often the first to detect an incident. CHP also serves as the communication center for FSP trucks, which are also dispatched through the CHP CAD.

Incident Verification Incidents are generally verified by the CHP officers on the site. They verify incidents upon instructions from the CHP dispatch center for incident verification. Depending on the type and severity of incident, the CHP officer will ask the dispatcher to summon other agencies. Upon verifying the incident, the officer takes control of the incident as the incident commander, while staying in touch by radio with the dispatcher.

Incident Response: Each day is divided into three watches and each highway is divided into beats. A beat is defined by a highway segment and by direction (a different officer may be responsible for each direction). During the course of his or her watch, an officer will be engaged in various activities, such as patrol, ticketing, roadside assistance, reporting (often in the office) and incident management.

When an incident is reported into the communication center, the dispatcher will first see whether the officer responsible for the section of roadway is "clear" (not otherwise engaged). If the beat officer is clear, then he or she will be dispatched to the incident. Otherwise, the dispatcher will assign the incident to the closest beat for which an officer is clear. However, if the incident has a high priority then he or she may be diverted to it.

The speed of response depends on how far the officer is from the incident, the incident's priority and traffic conditions. Response time can be reduced by turning on lights and sirens and traveling at a high speed, or by driving on shoulders. This is only merited for major incidents. Otherwise, the patrol car can only respond as quickly as traffic allows.

Incident Clearance CHP serves as the overall incident commander on scene, and remains at the incident site until it is completely cleared and traffic is restored. They are also responsible for investigation. CHP officers have a "clear the road" policy, whereby the officers can override the owner's wishes and clear the highway. In case of a fire, fire department vehicles will perform joint command of the incident to clear it. CHP also plays a crucial role in clearing the road to create fast access for other agencies, when required.

The CHP also makes information available to the media and public on incidents through its "Media CAD." Connections are provided to traffic reporting companies, such as Metro Networks and Shadow Traffic. Incident information can also be obtained through the Internet.

Fire departments also play a critical role in incident management, in the following areas:

- Fire: Fire on the highway (usually a vehicle), fires on the side of the highway (usually a brush fire), or spill of a flammable material that might cause a fire.
- Emergency: Medical emergencies or fatalities.

Unlike law enforcement, there is not a single fire department that serves all state highways. Instead, fire services are provided by local departments, operated by cities or the county. Fire stations are spread all over the county and some of them are located especially close to the highway so that they can provide quick response to incidents on the highway.

Incident Response: The fire department dispatch center contains a connection to the CHP, the sheriff's department, and 911 trunk facility connecting them to the local PD. After CHP identifies a fire, HazMat or rescue operation, they automatically contact the appropriate fire department. From this point, the FD dispatcher works with the police to gather information about the incident and send appropriate resources. The fire dispatch center handles all the dispatch operations through its own CAD. All responses are computer-generated and sent electronically to the fire stations over mobile data terminals. Then the dispatcher also gives a call immediately (unless in case of mass emergency) for voice transmission. Medical calls receive top priority but all calls are handled within seconds of detection.

Incident Clearance The fire department takes joint command at the scene with CHP for highway fires. Their roles in incident management are different: CHP evacuates the highway or the adjoining area if required (with help from local PD), and the fire department carries out its operation on putting out the fire. The entire operation of fire departments is based on Automatic Aid agreements and Mutual Aid agreements between the various adjoining city fire departments. The California Master Mutual Aid Agreement covers a broad state-wide mutual aid agreement for the various fire

departments to respond to a major incident requiring resources beyond the means of a single city or county fire Department. (e.g. for the Malibu Brush Fires, teams of fire fighters from Northern California assisted.) Automatic Aid agreements between cities cover areas adjoining the cities and border areas to avoid duplication of resources and at the same time, ensuring prompt services. It also makes available scarce resources, such as helicopters, to smaller cities adjoining larger cities.

Relevance of Information to Other Agencies

Incident management agencies, especially CHP, provide some of the most useful and important information in transportation. Knowing the status and location of an incident can assist travelers in selecting routes or making other travel decision. It is also useful in managing fleets and warning customers of delays. Incident data are useful to Caltrans and arterial systems in timing signals, controlling ramp meters and disseminating information to the public through changeable message signs. Location information on responding units can also be used for signal control in order to reduce response time. Traffic information can be useful to the CHP to prioritize responses to incidents and establishing incident management strategies that minimize congestion impacts.

Ports

California's location on the Pacific Rim has helped make it a major trade center with Asian countries. This has stimulated tremendous growth in containerized shipping through the state's three principal ports: Oakland, Los Angeles and Long Beach. Other ports, such as Richmond, San Diego and Sacramento, are smaller and more specialized.

Information Collected and Monitored

Electronic data interchange and automatic equipment identification (AEI) have become commonplace at marine container terminals. A recent survey (Holguin-Veras and Walton, 1996) found that 83% of terminals have implemented a container-status inquiry system. Usually, this entails touch-tone phone based access. The actual location determination component of the system is usually manual, with 67% relying on booth attendants, 16% using cameras and just 8% using transponders. The survey also found that EDI was the most widely used link connecting shipping companies to terminals, but that motor carriers typically did not have EDI access. As an example, three trucking companies and two steamship lines at the Port of Los Angeles and Long Beach are using a system developed by TranSystems (Salinas, California) called "ISIS." The system provides information to truckers via the Internet about the number of containers that are currently waiting for pick-up at the marine terminals.

Typically, ports do not operate transportation management centers. However, the ports of Long Beach and Los Angeles are in the process of establishing port-wide system for the collection and management of traffic information. The initial system will be a messaging system by which truckers can send messages to a central control center to determine the appropriate place and times for arrival and departure. The system has been championed by John Cushing of the Port of Los Angeles. The Ports of Long Beach and Los Angeles have also been active in the Alameda Corridor project, which may create an integrated center for managing train movements in and out of the port.

Relevance of Information to Other Organizations

Individual port terminals will continue to make information available to their own customers on container status and financial transactions. Sharing of information on ship arrivals with the local traffic agency could provide small benefits in controlling traffic signals. This could enable adjusting cycle lengths and phases to accommodate surges in truck flows, and reduce congestion in the port area.

Freight Railroads

Burlington Northern Santa Fe Corporation (BNSF) and Union Pacific Railroad (UP) form the backbone of the railroads in Western United States, and are the State's only Class I Railroads. The state also has one regional railroad (California Northern) and 15 local railroads. In 1995, they handled over 4,000,000 carloads, placing the state 8th in annual rail traffic.

Headquartered in Fort Worth, Texas, Burlington Northern Santa Fe Corporation (BNSF), through its subsidiary The Burlington Northern and Santa Fe Railway Company, operates one of the largest railroad networks in North America, with 34,000 route miles covering 28 states and two Canadian provinces. BNSF was created on September 22, 1995, from the merger of Burlington Northern Inc. (parent company of Burlington Northern Railroad) and Santa Fe Pacific Corporation (parent company of the Atchison, Topeka and Santa Fe Railway). The company employs more than 43,000 people, and owns 4,400 locomotives and 90,000 freight cars. BNSF was the first railroad to commit to alternating current (AC) traction locomotive technology in North American rail operations.

Union Pacific Railroad (UP), headquartered in Omaha, is an operating subsidiary of Union Pacific Corporation. The UP operations cover 23 states. UP took over Southern Pacific Railroad in 1996, and now it boasts 36,026 miles of track in the US while employing 53,000 people and owning 6,250 locomotives and 146,000 freight cars. Union Pacific's largest single customer is APL Land Transport Services, a steamship company that operates in the Pacific. Second is General Motors, followed by an assortment of chemical companies and utilities. The railroad is the nation's largest hauler of chemicals, much of which originates along the Gulf Coast near Houston, Texas. Union Pacific is also one of the largest intermodal carriers- that is the transport of truck trailers and marine containers.

Revenues for both of these companies are generated primarily from the transportation of coal, grain, intermodal containers and trailers, chemicals, metals and minerals, forest products, automobiles and consumer goods. Major intermodal terminals are located in Bakersfield, Barstow, Fresno, Modesto, Hobart and Richmond (BNSF) and Long Beach, Los Angeles, Roseville, Lathrop, and Oakland (UP).

Information Collected and Monitored

Both BNSF and UP employ *dispatchers* who are responsible for controlling and monitoring trains in pre-assigned sectors. The dispatcher is located at the central control

center (Fort Worth and Omaha respectively for BNSF and UP) with complete control over signals, crossovers and switches in their region. The dispatchers receive the position information of a train through signals sent by *control points,* which are strategically situated along the route at a spacing ranging from 0.5 to 15 miles. Exact location of a train cannot be obtained by this method, but trains can generally be tracked fairly accurately *within* a particular area defined by the separation between two control points. Signal transmission is done through a combination of open-wire pole lines, microwave radio and fiber optic network (laid down along the tracks). This information is utilized to coordinate *blocking signals*, which help keep trains at a safe braking distance from one another. The dispatcher is responsible for scheduling and tracking trains either themselves (Centralized Traffic Control) or through Track Warrant Control where in the train engineer is given a verbal warrant by the dispatcher to pass through a particular area. Once the area is passed, the warrant needs to be re-issued. Communication between the dispatcher and engineer is through traditional radio.

Automatic Equipment Inventory (AEI) readers are used extensively by both the railroads to track the locomotives and freight cars. These readers are simple transponders that read the tag on the passing locomotive/ freight car and send the read information to the central control, where it is archived in the mainframe system. This information is disseminated to the public through several channels. For example, BNSF offers several options:

- Using the World Wide Web, shippers can truck up to 150 shipments on-line.
- NetREDI, the Internet Electronic Commerce tool for railroad customers allows tracing of rail shipments on more than 300 rail carriers in North America from a central internet site.
- With necessary communications software and modem, customers can access the BNSF equipment location database any time through a direct, toll-free dial-in access. This can also be achieved using a third party communications provider.
- Toll-free number provides an automated Phone Trace of the shipment.
- The Customer Reporting System (CRS) offers BNSF customers real-time shipment status information in a proprietary, easy-to-read format. Reports are scheduled to run at predetermined times and are delivered via the customer's preferred method. Available delivery options include:

  - Internet E-mail
  - Fax
  - World Wide Web (View Reports previously generated via the Internet)
  - BNSF Integrator Software (special reports option)
  - Lynx Software
  - Electronic Delivery methods support comma delimited reports. If this format is chosen the information can be imported directly into a spreadsheet sheet or database package (Lotus 1-2-3, Approach, Excel, etc.)

