STRATEGIC DEPLOYMENT PLAN

INTELLIGENT TRANSPORTATION SYSTEM (ITS)

Early Deployment Study

Kansas City Metropolitan Bi-State Area

Submitted to

Kansas Department of Transportation

Missouri Highway and Transportation Department

Submitted by

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Executive Summary

This Strategic Deployment Plan summarizes the results of the Intelligent Transportation System (ITS) Early Deployment Study for the bi-state Kansas City metropolitan area. This plan was prepared by the HNTB Corporation, AlliedSignal Technical Services Corporation, and Edwards and Associates, Inc. study team under contract with the Kansas Department of Transportation (KDOT) and the Missouri Highway and Transportation Department (MHTD). A project Steering Committee, which includes representatives from KDOT and MHTD, as well as the Federal Highway Administration (FHWA) and the Mid-America Regional Council (MARC), provided suggestions and feedback throughout the study.

Intelligent transportation systems (ITS) are systems that utilize advanced technologies, including computer, communications and process control technologies, to improve the efficiency and safety of the transportation system. These systems encompass a variety of components that may be deployed by public and private agencies. The fact that these systems are often deployed incrementally by a number of agencies makes it especially important that they be coordinated. This Strategic Deployment Plan was developed to facilitate coordination of ITS activities in the Kansas City area, and to provide a common framework for deployment.

This Strategic Deployment Plan documents the transportation system characteristics in the Kansas City metropolitan area, the ITS user services appropriate for application, a system architecture for the intelligent transportation system to be deployed, the alternative technologies available, and a deployment plan.

The study focused on the freeway system, and considered the arterial and transit systems to the extent that they affect the operation of the freeway system and contribute to overall mobility in the metropolitan area. Kansas City has an extensive freeway system, and there are locations that experience recurring congestion, particularly I-70 east of downtown, I-35 south of and immediately north of downtown, and the south leg of I-435. Unless some action is taken, recurring congestion may be expected to increase as traffic volumes increase. Currently, much of the congestion in the urban area is related to incidents, and many issues that were identified as priorities are related to incidents. These issues include both technical issues, such as rapid identification and verification of incident location, as well as institutional issues, such as agency coordination and recognition of the goals and objectives of all the agencies at the incident site.

The highest priority user services, based on agency rankings and the results of a survey conducted at two public meetings, are Incident Management, Traffic Control, Emergency Notification and Personal Security, and Emergency Vehicle Management. These user services address both recurring and incident related congestion, and contribute to the prompt identification and removal of incidents.

Development of the system architecture was based on an examination of three different architecture alternatives. The recommended architecture includes two central servers with an information server. This control logic will provide autonomy for the two states, yet will facilitate coordination and provide redundancy. Coordination will also be enhanced by specification of a single traffic operations center (TOC). With respect to data processing, the recommended architecture utilizes centralized data processing, which is the standard and proven system used in most applications across the country. The communications network is a dual ring fiber optic backbone in a star/ring configuration, which will provide redundancy as well as capacity adequate for all anticipated components. Emergency management coordination will be based on the existing 911 dispatch system, TOC operators will contact emergency responders directly using the 911 system. The recommended architecture takes a hybrid approach to arterial signal control. Some arterial signal systems will be controlled from the TOC, while others will be controlled outside the TOC, for example by cities. The final characteristic identified by the architecture is coordination with public transit. Public transit functions will be maintained outside the TOC, although this does not preclude coordination of activities, particularly for the dissemination of information.

An examination of costs and benefits is provided for both the development of a freeway management system and selected transit ITS applications. The proposed freeway management system addresses roadway monitoring and incident detection, verification, and response, and includes vehicle detectors, closed circuit television cameras, highway advisory radio, variable message signs and a traffic operations center. The costs and benefits associated with the development of a freeway management system were calculated for four stages of deployment, as shown in Figure ES-1. The estimated annualized costs, annual benefits, and benefit cost ratio are shown in Table ES-1 for each stage, The values shown in Table ES-1 reflect each state paying a percentage of the shared costs (for the traffic operations center, hardware and software) proportional to the system roadway mileage in the state. The total capital cost for the deployment of Phase 1 is $29.1 million.

Table ES-1. Benefit Cost Ratio for Each Phase

Phase			1	2	3	4	All
Annual Benefits (in Millions)[1]			$13.5	$4.7	$5.6	$1.3	$25.2
	Kansas		$4.7	$1.3	$1.3	$0.7	$7.9
	Missouri		$8.9	$3.5	$4.4	$0.6	$17.3
Annualized Cost (in Millions)			$4.7	$2.5	$4.4	$5.7	$17.4
	Kansas	Capital	$1.2	$0.6	$0.5	$1.7	$3.9
		Operating and Maintenance	$0.7	$0.4	$0.4	$1.1	$2.6
		Total	$1.9	$1.0	$0.9	$2.7	$6.5
	Missouri	Capital	$1.8	$0.9	$2.0	$1.8	$6.5
		Operating and Maintenance	$1.0	$0.6	$1.5	$1.2	$4.3
		Total	$2.8	$1.5	$3.6	$2.9	$10.9
Benefit Cost Ratio			2.9	1.9	1.3	0.2	1.4

Total values may not be the sum of the values shown for Kansas and Missouri due to rounding.

The primary focus of the deployment plan is a freeway management system. System components have been identified for a freeway management system that provides coverage of the entire metropolitan area. Based on the estimated benefit cost ratios, a freeway management system is recommended on Phase 1 in the short term (within 5 years), Phase 2 in the medium term (in 5 to 10 years), and Phases 3 and 4 in the long term (10 or more years), when the benefit cost ratios will presumably be more favorable due to increased volumes and reduced technology costs. Figure ES-2 illustrates the recommendations for the freeway management system for Phase 1.

Other activities identified in the deployment plan, but not reflected in the costs shown in Table ES-1, include integration of weather information into the TOC (short term), ramp metering (short to medium term), coordination with transit for the provision of information (medium term), coordination with the provision of in-vehicle information (long term), and the deployment of technologies to encourage alternatives to the single occupancy vehicle and enhance compliance with clean air mandates (long term). Ramp metering is recommended as a demonstration project on I-35 in Kansas in the short term, and for evaluation elsewhere in the medium term.

A number of ongoing activities have also been identified. These activities include coordination of arterial signal systems on freeway diversion routes, coordination with the Kansas Turnpike Authority, and coordination with emergency responders and local public works agencies. The deployment plan also includes transit applications such as video monitoring, automated scheduling and transit information, expansion of the automatic vehicle location system and personalized public transportation.

A number of priority activities for early deployment were identified for implementation within two years. These include "early winners", projects that have a relatively low cost, require a short development time, are relatively high priority, contribute to the Intelligent Transportation Infrastructure, and are expected to be successful and enhance the public image of ITS. Priority activities also include activities which set the stage for future ITS activities. Projects representing priority activities include:

- Implement closed circuit television cameras in selected priority locations in Kansas and Missouri.
- Pursue activities to procure fiber optics on Kansas interstates and freeways.
- Procure additional portable variable message signs.
- Expand motorist assistance patrol.
- Install freeway reference markers and overpass signing on priority facilities.
- Coordinate arterial signals for freeway diversion .
- Procure total station accident investigation equipment to facilitate accident investigation and speed up incident removal.
- Develop standards for construction to include ITS elements.
- Develop a policy for the provision of traveler information.
- Develop legislation and regulations to allow immediate removal of disabled vehicles.
- Consider a partnership with a private entity for the provision of traveler information in the short term.
- Coordinate with planning agencies to assure inclusion of ITS projects in local and regional plans.
- Consider facility needs for the traffic operations center during the planning and design of MHTD's new District 4 facility.
- Incorporate of ITS elements into the segment of Bruce Watkins Drive currently planned for construction.

Chapter 1
Introduction

Introduction

This report summarizes the results of the Intelligent Transportation System (ITS) Early Deployment Study for the bi-state Kansas City metropolitan area. The purpose of this study was to identify the ITS user services appropriate for Kansas City and develop a Strategic Deployment Plan based on these user services. Following a discussion of the transportation characteristics in the Kansas City metropolitan area and an examination of the user services, this Strategic Deployment Plan documents the system architecture, alternative technologies, and deployment plan for an intelligent transportation system in the Kansas City area.

Participating Agencies

The Early Deployment Study is a joint project of the Kansas Department of Transportation (KDOT) and the Missouri Highway and Transportation Department (MHTD), and is being administered by KDOT. A project Steering Committee, which includes representatives from KDOT and MHTD, as well as the Federal Highway Administration (FHWA) and the Mid-America Regional Council (MARC), has provided suggestions and feedback throughout the study, meeting nine times during the course of the 12 month study.

Intelligent Transportation Systems

The United States has one of the most extensive and best transportation systems in the world. However, increasing vehicle miles of travel have resulted in increased congestion and decreased mobility in many urban areas. Highway travel delays in urban areas total more than two billion hours annually, costing billions of dollars in productivity and lost working hours[1] And the situation, left unchecked, may be expected to get even worse. According to a study by FHWA, delays on urban freeways are expected to increase by 360 percent in the central cities and by 433 percent in outlying areas in the twenty years between 1985 and the year 2005[2].

The increasing demand for transportation comes at a time when there are limited opportunities to build more roadway lanes. Construction and reconstruction activities are often physically constrained by urban development. The addition of roadway capacity is also limited by environmental regulations which discourage (or in some cases do not allow) the construction of additional facilities for single occupancy vehicles, and by social opposition to roadway projects which facilitate low density development and urban sprawl.

[1] US Department of Transportabon, *Moving America*, *New Directions, New Opportunities, A Statement of National Transportation Policy, Strategies for Action* February 1990.

[2] Federal Highway Administration *Urban and Suburban Highway* Congesbon, Working Paper No 10. Washington, DC, December 1987

In response to the need to address increasing congestion and increasing demand without building additional facilities, and in response to the need to better utilize the existing facilities, more and more urban areas are turning to advanced technologies. These advanced technologies are generally components of an intelligent transportation system (ITS).

Intelligent transportation systems were formerly called intelligent-vehicle highway systems (IVHS), however, the name was changed to reflect the fact that these systems encompass not only highways and cars, but all modes, including transit, rail, and air, as well as intermodal connections. Commercial vehicle operations, including highway, rail, air, waterway, and intermodal connections, are also incorporated into ITS. Furthermore, note the inclusion of the term system, which emphasizes that all modes and functions of the transportation system should be integrated to provide optimal efficiency and system performance.

As a general definition, intelligent transportation systems are systems that utilize advanced technologies, including computer and process control technologies, to enhance the safety and efficiency of the transportation system. Although there is no distinct origin to ITS, activities can be traced to a number of projects that began in the 1970s and 1980s'. These activities were initiated in a number of different countries, and involved government, industry, academic institutions, and trade and professional organizations. The various activities gradually merged into a single concept, evolving to focus on the transportation system, and not merely on discrete system components.

In the United States, individual cities and states undertook early activities. Federal involvement was formally initiated with the Intermodal Surface Transportation Efficiency Act (ISTEA), promulgated in December 1991. This legislation authorized $660 million of federal funds to support ITS activities over a six-year period. This funding, which has been supplemented by ITS funding in the annual U.S. Department of Transportation appropriation acts, has been used for early deployment planning studies such as this one, as well as other ITS projects.

Focus of ITS Study

The major focus of the Early Deployment Study is on the freeways in the Kansas City metropolitan area. This focus on the freeways is justified by the fact that freeways are the backbone of the transportation system in the Kansas City area. Kansas City has more freeway miles per capita than any other city, and freeways account for over 70 percent of the vehicle miles traveled in the metropolitan area[2]. Because freeways serve so much of the travel in Kansas City, investments that have a positive impact on freeway operations can result in substantial benefits.

Arterials and transit, while an important element in the transportation system, play a smaller role in terms of overall mobility in the metropolitan area. The smaller role of arterials and transit is reflected by the fact that arterials and transit are included in the plan where they

[1] Discussion based on *Smart Highways. Smart Cars,* Richard Whelan, Antech House, inc., 1995

[2] David L Schrank, Shawn M Turner, and Timothy J Lomax, *Trends in Urban Roadway Congestion* - 1982 to 1997, Volume 2: *Methodology and Urbanized Area Data,* Research Report 1131-6. Texas Transportation Institute, September 1994.

impact freeways (for example, arterials may serve as alternative routes when there is an incident on the freeway), and to the extent that they impact the transportation system as a whole.

Focus of Strategic Deployment Plan

The focus of the intelligent transportation system described in this Strategic Deployment Plan reflects the priority user services. The primary component of the Strategic Deployment Plan is a freeway monitoring and advanced traffic management system. This system addresses the highest priority user services: Incident Management, Traffic Control, Emergency Notification and Personal Security, Emergency Vehicle Management, and En-Route Driver Information. This system will also meet the objectives identified by the surveys provided at the public meetings: reduce congestion, manage traffic, and provide information. These and all of the user services are discussed in Chapter 3.

The Strategic Deployment Plan also contains provisions for the deployment of intelligent transportation technologies related to transit. This component addresses the transit related highest priority user services: Public Transportation Management and Public Travel Security. This component also encourages alternatives to the single occupancy vehicle, the fourth ranking objective identified by the surveys provided at the public meetings.

Organization of Report

Following this introductory chapter, Chapters 2 and 3 summarize the existing conditions and priorities. Chapter 2 provides a discussion of the transportation system characteristics, problems, and opportunities in the Kansas City area. Chapter 3 defines the user services, and identifies which ones are appropriate in the short, medium, and long term.

Chapters 4 through 7 address the system architecture, the technologies that may be used for an intelligent transportation system, the expected benefits and costs of the proposed system, and the plan for deployment.

Chapter 4, which examines the system architecture, presents the three alternative architectures considered, and discusses the analysis procedure used to select the recommended architecture.

Chapter 5 provides a discussion of the technologies that could be used for an intelligent transportation system. Following a discussion of the characteristics, benefits and limitations of various technologies, a discussion of strategies for the application of these technologies are provided, and ITS activities in selected urban areas are reviewed.

Chapter 6 analyzes the benefits and costs that would be expected to result from deployment of the proposed intelligent transportation system. Benefits are estimated for the recommended freeway management system, and costs are estimated for individual components, as well as for the recommended system.

Chapter 7 discusses the proposed deployment plan. Priorities, a deployment schedule, and an operations plan are presented, as is a discussion on interagency coordination and opportunities for public/private partnerships.

Chapter 2
Transportation System Characteristics

Jurisdictions and Affected Agencies

The focus of the ITS Early Deployment study is the Kansas City metropolitan area, which encompasses portions of Cass, Clay, Jackson and Platte counties in Missouri, and Johnson and Wyandotte counties in Kansas. Each county includes a number of incorporated cities, resulting in countless agencies that are responsible for activities related to some aspect of the transportation system. The large number of participants makes agency coordination and cooperation all the more important.

While the need for agency coordination and cooperation is significant at all times, it becomes especially critical during incident management and in other situations where a large number of agencies are involved and time is imperative. To provide some appreciation for the breadth of agencies that are involved in incident management activities, Table 2-l provides information about emergency management services in the larger cities in the six county region.

Major Facilities in the Kansas City Area

The primary emphasis of this study was on the freeway system in the Kansas City area, with a secondary emphasis on arterials and transit, to the extent that they affect freeway operations and contribute to mobility in the metropolitan area. Thus, the major facilities that were considered in this study include the freeways, both interstate and non-interstate facilities, as well as major arterials and transit facilities and services that influence freeway operations. Intermodal facilities and facilities planned for deployment are also briefly addressed in this section.

FREEWAYS

The freeway system in Kansas City is extensive, including both radial and circumferential facilities. Not unexpectedly, it serves a significant portion of the vehicle miles traveled in the city, as shown in Table 2-2. Note that while the freeway system has 30 percent more lane miles than the principal arterial system, it serves more than two and a half times the vehicle miles traveled[1], accounting for over 70 percent of the vehicle miles traveled in the metropolitan area.

1 David L. Schrank, Shawn M. Turner, and Timothy J. Lomax, *Trends in Urban Roadway Congestion - 1982 to 1997, Volume 2: Methodology and Urbanized Area* Data, Research Report 1131-6, Texas Transportation Institute, September 1994.

STATE	COUNTY	CITY	STATE SERVICES: HIGHWAY PATROL	STATE SERVICES: MOTORIST ASSIST	CITY SERVICES: 911 GROUP	CITY SERVICES: AMBULANCE CITY	CITY SERVICES: AMBULANCE CONTRACT	CITY SERVICES: AMBULANCE PRIVATE	CITY SERVICES: FIRE DEPARTMENT	CITY SERVICES: POLICE DEPARTMENT	CITY SERVICES: WRECKER CONTRACT	CITY SERVICES: WRECKER PRIVATE
MISSOURI	CASS	Belton	■		■	■			■	■	■	
MISSOURI	CASS	Kansas City (part)	■		■		■		■		■	
MISSOURI	CLAY	Gladstone	■		■	■			■	■	■	
MISSOURI	CLAY	Kansas City (part)	■	■	■		■		■	■	■	
MISSOURI	CLAY	Liberty	■		■	■			■	■	■	
MISSOURI	CLAY	North Kansas City	■	■	■	■			■	■	■	
MISSOURI	CLAY	Pleasant Valley	■	■	■	■			■	■	■	
MISSOURI	CLAY	Randolph	■	■	■	■			■	■		
MISSOURI	JACKSON	Blue Springs	■	■	■		■		■	■		■
MISSOURI	JACKSON	Grain Valley	■	■	■		■		■	■		■
MISSOURI	JACKSON	Grandview	■	■	■	■			■	■	■	
MISSOURI	JACKSON	Independence	■	■	■		■		■	■	■	
MISSOURI	JACKSON	Kansas City (part)	■	■	■		■		■	■	■	
MISSOURI	JACKSON	Lee's Summit (part)	■	■	■	■			■	■	■	
MISSOURI	JACKSON	Raytown	■	■	■	■			■	■	■	
MISSOURI	JACKSON	Unity Village	■	■	■	■			■	■	■	
MISSOURI	PLATTE	Ferrelview	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Houston Lake	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Kansas City (part)	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Lake Waukomis	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Northmoor	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Platte Woods	■	■	■		■		■	■	■	
MISSOURI	PLATTE	Riverside	■	■	■		■		■	■	■	
KANSAS	JOHNSON	DeSoto	■		■	■			■	■		■
KANSAS	JOHNSON	Edgerton	■		■			■	■	■		■
KANSAS	JOHNSON	Gardner	■		■	■		■	■	■	■	■
KANSAS	JOHNSON	Leawood	■		■	■			■	■		
KANSAS	JOHNSON	Lenexa	■		■	■			■	■	■	
KANSAS	JOHNSON	Merriam	■		■	■		■	■	■		■
KANSAS	JOHNSON	Mission	■		■			■	■	■	■	
KANSAS	JOHNSON	Olathe	■		■			■	■	■	■	
KANSAS	JOHNSON	Overland Park	■		■			■	■	■	■	
KANSAS	JOHNSON	Roeland Park	■		■			■	■	■	■	
KANSAS	WYANDOTTE	Bonner Springs (part)	■		■			■	■	■		■
KANSAS	WYANDOTTE	Edwardsville	■		■			■	■	■		■
KANSAS	WYANDOTTE	Kansas City	■		■	■			■	■		■

■ BY OTHERS

Table 2-1. Emergency Management Services in Kansas City Area

Table 2.2 Travel Characteristics in the Kansas City Area

Type of Facility	Daily Vehicle Miles Traveled (DVMT)	Lane-miles	Average Number of Lanes	DVMT per Lane-mile
Freeway	12,520,000	1,360	4.4	9,200
Principal Arterial	4,840,000	1,050	3.5	4,610

Source: David L. Schrank, Shawn M. Turner, and Timothy J. Lomax, Trends *in Urban Roadway Congestion - 1982 to 1997, Volume Methodology and Urbanized Area Data, Research Report 1131-6, Texas Transportation Institute, September 1994.*

Major freeway facilities in the Kansas City area are shown in Figure 2-1 and include:

- Radial interstates I-35 to the northeast and southwest, I-29 to the northwest, and I-70 to the east and west.
- Circumferential loop I-435.
- Partial loops I-635, west of downtown connecting I-35 to I-29; and I-470, connecting I-70 to the southeast portion of I-435.
- I-670, the south leg of the downtown loop, extending west to I-70.

Major non-interstate freeway and expressway facilities in the metropolitan area include:

- US 169, north of downtown connecting I-29 and I-435 in Missouri.
- US 71, south of downtown near I-435 in Missouri.
- M-152, north of downtown between I-435 and i-35 in Missouri.
- US 69, just east of the junction of I-35 and I-435 in Overland Park, Kansas,
- Segments of K-7 and K-10, west of I-435 in Kansas.
- 18th Street Expressway (US 69) between I-35 and I-70 in Kansas.

ARTERIALS

Kansas City has an extensive system of principle arterials, comprising 1,050 lane-miles and serving almost 5 million vehicle miles of travel daily. Principal arterials serve major activity centers, linking these activity centers to freeway facilities (for example, Bannister Road to I-435 in Kansas City, Missouri and Metcalf Avenue to I-435 in Overland Park, Kansas). Principal atterials also serve as a primary means for mobility for trips that are not served by freeway facilities (for example, a trip directly south from downtown Kansas City may be served by the Southwest Trafficway and Ward Parkway).

Ideally, arterials also serve as alternative routes to the freeway. Diversion of traffic from freeways to arterials when freeway facilities are under construction or when there is an incident on the freeway can result in reduced overall delay. However, not all arterials are suitable as alternative routes for freeway traffic. An arterial used as an alternative route would preferably run approximately parallel to the freeway, would have adequate access onto and off of the freeway, and would have adequate capacity and operating speeds. Arterial capacity is influenced not only by the number of lanes in each direction (a minimum of two lanes in each direction is appropriate in many circumstances), but also by the signal timing along the facility. Thus, the capability to vary signal timing plans in response to a large volume of traffic diverting from the freeway significantly enhances the effectiveness of an arterial as an alternative route. This is discussed in greater detail in a later section, System Characteristics.

Facilities that may be suitable as alternate routes to the freeway are shown in Figure 2-l and include:

- Missouri 9 to Missouri 283 as an alternate route for l-35/l-29 north of downtown.
- Southwest Boulevard as an alternate route for l-35 southwest of downtown.
- US 69 as an alternate route for l-35 northeast of downtown.
- Truman Road as an alternate route for I-70 immediately east of downtown.
- US 40 as an alternate route for l-70 east of downtown.
- Central Avenue as an alternate route for l-70 west of downtown and east of l-635.
- State Avenue as an alternate route for l-70 west of downtown.
- US 24/US 40 as an alternate route for l-70 west of downtown and west of l-635,
- 103rd and 111 th (College Boulevard) as alternate routes for the southern portion of l-435,
- North Broadway as an alternate route for US 169, north of downtown and south of Missouri 152.

TRANSIT FACILITIES AND SERVICES

There are three major transit providers in the Kansas City metropolitan area, the Kansas City Area Transportation Authority (KCATA) in Kansas City, Missouri; the Public Transportation Division, Public Works Department in Kansas City, Kansas; and Johnson County Transit in Johnson County, Kansas. These agencies provide fixed route transit service as well as paratransit services. Characteristics of the fixed route transit service provided in the metropolitan area are shown in Table 2-3.

Table 2-3. Fixed Route Transit System Characteristics in Kansas City Area

System	Fleet Size	Annual Service Miles	Weekday Ridership	1994 Annual Ridership
KCATA	265	7,933,322	49,950	14,573,656
KCK "The Bus"	12	420,750	1,070	272,078
Johnson County Transit	24	459,740	740	187,365
Total	301	8,813,812	51,760	15,033,099

Source: 1994 transit agency operatrng data

Ridesharing - All of the transit agencies currently refer requests for ridesharing to MARC's RideShare program. This program serves the entire metropolitan area, and was established in 1980 to help reduce air pollution, traffic congestion, and energy consumption.

Paratransit - Paratransit service is provided by over 40 agencies in the metropolitan area. Agencies providing paratransit service include county agencies (for example, Reserve-A-Ride in Cass County, Missouri), city agencies (for example, LIFT in Lenexa, Kansas), transit agencies (for example, KCATA's Share-a-Fare), medical organizations (for example, Research Mental Health Services), organizations for children (for example, Children's TLC), and organizations for the elderly (for example, Wyandotte Department of Aging). Paratransit services are generally managed and operated independently. A coordinated approach to operations and dispatch may result in increased efficiency.

INTERMODAL FACILITIES

There are a number of intermodal facilities in the Kansas City area, including aviation facilities, river facilities on the Missouri River, and facilities for truck/rail interface. These facilities are shown in Figure 2-2. Most of these facilities are in industrial areas along the Missouri and Kansas Rivers. ITS user services oriented toward commercial vehicles would need to consider the location and activities at these facilities.

PLANNED FACILITIES

A variety of transportation projects have been proposed or are planned for deployment in the Kansas City area. The impact of these proposed and planned projects on the transportation system would be expected to vary, depending on the magnitude of the project, The following information on planned facilities is based on MARC's *Draft Long Range Transportation Plan*[1], and on MARC's *Transportation Improvement Plan*[2].

Freeway Facilities - The *1994 Transportation Improvement Plan* includes recommendations for a number of facilities in both Kansas and Missouri. Although no new freeway facilities are currently proposed, there are recommendations to provide additional capacity on a number of existing freeways, and to provide 26.2 miles of new expressway in Missouri. New structures proposed include a new Chouteau Bridge in Missouri and a new Turner Diagonal Bridge in Kansas. Major capacity improvement projects recommended in the *2010 Interim Long Range Street and Highway Plan* (approved in 1990) include 58.8 miles of freeway widening, 16.7 miles in Kansas and 42.1 miles in Missouri. Additional capacity is recommended on the following facilities.

In Kansas:

- I-435, widen to 8 lanes between K-10 and the Missouri state line.
- I-635, widen to 6 lanes between Metropolitan Avenue and I-35 (a continuation of this project is also proposed: US 69 Metcalf Avenue, widen to 6 lanes from I-35 to Shawnee Mission Parkway).
- US 69, widen to 6 lanes from 95th Street to K-150.

1 *Draft* Long *Range Transportation Plan,* March 1995. Mid-America Regional Council, Kansas City, Missouri
2 *Transportation Improvement Plan,* 1994, Mid-America Regional Council, Kansas City, Missouri

In Missouri:

- I-29/I-35, widen to 8 lanes from the northeast corner of the downtown loop to the I-29/I-35 split.
- I-29, widen to 6 lanes between I-35 and US 169.
- I-35, widen to 6 lanes between I-29 and US 69.
- I-70, widen to 8 lanes between I-470 and Truman Road (another option being considered for I-70 east of downtown in Missouri is the addition of a high occupancy vehicle (HOV) lane).
- US 71, widen to 6 lanes from 155th Street to Route 58.
- US 50, widen to 6 lanes between I-470 and M-291 North.

The *Draft Long Range Transportation Plan* also provides information regarding proposed improvements on a number of facilities. The following projects are in the 2020 Long Range Transportation Plan for interstates, freeways and expressways.

In Kansas:

- I-35 in Wyandotte County, widen to 8 lanes from US 69 to Southwest Boulevard, and from K-150 to I-435 in Johnson County.
- I-435 in Johnson County, widen to 8 lanes from State Line Road to I-35.
- I-635 in Wyandotte County, widen to 6 lanes from Metropolitan Avenue to I-35 (as stated above).
- US 69 in Johnson County, widen to 6 lanes from I-35 to Shawnee Mission Parkway (as stated above), from I-35 to 119th, from US 169 to 151st Street, and from 151st Street to 155th Street.
- US 169 in Johnson County, widen to 6 lanes from College Boulevard to US 69.
- Southgate Road, add 2 lanes from Kansas Avenue to Harrison Street.

In Missouri:

- I-35 in Jackson County, widen to 8 lanes from I-70 to I-29.
- I-70 in Jackson County, add 2 lanes from M-7 to Lafayette County.
- I-435, add 2 lanes from M-210 in Clay County to US 71 (NB) in Jackson County.
- US 71/Bruce Watkins Drive in Jackson County, new 6 lanes from 12th Street to Truman Road, and widen to 6 lanes from Brush Creek Boulevard to Swope Parkway.
- US 71 in Cass County, widen to 6 lanes from 155th Street to M-58.
- US 169 in Clay County, widen to 4 lanes from I-435 to the metropolitan planning organization boundary.
- Jackson County Roadway, new 4 lanes from I-435 to I-470.
- M-210 in Clay County, upgrade to freeway from I-435 to M-291.
- M-152 in Clay County, new 4 lanes from Green Hills Road to Brighton Avenue.
- M-291 in Jackson County, widen to 4 lanes from M-210 to US 24.
- US 50 in Jackson County, widen to 6 lanes from I-470 to Rte RA.
- M-350 (Blue Parkway) widen to 6 lanes from Benton Boulevard to Elmwood.

High Occupancy Vehicle (HOV) Facilities - MARC has identified high occupancy vehicle (HOV) lanes as one approach to increasing vehicle occupancies in the *Draft Long Range*

Transportation Plan, and has identified a possible HOV Network, shown in Figure 2-3. The facilities shown in Figure 2-3 are line-haul HOV facilities. Other types of HOV facilities, such as queue bypass facilities that allow HOVs to avoid bottleneck locations, may also be appropriate for deployment. Although not addressed in the *Draft Long Range Transportation* Plan, HOV support facilities, such as park-and-ride lots, would also be necessary upon implementation of HOV lanes.

Transit Facilities - The 1994 Annual Element of the *Transportation Improvement Plan* for transit is comprised primarily of routine projects required for the maintenance of current services. Projects include bus replacement, acquisition of maintenance tools and equipment and upgrades to existing transit facilities.

A notable exception is a project for preliminary engineering services for a proposed light rail transit (LRT) line in south Kansas City. This study, sponsored by the KCATA, recommended the preferred alternative shown in Figure 2-4. The recommended alignment extends from its northern terminus at 3rd and Grand to Crown Center, then through Midtown along Broadway to the Country Club Plaza. South of the Plaza, the east branch parallels Volker Boulevard and 47th Street east toward Bruce Watkins Drive. The LRT would follow the Watkins roadway south to its terminus at 75th Street. The south branch proceeds from the Plaza along Brookside Boulevard and Wornall Road to a terminus at 85th and Holmes. Progress of the LRT project, including preliminary engineering, depends on the availability and receipt of federal funding.

Another fixed rail project involves a study of the feasibility of establishing commuter rail service between Olathe, Kansas, and downtown Kansas City, Missouri, generally following I-35. This study, sponsored by Johnson County Transit, is evaluating the use of existing Burlington Northern tracks for passenger transportation.

Several other transit related studies are currently underway in the metropolitan area:

- MARC is updating the transit element of the region's *Long Range Transportation Plan* with the 1994 Public Transit Planning Study. This study is expected to guide the development of a comprehensive and integrated public transportation system to serve the current and future mobility needs of the people and businesses in the region.

- KCATA is conducting a comprehensive analysis of its services intended to develop a short range transit plan for the KCATA services area.

- Kansas City, Kansas, is conducting a study of transit needs in that community to develop a short range plan for transit service improvements.

- The three Kansas counties in the metropolitan area (Johnson, Leavenworth, and Wyandotte Counties) are involved with an assessment of public transportation needs in part to develop a strategy for funding public transportation in the future.

While these studies are not specifically concerned with ITS applications, they are concerned with improving transit services and increasing efficiency. Coordination between service providers and the integration of service are common themes in all the study efforts. It is likely that the application of ITS technologies can assist the agencies in meeting the recommendations of these studies.

Current and Planned ITS Applications in the Kansas City Area

There are a number of activities being conducted in the Kansas City area that could be classified as ITS projects, these projects are discussed below.

AUTOMATIC VEHICLE LOCATION SYSTEMS

Automatic vehicle location (AVL) systems provide agencies with real-time information about vehicle location. In some cases, AVL systems also provide other information about vehicle status, such as speed, vehicle diagnostic information, audio and/or video monitoring. The specific benefits of an AVL system vary, depending on the capabilities of the system and the needs of the agency implementing the system. AVL systems may be used to facilitate dispatch in the case of enforcement and emergency vehicles; they may be used to better track performance and operating conditions in the case of transit vehicles; they may be used to track equipment and/or freight in the case of commercial vehicles. Thus, AVL systems may be considered an application of the Emergency Vehicle Management, the Public Transportation Management, and Freight Mobility ITS user services (discussed more fully in Chapter 3), depending on the type of agency that implements the system.

A number of agencies in the Kansas City area have, or are planning to implement, AVL systems. KCATA and MAST (the emergency medical responder in Kansas City, Missouri) both have AVL systems. Efforts are underway to procure an AVL system for the Johnson County Kansas Sheriff and Med-Act (the emergency medical responder in Johnson County, Kansas). A pilot study on an AVL system is currently being conducted by the Kansas Highway Patrol.

KCATA's AVL System - In 1988, KCATA initiated a project to replace their two way radio system and enhance operations through the addition of an AVL system. The signpost/odometer AVL system that was ultimately procured enhanced operations by utilizing vehicle location information to assist with dispatching functions (referred to as computer aided dispatch, or CAD), and increase overall efficiency.

Despite hardware failures, the AVL system has recouped the entire cost of installation directly from operating and capital cost savings. Beginning in 1991, the signpost equipment (referred to as AVLTs) used to provide positive location reference began to fail as a result of inadequate circuit design and substandard components. Because the AVLTs fail to consistently produce the required strength signal, the vehicle location system is no longer being used. The system is expected to be fully operational again, however, because the Federal Transit Administration (FTA) has approved a grant to acquire hardware to restore the system's capability.

KCATA's AVL system, when operational, may be considered an application of the Public Travel Security ITS user service, as well as the Public Transportation Management user service, because it enhances security by providing improved response time to incidents and an increased perception of security.

HIGHWAY ADVISORY RADIO

Highway advisory radio (HAR) provides information regarding current traffic, roadway, and/or weather conditions to commuters. The provision of this information may be considered an application of the En-Route Driver Information ITS user service.

A HAR system has been implemented by MHTD at the southeast comer of the downtown loop in Kansas City, Missouri. The system provides very good reception to the east and south on AM 1610. Prior to implementation, the system was tested at least three times: when the artwork on Bartle Hall was being erected, when there was a hazardous material incident on the south end of the loop, and at the 1995 St. Patrick's Day Parade. A number of advisory signs have been installed, in Kansas as well as Missouri (locations are shown in Figure 7-2). Signs in Kansas are needed on I-35 to intercept drivers coming into the downtown loop area.

The HAR signs have lights that flash only when messages are being conveyed. Messages are transmitted during maintenance and construction activities, as well as during incidents. The radio message can be deployed over the phone; there is a separate phone line to each sign with an automatic dialer. The dynamic capability of the signs (the lights will flash when there is a message) is expected to greatly enhance the effectiveness of the system.

FIBER OPTIC CABLE

Efforts to install fiber optic cable are underway by multiple entities in the Kansas City area. MHTD, KDOT and the Kansas Turnpike Authority (KTA) are all working towards the installation of fiber optic cable, and are in various stages of completion. In general, the fiber optic cable is being installed as part of a private/public venture. In exchange for use of right-of-way, the private entities installing the cable will allow the public entity use of a number of the fibers on the cables being installed. Fiber optics partnerships allow public agencies to save not only on capital investments, but also on maintenance expenditures. Fiber optics provide a communications infrastructure that can be utilized for monitoring equipment that supports Incident Management, Traffic Control and other ITS user services.

Kansas Turnpike Authority - Fiber optic cable has been installed on the Kansas Turnpike. Twelve fibers are dedicated for the turnpike's use.

Missouri Highway and Transportation Department - Installation of fiber optic cable in Missouri began in St. Louis, and is expected to be completed in Kansas City by the end of 1996. Installation has resulted in minimal disruption on freeways.

Kansas Department of Transportation - In Kansas, activities necessary for the installation of fiber optic cable have been initiated, and KDOT management has indicated that fiber optics is a priority.

ELECTRONIC TOLL COLLECTION

The Kansas Turnpike Authority (KTA) recently implemented an electronic toll collection (ETC) system. This system allows vehicles to pass through the toll collection area without stopping (the KTA system requires vehicles to slow down to approximately 20 mph). This system reduces vehicle delay and increases agency operating efficiency by reducing the personnel needed for toll collection, Vehicles using ETC are equipped with transponders, which allow payment on a monthly credit or debit system. Electronic toll collection is an application of the Electronic Payment Services ITS user service.

PUBLIC TRANSIT

KCATA has undertaken or is planning to undertake a number of activities that could be considered applications of ITS user services. In addition to KCATA's AVL system, discussed previously, KCATA has implemented two MetroFlex routes, plans to upgrade paratransit scheduling, and is exploring the feasibility of vanpooling and the electronic display of transit information.

MetroFlex - KCATA currently offers MetroFlex transit service on two routes. MetroFlex includes two services: rush hour service, during which the bus will deviate a few blocks (within a certain zone) from its designated route if a "standing order" has been requested (by phone); and midday service, during which door-to-door service can be arranged anywhere within the service area. This service, which became available on one route in April 1993, and on a second route in July 1994, has proven to be very successful and more cost effective than regular route transit. Cost effectiveness of the MetroFlex services is enhanced by a special wage agreement with the labor union. Arrangements for this service are currently provided by a single human operator/dispatcher. KCATA's MetroFlex service is an application of the Personalized Public Transit ITS user service.

Vanpooling - KCATA is planning to conduct a vanpooling feasibility study sometime within the next year. While specific details on the proposed study were not available, this kind of project does represent an application of the Demand Management and Operations ITS user service.

Paratransit - KCATA has programmed funding to upgrade the paratransit scheduling and reservation system. Although specific details on this study were not available, this kind of project may be considered an application of the Public Transportation Management ITS user service.

Electronic Information Display - KCATA is considering use of the electronic display of transit information at the transit facility at 10th and Main. Although specific details are not available, this kind of project may be considered an application of the En-Route Transit Information ITS user service.

TRAFFIC INFORMATION

Traffic information is currently provided on television and on the radio, as well as in the newspaper. Newspaper reports include information about lane closures, construction, and other planned events. Radio and television reports often provide current information not only about construction, but also about incidents, congestion, and alternate routes. Information may be based on a variety of sources. For example, radio reports rely on police and city wire, police radio, telephone dispatchers who are contacted on a regular basis, motorist assistance patrol, a network of reliable “stringers” or “spotters” who call in information, and even air monitoring. Reports are also based on information provided by local agencies, for example, KDOT provides daily information about construction activities and lane closures to traffic reporters as well as newspapers.

The information currently provided via radio and television traffic reports may be considered an application of the En-Route Driver Information, Route Guidance, and Pre-trip Travel Information ITS user services. Information regarding construction activities and lane closures provided in the newspaper may be considered an application of the Pre-Trip Travel Information user service.