Sample report layouts follow:

1. Carload Reports:

Custom Report	*Carloads moving into and/or out of a location for a shipper or consignee, 2 line output*
Custom Lite Report	*Carloads moving into and/or out of a location for a shipper or consignee, single line output.*
Shipper's Report	*All cars being shipped from a location*
Consignee's Report	*All cars coming into a location*
Automotive I	*Carloads moving into and/or out of a location for a shipper or consignee*
Interchange Delivered	*All cars delivered to another carrier at a junction point*
Interchange Received	*All cars received from another carrier at a junction point*
Interchange Haulage	*All cars in transit to a specific junction point*
Scale Weight Report	*Weigh detail for cars moving into and/or out of a location*
Bad Order Report	*List cars in bad order status*

2. Intermodal Reports:

Intermodal I & II Reports	*Intermodal equipment entering or leaving a location*
International Report	*Intermodal equipment including vessel and booking information*
Destination Release	*Shows all intermodal events for a destination release customer*

3. Other Reports:

Unit Train Report	*Summary of unit trains for a customer*
Track Inventory Report	*All cars at a given station and track number*
Private Fleet Report	*All cars within the specified pool id*

A majority of rail tracks in the state of California are owned by either UP or BNSF. Passenger train companies, such as AMTRAK, use their tracks. Signal and crossover controls along the shared tracks remain in the hands of the agency owning the tracks. This sharing necessitates co-ordination between the dispatchers of these companies to share track-occupancy information for efficient and non-conflicting schedules. Freight train schedules can vary on seasonal or demand bases. However, passenger train schedules remain fixed for relatively long periods of time (up to six months). These varying requirements have given rise to a simple "passage priority", simplifying the dispatcher communication needs. This priority, from highest to lowest is:

1. Passenger trains (frequent and regular)
2. Intermodal freight trains
3. Merchandise freight trains

4. Coal and grain trains (infrequent and on demand bases)

Signal actuation and coordination at grade crossings is achieved automatically through motion sensors that detect the passage of a train several hundred meters before and after the crossing. If needed, the dispatcher can also control these crossings. Grade crossings near big stations are more likely to create congestion as freight cars may be driven back and forth or travel at slow speeds. Two specific actions are taken by the rail companies to mitigate this problem. Major rail yards with multiple tracks are located away from city streets, reducing the probability of interaction with surface transport. Secondly, the control of signals and grade crossings near rail yards is handed over from the central dispatcher to the local station controller, resulting in a tighter control at these bottlenecks.

As another safety feature, passenger trains operating in excess of 79 mph are mandated by Federal law to be equipped with a system known as Automatic Train Stop (ATS). Each train carries an inductive sensor that can detect the signal from a coil located at each signal. The ATS system on the locomotive alerts the engineer if the train passes a signal that does not show a clear indication. If the engineer does not respond by starting to decrease speed within a few seconds, the ATS system automatically stops the train with a full normal brake application. The engineer cannot cancel this and must wait until the train comes to a complete stop before restoring normal control functions.

In addition, the locomotives also have a speed sensor that limits the train's speed. This is typically set at 90MPH. If the sensor is tripped, the train makes a complete stop with a full normal brake application. Not only does this sensor help prevent speeding, it also protects the locomotive's electric motors from spinning too fast and disintegrating.

Relevance of Information to Other Organizations

In isolated locations, travelers may desire to know train schedules at grade crossings, so as to avoid lengthy traffic delays. This could also be useful in setting traffic signals, to clear out queues in advance of the train's arrival. Unfortunately, railroad information is currently not precise enough to make exact predictions.

Mechanisms for controlling interfaces between passenger and freight trains, and between road traffic and rail traffic at grade crossings are well established.

Taxi Companies

Taxi companies are privately operated but regulated in California. Most cities issue a limited number of licenses, restricting the total number of taxis. Many operate as cooperatives, in which drivers act somewhat like independent businesses.

Information Collected and Monitored

The taxi companies, depending on their size and needs, employ two methods for tracking and communicating with their fleet. Regardless of the method, each taxi company starts by identifying a target market (i.e. the area or city that they are going to operate in). The next step is to create *stands*, which are strategic places in a particular area (e.g. a hotel), with whom the taxi companies are registered. The stands form the nodes of their network.

Large companies use computerized dispatching (Table 1). Taxi drivers have consoles in their cabs, in which they punch in their current address/location after each call is completed. This information is transmitted by radio system to the centralized dispatch center, where it goes directly into the computer. When a customer calls up a specific taxi company, the operator asks for the caller's phone number, which is entered in the computer. The address recognition software identifies the caller's address (it can be manually entered if not found) and also checks the driver availability and queue (there could be more than one driver at a stand) in the caller's area. After identifying the driver, the exact destination address is transmitted through radio and is seen by the driver on his console. Radio contact with individual drivers can be established if needed

Smaller companies use manual dispatching. The drivers radio in their status to the area dispatcher, who maintains the inventory at stands. Once a caller's address has been identified, the dispatcher sends a general message to the taxis in that area. This message is picked up, and the available driver responds by sending his identification number through the radio.

Bigger companies are planning to make a transition to GPS systems in the near future. One of the biggest advantages of such a system lies in the ability to archive the caller data (which is rarely done through present systems) for off-line analysis and to create a caller profile. Interestingly, it would also help alleviate a major problem: taxi drivers who lie about their present position. Drivers often misrepresent their locations to secure more customers.

Relevance of Information to Other Organizations

Taxis could conceivably act as probes to measure traffic delays. Though most taxi companies do not track taxi locations, this may well occur in the future. In addition, all taxis are equipped with communication devices, providing a capability for reporting incidents. Overall, this type of probe information could be useful to information consolidators and to the public.

As with all types of fleets, taxis would benefit from receiving information on current traffic conditions. Due to their mobile nature, this would best come through information

consolidators or changeable message signs. Information on delays at airports would also be useful, which might be passed through the dispatcher.

Traffic Agencies

Traffic control systems generally fall under either of two jurisdictions: (1) highways and freeways, under the jurisdiction of Caltrans, and (2) arterials, under the jurisdiction of

Table 1. Taxi Dispatching Software

Access Transit (Division of) Community Transportation Systems 226 Hood St. La Crosse, Wi 54601 (800) 554-9363 (608) 784-7233 fax Manufacturer of Tripsoft, a multimodule, Windows based software system for transit & paratransit operations	Aleph Computer Systems Inc. 1700 Shattuck Ave., #1 Berkeley, CA 94709 (510) 843-4443 (510) 841-6757 fax Customized computer software for transportation fleets
PC Dispatch Multisystems, Inc. 10 Fawcett St. Cambridge, MA 02138-1110 (617) 864-5810 (617) 864-3521 fax kdossin@multisystems.com	Cantech international Inc. 2140 Winston park Dr. Suite 202 Oakville, Ontario, Canada, L6H 5V5 (888) 478-444 (905) 829-0790 fax Taximan-a leading edge computerized dispatch program.
CES Wireless Technologies Corp. 925 S. Semoran Blvd. Winter Park, Fl 32792 (407) 679-9440 (407) 679-8110 fax plohan@cesusa.com Mobile terminals,GPS, dispatching software, and related signaling products.	Digital Dispatch Systems Inc. 11920 Forge Place, Richmond, British Columbia Canada, V7A4V9 (604) 241-1441 (604) 241-1440 fax Computer dispatch systems
Dr. Dispatch Systems PO Box 5306 Evansville, In 47716-5306 (812) 477-3090 (812) 477-3129 fax Low cost demand response dispatch systems for taxi, limo, paratransit service operators.	GMSI, Inc. 10999 Metcalf Overland Park, KS 66210 (913) 451-3003 (913) 338-0997 fax Automated dispatch systems
InStep Mobile Communications 2055 Boundary Road Vancouver, British Columbia, Canada V5M 3Z1 (604) 320-2100 or (800) 900-7116 (604) 320-2101 fax info@instepmobile.com Computerized dispatch	King Communications, USA Inc 5401 Alhambra Dr. Suite B Orlando, Fl 32808 (407) 293-1432 (407) 293-2907 fax KDT-5000 Mobile Data System FLEX taxi dispatch software with GPS/AVL and biking package
Mobile Computer Systems, Inc. 333 Jenkintown Commons, 93 Old York Rd. Jenkintown, PA 19046 (800) 338-6066 (215) 886-0430 fax Transportation software Shared-ride scheduling and Dispatching software.	MobileSoft Consulting Inc. 7592 Coventry Woods Dr.N. Dublin, Ohio 43017 (614) 717-0107 (614) 717-0106 fax jwelch@mbsoft.com Computer aided dispatch software management software
Orissa Inc. 12 W. 31st St. New York, NY 10001 (212) 279-6060 (212) 268-1008 fax Computer reservations and dispatching software	PC Dispatch Inc. 2160 Anchor Ave. Deland, Fl 32720 (904) 734-7775 (904) 736-1890 fax Fully integrated transportation software

cities and counties. Caltrans operates under a district structure, with each of its 12 districts responsible for the highways and freeways within its own area. All of the major urbanized districts have some type of transportation management center in place, with upgrades planned in various locations.

Arterial traffic systems usually fall under the public works department of cities, and occasionally counties. 44 California cities had population over 100,000 in 1990, each of which has considerable discretion over the types of traffic systems implemented. Even smaller cities have begun implementing advanced signal control systems. As a consequence, arterial control is fragmented at the regional level.

For this project, a questionnaire was mailed to the Deputy Director of Operations (or equivalent) in all Caltrans districts to obtain information on systems currently in place, and plans for the future. The questionnaire was also mailed to cities known to currently have centralized signal control systems (Anaheim, Irvine, Los Angeles, Sacramento, San Diego, San Jose, Santa Ana). Questionnaires were mailed in the fall of 1997, and follow-up calls were made up until winter of 1998 to increase response rates. Caltrans districts were classified as rural (1, 2, 5, 9 and 10) or urban (3, 4, 6, 7, 8, 11 and 12). Responses are tabulated in Tables 2-3.

Caltrans operates transportation management centers in all of the state's urbanized regions. In the Los Angeles region, all three of its Caltrans districts operate centers. The centers generally serve as the focal point for controlling ramp meters and changeable message signs, and for receiving surveillance information from loop detectors and closed circuit television (CCTV) cameras. They frequently provide co-location with the California Highway Patrol for information dissemination on incidents and for managing incidents. Caltrans also dispatches crews from some transportation management centers and from maintenance yards.

City transportation management centers tend to be smaller than Caltrans centers, with a narrow focus on controlling traffic signals. In some cases, this is completely automated, with only occasional human monitoring or intervention (typically for special events). An exception is Los Angeles, which has the largest system in the state and, perhaps, the country. Los Angeles has installed changeable message signs and closed circuit television within the "Smart Corridor" (paralleling the Santa Monica Freeway) to provide a more extensive traffic control capability, and has pre-set signal plans to absorb additional traffic in the invent of highway incidents.

Through the surveys, it is evident that California's TMCs focus on their modal responsibility, either city streets or highways. As shown in Tables 4 and 5, highest priorities in both the short term (5 years) and long-term (20 years) is in traveler information on traffic and route diversion, and in incident management and signal control.

Ramp metering, emergency vehicle management and real-time transit information also rate high among urban Caltrans Districts. Most other services rate relatively low in priority.