EMERGENCY VEHICLE SIGNAL PRE-EMPTION

Emergency vehicle signal pre-emption allows emergency vehicles to get preferential treatment at traffic signals. Emergency responders in Johnson County, Kansas (including Med-Act and the Overland Park Fire Department), and Independence, Missouri, both utilize traffic signal pre-emption to reduce response time. Signal pre-emption for emergency vehicles is considered an application of the Emergency Vehicle Management user service. It should be noted that not all emergency responders are interested in signal pre-emption. For example, MAST, the emergency medical responder in Kansas City, Missouri, prefers not to have signal priority based on the presumption that it is safer if drivers do not expect to have signal priority. MAST notes that this is particularly critical due to the fact that MAST serves multiple jurisdictions, and it would be dangerous with respect to driver expectation if some jurisdictions implemented signal priority, and some did not.

TRAVELER INFORMATION

Traveler information includes information about hotels, restaurants and other activities, facilities, and services. Electronic traveler information is currently available via a computer touch screen at each Visitor Center in Missouri and at a kiosk in Bartle Hall in Kansas City, Missouri.

The touch screens at the Missouri Visitor Centers, which were implemented over five years ago, allow travelers to select a region, and then receive information about restaurants, attractions, lodging, and events. Directions and maps are also available, and may be printed out. Each Visitor Center also has a hotel reservation board. Travelers can contact hotels and make reservations by using the phones provided and dialing a two digit code for the hotel. The deployment of touch screens in the Missouri Visitor Centers and the kiosk at Bartle Hall may be considered an application of the Traveler Services Information user service.

MOTORIST ASSISTANCE PATROL

Motorist assistance patrols have been implemented in both Kansas and Missouri. These programs provide motorists with assistance for minor problems (such as a stalled vehicle, a vehicle with a flat tire, a vehicle out of gas), and call a tow truck when the problem is beyond the scope of repair. These programs help reduce congestion by clearing the lane of traffic and the shoulder as quickly as possible, and thus may be considered components of the Incident Management user service.

Missouri - Missouri's motorist assistance patrol (MAP), run by MHTD, has two shifts that cover many of the busiest segments of freeway. The area is divided into zones, and is served by five vehicles and a staff of nine people (four per shift plus a supervisor). The existing zones serve:

- I-70 from west of the I-470 interchange to just east of the I-435 interchange.
- I-70 from east of the I-435 interchange to and including the south and east legs of the downtown loop.
- I-35 from the state line to M-210 north of downtown, I-70 and I-670 west of the downtown loop, and the north and west legs of the downtown loop.

The MAP service may be expanded to cover I-435 between I-70 and Grandview.

Kansas - Kansas started a motorist assistance patrol (MAP) in November 1994 with one vehicle. The program, which is run by the Kansas Highway Patrol (KHP) and funded by KDOT using safety set-aside funds, has since added a second vehicle. The program operates 20 hours per day, from 5 a.m. to 1 a.m., with a staff of five people. Although there are no specified routes or areas of assignment, much of the service is provided on the interstates. Service is provided on I-435, and on interstates north of I-435, particularly I-35. Service is also focused on areas under construction, which currently includes I-435, I-35, and K-7.

COMMERCIAL VEHICLE OPERATIONS

A number of ITS activities and studies related to commercial vehicle operations (CVO) have been underway in both Kansas and Missouri. These include the following:

- In 1994, a Kansas-Missouri ITS CVO Institutional Issues Study was completed. The purpose of this study was to determine legislative barriers that must be addressed in order to implement ITS CVO user services.
- Missouri is currently participating in a study to identify and prioritize issues related to the implementation of ITS CVO services. This study focused on services between the states of Missouri, Iowa, Nebraska, South Dakota, Minnesota, Wisconsin and Illinois.
- Both Kansas and Missouri are involved in an ongoing project to develop and perform an operational test of an electronic system that will enable motor carriers to request, pay for and receive registration, fuel tax, operating authority, and oversize/overweight permits from one state to legally operate in eight neighboring states (NE, SD, IA, IL, MN, WI).
- Missouri is currently determining the feasibility of combining electronic CVO screening and clearance with the electronic toll collection process used on the Kansas and Oklahoma turnpikes.

- Missouri is currently in the process of executing an agreement with the Center for Transportation Research and Education at Iowa State University to assist MHTD in researching and developing technical specifications necessary to implement electronic screening of commercial vehicles at the 36 Official Weigh Stations in Missouri at highway speeds. Implementation will include automatic vehicle identification, weigh-in-motion, and credential, safety, and permit verification.

System Characteristics

System characteristics include current and future freeway traffic volumes, freeway accident characteristics, freeway speeds in the morning and evening, signal control systems on selected arterials that may be appropriate for diversion from the freeway, and transit routes for the three major transit agencies in the metropolitan area.

FREEWAY TRAFFIC VOLUMES

Traffic volumes on major freeway facilities are shown in Figure 2-5. Traffic volumes shown are based on average annual daily traffic (AADT) for 1994 for Kansas and Missouri.

Note that a number of facilities have traffic volumes of 100,000 or more vehicles per day, including I-35 in Kansas from US 69 to south of downtown; I-435 from US 69 in Kansas to west of US 71 in Missouri, and immediately south of the interchange with I-70 in Missouri; and I-70 in Missouri from downtown to the interchange with I-470. The highest volume in the urban area occurs on I-35 in Kansas immediately north of the interchange with US 69. The 1994 AADT at this location was nearly 143,000 vehicles. Not only do higher volumes result in recurring congestion when demand exceeds capacity, but furthermore, incidents on these high volume facilities may be expected to result in greater delay due to the large number of vehicles affected.

Traffic volumes on major facilities are shown on a per lane basis in Figure 2-6. These values were calculated based on the 1994 AADT values for Kansas and Missouri. The highest volume per lane values occur in Kansas on I-35 between US 69 and I-635, and in Missouri on US 71 south of I-435. Note that an AADT/lane value in excess of 20,000 represents a peak hour volume in excess of 1,600 vehicles per lane, for a K-factor of 0.08. For a facility with a 70 mph design speed, volumes in excess of 1,600 vehicles per hour correspond to a level of service (LOS) D, at best.[1]

Facilities that exhibit recurring congestion, which may be evidenced by high AADT per lane values, are especially of interest if demand for the facility is expected to increase. In some cases, historical trends may be examined in an effort to ascertain future conditions. If trend analysis is considered in conjunction with high existing AADT per lane values, then I-35 in Kansas is of particular interest. I-35 has experienced steady increases in traffic volume. The increase in traffic on I-35 is evidenced by a 1989 AADT of 101,845 and a 1994 AADT of 142,630 (for the segment on I-35 just north of US 69). On the other hand, US 71, which also

[1] Transportation Research Board, 7985 Highway Capacity Manual, Special Report 209

demonstrates a high AADT per lane value, has experienced relatively steady volumes, as evidenced by a 1989 AADT of 97,690, and a 1994 AADT of 99,320.

Future traffic volumes on major freeway facilities are shown in Figure 2-7. These volumes, which were provided by MARC, are for the year 2020. Future traffic volumes on a per lane basis are shown in Figure 2-8.

FREEWAY ACCIDENTS

Freeway accident analysis was based on accident data provided by KDOT and MHTD. The results presented vary slightly on either side of the state line, due to variations in the information available.

In Kansas, KDOT accident data was provided for the five year period from 1989 through 1993. Accident data is compiled for each facility, by county. For example, all of I-35 within Wyandotte County is considered a single segment. High frequency accident spots and high frequency accident sections are also identified. High frequency accident spots are segments (0.1 miles long in urban areas and 0.3 miles long in rural areas) for which the accident rate exceeds the critical accident rate. The critical accident rate is the 95 percentile accident rate for similar roadways in the state. High frequency accident sections are roadway segments that include a number of high accident spots. The length of the high accident sections varies, depending on a variety of things, such as geometric characteristics and jurisdictional boundaries.

In Missouri, data from MHTD's Accident Master database was provided for each facility of interest. This data included information about each accident on every facility, by milepost, for a one year period (1994 for Jackson and Cass counties, 1993 for Clay and Platte Counties). Information regarding high accident locations was also provided by MHTD. Information about high accident locations included the number of accidents at each location for all legs of the interchange, and was based on a three year summary for the years 1991 through 1993.

Accident Rates - Accident rates for major freeway facilities are shown in Figure 2-9. Accident rates are expressed in terms of the number of accidents per million vehicle miles traveled. In Kansas, the accident rates were provided by KDOT and are shown for each facility by county. High frequency accident sections are also indicated. In Missouri, accident rates were calculated using the Accident Master database and average annual daily traffic volumes for the facility segment.

High Accident Locations - High accident locations on major freeway facilities are shown in Figure 2-10. The high accident locations in Missouri were provided by MHTD and are based on accident data for the years 1991, 1992 and 1993. These values include accidents on all legs of the entire interchange. For example, there were approximately 65 accidents a year on both I-70 and Van Brunt Boulevard at the I-70/Van Brunt interchange.

The values associated with the high accident locations in Kansas are based on the number of accidents in high frequency accident sections. These values are based on accident data for the five year period from 1989 to 1993. These values include only the accidents on the interstate facility itself, unless the interchange is a high frequency accident section for both the interstate and the intersecting roadway. For example, on I-35 at the Roe Avenue/18th Street Expressway interchange, the value includes only the accidents in the high frequency accident section on I-35, and does not include any accidents on Roe Avenue/18th Street Expressway. However, at the interchange of I-35 and US 69, there is a high accident section on each facility and thus the value shown includes the accidents in the high frequency accident sections on both US 69 and I-35 at the interchange.

FREEWAY TRAVEL TIMES

Freeway congestion may be evaluated by considering travel times, which reflect travel speeds. Travel speeds on major freeway facilities are shown in Figures 2-11 and 2-12 for the morning and evening peak periods. The information presented in this exhibit is based on travel time runs conducted in 1993 by the Mid-America Regional Council. Travel speeds in Missouri were modified to reflect the results of MHTD's freeway monitoring, which was conducted in 1994 and 1995. Note that the most significant congestion occurs on the north leg of the downtown loop, on I-35 north and south of downtown, on I-70 east of downtown, on I-435 south of town, and on US 71 south of I-435. Also note that the speeds on I-70 between I-435 and K-7 are less than 50 miles per hour, this is probably due to the delay caused by toll collection. This delay may be reduced to some extent by the recent deployment of electronic toll collection (ETC), however, it has not been eliminated because vehicles using ETC must still slow down to approximately 20 miles per hour.

Figure 2-13 shows "Areas of Concern" as indicated in the 79 responses to MARC's Congestion Survey (a 13 percent response rate). Note that both facilities, such as I-35 and I-70, as well as specific interchanges, such as I-29 and Barry Road, are indicated. While the results of this Congestion Survey may not be statistically representative of the viewpoint of local citizens, they do highlight some of the local concerns. Note that in many cases, the areas of concern correspond to locations that experience high traffic volumes, low travel speeds, and/or a high incidence of accidents.

ARTERIAL SIGNAL SYSTEMS

Selected arterial signal systems are shown in Figure 2-14. Systems shown include systems under the jurisdiction of Kansas City, MHTD, and Independence in Missouri, and Kansas City, Overland Park, and Lenexa in Kansas. Arterial signal systems are of particular interest on facilities that could potentially serve as alternative routes for the diversion of traffic from the freeway.

Coordination of signals on arterials that span more than one municipality is of interest not just during incidents, but also during typical operating conditions. The need for increased coordination among the various cities was noted at the public meetings.

Missouri - Kansas City, Missouri has extensive signal systems, encompassing all of the downtown loop, as well as numerous arterials. Most of Kansas City, Missouri's signals are included in either a system or network. Figure 2-14 shows some of the signal systems that may be most appropriate for diversion from the freeway. Kansas City, Missouri's system signals include both electromechanical and solid state controllers, coordinated by time clock, hardwire or communications cable interconnect. In terms of alternate routes, one example is Truman Road, which currently has solid state controllers and will have communications cable interconnect and telephone access to the system (planned for implementation). Truman Road can serve as an alternate route to I-70 between the downtown loop and I-435. As signal improvements are made, the capability of other facilities to serve as alternative routes will increase.

MHTD also maintains traffic signals in the Kansas City metropolitan area, both isolated intersections and signal systems. MHTD works closely with local jurisdictions, as evidenced by the fact that MHTD and Kansas City, Missouri, currently share signal systems on Bruce Watkins Drive. All of MHTD's closed loop signal systems utilize solid state controllers (NEMA and Type 170) and signal interconnect, and have the capability for remote access. The capabilities of -this sophisticated equipment enhance the effectiveness of facilities under MHTD's jurisdiction to be used as alternate routes for incident management. The fact that all of MHTD's signal systems are based on solid state equipment not only enhances current capabilities, but also provides flexibility with respect to expandability and the potential for future enhancements. For example, MHTD's current NEMA systems can utilize technologies such as changeable message signs and other auxiliary equipment that can be remotely activated.

Independence, Missouri has a signal system on Noland Road, between US 24 and 44th Street. Furthermore, there are currently plans to upgrade the controllers on Noland, at which time the controllers currently on Noland Road will be installed on Sterling, and Sterling will be timed as a system between Truman and US 40.

Kansas - Kansas City, Kansas, has 13 signal systems currently implemented, both network and arterial. Ten of these 13 systems are interconnected with a distributed master system and a telephone drop to the master; the remaining three use time clocks for coordination and operate as a master/slave. All signals utilize solid state controllers. In terms of alternate routes, State Avenue, Central Avenue east of I-635, and Kansas Avenue west of US 69 may be appropriate for diversion from I-70, especially given the fact that additional signal interconnect is planned for implementation on each of these facilities.

In Johnson County, Kansas, some of the arterials that could potentially be used as diversion routes are in the jurisdiction of either Overland Park or Lenexa. Overland Park has a distributed master system with 20 arterial sections, encompassing 88 coordinated intersections. All of Overland Park's signals are Type 170 microprocessor controllers, and thus signals currently operating independently could be integrated into a coordinated signal system without updating signal controller hardware. In some cases, this might be expected to result in significant benefits. For example, coordination of the signals on 103rd Street (immediately north of I-435) and/or 111th Street (immediately south of I-435), would allow these arterial facilities to be better utilized as alternative routes when there is an incident on I-435. Overland Park has communications capabilities with 120 intersections, which consists of telephone lines from the PCs to the master 170s in City Hall, and cable TV lines from the masters to the local intersections.

Lenexa, Kansas, has 43 traffic signals, over half of which are connected by fiber. All of the signals in Lenexa have solid state controllers, and there are currently eight signal systems (which encompass 34 signals), as shown in Figure 2-14. Six of Lenexa's eight signal systems have fiber interconnect, and the remaining two systems are identified as potential candidates for fiber installation. Signal systems on 87th Street, 95th Street, and Quivera have telephone access. This capability, coupled with location considerations, may make these facilities appropriate for diversion from I-35 and I-435 under some circumstances.

TRANSIT RIDERSHIP

Transit routes provided by KCATA, by the Public Transportation Division, Public Works Department in Kansas City, Kansas, and by Johnson County Transit (Kansas) are shown in Figure 2-15. Additional information about transit ridership characteristics was provided in a previous section, *Major Facilities in the Kansas City Area.*

Kansas City Area Transportation Authority - The KCATA provides service to portions of Clay, Jackson, and Platte counties in Missouri, and Wyandotte County in Kansas. However, over 95 percent of the service is concentrated in Kansas City, Missouri and Jackson County, Missouri .[1]

Public Transportation Division, Public Works Department, Kansas City, Kansas - The City of Kansas City, Kansas operates public transit, in addition to contracting with KCATA for the provision of transit service. Fares and operations are coordinated to some extent with KCATA services, although there are presently no connections between transit in Kansas City, Kansas with Johnson County Transit services.

Johnson County Transit - Johnson County Transit provides service primarily oriented to serve the commute from Johnson County to downtown and the Crown Center in Kansas City, Missouri. This service is currently provided through a contract agreement with Mayflower.

Other Transit Services - Transit service is also provided in a number of other municipalities within the Kansas City area. In some cases, transit service is provided within the city, and in other cases, transit service consists of commuter routes to downtown Kansas City, Missouri. Cities such as Independence and Excelsior Springs, Missouri, contract with KCATA for their transit service, while in other cities, such as Blue Springs, Missouri, transit service is provided by an independent operator.

Transit Service Utilizing Freeways - Because a primary focus of the Early Deployment Study is on freeways, it is useful to explore the extent to which existing transit service utilizes the freeway. Table 2-4 indicates ridership characteristics of transit routes that currently utilize the freeway.

Institutional Characteristics

The Kansas City metropolitan area encompasses a large number of jurisdictions and affected agencies, as discussed in a previous section, *Jurisdictions and Affected Agencies.* The large number of agencies operating in the metropolitan area complicates institutional issues by increasing the number of players that must be involved in any endeavor that affects the entire

[1] *Draft Long Range Transportation Plan.* March 1995, Mid-America Regional Council, Kansas City, Missouri.

Table 2-4. Transit Use of Freeways

Freeway	Location[1]	Morning Inbound		Afternoon Outbound	
		Bus Trips	Ridership	Bus Trips	Ridership
I-29 North	s/o 56th Street	2	40	2	50
Broadway Extension	n/o Broadway Bridge	6	110	6	130
I-35 North	n/o Chouteau	2	110	2	110
I-29/I-35 North	n/o Paseo Drive	5	170	5	190
I-70 East	e/o I-435	1	30	1	30
I-70 East	e/o Manchester	13	380	15	450
I-70 East	w/o Manchester	23	600	23	650
I-435 South	s/o I-70	5	140	5	160
Southwest Trafficway	s/o I-35	6	120	6	120
I-35 South	s/o Southwest Trafficway	13	215	13	215
I-35 South	n/o Southwest Trafficway	19	335	19	335
I-70 West	w/o CBD	19	220	19	290

[1] s/o = south of, n/o = north of, w/o = west of, e/o = east of.

metropolitan area. Alternately, the jurisdictions and agencies operate independently, which results in a variety of policies.

This section provides an example of one area in which cities operate independently, namely towing, as well as a general discussion of the opportunities for coordination in the metropolitan area.

TOWING OPERATIONS

One area in which the various cities operate independently is with respect to towing. Towing regulations can have a significant impact on transportation, because they impact incident management and incident removal. This impact is especially evident in the Kansas City area, where much of the congestion is related to incidents.

Currently, towing regulations vary throughout the metropolitan area. Because each city operates independently with its own regulations, tow truck operators generally must obtain a separate license for every city in which they operate. There are estimated to be approximately 50 tow companies in the metropolitan area; 15, 20 or 25 of these are in-depth operations. The remaining companies are small, with one to two trucks, and often are not in business very long.

There are a variety of tow policies demonstrated by the various cities and agencies in the Kansas City area. Some cities, such as Independence, Blue Springs, and Lee's Summit, Missouri, contract for tow services on a low bid basis. Other agencies, such as the Kansas Highway Patrol (KHP) and the City of Overland Park, Kansas, operate using a rotation system. Other cities, such as Kansas City, Kansas, have divided the city into districts, and have tow contracts within each district. Finally, some cities in the metropolitan area, such as Kansas City, Missouri, have no regulations regarding towing.

There are advantages and disadvantages to each system. Considering advantages, when a company contracts with a city, there are specifications for performance, such as response times, and there are penalties if these criteria are not met. Considering disadvantages, in some cities that have exclusive contracts with a single tow service, the contract may be for less than five dollars per tow for police tows, in which case the disabled vehicle is impounded in the police garage. A tow company would not be expected to cover its expenses by charging less than five dollars per tow, as is the case for some towing contracts. However, if the owner of the disabled vehicle has no preference as to whether or not the tow is a "police tow", or prefers to have the vehicle towed to a service station or garage, then the vehicle will not be towed as a police tow and the tow charge can be significantly higher ($65 or more). Furthermore, the tow company often receives money from a body shop if a damaged vehicle is brought in, which can make up for a loss on the tow.

In Kansas City, Missouri, vehicles are cleared on a first come, first serve basis. Tow truck operators listen to scanners and come to the scene. As a result, multiple operators may arrive at the scene, which may further delay traffic, and may contribute to congestion and traffic delays, and in some cases, additional accidents. However, Kansas City, Missouri, police note that response times are minimal under the current system, and thus incidents are cleared quickly, but not without a price, opponents contend. While charges vary significantly (sometimes depending on whether or not the motorist has insurance), towing charges as high as hundreds of dollars have been mentioned. Towing in Kansas City, Missouri, may be expected to change, however. The procurement of a new police radio system may limit access to police radio by tow truck operators, and furthermore, the city plans to introduce a bill that would divide the city into zones, and set up a primary and secondary contractor for each zone. Under this system, tow trucks would be dispatched from public works, when notified by the police.

Rotation systems, such as the ones used by the KHP and the City of Overland Park, Kansas, have generally worked satisfactorily. KHP tags abandoned vehicles, and calls tow trucks on a rotational basis. Although Overland Park utilizes a rotation system, and the Overland Park Service Commission previously set prices for towing, the practice of setting prices for towing has been called into question since a rider to a Federal Aviation Administration bill was passed in 1994. This federal deregulation legislation limits the ability of local and state jurisdictions to regulate towing operations. This legislation states that state and local jurisdictions cannot impose regulations regarding price, routes, or service on carriers of property. Although this regulation does not apply to emergency vehicles or when public safety is an issue, it does raise some questions regarding the ability of a local jurisdiction to regulate towing. This legislation has been challenged, and a ruling favorable to cities' rights to regulate towing has come down from a district court in Louisiana.

The controversy and issues surrounding tow trucks address not only police tows and removal of disabled vehicles, but also issues such as the motorist assistance patrol (MAP). Some tow agencies think that MAP should be provided by contracts with private tow truck operators, who would be paid to patrol during rush hours. Under this system, proponents say, the public would not incur equipment costs, and personnel resources could be focused only on peak hours. Some cities, such as San Diego and Los Angeles, California, have contracted with private patrols to provide this service. Other cities, such as Chicago, Illinois; Minneapolis, Minnesota; Houston, Texas; and both Kansas and Missouri in the Kansas City area, provide this service through the public sector.

OPPORTUNITIES

There are a number of activities and organizations in the metropolitan area that foster interagency communication and cooperation. These activities and organizations can contribute to the successful deployment of an intelligent transportation system both as a source of information and feedback, and as a foundation for further institutional communication and cooperation.

Incident Management Activities - Activities are currently underway to organize a bi-state incident management system. This system will provide basic guidelines for all agencies involved in incident management activities. Although incident management programs vary from region to region, in general, all address the following elements: incident detection, verification, response, removal, traffic management, and motorist information. Information about these elements will be included in an incident Management Manual, which will address everything from contacts for agencies to pre-planned alternate routes.

Incident management activities were initiated in the fall of 1994 by MARC, and have been continued by KDOT. The incident management activities have been met with a lot of interest by the agencies that have been contacted. The core group consists of approximately 25 people, and represents all the major public agencies, as well as some private groups, such as a motor club and towing companies.

While the activities for the development of an incident management program are currently underway and may be expected to facilitate and enhance incident management activities, it is important to note current practices for incident management. The agencies interviewed generally felt that the various agencies worked fairly well together at incident locations, and there is not usually any problem with respect to authority at the incident site. However, there is the potential to realize benefits from enhanced coordination and communication, which would be realized to some extent if there was an interagency plan for all activities at the incident site. Furthermore, development of an incident management program would provide agencies with a better understanding of the ramifications of one agency's activities on other agencies' activities.

Existing Organizations - The Kansas City area has Metropolitan Fire and Police Chiefs and Sheriffs Associations. These associations include members from both the State of Kansas and the State of Missouri. Organizations such as these that encompass various jurisdictions on both sides of the state line enhance communication and cooperation, which may be expected to be of benefit when interagency cooperation is required in a more structured environment, such as during large incidents that require response from multiple jurisdictions. There are also organizations that include members from smaller geographic areas, such as the Johnson County Police Chiefs Association.

INSTITUTIONALIZATION OF EARLY DEPLOYMENT PLAN

It is recommended that the ITS Strategic Deployment Plan be institutionalized. This is recommended not only with the hope that it then would have an advocate and a mechanism for deployment, but also because the document is intended to be a living document, one which will require modification and re-interpretation as local circumstances change, and as technology advances, making new technologies appropriate for deployment. Because the plan encompasses facilities in two states and multiple jurisdictions, it may be institutionalized in a regional entity, such as the Mid-America Regional Council. The institutionalization of the ITS Strategic Deployment Plan will require a team effort which includes KDOT, MHTD, and Kansas City local transportation organizations as well as MARC.

Chapter 3
User Services

Agency Perceptions of Local Applicability of ITS User Services

Twenty-nine intelligent transportation system (ITS) user services have been identified by the Federal Highway Administration (FHWA). These user services have been grouped into seven "bundles", each of which represents the application of advanced technology to a specific transportation function. The seven bundles of user services are:

- Travel and Transportation Management.
- Travel Demand Management.
- Public Transportation Management.
- Electronic Payment.
- Commercial Vehicle Operations.
- Emergency Management.
- Advanced Vehicle Safety Systems.

The following sections discuss the bundles of user services, provide a brief description of each user service,[1] and a discussion of its applicability in the Kansas City area. Each user service is discussed in the context of how it would potentially enhance the efficiency or capability of the transportation system, and how it would help meet the needs identified by the various users of the transportation system. The discussion of each user service is based on input received during interviews with local agencies. Over twenty interviews were held with local agencies, including public works, emergency response, transit, and private agencies (such as towing and freight). Input on the user services was also received during two public meetings.

TRAVEL AND TRANSPORTATION MANAGEMENT

The Travel and Transportation Management bundle includes six user services that are designed to use advanced systems and technologies to improve the safety and efficiency of the transportation system, and to provide motorists with current information about traffic and roadway conditions, as well as traveler services. The user services in the Travel and Transportation Management bundle are shown in Table 3-l and discussed in greater detail below.

En-Route Driver Information - The En-Route Driver information user service provides motorists with information about traffic and roadway conditions due to both scheduled activities (such as construction or special events) and unscheduled activities (such as accidents). En-Route Driver Information is provided after the trip has begun. Driver information may be provided via radio, variable message sign (VMS), or in-vehicle signing. Because anything that would divert the driver's eyes from the road might have a negative impact on safety, it has

[1]Descriptions of user services and user service bundles are based on the definitions provided in National *ITS Program Plan, Intelligent Transportation* System, edited by Gary W. Euler and H Douglas Robertson, March 1995

Table 3-1. Travel and Transportation Management User Services

Bundle	User Services
Travel and Transportation Management	En-Route Driver Information
	Route Guidance
	Traveler Services Information
	Traffic Control
	Incident Management
	Emissions Testing and Mitigation

been suggested that in-vehicle visual displays would be limited when the vehicle is moving. Furthermore, alternatives such as "heads up" displays would be used to display the limited visual information provided when the vehicle is in motion.

Local Applicability: En-Route Driver Information was identified as an appropriate user service for the Kansas City area by a number of agencies. En-Route Driver Information meets the critical need for communication with motorists. One mechanism for En-Route Driver Information, a highway advisory radio (HAR) system, has been set up by the Missouri Highway and Transportation Department (MHTD) and was discussed in a previous section, *Current and Planned ITS Applications in the Kansas City Area.*

Multiple agencies would expect benefits from the provision of En-Route Driver Information. In addition to allowing public works and engineering agencies to communicate information about road closings and road construction, En-Route Driver Information may benefit emergency response agencies, because it may facilitate access to incidents, and decrease response time. Fire departments, in particular, noted the advantages of warning drivers that equipment would be accessing the incident site by traveling on the freeway in the "wrong" direction (fire equipment often accesses an incident on the northbound lanes by traveling northbound on the southbound lanes from the nearest interchange).

Although transportation and public works agencies did perceive a potential benefit from the provision of En-Route Driver Information, some agencies felt that the benefits were limited by a lack of alternative routes. This illustrates the close link between user services, in this case between the En-Route Driver Information user service and the Route Guidance user service, which is discussed next.

Route Guidance - The Route Guidance user service provides motorists with a suggested route to reach their destination, along with instructions for upcoming turns or other maneuvers. Ultimately, a route guidance system would provide travelers utilizing all modes with directions to their destinations based on real-time information about the transportation system, including lane closures, traffic conditions, and transit information.

Local Applicability: Route Guidance was considered a priority for many agencies because it provides another mechanism for communication with motorists. The role of Route Guidance during incident management was of particular interest, as indicated by local agency comments.

Public works agencies noted that the success of route diversion was constrained by the availability of alternate routes. Johnson County indicated that the potential for diversion in their jurisdiction was constrained by a lack of alternative routes, and a lack of available capacity on the alternative routes that do exist. In these cases, it was noted that congestion would merely be moved, rather than reduced. On the other hand, Kansas City, Missouri, felt that capacity was available in some cases, and identified Route Guidance as a priority.

Enforcement agencies felt that route guidance information would be very helpful. It was noted that such a system could be used to direct motorists back onto the freeway when the freeway is closed due to an incident, thus freeing officers to direct traffic rather than give directions. One enforcement agency noted that even local motorists can easily lose their bearings when they are diverted from the freeway into an unfamiliar neighborhood. The importance of route guidance information was also supported by a traffic reporter, who said that listeners indicate that route guidance information is the most valuable information provided.

Traveler Services information - The Traveler Services Information user service provides the traveler with information regarding local services and facilities, and has been compared to a computerized version of the "yellow pages". This information would be available for pre-trip planning via a terminal in the home, office or hotel. This information would also be available en-route via either a terminal in the vehicle or at public facilities such as highway rest stops or transit terminals. Information regarding the location, services or amenities, and operating hours would be available for a variety of goods and services, including food, lodging, parking, auto repair, hospital and medical, and police stations. This service would also allow the traveler to communicate with service providers interactively, which would allow travelers to reserve rooms or confirm services.

The type of information provided would vary depending on whether the information is accessed at a fixed location (such as a hotel lobby or transit center) or en-route (such as in a transit vehicle, private auto, or commercial vehicle). The type of information and method of presentation would also vary, information presented to drivers while the vehicle is in motion would be restricted for safety reasons; when the vehicle is parked, the driver would be free to access and utilize all available information.

Local Applicability: The perceived importance of Traveler Services Information varies from agency to agency. From one perspective, this kind of service is of little importance, at least in the short or medium term. Another perspective considers traveler information fairly important due to Kansas City's role as a regional center.

Some applications of the Traveler Services Information user service have been implemented in the area. Missouri currently has computer touch screens that provide traveler information at all visitors centers, and there is a kiosk with traveler services information at Bartle Hall, as discussed in a previous section, Current *and* Planned *ITS Applications in the Kansas City Area.*

Traffic Control - The Traffic Control user service focuses on increasing the safety and efficiency of traffic flow on streets and highways. It includes adaptive signal systems on surface streets and freeway control techniques such as ramp metering on freeways.

The Traffic Control user service would gather data from the field, analyze it, and use it to assign right-of-way to users of the transportation system. The goal is to maximize the efficiency of the movement of people and goods through the roadway network, thus it may provide preferential treatment to transit and other high occupancy vehicles (HOVs), if preferential treatment is in accordance with local objectives and operating policies. The proper deployment of traffic control would help alleviate congestion problems and improve air quality. The information generated by the Traffic Control user service can also be disseminated to the general public and to service providers, laying the foundation for other user services.

Traffic Control, which includes monitoring, control, and communications, provides the basis for many of the other user services. The data collected, processed and used by traffic control will be utilized by virtually all of the other services in the Travel and Transportation Management bundle, as well as some of the services in the Public Transportation Operations and Emergency Management bundles.

Local Applicability: Many agencies identified Traffic Control as a priority for Kansas City. Traffic control is considered a priority partly because it is necessary for deployment of other user services that depend on the information gathered and processed by the Traffic Control user service.

Not all elements of Traffic Control are necessarily desirable in the Kansas City area, at least in the short term. For example, while some agencies expressed a great interest in ramp metering and thought that it had the potential to reduce recurring congestion and increase safety on the freeway, not all agencies thought that ramp metering would be an appropriate strategy. Some agencies felt that freeway ramp metering would create more problems than it would solve, and many noted the difficulty ramp metering would create with respect to driver education and enforcement.

Advanced signal systems for arterial traffic control are also of interest. Overland Park and Lenexa, Kansas, both have plans to implement video monitoring at selected high volume intersections. Plans for deployment in Overland Park may, however, be delayed due to a lack of available capacity on the communications cable currently used.

Incident Management- The Incident Management user service focuses on enhancing incident detection and response. Incident detection would be enhanced by advanced sensors, data processing, and communications, which would allow officials to quickly and accurately identify a variety of incidents, and would allow immediate deployment of actions to minimize the effects of incidents. The service would also help officials identify and forecast hazardous weather, as well as traffic and roadway conditions, so that preventative action could be taken to minimize the possible consequences. Incident Management also involves activities that minimize the negative impacts of planned events, such as lane closures or special events. Incident Management may include coordinating the schedules of construction or other planned roadway activities.

Local Applicability: An effort to coordinate incident management activities is currently underway in the Kansas City area as discussed in the section, *Institutional Characteristics.* These activities may help provide the framework for the institutional coordination needed for incident management. Many of the agencies interviewed felt that Incident Management was an important user service, and identified it as a priority area.

All agencies who respond to incidents noted that information regarding the exact location of the incident would be very helpful. Information called in by motorists is often vague and/or inaccurate, and multiple callers referencing the same incident may tie up the dispatcher. Video monitoring or some other mechanism for identifying the kind of emergency equipment needed would also be helpful. This information would not only assure that the needed equipment was available in a timely manner, but would also help avoid situations where large equipment is brought to the scene when it is not needed, which not only further disrupts traffic flow, but also ties up equipment that may be needed elsewhere.

MAST, the emergency medical provider in Kansas City, Missouri, noted that information regarding weather and roadway conditions would be very helpful. Because MAST services a wide geographic area, and because roadway and weather conditions vary throughout the region, these conditions have a significant impact on which ambulance can most quickly access the incident. Weather information is currently collected by the Kansas Department of Transportation (KDOT) and MHTD, Kansas City, Missouri, and Olathe, Overland Park, and Lenexa, Kansas.

It was also noted that there would be some benefit to the coordination of planned events, such as construction. By coordinating the construction schedules of various agencies, disruption may be minimized. For example, ideally construction activities on a major facility would not occur concurrently with construction activities on an alternative route. The need for coordination of construction projects is relevant for arterials, as well as freeway facilities, as was noted at the public meetings.

Most of the agencies felt that coordination among the various agencies working at the incident site is generally very good, and there are rarely any problems with respect to authority. However, one agency noted that all agencies could benefit from a better understanding of the objectives of other agencies, as well as a better understanding of the effects of one agencies activities on the activities of other agencies. Another agency noted that incident management activities would benefit from a plan for traffic control. Currently, traffic control is handled by the police officer, who bases decisions on judgment and experience, but not with guidance from any plan. Many of the public works and engineering agencies, agencies that might have some valuable insight regarding traffic control, indicated that they are not involved in any incident management activities, however, in other jurisdictions such agencies are involved. For example, KDOT is a key player with respect to incident management on Kansas freeways.

The representative from the Visitors and Convention Bureau further noted that an incident involving a motor coach could be particularly disastrous. Evacuation would be complicated not only by the fact that many emergency responders are not trained to evacuate a motor coach, but also by the fact that many of the passengers may be older and less mobile.

Emissions Testing and Mitigation - Emissions Testing and Mitigation can be used to provide area-wide pollution information for use in monitoring air quality and providing data to be used to develop strategies to improve air quality. Emission information may be used to re-route traffic around sensitive air quality areas, or even, under severe conditions, to control access to such areas. Other applications include roadside monitoring of individual vehicles to identify vehicles that exceed emission standards and diagnostic systems that provide in-vehicle monitoring of emissions levels. In-vehicle monitoring systems would alert the driver of non-compliance so that corrective measures could be taken.

Local Applicability: Kansas City generally has very few problems with respect to air quality. In fact, Kansas City has been an attainment area for all "criteria" pollutants defined in the 1990 Clean Air Act Amendments. However, there were a number of ozone exceedances in the summer of 1995. As long as Kansas City does not have significant problems with respect to pollution, Emissions Testing and Mitigation would not be considered a priority by any of the agencies surveyed.

TRAVEL DEMAND MANAGEMENT

The Travel Demand Management (TDM) bundle includes three user services that are designed to reduce congestion on the transportation infrastructure by encouraging commuters to use modes other than the single occupant vehicle (SOV), to alter the time and/or location of their trip or to eliminate a trip. In response to congestion and air quality concerns, many cities have already initiated travel demand management activities, and others will be required to in response to the mandates of the 1990 Clean Air Amendments. The user services in the Travel Demand Management bundle are shown in Table 3-2 and discussed in greater detail below.

Table 3-2. Travel Demand Manaaement User Services

Bundle	User Services
Travel Demand Management	Demand Management and Operations
	Pre-Trip Travel Information
	Ride Matching and Reservations

Demand Management and Operations - The Demand Management and Operations user service attempts to accomplish three primary goals: reduce SOV travel, particularly SOV commuting; affect a mode change from SOVs to HOVs, specifically in certain targeted markets; and provide a variety of mobility options. In an effort to accomplish these goals, demand management and operations may facilitate convenient alternatives to the SOV in an effort to affect a change in mode, such as transit service enhancements, the development and/or improvement of HOV facilities, and the deployment of Carpool and Vanpool programs.

This user service may also affect mode choice through travel incentives and disincentives, through controls on the availability, location, and price of roadways and parking. These measures are expected to improve traffic and transit operations, and increase auto occupancies. Alternative work arrangements, such as variable work hours, compressed work weeks, and telecommuting may also be implemented to in an effort to manage demand.

Local Applicability: Air quality concerns and congestion are often the primary impetus for the deployment of Demand Management and Operations activities. Because Kansas City has not had significant problems with respect to either air quality or congestion, Demand Management and Operations activities may be more appropriate in the medium to long term.

Various agencies, for example MHTD, did state that strategies that provide and encourage alternatives to the SOV would be needed in the long term. This perspective is also illustrated by studies such as the commuter rail study currently being conducted for Johnson County, and the light rail study recently completed for the Kansas City Area Transportation Authority (KCATA). Furthermore, the KCATA has plans to implement a Vanpool program, although the details of the plan were not available.

Pre-Trip Travel Information - The Pre-Trip Travel Information user service provides travelers with information prior to departure, before a mode has been chosen. This information may encourage alternatives to SOV travel, including either an HOV mode or the elimination of a trip. Information about transportation demand management (TDM) pricing strategies may also be available to further encourage alternatives to the SOV. Coordination with electronic payment services (discussed later) would further enhance the capabilities and presumably the effectiveness of Pre-Trip Travel Information.

Pre-trip information includes a range of multimodal transportation information that may be accessed at home, work, or other major sites where trips originate. Information to be provided may include transit routes, schedules, transfers, fares, intermodal connections, and ride matching services; current traffic and highway conditions, regulations and tolls; information on incidents, accidents, and road construction; current and predicted congestion and traffic speeds on specific routes; parking conditions and fees; availability of park-and-ride facilities, special event information, and weather information.