Table 2. Surveillance and Communication Capabilities of TMCs

	Loop Detectors – Locations	Miles	Avg Spacing	Dual	On Ramp	Off Ramp	Call Boxes – Number	Spacing	CCTV	Passive IR	Active IR	Pass Mag	Acoustic	Doppler MW	Radar	Ultrasonic	Wthr Snsrs	WIM	ATC	Phone	Cellular	MW	Satellite	Fiber Opt	Twisted Pair
CITIES																									
Anaheim	40	40	1				0	0	18	0	0	0	0	0	0	0	0	0	0					P	P
Irvine	220	-	0.25	M			0	0	30	0	0	1	0	0	0	0	0	0	0	s				P	P
Los Angeles	12000	200+	0.25	S		N	0	0	145	0	0	0	0	0	0	0	0	0	0			s		P	P
Sacramento	550			N	N	N			12[1]	0	0	0	0	0	0	0	0	0	0						
San Diego	0	0	0	N	N	N	0	0	3[1]	0	0	0	0	0	0	0	0	0	0	P		P		P	
San Jose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	s					P
San Francisco																									
Santa Ana	550	65	0.55	A	N	N	0	0	19	0	0	0	0	1	0	0	0	0	0	s					P
CALTRANS																									
District 1	0	0	0	0	0	0	65[1]	8.5	0	0	0	0	0	0	0	0	Y	1	0	s	P				
District 2	248	1600	NA	S	S	S	0	0	3	0	0	1	0	0	X[1]	0	Y	5	0	P	s				
District 3	98	54	0.5	S	S	S	>1200	0.5	20	0	0	0	0	0	0	0	Y	0	0	P	P				
District 4																									
District 5	0	0	0	N	N	N	300	1	0	0	0	0	0	0	0	0			0						
District 6	30	40	0.5		17	0	0	0	10	0	0	0	0	0	0	0	10	0	0	s		s			
District 7							4474	5-700																	
District 8	141	69	1	M	S	S	2777	0.25	69	0	0	0	0	0	0	0	Y	10	0	s	s	s	s	s	s
District 9	265	NA	NA	S	N	S	0	0	0	0	0	Y	0	0	0	0	Y	1	0	P	s			P	

COMMUNICATION — Primary: P Secondary: s

Table 3. Services Provided by TMCs

	TRAVELLER INFO – HAR / CMS / ISPs		CMS No	CMS STATUS	ISP STATUS	ISPs	TATS	TRAFFIC – SIGNALS	MET. RAMPS No	CONNECTED	FIXED	ADAPTIVE	VIOL. TOLL	SIGNAL	RAIL	CROSS	OTHER	EVENTS – EVACUATION	SPEC EVENTS	HAZMAT	INTERMODAL – TRANSIT	COMM FLTS	ETCs	RIDESHARE	TRAFFIC
	COVERAGE	SITES																							
CITIES																									
Anaheim	70	2	8	O		0	O	209	0	0	0	0	0	0	0	0	0	Y	Y		Y	N	Y	N	Y
Irvine	0	0	5	O		0		220	0	0	0	0	0	0	0	0	0	N	Y	N	N	N	N	N	N
Los Angeles	–	–	8	O		0	O	2100	0	0	0	0	0	0	0	0	0	Y	Y	Y	Y	N	N	N	Y
Sacramento	0	0	0	O		0		250[1]	0	0	0	0	0	30	0	0	0	N	N	N	N	N	N	N	N
San Diego	1	1	2	O		0		400[4]	0	0	0	0	0	0	0	0	0	Y	Y	Y	N	N	Y	Y	N
San Jose	25	1	9	O	O	0		507	0	0	0	0	0	0	0	0	1[3]	N	Y	N	N	N	N	N	N
San Francisco				O	O		T																		
Santa Ana	33	1	13	O	O	0	T	245	0	0	0	0	0	0	0	0	0	N	N	N	N	N	N	N	N
CALTRANS																									
District 1	1%	3[6]	14[5]	O		0	O	42	0	0	0	0	0	0	0	0	0	N	Y	Y	N	N	N	N	N
District 2	Low	8[8]	14[2]	O	O	0	O	53	0	0	0	0	0	0	0	0	0	N	Y	Y	N	N	N	N	N
District 3	N/A	16	11	O	O	0	O	0	47	47	X	X	0	0	0	0	0	N	Y	Y	N	N	N	N	Y
District 4				O	O																				
District 5	–	3	0	O		0	O	0	0	0	0	0	0	0	0	0	0	Y	Y	Y	N	N	N	N	N
District 6	–	11	46	O		0		0	17	17	17	0	0	0	0	0	0	N	N	N	N	N	N	N	N
District 7				O	O	10	O														Y	N	N	N	Y
District 8	–	4	26	O		2	O	0	120	0	X	X	0	0	0	0	0	Y	Y	N	N	N	N	N	N
District 9	1%	2	6[1]	O		0	O	0	0	0	0	0	0	0	0	0	0	Y	Y	N	N	N	N	N	N
District 10	1%	6	45[7]	O		0		0	0	0	0	0	0	0	0	0	0	N	Y	Y	N	N	N	N	N
District 11	50%	4	34	O	O	2	O	250	163	163	X	X	1	0	0	0	0	N	Y	Y	N	N	N	N	N
District 12	50%	1	40	O	O	1	O	–	ALL	–	X	X	2	0	0	0	0	N	Y	N	N	N	N	N	N

1: One is in operation and 5 sites are under construction
2: 8 Permenant, 6 Temporary
3: Speeding violations
4: Planned increase to 609
5: 1 Fixed, 9 Portable and 4 to be fixed by 6/98
6: 2 Fixed, 1 portable
7: 19 Permenant / 26 Portable
8: 6 Fixed, 2 Portable
TATS: O: Operational, T: Under deployment testing

Table 4. ITS User Services: 5 Year Priority of Agencies

PRIORITY 5 Year	Traveller Information					Traffic Management					Comm Veh Ops				Public Transit				Travel Safety								
	Rt Guidance	Traffic	Trav Serv	Rt Diversion	In Veh Sign	Inc Mgmt	Emer Veh Mgmt	Ramp Meter	Etc	Signal Ctrl	Pre Clearance	Admin	Fleet Mgmt	Wim	Ride Match	Real Time Info	Bus Control	Transit Sch	Pub Security	Safety Insp	Safety Monitor	Theft	Lat Avoid	Long Avoid	Inter Avoid	Pre Crash	Avo
Cities																											
HIGH	2	6	2	6	1	3	1	0	0	5	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
MED	2	0	1	0	1	2	2	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
LOW	3	1	4	1	3	2	3	3	3	1	4	4	4	4	3	3	3	3	4	3	3	3	3	3	3	4	4
NO ANS	0	0	0	0	2	0	1	4	4	0	2	2	3	3	4	3	4	3	2	4	4	4	4	4	3	3	3
CT Urban																											
HIGH	2	4	1	2	0	4	3	4	0	4	1	1	1	2	1	3	2	1	2	0	0	0	0	0	0	0	0
MED	1	0	2	2	1	0	0	0	1	0	1	0	0	1	1	1	1	2	2	1	0	0	0	0	0	0	1
LOW	1	0	0	0	2	0	1	0	2	0	1	2	2	1	1	0	0	0	0	2	3	3	2	2	2	2	1
NO ANS	1	1	2	1	2	1	1	1	2	1	2	2	2	1	2	1	2	2	1	2	2	2	3	3	3	3	3
CT Rural																											
HIGH	0	3	0	2	0	3	1	0	0	1	2	0	0	0	0	1	1	1	1	0	0	0	0	1	2	1	0
MED	2	1	1	2	0	2	1	2	1	4	0	0	0	4	1	0	0	0	1	1	2	1	2	1	1	1	0
LOW	2	1	4	1	5	0	3	3	4	0	2	4	5	1	3	3	3	4	3	4	3	4	3	3	2	3	5
NO ANS	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
AVG	1.9	2.7	1.7	2.5	1.3	2.5	1.9	1.8	1.2	2.6	1.8	1.3	1.2	1.7	1.4	1.8	1.7	1.6	1.8	1.2	1.2	1.1	1.2	1.3	1.6	1.3	1.1

Table 5. ITS User Services: 20 Year Priority of Agencies

PRIORITY 20 year	Traveller Information					Traffic Management					Comm Veh Ops				Public Transit				Travel Safety								
	Rt Guidance	Trafic	Trav Serv	Rt Diversion	In Veh Sign	Inc Mgt	Emer Veh Mgmt	Ramp Meter	ETC	Signal Ctrl	Preclearance	Admin	Fleet Mgmt	WIM	Ride Match	Real Time Info	Bus Control	Transit Sch	Pub Security	Safety Insp	Safety Monitor	Theft	Lat Avoid	Long Avoid	Inter Avoid	Pre Crash	AVO
Cities																											
MED	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LOW	3	0	3	0	3	2	3	3	3	2	5	5	5	5	4	4	4	4	5	4	4	4	4	4	4	4	3
NO ANS	2	2	2	2	1	1	1	3	4	1	1	1	2	2	3	2	3	2	1	3	3	3	3	3	2	3	3
CT Urban																											
HIGH	2	4	2	3	1	3	3	4	1	4	1	0	1	0	1	3	2	2	2	0	0	0	0	0	0	0	0
MED	2	0	1	1	1	1	1	0	1	0	1	1	0	2	2	1	1	1	2	2	1	1	0	0	0	0	0
LOW	0	0	0	0	1	0	0	0	1	0	1	2	2	1	0	0	0	0	0	1	2	2	2	2	2	2	2
NO ANS	1	1	2	1	2	1	1	1	2	1	2	2	2	2	2	1	2	2	1	2	2	2	3	3	3	3	3
CT Rural																											
HIGH	1	3	0	3	0	4	2	2	1	5	2	1	1	2	1	1	1	1	2	0	1	0	2	2	2	1	1
MED	1	2	3	2	1	1	1	2	0	0	0	0	1	2	1	0	0	0	0	1	1	1	0	0	1	1	1
LOW	2	0	2	0	4	0	2	1	4	0	2	3	3	1	2	3	3	4	3	4	3	4	3	3	2	3	4
NO ANS	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
AVG	1.8	2.7	1.8	2.6	1.4	2.4	2.0	2.2	1.5	2.6	1.6	1.3	1.4	1.6	1.6	1.8	1.6	1.6	1.7	1.3	1.3	1.2	1.4	1.4	1.5	1.3	1.4

Strategic Objectives Most cities' strategic objectives are to consolidate TMC operations and improve city traffic flow. Sacramento is planning a TMC to cover downtown and other areas, and curbing red-light running. San Diego is planning ATIS for major destinations including the border and zoo as well as interconnecting all the major traffic signals and controlling them centrally. San Jose will coordinate signal timing across jurisdictional boundaries and deploy video vehicle detection to replace loops and deploy GPS on city probe vehicles. Anaheim will implement adaptive signal control algorithms and a new central signal system. Santa Ana will upgrade its traffic signal control system and improve coordination with Caltrans District 12 by expanding the inter-tie. Los Angeles will implement all signals under ATSAC control and add an adaptive traffic control system. It also seeks to improve communication with neighboring cities. Irvine will upgrade its existing traffic control systems in the next five years. At least three cities, including Irvine and Los Angeles have demonstrated interest in applying new technologies.

The urban Caltrans districts place traveler information as an important objective. Other priorities are incident management (District 7) , intermodal TMC and CCTVs (Districts 11 and 8), partnering with local governments for ITS and data exchange (District 3). The rural districts had similar objectives; including traveler information, incorporation of ITS, development of TMCs, installation of CCTVs, increased loop detectors and CMSs (District 10), improved communication, fleet management and improved operation (District 1).

The cities interviewed had the following programs to achieve their objectives: Sacramento had the downtown TOC under construction, San Diego has federal ITS grants and TSM state grants. San Jose has implemented the Silicon Valley smart corridor. Anaheim has commissioned an analysis and a decision support system in addition to CCTVs to provide better traveler information. Los Angeles is working on research and development and Irvine is developing traffic systems.

Among the Urban Caltrans districts, District 11 has begun infrastructure programming via the state transportation improvement program. The rural Caltrans districts have prepared initial reports and implemented a rural ITS program (District 2), participated in rural ITS demonstration, installed CMS and HAR (District 1) and preparation of-range master plan and TMC master plan (District 10).

Needed Surveillance/Information Collection Capabilities The cities require camera installations (Sacramento, San Jose, Anaheim), system integration (Irvine), system detectors (Anaheim and Santa Ana), fiber optic network and CMS for San Jose, new controllers for Anaheim and implementation of all signals under ATSAC control for Los Angeles. The Urban Caltrans districts require CCTVs and fiber optics (Districts 11 and 8), communication systems and TCP/IP for District 3. The rural districts require traveler

information kiosks, CMS and HAR (District 2), real-time maintenance fleet and equipment tracking (District 1) and CCTV and weather sensors for district 9.