Local Applicability - Pre-Trip Travel Information was deemed appropriate for deployment in the medium to long term. While some agencies thought it would be of minimal benefit, others thought it was important and noted that once the information was available for En-Route Driver Information, it would be easy and relatively inexpensive to provide this information for pre-trip planning.

Enforcement and emergency response agencies indicated that Pre-Trip Travel Information would be beneficial to the extent that it would reduce the volume of traffic near an incident location. If this information causes motorists to alter their travel plans (time of travel, travel route, mode of travel or the elimination of a trip), then it would be beneficial.

Interviews with transit agencies suggest that Pre-Trip Travel Information would be of interest only if it were proven to pay for itself in terms of increased efficiency or decreased personnel costs (if it would eliminate or reduce the need for operators answering individual questions on the transit information line). Furthermore, the information provided would have to be simple to understand.

Ride Matching and Reservations - Ride Matching and Reservations provide a strategy for reducing demand by facilitating and encouraging ridesharing as an alternative to the SOV. This service expands the market for ridesharing by providing real-time ride matching information along with reservations and vehicle assignments.

Under this service, people who wish to rideshare would provide a travel itinerary (date, time, origin and destination) and any specific restrictions or preferences (the need for wheelchair access, mode preference, etc.) to a ride matching service. The traveler would then receive ridesharing options for that itinerary, considering the preferences noted.

Local Applicability: All of the agencies surveyed currently direct ridesharing inquiries to the Mid-America Regional Council's (MARC) ridesharing program. Although MARC has no plans to change their ride matching program, they are interested in new technologies. Because Kansas City has been an attainment area with respect to pollution, there have been few employers that have offered incentives for ridesharing. Due to the preference for autos and the current lack of disincentives associated with the personal auto, as well as the current lack of incentives for HOVs (there are no preferential facilities such as freeway HOV lanes or preferential parking), the current potential for ride matching is limited.

In the long term, however, circumstances may change, and there may be a greater potential for Ride Matching and Reservations. Various agencies mentioned that HOV lanes might become a viable alternative in the future. In fact, in 1995 Missouri attempted to introduce laws that would enable MHTD to build, operate, and maintain HOV facilities, and would allow penalties for violations. The deployment of HOV lanes or other incentives to ridesharing would complement the deployment of user services such as Ride Matching and Reservations, making deployment more feasible.

Interviews with transit agencies suggest that some agencies believe that ride matching and vanpooling have the potential for growth in the future, and some agencies are exploring the market. KCATA has plans underway for a Vanpool program. However, a ride matching and reservation system would be of interest only if it were proven both in terms of hardware and software capabilities, as well as cost effectiveness.

PUBLIC TRANSPORTATION MANAGEMENT

The Public Transportation Management bundle includes four user services that are designed to utilize advanced vehicle electronic systems to provide data which is then used to improve transit service to the public. The user services in the Public Transportation Management bundle are shown in Table 3-3 and discussed in greater detail following a general discussion regarding the local applicability of this bundle of user services.

Table 3-3. Public Transportation Management User Services

Bundle	User Services
Public Transportation Management	Public Transportation Management
	En-route Transit Information
	Personalized Public Transit
	Public Travel Security

Local Applicability - Transit agency interest in ITS user services is tempered due to financial limitations. Faced with tight budgets and threats of federal budget cuts, transit agencies are more concerned with providing basic services than with advanced technologies and ITS user services. In this environment, it appears that the only ITS user service elements of interest are those that are proven with respect to technology, user acceptance, and cost effectiveness. Thus, in general, the Public Transportation User Services may be considered appropriate for deployment in the medium or long term, unless noted otherwise below.

Public Transportation Management - Public Transportation Management automates the operations, planning, and management functions of public transportation systems. It would provide real-time computer analysis of vehicles and facilities to improve transit operations and maintenance. The analysis would identify deviations from the schedule and offer potential solutions to dispatchers and drivers. This service would help maintain transportation schedules and assure transfer connections from vehicle to vehicle and between modes, and could be coupled with traffic control services to facilitate quick response to service delays.

Information regarding passenger loading, vehicle running times, accumulated miles and hours, and vehicle maintenance would help improve service and provide managers with extensive information on which to base decisions. Service schedulers would have timely data to adjust trips. Personnel management would be enhanced with automatic recording and verification of driving and maintenance task performance. Reports, including management, operations, and Section 15 reports, would be prepared with greater efficiency.

Local Applicability: KCATA currently has an automatic vehicle location (AVL) system, a critical component in a Public Transportation Management system, as was discussed in a previous section, *Current* and *Planned ITS Applications in* the *Kansas City* Area. Although the AVL system is not currently working due to hardware failure, a grant has been awarded by the Federal Transit Administration (FTA) to purchase equipment that will return the AVL system to working order.

En-Route Transit information - En-Route Transit Information would provide information to travelers using public transportation after they begin their trips. Real-time, accurate transit service information would be available on-board the vehicle, and at transit stations and bus stops to assist travelers in making informed decisions and itinerary modifications once a trip is underway.

Personalized Public Transit - Personalized Public Transit would provide transit vehicles with flexible routes which offer more convenient, and often more cost effective, service to customers where traditional, fixed route operations cannot be economically justified. Small, publicly or privately operated vehicles would provide on-demand routing to pick up passengers who have requested service and deliver them to their destinations. Route deviation schemes, where vehicles leave a fixed route for a short distance to pick up or discharge passengers, is another possible approach. Vehicles providing this service include small buses, taxis, or other small, shared-ride vehicles. This type of service could expand transit service to lesser populated locations and neighborhoods and could potentially provide transportation at a lower cost and with greater convenience than conventional fixed route transit.

Local Applicability: KCATA currently offers one version of Personalized Public Transit, called MetroFlex, on two routes. MetroFlex includes two services: rush hour service, during which the bus will deviate a few blocks (within a certain zone) from its designated route if a “standing order” has been requested (by phone); and midday service, during which door-to-door service can be arranged anywhere within the service zone. This service, which became available in April (the first route) and July 1994 (the second route), has proven to be very successful and more cost effective than regular route transit (a special wage agreement with the labor union has enhanced the cost effectiveness of the service). Arrangements for this service are currently provided by a single human operator/dispatcher.

Public Travel Security- The Public travel Security user service would create a more secure environment for transit patrons and operators by providing systems that monitor the environment in transit stations, parking lots, bus stops, and on transit vehicles. These systems would generate alarms, either automatically or manually, when necessary. Deployment of this user service would improve security, and the perception and acceptance of transit. This service can be integrated with other anti-crime activities.

Local Applicability: Security on public transit is reported not to be a major issue for Johnson County. KCATA and Kansas City Kansas, however indicate that personal safety and security is a major issue, particularly with respect to the perception of security. However, security is an issue not necessarily on the bus itself, but on the street and in the neighborhood where patrons must wait for the bus. Security at park-and-ride lots is also a concern. Note that safety in this case refers not so much to freedom from accidents (as is implied when discussing freeway safety), but rather freedom from incidents of crime.

ELECTRONIC PAYMENT

The Electronic Payment bundle includes one user service, Electronic Payment Services, shown in Table 3-4 and discussed below.

Table 3-4. Electronic Payment User Service

Bundle	User Service
Electronic Payment	Electronic Payment Services

Electronic Payment Services would allow travelers to pay for travelers to pay for transportation services with electronic cards or tags. The goal is to provide travelers with a common electronic payment medium for all transportation modes and functions, including tolls, transit fares and parking. Electronic payment services would encompasses the integration of payment systems of various modes to create an intermodal user service, as well as the improvement of payment systems for separate transportation modes. Payment systems for various modes would have to be perfected independently before they could be integrated.

Another goal is integration among systems in different states, especially with respect to toll payment. Electronic toll collection, transit fare payment, and parking payment would be linked through an intermodal multi-use electronic systems. A common fee payment structure could be used with all modes, possibility tying into roadway pricing options. Coordinated pricing strategies and incentives for HOV travel would be Facilitated by such a system. Components of Electronic Payment Services include electronic toll collection, electronic fare collection for transit, and electronic parking payment.

Local Applicability - Electronic toll collection was recently implemented on the Kansas Turnpike. Additionally, there are some potential applications for Electronic Payment Systems in the medium to long term. Public works and engineering agencies note that, in the long term, some form of congestion pricing might be viable. Under a congestion pricing system, commuters would pay a premium for use of roadways that are in high demand during the peak period, with reduced cost or no cost travel during the off peak period. While there may be limited applications for this scenario, one concept explored in other metropolitan areas is the deployment of an HOV facility that may be used by single occupant vehicles during the peak period for a fee.

Local transit agencies may wish to explore a "smart card" technology to facilitate electronic payment, particularly for patrons transferring from one transit provider to another. This would be especially beneficial if commuter rail, which is currently being studied by Johnson County, is implemented and coordinated with KCATA transit services at the proposed Union Station intermodal facility. Ideally, transit patrons would pay for transit services on a weekly, monthly or even annual basis, rather than on a per-ride basis. Eventually, a "cashless system" would be preferred. This would not only be more convenient for transit patrons but it would also allow bus drivers to focus on driving, rather than fare collection. A cashless system would also provide benefits if it would allow patrons to board the bus more quickly.

The potential for integration and coordination is illustrated by the fact that the Kansas Turnpike has offered to let KDOT use the "toll tags" for commercial vehicle operations services, if needed.

COMMERCIAL VEHICLE OPERATIONS

The Commercial Vehicle Operations (CVO) bundle includes six user services that are concerned primarily with freight movement and focus in two specific areas, one to improve private sector fleet management, and one to streamline regulatory functions, The user services in the Commercial Vehicle Operations bundle are shown in Table 3-5 and discussed in greater detail following a general discussion of the local applicability of this bundle of user services.

'able 3-5. Commercial Vehicle Operations User Services

Bundle	User Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance
	Automated Roadside Safety Inspection
	On-Board Safety Monitoring
	Commercial Vehicle Administration Processes
	Hazardous Material Incident Response
	Freight Mobility

Local Applicability - An interview with Yellow Freight indicated that they have explored the feasibility of CVO user services through a number of pilot studies. Although in every case the results of the studies showed that the ITS technology worked as it should, the benefits were not great enough to offset the costs. Many of the ITS user services may, however, be very well suited to serve niche markets, for example, trucks delivering goods to "just-in-time" customers and other trucking entities whose services are very time sensitive.

An *Intermodal freight Strategies Study*[1] provides some insights regarding the major issues confronting the trucking industry in Kansas City. Survey responses indicate that trucking efficiency and roadway congestion are both significant issues.

Trucking efficiency is usually measured in terms of profit, which is affected by cargo losses due to damage, transit time, cost per pound, and on-time delivery for "just-in-time" customers. In an effort to enhance efficiency, many trucking agencies apparently would like to use triple trailers, which would also alleviate problems associated with driver shortages. Although the subject was not specifically addressed, use of triple trailers would probably be opposed by many of the agencies interviewed for the ITS study, based on the fact that many of these agencies wanted to limit even conventional truck traffic to certain roadways and during certain hours.

Roadway congestion, another major issue, affects both truckers and motorists. With respect to congestion, trucking agencies noted that both access and traffic flow need to be addressed. Trucking agencies apparently try to avoid commuter peaks, which benefits both truckers and commuters. Trucking agencies' interest in avoiding congestion would also imply that additional benefits that could be gained from information systems that provide truckers with real-time traffic information. This is supported by the fact that Yellow Freight works very closely with the traffic control center in Minneapolis, Minnesota, providing traffic information as well as receiving it. In Kansas City, specific facilities that were noted for congestion include the Chouteau Bridge and I-70, which trucking agencies noted carries too much traffic, but is a key corridor for highway use.

Trucking agencies also indicated interest in a number of issues related to public policy. These include a need for better understanding of new technologies and their effects, public and private partnerships including issues of equity, and movement and routes for hazardous material. These issues may relate to ITS in a number of ways. The need for a better understanding of new technologies relates to ITS and the need to better communicate its capabilities and limitations; public and private partnerships relate to ITS funding issues; and routes for hazardous materials tangentially relate to the ITS user service Hazardous Material Incident Response.

Commercial Vehicle Electronic Clearance - Commercial Vehicle Electronic Clearance would allow enforcement personnel to electronically check safety, credentials, and size and weight data for transponder-equipped vehicles before they reach an inspection site, selecting only illegal or potentially unsafe vehicles for an inspection. Safe and legal carriers would be able to travel without stopping for compliance checks at weigh stations, ports-of-entry, and other

1 *Intermodal Freight Strategies Study, Working Paper No 3: Industry Input* and Survey, JBM In association with R L Banks and Associates, Inc , eTc Institute, and Jane Mobley Associates. March 1995

inspection sites. This service will also support the North American Free Trade Agreement (NAFTA) by expediting international carriers at the Mexican and Canadian borders.

Local *Applicability* There are a number of local applications of the Commercial Vehicle Electronic Clearance user service. For example, Missouri is conducting a study to determine the feasibility of combining electronic CVO screening and clearance with the electronic toll collection process presently used on the Kansas and Oklahoma Turnpikes. This activity demonstrates the potential not only for CVO activities, but also for coordination between various ITS activities for enhanced effectiveness.

If state agencies did not initiate activities such as Commercial Vehicle Electronic Clearance, it is likely that would be slow to be initiated by the private sector. Benefits of the Commercial Vehicle Electronic Clearance user service to large carriers are limited by the fact that large carriers such as Yellow Freight are often waved through when there is a queue, which is when time savings would be most significant. Furthermore, Yellow Freight indicated that their drivers are paid based on mileage, and thus time savings from electronic clearance are not of benefit to the company. Thus, one barrier to implementation of this and other CVO user services is the fact that the individual drivers who would stand to benefit significantly from the time savings due to deployment are unable to benefit from any economies of scale (as would a large trucking firm), and probably have limited capital available to invest in the necessary equipment.

Automated Roadside Safety Inspection - Automated Roadside Safety Inspections would use safety data provided by electronic clearance combined with advanced technologies to allow more selective and rapid inspections. Through the use of sensors and diagnostics, inspectors will eventually be able to check vehicle systems and driver requirements and ultimately driver alertness and fitness for duty.

Local Applicability: Enforcement agencies noted that vehicle inspections serve not only to identify unsafe vehicles and vehicles that are in violation of trucking regulations, but vehicle inspections also result in the apprehension of narcotics and other illegal substances.

With respect to advanced sensors and diagnostics, technology capable of identifying driver alertness may be beneficial, because it is not uncommon for drivers to keep multiple log books to avoid compliance with regulations. Application of this element of the user service is currently constrained by a lack of available and proven technology.

On-Board Safety Monitoring - On-Board Safety Monitoring would allow non-intrusive monitoring of the driver, vehicle, and cargo and notification of the driver, carrier, and possibly enforcement personnel if an unsafe situation arises. An unsafe situation might involve driver fatigue, vehicle systems, or cargo shifting. Eventually, this service would tie into the Automated Roadside Safety Inspection and Commercial Vehicle Electronic Clearance user services.

Local Applicability: Although On-Board Safety Monitoring is of interest to numerous local agencies, limited available technologies currently preclude deployment.

Commercial Vehicle Administrative Processes - Commercial Vehicle Administrative Processes would allow carriers to purchase credentials and collect and report fuel and mileage tax information electronically. Through automation, this user service should significantly reduce the paperwork burden for both carriers and states, and furthermore, it has the potential for simplifying compliance operations.

Local Applicability: Some action has been taken to coordinate trucking permits across state lines. Missouri and Kansas are both currently working with other states to provide cooperative permitting agreements. Such agreements could eventually provide the foundation for the elimination of "invisible barriers" between states. Kansas and Missouri are both participants in an ongoing project to develop and perform an operational test of an electronic system that will enable commercial vehicles to request, pay for and receive registration, fuel tax, operating authority, and oversize/overweight permits from a single state and legally operate in up to eight states. Missouri is also developing technical specifications for vehicle screening at weigh stations that would include automatic vehicle identification, weigh-in-motion, and credential, safety and permit verification.

Hazardous Materials Incident Response - Hazardous Materials Incident Response would provide emergency response personnel at the scene of a hazardous materials incident immediate information on the types and quantities of hazardous materials present in order to facilitate a quick and appropriate response.

The National Academy of Sciences has determined that it is not cost effective to track all hazardous material shipments. For certain types and quantities of hazardous materials, it may be important to locate shipments only when they are involved in a serious accident or incident. This specific cargo information would then be provided to the appropriate emergency responders.

Local *Applicability:* Although it may not be cost effective to track all hazardous material shipments, hazardous material emergency response personnel indicated that it would be beneficial to track certain kinds of hazardous material. Furthermore, the volume of hazardous material traveling through the Kansas City area is of interest. It has been estimated that Kansas City ranks fourth in the nation in terms of hazardous cargo in transit.

Yellow Freight indicated that all trucks carrying hazardous material are legally required to bear yellow placards and carry associated paperwork on board. Furthermore, their existing computer system already has the capability to locate and identify cargo, including hazardous material. Enforcement agencies indicate that small, independent truckers may be less familiar with the regulations regarding the transport of hazardous material, and in some cases are even unaware that the cargo being carried is, in fact, considered hazardous.

Freight Mobility - Freight Mobility would provide links between drivers, dispatchers, and intermodal transportation providers, enabling carriers to take advantage of real-time traffic information, as well as vehicle and load location information, to increase productivity.

Local *Applicability:* There would presumably be some local applications for the Freight Mobility user service, based on the volume of truck and train cargo that comes through Kansas City. However, deployment of this user service would perhaps be more appropriate by private entities. Private entities may not be interested in deployment of this user service until the benefits outweigh the costs. Yellow Freight has conducted pilot studies on Freight Mobility projects, and found that although the systems worked as they should, the costs were greater than the benefits. This is partly due to the fact that Yellow Freight already has a system to track its cargo, and thus some of the benefits are redundant and/or marginal.

EMERGENCYMANAGEMENT

The Emergency Management bundle includes two user services that relate directly to the detection, notification, and response to emergency and non-emergency incidents which take place on or adjacent to the roadway. The focus is the improvement of the ability of roadside service providers, as well as the ability of police, fire, and rescue operations to respond appropriately, thereby saving lives and reducing property damage. The user services in the Emergency Management bundle are shown in Table 3-6 and discussed in greater detail below.

Table 3-6. Emergency Management User Services

Bundle	User Services
Emergency Management	Emergency Notification and Personal Security
	Emergency Vehicle Management

Emergency Notification and Personal Security - Emergency Notification and Personal Security focuses on decreasing the time it takes for responding agencies to be notified of emergency and non-emergency incidents, and providing an accurate estimate of the location of the vehicle in need of assistance. This service includes both driver safety and personal security, in instances where manual notification of incidents is possible, and automated collision notification, in cases where incident severity precludes manual notification of incidents.

Local *Applicability:* As noted with respect to the Incident Management user service, both enforcement and emergency response personnel would benefit from rapid identification of incidents, as well as from accurate identification of incident location. Currently, incidents are often identified by motorists who call in using cellular telephones. These motorists frequently provide insufficient and inaccurate information regarding the type and location of incident,

Emergency Vehicle Management - Emergency Vehicle Management focuses on decreasing the time it takes for agencies to respond once the incident is reported to the operator or dispatcher. This includes three subset-vices, emergency vehicle fleet management, route guidance, and signal priority. Emergency vehicle fleet management would provide information regarding emergency vehicle location, and automated support to dispatchers to help determine which vehicle can most quickly reach the incident site. Route guidance would assist in the determination of the quickest route to the incident scene, and from the scene to the hospital, if needed. Signal priority would provide the capability to pre-empt traffic signals on emergency vehicle’s route, and the capability to warn drivers that an emergency vehicle is approaching.

Local Applicability: There appear to be some opportunities for the local application of components of the Emergency Vehicle Management user service. Automatic vehicle location (AVL) systems, the basis for emergency vehicle management, have been considered at many of the enforcement and emergency response agencies, although few are planning to implement such systems in the near future due to cost restraints. And, in fact, some agencies indicated that such an AVL system would not be desirable, because personnel would resist having their location tracked.

Med-Act (the emergency medical response agency in Johnson County, Kansas), has plans to procure an AVL system, and MAST (the emergency medical response agency in Kansas City, Missouri) currently has an AVL system, as discussed in a previous section, *Current and Planned ITS Applications in the Kansas City Area*. MAST has tried various fleet management systems to identify the vehicle that can most quickly reach the incident site, but these systems have not proven satisfactory. MAST noted that a route guidance system that provided information about weather and roadway conditions would be of particular benefit. Weather information is currently collected by KDOT, Kansas City, Missouri, and the Cities of Overland Park, Olathe, and Lenexa, Kansas. This weather information could presumably be utilized by MAST and other emergency vehicle responders.

With respect to signal priority, there are a variety of perspectives. Some jurisdictions have implemented such systems with satisfactory results (such as the Overland Park Fire Department and Med-Act in Johnson County Kansas, and the City of Independence, Missouri), but other agencies (such as MAST) prefer not to have signal priority because they feel that it is safer if their drivers do not expect to have signal priority, as discussed in the section, *Current and Planned ITS Applications in the Kansas City Area.*

ADVANCED VEHICLE SAFETY SYSTEMS

The Advanced Vehicle Safety Systems bundle includes seven user services that are related primarily to the safety goals of ITS. These user services enhance safety by introducing technologies that would diminish the number and severity of crashes. The user services in the Advanced Vehicle Safety Systems bundle are shown in Table 3-7. A brief definition of each user service is provided following a general discussion regarding the local applicability of this bundle of user services.

Local Applicability: The technologies necessary for user services in the Advanced Vehicle Safety System bundle are not appropriate for local application during the planning horizon considered in this study. Many of these technologies are currently in the research and development stages. Technologies that have been developed are perhaps more appropriate for deployment by private entities, such as car manufacturers, rather than public agencies at this point in time. When the technologies needed for these user services are fully developed and tested, there may be some applications in the Kansas City area. For example, Delco is working on FOREWARN, a microwave radar detector device introduced in 1993 to alert school bus drivers to the presence of children in the driver's blind spots.' This kind of system could be implemented not only on school buses, but also on transit vehicles.

1" Closing the Gap on Intelligent Vehicles, Traffic Technology International Talks to Gary Dickenson, Delco Electronic Corporation" *Traffic Technology International,* Spring 1995

Table 3-7. Advanced Vehicle Safety Systems User Services

Bundle	User Services
Advanced Vehicle Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Collision Avoidance Safety Readiness Pre-Collision Restraint Deployment Automated Highway Systems

Longitudinal Collision Avoidance - Longitudinal Collision Avoidance systems address vehicle collisions in which one or two vehicles are moving in essentially the same path prior to the collision, or in which one of the vehicles is stationary (for example, a rear end collision).

Lateral Collision Avoidance - Lateral Collision Avoidance systems address one or two vehicle collisions that arise when a vehicle leaves its own lane of travel while moving forward, for example, for the merge or lane change maneuver.

Intersection Collision Avoidance - Intersection Collision Avoidance systems address collisions that arise when vehicles improperly violate the right of way of other vehicles, or when right-of-way at an intersection is not clear (for example, right angle accidents). This service would provide warnings of imminent collisions with crossing traffic, as well as warnings of control devices at upcoming intersections.

Vision Enhancement for Collision Avoidance - Vision Enhancement for Collision Avoidance would address collisions in which limited visibility is a factor. The system will enhance visually acquired information when driving visibility is low, such as at night or in fog. It will not, however, compensate for blind spots or other visual obstructions.

Safety Readiness - Safety Readiness addresses collisions caused by fatigued or impaired drivers, malfunctioning vehicle components, or degraded infrastructure conditions. Safety Readiness includes three subsystems: driver condition warning and control override, vehicle condition warning, and in-vehicle infrastructure condition warning.

Pre-Collision Restraint Deployment - Pre-Collision Restraint Deployment provides a means to anticipate an imminent collision and activate safety systems (such as side impact airbags) prior to impact. The equipment is contained entirely in the vehicle.

Automated Highway Systems - The Automated Highway Systems user service focuses on improving the safety, efficiency, and comfort of the roadway system by providing fully automated control of instrumented vehicles on instrumented highways, as well as partial vehicle control (an extension of the collision avoidance systems).

Agency Rankings of ITS User Services

All of the representatives of the agencies interviewed were requested to rank the 22 ITS user services in terms of priority (all user services were ranked except those in the Advanced Vehicle Safety Systems bundle). User services were ranked from 1 to 22, with 1 indicative of the highest priority. Twenty-six completed priority rankings were returned, and the results are shown in Table 3-8 (on the next page). Although the priorities in Table 3-8 include the responses from the three local transit agencies, the priorities of the transit agencies are obscured due to the fact that most of the agencies responding were interested primarily in the roadway system. In an effort to adequately address the needs of local transit agencies, the priority rankings indicated by the three local transit agencies were considered separately for the transit related user services; these transit priority rankings are shown in Table 3-9. Based on the agency rankings, the user services were divided into four groups, indicating relative priority.

Table 3-9. Priority Rankings of Transit Related User Services by Local Transit Agencies in Kansas City Area

User Service	Transit Ranking[1]		Overall Ranking[2]		Priority Based on Transit Rankings[3]
	Average Value	*Rank*	Average Value	*Rank*	
En-Route Transit Information	3.7	*1*	13.3	*17*	Highest
Public Travel Security	4.0	*2*	10.3	*10*	
Public Transportation Management	4.3	*3*	11.8	*14*	
Ride Matching and Reservation	8.3	*4*	13.2	*16*	Medium-High
Personalized Public Transit	8.7	*5*	14.3	*18*	
Demand Management and Operations	13.0	*6*	11.6	*12*	Low

Based on 3 returned surveys from local transit agencies.
2 Based on 26 returned surveys from all local agencies. Some surveys reflect the input of more than one person.
3 Priority determined by using the average rank indicated by transit agencies, and the categories defined in Table 3-8 For example, in Table 3-8, the highest priority user services have an average rank of less than or equal to 6.8, thus all transit related user services in Table 3-9 with an average rank of less than 6 8 are considered highest priority.

HIGHEST PRIORITY

The highest priority group includes the ITS user services in the first four rows of the Table 3-8: Incident Management, Traffic Control, Emergency Notification and Personal Security, and Emergency Vehicle Management. These user services address both recurring and incident related congestion. Note that these user services all contribute to the efficient identification and removal of incidents, and contribute to a reduction in the impact of incidents. These user services address both typical conditions such as recurring congestion (Traffic Control), as well as conditions related to incidents (Traffic Control, Incident Management, Emergency

Table 3-8. Overall Priority Rankings of ITS User Services by Local Agencies in Kansas City Area

User Service	Average[1]		Median		Priority
	Value	Rank	Value	Rank	
Incident Management	3.6	1	2.5	1	Highest
Traffic Control	4.7	2	4	3	
Emergency Notification and Personal Security	5.5	3	3.5	2	
Emergency Vehicle Management	6.8	4	4.5	4	
En-Route Driver Information	8.1	5	7.5	5	Medium-High
Route Guidance	8.5	6	8	6	
Hazardous Material Incident Response	9.4	7	9	7	
On-Board Safety Monitoring	10.0	8	10	8	
Pre-Trip Travel Information	10.2	9	10.5	9	
Public Travel Security	10.3	10	11.5	10	
Automated Roadside Safety Inspection	11.4	11	13	14	Medium
Demand Management and Operations	11.6	12	11.5	10	
Traveler Services Information	11.7	13	11.5	10	
Public Transportation Management	11.8	14	11.5	10	
Commercial Vehicle Electronic Clearance	13.1	15	14	15	Low
Ride Matching and Reservations	13.2	16	14.5	18	
En-Route Transit Information	13.3	17	14	15	
Personalized Public Transit	14.3	18	16	20	
Freight Mobility	15.0	19	14	15	
Emissions Testing and Mitigation	15.0	20	15.5	19	
Commercial Vehicle Administrative Processes	15.2	21	17	21	
Electronic Payment Services	15.9	22	20	22	

All values are based on 26 returned surveys. some surveys reflect me input or more man one person.

Notification and Personal Security). The fact that all user services of the highest priority relate to incidents reflects the fact that much of the delay in the Kansas City area is incident related.

Transit Agency Priorities - Transit related user services identified as highest priority by transit agencies are shown in Table 3-9 and include En-Route Transit Information, Public Travel Security, and Public Transportation Management. These user services address the need for communication with the public, the need for enhanced security, and the need for enhanced management of resources. Note that the highest priority user services identified by transit are, to some extent, analogous to the user services identified for roadways. For example, Public Transportation Management for management of transit resources may be considered analogous to Traffic Control for management of roadway resources, and Public Travel Security address incidents on transit, just as Incident Management and Emergency Notification and Personal Security addresses roadway incidents.

MEDIUM-HIGH PRIORITY

The medium-high priority group includes six ITS user services: En-Route Driver Information, Route Guidance, Hazardous Material Incident Response, On-Board Safety Monitoring, Pre-Trip Travel Information, and Public Travel Security. These user services relate primarily to communications with motorists (En-Route Driver Information, Route Guidance, Pre-Trip Travel Information), as well as incident response (En-Route Driver Information, Route Guidance, Hazardous Material Incident Response, On-Board Safety Monitoring, Pre-Trip Travel Information) and safety (Hazardous Material Incident Response, On-Board Safety Monitoring, Public Travel Security). Note that, in many cases, there is overlap between the user services and the functions that they contribute to. For example, the user services related to communications (En-Route Driver Information, Route Guidance, Pre-Trip Travel Information) not only inform the public about roadway conditions and alternate routes, but also facilitate the Incident Management user service.

Transit Agency Priorities - Transit related user services identified as medium-high priority by transit agencies included Ride Matching and Reservations and Personalized Public Transit. These user services offer alternatives to traditional, fixed route transit, and may be more appropriate in areas of low density development that are not easily served by traditional transit,

MEDIUM PRIORITY

The medium priority group includes four ITS user services: Automated Roadside Safety Inspection, Demand Management and Operations, Traveler Services Information, and Public Transportation Management. Although some of these user services relate to safety (Automated Roadside Safety Inspection) and communications (Traveler Services Information), which are issues that are considered a priority, these user services are generally more specific and serve a smaller audience. For example, Automated Roadside Safety Inspection is targeted to commercial vehicle operations, and might be expected to have a minimal impact on the overall operations of the transportation system. Traveler Services Information, while it might be used to some extent by all motorists, would probably address the needs of visitors and tourists to a greater extent than it would address the primary concerns of local transportation users. Similarly, the Demand Management and Operations and Public Transit

Management user services are not targeted to benefit the primary roadway user, which at this time is the single occupant commuter.

Transit Agency Priorities - No transit related user services are identified as medium priority by transit agencies

LOW PRIORITY

The low priority group includes eight ITS user services: Commercial Vehicle Electronic Clearance, Ride Matching and Reservations, En-Route Transit Information, Personalized Public Transit, Freight Mobility, Emissions Testing and Mitigation, Commercial Vehicle Administrative Processes, and Electronic Payment Services. These are user services that would primarily benefit a smaller audience, and address issues that are not currently of the highest priority in the Kansas City area. Some of these user services are primarily targeted to commercial vehicle operators (Commercial Vehicle Electronic Clearance, Freight Mobility, Commercial Vehicle Administrative Processes), others are primarily targeted to transit and ridesharing (Ride Matching and Reservations, En-Route Transit Information, Personalized Public Transit), and others address issues that have not been identified as critical problems in the metropolitan area (Electronic Payment Services, Emissions Testing and Mitigation).

Transit Agency Priorities - Demand Management and Operations was the only transit related user service identified as a low priority by transit agencies. This user service may be of relatively low priority because the Kansas City area does not have significant air quality problems or extreme traffic congestion.

Public Involvement Activities

The public involvement activities reflected the fact that an early deployment study differs from more traditional transportation planning projects in many respects. The lack of direct impact to property or land use and the abstract nature of the subject required not only that the public be informed, but perhaps more importantly, that public interest be generated, and that the public be educated about ITS concepts and applications.

Two sets of public meetings were held. The first set was held in July 1995, and the second set in January 1996. Each set included a meeting at Johnson County Community College in Overland Park, Kansas, and at the Adam's Mark Hotel in Kansas City, Missouri. All meetings were held from 6:30 to 8:30 p.m., with a presentation at 7 p.m., followed by a question and answer period.

The meetings also included an interactive multimedia presentation explaining the Kansas City Early Deployment Study. This presentation, which allowed users to selectively explore ITS concepts at their own pace, included descriptions of ITS and the user services, film clips demonstrating transportation problems and solutions, and brief interviews with local citizens and agency representatives regarding their perceptions of transportation problems.

Activities to generate interest and inform the public included press releases, newspaper advertisements, and media coverage. For the first set of meetings, newspaper advertisements appeared in the *Kansas City Star*, *The Examiner,* the *Lee's Summit,* the *Kansas City Kansan,* the *Johnson County Sun* papers, the *Townsend Publications,* the *Advocate,* and the *Call.* Media coverage of the first set of meetings also included two newspaper articles (in the *Kansas City* Star and *The Examiner),* radio broadcasts on two stations (including the one hour "Russ Johnson Show"), and two television interviews (Channel 4 and Channel 9). Media coverage for the second set of meetings included a feature article and editorial in the *Kansas City Star,* an article in *The Examiner,* and a segment on the Channel 9 news.

In addition to the newspaper, radio and television coverage, which was directed at the general public, efforts were made to directly contact people who had a professional interest in ITS. Letters of invitation to the public meetings were sent to people in both the public and private sector who had some tie to transportation. The mailing list, which was based on the mailing list used by the Mid-America Regional Council for the 1994 Incident Management activities, included local politicians, emergency responders, transit employees, and public works engineers, as well as people in the private sector who might have an interest in transportation issues. Over 700 letters of invitation were sent out for the July public meetings. By January, the mailing list for letters of invitation had grown to over 900.

Turnout at the public meetings was higher than expected. More than 40 people attended each of the meetings. The aggressive effort for media exposure and the large number of letters of invitation may be one factor contributing to the turnout at the meetings.

There were a variety of interests and concerns expressed at the public meeting, including: the impact of trucks on safety; the need for coordination of construction activities and signal operations among jurisdictions; the benefits and costs of the system, including the operating costs and who would be responsible for these costs; the need for public education; applications for public transit; and the inclusion of facilities to encourage high occupancy vehicles. Concern was also expressed that ITS facilitates travel by personal auto, whereas public policy and activities should encourage less dependence on the auto, with more opportunities for mobility by transit, bicycle, and pedestrian modes.

SURVEY RESULTS

Surveys were conducted at each set of public meetings. The surveys were designed to identify the transportation concerns of local citizens and interested professionals, and relate these concerns to the ITS user services and applications. Forty-two surveys were completed and returned during the first set of public meetings, and 34 were returned during the second set of meetings.

The survey completed at the first set of public meetings obtained feedback regarding the objectives and user services. The results confirm the priorities identified by the agency rankings. The general objectives identified by the survey results were (in decreasing order of priority):

- Reduce congestion.
- Manage traffic.
- Provide information.
- Encourage alternatives to single occupancy vehicles.

The user services identified as most appropriate include (in decreasing order of priority):

- Incident Management.
- En-Route Driver Information.
- Traffic Control.
- Emergency Notification and Personal Security.
- Emergency Vehicle Management.

The survey completed at the second set of public meetings obtained feedback regarding the preferred technologies in the metropolitan area. The results confirm the recommendations of the Strategic Deployment Plan. The preferred applications include (in decreasing order of priority):

- Incident detection and freeway monitoring.
- Variable message signs.
- Arterial signal coordination.
- Transit Improvements.

The preferred means for traveler information include (in decreasing order of priority):

- Variable message signs.
- Highway advisory radio.
- Commercial radio and television.

Performance Criteria for ITS User Services

Fifteen performance criteria have been developed to evaluate the impacts of the deployment of ITS user services. These performance criteria may be used in the project selection process or for project evaluation after deployment. The performance criteria, which are shown in Table 3-I 0, address a variety of transportation issues:

- Capacity, including recurring congestion (#1) and transportation efficiency (#2).

- Incidents, including incident related congestion (#3), and incident management activities (#4).

- Safety, including the safety of emergency personnel at an incident site (#5) and public safety in private vehicles and on public transit (#6).

- Alternatives to the single occupant vehicle (SOV), including transit service (#7), ridesharing (#8), and the provision of the incentives for the use of high occupancy vehicles (HOVs) (#9).

- Environmental, including compliance with mandates for clean air (#IO).

Table 3-10. Performance Criteria and Sample Measures of Effectiveness

Transportation Issue	Performance Criteria	Sample Measure of Effectiveness
Capacity	1. Reduce Recurring Congestion	Vehicle hours of delay in peak hour
	2. Increase Transportation Efficiency	Person miles traveled per lane mile
Incidents	3. Reduce Incident Related Congestion	Vehicle hours of delay due to incident
	4. Enhance/Facilitate Incident Management	Capability to detect incident and identify incident location
Safety	5. Improve Safety of Emergency Personnel at Incident Site	Volume and speed of traffic adjacent to incident site
	6. Increase Safety	Accident rate
Alternatives to the Single Occupant Vehicle	7. Enhance Transit Service	Schedule adherence, on-time performance
	8. Enhance Ridesharing	Number of employer and employee participants in ridesharing program
	9. Increase Average Vehicle Occupancy / Provide Incentives for HOV Use	Number and percentage of SOV, carpool, vanpool, and bus trips
Environmental	10. Facilitate Compliance with Clean Air Mandates	Capability to monitor vehicle emissions
Institutional	11. Enhance Agency Activities	Reduction in personnel hours required to perform necessary functions
	12. Integrate Transportation Services	Number of coordinating agencies
User Related	13. Improve User Convenience	Qualitative assessment of convenience
	14. Enhance Communications with Public	Number and percentage of public with access to information
	15. Affect Commuter Behavior	Number and percentage of commuters who change travel route, time of travel, or travel mode

- Institutional, including activities within an agency (#11), and the coordination of the activities of various agencies (#12).

- User Related, including user convenience (#13), communications with users (#14), and impacts on user behavior (#15).

Because multiple performance criteria often address various aspects of a single issue, the inclusion of one performance criteria often leads to the inclusion of other performance criteria, for example:

- A user service that enhances/facilitates incident management (#2) would often be expected to reduce incident related congestion (#3).

- A user service that enhances transit service or ridesharing (#7 and #8), may be expected to increase average vehicle occupancy levels (#5), which would in turn increase transportation efficiency (#2) and facilitate compliance with clean air mandates (#10).

- A user service that reduces recurring congestion (#1) would be expected to increase transportation efficiency (#2).

Note that, in general, the performance criteria may be used to evaluate impacts either for specific projects or on an area wide basis. For example, attainment of the first performance criteria, Reduce Recurring Congestion, can be evaluated by examining either a specific facility or facility segment, or by examining all major facilities in the area to determine an average or aggregate level of recurring congestion on an area wide basis.

MEASURES OF EFFECTIVENESS

The performance criteria are generally quantified by measures of effectiveness (MOEs), which may be used to compare actual performance to project objectives. MOEs for each of the 15 performance criteria have been identified, sample MOEs are shown in Table 3-10.

Multiple MOEs have been identified for each performance criteria, both qualitative and quantitative measures are included for many of the performance criteria. Qualitative measures are especially important for the evaluation of agency coordination, user convenience, and other measures that are critical to the success of a project but that are difficult to quantify.

Note that the performance criteria do not address all of the issues that would need to be evaluated upon deployment of a user service. For example, the maintenance, reliability and accuracy of a system would be critical to its success, although these issues are not directly addressed by the performance criteria. Furthermore, impacts of maintenance activities (frequency of maintenance, disruption of traffic due to maintenance, etc.) and impacts of equipment reliability and accuracy (frequency of “false alarms” for incident detection systems, disruption of traffic due to such false alarms in terms of deployment of emergency response vehicles, inaccurate reports to motorists, etc.) must be considered, although they are not addressed by these performance criteria.

The following text discusses the performance criteria for the user services identified as highest priority and medium-high priority, based on agency rankings.

PERFORMANCE CRITERIA FOR HIGHEST PRIORITY USER SERVICES

Performance criteria that may be appropriate for the evaluation of each of the user services identified as highest priority in the section Agency Rankings of ITS User Services are shown in Table 3-l 1 and briefly discussed in the following text.

Performance Criteria for Incident Management and Traffic Control - The performance criteria for both Traffic Control and Incident Management reflect the fact that these user services would be expected to increase the safety and efficiency of the transportation system during and after incidents. Thus performance measures include those related to incidents: Reduce Incident Related Congestion (#3), Enhance/Facilitate Incident Management (#4), Improve Safety of Emergency Personnel at Incident Site (#5); and those reflecting the resulting increase in safety and efficiency: Increase Safety (#6) and Increase Transportation Efficiency (#2). Enhance Agency Activities (#11) is also identified as a performance measure, because deployment of these user services would be expected to provide agencies with data and information not currently available. Traffic Control would also be expected to provide benefits during typical operating conditions, and thus it would Reduce Recurring Congestion (#1) and Facilitate Compliance with Clean Air Mandates (#10). Incident Management would be expected to Integrate Transportation Services (#12), because it would enhance coordination between agencies involved in incident management activities.

Performance Criteria for Emergency Notification and Personal Security and Emergency Vehicle Management - Performance criteria for Emergency Notification and Personal Security and Emergency Vehicle Management reflect the fact that these user services would be expected to Reduce Incident Related Congestion (#3) and Enhance/Facilitate Incident Management (#4) because they would facilitate incident detection and emergency response to incidents. Emergency Notification and Personal Security would also Increase Safety (#6) for the public, by assuring that an incident would be quickly identified and located, while Emergency Vehicle Management would Enhance Agency Activities (#11) for the emergency response agencies.

Performance Criteria for Transit Related Highest Priority User Services - Note that all of the highest priority transit related user services have four performance criteria in common. All of these user services would be expected to Enhance Transit Service (#7), and subsequently to Increase Average Vehicle Occupancy/Provide Incentives for HOV Use (#9). An increase in vehicle occupancy would be expected to Increase Transportation Efficiency (#2) and Facilitate Compliance with Clean Air Mandates (#10).

En-Route Transit Information: En-Route Transit Information performance criteria focus on the convenience and the communications capabilities of the provision of transit information, as well as the impact that this information has on commuter behavior, and ultimately, on increased vehicle occupancies. Performance criteria include those common to all the highest priority transit related user services (#2, #7, #9, #10). En-Route Transit Information would also be expected to Improve User Convenience (#13), Enhance Communications with Public (#14), and Affect Commuter Behavior (#1 5).

Table 3-11. Performance Criteria for Highest Priority User Services

Performance Criteria	Overall Highest Priority User Services				Transit Related Highest Priority User Services		
	Incident Mgmt.	Traffic Control	Emergency Notification and Personal Security	Emergency Vehicle Mgmt.	En-Route Transit Information	Public Travel Security	Public Transp. Mgmt.
1. Reduce Recurring Congestion		X					
2. Increase Transportation Efficiency	X	X			X	X	X
3. Reduce Incident Related Congestion	X	X	X	X			
4. Enhance/Facilitate Incident Management	X	X	X	X			
5. Improve Safety of Emergency Personnel at Incident Site	X	X					
6. Increase Safety	X	X	X			X	X
7. Enhance Transit Service					X	X	X
8. Enhance Ridesharing							
9. Increase Average Vehicle Occupancy/ Provide Incentives for HOV Use					X	X	X
10. Facilitate Compliance with Clean Air Mandates		X			X	X	X
11. Enhance Agency Activities	X	X		X			X
12. Integrate Transportation Services	X						X
13. Improve User Convenience					X		
14. Enhance Communications with Public					X		
15. Affect Commuter Behavior					X		

Public Travel Security: Public Travel Security performance criteria focus on the increased security of transit, and the extent to which this enhances transit service and increases vehicle occupancies. Performance criteria include those common to all the highest priority transit related user services (#2, #7, #9, #10), as well as Increase Safety (#6).

Public Transportation Management: Benefits of Public Transportation Management include applications of the data collected and resulting increases in efficiency. Performance criteria include those common to all the highest priority transit related user services (#2, #7, #9, #10), as well as Enhance Agency Activities (#11) and Integrate Transportation Services (#12), which are included because the data resulting from deployment of this user service would be expected to benefit transit agencies, and might allow multiple transit agencies to better coordinate their services. Some elements of this user service would also Increase Safety (#6). For example, an automatic vehicle location (AVL) system would increase safety because it would notify the transit dispatcher if a vehicle were stopped for an unusual length of time, or were off the transit route. Many AVL systems also come with an emergency button which would allow the bus driver to alert the dispatcher in case of an emergency.

PERFORMANCE CRITERIA FOR MEDIUM-HIGH PRIORITY USER SERVICES

Performance criteria that may be appropriate for the evaluation of each of the user services identified as medium-high priority in the section *Agency Rankings of ITS User Services* are shown in Table 3-12 and briefly discussed in the following text.

Performance Criteria for En-Route Driver Information and Route Guidance - In terms of impacts on the transportation system, the most significant benefits of En-Route Driver Information and Route Guidance would be expected to result during and after incidents. The capability to communicate current conditions to drivers may result in drivers taking alternative routes (reducing the volume of traffic adjacent to an incident), or at least approaching the incident site with greater caution. Thus, performance criteria include those related to incidents: Reduce Incident Related Congestion (#3), Enhance/Facilitate Incident Management (#4), and Improve Safety of Emergency Personnel at Incident Site (#5); as well as those related to communications with the user: Improve User Convenience (#13), Enhance Communications with Public (#14), and Affect Commuter Behavior (#15). Performance criteria also address the impacts of any changes in commuter behavior, which would potentially Increase Transportation Efficiency (#2).

Reduce Recurring Congestion (#1) and Enhance Agency Activities (#11) are also identified as performance criteria for Route Guidance. Enhance Agency Activities (#11) is identified as a performance criteria because the provision of route guidance information via advanced technologies would allow enforcement personnel to concentrate on traffic control during incidents, and relieve them of the duty of providing directions. Reduce Recurring Congestion (#1) is specified as a performance criteria based on the assumption that some recurring congestion is due to the fact that drivers do not always select their route based on a complete analysis of all the available routes. A Route Guidance user service that provides the “minimum time route” would reduce the impacts of recurring congestion by diverting motorists from routes that are typically congested to less congested routes, assuming that less congested routes exist. While many of the benefits of Route Guidance on a systemwide basis are related to incidents, it is important to note that the Route Guidance user service also provides valuable information to tourists and motorists unfamiliar with the local roadway network. This benefit would be quantified under the performance criteria Improve User Convenience (#13).

Performance Criteria for Hazardous Materials Incident Response - Hazardous Materials Incident Response performance criteria reflect the fact that the provision of immediate information about hazardous material would be expected to improve safety, both Improve Safety of Emergency Personnel at the Incident Site (#5), as well as Increase Safety (#6) for the motorists. The provision of hazardous material information would also Enhance/Facilitate

Table 3-12. Performance Criteria for Medium-High Priority User Services

Performance Criteria	Overall Medium-High Priority User Services					Transit Related Medium-High Priority User Services	
	En-Route Driver Information	Route Guidance	Hazardous Material Incident Response	On-Board Safety Monitoring	Pre-Trip Travel Information	Ride Matching and Reservation	Pers. Public Transit
1. Reduce Recurring Congestion		X					
2. Increase Transportation Efficiency	X	X			X	X	X
3. Reduce Incident Related Congestion	X	X			X		
4. Enhance/Facilitate Incident Management	X	X	X				
5. Improve Safety of Emergency Personnel at Incident Site	X	X	X		X		
6. increase Safety			X				
7. Enhance Transit Service					X		X
8. Enhance Ridesharing					X	X	
9. Increase Average Vehicle Occupancy/ Provide Incentives for HOV Use					X	X	X
10. Facilitate Compliance with Clean Air Mandates					X	X	X
11. Enhance Agency Activities		X	X	X			
12. Integrate Transportation Services					X		
13. Improve User Convenience	X	X		X	X	X	X
14. Enhance Communications with Public	X	X			X		
15. Affect Commuter Behavior	X	X			X	X	X

Incident Management (#4), as well as Enhance Agency Activities (#11) for the agencies responsible for identifying and cleaning up hazardous materials.

Performance Criteria for On-Board Safety Monitoring - Performance criteria for On-Board Safety Monitoring reflect the fact that it would be expected to Improve User Convenience (#13) for commercial vehicle operators and Enhance Agency Activities (#11) by improving the efficiency of operations for enforcement agencies.

Performance Criteria for Pre-Trip Travel Information - Many of the benefits of Pre-Trip Travel Information are expected due to the fact that information regarding transportation alternatives is provided before a mode choice has been made, thus performance criteria focus on changes in commuter behavior that result from provision of this information and the impacts of these changes.

Pre-Trip Travel Information performance criteria related to a change in mode include Enhance Ridesharing (#8), which would be expected to Affect Commuter Behavior (#15) and Increase Average Vehicle Occupancy/Provide Incentives for HOV Use (#9). An increase in vehicle occupancy would be expected to Increase Transportation Efficiency (#2) and Facilitate Compliance with Clean Air Mandates (#10). While performance criteria such as these related to increases in HOV modes are included for this and other user services, it is important to note that such mode changes would only be expected if there were some incentives for HOV use (employer incentives, exclusive HOV lanes, pricing incentives, etc.).

In addition to impacts related to changes in mode choice, Pre-Trip Travel Information would be expected to have impacts due to incidents or other unusual conditions. Because some motorists may be expected to delay or re-route their trip when they find out about an incident, Pre-Trip Travel Information would be expected to Reduce Incident Related Congestion (#3), and thus Improve Safety of Emergency Personnel at Incident Site (#5) by reducing the volume of traffic adjacent to the incident location. Pre-Trip Travel Information would also Enhance Transit Service (#7), Improve User Convenience (#13) and Enhance Communications with Public (#14), as well as Integrate Transportation Services (#12) by providing information about a variety of transportation alternatives.

Performance Criteria for Transit Related Medium-High Priority User Services - Note that all of the medium-high priority transit related user services have five performance criteria in common. All of the user services would be expected to Improve User Convenience (#13), Affect Commuter Behavior (#15), and Increase Average Vehicle Occupancy/Provide Incentives for HOV Use (#9). An increase in vehicle occupancy would be expected to Increase Transportation Efficiency (#2) and Facilitate Compliance with Clean Air Mandates (#10). In addition, Ride Matching and Reservations would Enhance Ridesharing (#8), while Personalized Public Transit would Enhance Transit Service (#7).

Intelligent Transportation Infrastructure (ITI)

The Intelligent Transportation Infrastructure (ITI) consists of nine elements that contribute to the deployment of ITS user services in a metropolitan area, and will establish a foundation for the deployment of future ITS user services'. The ITI focuses on metropolitan traffic, information, and safety systems, and does not address the user services in the Commercial Vehicle Operations bundle. The nine elements included in the ITI are as follows:

1. Regional Multimodal Traveler Information Center (RMTIC). The RMTIC compiles and maintains current roadway and transit information, and is the link between the general public and the transportation system managers.

2. Traffic Signal Control Systems: Signal control systems increase transportation efficiency by adjusting green times to maximize vehicle and person capacity and minimize delay.

3. Freeway Management Systems: Freeway management systems monitor freeway traffic conditions, identify recurring and non-recurring congestion, and allow deployment of control and management strategies such as route diversion and traveler information via variable message signs (VMS) and highway advisory radio (HAR).

4. Transit Management Systems: Transit management systems include fleet management systems, and advanced computer and communications equipment on vehicles and in dispatching centers. These systems improve security and increase the efficiency of operations and maintenance.

5. Incident Management Program: Incident management programs facilitate the rapid identification and removal of incidents on freeways and atterials, reducing delay and driver frustration.

6. Electronic Fare Payment: Electronic fare payment for transit eliminates the need for transit patrons to provide exact change, and facilitates the coordination of fares among multiple transit providers.

7. Electronic Toll Collection: Electronic toll collection allows drivers to pay tolls without stopping, decreasing delays and enhancing transportation efficiency.

8. Regional Grade Crossings: Regional grade crossings would utilize in-vehicle warning systems to encourage safe driving behavior by better focusing driver attention on the danger of trains approaching a railroad crossing.

9. Emergency Management Services: Emergency management services save people's lives and improve security through immediate notification of the precise location of crashes and breakdowns.

The identification of ITI elements is intended to guide near-term deployment decisions, and at the same time to facilitate future opportunities for the deployment of ITS user services. Deployment of the ITI is expected to be led by the public sector, although private sector participation is encouraged. The deployment of ITI elements is expected to provide a

1Discussion based on *The Department of Transportation Initiative Intelligent Transportation Infrastructure (ITI)* January 1996 and Draft *Core ITS Infrastructure Elements for Metropolitan Areas, ATMS/ATIS Deployment,* provided at the *Early Deployment Planning Workshop,* March 14, 1995 foundation which will allow the private sector to develop products and industries for future ITS user services.

The following sections discuss the principles which guided the definition of the ITI elements, and key considerations for deployment of the elements of the ITI. These principles and key considerations provide insight into justification for the elements in the ITI, as well as guidance regarding deployment of projects that contribute to the ITI.

ITI PRINCIPLES

A number of principles were considered in the definition of the ITI elements, these include:

- Implementation of elements will enable deployment of advanced traffic management and advanced traveler information systems and supporting user services, and facilitate deployment of other ITS user services.

  Each element can be deployed independently, although concurrent deployment would provide economies of scale through either increased overall benefits or decreased marginal costs.

- Elements can be deployed in the near term using state-of-the-art concepts and technologies, and would often be eligible for federal funding.

- Elements can be deployed using varying technologies, from low-tech to high-tech.

- Elements are appropriate for deployment in a variety of environments (considering institutional arrangements, geographic/spatial development patterns, etc.) and elements will evolve to provide increased benefits and/or lower costs.

  Private sector participation in the development of ITI elements and ITS user services is encouraged, particularly with respect to the collection and provision of traveler information.

KEY CONSIDERATIONS FOR DEPLOYMENT

Key considerations for the deployment of the ITI elements include the fact that multiple elements utilize common hardware and software components, and face similar institutional issues prior to and upon deployment. Many of the key considerations address equipment, communications, institutional, and management issues, as noted below:

- Capability to distribute multimodal traveler information to the general public,

- Capability for monitoring and detection, resulting in current, complete and accurate traffic and transit information.

- Communications systems linking field equipment with central systems for database management.

- Communications among jurisdictions, agencies and organizations, in both the public and private sectors, without any implied change in control and/or responsibility (for example, information sharing and coordination with emergency and hazardous material responders).

- Proactive management of resources, both roadway and transit, to achieve the transportation objectives of the metropolitan area.

- Continuing support for system operations and maintenance needs, including personnel requirements, such as training.

Short, Medium, and Long Term ITS User Services

A time frame for deployment has been identified for each of the ITS user services, and is shown in Table 3-13. The time frame associated with each user service was based on a number of things, including input from local agencies (discussed in the section *Agency Perceptions of the Local Applicability of ITS User Services),* agency rankings of priority (discussed in the section *Agency Rankings of ITS User Services),* the state of the technology that is needed to implement various aspects of the user service, and whether or not the user service contributes to the ITI. In general, the specified deployment time frame corresponds to the priority indicated by the local agencies unless there are other limiting factors, such as available technology. User services are identified for deployment in the short term, medium term or long term. In general, short term is considered within five years, medium term is considered within ten years, and long term is considered more than 10 years,

It is important to note that a single user service could encompass any number of specific projects, some of which require minimal technology and thus could be implemented in the short term, and others which require very sophisticated technology that is currently in the research, or even theoretical, stage. For example, consider the Emergency Notification and Personal Security user service. A "low tech" project geared toward the objectives of this user service would be to install reference markers on the freeway, as well as identify the roadway on bridge overpasses, so that people calling in to report an incident could more accurately communicate their exact location. On the other hand, a "high tech" project geared toward the objectives of this user service would be automatic collision notification, which might be an in-vehicle device that would be activated upon impact (much like an airbag) and would automatically send out a distress signal that would be received at the traffic control center or by emergency dispatch.

The issue of technologies brings up the point that any plan that incorporates "advanced technologies" as a component must necessarily be dynamic, changing to reflect and utilize new technologies and applications. Many technologies are rapidly evolving, and these evolutions cannot always be anticipated. This plan must be modified to reflect not only changing circumstances, but also changing technologies.

It is also important to re-iterate that there is often overlap between the various user services. A single project might fulfill the objectives of two or more of the user services. For example, a able 3-13. Priority and Deployment Time Frame for ITS User Services

User Service	Deployment Time Frame			
	Existing or Planned	Short	Medium	Long
Incident Management	X	High		
Traffic Control		High		
Emergency Notification and Personal Security		High		
Emergency Vehicle Management		High		
Public Transportation Management	X	High		
Public Travel Security	X	High		
En-Route Driver Information	X	Medium-High		
Route Guidance		Medium-High		
En-Route Transit Information	X	Medium-High		
Hazardous Material Incident Response			Medium-High	
Pre-Trip Travel Information	X		Medium-High	
Personalized Public Transit	X		Medium	
On-Board Safety Monitoring				Medium-High
Traveler Services Information	X			Medium
Demand Management and Operations	X			Medium
Automated Roadside Safety Inspection				Medium
Commercial Vehicle Electronic Clearance	X			Low
Ride Matching and Reservations				Low
Freight Mobility				Low
Emissions Testing and Mitigation				Low
Commercial Vehicle Administrative Processes	X			Low
Electronic Payment Services	X			Low

variable message sign could be used to provide En-Route Driver Information, moreover, the information provided could be regarding a detour or alternate route around an incident, thus providing Route Guidance, and enhancing Incident Management.

The many factors discussed above that relate to the ITS user services, priority, and deployment time frame are not intended to negate the value of the identification of priority and deployment time frame for each user service, but are rather intended to emphasize the limitations of the identification of priority and deployment time frame. In summary, the priority and deployment time frame noted for each user service should perhaps be considered a general, rather than an absolute, guideline. Actual deployment time frame would be affected not only by priority and the availability of proven technology, but also by opportunity and available funding. Road widening projects and other activities may present the opportunity to implement advanced technologies at a much lower cost, making deployment of certain user services appropriate, even though they might not otherwise be.

EXISTING OR PLANNED ITS USER SERVICES

Twelve user services are identified as either existing or planned, as shown in Table 3-13. Additional details about the projects that have been implemented for each of these user services were provided in a previous section, *Current and Planned ITS Applications in the* Kansas *City Area.* A priority and deployment time frame have also been identified for each of these user services, this is intended to address other projects that would also address the objectives of the user service.

USER SERVICES FOR DEPLOYMENT IN THE SHORT TERM

Nine user services are identified as appropriate for deployment in the short term. These user services include all of the user services that were identified as highest priority in the agency rankings. These user services address both recurring congestion (Traffic Control) and incidents (Traffic Control, Incident Management, Emergency Notification and Personal Security, Emergency Vehicle Management). These user services also enhance communications with drivers (En-Route Driver Information, Route Guidance). The user services related to recurring congestion and incidents are considered highest priority, while those related to communications with the driver are considered medium-high priority, reflecting the input of all of the agencies surveyed. All of these user services provide significant contributions to the ITI.

Transit Related User Services for Deployment in the Short Term - Three transit related user services are identified for deployment in the short term. These user services include all of the user services that were identified as the highest priority by the transit agencies: Public Transportation Management, Public Travel Security, and En-Route Transit Information. Note that these user services contribute to the ITI.

USER SERVICES FOR DEPLOYMENT IN THE MEDIUM TERM

Three user services are identified as appropriate for deployment in the medium term. These user services reflect agency interests in communications with motorists (Pre-Trip Travel Information) and incident response (Hazardous Material Incident Response, Pre-Trip Travel Information). Although a medium high priority, On-Board Safety Monitoring not specified for implementation in the medium term. Limited technologies have been proven for On-Board Safety Monitoring and moreover, deployment will be governed more by national standards than by the activities of local agencies at the metropolitan level.

Transit Related User Services for Deployment in the Medium Term - The only transit related user services identified for deployment in the medium term is Personalized Public Transit. This user service, which is considered a medium priority, would allow transit to provide more convenient service which would be more competitive with the automobile.

USER SERVICES FOR DEPLOYMENT IN THE LONG TERM

The remaining ten user services are identified as appropriate for deployment in the long term. These user services address a variety of issues, including issues primarily targeted to commercial vehicle operators and enforcement agencies (Commercial Vehicle Electronic Clearance, Freight Mobility, Commercial Vehicle Administrative Processes, On-Board Safety Monitoring, Automated Roadside Safety Inspection), issues primarily targeted to ridesharing (Ride Matching and Reservations and Demand Management and Operations), and issues that have not been identified as critical problems in the metropolitan area (Electronic Payment Services, Emissions Testing and Mitigation). None of these user services makes significant contributions to the ITI for metropolitan areas.

It should be noted that some of the user services related to commercial vehicle activities are identified for deployment in the long term, and are also indicated as existing or planned. The apparent discrepancy is due to the fact that the CVO activities currently underway are being implemented at a regional or state level, rather than by local agencies at the metropolitan area level. While state and regional activities will certainly continue, it is anticipated that CVO user services will not become a priority for local agencies until other ITS user services that address the ITI are deployed. The priority and time frame indicated do not preclude coordination of user services being deployed by various entities. In fact, local ITS activities will need to be coordinated with other ITS activities, including CVO services implemented at the state and regional level, whenever possible. This coordination should be on-going throughout the short, medium, and long term.

Note that the priority of some of these user services would be expected to change with changing circumstances. For example, if Kansas City becomes a non-attainment area with respect to ozone or carbon monoxide, then Emissions Testing and Mitigation may become a higher priority. In other cases, changing circumstances would be expected to affect the deployment time frame. For example, On-Board Safety Monitoring would be appropriate for deployment in the medium term, if proven technologies to provide this user service are developed.

Chapter 4
System Architecture

Alternatives Considered

The system architecture provides a framework for the coordination of the various elements that comprise the intelligent transportation system (ITS). Three alternatives were considered in the process of selecting an architecture for the Kansas City area. Each architecture was evaluated for three scenarios representing various levels of geographic coverage and infrastructure investment, as shown in Figure 4-l.

The Level 1 System includes a limited number of corridors, namely the downtown loop, I-35 north to I-29, I-35 south to I-435, I-70 east to US 40 (east of I-435), I-435 from Bannister Road in Missouri to I-35 in Kansas, and US 71 from I-470 to the Blue Ridge Extension. This system provides coverage on approximately 48 miles of freeway. The Level 2 System includes all of the Level 1 System, as well as 34 additional miles. The Level 2 System extends to include I-670, I-70 west of downtown to I-635, I-70 from US 40 to I-470, I-635 between I-70 and I-35, US 69 between I-35 and I-435, I-29 in Clay County north of I-35, and I-435 from Bannister Road to Independence Avenue. The Level 2 System would be expected to provide benefits not only from the standpoint that it substantially increases the freeway coverage, but also from the standpoint that it provides additional redundancy by completing several loops. The Level 3 System includes full deployment on all interstates and major freeways in the metropolitan area (approximately 258 miles of roadway).

Level 1, 2 and 3 scenarios were evaluated so that the full impact of various characteristics, such as the number of traffic operations centers, control logic, and data processing, could be examined, particularly with respect to cost. For example, the cost associated with two traffic operations centers may be relatively insignificant when compared to the cost of the Level 3 System, however, this cost may be very significant when considered relative to the cost of the Level 1 System.

The analysis discussed in this chapter was designed to determine which architecture (A, B, or C) was most appropriate for the Kansas City intelligent transportation system, This analysis was not designed to determine the geographic extent of the system. The geographic extent of the system recommended for deployment is based on the benefit cost analysis discussed in Chapter 6. Because the utility factors specified for each alternative are considered valid only relative to the various architecture alternatives, and not relative to the geographic extent of the system, comparisons should be made only between alternatives (A, B and C) at the same “level”.

CHARACTERISTICS

The three architecture alternatives are defined by seven characteristics, which are shown in Table 4-l and discussed in the following text.

Table 4-1. Description of System Architecture Alternatives

Characteristic	Alternative A Centralized	Alternative B Decentralized	Alternative C Hybrid Recommended
Control Logic	Single server	Two servers with central information server	Two servers with central information server
Number of Traffic Operations Centers (TOCs)	1	2	1
Data Processing	Centralized	Decentralized	Centralized
Communications Network	Fiber - star/ring configuration	Fiber - star/ring configuration	Fiber - star/ring configuration
Emergency Management Coordination	Maintain existing 911 dispatch and move some emergency personnel into traffic operations center	Maintain existing 911 dispatch, traffic operations center will contact emergency responders directly	Maintain existing 911 dispatch, traffic operations center will contact emergency responders directly
Arterial Signal Control	Hybrid system (some arterials integrated into traffic operations center)	Stand-alone control (existing system)	Hybrid system (some arterials integrated into traffic operations center)
Public Transit	Hybrid system (incorporate some transit agencies into traffic operations center)	Maintain public transportation management functions outside of traffic operations center	Maintain public transportation management functions outside of traffic operations center

Control **Logic** - The first characteristic is control logic. The alternatives considered include single server control logic (Alternative A), in which all of the data processing for the entire metropolitan area is conducted through a single server, or a system with two servers, one for each state, with a central information server to exchange information between the servers and to provide information to outside sources, such as the media and traffic reporting agencies (Alternatives B and C).

Number of Traffic Operations Centers (TOCs)- The options considered with respect to traffic operations centers (TOCs) include either a single traffic operations center for the entire metropolitan area (Alternatives A and C), or separate traffic operations centers for each state (Alternative B). One advantage of the latter option is that it would allow each state to move forward independently, as funding permits. An advantage of a single traffic operations center is that it would facilitate coordination of activities on both sides of the state line. A single TOC might also present some economies of scale. Note that specification of a single TOC does not imply that there has to be single server control logic, and in fact, Alternative C specifies two servers housed in a single TOC, which would allow autonomy for each state while facilitating coordination between states.

Data Processing - Data processing alternatives include centralized (Alternatives A and C) and decentralized data processing (Alternative B). In centralized data processing, most of the data is processed at the central server. In decentralized data processing, more of the data processing is conducted in the field, and processed data is returned to the TOC. With decentralized data processing, some control decisions are automatically made in the field based on the results of the data processing. Decentralized data processing reduces the amount of data communicated to the TOC as well as the load on the central server(s). Decentralized control may imply increased reliability, because the system is less dependent on the central server. However, any increase in reliability due to increased redundancy with respect to data processing and control capabilities would be expected to result in an associated increase in cost. Furthermore, there may be increased maintenance requirements due to the fact that the equipment is not housed in a single location.

Communications Network - The communications network specified for all three alternatives is a dual ring fiber optics network in a star/ring configuration. Fiber optics was selected because it provides capacity adequate for most ITS applications and has been proven in applications in other urban areas. Fiber optic communications was also chosen because fiber has been installed in the right-of-way on all Missouri's interstates (and some freeways). This installation is the result of a private/public partnership. The Kansas Department of Transportation (KDOT) is pursuing a similar arrangement.

The star/ring configuration was chosen for a couple of reasons. One reason is because the star/ring configuration provides more redundancy than many other configurations. Information can always travel in the opposite direction in the event of a break in the line or an equipment failure. Another reason is because this configuration best suits the geometry of the freeways in Kansas City. There could ultimately be a number of rings and partial rings, including I-435, I-635 and I-470. The spokes, or legs of the star, include I-35, I-29 and I-70. Note that the system may initially include only selected facilities and would be expected to evolve, encompassing additional spokes and ring segments as is justified by volume and accident characteristics.

Emergency Management Coordination - All of the alternatives would maintain the existing 911 dispatch system.[1] The existing 911 dispatch system began operating in February 1983, and now encompasses the seven county region of Johnson, Leavenworth, and Wyandotte Counties in Kansas, and Cass, Clay, Jackson, and Platte Counties in Missouri. There are over 30 primary and secondary answer points in the region, which is served by four telephone companies. Southwestern Bell Telephone provides service to the majority of the area, with the remainder served by Sprint/United Telephone, which provides service to the rural portions of several counties, and by GTE and Mo-Kan Dial, which serve portions of Cass County. Sprint/United, GTE, and Mo-Kan Dial route calls from their central offices to the 911 tandem computer which is located in Southwestern Bell's Hedrick Office in Overland Park, Kansas. The calls are then routed to the appropriate answer point.

The variance between the alternatives with respect to Emergency Management Coordination is the degree to which and the way in which the TOC interfaces with the emergency responders. Under Alternative A, representative emergency personnel would be located in the TOC. This staff would serve as a liaison with emergency responders; for example, they may suggest the

1 Discussion of the 911 system is based on Information provided in the Draft 9-l-l Policy Statement, Mid-America Regional Council, November 1993

quantity and kind of emergency personnel and equipment needed based on the video provided by the closed circuit televisions operated by the TOC. Under Alternatives B and C, the TOC and the emergency management agencies function more autonomously. The TOC staff would contact the emergency responders directly, for example by telephone or radio, in the event of an emergency identified by the monitoring system. Under this alternative, it would also be possible for some 911 answer points to have video feed from the closed circuit televisions controlled by the TOC.

Arterial Signal Control - The management of signal systems is of particular importance on arterials that might be used for diversion of traffic from the freeway following an incident. One alternative is to allow local jurisdictions to maintain control of their arterial signal systems (Alternative B). Under this scenario, the TOC would notify the local jurisdiction when there is an incident that might result in increased traffic on local streets. The city could then modify the signal timings as they deem appropriate. Another alternative would be to control selected arterials from the TOC, while the remaining signals would continue to be controlled by local jurisdictions (Alternatives A and C). Traffic signals that might be controlled by the TOC include signals on major arterials identified as diversion routes, as well as signals under the jurisdiction of Missouri Highway and Transportation Department (MHTD).

Public Transportation - The management of public transportation includes dispatching transit vehicles and monitoring transit vehicle location, both through traditional radio communications, as well as through more advanced systems such as automatic vehicle location systems. The options considered for coordination between the **TOC** and public transportation include locating selected local transit systems in the TOC (Alternative A), or maintaining public transportation management activities outside the TOC (Alternatives B and C). Locating some transit management functions in the TOC is justified by the fact that monitoring activities allow public transit vehicles to serve as traffic probes, providing information to the TOC on traffic conditions and incidents. Furthermore, public transit can benefit from the information provided by the TOC, as buses can be re-routed to avoid congestion due to an incident. Keeping transit management outside the TOC is justified by the fact that relatively few buses use the freeways in Kansas City, which is the focus of the ITS system.

Evaluation Criteria

Evaluation of the three alternative architectures was conducted based on the utility-cost analysis using the seven evaluation criteria shown in Table 4-2 and discussed in the following text.

Cost - The evaluation with respect to cost includes consideration of capital costs, both the initial cost of equipment and software, as well as the cost for later enhancements to the system. The evaluation with respect to cost also must consider ongoing costs, namely the maintenance and operating costs of the system.

Reliability - The evaluation criteria reliability includes consideration of the reliability of the field equipment, communications equipment and data processing equipment, as well as the impacts

Table 4-2. System Architecture Evaluation Criteria

Criteria	Description
Cost	Initial cost for equipment and software
	Incremental cost for later enhancements
	Maintenance cost
	Operating cost
Reliability	Field equipment reliability
	Reliability of communications media
	Reliability of data processing equipment
	Reliability of TOC software/hardware
	Capability to monitor and control operations in the event of a break in communications capability
	Extent of loss in capability due to a single break in communications capability
Flexibility	Capability for equipment to operate independently or be controlled by the TOC
	Capability for one state to proceed independent of the other
Expandability	Extent to which system can be modified to provide additional capabilities at a later time (e.g. equipment)
	Ease with which the system can be expanded to encompass additional geographic areas
Staged Deployment	Ease of staged deployment with respect to geography and technology
Arterial Diversion	Ease with which an arterial diversion scheme could be implemented, for example, number of TOCs or entities that would need to be involved to change signal timing along an alternate route following an incident
Institutional Considerations	Whether architecture is compatible with existing institutional framework, or whether new institutional arrangements would be necessary (for example, coordination with KDOT, MHTD and emergency responders)

that result from an equipment failure. The impact of an equipment failure includes consideration of the expected failure rate, as well as well as the capability of the system to accommodate failure, which is based on the level of redundancy in the system.

Flexibility - The flexibility of the system refers both to the capability of system functions to be operated independently of the TOC, and for one state to proceed independently of the other.

Expandability - The expandability of the system includes the expandability with respect to the capability to include new technologies in the future, as well as the capability to expand geographically to encompass additional corridors or extensions of existing corridors.

Staged Deployment - Staged deployment refers to the ease with which the proposed architecture can be deployed in discrete but operable segments over a period of time. The project may be segmented with respect to either geography, with certain corridors operational prior to others, or with respect to technology, with more advanced equipment being implemented as funding is available or as is justified by changes in operating conditions.

Arterial Diversion - The ease with which an arterial diversion scheme can be implemented will impact the effectiveness of such a response, as well as the propensity for an arterial diversion scheme to be implemented. The capability for arterial diversion will depend on the operating agreements with local jurisdictions, as well as the sophistication of the signal control equipment on the affected arterials.

Institutional Considerations - The feasibility of each alternative with respect to institutional considerations must be evaluated. A system that is technically satisfactory will be of no benefit if it cannot be implemented due to institutional obstacles.

Analysis Procedure

A utility-cost analysis procedure was used to evaluate the three system architectures proposed by the study team for the Kansas City area'. This technique is commonly used because the comparative factors are easily computed. The utility-cost factor (U-C) was computed for each architecture alternative as the sum of the system utilities (defined by the evaluation criteria) divided by the sum of the system costs. A higher utility cost factor represents a preferable system, because the benefits are higher in proportion to the costs. Note that in this analysis, the cost of the system was considered as a benefit or utility (with lower cost resulting in a higher utility) in the numerator as well as the denominator.

UTILITIES

The sum of the utilities is the weighted combination of the individual evaluation criteria.

(Eqn 4-l)

$$U = k_1u_1 + k_2u_2 + k_3u_3 + k_4u_4 + k_5u_5 + k_6u_6 + k_7u_7$$

where:
U = Sum of Utilities
u_1 = Utility due to Cost
k_1 = Weighting Factor for Cost
u_2 = Utility due to Reliability of System
k_2 = Weighting Factor for Reliability
u_3 = Utility due to Flexibility
k_3 = Weighting Factor for Flexibility
u_4 = Utility due to Expandability
k_4 = Weighting Factor for Expandability
u_5 = Utility due to Capability for Staged Deployment
k_5 = Weighting Factor for Staged Deployment

1Discussion of utility-cost analysis IS based on methodology described in "Computerized Signal Systems", an FHWA student workbook, June 1979.

u_6 = Utility due to Capability for Arterial Diversion
k_6 = Weighting factor for Arterial Diversion
u_7 = Utility due to Congruence with Institutional Considerations
k_7 = Weighting Factor for Institutional Considerations

The values for u_1 through u_7 were determined by the study team, and are shown in Table 4-3. Values for u_i range from 0 to 10, with 10 indicative of the highest utility. In Table 4-3, the values in bold indicate the utility factors for each criteria, values not in bold indicate utility factors for each component of the criteria. The values for k_1 through k_7 were determined based on input provided by the Steering Committee regarding the relative importance of each evaluation factor, as shown in Table 4-4. The average values excluding the high and low responses were used for the weighting factor, however examination of the other values calculated demonstrates that there was little variance between the mean, median, and mode. Note that the sum of k_1 through k_7 is equal to 100 percent. Additional information on the determination of the utility and weighting factors is provided in Appendix A.

COSTS

For evaluation purposes, the sum of the costs is calculated based on an equivalent annual value of the initial cost for equipment and software, plus the annual maintenance and operating costs:

(Eqn 4-2)

$$C = C_{CAPITAL} * /_{C-R} + C_{O-M}$$

where: C = Sum of Costs
$C_{CAPITAL}$ = Initial Capital Cost
C_{O-M} = Annual Operating and Maintenance Cost
$/_{C-R}$ = Capital Recovery Factor to Convert Capital Cost to Equivalent Annual Payments (over a 15 year period at 6% interest)

Cost estimates for all alternatives are shown in Table 4-5. These values were used to calculate the utility for each alternative, and are also used in the denominator of the utility-cost factor.

UTILITY-COST FACTOR

Based on the values for the utility and weighting factors for each criteria (shown in Tables 4-3 and 4-4), as well as the costs shown in Table 4-5, the utility-cost factor for each alternative was calculated and is shown in Table 4-6. Note that the utility-cost factor for Alternative C is highest for each level of system deployment. This indicates that Alternative C is the most cost effective alternative. With respect to the utility associated with each alternative, Alternative B provides the highest expected benefit. This is offset, however, by the higher associated costs. Also note that as the system expands, the difference between the alternatives becomes less significant.