Needed Control Sacramento requires staffing and monitoring of its TOC. Anaheim requires adaptive signal timing, adaptive event management and better user interface for its traffic system. Santa Ana requires real-time control from its TMC based on surveillance or system detectors. Irvine requires traffic signal control. Urban Caltrans districts require an interface with regional signal system (District 11).   Among rural districts, District 2 would like more interconnected systems. District 9 requires better cellular coverage and District 10 requires a fast link for signals and ramp meters.

Needed Information Dissemination These include kiosks (Santa Ana and Anaheim), cable and CCTV for Los Angeles and Anaheim, HAR at Anaheim, CMS at Los Angeles, new technologies like ATM for TMCs (Santa Ana and Irvine), cross communication with county and state and regional transit at Sacramento. Urban Caltrans Districts had no responses, and among rural Caltrans Districts, District 2 would like to link traveler information to the Internet in real time and have traveler information kiosks. Districts 1 and 9 require additional CMS and HAR.

Needed Communication Sacramento and Irvine will install fiber optic lines throughout the cities. Anaheim will strive for better maintenance of equipment and more work on communication expansion. San Jose and Irvine will develop a wide-area-network. Los Angeles requires fast and reliable communication capability. In urban Caltrans districts, District 11 requires fiber optics on the entire urban freeway system, complete communication links to all arterial traffic signals, and showcase communication link to local agencies. In rural districts, District 2 requires rapid controller interconnect capabilities, District 1 improved cellular coverage and District 10 fiber optic links.

Needed TMC Capabilities Anaheim requires more money for operations, training and better user interfaces. Santa Ana would like to integrate ATMS with GIS and GPS. Irvine would like surveillance systems. District 11 requires completed ATMS, quicknet upgrade and complete TMC video display system. District 2 requires a full-time TMC instead of its current part-time TMC. District 9 needs to develop a TMC. District 10 requires operating systems, additional space and video systems.

Needed Managerial Information Capabilities Sacramento requires planning with other agencies for emergencies and special events. San Jose requires operational procedures accepted by all agencies. Anaheim requires incident detection, hotel and event center schedules and vehicle tracking ability for probe use. Irvine would like to focus on system security in terms of the firewall application. No Caltrans district responded to this question.

Relevance of Information to Other Organizations

Caltrans collects useful real-time information on freeway speeds in many locations, which is already made available to the public through web pages and, indirectly, through the media. This information is clearly useful to both individual travelers and fleets. Caltrans also provides information on road closures and construction through the "media CAD", through its web page, and through telephone services. Arterial data usually are not disseminated to the public. This is in part due to the fragmented nature of the systems, and in part because the systems have not been designed for collecting accurate performance measures such as speed or travel time. While it would be desirable to develop this capability in the future, it may be unrealistic to do so any time soon.

Caltrans information is highly relevant to incident agencies. Speed data can be used in dispatching crews, and prioritizing incident removal tasks. In the reverse, information on the status of an incident is highly relevant in creating messages on changeable message signs and in controlling ramp meters.

Information on city and county traffic signal plans could be useful to Caltrans in developing traffic diversion strategies in the event of major incidents. Unfortunately, cities rarely generate speed or travel time data, so they currently have little to provide to the driving public.

Transit Agencies

California has more than 70 transit agencies, most of which are quite small (fewer than five million trips annually). These agencies operate a variety of modes, including subway (BART and LA County MTA), light rail (SF MUNI, Sacramento Regional Transit, LA MTA, San Diego Trolley, Valley Transit), conventional trains (Amtrak, CALTRAIN, Southern California Metrorail, San Diego Coaster), ferries (Golden Gate Transit District), cable car (SF MUNI) and, most significantly, busses (many, the largest being LAMTA and SF MUNI). Despite this diversity, the vast majority of boardings are by bus, two agencies have far more passengers than any other: San Francisco Municipal Railway (215 million per year) and Los Angeles MTA (365 million per year).

Information Collected and Monitored

Technology is being used in some systems to track vehicle locations and communicate with drivers. However, this information is rarely used for real-time schedule control for buses. Rail systems tend to be the most sophisticated, as computers are used to control vehicle speeds and maintain schedules. California's transit systems do not generally provide real-time information on vehicle arrivals and departures, though this may be possible in the future. Most do operate telephone information lines for obtaining schedule information, and many (MTA and the Metropolitan Transportation Commission in the Bay Area) provide schedules on web sites. In the Bay Area, TravInfo

provides a single telephone number, which can relay callers to selected transit systems. The following provides examples of how information technologies are being used.

Amtrak's monitoring and control operations in California are carried out from its satellite station at Oakland. A *dispatcher* is employed for supervising the progress of trains in a particular region. Major controlling activities along the Amtrak train routes are performed either by UP or BNSF, as they own most of the tracks. In order to have a non-conflicting schedule with these agencies, Amtrak undertakes a review of its current schedule once every six months with representatives from both UP and BNSF. Amtrak tracks its trains through a combination of individual station agents (who enter the passage of a train through their station into the computer mainframe system) and strategically located control points. Along longer routes, Amtrak uses GPS transponders. Train engineers, through the traditional radio system, communicate with their dispatchers to keep them informed of the progress.

LAMTA uses two methods to track its buses. Every schedule summary report is divided by bus line and bus run, with a tabulation of actual and scheduled times. This acts as a comparison table for manual tracking of buses. This method is employed for tracking half the present LAMTA fleet. The other half is equipped with a Transit Radio System (TRS). Strategic locations (bus stops) along the routes are equipped with sign post transmitters that have the location information encoded in them. A transponder atop every bus helps in transmitting its real time location information through these transmitters to the dispatcher unit. Odometers on these buses are also constantly in touch with the dispatch center through radio, and send out signals every 1/10 of a mile. By knowing the initial odometer reading and the pre-plotted route of the bus, dispatcher consoles can graphically track the progress of a bus. The TRS readings are used primarily for safety purposes and for obtaining delay trends of different buses (which bus is late, during which time, etc.). As of now, the running time data obtained through TRS is not used for scheduling purposes.

Caltrain uses selective Centralized Traffic Control (CTC) to track trains. There are two traffic centers, one at San Francisco and the other at San Jose. Each center can control train movements within 7-8 miles of itself. There is little or no real-time data collection. Public address systems at individual stations and local radio are used to announce exception information to the general public.

The San Francisco MUNI employs a Motorola radio system, where-in the bus driver punches the *run* number for the bus into a key-pad at strategic points along its route. This number is then radioed to central control, which can compare the time of the number arrival with a previously laid-down timetable. This comparison can reveal the instantaneous position of the bus with a fair amount of accuracy. The information obtained is utilized for off-line analysis of the bus performance.

The operation of BART is simplified because it uses its own tracks and has no at-grade crossings. As a result, BART's on-time performance averaged 96% in 1995. The control is centralized and is done through the Operations Control Center (OCC). The OCC functions as the nerve center of BART's 81-mile system performing supervisory control of train operations and remote control of electrification, ventilation and emergency response systems. The display boards use computer imaging and video projection to display the entire system, combining information from two categories: one for track and train positions and the other for maintenance information and electrification. The schedule information is used for off-line analysis and is also used by other agencies (e.g. MUNI) for schedule synchronization purposes.

AC Transit fleet tracking and control is mostly carried out manually, with the scheduling department maintaining a "performance" file. The "Fleetwatch" system, where the driver enters his code on the dashboard for transmission to the scheduling department, is used sparsely. However, there is little or no real-time information collection and dissemination. The schedule writers modify timetables to reflect connectivity with BART (such centers with direct time-connectivity with BART are called timed transfer centers). Plans are underway to implement a GPS based system for instantaneous tracking and also kiosks to provide up-to-date information to the public.

Relevance of Information to Other Organizations

As with other fleets, bus and trolley systems would benefit from receiving real-time information on traffic delays and travel times, for better schedule control. Unfortunately, because buses operate mostly on city streets and not highways, quality information is not readily available. Buses themselves might act as probes to report incidents on streets, though this would only be effective on short headway lines.   As transit systems implement tracking systems, it may also be important to share delay information between connecting agencies, to provide better connections for transferring passengers.

Some systems have experimented with signal preemption, though this is not common in California. By its nature, signal preemption necessitates a remote link between buses and signal systems, detecting buses as they approach intersections.

Traveler Information

In California, like all of the United States, broadcast radio is the most common method by which travelers receive information on current travel conditions.   But other sources exist, including television, telephone, the worldwide-web and, soon, in-vehicle navigation products.

Information Collected and Monitored

Most radio stations rely on "content providers" for their traffic information. The content industry exhibits strong scale economies, due to the high cost of collecting information. So it is not surprising that it has come to be dominated by just two major players: Metro Networks and Shadow Traffic. Both companies obtain information through public sources (California Highway Patrol and Caltrans), and from a variety of private sources (their own observers in aircraft along with callers). Information is communicated through periodic broadcasts on radio stations, for which the content provider is compensated through selling advertisements. Smart Route Systems is a third competitor that grew out of the Boston SmarTraveler project.   It has yet to establish a base of operation in California.

Radio stations outside of the Bay Area generally do not broadcast information on other modes of transportation, such as transit, rail, or airports, except under unusual circumstances. These major incidents are ordinarily handled as news rather than as ordinary traffic reporting. Within the Bay Area, transit reports are typically limited to BART and Caltrain delays, and other modes are typically excluded.

Automated telephone services are available in Northern California through TravInfo and through TransCal (I-80 corridor), and in Southern California and parts of northern California through "Smart Commute" (1-800-COMMUTE). Smart Commute receives about 200,000 calls per month and TravInfo receives about 60,000 calls per month. Users can navigate through an automated menu, to hear recordings on the latest traffic conditions by road segment, or to be connected to a transit agency or rideshare agency for other information. TravInfo includes periodic updates of voice recorded messages covering the entire Bay Area. Smart Commute includes automatic messages on the Santa Monica Freeway. Statewide, road conditions can be obtained through the Caltrans Highway Information Network (CHIN), whose focus is on major weather related problems, road closures and construction delays.

Traffic conditions can also be obtained through web pages, such as Etak, KPIX, and Maxwell Laboratories, and the Caltrans operated Smart Traveler. Two categories of information are generally available: freeway speeds or incident reports. Speed data always originate at Caltrans. Data are most complete in the Los Angeles and San Diego areas. Incident reports either originate at CHP or from the traffic content providers (Metro or Shadow Traffic). The Etak webpage (which obtains CHP data via TravInfo) provides a graphical interface, with incidents displayed on maps. Icons can be "clicked on" to obtain text descriptions of the incidents. Other incident web pages are text only. The CHP web page provides detailed data on when the incident was first reported and on when response crews arrived at the scene.   All of these web pages are refreshed in frequent intervals. Many airports have created web pages as well, though none in California provide real-time information. Transit web pages have also been created, including one that provides access to schedules for all Bay Area agencies. None provides

advanced features, such as navigation or real-time bus information (such a service is being developed in Seattle).

Within the near future, Clarion will be selling its "AutoPC" product, which offers real-time traffic information in the automobile. This will be the first commercial product of its type in the United States. The product will be able to receive CUE's FM sub-carrier broadcast containing information collected by Metro Networks. The technology for communicating and recording the traffic information was developed as an alliance between Etak and Metro Networks. It is being rolled out on a nationwide basis.

Finally, most air carriers and Amtrak provide telephone information services for estimated arrival and departure times. Callers usually have the option of speaking with an operator, or using a touch-tone based system. Services are not available that span multiple airlines, or cover traffic conditions around airports. However, an individual has created a web-page that extracts data from the FAA to forecast arrival times.

Trucking

Trucking is an extremely diverse industry. Principal segmentations include private versus for-hire carriage, long-haul versus regional, less-than-truckload (or small package) versus truckload, and various commodity segmentations (general freight, tanker, agricultural, etc.). California is home to one of the largest less-than-truckload carriers in the country (Consolidated Freightways), as well as two of the major overnight package companies (DHL and Emery).