Table 4-3. Utility for Each Criteria by Architecture Alternative

	Utility	Level 1[1]			Level 2			Level 3		
		A	B	C	A	B	C	A	B	C
u_1	**Cost**	**7.4**	**7.2**	**7.4**	**6.1**	**5.9**	**6.0**	**0.5**	**0**	**0.5**
	Capital cost	7.3	7.2	7.3	6.0	5.8	6.0	0.5	0	0.5
	Maintenance and operating cost	7.7	7.1	7.7	6.2	6.0	6.2	0.5	0	0.5
u_2	**Reliability**	**4.2**	**5.8**	**6.2**	4.8	5.8	6.4	5.4	5.8	6.6
	Field equipment reliability	5	5	5	5	5	5	5	5	5
	Reliability of communications media .	5	5	5	5	5	5	5	5	5
	Reliability of data processing equipment	5	4	7	5	4	7	5	4	7
	Capability to monitor and control operations in the event of a break in communications capability	3	8	7	4.5	8	7.5	6	8	8
	Extent of loss in capability due to single break in communications capability	3	7	7	4.5	7	7.5	6	7	8
u_3	**Flexibility**	**3.5**	**8**	**7**	**3.5**	**8**	**7**	**3.5**	**8**	**7**
	Capability for equipment to operate independently or be controlled by the TOC	3	7	6	3	7	6	3	7	6
	Capability for one state to proceed independent of the other	4	9	8	4	9	8	4	9	8
u_4	**Expandability**	**5**	**6**	**5**	**5**	**6**	**5**	**5**	**6**	**5**
	Extent to which system can be modified to provide additional capabilities at a later time	5	7	5	5	7	5	5	7	5
	Ease with which system can be modified to encompass additional geographic areas	5	5	5	5	5	5	5	5	5
u_5	**Staged Deployment**	**4**	**5**	**4**	**4**	**5**	**4**	**4**	**5**	**4**
u_6	**Arterial Diversion**	**8**	**4**	**8**	**8**	**4**	**8**	**8**	**4**	**8**
u_7	**Institutional Considerations**	**3**	**7**	**6**	**3**	**7**	**6**	**3**	**7**	**6**

Level 1 System is 48 miles, Level 2 System is 82 miles, Level 3 System is 258 miles Architecture Alternatives A, B and C are defined i Table 4-I.

Table 4-4. Steering Committee Recommendations for Weighting of Evaluation Criteria

Criteria		Mean[1]		Median	Mode	Value Used
		M_1	M_2			
k_1	Cost	19	19	20	20	19
k_2	Reliability	19	18	15	15	18
k_3	Flexibility	14	14	15	15	14
k_4	Expandability	16	16	15	15	16
k_5	Staged Deployment	13	14	15	10	14
k_6	Arterial Diversion	7	7	5	10	7
k_7	Institutional Considerations	12	12	10	10	12
Total		100	100	95	95	100

[1] M_1 is the mean value of all responses, M_2 is the mean value of all responses excluding the highest and lowest responses.

Recommended Architecture

The architecture recommended for deployment in the Kansas City area is Alternative C. This alternative includes two central servers with a central information server. This control logic will provide autonomy for the two states, yet will facilitate coordination and provide redundancy. Coordination will also be enhanced by specification of a single traffic operations center (TOC). With respect to data processing, the recommended alternative utilizes centralized data processing, which is the standard and proven system used in most applications across the country. The communications network is a dual ring fiber optics backbone in a star/ring configuration, which will have adequate capacity for all anticipated components. Emergency management coordination will be based on the existing 911 dispatch system. TOC operators will contact emergency responders directly using the 911 system. Follow up coordination may be via either telephone or radio. The recommended architecture takes a hybrid approach to arterial signal control. Some arterial signal systems will be controlled from the TOC, while others will be controlled outside the TOC, for example by cities. The TOC should work closely with cities that will maintain signal control, pre-planning appropriate timing plans and notifying city personnel in the event of an incident. The final characteristic identified by the architecture is coordination with public transit. Public transit functions will be maintained outside the TOC, although this does not preclude coordination of activities, particularly for the dissemination of information.

The recommended architecture includes some of the best features of both the completely centralized and decentralized systems. This architecture is compatible with the large number of local agencies, because it takes a hybrid approach to characteristics such as signal control. At the same time, specification of a single TOC will facilitate coordination and communication between the states, resulting in a seamless system for the entire metropolitan area.

'able 4-5. Estimated Cost for Each Alternative Architecture ($M)[1]

Item		Level 1[2]			Level 2			Level 3		
		A	B	C	A	B	C	A	B	C
$C_{CAPITAL}$	**Capital Cost**	**28.9**	**29.5**	**29.1**	**43.0**	**44.5**	**43.3**	**101**	**107**	**101**
	Closed circuit television (CCTV) cameras	2.88	2.88	2.88	4.92	4.92	4.92	15.5	15.5	15.5
	Detection	0.96	0.96	0.96	1.64	1.64	1.64	5.16	5.16	5.16
	Variable message signs	4.2	4.2	4.2	5.40	5.40	5.40	9.48	9.48	9.48
	Highway advisory radio	0.17	0.17	0.17	0.22	0.22	0.22	0.43	0.43	0.43
	Power, communications and conduit to equipment	12.1	12.1	12.1	18.8	18.8	18.8	44.6	44.6	44.6
	Field data processing equipment	0.96	1.92	0.96	1.64	3.28	1.64	5.16	10.3	5.16
	TOC	1.32	1.32	1.10	1.32	1.32	1.10	1.32	1.32	1.10
	Central hardware	0.81	0.60	0.96	0.92	0.71	1.07	1.51	1.30	1.66
	Software and systems integration	0.75	0.50	1.00	1.00	0.75	1.25	1.25	1.00	1.50
	Contingency and construction	4.82	4.92	4.86	7.17	7.41	7.21	16.9	17.8	16.9
$C_{O\text{-}M}$	**Annual Operating and Maintenance Cost**	**1.67**	**2.11**	**1.68**	**2.75**	**2.87**	**2.76**	**6.91**	**7.26**	**6.92**
	TOC personnel	0.35	0.70	0.35	0.70	0.70	07.0	1.75	1.75	1.75
	Maintenance personnel	0.25	0.30	0.25	0.40	0.45	0.40	1.10	1.20	1.10
	Replacement and spare parts and equipment	1.10	1.14	1.11	1.68	1.75	1.68	4.09	4.34	4.10
$I_{C\text{-}R}$	**Capital Recovery Factor**[3]	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**
C	**Sum of Costs per Year**	**4.68**	**5.18**	**4.71**	**7.21**	**7.48**	**7.24**	**17.4**	**18.3**	**17.4**

All values are in millions of dollars except for the capital recovery factor.

Level 1 System is 48 miles, Level 2 System is 82 miles, Level 3 System is 258 miles. Architecture Alternatives A, B and C are defined in Table 4-l.

3Based on 15 years with an interest rate of 6 percent.

Table 4-6. Calculation of Utility-Cost Factor for Each Architecture Alternative

	Level 1[1]			Level 2			Level 3		
	A	B	C	A	B	C	A	B	C
u_1	7.4	7.2	7.4	6.1	5.9	6.0	0.5	0	0.5
k_1	19	19	19	19	19	19	19	19	19
u_2	4.2	5.8	6.2	4.8	5.8	6.4	5.4	5.8	6.6
k_2	18	18	18	18	18	18	18	18	18
u_3	3.5	8	7	3.5	8	7	3.5	8	7
k_3	14	14	14	14	14	14	14	14	14
u_4	5	6	5	5	6	5	5	6	5
k_4	16	16	16	16	16	16	16	16	16
u_5	4	5	4	4	5	4	4	5	4
k_5	14	14	14	14	14	14	14	14	14
u_6	8	4	8	8	4	8	8	4	8
k_6	7	7	7	7	7	7	7	7	7
u_7	3	7	6	3	7	6	3	7	6
k_7	12	12	12	12	12	12	12	12	12
U	493	631	615	479	607	593	384	494	490
C[2]	4.68	5.18	4.71	7.21	7.48	7.24	17.4	18.3	17.4
U-C[3]	105	122	130	66	81	82	22	27	28

[1] Level 1 System is 48 miles, Level 2 System is 82 miles, Level 3 System is 258 miles. Architecture Alternatives A, B and C are defined in Table 4-1.
[2] Annual cost in millions of dollars.
[3] Utility cost factor.

Chapter 5
Technologies

Types of Technologies

This chapter discusses the various technologies that may be used for ITS applications, addressing both their merits and limitations. Following this introductory section, this chapter addresses technologies related to monitoring, communications, traveler interface, data processing and public transportation functions, as well as an evaluation of possible strategies. Figure 5-l illustrates some of the technologies commonly used in ITS applications across the country.

Monitoring technologies, which are discussed in the second section of this chapter, include vehicle detection technologies, closed circuit television (CCTV), and technologies for electronic toll collection (ETC). Vehicle detection technologies, which comprise the majority of the technologies discussed, include passive technologies and active technologies. Active technologies require that the vehicle be equipped with special devices. Discussion addresses traditional passive technologies, such as induction loops, as well as newer passive technologies, such as microwave detectors. Technologies used for active vehicle detection include technologies such as automatic vehicle location (AVL) and automatic vehicle identification (AVI), as well as transponders for ETC.

The discussion of communication technologies in the third section begins with a discussion of fiber optics, which is expected to be the primary communications medium for the Kansas City Intelligent Transportation System. Other communications technologies are also discussed. Those technologies will potentially be used for communications in areas where fiber optics have not been placed, for example on arterial streets which will be used for incident diversion, and for communications with emergency responders.

Technologies that may be used to communicate with the public are discussed in the fourth section. These technologies, which are critical because they allow the public to make informed decisions, include variable message signs (VMS), highway advisory radio (HAR), information kiosks, and dial-in information systems, such as highway advisory telephone systems.

Data processing technologies are discussed in the fifth section, This section addresses technologies used to process the data collected by detectors, as well as incident detection algorithms used to analyze this data to identify incidents.

Various strategies are discussed in the sixth section. Strategies discussed include incident detection and verification options, options to improve response time, options for site management, options to reduce clearance time, and options for traveler and motorist information. ITS applications in other cities are also presented.

Technologies that may be used for public transit applications are discussed in the last section. These technologies include transponders installed on vehicles for automatic vehicle location and identification.

Monitoring Technologies

Advanced traffic management systems (ATMS) typically provide two different sub-systems for roadway monitoring: vehicle detection and closed circuit television (CCTV). These two sub-systems provide different functions, and operate together to provide the traffic operations center (TOC) with real-time status of traffic conditions. The vehicle detection sub-system electronically monitors the flow of traffic on the roadways, and transmits this information in "real-time" to the TOC for analysis and status displays. The operators utilize the results of the analysis and the status information to make decisions regarding management of the traffic, The CCTV sub-system provides the operators with a visual means for verification of the conditions reported by the vehicle detection sub-system. The CCTV images also provide the operator with an independent evaluation of traffic conditions.

Each of these two sub-systems can be deployed and utilized jointly as well as independently. However, the complementary interaction of the two sub-systems improves the overall system operation in a manner that neither system can provide alone. The vehicle detection system, since it is automated and can function with minimal human intervention, provides continuous monitoring and up-to-the-minute data. The CCTV system allows the human observer to view and interpret an incident, or other traffic conditions, and determine an appropriate response. As more progress is made in the technologies of image processing, artificial intelligence, and expert systems, it is inevitable that computer systems will augment the capabilities of the human observer.

VEHICLE DETECTION

Vehicle detection technologies form the foundation of the monitoring sub-system used for automated incident detection and traffic management. Monitoring information provided by vehicle detection enables collection of a range of traffic data including speed, volume, density, travel time, and in some cases, vehicle position. Control strategies, incident management procedures, and motorist information displays are selected based upon the data collected by the vehicle detection system. The collected data is used in real-time for making traffic management decisions and stored to provide a historical data-base of traffic conditions. Monitoring can also be used to obtain information on vehicle classification, length, speed, acceleration characteristics, and hazardous materials.

Operational environment and maintenance requirements are two of the most critical factors in determining the types of detectors for the system. Systems that involve cutting existing road surfaces and pavement (such as induction loops) can create installation and maintenance problems or compromise the structural integrity of the roadway, especially on bridges and other structures. Technologies that do not require these modifications are termed non-intrusive installations, and minimize the traffic diversion and control problems.

The choice of detectors for an automated system depends on the data requirements. To meet the functional requirements of the recommended user services, real-time data to ascertain vehicle speed, counts, lane occupancy, classification, and changes in motion and position will be required for automated incident detection. This real-time data should be stored for historical as well as planning use.

There are two separate approaches to vehicle detection, those that are passive and involve no electronics in the vehicle, and those that utilize electronics in the vehicle and alongside the roadway. As with all areas of electronic technologies, changes occur regularly, providing new solutions to existing problems, but conversely requiring that systems be flexible enough to accommodate change on a regular basis.

Various technologies that may be applicable are discussed below. There are numerous other technologies that have been experimented with and tested by various departments of transportation (DOTs) and the Federal Highway Administration (FHWA). In particular, the "Detection Technology for ITS" project sponsored by FHWA is evaluating a wide range of equipment under laboratory and field conditions. Although many of these technologies show promise, they have not progressed to reliable field operation. In order to limit system complexity and resultant operations and maintenance costs, minimizing the number of different technologies is preferred.

Passive Vehicle Detection - Technologies that do not require any devices in the vehicle are the basis for most current vehicle detection systems. Passive approaches allow all vehicles in the vicinity of the sensor to be detected and monitored, but provide less information than will be available in the future.

Induction Loops: The most commonly used vehicle detection technology is the induction loop. This technique is extensively used for arterial signal control and freeway monitoring and has a long history of successful field deployment. The advantages of induction loops are their well-known performance characteristics, maturity, application flexibility, and multiple vendor availability. Over the years the manufacturers have enhanced and refined their equipment, providing numerous options and alternatives to meet a wide range of application needs. Pairs of loops can be used to measure speed and vehicle length for classification purposes. Some vendors have announced products that measure speed with a single loop, but field experience is limited. Some disadvantages of induction loops result from the need to embed the loops in the pavement surface, including problems associated with pavement deterioration and freeze-thaw damage. Other difficulties include damaging the loop conductors during resurfacing operations or construction, and the reduced effectiveness of loops when in close proximity to reinforcing steel.

Recent improvements have been made in inductive loop technology. Loop detectors have been primarily utilized to provide a digital output that is representative of vehicle presence above the induction loop in the pavement. In this regard, a sophisticated computer system is unable to gain access to any information contained in the magnetic or inductive signal collected by the detector amplifier. New products are available with on-board microprocessors that are able to monitor the "signature" of the detected field. Use of this data allows accurate speed measurement and provides some capability for classification. Serial data ports with RS-232 communication allow systems to access a detector amplifier internal database to perform remote sensitivity adjustments and compensate for weather conditions.

Another development is the manufacture of pre-formed loops, which are available from a number of suppliers. This type of loop is pre-assembled, with the wires encased in a filled conduit. This assembly is embedded in the pavement, typically several inches below the surface, during the construction of the roadway. This technique offers improved reliability and life expectancy.

A similar approach, that of embedding the loop in the pavement, is being utilized in some areas as part of roadway reconstruction projects. After the milling operation that is used to remove old pavement, the induction loop is saw-cut into the milled surface. After the new pavement is applied, the loop is buried several inches below the road surface, where it is less subject to damage from traffic, construction or weather.

While induction loop detectors are often maligned because of the problems noted previously, they are currently the primary source of vehicle detection in most systems around the country. Studies in Los Angeles were performed by video taping the traffic stream, time-stamping and manually counting the vehicles on the video tape. Results show that the accuracy of induction loop data with respect to vehicle counts is t-O.6 percent.

Magnetometers: Magnetometers, and the related micro-loop technology, are often suggested for deployment on bridges and other areas where loop installation in the existing pavement area could affect structural integrity. Magnetometers have had spotty operational success, and other technologies have often been considered for these particular needs. However, the use of new digital processing technology has the potential to significantly improve the performance of magnetic detectors. A re-evaluation of their role will be appropriate after sufficient field experience is gathered. Preliminary results from the ITS Detection Technology project show that magnetometers have an accuracy in the ±5 percent range.

Ax/e Counters: The FHWA requirement for vehicle classification on certain roadways generates the need to count axles. The most commonly used technology uses a bending beam piezoelectric strip embedded in the roadway surface. These devices, working in conjunction with inductive loops, measure the vehicle length and speed, and count the axles. The vehicle length, combined with axle count, is used to classify the vehicle.

Radar: Radar detectors operate by emitting a signal in the microwave portion of the electromagnetic spectrum, and analyzing the returned signal. These detectors are in limited use in incident detection and freeway management projects. Continuous wave (CW) radar detection operates on the Doppler effect (measuring frequency shifts between the transmitted and received beam caused by vehicle motion), and thus directly measures vehicle speed. Vehicle counts can be determined by accumulating each vehicle detected, but this approach does not directly provide lane occupancy and vehicle length information. Similarly, detection of stopped vehicles, or very slowly moving vehicles, is difficult.

Another type of CW radar detector transmits a signal that is swept over a range of frequencies. This technique allows measurement of the range from antenna to vehicle, and is thus able to function as a presence detector. The sweep frequency functions as the sample rate to quantify presence.

Pulsed radar operates by transmitting a burst of microwave energy, and interpreting the “echoes” reflected from vehicles in its “field of view”. Because of the complications involved in processing multiple reflection, pulsed radar units utilized for traffic detection limit their field of view to a portion of the lane, such that a single vehicle is present in their detection zone. This technique permits the determination of the distance to the nearest reflection, and by monitoring this reflection over time, the position and resultant speed of the vehicle can be determined. This type of radar can be used to sense stopped vehicles, but has the limitation that the sample rate must be frequent enough to provide accurate presence calculations to determine other traffic parameters.

Continuous wave radar detectors of the Doppler and swept frequency types require one antenna per lane, mounted on a structure or a sign bridge over the lane. The same limitation applies to pulsed radar units. The ITS Detection Technology project early results show that these radar detectors have accuracies that range from ±0.5 to ±6 percent.

Microwave Detector: When mounted at the side of the roadway, a microwave detector is able scan up to twelve lanes. Since side mounting facilities are often available or can be readily installed, the device is more cost effective than other detectors. The device can also detect vehicle presence, and is thus able to determine occupancy and the existence of stopped vehicles. However, it does not measure speed directly, relying upon "single loop" speed estimation techniques based on average vehicle length. The accuracy of this device, as stated in the early results from the Detection Technology project, is in the ±5 percent range for volumes. Test results indicate missed and duplicated counts across multiple roadway lanes upon the passage of large vehicles.

The advantages of radar and microwave devices include the ease of use, requiring no cutting of pavement and disruption of traffic flow for installation or maintenance (if mounted on a structure or sign bridge where overhead access is possible). For the Doppler units, direct speed measurement is a significant benefit. If traffic lanes are shifted, radar antennas can be easily re-aimed. The disadvantages of radar are: the overhead mounting requirement, limited field operational experience for many of the new units, a small number of vendors in the market, and difficulties of accurately sensing lane occupancy and slow moving or stopped vehicles with Doppler units.

Radar detectors can be configured with two types of interfaces: RS-232 serial data and two pulse-type contacts. The serial output provides data (volume, speed, etc.) in an ASCII text string. Modifications to this format to incorporate an error checking communications in a standardized protocol would allow a multi-lane unit to be installed without a local field microcomputer. The dual pulse-type contact closures provide for emulation of a loop-pair speed trap. The first contact closure occurs when the vehicle enters the detection zone, and the second contact closure is timed relative to the first closure by the detector to provide the correct travel time based upon a calibrated "loop spacing".

Infrared: Infrared detectors monitor electromagnetic energy in the band above the visible spectrum. Both active and passive devices are marketed that utilize infrared detection.

Active infrared devices illuminate the detection zone with infrared energy supplied by either light emitting diodes (LEDs) or lasers. Lasers can provide a higher level of output energy. A portion of the energy reflected back from the vehicle is detected and processed. The detector consists of optical elements to focus the returned signal onto a matrix of infrared sensors. The two-way travel time of the infrared pulse from the source to the sensors is used to measure the distance to the vehicle. This strategy is similar to that used in a pulsed radar detector. Processing of the data provides vehicle counts, occupancy, presence, speed and classification information. Because infrared energy is attenuated and scattered by rain, snow, fog and mist in the air, active infrared detectors are vulnerable to these atmospheric conditions. In addition, other obscurants in the air, such as smoke and dust, can reduce the effectiveness of the detector.

Passive infrared devices do not emit any energy themselves, but utilize the characteristic that all objects emit heat (infrared radiation) as a function of their surface temperature. The amount of infrared energy is also a function of the emissivity of the object itself. By detecting the difference between the temperature/emissivity of vehicles and the roadway surface, a passive infrared detector can determine the presence and passage of vehicles. The infrared energy is focused through an optical system onto the infrared sensors. The resultant signal is processed to provide presence, vehicle counts and occupancy. As noted above, infrared energy is obscured by atmospheric effects. Because passive infrared detectors are dependent upon the sun and other infrared sources for their input energy, diurnal changes, cloud cover, and glint from bright objects reflecting sunlight can all create confusing and unwanted signals.

By increasing the number of sensors in a passive infrared detector, an "image" of the scene of interest can be generated. This increase in detail allows additional information from the scene to be discerned and analyzed. As the number of individual sensors becomes large enough, the boundary between an infrared detector and an infrared sensitive CCTV camera becomes blurred. For practical applications, an infrared imaging system has essentially all the same characteristics of video image detection (VID) systems discussed below.

Sonic: There are several techniques that have been explored utilizing sound energy. Some devices operate as sonar devices, sending out sound waves and analyzing the returned echoes from the vehicles - much like the radar systems. The early results from the ultra-sonic unit included in the ITS Detector Technology test show an accuracy in the ±2 percent range. Other sonic detectors passively "listen" to the noise generated by the vehicles, and analyze this noise energy to detect individual vehicles and resultant location and speeds. These devices have not yet been extensively used, and thus field experience is limited. However the technology has been applied for submarine noise signature detection by the military and could become a valid tool for classification of vehicles.

Video Image Detection: Video image detection (VID) systems (sometimes referred to as machine vision systems) are comprised of fixed orientation CCTV cameras strategically located to provide views of specific areas or long sections of roadway, coupled with a computer that analyzes the video image in real-time (30 times per second). This technology has been developed for various industrial, manufacturing, military and aerospace applications. It has been applied to traffic management in recent years, with growing success. Early systems were troubled by harsh environments, adverse and changeable lighting conditions, shadows, differing vehicle shapes, and sometimes difficult operating conditions. These difficulties have, for the most part, been solved by extensive field testing, actual deployment, more powerful computers, and increasingly sophisticated software.

Two fundamentally different strategies are used to analyze the video images: fixed analysis zones that detect vehicles moving through them, and vehicle identification and subsequent tracking. A third strategy, involving reading license plates "on-the-fly" may be appropriate for toll violations and related applications, but is not directly applicable to this Early Deployment Study. The technique utilizing fixed analysis zones, analogous to a "loop" in the video image, is the most stable and best tested approach. Equipment based on this approach can provide vehicle counts, lane occupancy, speeds, and lengths. Software in the VID processor collects the standard information (volume, occupancy, and speed) and can also provide some analysis and processing of this data, including statistics accumulation, data smoothing, and level of service calculations.

A key benefit of a VID system is its ability to monitor large areas of roadway from a single equipment location. Because the CCTV camera can be oriented to monitor a section of roadway (up to one-quarter mile), and the entire image can be analyzed, significantly more roadway and a greater number of vehicles can be monitored. The most promising use of a VID system is detection of stopped or stalled vehicles (either in a travel lane or on the shoulder), providing direct detection of an incident. The monitoring of wide areas of roadway, coupled with individual vehicle detection, is expected to provide significantly more information than existing point source (such as induction loop or radar) technologies.

While the promise of VID systems is significant, it is still a young technology that will evolve and grow for many years. There are operational problems under adverse lighting and during transitions between daylight and darkness (including storm conditions) that require additional refinement. Camera placement must be carefully considered, as shadows from objects outside the detection area may affect performance. The early results from the Detector Technology project report show accuracies ranging from ±0.3 to ±2.3 percent, with accuracy decreasing under dark or adverse weather conditions.

Passive Vehicle Detector Cost Comparisons - Two different categories of passive vehicle detectors are discussed above: those that are embedded in the road surface, such as induction loops, and those that are mounted overhead, such as a radar detector or a video image detector.

As discussed, embedding detectors in the roadway requires that the road surface be cut or drilled, and subjects the detector to failure due to pavement deterioration and other environmental factors. This can create ongoing maintenance problems, and/or poor detector reliability. Newer construction techniques which embed the detector several inches below the pavement surface are being used to solve some of these problems.

Detectors that are mounted above each lane, such as most radar detectors and ultrasonic detectors, require some form of support structure. A claimed advantage of this installation location is minimal traffic disruption during installation and maintenance. Mounting on an existing overcrossing is an option, but can create aesthetic concerns and often results in limited accessibility requiring that a traffic lane be closed to service the unit. The use of signal head mast arms is another possibility, but is of limited use on a freeway, and has the drawback of motion under high wind loading and the need to block traffic for installation and servicing. Sign bridges are a third possibility, and where they already exist they are excellent choices, especially if they include a cat-walk so that the units can be installed and serviced without shutting down traffic. However, the installation of new sign bridges for the mounting of detectors is an expensive alternative.

In general terms, many of the overhead detectors cost between $750 and $1,000 per unit that monitors a single lane. Poles and mast arms cost about $200 per foot (with foundation and installation), resulting in a cost of roughly $2,400 for a 12 foot lane. This is about 2.5 times the cost of the detector. Sign bridges roughly cost $500 per foot (with foundation and installation), or $6,000 for a 12 foot lane. This is about 6 times the cost of the detector. This needs to be compared to the installed cost of induction loops of about $1,000.

Thus, overhead mounted detectors that must be positioned over each lane can be significantly more expensive than induction loops, when the cost of a mast arm and pole or sign bridge must be included. Under those situations where an existing structure or sign bridge is available, they can be cost effective - but may still require traffic disruptions for installation and servicing.

Another category of overhead devices, side fired radar and VID, can be mounted off the side of the road or on a pole in the median. This reduces the cost of mounting to roughly $5,000, and does not require stopping traffic for access to the unit. These devices also have the advantage of being able to monitor several lanes from a single unit, thus spreading the cost of the unit and the mounting pole across several lanes. A disadvantage of side mounting or an oblique camera view is the fact that trucks may obscure smaller cars. This results in missed counts. With VID, the ability to discriminate between two closely spaced vehicles is a function of mounting height and angle of view. Increased height improves the discrimination ability, but results in a more costly pole and foundation. Another problem noted with VID is motion of the mounting pole under wind loading, or twisting of the pole due to differential solar heating. These conditions result in the camera field of view changing and "moving" the fixed analysis zones to another portion of the image.

For comparison purposes. costs for different technologies have been estimated for an eight lane cross section of freeway, as shown in Table 5-l. Five different equipment configurations are shown:

- Induction loops, with lead in wires saw-cut into pavement surface and processor cabinet on one shoulder.
- Side fired radar, with unit mounted on a pole located on one shoulder adjacent to the processor cabinet.
- Video image detector (VID), with two cameras mounted on a pole in the median and the processor cabinet on one shoulder.
- Overhead mounted sensors on mast arm with the pole in the median and the processor cabinet on one shoulder.
- Overhead mounted sensors on sign bridge with processor cabinet on one shoulder.

Table 5-1. Estimated Costs for Passive Vehicle Detection

Configuration	Cost Per Lane	Eight Lanes
Induction Loops	$3,400	$20,300
Side Fired Radar	$3,725	$22,350
Video Image Detector (VID)	$10,100	$60,600
Overhead Mounted Sensors on Mast Arm	$6,250	$37,500
Overhead Mounted on Sign Bridge	$13,250	$79,500

For all configurations, it is assumed that power and communications conduits are available at the location of the processor cabinet. With the exception of the VID, a Model 170 processor and cabinet is included. Conduit, cable, installation and testing costs are included for all cases. For the two configurations with median located poles (VID and overhead sensors on mast arm), costs for jacking conduit under four lanes are included.

Maintenance costs must also be considered. Maintenance costs are usually calculated on an annual basis as 10 percent of the original equipment cost. Maintenance costs associated with induction loops may be higher, as indicated by local experience.

Active Vehicle Detection - Technologies that include electronics in the vehicle that interact with the roadside infrastructure and other vehicles in the immediate vicinity appear to be the next step toward automated guidance and highway systems. Although it is expected to be at least two decades before these technologies become widespread, devices in this category are currently being used for specific applications around the country.

Automatic Vehicle Identification: The recent conversion of many toll facilities to electronic toll tags for electronic toll collection (ETC), also referred to as automatic vehicle identification (AVI), creates a potential for vehicle detection and monitoring in some areas. By monitoring the movement of individual vehicles past various AVI antennas, the vehicles become active probes and link travel times can be determined. This technology is successful in areas where AVI tags are being used for toll roads, but is of limited applicability elsewhere. The installation of AVI on the Kansas Turnpike may eventually result in an adequate population of AVI equipped vehicles in the Kansas City area, however, other technologies are probably more appropriate in the near future.

Another use of AVI technology is its use on transit vehicles to determine their location. The use of induction loops as the reading antenna has been successfully deployed in some areas. This use of AVI has found a receptive audience as a method for more accurate tracking of bus fleets for control and dispatch.

Global Positioning Systems (GPS): GPS equipment is being used by various emergency (police and emergency medical) and fleet (trucking) organizations to permit continuous tracking of vehicle locations. In fact, a number of emergency response agencies in the Kansas City area have plans to acquire these systems in the near future. The costs per vehicle are still too high for widespread use by the general public, but the technique is very beneficial in those cases where it can be justified. Accuracies range from a few hundred feet to a few feet, depending upon the capabilities of the GPS receiver. The more accurate units are proportionally more expensive. GPS receivers as accessories for PCs are now available at prices of less than $1,000. As sales volumes increase, prices will continue to come down and additional hardware and software features will be added.

GPS receivers are an important component of vehicle navigation systems currently being tested. It is included as a component of the in-vehicle navigation systems and vehicle emergency notification systems (such as MAYDAY system discussed later in this chapter) being considered as part of the National ITS Architecture. Vehicle location using this technology coupled with a data channel linking a public service vehicle (such as police, fire, or transit) to the TOC is being evaluated as a component of incident response systems elsewhere in the United States. The ability to locate emergency response vehicles in real-time on a status map is a very useful tool in managing and coordinating incident response over a wide area. After some initial operational experience is gained from systems currently in development, the effectiveness and costs can be evaluated for possible use.

Automatic Vehicle Location (AVL): A variation on the GPS strategy is the use of fixed location beacons that can be monitored by a vehicle, such as a bus. Through the use of an on-board computer, monitoring of the vehicle's movement with an electronic odometer, and known information about a route to be followed, the location of the vehicle can be estimated. The location beacon allows the strategy to be refined by providing "check-points" that permit the on-board computer to update and correct its estimates of location. This is basically the system used by the Kansas City Area Transportation Authority (KCATA) and MAST, the emergency medical responder in Kansas City, Missouri. Although the KCATA's system is not currently operational, the KCATA does have a grant to replace the equipment which will make the system operational.

The periodic transmission of vehicle location to a central computer allows a central dispatcher to track the vehicle. This tracking can be matched to a bus schedule, for example, and alert the driver and the dispatcher if the bus is ahead of or behind schedule. This automated vehicle monitoring can be input to the traffic management system, providing active probes in the vehicle stream, similar to the AVI system discussed above. When transit vehicles are used as probes, the start/stop nature of transit vehicles must be taken into account when estimating the flow of traffic. The integration of this tracking with voice communications to the bus driver is a very useful tool in locating incidents, and determining their nature and severity. Although monitoring transit vehicles through an AVL system would be possible in Kansas City, it would be of limited benefit for freeway monitoring due to the lack of transit vehicles regularly using the freeway.

Detector Comparison Matrix - Table 5-2 illustrates the major features of the most common types of vehicle detectors. This table includes the primary parameter that is most directly measured by the detector and the preferred mounting.

CLOSED CIRCUIT TELEVISION

Closed circuit television (CCTV) provides the eyes for the operator at the TOC, and has proven to be one of the most valuable elements of an advanced traffic management system. Operational experience shows that constant monitoring of CCTV images by operators is not effective, as the operator soon becomes "numbed" by the constant repetition of vehicles moving across the screen. The primary role of CCTV is to verify a reported incident or other traffic condition, to evaluate its severity, and determine the appropriate response vehicles and personnel to dispatch to the incident scene.

In addition to its primary role in incident verification and response coordination, CCTV can also be used for other purposes, including:

- Monitoring the operation of critical signalized intersections that are in the vicinity of the CCTV camera. This allows evaluation of signal timing and the related functions of the controller. Overland Park and Lenexa, Kansas, are considering the use of CCTV for monitoring selected intersections.

Table 5-2. Major Features of Common Vehicle Detectors

Detector Type	Primary Data	Mounting Location	Comments
Loop	Presence	Roadway per lane	Roadway cut installation life is approximately 3 years.
Piezoelectric	Axle count, Weight	Roadway per lane	Installation involves roadway cut.
Radar (CW)	Speed	Overhead per lane	Poor results at low speeds.
Radar (multi-zone)	Presence	Overhead, Side, Multi-lane	Some tests show difficult calibration.
Passive IR (non-image)	Presence	Overhead per lane	Few installations.
Passive IR (image)	Presence	Overhead, Side, Multi-lane	Few installations.
Active IR (non-image)	Presence	Overhead per lane	Few installations.
Acoustic (passive)	Presence	Overhead per lane	Some tests show reliable operation. Few installations.
Ultrasonic (pulsed)	Presence	Overhead per lane	Poor sample rate for high speed flow statistics.
Ultrasonic (CW)	Presence	Overhead per lane	Poor results at low speeds.
Magnetometer or Microloop	Presence	Roadway per lane	Manufacturer claims good results on bridge decks.
Video Image	Tracking	Overhead, Side	40 ft mounting height suggested.
AVI	Travel time, Location	Overhead, Side, Limited Range	As electronic toll use increases, population of users should grow.

- Utilizing the CCTV camera to monitor freeway diversion routes to determine current operating conditions. This allows verification that the arterial streets have adequate capacity.

CCTV cameras, lenses and typical mounting heights (40 feet above the roadway surface) allow monitoring of roughly one-half to one mile each direction from a camera location. This is, of course, restricted by topography, roadway geometry and vegetation. Some installations have mounted CCTV cameras on high-mast poles or towers more than 100 feet above the road. This added height provides a larger area of coverage, if topography and vegetation are favorable.

Specific selection of camera locations is controlled by the desire to monitor high-incident locations and other areas of interest. Ability to view parallel surface streets and ramps should also be considered in site determination. The constraints imposed by access, available locations for cabinets and pole foundations, and communications often limit the optimum selections. Each prospective site must be investigated to establish the camera range and field-of-view for the mounting height and lens combination selected.

The biggest issue with respect to CCTV is the transmission of the image from the camera location to the control center. Direct video requires a communications channel that is equivalent to more than 1,500 voice grade audio channels. Thus, most efforts in optimizing CCTV systems are directed toward reducing the bandwidth of the CCTV communications channel. These efforts range from not updating the image in real-time (real-time requires 30 updates per second), to digitally compressing the image, through analyzing the image and transmitting only the moving elements of the image.

The standard for CCTV pictures is a "broadcast" quality, full-motion, real-time image. At present, this is usually implemented by use of a fiber optic communications system, with a separate full bandwidth fiber allocated for each CCTV camera. With the tremendous bandwidth available on a fiber optic system, this direct approach is often the least costly and provides the best performance. When this direct approach is not cost effective, alternative solutions must be utilized.

Camera Type - Color images provide the greatest amount of visual information and are the preferred choice of most TOCs. However, color CCTV cameras rapidly lose their sensitivity under night, or other dim lighting conditions. Black-and-white cameras, on the other hand, are available that will produce usable images even when it is too dark for a person to see. A black-and-white camera is able to produce a usable image with 10 percent or less of the light level required for a color camera. Some vendors have solved this dilemma by packaging both a color camera and a black-and-white camera in the same housing. This increases the price of the assembly, but the added cost may be acceptable in some locations. Actual field testing should be performed, or the performance of cameras at existing TOCs should be verified before committing to a specific equipment selection. The typical cost of a color camera, with field controller and cabinet, pan/tilt unit, housing and mount, and installation and testing is roughly $20,000.

Pan/Tilt/Zoom/Focus Control - The CCTV camera in the field must be moveable (left and right, and up and down) in order to permit it to monitor the greatest possible area. Similarly, a zoom lens to allow viewing of vehicles at varying distances and associated focus control is required. These functions must be capable of being controlled by all operators who have access to the CCTV images. This functionality is implemented by placing a microcomputer at each CCTV location that receives commands from the traffic operator. This microcomputer turns on and off the appropriate motor in the pan/tilt unit or the motorized lens.

Each CCTV system vendor has its own proprietary system for this type of control. As systems grow and expand over time, control compatibility must be maintained so that the operator is not faced with several different camera control systems. The needs of the control system, both initial and long-term, must be addressed during the system design, considering the growth requirements and future needs.

Digital vs. Analog Transmission - The technology used to date for most long haul, "broadcast quality" CCTV systems has been analog transmission. Within the past five years, significant progress has been made in the development of cost-effective digital transmission equipment. Once video is converted to the appropriate digital format, it can be transmitted long distances over a fiber optic link using a digital protocol such as a Synchronous Optical Network (SONET) communications system with no further conversion and without degradation of image quality. Additionally, digital video switches are smaller and less expensive than analog switches.

Another benefit of digital video is the ability to compress the video image, and thus utilize lower bandwidth on a less expensive data communications channel, which may be used to transport the video to another facility. Typical compression ratios are 40:l. The cost of compression/decompression (codec) equipment is currently about $5,000 per unit.

Fiber vs. Coaxial Transmission - The use of fiber optics for transmission of video has almost completely replaced the use of coaxial cable, except for very short runs of less than 500 feet. Disadvantages of coaxial cable include requirements for amplification of the transmitted signal every few thousand feet (to compensate for signal attenuation), the susceptibility of the cable to induced noise, and damage to the electronics from lightning strikes. Fiber optic transceivers are now available with ranges up to five miles for multi-mode fiber, and over 20 miles for single-mode fiber. These transceivers range from less than $300 for short range units to over $2,000 for long range devices.

Geographically Distributed Control - An effective and needed strategy in modern incident/traffic management systems is distributing video images to the multiple locations and agencies that can utilize them. This provides for joint, coordinated response to an incident. In addition to the video images, camera selection and pan/tilt/zoom control may also need to be distributed. Geographic distribution of these control functions should be considered in the basic design of the CCTV system, since adding these capabilities to a simpler system is often difficult and costly.

Video Switch - A key component of the CCTV system is the video switch that allows any CCTV camera to be viewed on any monitor, at any location that has access to the CCTV system. A variety of switch architectures are available, from fully centralized to fully distributed. Each has its own advantages and disadvantages, and associated costs. Most CCTV systems have more cameras than monitors, with typical ratios ranging from 3:1 to 10:1.

The cost of analog video switches is a function of the number of switching points, which is the product of the number of camera inputs and monitor outputs. Thus, prices can increase exponentially as the size of the switch grows. For a relatively small switch (30 camera inputs and 10 monitor outputs), the installed cost is about $20,000. Doubling the size of the switch to 60 camera inputs and 20 monitor outputs results in the cost increasing to about $75,000.

Newer digital techniques, similar in concept to a local area network (LAN), are being utilized to transmit and switch video images. With these techniques, the video image is digitized and divided into small segments. These segments (or packets) are then distributed on a very high speed transmission system, and those users who need to view a particular image copy the packets for that image and reassemble the image for viewing. This strategy is commonly used in the telephone industry for switching voice conversations. Since switches of this nature do not increase exponentially in size, they have the potential for being less expensive than analog switches. However, because of the high bandwidth and transmission speeds required, these devices are still more expensive than moderate sized analog switches. With the typical decline in costs for all digital based systems, digital switching of video images is expected to become a cost effective alternative.