Goods movement in California is dominated by trucks to a much greater degree than other states. According to the 1993 Commodity Flow Survey[1], 74% of shipment weight originating in California is transported by truck, compared to just 2.2% by rail (pipeline is the number two mode). Nationwide, the percentages are 66% by truck and 16% by rail (however, rail carries 39% of ton-miles on a nationwide basis.)

Information Collected and Monitored

Most carriers use fairly simple technologies for tracking and communication, such as pagers, conventional two-way radio and ordinary telephones. Cellular phones are used infrequently due to their higher cost and potential for abuse. However, there is something of a trend toward adopting on-board computers for both monitoring and communication purposes. The most prominent product in the market is offered by Qualcomm (of San Diego), with about 200,000 trucks equipped nationwide. Its target market is large long-haul truckload carriers (such as JB Hunt). They provide satellite communication and GPS tracking, as well as base station software to monitor truck locations (the base station

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[1] 1993 Commodity Flow Survey, State Summaries (US Department of Transportation, Bureau of Transportation Statistics) and United States (US Department of Commerce, Bureau of the Census).

software line of business was recently purchased by Sabre Technologies, a subsidiary of American Airlines). All information is fed through a control center near Las Vegas, and then distributed to individual trucking companies. Talks with Qualcomm reflected a possible interest in sharing tracking information with government agencies. Competitors include Highway Master (principally a cellular network) and American Mobile Satellite Corporation (a mixed terrestrial and satellite network).

Major competitors in the regional market are Cummins/Cadec, Meritor's DataTrax (formerly Rockwell), and Xata. These products are mostly targeted at private carriers, especially in the food industry. They provide a capability to communicate load information to drivers, to record delivery information, and to monitor how the truck is performing and how it is driven. The products are often (not always) coupled with GPS based tracking and wireless communication (usually not satellite). A variety of software is offered for reporting and analysis purposes.

In general, it is possible for a trucking company to remotely monitor the state of the vehicle (speed, RPM, engine fault codes, load temperature, etc.), and the vehicle's location in real-time. To some degree, corrective action can be taken remotely. In the future, these products will likely have the ability to advise the driver on how to correct faults, and provide advance prognostics of impending problems.

Many trucks in California also participate in the HELP (Heavy Equipment License Plate) program, administered by Lockheed-Martin IMS. The system enables pre-registered vehicles to bypass the weigh station and avoid delays. Vehicles equipped with transponders communicate with the weigh station as the truck passes over a weigh-in-motion scale. The transponder transmits the truck's registration data to the weigh station, which is coupled with the truck's total weight and axle weight. If the truck is in compliance, a signal is automatically sent to the in-vehicle transponder, which allows the truck to bypass the station. Trucks are billed on a per use basis.

The most prominent government project in trucking at the national level is the CVISN (Commercial Vehicle Information Systems and Networks) project. CVISN is directed at providing standardized interfaces between trucking companies and governmental systems, in the areas of safety information exchange, roadside electronics screening and credentials administration. California is participating as a model deployment state in CVISN.

Relevance of Information to Other Organizations

Traffic congestion, road closure and weather information is highly relevant to trucking. Trucks themselves generate little information of general interest, other than for regulatory purposes. They travel at slower and less consistent speeds than general traffic, so they are not very attractive as probes. They have some potential for reporting incidents, which could be processed through information consolidators.

4. VISION FOR THE FUTURE

California does not currently have a system for coordinating transportation operations of different modes. But it does have a variety of systems serving individual modes. These can be broadly classified as:

Traffic Systems: Systems for coordinating the movement of vehicles along some infrastructure, including traffic control on highways, arterials, railroads and air corridors.

Fleet Systems: Systems for managing the movement of vehicles and controlling their schedules, in trucking, transit and taxi fleets.

Terminal Systems: System for managing the movement of goods or people in and out of a terminal, at airports, ports and rail yards.

Incident Systems: Systems for dispatching crews to respond to incidents and managing the incident clearance process, in police, fire, tow and HAZMAT.

Information Systems: Systems for disseminating information to the public on travel conditions, through private sector information consolidators, such as Metro Networks or Shadow Traffic.

Recommended Approach

We envision that these systems will retain their current organizational and modal identifies in the future. However, systems should be developed to provide interconnections when benefits are significant, examples of which follow:

- Minimize delays at city boundaries, where traffic control systems must be interfaced
- Maximize capacity within a corridor of roadways, especially in the event of incidents
- Reduce the time required to clear incidents and restore capacity, while ensuring safety
- Make quality information available to travelers and fleets to optimize their travel and goods movement decisions

We also envision that the operational functions of transportation management centers will become interconnected with the planning and regulatory functions, so that operational data can be applied to the design of transportation infrastructure and deployment of resources. This would include the Intermodal Transportation Management System operated by Caltrans' Planning Division (Booz, Allen and Hamilton, 1996).

Figure 1 presents our preferred vision of the intermodal transportation operation system (ITOS) of the future, linking the five categories of systems to each other, and to travelers and shippers.   Arrows in this and the following diagrams represent a strong linkage between entities, usually representing a physical interface combined with a need for information transfer and coordination (types of information exchange are summarized in Table 6). Linkages also exist between organizations residing within each box, but are not shown for the sake of simplicity. Traffic systems interact with peer entities, as do incident systems and fleet systems. Interaction occurs to a lesser degree among terminal systems and information consolidators.

Linkages are created when there are critical physical or operational interfaces. Incident systems and traffic systems are naturally connected, as they are jointly responsible for managing the infrastructure. Terminal and fleet systems are also naturally interconnected due to the role of terminals in processing vehicles. And though highways and streets are required for the operation of fleets, we do not show a strong connection between traffic and fleet systems. This is because we envision that mobile fleets will obtain information through consolidators (as they currently do), rather than directly from traffic agencies.

Figure 2 provides more detail in the area of traveler information. A four-layer architecture is presented.   Information collectors are the source of information, retrieved
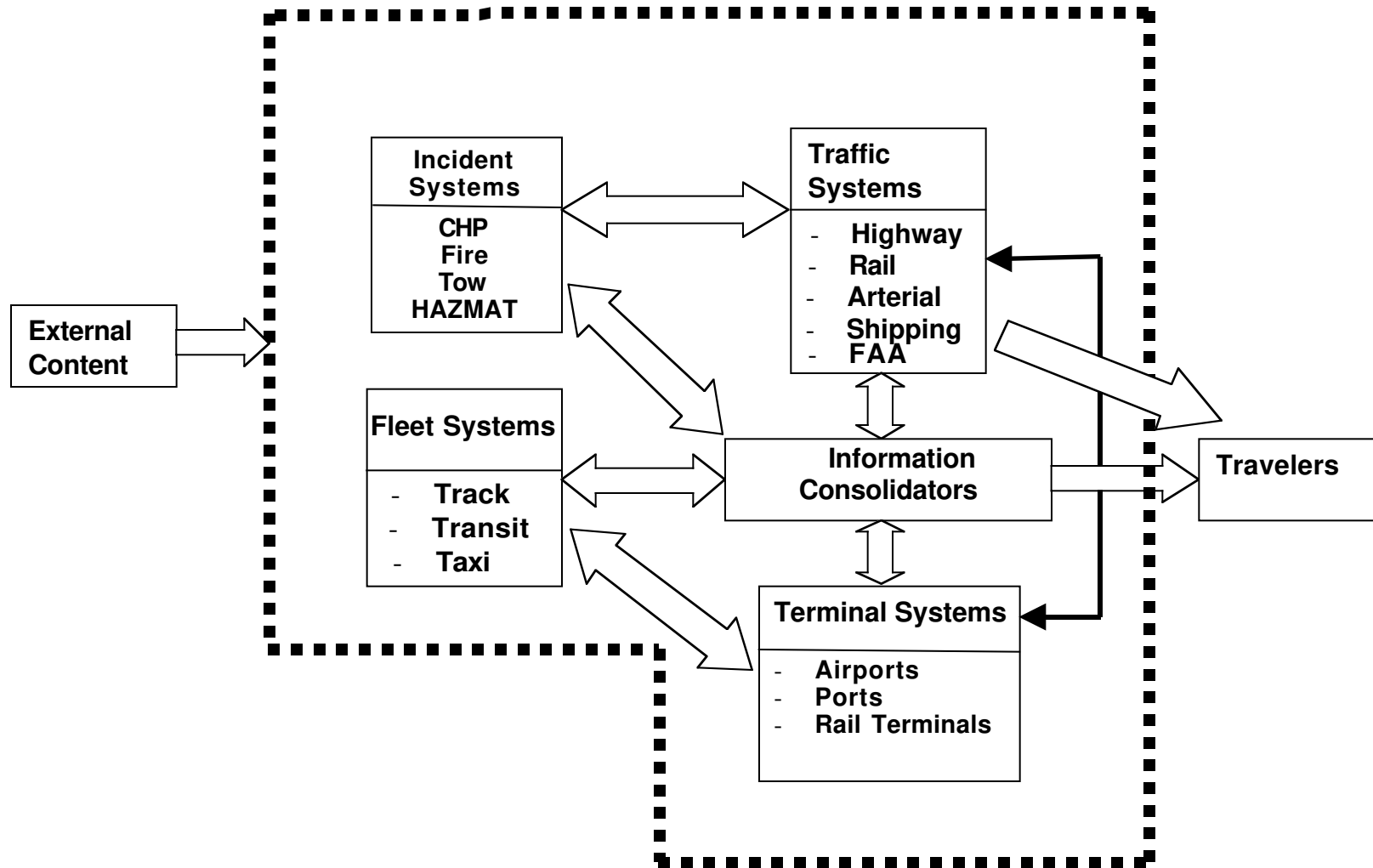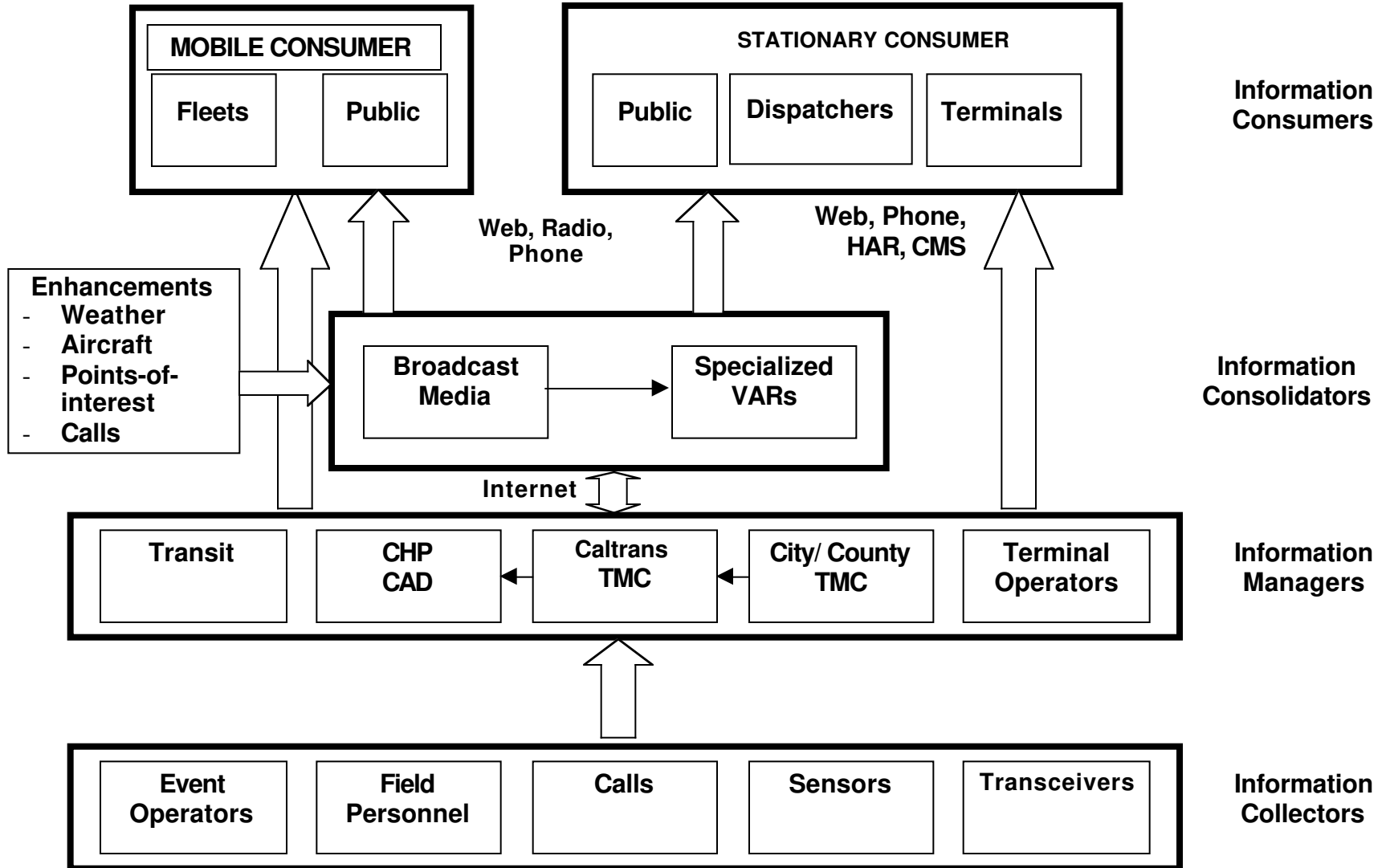
FIGURE 1. INTERMODAL TRANSPORTATION MANAGEMENT SYSTEMS

Table 6. Examples of Information Exchanges Between Systems

From System	To System	Information
Airport	Information Consolidator	Parking status
		Real-time congestion
	Local Traffic	Signal plan
		Real-time congestion
	Taxi	Real-time congestion
		Taxi queue status
Incident Responders	Local Traffic	Locations of responding vehicles
		Incident status
	Information Consolidator	Incident status
	Highway Traffic	Incident status
Port Terminals	Local Traffic	Ship arrivals/departures
	Freight Railroads	Ship arrivals/departures
Freight Railroads	Local Traffic	Train schedules
Taxi	Traffic	Speeds/travel times
Traffic (highway)	Fleet Systems	Speeds/travel times
	Traffic (local)	Speeds/travel times
		Meter plans
	Incident Responders	Speeds/travel times
		Road closures/maintenace
	Information Consolidators	Speeds/travel times
		Road closures/maintenace
Traffic (local)	Traffic (highway)	Signal plans
Transit	Other Transit	Route delays
	Traffic (local)	Vehicle locations
		Incident observations
	Information Consolidators	Route delays

FIGURE 2. TRAVELER INFORMATION FUNCTION

MOBILE CONSUMER
- Fleets
- Public

STATIONARY CONSUMER
- Public
- Dispatchers
- Terminals

Information Consumers

Web, Radio, Phone

Web, Phone, HAR, CMS

Enhancements
- Weather
- Aircraft
- Points-of-interest
- Calls

Broadcast Media → **Specialized VARs**

Information Consolidators

Internet

| Transit | CHP CAD | Caltrans TMC | City/ County TMC | Terminal Operators |

Information Managers

| Event Operators | Field Personnel | Calls | Sensors | Transceivers |

Information Collectors

from electronic sensors and observers. Information managers retrieve and store the information, and process it for their internal use. Information consolidators enhance the information and communicate it individuals and companies that utilize the transportation systems. And information consumers are the end users of the information, including mobile consumers (in their vehicle) and stationary consumers (at home or business). Our vision is that consumers will have some direct access to information from the managers of information (most importantly through message signs, but also advisory radio, web pages and telephone) on a source specific basis. However, the bulk of the needs for road information will be served by information consolidators through broadcast media (ordinary radio and television, plus data broadcasts received through electronic devices and enhanced web pages), as they are today. However, information quality and completeness would be enhanced as consumers acquire portable devices for receiving information broadcasts. These could provide information that is specific to the time of travel and origin/destination.

Figure 3 provides detail in the incident clearance function for highways. California Highway Patrol is the focal point here, and serves as the dispatcher and coordinator of all entities engaged in clearing the incident. CHP, along with Caltrans, is also a source of information on incidents, though not the disseminator to the general public. This would be through information consolidators and the broadcast media.

Figures 4 provides detail in the signal control area. Here, a regionalized architecture is presented, corresponding to Caltrans districts. Arterial systems directly exchange information with neighboring arterial systems as needed to minimize interface delays. They also exchange information with Caltrans to minimize delays surrounding ramps and to manage traffic along corridors. Region to region coordination occurs among Caltrans districts.

Figures 5 and 6 provide detail in fleet and terminal areas (either passenger or freight). These are shown as weakly connected to traffic control systems, largely obtaining traffic information through information consolidators. The focus of the fleet system is on exchanging information between the driver/vehicle, home office and customer. The focus of the terminal system is exchanging information between fleets, customers and the terminal manager.

Lastly, Figure 7 presents a function that is currently not included in California's systems: travel time forecast. This would provide estimates of how long it would take to travel between an origin/destination pair for departures immediately in the future. The forecasting function is envisioned as a Caltrans responsibility, though it might also be created by information consolidators. Forecasts would make incident and congestion data more tangible to travelers, and provide a more meaningful basis for route selection and other travel decisions.

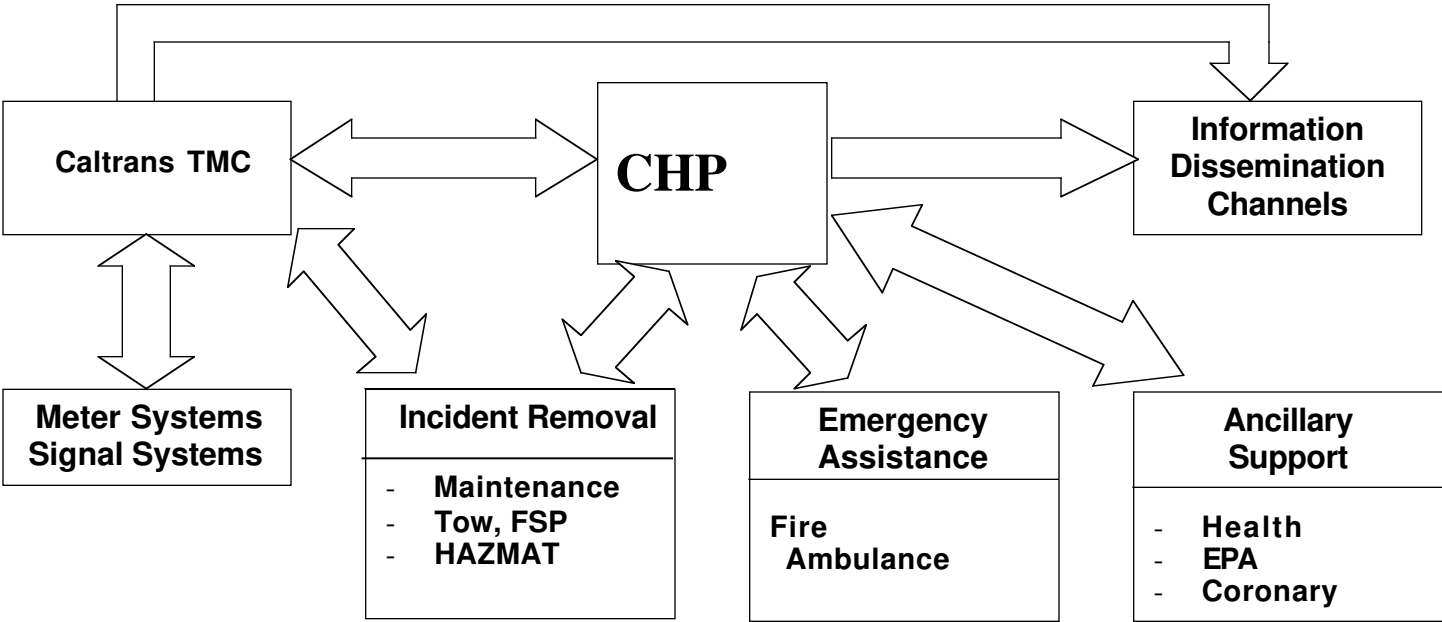# FIGURE 3. INCIDENT CLEARANCE FUNCTION- HIGHWAYS
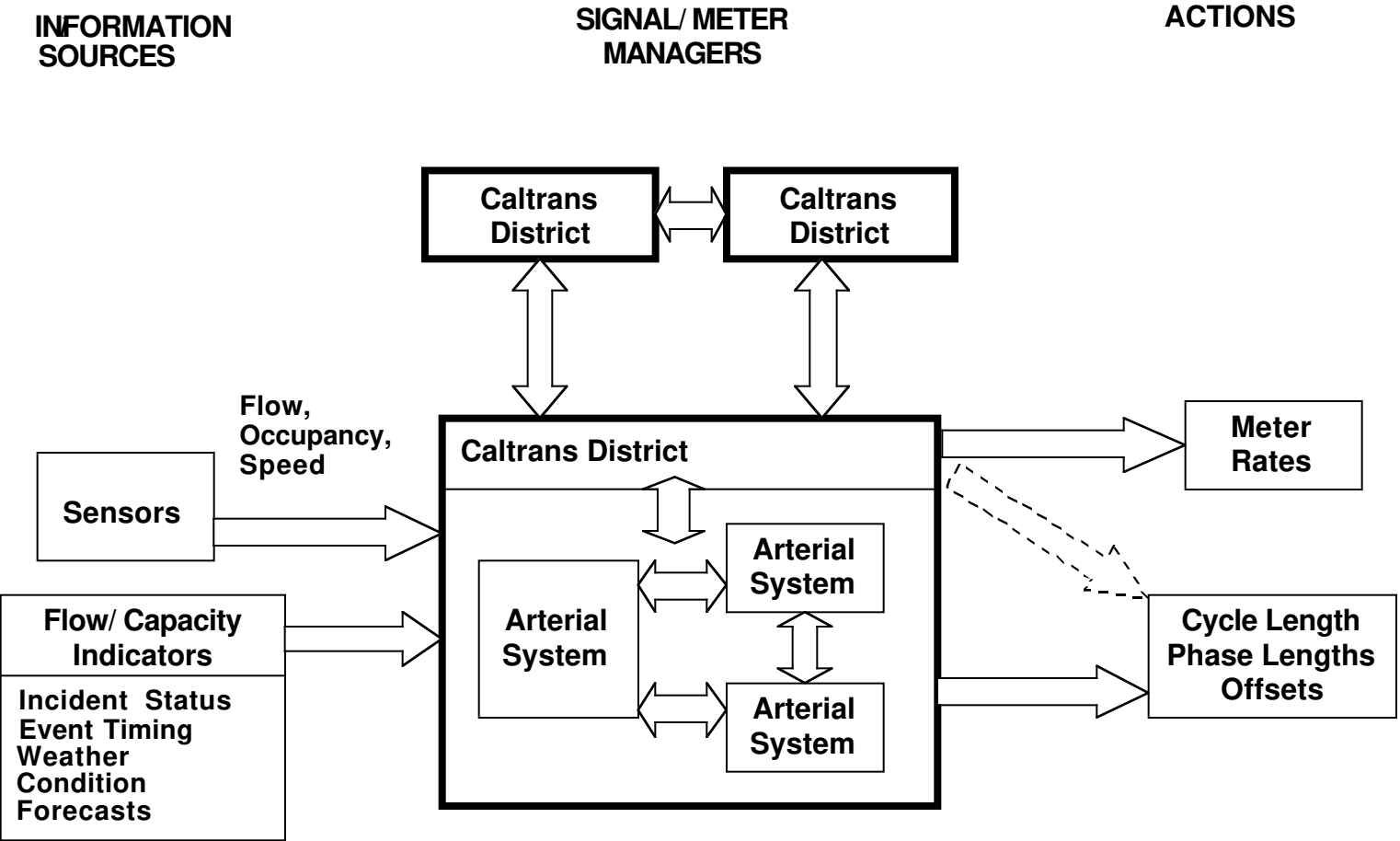
FIGURE 4. SIGNAL CONTROL FUNCTION