In all cases, the cost of video monitors, interconnection to the video transmission system and monitors, operator controls and system integration must be added to the cost of the basic switch.

Large Screen Video - A large video screen (Often 3x4 feet, or larger) is frequently included in TOCs. The ability to project either an enlarged video image, or an enlarged computer generated graphic can be useful for decision support during incident response or for public relations during tours or demonstrations. Operators in TOCs with large screens report that they seldom use these enlarged images during normal operations.

Two fundamental technologies are available, video projection, and video wall. Video projection utilizes either a cathode ray tube (CRT) or an liquid crystal display (LCD) system to optically enlarge the image and display it on a screen (using either front or rear projection). Care must be exercised with respect to room lighting since the projected image is easily washed out by typically available light. A video wall provides a large display area that overcomes this problem. The video wall combines a number of moderate sized (21 inch typical) video monitors into an array. This array is often four monitors high and four monitors across. Electronic circuitry divides the original image into smaller parts (for example, sixteen images for a 4x4 array) and displays each sub-image on a separate CRT. Current cost for large screen projectors is in the $35,000 range, while video walls are often more than $50,000.

ELECTRONIC TOLL AND TRAFFIC MANAGEMENT

Electronic toll and traffic management (ETTM) systems encompass automatic vehicle identification (AVI) and electronic toll collection (ETC) with communication between vehicle and roadside. Transponders carried by vehicles participating in the program can be used to track travel times of vehicles on the roadway. The information obtained in this manner can be used to improve detection of incidents that create significant impacts on the level of service provided by the roadway system.

The use of ETC has recently been implemented on the Kansas Turnpike (the electronic tag is called a “K-tag”). Electronic tags, slightly larger than credit cards, are placed on the inside of the vehicle windshield. The tags communicate on high frequency radio links with equipment at a toll plaza as the vehicle passes through the toll lanes. These tags may eventually be used for vehicle identification for commercial vehicle applications, including enforcement activities. Furthermore, vehicles with K-tags may eventually be used as traffic probes, as discussed next.

Vehicle Probes - ETC provides the opportunity for vehicle tracking that was formerly not possible. Each K-tag has a uniquely identified electronic serial number and can be read at highway speeds. The use of equipment to read the tags at opposite ends of a highway link allows the system to track the passage of individual vehicles and thus provide a direct measurement of link travel time. Each equipped vehicle provides the system with an origin location and time and a destination location and time for each equipped link and hence becomes a probe vehicle without disturbing the traffic flow.

Installation of the antenna to communicate with the in-vehicle transponder must usually be done so that the communications range can be kept below a distance of about 30 feet, An overhead antenna may be able to cover three or four lanes simultaneously. The question of interference from multiple tags responding simultaneously has been considered by the various manufacturers, although this would probably not be an issue in the Kansas City area due to the fact that only one entity currently uses ETC and the population of users is relatively small. For the purpose of collecting travel time data, a lower cost "compact reader" interfaced to only one antenna could be used to scan multiple lanes. Some vehicles will be missed when in the shadow of another vehicle or when simultaneous responses cause the return data to be garbled. Vehicles will also be missed if they are beyond the range of the equipment. If the population of ETC users increases significantly, data collected from a few stations should provide enough matches of transponder reads to calculate an estimate of travel time.

Alternative Probe Technologies - Investigations are being performed that utilize cellular telephone serial number tracking with direction finding capability at some cell towers to determine average vehicle speeds. Legislation concerned with privacy may affect the use of this type of device, but products that do not monitor conversations and do not use actual telephone number identification are still in development.

Communications Technologies

Two primary alternatives are available for system communications, commercial circuits and agency owned circuits. Typical systems use a mix of these alternatives, driven by costs and requirements. Communications technologies are rapidly changing, providing faster and higher capacity circuits at lower costs. New wireless options are emerging, spurred by growth in portable computers and personal communications. To take advantage of these changes, the system communications architecture must be flexible and designed around common and commercially supported standards.

The following summary reviews selected communications options. Since the primary communications for the Kansas City ITS system will be based on fiber optics, this technology is discussed first. Other alternatives are also discussed, because there may be some applications for their use on arterials where fiber optics have not been installed, to connect field equipment to the fiber optic network, for communications with emergency responders and other secondary functions.

FIBER OPTIC CABLE

Fiber optic cable is being installed in all new communications systems used for incident/traffic management, and is the proposed communications medium for the ITS system in Kansas City. Fiber optic cables provide very high data rates (2.5 gigabits per second, Gbps) over long distances (over 25 miles) without amplification. Other advantages are the small cable diameters (a 0.5 inch cable can contain 72 fibers), immunity from electrical interference, and avoidance of ground loop and lightning strike problems encountered with metallic conductors.

Fiber optic cable is commonly manufactured with two internal structures: those fibers that support single-mode transmission and those that support multi-mode transmission. Single-mode fibers are used for long haul circuits that are longer than a few miles, but require more expensive transmission and receiving equipment to take advantage of its higher performance characteristics. Multi-mode fibers are typically used to transmit video images a short distance from the CCTV camera to a communications hub that is at most a few miles away, where the images are combined, or multiplexed, onto a long haul single-mode fiber for transmission to the control center. Multi-mode fiber utilizes lower cost transmission and receiving equipment, but has a limited transmission range.

Because fiber optic communications is the primary technology being installed, and because it is expected to be the backbone for the communications system in Kansas City, additional details are provided in the following two sections, *System Architecture and Network Configurations.*

Fiber Optic System Architecture _ Fiber optic communications systems were initially developed in the 1960s by the telephone companies for long haul transmission of voice and data. The technology has undergone successive refinement over the past quarter-century, and is today the technology of choice for essentially all new communications systems. Early deployments of fiber optic systems replicated the existing systems that were based on twisted pair, coaxial cable and microwave channels, implementing digital carrier systems at DS-1 (1.544 megabits per second, Mbps) and DS-3 (43.232 Mbps) transmission rates.

Within the past 10 years, a new standard termed Synchronous Optical Network (SONET) has been developed. The SONET standard is based on multiples of 51.84 Mbps, which is known as an Optical Carrier 1 (OC-1) channel. An OC-1 channel carries a DS-3 data stream, plus additional control and status information. SONET systems typically are installed with OC-3 (155.52 Mbps), or OC-12 (622.08 Mbps) capacity, with some systems implementing OC-48 (2488.32 Mbps). Faster data streams are being planned.

A key design concept of SONET is redundancy. This redundancy is achieved by the use of dual counter-rotating ring circuits. These rings provide for automatic rerouting of traffic onto the secondary ring, in the event of a failure in the primary ring. Since the secondary ring transmits data in the opposite direction from the primary ring, a cable break at one location does not result in a system failure. This re-routing capability is referred to as a self-healing ring. The switch-over from the primary to secondary ring occurs rapidly enough that most data communications can recover without data loss, however, real-time traffic such as voice or video may incur a momentary loss of communications. Restoration of full system functionality requires field repair of the broken cable. Equipment failures are also contained by the inclusion of redundant components at all key locations. This redundancy is included in the basic design of the SONET system.

While alternative configurations may be considered, SONET is the preferred choice of all new communications systems. The use of SONET by the telephone companies and long distance carriers has resulted in a wide range of manufacturers and vendors of equipment. The resulting competition has generated a wide range of features and capabilities, and very attractive benefit cost ratios. Other alternatives do not have the range of options and features, and typically are more expensive when compared to SONET on a functionality basis.

The advantage of SONET is also its greatest drawback, namely the very wide bandwidth that is supported. This communications capacity results in higher costs when compared to the lower bandwidth solutions, but extending the lower end solutions to SONET capabilities ultimately requires a higher system cost. The other limitation of the higher bandwidth is the impact of a system failure, in that it impacts more field devices and communications channels. However, the self-healing capability and designed-in redundancy of SONET typically results in a more reliable overall system.

The design of a SONET system utilizes four single-mode fibers on each link, preferably with two separate routings, using 1310 nanometers (nm) or 1550 nm for transmission. Interconnection of field devices to the SONET backbone requires the use of a "communications hub". A hub serves to interconnect low speed (1200 to 9600 bits per second, bps) data streams from field equipment, such as individual 170 controllers and VMSs, to the much higher data rates of the SONET backbone. This interconnection is performed by devices knows as multiplexors/demultiplexors. Data originating at several field devices is combined together in a "time-slice" format for transmission to the central facility. This combination makes best use of the capacity of the SONET system. In the reverse direction, the data coming from the central facility is extracted from, or demultiplexed, from the combined data stream and routed to individual field devices. An equivalent set of multiplexors/demultiplexors exists at the central facility to perform the same functions of combining and separating data.

Since voice can be represented in a digital format, the SONET system can also be used for voice communications. Digital transmission of voice is extensively used by all the telephone companies and long distance carriers, and has been the driving force behind the development of digital carrier and SONET technologies. Highly cost-effective and very reliable systems are thus available from the telephone company equipment suppliers. Agencies often utilize this voice capability of a SONET system to implement PBX-to-PBX links between various locations, and to bypass the telephone companies to reduce their long distance charges.

FIBER OPTIC NETWORK CONFIGURATIONS

There are three basic network configurations, or topologies, that are used to design fiber optic systems: star, bus, and ring.

Star Configuration: In a star configuration, separate fiber optic trunks are used to connect the communications hubs to the central facility. At each hub, connections are made to the field devices through a local distribution network which can consist of several different types of media, such as fiber optic cables, twisted pair, or radio based communications. The data to and from the central facility is multiplexed and demultiplexed at the communications hub.

This type of configuration has a disadvantage in that separate "home runs" are required from each hub to the central facility, and that it is typically not configured with redundant, automatic switch-over, fibers or equipment. However, this is a proven system and has been successfully used in many traffic management systems.

Bus Configuration: In a bus configuration each communications unit, which may be a device located at a node or communications hub, or a field device such as a 170 controller, is connected to a fiber optic link or series of fibers carrying data in two directions, i.e., full duplex. Every device connected on the bus is assigned a channel and an address. Each device is accessed by polling it on its assigned channel, using the specified address, to retrieve data in the device and to send it control information. This bus configuration is commonly used in local area networks (LANs) used to link together personal computers.

The advantage of this configuration is the use of a single communications facility reaching from the central location to each field device. However, low cost fiber optic modems that are directly compatible with 170 controllers, VMSs, and related equipment are not readily available. This technology has not been utilized in operational traffic management systems, and thus there is very limited experience.

Ring Configuration: Ring configurations can be implemented as either a single ring, or as a dual (redundant) ring. Most ring configurations being installed today utilize a dual ring to take advantage of automatic reconfiguration, or self-healing capability of the system. This fault-tolerant approach significantly increases system reliability.

The operational advantages of self-healing rings are clear. Because this configuration is being widely implemented and utilized, a full range of equipment at competitive prices is readily available. The disadvantages are the requirement for additional fibers, and redundant equipment at the communications nodes. However, the incremental costs of additional fibers within the same cable is very small (approximately $150 per fiber per kilometer). Similarly, the incremental costs of redundant equipment when compared to the life-cycle cost of system failures is quite small.

Star-Ring Configuration: A combination of the star and ring configurations is recommended in the Kansas City area due to the geometric configuration of the roadways, and the redundancy provided by such a configuration.

COMMERCIAL COMMUNICATIONS CIRCUITS

The local telephone company, cellular carriers, and other communications service suppliers provide a variety of circuits operating at a wide range of speeds. Initial installation costs and short term monthly costs for low speed data circuits are low, and are thus advantageous for vehicle detection and variable message sign circuits. Maintenance and repair is provided by the commercial service provider, removing the requirement for special training or equipment within an agency. The drawback of this arrangement is the “finger pointing” that often occurs when multiple parties are involved. The primary disadvantages are the long term costs (recurring monthly billings), and the expense of high speed circuits. Since the monthly costs are considered operational expenses, they must be budgeted from annual operations budgets and are thus often more difficult to obtain than initial capital funds.

Commercial communications circuits are available as either switched (dial-up) or dedicated (private line) facilities. Each of these basic types can be configured as point-to-point (two parties) or multi-point (three or more patties) circuits. For dial-up service, a multi-point circuit is usually referred to as a “conference call”. For dedicated circuits, the term multi-drop circuit is often used interchangeably with multi-point. A further distinction is the transmission technique used, analog or digital. The original telephone network was designed as an analog system for the transmission of voice. The availability of low-cost, high-performance computer circuits has allowed the telephone system to convert much of its transmission and switching equipment to digital technologies, resulting in better quality and performance at reduced cost.

Pricing of commercial circuits typically involves a one-time installation charge, and a recurring monthly charge. Circuits can be obtained on a month-by-month basis, or on various contractual terms ranging from 1 year to 10 years. Month-by-month service provides the most flexibility since service can be terminated when required, but it is the most expensive option. Multi-year contracts provide lower monthly costs, but include penalties for cancellation prior to the end of the contract period.

Dial-up Analog Service - This is the basic voice-grade telephone service provided for residences and businesses. These channels are provided to support voice communications and are universally available. Currently available modems (modulator/demodulator) provide data transmission speeds in excess of 14.4 kilobits per second (Kbps) on dial-up phone lines. These units are inexpensive (about $250) and are widely available with numerous features and options. They are extensively used on personal computers for data and fax transmission, and well supported by commercially available PC software.

Dial-up telephone service is a useful alternative for occasional, relatively short-term data transmission. The dialing and connect time (15-30 seconds) does not realistically permit data collection or control of devices more frequently than every five minutes. The dial-up telephone network is designed and configured for human calling patterns and call holding periods, allowing the expensive central office equipment to be shared among many subscribers. Use of dial-up circuits for frequent data calls, or for long holding times, or for many hours of use per day, ties up the central office equipment and results in the local telephone company complaining about inappropriate usage.

The other concern with any dial-up configuration is security. The ability of “hackers” to break into computer systems has been widely reported, and cases of inappropriate or unsafe messages being displayed on VMSs through dial-up access have been documented. The use of dial-up/dial-back, encryption, security passwords, and other safeguards reduces the risk, but at the expense of increased system complexity and additional inconvenience for the personnel who have to support and maintain the system.

Integrated Services Digital Network - The technology for integrated services digital network (ISDN) was developed by the telephone industry during the early 1980s but has seen a very slow deployment. In the past few years, however, the penetration has increased significantly in many areas. The key benefit claimed for ISDN is the availability of 144 kilobits per second, Kbps (divided into two 64 Kbps data channels and one 16 Kbps control channel) of switched digital data over two pairs of wires. Another benefit is the reduced switching/interconnect time, making it feasible to support more field devices on dial-up connections. There are two ISDN user offerings, the basic rate interface (BRI), and the primary rate interface (PRI). Basic rate ISDN is the digital equivalent of dial-up analog service. Primary rate ISDN is the equivalent of T-l service, it provides the user with 23 channels of 64 Kbps data and one control channel operating at 64 Kbps. Interface boards (equivalent to modems) for certain types of computers are coming down in price (into the $1 ,OOO-$2,000 range) and increasing in availability.

For the current generation of incident traffic management system equipment, utilization of ISDN circuits is probably not feasible due to the lack of interface boards for the equipment. Circuit availability is also a limiting factor. However, the next generation of equipment may well be able to take advantage of ISDN. Since ISDN was developed as a digital service, its error characteristics and operational parameters will result in excellent performance. The current lack of interface boards, and limited availability of ISDN service limits the usefulness for current projects. Furthermore, since ISDN is basically a dial-up service, its use for full-time channels, as typically used for traffic monitoring applications, may not be effective.

Video devices, on the other hand, are coming on the market with ISDN compliant interfaces. It may be feasible to utilize this technology to access remote cameras and transmit the video images to the TOC or to transmit video images from the TOC to emergency responders. The bandwidth available on a single BRI circuit is probably not enough for most applications to show traffic motion. Some manufacturers are providing inverse multiplexing capabilities in their equipment that obtains the required bandwidth from the inclusion of additional BRI data channels.

Dedicated Voice Grade Analog Channels - These circuits have been the backbone of many traffic management and arterial control systems over the past twenty years. Modems to utilize these circuits are included in the design of 170 and NEMA equipment. They can be configured as either point-to-point or multi-point circuits, and can support speeds in excess of 9600 bps with current modem technology. There is a wide range of equipment available for interface to these channels. There are reports of telephone companies changing their tariffs and pricing policies to discourage use of these channels over the long term, in an attempt to move customers to digital channels. The primary advantages of these circuits is their wide-spread availability and their low cost for low speed circuits. Since these channels are designed for voice, they are not optimized for the transmission of data.

Digital Data Channels - The telephone companies offer a range of digital channels running from 2.4 Kbps to 64 Kbps. They are often referred to as DATAPHONE Digital Service (DDS) circuits. These circuits are primarily dedicated circuits, but are occasionally available in a switched configuration. One difficulty with these circuits is that they are usually configured as synchronous data circuits, while most communications for incident/traffic management systems are asynchronous, requiring adapters at each end of the circuit. Since these channels are designed for data transmission, their reliability and operational characteristics are very good. The principle disadvantages are the fundamental synchronous nature of the channels and the limited availability of the data/channel service units (DSU/CSU) needed to connect to the circuits.

Digital Carrier - In the mid-1960s the telephone companies began converting their long haul trunk circuits from analog technology to digital technology. The basic deployment was the DS-1 (digital service 1) channel, operating at 1.544 Mbps. Note that this channel is commonly referred to as a T-l circuit. This T-l circuit is configured to support 24 voice grade channels, each requiring 64 Kbps of digital bandwidth. There is a hierarchy of faster digital circuits, each built upon various combinations of T-l circuits. A typical combination is DS-3 (T-3) at 43.232 Mbps, or 672 voice grade channels. The emerging Synchronous Optical Network (SONET) standard builds upon DS-3, and is defined in various combinations as high as OC-48 (Optical Carrier 48), which operates at 2,488 Mbps, or the equivalent of 32,256 voice grade channels. Within the past few years, T-l service has become more readily available to end users, driven by the demand for higher speed communications channels to link computers and local area networks together. The primary interest in T-l for traffic/incident management systems is digital transmission of video signals. T-l provides a reasonable option to agency owned fiber optic cable for a few circuits and limited period of time, but quickly becomes quite expensive if large numbers of circuits are involved.

Cellular Telephone - Cellular telephones have rapidly expanded their market penetration over the past five years, pushed by the convenience and declining prices. The cellular telephone network now covers over 93 percent of the United States population. Off-the-shelf cellular modems permit the transmission of data over the cellular network. Note however, that cellular modems utilize different techniques for error correction and circuit initialization, and thus are often not compatible with landline modems, The use of cellular telephones by field personnel has simplified many maintenance and incident response procedures.

The ready availability of service and capability to locate equipment anywhere within the coverage area provides a high degree of flexibility, especially for temporary installations and portable or mobile equipment. Cellular equipment eliminates the need to connect to a telephone company service point. This capability of establishing a circuit on an as needed basis may prove cost effective for infrequent communications.

The primary disadvantage of cellular service is its cost. Each cellular "telephone" incurs a monthly service charge ranging from $15 to $45 per month, and a per-minute airtime charge ranging from $0.10 to $0.50 per minute. Due to competition, increasing numbers of users and the resulting additional volume, prices are falling. These price decreases are being driven by reduced unit cost reductions and "innovative" service plans. However, even if costs were as low as 10 cents per minute, airtime costs $144 per day, making full-time cellular communications prohibitively expensive. Since the existing cellular network utilizes analog transmission, it is somewhat noisy and thus limits the speed of data transmission.

Packet Radio - Packet radio is a wireless technique that is designed specifically for the transmission of data. Commercial suppliers utilize radio base stations to communicate with multiple field transceivers via time synchronized bursts, or packets, of data. Since many field transceivers share the same frequency pair for transmitting and receiving data, a cooperation strategy (or communications protocol) is utilized to coordinate this sharing. Because of this sharing, there can be delays of several seconds in delivering a packet. The pricing structure of packet radio is based upon the amount of data transmitted, measured either in bytes or packets. This pricing structure, and the basic architecture of packet radio, is most effective when transmitting short messages, and not large quantities of data. Typical prices are $0.03 per 100 bytes transmitted, which results in a cost of about $5.00 per hour for real-time communications with a traffic monitoring processor. This cost is prohibitive for continuous communications, but may be attractive for occasional use to some remote VMS or other field equipment that would have been reached by cellular telephone. Considerable development may be required to convert the remote device and central processor to communicate in packet network protocol.

Satellite - Satellite communications services have been available for many years, and have proven cost effective for long distance point-to-point circuits and for wide area broadcast applications. However, for "local" applications (distances less than a few hundred miles), the costs of ground stations and satellite transponder rentals are prohibitive for traffic management applications. A typical monthly cost for a 56 Kbps circuit is $10,000, however, this is essentially independent of circuit distance, with a 200 or 2,000 mile circuit costing the same.

The one case where satellite communications has proven useful for traffic management is incident response in rural areas. The ability to deploy an incident response vehicle, with voice, data and limited-motion video communications to a central control facility, has proven effective in field trials. The flexibility of this approach is a significant benefit, but the cost needs to be weighed against other communications channels.

AGENCY OWNED FACILITIES

In an effort to reduce monthly operating costs, and to provide the communications bandwidth needed for large numbers of video cameras, many agencies install their own communications facilities. For cable based land line systems, the cable and electronics are moderately priced; but the cost of trenching, installing conduits and ducts, backfilling and patching is significant. Depending upon construction conditions, conduit installation costs can range from $20 per foot to $40 per foot. This translates to between $100,000 and $200,000 per mile. If structures need to be crossed, or if roads must be bored under, these costs can even be higher. The cable, installation costs, splicing, and electronics termination equipment costs from $5 per foot to $15 per foot, depending on the specifics of the installation. The costs can be born by private agencies in exchange for use of roadway right-of-way. This kind of public/private partnership was used by the Missouri Highway and Transportation Department (MHTD) to obtain fiber on all interstates in Missouri, and the Kansas Department of Transportation (KDOT) plans to explore the feasibility of such an arrangement in Kansas.

Twisted Pair - Twisted pair cable has been the backbone of "the last mile" in communications systems for decades. It provides a simple, straightforward and low cost method for the short haul circuits from the termination of high capacity backbone (long haul) circuits to the individual vehicle detector cabinets or VMSs. Twisted pair works well for speeds up to 9600 bps for distances of several miles. It is usually installed in combination with a fiber optic long haul system to interconnect the field equipment to the communications hub.

Fiber Optic - Fiber optic cable, which is often agency owned, was discussed in earlier segments of this section.

Coaxial - Coaxial cable was previously used for transmission of video images from CCTV cameras into a control center. Due to the need for active amplification every half mile, image degradation over long cables, and maintenance problems, coaxial cable is no longer recommended for this application.

Conduit Installation Standards - A major cost element of a cabled communication system (twisted pair, fiber or coaxial) is the installation of conduit. Conduit can be installed at minimal cost during highway construction and re-construction activities. It seems reasonable to provide for future needs by placing conduit during any major roadway construction, provided that a means of record keeping can be utilized to locate this conduit when it is needed. Innerduct can be added at a later time if necessary. Conduit may be stacked on top of each other or buried side by side.

Several agencies include innerduct in their conduit. This provides extra non-obtrusive space for additional cable to be pulled through the conduit. There are different types of conduit with innerducts. Fiberglass conduit has four chambers molded right into the conduit. With the standard rigid metallic and non-metallic conduit, innerduct must be pulled through the conduit to provide separate raceways for cable.

Microwave - Point-to-point microwave is an attractive alternative for initial or limited usage transmission of video images from CCTV cameras. For those cases where it is neither technically feasible nor cost effective to install conduit and fiber optic cable, microwave can be utilized. Depending upon performance, a microwave system (transmitter and receiver, usually with a reverse direction control channel) for video transmission costs from $20,000 to $40,000. This equipment is very useful in the initial stages of system deployment, before a fiber optic system can be installed. As the fiber optic system is installed, the microwave equipment can then be re-used to extend CCTV coverage out beyond the end of the fiber optic network. A key limitation of microwave is the requirement for line-of-sight. Another problem with microwave is its degradation under adverse weather (heavy rain, etc.) conditions, A microwave installation must receive a license on a site by site basis from the Federal Communications Commission (FCC).

Wireless Video - A recent development in video transmission equipment is wireless video. This equipment transmits full motion video over a radio circuit, in a manner similar to that used by microwave, but without the stringent installation requirements. Wireless video does require line-of-sight, but the antennas are much less sensitive to alignment. The wireless video also does not require the licenses needed by microwave, because the equipment is class licensed by the manufacturer.

Spread Spectrum Radio - Spread spectrum radio transmission was developed nearly 50 years ago by the military as a security measure. These techniques were commercialized starting in 1985 when the **FCC** assigned frequency bands to spread spectrum radio. The technology spreads the signal bandwidth over a wide range of frequencies at the transmitter. The receiver knows the technique (or coding) utilized, and it thus able to recover the transmitted signal and reconstruct the original message.

Because each communications circuit within a given band utilizes a different coding technique, multiple, simultaneous circuits can co-exist. Spread spectrum generally requires line-of-sight, limiting its range to about six miles. The signal is attenuated by vegetation, so a site survey is recommended before committing to this technology. Field equipment can be placed anywhere within the range of a base station, thus very flexible installations can be developed. The basic technique of spreading the transmitted signal over multiple frequencies results in high noise immunity. The FCC has assigned the 902-928 MHz band for which no facilities license is required. However, spread spectrum equipment operating in this band cannot interfere with licensed equipment and must accept interference from licensed services.

For traffic management applications, there is significant potential for spread spectrum radio. The work that is currently under way to evaluate spread spectrum for the next generation of digital cellular telephones may result in a wide spread application of the technology. If this occurs, there will be an increased availability of equipment and resultant price reductions, However, technological advances may result in the need for increased personnel training and specialization, as well as more sophisticated equipment.

Traveler Interface Technologies

Traveler interface technologies commonly used and discussed in this section include VMSs, HAR, information kiosks, and dial-in information systems. As technologies become increasingly sophisticated, the potential applications of traveler interface technologies will increase. For example, in the future route guidance systems may automatically query the TOC for real-time and projected travel speeds, incorporating this information into route selection algorithms. In the meantime, proven technologies such as those discussed next may be used to keep the motorist informed about current conditions.

VARIABLE MESSAGE SIGNS

Variable message signs (VMSs), both fixed and portable, are widely used to provide motorist information during an incident. The ability to quickly alert motorists of a problem ahead and provide for diversion to an alternate route is a successful strategy for minimizing the impact of an incident.

A VMS consists of a matrix of dots or pixels, each of which can be individually controlled. The minimum group of dots for a single character is five dots horizontally and seven dots vertically. Larger "character cells" are often implemented for improved character resolution, the use of lower case letters, and "double stroke" characters. Since individual characters on a VMS are composed of discrete dots, the "sharpness" of a character is controlled by the number of dots per character. The tradeoff is cost, with cost of the sign being proportional to the number of dots on its surface. The human eye fuses together the adjacent dots in the character pattern, and recognizes the character as a whole. In general, the legibility of a 5 by 7 character cell dot VMS is very acceptable, especially if only upper case letters are used, which is typical for roadway applications. When lower case is required, or other effects are needed, larger character cells, and proportionally more expensive signs, are necessary.

If the VMS is intended for text messages only, adjacent "character cells" can be separated by a blank space to minimize the cost of the sign. An alternative approach is the "continuous matrix" sign, in which the separating blank space is deleted, resulting in all locations on the surface of the sign being controllable. This permits moving text, "exploding" and "collapsing" images, roller blind, horizontal shutter, and other types of special effects to be implemented. These special effects are more commonly used in commercial displays than in roadway applications. Use of a proportional font for improved readability or graphics is a common use of continuous matrix signs on a roadway.

Various display philosophies are in use by different agencies. Some feel that a VMS should only be used when necessary to display instructions or information about roadway conditions, feeling that if routine messages are displayed, driver awareness of the sign becomes numbed. Other agencies display a routine or safety message on the signs to confirm operability, while some agencies use their signs to advertise events. Because a VMS can display a wide variety of characters in each character ceil, dynamic messages can be created by manipulating the timing of the display of individual characters, or groups of characters. Simple effects that are quite effective for roadways include blinking text, moving arrows, and the cyclic display of a sequence of messages with delays between them. An example of the latter is displaying a repeating series of safety messages, such as "BUCKLE UP", "DRIVE 55 FOR SAFETY" and

"USE **YOUR** SEATBELT". Message complexity, information acceptance rate, and driver attention span all must be considered when utilizing these features on high speed roads.

Two fundamental technologies, light reflectance and light emission, are used to form the individual dots that create the letters of the message on VMSs. These technologies are discussed in the following two sections.

Light Reflective Signs - Light reflecting VMSs consist typically of a matrix of mechanically changed dots. The individual dot can be a flat disk that is black on one side, and colored on the other, a ball or cube that has color on one half, or a split flap that exposes a colored surface when opened. Other deployments consist of a multi-part flap that some vendors have utilized to implement a "white" character for daytime usage, and a "fluorescent color" character for improved visibility at night. This technique has been extended by one vendor to allow display of six different colors for each pixel. A variety of techniques have been used to improve the visibility of these signs, including internal illumination and retroreflective surfaces. Because the dots are mechanically moved, a finite amount of time is required to change the message displayed on the sign. Different vendor deployments result in a range of timing characteristics. On the slow end of the spectrum, rates of 30 characters per second are typical. At this speed, a sign with three rows of twenty-two characters per row will require over two seconds to change its message. Faster character write rates are available, with some capable of changing the entire message in parallel, but tradeoffs of power consumption, dot inertia, overshoot, and flutter all enter into the dynamics of the deployment.

To provide stability during periods of power outage so that dots do not randomly change position and display "garbage" on the sign face, and to reduce power consumption, some method of latching the dots into a fixed position is normally used. A common technique is magnetic, where a small fixed magnet is attached to the shaft on which the dot rotates. The dot is changed from its "dark" state to its "bright" state with a pulse of an electromagnet, thereafter remaining stable with no power input required. This has the advantage that a message that was displayed prior to a power failure will remain on the sign face.

These signs have a proven field track record, with a generally high reliability rate. Individual dots are rated in the range of 100 million operations. However, it is not uncommon to find individual dots stuck, either "dark" or "bright", as a sign ages. The signs are fabricated for easy repair, with each character cell being quickly replaceable, and individual dots repairable. The technology is easily scaleable, with character sizes ranging from 2 to 18 inches in height. A wide range of colors can be used on the "bright" side of the dot, with white or yellow being most common, but green, red, orange, gold, and others becoming available. Because of the mechanical nature of this technology, a weatherproof enclosure is required. Cost of these signs is in the medium to expensive range, depending on size, mounting, enclosures, and various options. For many agencies, these signs have accounted for the majority of their VMS deployments.

By mechanically rotating the disk, ball, or flap with different colors on the surfaces, the dots on the surface of the sign form letters The key advantage of this type of sign is the maturity of technology, and the long experience of their usage. Another advantage is the continued operation of the sign during a power outage, since the dots are bi-stable, requiring power to change their state, but not to maintain them in a particular state. The disadvantages include limited visibility under some lighting conditions, fading of color contrast over time, and mechanical failures resulting in a “stuck dot”.

Costs of these signs is a direct function of the number of characters on the sign face, the attention to detail and the quality. Since this type of sign is electromechanical, operational experience and product refinement based on many years of development have an impact on long term reliability. Large signs (3 rows by 20 characters per row) range in cost from $50,000 to $90,000, including installation and commissioning. Small signs (3 rows by 8 characters per row) cost $25,000 to $50,000. The cost of the support structure (sign bridge, attachment to overpass, or roadside poles) must be considered in addition to the basic sign cost.

A related type of sign is the changeable seven segment numerical display. This technology is useful for the display of variable speed limits. A sign may be fabricated in the form prescribed by the Manual on Uniform Traffic Control Devices for a speed limit signal with the numerical digits formed by remotely controlled displays. This technique produces an easily recognized, variable speed limit that is less costly than a full VMS.

Another related sign is the rotating drum sign, where several faces of a rotating drum (or several drums) can be used to display one of several messages. These signs can be configured with the same size, shape, and letter fonts as traditional static signs. Further advantages are their lower cost when compared to a “dot matrix” sign, and mechanical simplicity resulting in higher reliability. Their prime disadvantage is the limited number of messages that can be displayed on a single sign.

Light Emitting Signs - The use of an active light source at each dot (or pixel) of a VMS produces a light emitting sign. The original light emitting sign is the incandescent bulb matrix. This type of sign provides good visibility, and is currently used in commercial applications. However, it has fallen into disfavor for roadway applications due to the low reliability and high maintenance costs incurred due to bulbs burning out. Another major problem is the heat that is a result of the high bulb wattage and the high power consumption. Some agencies in warm climates have found that they have to limit the number of bulbs that are simultaneously on due to heat rise in the sign enclosure. In general, these signs are not favored because of these limitations.

Current technology developments utilizing “solid state” lamps over the past several years have produced signs with high brightness, simple control, and long life. The light source in these signs is the light emitting diode (LED). Until recently, the brightness of the LED was inadequate for bright daylight conditions. In particular, the “amber” LED, which is preferred for roadway usage, has been difficult to manufacture with the desired characteristics. Early LEDs suffered from variability in light output between “identical” LEDs, and aging effects which reduced brightness (often non-uniformly) over time. However, these problems appear to have been solved and the LED sign is finding acceptance in the field with many major manufacturers fabricating these signs.

A typical deployment utilizes a group of LEDs (on the order of 15) to form each individual pixel. This increases the brightness of each pixel and averages any small differences between adjacent LEDs. These signs have a very fast turn on and turn off time, eliminated the problems noted above with the rotating disk type signs. Because of the physics of the semiconductor junction and wavelength of emitted photons, LEDs have a limited range of colors. Red is the most common color, but yellow is preferred for most roadway sign applications. Green is also commonly available. Combinations of different colored LEDs are being used to implement colored signs. The small size of the LED, coupled with computer type integrated circuits, can produce displays with large numbers of individually controllable dots for special effect applications. The long life of the LED, combined with the inherent simplicity of the design concept, should result in very good reliability. Actual field experience, as these signs are deployed in large numbers, will have to be gathered to verify this expectation. Cost of these signs is moderately expensive, but that should change as usage increases.

Enhanced visibility is the key advantage of light emitting signs. The ability to mix various color light sources to produce differently colored messages is also useful. The biggest disadvantage of these signs is their requirement for continuous power, making them non-operable during power failures. If power failures are common, and the sign is critical to continued operations, some sort of back-up power is required.

LEDs have had some problems due to loss of light output intensity due to the aging of the light emitting active elements. Intensity reductions on the order of 50 percent have been observed after 30,000 hours of operation. A side-effect of this problem has been brightness differentials as a result of differing power-on times. This results in variations between different dots on the sign. Newer generations of LEDs appear to have solved these problems, with preliminary reports indicating either no intensity loss or even a slight gain. This is based on initial testing, with long term field results not yet available. Another benefit of these newer LEDs is their increased intensity, allowing a sign to be fabricated with fewer LEDs per pixel (resulting in a lower fabrication cost), a brighter sign with the same number of LEDs, or the ability to operate the LEDs at lower power (prolonging their life and reducing the aging effects).

Costs of LED signs is controlled by the size of the sign (number of characters on the sign face), the quality and reliability of the manufacturer, and the type of LED used. The newer, high-output amber LEDs are more expensive than older devices because of limited manufacturing yield and the need for the supplier to recover development costs. As with all semiconductor devices, component prices will decline fairly rapidly, especially as sales volumes increase. Large signs (3 rows by 20 characters per row) range in cost from $60,000 to $130,000, including installation and commissioning. Small signs (3 rows by 8 characters per row) cost $40,000 to $60,000. Cost of the support structure (sign bridge attachment to overpass, or roadside poles) is in addition to the basic sign cost.

Hybrid Technology Signs - The combination of a rotating disk or shutter in front of a light source produces a hybrid of mechanical motion and light emission. If the rotating disk is colored on one side, the light source enhances the message on the sign, providing additional visibility and contrast for longer distance viewing. Some vendors consider this an enhancement of the basic rotating disk/shutter sign, while others explain their product as a totally different technology.

The LED is often used as the light source, with the LED mounted behind the disk, and the disk serving as a shutter to permit the LED to be seen when the disk in the “bright” position, and masking the LED when the disk is in the “dark” position. One deployment mounts the LED off center, with a hole through the disk. When the “bright” side of the disk is visible, the hole is positioned over the LED. When the disk is rotated so that the “dark” side is exposed, the hole and the LED no longer coincide, and the LED is masked. Different vendors implement this same basic idea with a range of schemes, all effectively performing the same task.

A variation of this approach utilizes digital control technology that is connected to the circuit that controls the disk, and turns off the LED at each pixel when the “dark” side of the disk is exposed. This technique requires a location within each pixel that is constantly visible and works well with circular dots where the LEDs can be located in a “corner” of the pixel. However, with split flap pixels that are square or rectangular in shape, the locations for mounting the LEDs are limited.

The approach of combining a light source with a light reflecting sign is an effective manner for increasing the visibility of the basic VMS, producing a good combination for daytime and nighttime usage. The prime reliability concerns are those of the basic sign. Cost is greater than that of the basic sign, and the performance enhancement must be considered within the constraints of the project.

A matrix of shuttered pixels, with each pixel containing a fiber optic bundle that is illuminated by a high intensity light source is another combination used by some vendors. The concept utilized with this design is that of a light source for several characters (on the order of three or more), and bundles of optical fibers to “pipe” the light to each individual dot on the sign face. One configuration utilizes a rotating disk as the shutter. In another configuration, the shutter is assembled with its rotational shaft perpendicular to the sign face. This shutter functions in a manner similar to that of a camera, alternately blocking or uncovering the light source. The mechanical orientation of the shutter, and its motion, seem to result in enhanced reliability.

The light source is a high intensity light bulb, similar to that used in a slide projector. The brightness of each individual dot is several times brighter than that obtainable with the hybrid LED sign. A useful design feature is to utilize two separate bulbs for each fiber bundle, with an automatic switch over circuit when a bulb fails. Monitoring the current flow of the small number of bulbs involved in this design is convenient, resulting in the ability to report a bulb failure to the central control station. The second bulb can also be used to produce an “overbright” condition for poor visibility conditions, such as fog. Another convenient feature utilizes a motor driven colored filter between the bulb and the fiber optic bundle to produce different colored characters on the sign face.

This type of sign has carried a higher price tag, making it the “Cadillac” of VMS applications. The prime selling feature of these signs has been their brightness and the resulting high visibility. Some vendors emphasize the reliability of their signs, which may be more a result of high quality manufacturing and engineering than the fundamental technology. Competition, other market forces, manufacturing efficiencies, and related factors may eventually push the price down to make it more competitive with other technologies. As more of these signs are installed and field experience gained, their relative merits will be more sharply focused.