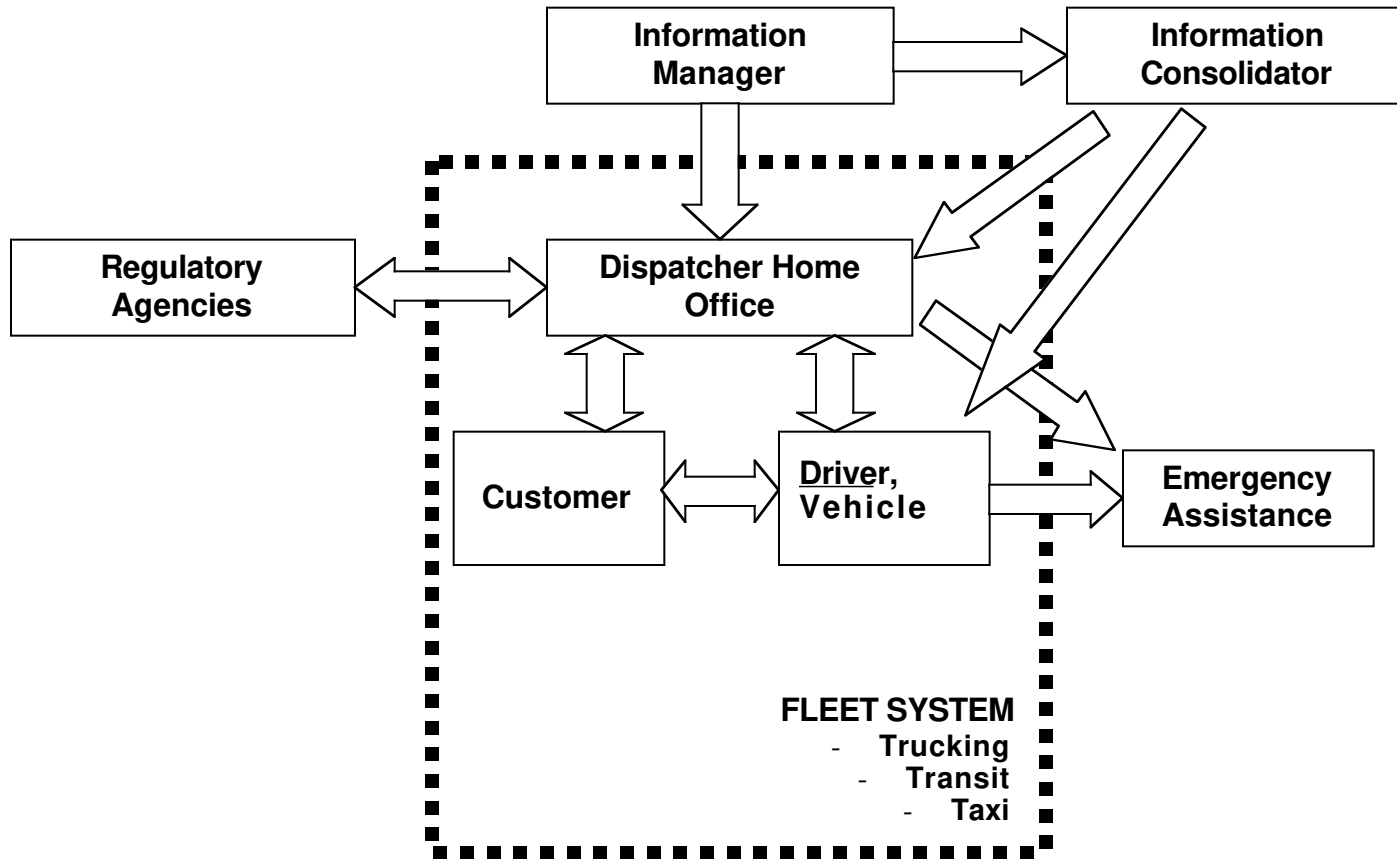| INFORMATION SOURCES	SIGNAL/ METER MANAGERS	ACTIONS

FIGURE 5. FLEET SYSTEM

Information
Manager

Information
Consolidator

Regulatory
Agencies

Dispatcher Home
Office

Customer

Driver,
Vehicle

Emergency
Assistance

FLEET SYSTEM
- Trucking
- Transit
- Taxi

FIGURE 6. TERMINAL SYSTEM

Terminal Area Traffic Control

Terminal Manager

Information Manager

Fleet Systems

Customers

Information Consolidator

TERMINAL SYSTEM
- Airports
- Ports
- Rail Terminals
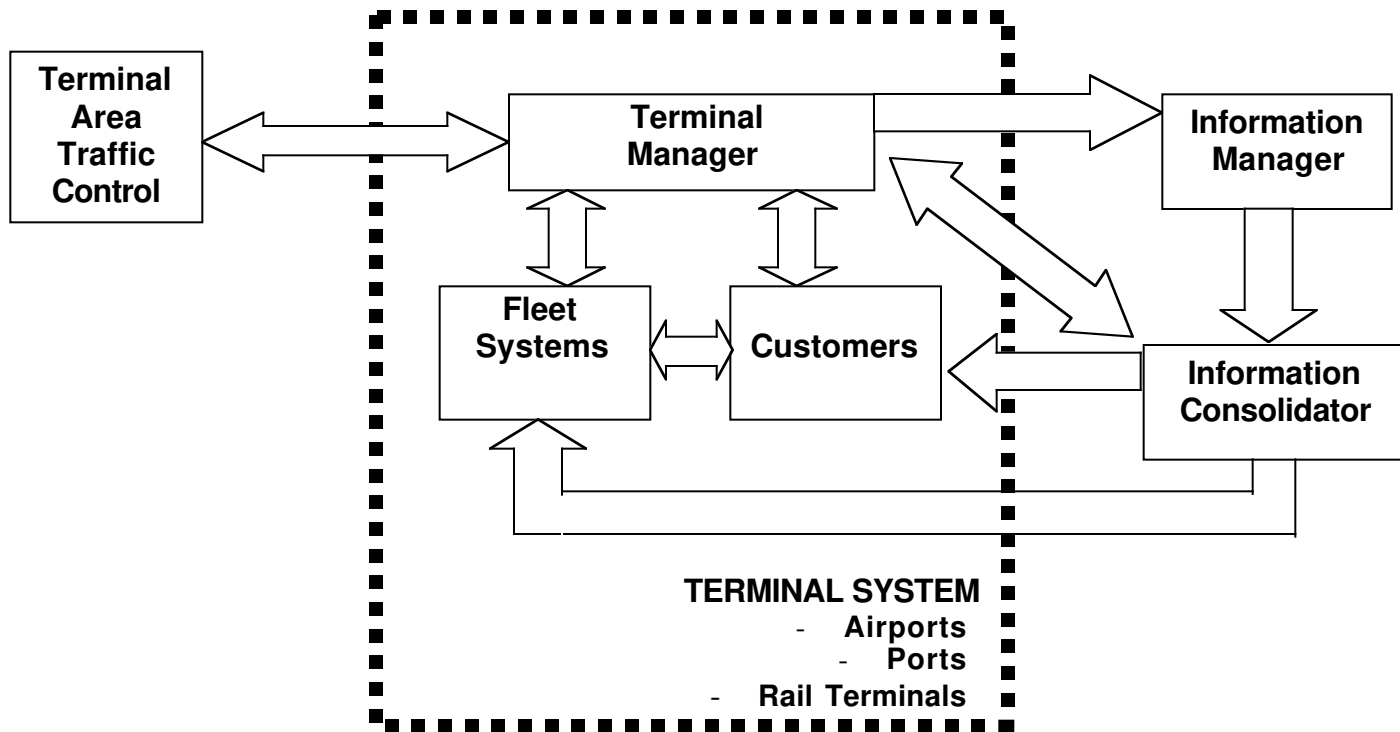
FIGURE 7. TRAVEL TIME FORECAST FUNCTION