The combination of devices (light source and mechanical shutters) used to create a hybrid sign increases the cost about 20 percent over either a light reflective or a light emitting sign. However, the increased visibility is a key benefit that is often required.

The cost of hybrid signs also depends on the size of the sign (number of characters on the sign face) and the approach taken by the manufacturer. The “flip-disk” signs, to which LEDs or fiber optic light sources are added as an enhancement, cost 15 to 20 percent more than the basic sign. Thus, for a large sign (3 rows by 20 characters), the cost will be in the $60,000 to $105,000 range. And a small sign (3 rows by 8 characters) will cost $30,000 to $60,000. The fiber optic sign that utilizes shuttered pixels is primarily available in a 3 row by 18 character configuration and costs about $135,000, including installation and commissioning. The cost of the support structure (sign bridge, attachment to overpass or roadside poles) must be added to the basic sign cost.

VMS Control Systems - As the number of individually controllable elements on the sign face increases, the complexity of the control requirements increases. For all but the simplest rotating drum signs with just a few messages, some sort of computer based control is required. The manufacturers have selected a variety of microcomputers to meet this need. A few manufacturers have selected the Model 170 intersection controller as the microcomputer, which has the advantage of utilizing a standard item of hardware that is familiar to highway agencies. In other cases, the vendor has developed a special purpose microcomputer for controlling the specific sign they manufacture. In all cases, a unique software package has been developed for each deployment. Similarly, the command set used for communication between these signs and a control location is unique to each vendor's system. This command set is called the "communications protocol".

For an agency getting started with VMSs, a fully packaged system from a single supplier is simpler because the vendor can be assigned total responsibility for the system. But the proprietary nature of each vendors deployment (because standards have not yet been defined) creates difficulties when trying to integrate equipment from several vendors into an overall system. An agency can easily get locked into a single supplier, when there are superior or more cost effective products available. The agency may also suffer from poor support, or a product being "orphaned" when a newer model is introduced or a company is bought out.

In any application of VMSs where more than a few different messages are to be displayed, some form of central control and operator interface is required. The central control computer supplied by the vendor for remote access to and monitoring of the signs is usually a PC, but often with vendor specific hardware enhancements such as unique serial communications boards. The software that runs on the PC is unique to each manufacturers deployment, and ranges from convenient to obtuse in its user interface. Prices for the central system range from little more than the cost of the PC itself, to many times that, depending upon the features, the total system size, and the vendor's perception of the value of the central control system. The complexity of this software must not be underestimated. There are a great many features, interdependencies, database management issues, and operating subtleties to be handled, all of which contribute to the deployment difficulty and resultant cost.

The challenges associated with the control system can be addressed by carefully understanding the operational needs of the system, considering the growth requirements and future needs. In all cases, the vendor must be required to supply full documentation of all system components. The details of the communications protocol are especially important, so that existing signs can be integrated into a larger system when the agency's needs evolve and expand. Another option that will be available in the near future is the specification of the National Transportation Controller/ITS Protocol (NTCIP). This protocol is currently under development by NEMA/FHWA for NEMA/170 controllers, and will be extended to VMSs after the initial traffic controller work is completed. Selection of a VMS on the basis of ease of integration into a future larger system will usually be beneficial as the overall scope of this type of traffic information system increases.

VMS Communications - The connection between a VMS and the central processor can be provided by a standard serial data communications link. Data requirements for signs are usually small. VMS systems are often implemented with a library of messages. An operator usually needs only to select a pre-composed message, resulting in a very small communication load. If a completely new message is typed in by an operator, the communication load is only slightly higher. A complex message with graphics will require a larger amount of data to communicate the display to the sign. The communication link to a VMS will not generally need to operate above 1200 bps. This data rate will allow roughly 120 characters per second to be transmitted.

When a secure closed communications system is required to prevent unauthorized access to VMS control capability, an owned or leased communication link is necessary. Although the public switched telephone network is an open system, security measures can be added. Security measures could include the use of encryption devices and/or call-back security. Encryption involves the transmission of messages in a code that cannot be easily reproduced with a personal computer. Call-back security involves the placement of a call to the VMS and entry of an identification code. The VMS then places a call back to the control point before allowing access to changes in the sign message.

HIGHWAY ADVISORY RADIO

Highway advisory radio (HAR) is widely used to provide motorist information to travelers in a limited geographic area. Non-commercial information services include construction and traffic congestion information, possible alternate routes, traveler advisories, parking information at major destinations, safety information, and availability of lodging, rest stops and local points of interest. AM broadcast-band, low power level equipment has been used to provide this information on two frequencies, 530 kilohertz (KHz) and 1610 KHz. Presently, the standard broadcast frequencies between 530 KHz and 1700 KHz are available in 10 KHz increments, provided there is no interference with existing stations. The transmitter signal must also be low pass filtered in the audio range, to about 4 KHz resulting in a voice quality much like telephone transmission (between 3 KHz and 20 KHz the filter must attenuate at 60 log (f/3) decibels, dB where f is the audio frequency in KHz). The HAR transmitter consists of a device to record and playback messages, a radio transmitter, and an antenna. There are three different configurations used for HAR: vertical antenna, “leaky cable”, and micro-transmitter. Regulations governing the operation of HAR systems are defined by the FCC rules in Part 90.242.

Vertical Antenna - Probably the most commonly used HAR system utilizes a vertical antenna. This type of HAR is termed a traveler information system (TIS) and must be appropriately licensed. A single vertical antenna produces an omnidirectional (circular) radiation pattern that diminishes uniformly as the square of the distance from the antenna, provided there are no geographical obstructions.

FCC regulations for vertical antenna HAR/TIS stations include the following requirements:

- A separation of at least 15 kilometers from the 0.5 millivolt/meter daytime contour of any AM broadcast station operating on the adjacent frequency.

- A separation of at least 130 kilometers from the 0.5 millivolt/meter daytime contour of any AM broadcast station operating on the same frequency.

- The height of the antenna must not exceed 15 meters above ground level.

- The radio frequency (RF) output of the transmitter must not exceed 10 watts.

- A minimum distance of 15 kilometers must be maintained from any other vertical antenna HAR/TIS station.

- A minimum distance of 7.5 kilometers must be maintained from a "leaky cable" antenna HAR/TIS at the same frequency.

- A frequency stability of ±20 hertz (Hz) must be maintained.

- Signal field strength of antenna emission at the operating frequency must not exceed 2.0 millivolts/meter at a distance of 1.5 kilometers from the HAR antenna.

"Leaky Cable" Antenna - A specially designed lightly shielded coaxial cable is used to provide the antenna for this type of HAR/TIS transmitter. The signal transmitted from this arrangement is strong near the antenna, but dissipates rapidly when the distance from the antenna increases. Compared to a vertical antenna system, much more control of the emission field strength is available. There is less chance of interference with other radio services. Multiple HAR/TIS systems could be operated along a roadway with different messages for traffic in each direction.

FCC regulations for a leaky cable antenna HAR/TIS stations include the following requirements.

- A separation of at least 15 kilometers from the 0.5 millivolt/meter daytime contour of any AM broadcast station operating on an adjacent frequency.

- A separation of at least 130 kilometers from the 0.5 millivolt/meter daytime contour of any AM broadcast station operating on the same frequency.

- The maximum length of the cable antenna must not exceed 3 kilometers.

- The RF output of the transmitter must not exceed 50 watts.

- A minimum distance of 0.5 kilometers must be maintained from any other HAR/TIS leaky cable station.

- A minimum distance of 7.5 kilometers from a vertical antenna HAR/TIS at the same frequency.

- A frequency stability of ±20 Hz must be maintained.

- Signal field strength of cable antenna emission at the operating frequency must not exceed 2.0 millivolts/meter at a distance of 60 meters from any part of the station.

Micro-Transmitter - Very low power HAR transmission is permitted by Part 15 of the FCC regulations without requirements for a license. The area covered by a micro-transmitter is usually defined by a radius of 0.15 to 0.4 kilometers (0.1 to 0.25 miles) although some manufacturers claim that their systems cover an area with a radius twice as large. Part 15 of the FCC code includes the following requirements:

- The lead length of antenna and ground may not exceed 10 feet.
- Any standard AM frequency between 530 KHz and 1705 KHz may be used.
- The RF output of the transmitter must not exceed 100 milliwatts.

Message Record/Playback - Messages to be broadcast on a HAR are usually recorded on an audio tape recorder and more recently in digital memory. Digital memory is preferred since it uses no moving parts, and thus does not require periodic cleaning or maintenance. Some devices offer features that include:

- Message capacity of nearly half an hour.
- Ability to retain messages during power failures.
- Ability to provide a series of previously recorded messages strung together in any order to form the broadcast message.
- Double buffer to allow playing one message while recording another.

Digital memory is available in several varieties:

- EEPROM (Electrically Erasable Programmable Read Only Memory).

- DRAM (Dynamic Random Access Memory), a low cost alternative, but one that is inefficient and sensitive to power fluctuations.

- SRAM (Static Random Access Memory), which features low power consumption and can be battery backed-up with on-board lithium battery. Decreasing costs make SRAM a good candidate for digital memory.

Transmitter - The function of the transmitter is to convert the audio signal from the message record/playback subsystem into a modulated AM radio signal to be transmitted from the antenna. Various classifications of transmitters are available. The power amplification stage of the transmitter is characterized by an alphabetic letter A through D to describe the linearity and efficiency of operation. Class A is the most linear and least efficient, while Class D is essentially switched on and off for various parts of the output signal and hence is the most efficient. Class D transmitters have a typical efficiency of 75 percent. Greater efficiency results in less heat loss and hence better operation. Efficient transmitters can be kept in sealed enclosures to protect them from dirt and moisture, thereby extending their useful life. Highly efficient transmitters will be more conservative with respect to use of battery power during power outages,

Vertical Antenna Systems - It is desirable to place a HAR antenna in an area that has few obstructions to radio signals. Large buildings, geographic obstructions, trees, metal towers and overhead power lines should be avoided. An ideal site is a flat open field that is several hundred feet across. Good soil conductivity is another important factor. A radio ground plane can be improved with radials composed of heavy gauge copper wire buried about one foot below the surface and extending about one hundred feet in all directions from the base of the antenna. Ground rods are usually attached at the ends of the radials as well. Special chemical systems are available to provide a ground plane where available space may be as small as 10 feet in diameter.

The antenna must be tuned to the operating frequency. Both electrical and mechanical means are usually used to adjust the antenna and lead in cable to the transmitter output, since this provides maximum radiation from the antenna.

"Leaky Cable" Antenna Systems - Cable antenna systems are usually run in conduits and either suspended near the roadway or directly buried. A cable antenna is generally considered to be more expensive to install than a vertical antenna. If buried, the antenna is easily damaged by roadway construction, roadside guiderail, sign and delineator installations as well as attack from rodents.

System Control - Most systems allow remote control that can be provided either from a touch-tone telephone or a personal computer. Telephone control is accomplished by interpretation of dual tone multi-frequency (DTMF) tones as commands from a touch-tone phone. Some systems utilize voice prompts to instruct the operator to utilize the remote control features of the recorder and provide status messages. Under computer control, all functions and diagnostics can be controlled from a PC. The control software could incorporate a graphical user interface (GUI) to make system operation clear and intuitive.

Some systems allow the message to be composed and digitized at the PC before transmission to the HAR. The use of such a digital transmission reduces noise that might be introduced by this transmission. The resultant broadcast is clearer and more easily understood.

The communications link between the HAR site and the control point could be standard telephone, cellular telephone, owned cable, radio or fiber optics. Multiple HAR micro-transmitters could be utilized on the same frequency, transmitting the same message, provided that they are carefully synchronized. A fiber optic interconnect could be utilized to provide this means of synchronization.

Most HAR systems are able to operate in a mode that provides live message broadcast should the need arise.

Notification Signs - Signs advising drivers to tune their radios to the frequency required to receive a HAR broadcast should be placed near the edge of the reception area. Signs with flashing attention lights that are activated when an important message is being broadcast (such as those implemented by MHTD) would be expected to enhance the effectiveness of HAR.

KIOSKS

Another medium for traveler information is the use of information kiosks. Kiosks, in this instance, are video screens that display maps and/or text information regarding traffic, incident and/or transit information. Placed strategically at shopping malls, schools or large places of business, kiosks can provide pre-trip information and en-route information for transit strips. Pre-trip information can be used by motorists to plan alternate routes around congested areas or around incidents. Transit users can plan alternate routes with information provided on the status of transit vehicles. Communications from the TOC to the kiosks is vital to the success of a kiosk system. The application of kiosks in Kansas City may be limited due to the lack of concentrated trip origins. However, placement of a kiosk with real-time traffic information at a shopping mall (such as Bannister Mall or Oak Park Mall) or at an office complex may be beneficial in terms of public information and public support for ITS.

DIAL-IN SYSTEMS

A useful pre-trip informational tool is the dial-in system, or highway advisory telephone. A telephone number is established for the public to call for current traffic conditions. Usually, the messages are pre-recorded with the time and date so the caller knows the age of the traffic information. This system could be set up as a toll-free number or as a toll call. Once the call is placed, choices could be given to enter the highway route number, or in the case of transit, the bus route number. The recording would provide details as to traffic conditions at various interchange locations. Information from the TOC must be fed to the dial-in system operator to update the recordings.

Data Processing

Data processing functions primarily consist of analysis of the data gathered by detector equipment in the field, and the use of incident detection algorithms, which use the data gathered by detectors to identify potential incidents. The data processing for each of these functions is discussed in the following sections.

DETECTOR DATA PROCESSING

The processing of the data collected from the vehicle detection system requires that a balance be maintained between the location of data available for processing, processing capability, communications circuit loading, and access to the data for analysis and presentation. Three options are typically considered:

1. Transmit the data to a central location every second.

2. Aggregate the data in the field for a specified time period (typically 20 seconds, 30 seconds or 1 minute) and transmit the aggregated data to the central location at the end of the collection interval.

3. Aggregate the data over a collection interval (20 seconds, 30 seconds or 1 minute), store this data in the field for an extended time period (up to several hours), and transmit it to the central location when required. The requirement for the data can be based upon an “event” occurring in the field, such as the detection of an incident, or upon the request of the central system.

The first option requires relatively few bits to transmit vehicle counts because of the limited number of vehicles passing by a detector in one second. However, lane occupancy and vehicle speeds require about 10 bits per data item in order to maintain accuracy. This combination of number of bits to transmit and the one second transmission frequency places a heavy burden on the communications network (typically 1200 bps). It also requires a central computer system able to handle the data volumes and the data updates every second.

A second by second update is required when monitoring an arterial intersection controller or an individual freeway monitoring computer. This monitoring is typically required for only a few such controllers simultaneously, so the overall system design need not provide the capability for every location to communicate with the TOC every second.

Option two utilizes the power and processing capabilities of currently available microprocessors. As the processors that are deployed in field locations become more powerful and less expensive, distribution of the data processing is advantageous. This lessens the load on the communications network, and reduces the need for a larger central computer. The dynamics of traffic flow, and the rate of update of status maps and displays at the TOC establish the frequency of data transmission from the field devices. Operational experience has shown that updates every minute are not frequent enough, and updates every 10 seconds appear to be too frequent. This range has resulted in a 20 or 30 second communications time interval being utilized by several operational systems.

With this option, the field processor collects data for the selected time interval and stores it in an intermediate data buffer until polled by the central computer at the TOC. There are numerous operational results, levels of service and summaries that can be calculated from the collected data. Since these calculations can be performed at either the field processor or the central computer, there is no advantage of transmitting these derived values to the central system. They can be computed on an as-needed basis at the TOC (or other location) from raw field data less expensively than they can be transmitted. If they are needed at the field processor, for example by a technician reviewing the operation of field equipment, they can be calculated at that time in the field. This requires that the field processor have sufficient memory to store several hours (or days) worth of data. Computer memory in the megabyte (million byte) range is now very inexpensive, allowing this strategy to be implemented.

The data collected from an induction loop in a 20 second period can typically be represented with three bytes of data, and speed/length/classification counts obtained from a speed loop pair require less than six bytes of data. Thus, with six mainline lanes, one entrance ramp and one exit ramp being monitored, six speed pairs and four individual loops would be utilized. This results in about 48 bytes of data, plus overhead of about 20 bytes, being transmitted between the central computer and the field controller each 20 second period.

The case noted above, where second by second monitoring of a controller is required, must be included in the design of a periodic data collection/polling system. Since 20 second data collection and second by second reporting are both equally important, the communications system must be designed to permit 20 second data collection to be interwoven with second by second reporting. This interweaving must occur in a manner that does not exceed the delay requirements of either data stream, and fits within the available bandwidth of the communications channel.

The third option is useful when routine, periodic refreshment of status maps or data displays is not required. A data collection example would be the transmission of stored volume/occupancy data from the second loop of a speed loop pair only on as requested basis. Another example would be an incident detection algorithm running in the field microprocessor based upon variations in speed of individual vehicles, detailed data that is lost when speeds are averaged over a 20 second period. Error reporting also falls into this category, since errors are infrequent events and need to be reported only when they occur.

The goal of most traffic monitoring and management systems is to reflect the real-time status of the roadway at the TOC or other centralized location. This requires that data be transmitted from the field to the central computer on a regular basis. However, as noted in the examples above, there are categories of information that are infrequent (errors or detected incidents), stored data that is needed only on an occasional basis (on demand), or data that is available in the field processor but normally not used at the central computer (for example, the standard deviation of speed.) All of these situations require that the communications protocol and data formats be flexible enough to allow the system user to request or receive notification of this data when needed.

Example **Application** - One example of an intelligent transportation system for incident detection is the Tunnel Operations Monitoring And Control (TOMAC) project in Baltimore, Maryland. In this case, a TOMAC system was implemented for the Hampton Roads tunnel complex. This control system has been applied at several facilities including the Elizabeth River Second and Third Downtown Tunnels, and the new four tube I-95 Fort McHenry Tunnel in Baltimore.

The system operates with automatic incident detection based on a modified California algorithm using absolute and relative occupancy. Detector communication is performed in one second increments, with a small degree of pre-processing, to convey accurate occupancies. When the software determines that a detected occupancy is likely to have been caused by an incident, the suspected incident is reported to the operator. An adjustable threshold of sensitivity is used. An excessively low threshold can result in a high false alarm rate, however, an overly high threshold may result in missing a real incident. The occupancy threshold is automatically adjusted every four hours to compensate for recurring traffic conditions such as morning and evening peak periods.

When a suspected incident is detected, the location of the suspected incident is identified and the operator is notified. The operator examines CCTV monitors to determine the nature and validity of the reported condition. The required emergency operation procedures are then manually entered. The Fort McHenry version of TOMAC is capable of entering emergency operation procedures without operator intervention, however, the system is not operated in a fully automatic mode. The emergency operation procedures have been developed in a rudimentary expert system that controls variable message and lane use signs in the tunnel, The course of emergency action depends on the current state of the tunnel and the location of the incident. The TOMAC System assists in changing all signs forward and behind the incident to appropriate status. Variable message signs and changeable speed limit signs that have been pre-programmed are commanded for display under the appropriate circumstances.

The ability of TOMAC to detect possible incidents and direct an operator to a specific monitor to observe and verify a possible incident is beneficial in the operation of an automated incident detection and management system.

INCIDENT DETECTION ALGORITHMS

An incident is usually defined as any event that causes a temporary reduction in the capacity of a facility or roadway. Incidents may result from occurrences that physically block a portion of the active roadway or from occurrences entirely off the roadway that cause rubbernecking or friction effects (such as an accident on the shoulder). When a roadway is operating at a level below its capacity due to an incident that reduces capacity but leaves the roadway with enough capacity to handle the existing traffic, there are few effects on operating characteristics and it will be difficult to detect by traditional means. However, if capacity is adequate, the impact of a longer response time (with respect to traffic delay) is less significant.

Various algorithms have been developed to perform automated incident detection. Different traffic parameters are measured and compared in a number of ways, each variation results in a new algorithm.

Traffic Parameters - The standard parameters used to quantify traffic are occupancy, speed and volume.

- Occupancy - The percentage of a given time period that a vehicle covers a particular point on the roadway.

- Speed - The average velocity of vehicles passing a point on the roadway during a given time period.

- Volume - The number of vehicles passing a point on the roadway during a given time period.

Comparisons of different types of time averages considering new data as well as data from adjacent detector stations are the basis for incident detection.

Recurring congestion, due to operation of a roadway above its capacity, may be detected as an incident by some algorithms. A means of incident verification is needed to determine the cause of detected congestion. Incidents that occur on an already congested section of roadway are also difficult to detect, because operation is already below capacity.

Incident detection algorithms measure and compare various parameters of the traffic stream to parameters demonstrated during typical conditions. Traffic tends to flow with a direct linear relationship between volume and occupancy (See Figure 5-2, line segment ab) under normal conditions. In congested operation, the relationship is shifted to restricted flow, resulting in a decreased volume and higher occupancy (See Figure 5-2, line segment cd. Point d represents standstill conditions.)

Examining Figure 5-2, if an incident occurs at a time that the roadway is operating at point b, the volume will be reduced and occupancy will be increased to provide operation at point c. Downstream of the incident, operation shifts from b to e.

Direction of Incident Conditions - When a queue develops from an incident, a shock wave travels upstream as additional vehicles are added to the queue and a metered wave travels downstream due to decreased volume and occupancy in the free flow after the restriction. The waves eventually reach detector stations where their effects can be sensed.

Detection of the metered wave that travels downstream at the highway flow rate may provide a rapid indicator of the occurrence of an incident. Detection of the shock wave resulting from a queue traveling in the upstream direction provides further indication of an incident. Normal traffic flows that result in detection of parameters similar to the effects of both the metered and shock waves could be a result of normal bunching of traffic or “noise” in the flow causing false alarms.

The time taken by an algorithm for calculations to provide incident detection is usually not a major factor in detection time. The comparisons between algorithms usually depend on the time that it takes the parameters at the detection stations to reach values that the particular algorithm requires before declaring an incident.

California Algorithm - The California algorithm relies on the detection of three parameters or features between an upstream and downstream detector that are specific to incidents. These features must exceed all three specific thresholds:

- Spatial difference in occupancies (OCCDF), the absolute (arithmetic) difference in occupancies, from data in the same time period, between upstream and downstream detectors.
- Relative spatial difference in occupancies (OCCDRF), a test to determine the relative size of the difference by dividing the absolute difference by the occupancy found at the upstream detector.
- Relative temporal difference in downstream occupancy (DOCCTD), similar to OCCDRF except the test compares downstream occupancies at different times, time (0) and time (-5) seconds.

The modified California algorithm simply uses a different time period for comparison of DOCCTD, the times used are time (0) and time (-2) seconds. This results in a shorter interval used for the comparison test. There are a number of variations that improve some aspects of, or provide additional features for, the basic California algorithm. Some of these variations allow the detection of incident termination, others provide less sensitivity to compression waves in the traffic stream, and others offer improved detection or have lower false alarm rates. A combination algorithm could be developed to provide the features desired at the project site.

Time Series Models - Another class of algorithms uses recent past occupancy history to model, through time series, the near future values of occupancy parameters. When the projections differ by more than the threshold, an incident can be declared. Various statistical measurements of traffic parameters are used to detect incidents. The standard normal deviation algorithm considers the mean and standard deviation of occupancy over a period of about five minutes. An incident is declared when the measured value differs by more than one standard deviation from the mean. The double exponential smoothing algorithm employs absolute error between the observed and predicted value of volume and occupancy for one minute intervals. The ARIMA, or autoregressive integrated moving average algorithm, declares an incident when the observed occupancy is found to be outside the 95 percent confidence limit. The time series approach will detect congestion as well as incidents and does not offer any advantage regarding false alarms

McMaster Algorithm - This is a single station algorithm that operates on two-dimensional classification of flow and occupancy. The algorithm basically relies upon the determination of the roadway operating volume-occupancy region as shown in Figure 5-2. A congestion flag is raised when operation is in area 2 or 3, or a slow highway speed is detected. When the flag is present for a specific number of consecutive periods, a potential incident is signaled. Since speed calculated from a single loop detector is unreliable due to a non-homogeneous traffic stream, most systems use paired loops to extract speed. The logic is more efficient if data is collected from a lane with few or no trucks, as trucks tend to disrupt normal traffic flow. This algorithm tends to be successful at detection of congestion, however, video confirmation is recommended to determine the cause of the detected congestion. Later developments of the algorithm apply comparison logic. Once congestion is detected, a check of adjacent station conditions is used to test for the incident that caused congestion.

HIOCC - Developed for the British United Kingdom Transport and Road Research Laboratory, HIOCC seeks to identify slow moving and stopped vehicles. When several consecutive seconds of instantaneous occupancy are found to exceed a threshold, an incident is identified. Separation of incidents from other types of congestion is not performed by the algorithm.

Other Algorithms - There are numerous other algorithms that are either variations on standard algorithms or are experimental and still in development. These include the Minnesota algorithm, which utilizes data filtering and assumes that a large deviation in a system parameter must be caused by a malfunction; the Willsky algorithm, which uses macroscopic modeling of traffic flow; the Cremer algorithm, which models the reduction of capacity at incident locations by considering an imaginary volume input at the incident location; and Algorithm #7, as it has been referenced in the literature, which is an adaptation of the California algorithm. The availability of these and other algorithms is noted although it is not considered here.

Video Incident Detection - Several approaches to incident detection described in the literature are being applied as a result of video detection capabilities. Video detection offers the possibility of wide area detection from a camera location. One algorithm, called Speed Profile Incident Evaluation System (SPIES) employs several speed traps in each lane of traffic. The speed traps are positioned a few hundred feet apart to allow the system to analyze speed changes within view of the camera. Speed data is gathered and smoothed on the basis of volume, resulting in samples every 15 seconds or so. The samples are compared with 15 minute data in a historical database. An incident is detected by comparison of speeds measured at the upstream and downstream detectors, with expected speeds from the database and an alarm threshold.

Another video detection algorithm called Autoscope Incident Detection Algorithm (AIDA) uses the variation of traffic flow data with regard to both time and distance. A rapid breakdown such as a speed-drop or occupancy increase and speed thresholds are used to determine congestion levels.

A new type of incident detector has recently been developed for Autoscope by Image Sensing Systems Inc. This incident detector is designed to reside within the Autoscope and can be configured on the unit's monitor in a fashion similar to the way standard detectors are configured. The incident detector will sense an unusual drop in speed coupled with an increase in occupancy. Comparisons are made with recent history using a dynamic threshold which automatically adjusts with the amount of traffic detected. Incident detection is expected to be available as an upgrade to older Autoscope models, Detected incidents will be reported on a serial communications port of the Autoscope using a non-proprietary multidrop protocol.

An evaluation of a traffic scene concentrating on the two dimensional data provided from a video camera is performed by another prototype system, Image Processing for Automatic Traffic Monitoring (IMPACTS). This system evaluates the spatial distribution, movement, and stops of traffic in the field of view. The roadway is divided into small areas called cells. The algorithm determines the magnitude of change for three variables in each cell. Spatial occupancy, weighted occupancy and lane state are tracked and relational changes in these variables are used to detect incident congestion. In a test near London, Great Britain, which ran for 170 hours, a total of 74 incidents were properly detected, two incidents were missed and four false alarms were logged. This system shows promise for further development.

Conclusions - It appears that for the present, if a high percentage of incidents are to be detected, a high false alarm rate will need to be tolerated. A false alarm rate of one percent will result from one false detection in one hundred tests, A technique is described in the literature which proposes a means for distinguishing between recurrent and incident congestion. This approach is good for single station algorithms but will not prevent false alarms. If data from the IMPACTS tests is reliable, systems of this type may provide true wide area detection. Since there is little experience with video detection and its ability to perform incident detection, the use of this technology may involve some degree of risk.

Detection algorithms cannot be expected to find every incident, nor can they be expected to perform without false alarms. Automatic detection of incidents provides the operator with a source of information about possible incidents on the roadway. The information obtained must be confirmed and dealt with no differently than any other source of information that may need to be questioned.

Several major factors surface from a study of incident detection algorithms:

- Single station algorithms detect congestion. A secondary means must be used to verify conditions and determine the cause of the congestion.

- A multistation algorithm depends upon the continued operation of each detector. When one station fails, three comparisons cannot be performed. If detector stations are placed every quarter-mile, a half mile section would be lost with a single failure. It should be possible however, to bridge over the failed section and perform the comparisons with data from the adjacent detector stations.

- Incident detection requires that traffic parameters be checked for operation outside of certain thresholds. When data is found that exceeds some threshold by a large margin, an incident could possibly be reported without the need for additional testing. If the threshold is exceeded by only a small margin, further testing is justified. This type of magnitude testing might allow some incidents to be reported more quickly. Some algorithms consider overly large margin variations as probable hardware faults. Tests could be included in any developed algorithm to consider this possibility.

- Variable thresholds may be applicable for various levels of traffic and may be adjusted by time of day and day of week. For example, it may not be desirable or necessary to detect the recurring congestion during the typical peak periods.

Strategies Evaluation

The heart of a transportation management program is the monitoring sub-system. This sub-system supports three different types of functions: counting and monitoring individual vehicles, analyzing vehicle flow information for incident and subsequent congestion detection, and providing visual images for confirmation, interpretation and analysis.

Various algorithms have been developed to detect incidents (as discussed in the previous section). Most algorithms compare traffic parameters such as vehicle occupancy (the amount of time a vehicle's presence is detected at a particular point on the roadway), speed or volume between adjacent detector stations. The California class of algorithms which do this type of comparison have been used with reasonable success for many years. The McMaster algorithm has been developed to operate with single station detection where specific characteristics of the measured speed, occupancy and volume are used to indicate the existence of congestion. The determination of whether this congestion results from an incident or excess volume also needs to be performed. This determination is not necessary if the highway has excess capacity and is not subject to recurring congestion.

Incident detection and management relies on accurate real-time traffic flow data. A hybrid of automated detection, with computers monitoring detector locations, and human observation using closed circuit television is commonly used for advanced traffic management systems (ATMS). Although each of the sub-systems can work independently, automated detection and visual verification are functions that complement one another. The best performance results from an automated detection system that calls upon a human observer to view a possible incident and determine an appropriate response. As more progress is made in ITS technologies, including image processing, artificial intelligence, and expert systems technology, it is inevitable that computer systems will augment the capabilities of the human observer.

Transmission of information to the motorist is an integral part of an incident management system. This provides the mechanism to alert the motorist of problems ahead, so that an alternate route can be taken. The most commonly used technology installed along the road is the VMS, Another commonly used method to communicate with motorists is HAR. Effectiveness of HAR is improved when signs alert drivers to new messages with flashing lights. Dial-in telephone services have been implemented in various forms, and highway advisory telephone (HAT) is becoming common. An innovative traveler interface has been utilized by some systems involving public kiosks and terminals. Units might be located at convenient locations such as hotels, shopping malls and major workplaces. Direct information about highway congestion and travel time can be provided for user designated routes. General information about area highways might be displayed without specific requests. Cellular telephones are often used to inquire about roadway congestion and to report incidents. Commercial radio and television stations broadcast periodic traffic reports in many metropolitan areas and studies have shown that this is presently the most commonly used source of traffic information.

Computer equipment and software located at the TOC collects and centralizes all the various types of data and information generated by the monitoring sub-system. It also provides a control interface for motorist information sub-systems. Modern computer technology has reduced the size and cost of the computer hardware. However, the complexity of the software continues to increase as the functional demands for graphical user interfaces, and other state-of-the-art features, are included in the overall computer system.

POTENTIAL IMPROVEMENT OPTIONS FOR TRANSPORTATION MANAGEMENT

Potential improvement options for a transportation management system range from capital and operating expenditures to institutional and jurisdictional measures. A wide variety of options are used successfully elsewhere. Although all of these options may not be applicable in Kansas City, it is useful to review them prior to selecting a recommended system.

Potential system components can be categorized by the incident management process: detection and verification, response, site management, clearance, and traveler/motorist information. Congestion management options are also important This section provides information on potential options considered for the Kansas City area.

Detection and Verification Options - The sooner an incident can be detected and verified on the primary route, the less impact the incident will have on the normal flow of traffic. Statistics have shown that every minute of roadway blockage can result in five to six minutes of congestion and delay prior to recovery. The following options for detection and verification may be used to bring an incident to the attention of the responsible agencies or authorities:

Dedicated Freeway Service Patrols: Dedicated freeway service patrols (also called motorist assistance patrols), such as the ones currently operating in both Kansas and Missouri, are important in areas where timely incident detection and response is particularly critical or where other electronic detection equipment is not available. Many minor accidents and incidents can be cleared with the patrol vehicle, eliminating the cost and delayed response of tow trucks. The supplies carried by service patrols are sufficient to clear many incidents related to vehicle breakdown. In addition, push bumpers mounted on the service vehicle allow for quick clearance of small accidents. Once the patrol stops at an incident scene, its detection capability on the rest of the primary routes is eliminated. Several private companies have successful organized service patrols. They train the personnel, equip the vehicles, and operate the service. Other freeway service patrols are operated in a similar manner by transportation agencies, such as the one operated by MHTD in Missouri, or by enforcement agencies, such as the one operated by the Kansas Highway Patrol in Kansas.

Motorist Aid Call Boxes/Telephones: Motorist aid call boxes/telephones are appropriate in isolated areas, where detection times are lengthy. Reporting can be done 24 hours a day directly to the responding agency. The units can be solar powered with cellular communications. There are, however, sometimes problems such as crank calls and vandalism.

Incident Reporting with Cellular Telephones: Incident reporting with cellular telephones is similar to a "911" system, but may use a different phone number. In many cases, these systems can be monitored by existing dispatch staff, requiring no additional training. Motorists usually provide timely information about a particular incident. However, the use of the system is limited to cellular telephone owners, the workload of the dispatcher is increased dramatically, and roadside signs are required to inform motorists of the system and to locate the incident. Capital, operating and maintenance costs are relatively low and the benefits are generally high. To increase these benefits, cellular telephones should be distributed to the transportation agency personnel who frequently use the freeways during commuting hours in return for calls at regular intervals to track travel speeds and report incidents, If the system is set up such that a different number is used for non-injury freeway incidents, a disadvantage of the system is that it requires the motorist to make a decision as to whether the incident is an emergency (in which case 911 should be dialed) or not.

Citizens' Band (CB) Radio Monitoring: Citizens' Band (CB) radio monitoring is similar to the cellular telephone system. Over a dedicated CB channel, these communications can be monitored by service patrol vehicles on patrol as well as by existing police dispatchers. Multiple transmissions will help to verify and locate the incident. Much of this potential is focused on the truck driver. As with the cellular system, there will be an increased workload for the dispatcher and roadside signs are necessary to inform the CB user of the system. This can also be used to broadcast information of incident related congestion to CB users.

Volunteer Watch: Volunteer watch involves citizen observation of the freeway from vantage points in high incident areas or directly in vehicles calling in observations on a periodic time basis. The advantages of a volunteer watch include visual verification and initial assessment of the incident. Disadvantages might include lack of available volunteers for a particular high incident area, as well as the need for training or instruction to acquire reliable information.

Ties with Transit, Taxi, *and Shuttle Companies:* Ties with transit, taxi, and shuttle companies can take advantage of vehicles already on the road with two-way radio communications. This method of detection would allow the system to expand to cover the entire city street system in addition to local freeways. Travel times and roadway conditions could be determined from the KCATA Automatic Vehicle Location (AVL) equipment, which will be operational again in the near future. This method of detection and verification requires very little training. Incident data would be reported to the transit, taxi or shuttle dispatcher and relayed to the TOC. The dispatcher would then relay the information to the appropriate agency. This improves the efficiency of transit, taxi, and shuttle operations in that the dispatcher shares the information with the other vehicle operators. This is a very low cost option that has produced significant benefits in other areas. The benefits of this option in the Kansas City area would, however, be limited by the fact that there are relatively few services that regularly use the freeways, which is the focus of the system in Kansas City.

Aircraft: A fixed wing aircraft is currently used in the Kansas City area for commercial radio traffic updates. This method has potential for monitoring shifts in traffic to diversion routes and visually analyzing traffic distributions. One disadvantage of patrols is the high cost, which typically limits patrols to peak periods. Also, weather conditions can reduce flying times. The aircraft patrol would provide timely information by calling directly into the TOC. Data compiled at the TOC would be made available to the operators of the aircraft patrols and as well as to operators of vehicle probes providing information to the TOC. Since these types of commercial patrols are not often funded by the transportation agency or police, the exchange of information can result in a high return.

Electronic Detection: Electronic detection includes inductance loops, radar detection units, infrared detection units, microwave detection units, and video imaging detection systems (VIDS). These systems vary in cost, accuracy, and proven reliability. Traffic flow information collected by these devices is sent through a communications link (leased telephone lines, twisted pair wire, fiber optic cable, coaxial cable, etc.) from the detector's roadside processor to a central computer with incident detection software. The advantages of electronic systems include 24-hour operation and traffic data collection capability. Some disadvantages are high initial cost, false alarms, and potentially high maintenance costs.

Closed Circuit Television (CCTV): Closed circuit television provides quick incident assessment and promotes proper response to incidents. This system also provides a method to record selected incident response activities for later review. Full system coverage of the freeway would require one to two cameras per mile plus additional cameras at interchanges. Manually monitoring these cameras is ineffective. Cameras can be linked directly to detection subsystems to automatically activate an alarm and call up the appropriate camera. Other potential users of a fiber optic cable system, such as universities and private industry, may be contacted to explore the potential of shared funding. Or partnerships with the fiber optics company may be directly pursued, as was the case in Missouri.

Traffic Operations Center (TOC): The TOC is a central information processing, dispatch and control site for the management of a transportation system. In a multi-jurisdictional situation, it is advisable to develop one overall TOC, providing better service than several uncoordinated centers. Since the primary function of TOC is information sharing, it is best to link its operations with existing agencies. Ideally, it would include all of the decision makers involved in a major incident. Some of the service patrol vehicles and personnel could also be housed at this center.

Response Time Improvement Options - Identifying the proper response to an incident and getting the appropriate equipment to the scene as quickly as possible are the keys to efficient and reduced response times. Interagency communications and cooperation are very important where fast response is needed.

Personnel, *Equipment, and* Materials *Resource* Lists: Personnel, equipment, and materials resource lists provide information on who should respond in each particular jurisdiction. Police, fire, emergency medical responders, transportation, media, and private agency contacts, as well as the method of communication, should be specified. Radio channels and telephone numbers should be clearly identified. This list would be distributed to the appropriate responding agency personnel. The same type of list would be compiled for equipment and materials in the area. These relatively inexpensive tools will save time and effort in the event of an incident. These lists are being developed in conjunction with the incident management activities being spearheaded by KDOT, but efforts will need to be made to assure that they are updated (and distributed) regularly.

Dedicated Freeway Service Patrols: See previous section in Defection *and Verification Options.*

Personnel Training Programs: Personnel training programs emphasize the coordination aspect of incident response, making each agency aware of the other agencies' needs and requirements. A demonstrated willingness to participate and cooperate is required by all agencies if the incident response team approach is to be successful.