REAL- TIME INPUTS

Recent Sensor Readings

Weather

Incident Status

Event Status

CT TMC Travel Time Forecasts

HISTORICAL INPUTS

Traffic Trend

Capacity Characteristics

Consolidators

Signal Control

Travelers

OUTPUTS
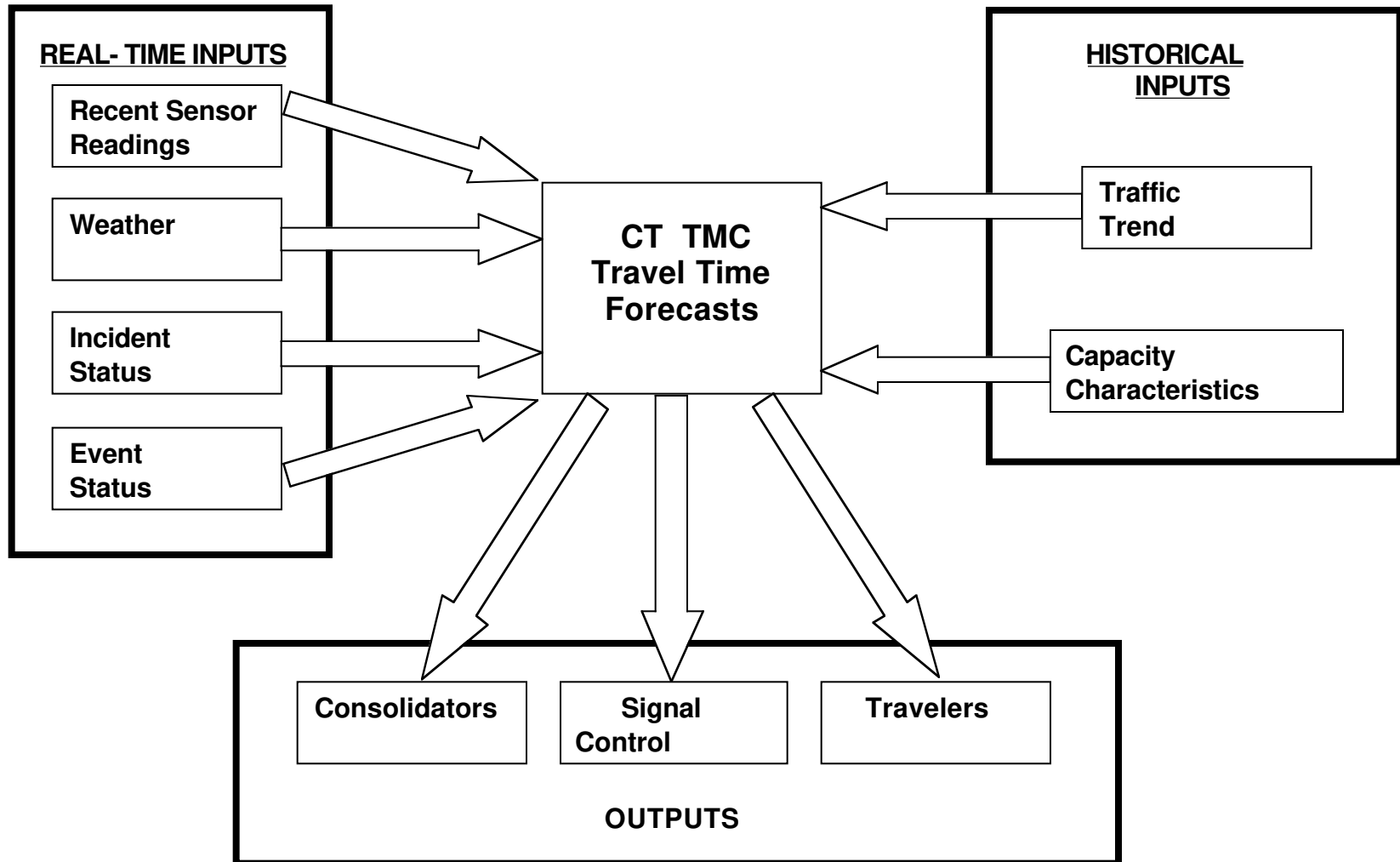
Alternative Approaches

Figures 8 and 9 present alternative visions for an Intermodal Transportation Operation System. Figure 8 envisions TMCs as centralized control centers, spanning multiple modes of transportation under one roof. The public agencies jointly create an information consolidation function, which is linked to the media and directly to travelers. Agencies share information with each other through the consolidator, and through Caltrans/CHP, which acts as the regional coordinator.

Figure 9 envisions a decentralized intermodal transportation operation system, in which the management center is greatly de-emphasized. Instead, transportation is managed within localized cells, in which controllers interact directly with travelers and vehicles, and interact directly with their neighbors. Centers can extract information from these cells, but control actions and information dissemination largely occur at the local level.

We believe that a single centralized intermodal TMC is not desirable because it would create organizational inefficiencies. Centralization would disconnect the control functions of arterials and transit from their own agencies, reducing their own effectiveness. This would make the transportation center less effective at resolution of longterm problems, which may require construction, planning and scheduling. It is more important for a TMC to be connected with other departments within its own agency, than to be connected with TMCs for other agencies.

Information consolidation could be more efficiently accomplished in the private sector, as demonstrated by the TravInfo project (Hall, 1998). The private sector can seek out and integrate the most relevant information, without being burdened by the slow process of forming consensus through committees. Reaching agreement on the design and operation of the intermodal TMC carries enormous institutional burden, including the formation of agreements spanning agencies that require multiple levels of review.

Our conclusion is also influenced by a report on integrating transit into TMCs written in 1994 (Schweiger). The author offers these findings:

The issue of co-location was addressed by the TMCs in two ways. In the case of Montgomery County, the DOT felt that collocating transit dispatch, the transit information center and traffic management afforded them the greatest opportunities for exchanging valuable data and information. Most others suggested that communications links, such as fiberoptic connections, were just as successful at exchanging data as collocating ...Furthermore, transit agencies have usually built their own operations facilities, and it would not be feasible for them to move into the TMC just for the sake of being co-located.

The roles and responsibilities of transit and traffic agencies participating in a TMC do not have to drastically change for the organizations to cooperate. Transit

agencies will still be focused on all the aspects of providing their services, and traffic management will still be focused on improving the traffic flow and managing incidents.

We also do not believe the decentralized concept is appropriate for California today. It requires an enormous technological leap from how systems have been deployed to date, and demands a much higher level of technology to be deployed on the vehicle, though it may be that decentralization will work some day far in the future.

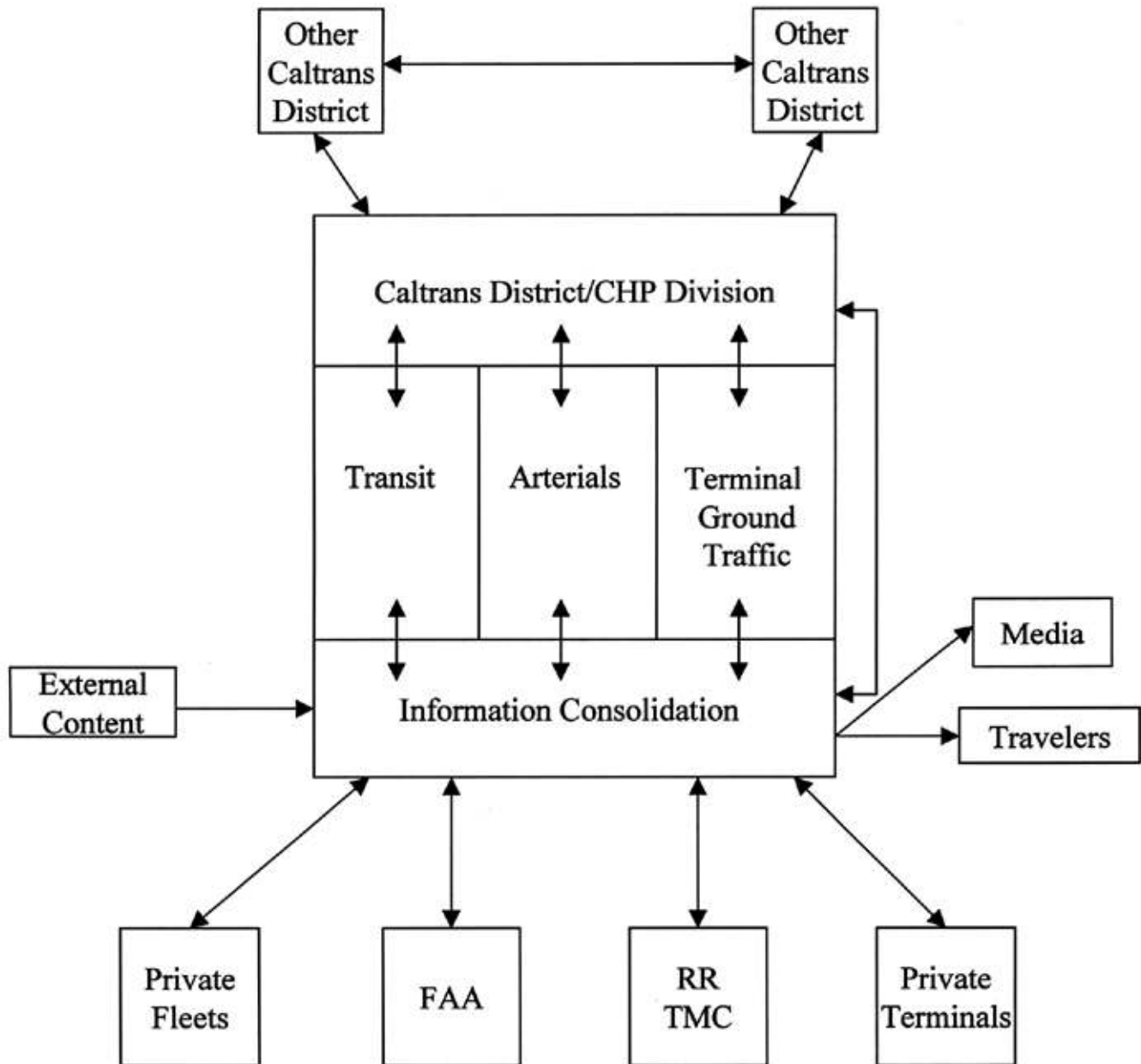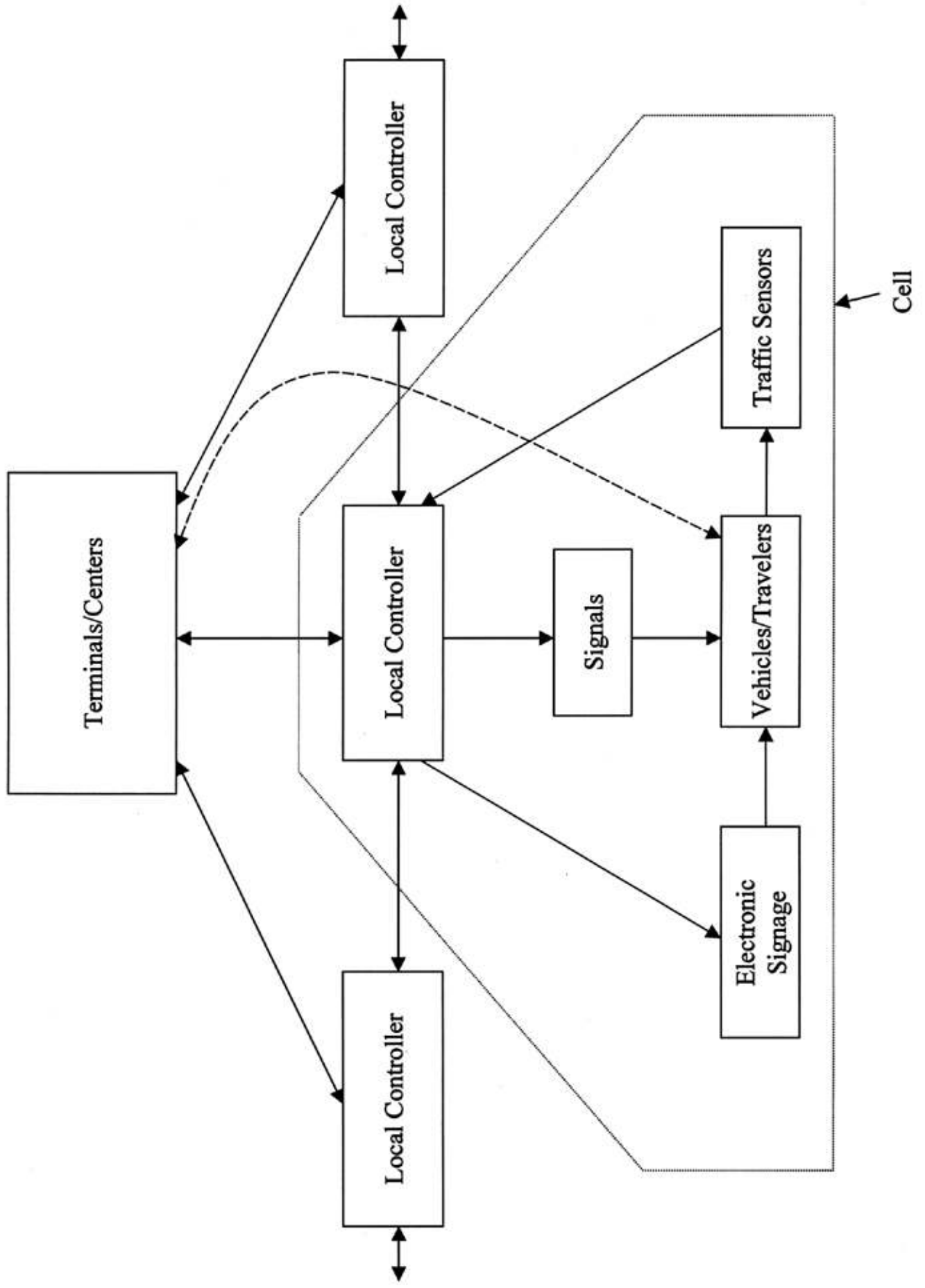# FIGURE 8. CENTRALIZED TRANSPORTATION MANAGEMENT CENTER

FIGURE 9. CELLULAR SYSTEM

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