Tow Truck/Removal Crane Contracts: Tow truck and removal crane contracts may be established with private firms to reduce the response times at frequent incident locations, and to allow immediate use of necessary equipment. These contracts eliminate the question of who to call when specific equipment is required. Agency owned tow trucks are typically costly to purchase and operate. Private contracts offer financial incentives for the tow truck company to clear the freeway as quickly and safely as possible. Heavy duty wreckers stationed at key points allow for the quick removal of major equipment, debris, and spills. Generally these are warranted for short sections (usually bridges and tunnels) with high truck volumes.

Improved Interagency Radio Communication: Improved interagency radio communication may require the purchase of compatible two-way radio equipment and the use of a common nomenclature or terminology. This would improve site management and provide better information to the responding personnel. However, it may not be feasible for all agencies to participate and to invest in new equipment. Costs vary depending on specific equipment needs. Command posts such as mobile command centers may be needed at incidents where two or more agencies are involved. This facilitates communications and saves time by reducing repetition of commands.

Ordinances Governing Travel on Shoulders: Ordinances governing travel on shoulders will be possible only in areas where shoulder widths are wide enough for emergency equipment. In order for emergency vehicles to reach the scene of an accident, it may be necessary for vehicles to travel on the shoulder. In some situations during incidents, travel by the public on shoulders to circumvent the incident may be necessary. It would be a wise decision to incorporate sufficient shoulder widths in any redesign projects.

Emergency Vehicle Access: Emergency vehicle access, such as movable barriers and U-turns at key locations along the freeway, reduce response times for emergency vehicles. These techniques are useful for response vehicles when one direction of the highway is completely blocked and access is only possible by approaching the scene contraflow to the travel direction. However, unauthorized motorists may be tempted to use these U-turn facilities, and movable barriers are expensive.

Diversion Rode Planning: Diversion route planning is useful when the capacity of the primary route is reduced by an incident. It is important to plan routes that avoid low overpasses or severe turns. Either temporary or permanent signing is required at junctions and along the route to reduce confusion and provide for smooth traffic flow. Use of VMSs and/or HAR to inform motorists of the alternate route is very effective.

Diversion Route Management: Diversion route management is needed to adjust traffic signal timings to accommodate additional traffic flow after a diversion plan is implemented. The computerized arterial traffic signal system should incorporate a feature to automatically recommend and/or implement an incident response timing plan. Diversion route management techniques can also be used to locate underutilized alternate routes and redirect traffic to them on a real-time basis.

Equipment Storage Sites: Equipment storage sites would reduce response times by providing special removal equipment at high incident locations. Costs are minimal if this space already exists, but it may be difficult to find additional space at some high incident areas. Large equipment to be stored might include wreckers, sand trucks, and other large vehicles. Smaller items include cones, signs, flares, portable barriers, and other equipment for traffic control.

Administrative Traffic Management Teams: Administrative traffic management teams include officials from transportation, police, fire, and rescue agencies. This strategy requires a willingness to cooperate by all participating agencies. The intent is to provide a forum for discussion of unresolved incident management issues, preplanning for response, and improved communications.

Public Education Programs: Public education programs inform motorists of their rights and responsibilities when they are involved in a traffic accident. Motorists may be permitted to move their vehicles from the scene of an accident according to Kansas and Missouri state law, but may not do so. Most are reluctant to do so in any case because of misconceptions regarding the legality or liability of the action.

Traffic Operations Center: See previous section in *Detection and Verification Options.*

Closely Spaced Reference Markers: Closely spaced reference markers, as well as other landmark and directional markers, help in locating incidents. These markers aid cellular telephone callers in reporting incident locations, and provide improved record keeping for analysis of incidents. The markers could be located on the center median barrier to enhance visibility and reduce costs of sign posts. For ramps and collector-distributor roadways, special numbering, colors, and/or patterns would be necessary, due to the potential for confusion. Utility poles might also be designated with markers to identify locations along the freeway. These markers might be placed every 1/10 of a mile or every 2/10 of a kilometer.

Site Management Options - Incident clearance can become more effective if the site management techniques are well executed. Coordination of personnel and control of traffic help to reduce the likelihood of secondary accidents.

Incident Response Teams: Incident response teams would be comprised of personnel from various agencies. These teams would be trained to handle unusual incidents and would be familiar with one another. Incident response teams might improve site management and clearance efforts in special circumstances, but they are likely to be ineffective if not properly trained and equipped. Similarly, the effectiveness of incident response teams is limited if refresher courses are not provided frequently, and if there is high turnover in agency staff.

Personnel Training Programs: See previous section in *Response Time Improvement Options.*

Improved Interagency Radio Communications: See previous section in *Response Time Improvement Options.*

Properly Defined Traffic Control Techniques: Properly defined traffic control techniques are standard guidelines for lane closure which are identified and agreed to in advance. The guidelines should be consistent with the Federal Highway Administration's (FHWA) Manual on Uniform Traffic Control Devices and any superseding state guidance. This action requires cooperation among agencies. The incident management team would provide an appropriate forum for this activity.

Property Defined Parking for Emergency Response Vehicles: Properly defined parking for emergency response vehicles is a technique of identifying, in advance, the appropriate place at an incident site for placement of response vehicles. This placement depends on the nature of the incident. As with the traffic control techniques, this is a cooperative action. In a related policy, some cities recommend that emergency vehicles be positioned so as to close no more travel lanes than those already blocked by the incident.

Flashing Lights Policy: Flashing lights policy would be considered to reduce distraction to non-involved motorists. Flashing lights may not be required when the responding vehicles are on the shoulders. The drawback is that the response team members may not feel as safe. Field testing may be necessary to get reactions from incident response team members and the public, and legislative work may be required.

Administrative Traffic Management Team: See section in *Response Time Improvement Options*

Traffic Operations Center See section in *Defection and Verification Options.*

Diversion Route Planning: See section in *Response Time Improvement Options.*

Incident Response Manual: An incident response manual would be developed to increase the efficiency of responders activity at the incident site. Input by all involved agencies is required to produce a document that accurately defines all procedures for site management. It should be specific to the facility, roadway or corridor it deals with. Frequent updating and training are also required.

Clearance Time Reduction Options - A reduction in clearance time results in a reduction in vehicle delay. Options to reduce clearance time are presented below.

Policy Requiring Fast Removal of Vehicles: A policy requiring fast removal of vehicles is a low cost method of returning the roadway to normal operating conditions where shoulders exist or where there is adequate space for a holding area. Liability may be an issue if damage to the disabled vehicle occurs. Generally, however, this policy has no cost to the transportation agencies, and would make police and other response personnel available to perform other more important duties.

Accident Investigation Sites: Accident investigation sites allow operable vehicles involved in non-injury accidents to be removed from the travel lanes immediately. In many situations, secondary accidents occur due to blockage of travel lanes. With the use of off-road or out-of-sight accident investigation sites, secondary accidents are less likely. Accident investigation sites are used to interview those involved, fill out police reports, and make necessary telephone calls. The area should be flat and well lighted with a telephone or call box. Finding an appropriate location may be difficult, and site preparation, signing, and publicity will require some investment. Signs along the freeway are needed to inform motorists of accident investigation sites, and education would be required to inform motorists of the use of these sites, These sites are only effective to the extent that they are used by motorists. Some cities have indicated that motorists are reluctant to use them, these motorists believe that they should not move their cars until the police come.

Dedicated Freeway Service Patrols: See section in *Detection and Verification Options.*

Push Bumpers: Push bumpers can be added to the tow trucks, emergency service patrols and police vehicles. They are especially beneficial for quick clearance along elevated roadways and sections with inadequate shoulder widths.

Responsive Traffic Control Systems: Responsive traffic control systems, such as the computerized traffic signal system currently in use in some cities, will aid in diversion route management. When diversions become necessary, the traffic operations staff implement or request implementation of a pre-determined traffic signal timing plan which provides more capacity to the diversion route for the duration of the incident.

Ordinances Governing Travel on Shoulders: See section in *Response Time Improvement Options.*

Emergency Vehicle Access: See section in *Response Time Improvement Options.*

Diversion Route Planning: See section in *Response Time Improvement Options.*

Incident Response Teams: See section in *Site Management Options.*

Personnel Training Programs: See section in *Response Time Improvement Options.*

Incident Response Manual: See section in *Response Time Improvement Options.*

Administrative Traffic Management Teams: See section in *Response Time Improvement Options.*

Public Education Program: See section in *Response Time Improvement Options.*

Total Station Accident Investigation Equipment: Total station accident investigation equipment is a combination of electronic surveying and distance measuring devices developed exclusively for the investigation of accidents. This type of equipment reduces delays, personnel requirements and exposure of personnel to traffic hazards since accident investigations can be carried out more quickly.

Traveler/Motorist Information Options - Communication with travelers is an important component of any intelligent transportation system. Options for communications include the following.

Highway Advisory Radio (HAR): Highway advisory radio is a powerful instrument to share information with travelers in their automobiles. Information regarding planned lane closures due to construction or maintenance is broadcast repeatedly over the HAR. Advanced warning to motorists of lane closure schedules, incidents, or special events will help to reduce the traffic demand at the closure, and may reduce the number of accidents in the area. HAR transmitters would be needed to provide coverage for motorists in and around the metropolitan Kansas City area. If a high power transmitter is used, motorists can be informed prior to their trip.

Variable Message Signs (VMS): Variable message signs are used alone and in conjunction with HAR to inform motorists of planned lane closures, incidents and special events. Truck mounted or trailer mounted VMS can be very effective in incident management. These can be located and moved in response to a major long term incident.

Traffic Operations Center: See section in *Detection and Verification Options.*

Commercial Radio and Television Broadcasts: Commercial radio and television broadcasts are good sources of information for the traveling public in most cases. Commercial radio is a well known source for traffic information in the metropolitan Kansas City area. In some communities, commercial broadcasts have been known to provide outdated or incorrect information.

Kiosks: Kiosks may be used for special traffic generators such as shopping malls and large employment buildings, and could be used to inform motorists of traffic conditions. On-screen graphics and text could convey accident and incident information, travel times, or even provide suggestions for the best route to a motorist's destination.

PC/Modem: PC/modem systems could be used to tap into the TOC's computer from home or work. A telephone hotline would be established so that travelers could call in for conditions on the primary route. A caller would enter the route number, the entry and exit interchange number and the direction of travel using a key pad or mouse. The computer would dispatch information to the caller on current roadway conditions. Private sector firms could become involved in establishing this service. The information could also be located on an Internet home page, automatically being updated every few minutes.

Congestion Management Options - Several techniques exist for decreasing congestion on freeways. Ramp metering can be used to divert traffic that utilizes the freeway for short trips and can also smooth out the flow of traffic on the freeway. High occupancy vehicle (HOV) lanes can be implemented to move more people in fewer vehicles by providing exclusive lanes on the mainline and queue by-pass lanes at congested interchanges (including freeway to freeway). Predictive algorithms can be used to balance traffic between freeways and alternate arterials within a corridor.

Ramp metering requires analysis and determination of congested sections of freeways. A threshold of volume to capacity ratios would be determined to identify congested segments. Congested segments would be linked together to form a larger section. The ramps within this section as well as several ramps upstream of the beginning of the section will be field checked to determine the length of queued vehicles that could be stored. To properly deploy ramp metering, it may be necessary to reconstruct those ramps which have very little storage length. Detectors on the ramps for queues spilling back onto local streets, detectors at the stop bars near the signal heads, and the controller and cabinet are the equipment needed for ramp metering. In some cases, detection in the right lane of the freeway upstream of the ramp is used to identify available gaps in the mainline.

High occupancy vehicle (HOV) lanes can be deployed in areas where existing Carpool, vanpool and bus traffic would benefit from an exclusive lane. At interchanges where on/off ramps are congested, queue by-pass lanes could be implemented for HOVs. This would provide an additional travel time incentive Congested areas of freeways could be equipped with an HOV lane where travel time savings would be at least one minute per mile, and overall travel time savings would be at least eight to ten minutes per trip.

By instrumenting the freeways and the parallel arterials, predictive algorithms could be utilized to balance traffic flow between the freeways and the parallel arterials. Variable message signs and HAR could be used to send messages to the motoring public regarding which route is less congested or which route is more congested. The algorithm predicts when the less congested route will become more congested and relays the message to the VMS and HAR to stop shifting traffic. This balancing may change from time of day or time of year and may be based upon historic data as well as sensor information that counts the number of vehicles shifting.

ITS ACTIVITIES IN OTHER URBAN AREAS

Intelligent transportation systems have been implemented in many cities across the United States. While some of these systems are the result of recent programs and activities, many others have evolved from activities that were initiated years ago. Examining ITS activities and programs underway elsewhere provides an appreciation for the potential, and in some cases the limitations, of intelligent transportation systems. The following discussion is by no means all inclusive, it is merely intended to provide a brief look at various approaches to incorporating ITS into an urban area. Although many systems use common technologies, each urban area has tailored ITS applications to meet their needs.

Chicago, Illinois - Chicago's ITS system encompasses components managed by the City of Chicago, as well as Departments of Transportation in Illinois (IDOT), Indiana (InDOT), and Wisconsin (WisDOT). In terms of fixed equipment for traffic information, the Chicago area relies primarily on loop detectors in the pavement. The IDOT Traffic Systems Center has over 2,000 loop detectors covering 136 centerline miles.

Chicago has focused significant resources on one of the most extensive motorist assistance programs in the country. The "minutemen", also known as the IDOT Emergency Traffic Patrol, have been responding to motorist needs since 1960. The program was initiated with a couple pick-up trucks with push bumpers, and has expanded significantly over the last 36 years. It now includes emergency patrol vehicles with relocation tow rigs, light 4x4s, heavy duty tows, a crash crane, tractor-retriever, sand spreader, heavy rescue and extrication truck, and trailer mounted variable message signs. The minutemen provide service 24 hours a day, seven days a week. Chicago's incident management program has reduced the time to clear an incident by

50 percent. This reduction in incident duration can have a significant impact not only on delay but also on safety, particularly when secondary accidents are considered. Secondary accident rates are six times higher than primary accident rates.

In Chicago, ITS technologies are used not only for incident management, but also to support traffic control activities such as ramp metering and to inform motorists. Motorist information is provided through VMSs, highway advisory telephone, and the Internet. Deployment of ITS technologies is facilitated by the fact that the Chicago metropolitan area has one of four "Priority Corridors" throughout the country. The Gary-Chicago-Milwaukee (GCM) Priority Corridor is a joint effort of IDOT, InDOT, and WisDOT.

Minneapolis, Minnesota - The State of Minnesota has a statewide ITS program, Guidestar. Coordinated with this effort is the intelligent transportation system of the Minneapolis/St. Paul Twin Cities metropolitan area. This system provides coverage of 160 centerline miles of interstate and state highway, monitoring traffic with autoscopes, loop detectors, more than 150 CCTV cameras, and aerial monitoring (via a partnership with private aircraft). The traffic management center uses this information to manage traffic through HOV lanes and over 360 ramp meters, and provides this information to motorists through almost 50 VMSs, metrowide HAR, and a cable television traffic channel. "Highway Helper" trucks, private tow trucks, and accident investigation sites are used to remove incidents from the roadway. This program provides $1.4 million in estimated benefits, at a cost of 0.6 million, resulting in a benefit cost ratio of 2.3.

The Minneapolis/St. Paul areas has seen significant benefits from the implementation of ITS programs and infrastructure. The incident management program in Minnesota has reduced incident clearance times by 8 minutes, wrecker response times by 5 to 7 minutes, and fatalities in urban areas by up to 10 percent. Accident rates have fallen by 25 percent since the comprehensive freeway management system was put into operation. Benefits accrue not only due to fewer incidents and faster response time, but also during non-incident conditions. Average freeway speeds in Minneapolis have increased by 35 percent and capacity has increased by 22 percent.

In addition to providing traveler information through more traditional means such as VMS and HAR, the Twin Cities area is also testing new technologies for communications with travelers through the Genesis system and the Trilogy system.

The Genesis system uses personal communications devices such as pagers and personal memo computers to provide information to travelers wherever they are. Operators at the traffic management center receive the data, evaluate it, and announce roadway incidents on the Genesis system. Traveler messages include information not only about incidents, but also about special events such as parades or construction. Genesis users can receive up to 12 messages at one time, with older messages automatically overwritten. Information is accessed at the convenience of the user, to avoid the disruption of beeping pagers.

The Trilogy project provides traveler information through three different communications techniques: the Radio Broadcast Data System-Traffic Message Channel, an FM subcarrier, and a high-speed RF subcarrier. These devices will provide end users with area and route-specific en-route advisories on the highway operating conditions in the Twin Cities area.

The Twin Cities region has been aggressive not only with respect to ITS traffic applications and traveler information, but also with respect to encouraging transit and other high occupancy modes. One demonstration of the multimodal approach is the Travlink project. Travlink, a partnership of public, private, and academic institutions, utilizes a GPS AVL system to monitor and dispatch buses for improved efficiency and on-time performance. The system also features a communication system that facilitates notification of either a mechanical problem or emergency situation (including a silent alarm to call for help).

The real-time bus status gathered through the Travlink project is used not only for fleet management, but also to keep transit patrons informed. Real-time bus status messages are displayed via electronic signs at three commuter park-and-ride lots, allowing commuters to wait in their cars until the bus approaches. Bus status, route planning, Carpool information, and traffic and road information are also available through kiosks and special videotext terminals. Benefits of Travlink include decreases in travel times. Travel time savings are estimated to be as high as 17 minutes during incident conditions, resulting in time savings as high as 1,900 vehicle-hours of delay per incident.

San Antonio, Texas - San Antonio has recently completed a transportation management center that will be the focal point for San Antonio's ITS system. The initial phase controls 25 centerline miles of the proposed 190 mile system. A unique feature of San Antonio's system is the extent to which it is centralized. The transportation management center, which represents an investment of at least $36 million, will handle freeway monitoring and control, and provide traveler information, incident management, transit management and emergency management. In addition to system operators and other traffic management personnel, law enforcement, transit, emergency response, and state and local engineering personnel are all housed in the same facility, which is in a three-story building in a major interchange. The close proximity of all affected agencies will presumably facilitate coordination and cooperation.

San Antonio's advanced traffic management system, TransGuide, depends on detectors at half mile intervals and high resolution color CCTV cameras (with remote zoom and focus capabilities) for information on roadway conditions. The San Antonio system boasts a complete digital communication network (voice, data and video), a fully redundant fiber optic network, a fault tolerant computer system, an incident detection goal of 2 minutes, and a system response goal of under 1 minute after detection.

Attainment of the goal for incident detection within 2 minutes will be facilitated by a central computer which controls detection, analysis and response, with over 34,000 pre-programmed solutions to specific incidents (as many as 128,000 solutions will eventually be developed and stored). Identification of an incident will trigger not only emergency response personnel, but also VMSs, lane-control signals, and signal timing. The frontage roads adjacent to most urban interstates in Texas provide an ideal diversion route in the event of an incident or lane closure.

In addition to providing motorist information through traditional technologies such as VMSs, the San Antonio system also has a direct link to local television stations. Funding for the television link was a unique public/private arrangement. The Texas Department of Transportation funded just over half, maintaining control. The remaining funds were obtained from a consortia of local television stations.

Los Angeles, California - Los Angeles has the largest roadway system and the most congestion of any urban area in the United States. Los Angeles also has one of the most extensive and established ITS systems. The traffic management center operated by Caltrans controls 700 centerline miles of interstate and state highway.

ITS activities in Los Angeles have been enhanced by demonstration projects such as the Pathfinder project and the SMART Corridor program. The Pathfinder project, a cooperative effort by Caltrans, FHWA, and General Motors, was the first test in the United States of an in-vehicle navigation system for the provision of real-time traffic information to drivers. Pathfinder provided drivers of 25 specially equipped cars with up-to-date information about accidents, congestion, highway construction, and alternate routes in the Los Angeles SMART corridor. A control center managed the communication, detected traffic density and vehicle speeds via detectors and by using the Pathfinder vehicles as probes, and transmitted congestion information to equipped vehicles. The information was then presented to the driver in the form of an electronic map on a display screen or digital voice.

The SMART Corridor program, another ITS demonstration project underway in Los Angeles, is sponsored by the City of Los Angeles, the Los Angeles County Transportation Commission and FHWA. The objectives of the SMART Corridor, located along 12.3 miles of the Santa Monica freeway, are to relieve congestion, reduce accidents, reduce fuel consumption and improve air quality. This is to be accomplished by advising travelers of current conditions and alternate routes using HAR, VMSs, kiosks and teletext, by improving emergency response, and providing coordinated interagency traffic management. The goals and strategies of the SMART Corridor program mirror the goals and strategies of the ITS system in general.

The ITS system in Los Angeles includes a Freeway Service Patrol (initiated in July 1991) electronic monitoring via loop detectors and 27 CCTVs, citizen call-in and call boxes, more than 800 ramp meters, and incident management teams. Motorist information is provided through HAR, more than 70 VMSs, information kiosks, media partnerships, and the Internet. Incident management activities are also facilitated by the use of pre-planned diversion routes to manage traffic. In some cases, diversion routes utilize arterial street facilities. Use of arterial facilities as diversion routes is facilitated by a sophisticated signal control system.

Los Angeles also has one of the most advanced arterial control systems in the United States. The Arterial Traffic Monitoring and Control (ATSAC) system has an extensive detector system to obtain data on arterial traffic flow and color graphic monitors to display real-time information. To supplement the information from the detectors, CCTV is placed at critical intersections. This allows verification of congestion indicated by detectors, and helps the operator during manual override control during incidents. There are four modes of control used by the system: time of day, critical intersection control, traffic responsive, and manual override.

Los Angeles has utilized ITS technologies not only for traffic and incident management, but also to respond to planned events, such as the Olympics, and even to respond to disasters such as the Northridge earthquake. Variable message signs and other means of motorist information were especially critical following the earthquake, when many facilities were closed, and some of the ones that were open were restricted to HOVs. Another strategy used following the earthquake was information kiosks. As many as 80 kiosks were located in shopping malls, police buildings, business parks and community facilities such as the YMCA. Travelers could use the kiosks to plan transit trips, find carpools, check traffic conditions, and print itineraries. Although the kiosks were removed once Los Angeles recovered from the earthquake, they are being returned due to their popularity.

Seattle/Tacoma, Washington - The Seattle/Tacoma area has a number of ITS activities underway, and at least $35 million has already been invested in monitoring, control and driver information components, including a traffic management center operated by the Washington State Department of Transportation (WSDOT), ramp meters, loop detectors, CCTV cameras, VMSs, HAR, and weather stations.

The benefits of ITS in the Seattle area have been significant. Ramp metering has proven particularly successful. Ramp metering in Seattle has cut accident rates to 62 percent of the previous rate, despite increases in traffic ranging from IO to 100 percent (average approximately 20 percent). Speeds have remained steady or increased up to 48 percent, resulting in a 20 to 37 percent decrease in travel times. Ramp delay has remained at 3 minutes or less. Travelers have also benefited from the provision of information. Thirty to 40 percent of travelers adjust their plans, and 5 to 10 percent of these travelers change their mode, based on the information they receive.

An interesting aspect of the Seattle area system is the approach to information sharing. The ITS Backbone Project, co-sponsored by the Puget Sound Regional Council (PSRC) and the WSDOT, is designed to create a common information pipeline over the Internet for advanced data collection systems. This system allows agencies and travelers to access a variety of travel data and use it to make decisions.

The ITS Backbone incorporates information from the North Seattle Advanced Traffic Monitoring System (ATMS) , the loop detection system run by WSDOT, Metro and Community Transit Traffic Signal Priority Project, and Metro Transit and University of Washington AVL systems. The Backbone gathers travel times for automobile, freight and transit traffic, involving many agencies and extensive use of the region's ITS data collection activities. For example, interfacing with existing AVL systems allows real-time transit vehicle locations to be obtained. Freeway congestion information is obtained by interfacing with the loop detection system owned and operated by WSDOT. Using data acquisition control systems, global Information system (GIS) command and control consoles, display systems and communication ports, the data from the AVL and loop sources are fused, yielding detailed information about the region's transportation system and travel conditions.

One advantage of the system is that the cost of making data available through the ITS Backbone and Internet connection is minimal to the agency, yet the benefits are considerable. Furthermore, it overcomes the barrier that independent agencies are often unwilling to share data for joint development if it means they must adjust current procedures or sacrifice the security and integrity of their data. The ITS Backbone also encourages regional cooperation, as each agency benefits by cooperating. Agencies can access information without delving into the operations, philosophies, or objectives of the agency responsible for gathering the data.

Despite the advantages, several issues must still be addressed. Some data collection systems are proprietary in nature, which complicates the design and development of information sharing techniques. Furthermore, real-time validations and processes for ensuring system maintenance must be addressed if real-time information is to be openly broadcast to transportation agencies.

In another effort to coordinate agency activities, the North Seattle ATMS is undertaking a project to explore methods for adjacent traffic signal systems to share loop detector and operational data to improve operations across boundaries and between adjacent systems. Jurisdictional issues which often prevent coordinating adjacent systems will also be addressed. Data will be obtained from several systems in the I-5 corridor north of Seattle by a single microcomputer connected with street or central master controllers belonging to the various jurisdictions within the corridor. The microcomputer will compile the volume, occupancy and operations data and transmit it back to the participating control systems. Each system will use the data to improve its traffic management capabilities.

Another ITS activity of interest in the Puget Sound area is the evaluation of technologies for emergency notification and personal security. A specially equipped two-way pager and cellular telephone are being tested as MAYDAY devices for notification of accidents, mechanical failure, or carjacking. The two-way pager offers three buttons, one for emergency situations, one for medical help, and a third for mechanical assistance. The pager device cannot transmit voice, but two-way communication is possible if a traveler pushes buttons in response to digital messages or questions.

The cellular telephone offers two-way voice communications with a silent alarm panic button activating a voice link that can be monitored until help arrives. Other buttons can be pushed to identify a situation as a accident, mechanical failure, or request for directions. Once activated, the MAYDAY devices automatically transmit a signal to a 911 dispatch center, where an electronic map pinpoints the signal location, generally within 30 feet.

Northern New Jersey - Northern New Jersey has been involved in what would now be considered ITS activities since the 1970s when the Metropolitan Area Guidance Information and Control, commonly known as MAGIC, system was initiated. MAGIC, which is sponsored by the New Jersey Department of Transportation, focuses on I-80 (an east-west route into New York City via the George Washington Bridge) and parallel facilities (such as US 46 and New Jersey 4).

One notable feature of the MAGIC system is the choice of detection technology. New Jersey has used radar based detection every half mile. The primary disadvantage of radar is that it averages speeds across all three lanes, and in some cases, the average speed includes the HOV lane, which should have freeflow speeds at all times. For incident detection purposes, it is preferable to have speeds for each lane, otherwise the decreased speed in a single blocked lane may be obscured by the higher speeds in the open lanes. New Jersey is now also installing loop detectors. Loop detectors are being placed at 0.7 mile intervals, in an effort to increase coverage without increasing costs. The effectiveness of this strategy has not been evaluated.

New Jersey has also been active with respect to electronic toll and traffic management (ETTM) technologies. The implementation of ETTM technologies by three New Jersey toll authorities will permit commuters to use a single electronic toll tag, or EZ-Pass, throughout the region. In general, electronic toll collection systems have been shown to decrease operating expenses up to 90 percent, increase toll plaza capacities by up to 25 percent, and decrease fuel consumption by up to 12 percent, and decrease harmful emissions by 45 percent (nitrous oxides) to 83 percent (hydrocarbons). The effort to implement ETTM technology in New

Jersey is part of the larger EZ-Pass Interagency Group, which is a coalition of seven toll authorities in New York, New Jersey, Delaware and Pennsylvania.

In some cases, toll authorities have their own ITS systems. For example, the New Jersey Turnpike Authority operates a TOC in New Brunswick, New Jersey. This system covers almost 150 centerline miles of interstate and state tollway, monitoring traffic through loop detectors, video imaging, microwave detectors, and 2 CCTV cameras. Over 100 variable speed limit and speed warning signs and more than 100 variable messages signs are used to keep motorists informed.

New York- New York has a variety of ITS activities underway, including both traffic and transit applications. One noteworthy project is the INFORM corridor traffic management system on Long Island in New York State. The major facility in this corridor is the Long Island Expressway, I-495. The INFORM system manages 35 centerline miles of interstate, parkway, and state arterial, including more than a hundred signalized intersections (on the service roads and selected arterial routes). An important feature of the INFORM system is the integration of the management of the arterial and freeway system.

Although some of the system elements have been in use for many years, the design of the INFORM system has evolved and includes a higher level of corridor traffic management automation. Low level tasks include data collection and communication, computation of traffic flow characteristics, and reporting of traffic flow characteristics. Medium level tasks include intersection control, ramp meter control, and equipment failure monitoring. High level tasks include generation of messages for VMSs (delay messages are automatically activated), intersection control (upon diversion of traffic from the freeway the system adjusts the affected arterial timing plan based on a diversion database), ramp meter control (ramp metering becomes more permissive when congestion backs up on arterial streets), and incident management and diversion strategies (theoretically incidents can automatically be detected and diversion strategies implemented).

Delay savings due to motorist information are significant. Travel time savings of 17 minutes are estimated during incident conditions, this results in delay savings of 1,900 vehicle-hours for a peak period incident, and 300,000 vehicle-hours in incident related delay annually. Traveler information also provides important benefits. Drivers will divert 5 to IO percent of the time when information does not include any action, and will divert 10 to 20 percent of the time when diversion messages are provided.

Basic elements of the system include vehicle detection through more than 2,000 loop detectors, monitoring through 34 CCTV cameras, an operations facility, radio communication monitors, intersection control, ramp metering (using 75 ramp meters) and more than 100 VMSs. The INFORM system also has a subscription service, the Video Traffic Information Program, which provides color computer graphics of traffic conditions. INFORM operators also monitor CB and police radio for incident detection and verification. This is considered critical due to the lack of corridor-wide monitoring by CCTV.

Monitoring capabilities may soon be enhanced by a traffic flow visualization and control program recently initiated. This program investigates a video-based vehicle detection, visualization and management system which employs technology developed in the military. Through advanced video data processing, neural network analysis and intelligent command

and control technologies, the traffic adaptive system will identify and alert the system operator to real-time traffic conditions such as recurring congestion, non-recurring incidents, and other traffic problems normally associated with freeway operations. Once the system has been demonstrated in the lab, the system will be field tested as part of the INFORM corridor.

ITS activities in New York are also underway on a larger scale. The Transportation Operations Coordinating Committee, TRANSCOM, is a consortium of 15 transportation and public safety agencies in the New York, New Jersey and Connecticut area whose goal is to improve inter-agency response to traffic incidents. A number of project initiatives have been undertaken to support this goal, and to advance the use of ITS technologies in the metropolitan area. Activities include:

- Regionwide initiatives for coordinated deployment and operation of VMSs, HAR, and enhanced traffic monitoring including CCTV.

- Development of an ITS Regional Implementation Strategy, a program for coordinated implementation of ITS throughout the multijurisdictional area.

- An enhanced traffic advisory/diversion system at the intersection of the New Jersey Turnpike and Garden State Parkway, which will focus on alternate routing for New Jersey Transit buses.

- Expansion of traffic monitoring along the I-287 Tappan Zee Bridge corridor.

- The TRANSCOM System for Monitoring Incidents and Traffic, TRANSMIT, an operational test project that will manage vehicles with transponders on a highway system equipped with readers and antennas, to collect travel times, speeds and with dynamic software, to detect incidents.

Washington, District of Columbia - There are a number of ITS activities underway in the Washington, D.C. area. Coordination of these ITS activities is very important due to the fact that the metropolitan area encompasses the District of Columbia, the States Maryland and Virginia, and many local jurisdictions. Many of the ITS activities in the region are conducted in Maryland and Virginia.

Many of the ITS activities in Maryland are affiliated with CHART (Chesapeake Highway Advisories Routing Traffic), which was initiated in 1989 as the statewide transportation management program. CHART originated to meet the need for monitoring, incident response, traveler information and traffic management. In conjunction with CHART, the State of Maryland has a 24 hour, 17,000 square foot traffic control command center which serves as an information hub. This center is coordinated with the activities of the Maryland State Police, who help staff the operations during morning and evening rush hours, extreme weather, and in other circumstances where additional personnel are warranted.

The traffic control command center is networked to CCTV cameras and other data gathering equipment such as radar and road-embedded traffic detectors, and pavement condition sensors. Information is also received from a cellular call-in system. The detection system uses bi-directional overhead, wide-beam, radar based traffic detectors to monitor speeds at 1.5

mile intervals. Detection has been installed at 77 sites, and another 250 sites are planned or underway. CHART is expected to have a benefit cost ratio of 10.

Information is displayed at the command center via six large-screen, rear-projection systems on the wall, a video bank of five 120 inch rear-projection units, a 4x4 matrix rear-projection video wall, and a dozen 20 inch color monitors. The traffic control command center responds to incidents through links to emergency traffic patrols and emergency response units, and notifies motorists via VMSs and HAR, which currently includes 25 permanent stations, and four more planned in the next 2 to 4 years.

CHART also has regional TOCs, which are located at several State Police facilities, at the Fort McHenry Tunnel in Baltimore, and at the Chesapeake Bay Bridge during the summer. The state traffic control command center shares information, including video feed, with the Montgomery County traffic management center, which serves suburban Washington, D.C.

The Montgomery County traffic management center, which opened last year and is the result of an $8 to $10 million investment, has coordinated signals, loop detectors, and 22 CCTV cameras at IO locations along the Baltimore-Washington corridor. In addition to aggregating data from sources such as freeway detectors, CCTV, and local street signals, the Montgomery County Traveler Information System provides real-time information to 180,000 homes via cable TV to show traffic conditions on major roadways.

Another $3 million is being used to integrate traffic and transit management activities. The resulting system will include an AVL equipped bus fleet, intelligent in-vehicle units, two-way communications, real-time graphics, relational database, monitoring, and control software, transit priority and system information dissemination.

Montgomery County is also exploring live aerial video monitoring. In this case, the video is shot from fixed-wing aircraft and video footage is sent to both the state and county traffic management centers. Maryland and Virginia are cooperating in this effort and will transmit video to traffic management centers in both states, and are beginning to transmit live video to mobile command centers.

Fairfax County, Virginia and the Virginia Department of Transportation are also exploring aerial monitoring. More specifically, a gyro-stabilized camera mounted on helicopters is being used for observing, evaluating, and managing major highway incidents and situations of a public safety nature. The live color video is transmitted to police and state highway traffic management centers and mobile command centers at incident sites. Communications technologies being used include microwave, community access TV, and state owned coaxial cable. It is expected that the use of real-time airborne video will serve as a valuable component of the advanced traffic management system, particularly during the management of major incidents.

Northern Virginia also has a number of other activities underway with respect to traffic management and control. ITS activities include the Northern Virginia freeway traffic management system and TOC, a statewide emergency operations center for the State of Virginia, Hampton Roads tunnel and bridge traffic management systems, the City of Richmond signal system, truck rollover warning systems on the Capital Beltway, wide area cellular monitoring operational test, and SCAN weather monitoring. The Northern Virginia traffic management center, which is operated by the Virginia Department of Transportation, manages

32 centerline miles of interstate with 550 loop detectors, almost 50 CCTV cameras, over 25 ramp meters, and 100 VMSs.

In addition to the ITS applications for traffic management, Northern Virginia is also conducting an operational test to evaluate an enhanced ridesharing route deviation transportation system integrated with conventional transit and ridesharing in the suburbs of Washington, D.C. The system provides on-demand service through an audiotext request system which uses scheduling software similar to the software used by the taxi industry. Door-to-door transportation is provided using both public and privately owned vehicles operated by paid volunteer drivers using vans, minibuses, specialized public vehicles, fixed-route buses, and taxis. Users are charged a standard per mile rate regardless of the type of vehicle used. System cost not recovered by these fares are to be covered by local agencies. Smart cards are used to process transactions. It is hypothesized that this service may be provided at a much lower cost than conventional transit service.

Public Transportation Technologies

This section addresses ITS transit technologies and their applications in the Kansas City metropolitan area.

Advanced Public Transportation Systems (APTS) is the program name describing the application of advanced navigation and communication technologies to transit system operations. APTS applications can assist transit system managers provide timely accurate information on transit services to transit passengers, and improve the efficiency, reliability and safety of the service.

APTS applications are often summarized into three categories:

- Smart traveler technology, which focuses on the provision of basic user information to transit users before they make decisions on how they will make a particular trip. An important objective is to make real-time information available through the use of advanced computer and communications technology.

- Smart vehicle technology, which involves the integration of various vehicle-based technologies to improve vehicle and fleet planning, scheduling and operations.

- Smart intermodal systems, which combine APTS technologies with traffic management and other non-transit applications. The objective is to create multi-modal transportation networks to optimize the transportation system as a whole.

Many APTS technologies exist. The most popular APTS applications are:

- Automatic Vehicle Location (AVL) and Computer Aided Dispatch (CAD). AVL utilizes one of several technologies to determine the location of transit vehicles and relate this location information to scheduled location and time. Through specialized data processing and communications, this information is integrated with CAD to achieve improved operations control and management. AVL is the APTS technology with the most applications throughout the industry.

- Smart Cards. These are personal debit cards that can be used for payment media for other modes and parking lots, as well as transit fares.

- Automatic Passenger Counting (APC). APC employs devices that keep track of transit patrons as they board and exit vehicles, and relate this activity to a place (the specific transit stop) and time.

- Automatic Stop Annunciation. This application provides audio announcements of the next stop, transfer points, areas of interest at stops, and other information useful to transit patrons. Automatic stop annunciation is often used to assist transit system managers meet Americans with Disabilities Act (ADA) regulations regarding the provision of stop information to persons with visual impairments.

- Passenger Information Systems. This area covers a broad range of applications that involve the provision of transit user information in an enhanced manner, including interactive systems and real-time information. APTS projects in this category include interactive kiosks at stops and stations, automated telephone systems and the use of various electronic media, such as cable television.

- Adaptive Traffic Signal Control. This involves providing transit or traffic managers a degree of control over traffic signals by transit vehicles to provide preference over general traffic, thereby reducing transit travel time and improving reliability.

Other examples of the use of technology in transit are not usually regarded as APTS or ITS applications. For example, automated fixed route scheduling systems are not usually included, although these automated management aids can be integrated with AVL systems and passenger information systems resulting in more effective application of these APTS technologies. Automated paratransit scheduling and dispatching systems are categorized as APTS if they employ advanced communications and navigational technologies.

AVL is the most widely used APTS-type application, probably because it is the only one that has been economically justified from a public investment standpoint. AVL's capability to make vehicle scheduling more effective can result in the amortization of AVL's initial cost in three to five years.

In addition, AVL represents infrastructure in that other APTS applications require data from an AVL system. For example, passenger information systems providing real-time service information integrate passenger displays with vehicle locational information from an AVL system.

The linking of APTS technological applications with similar applications relating to traffic management and control has the ability to enhance the operation of both modes, and generate greater benefits for transit passengers and automobile users.

Transit related ITS user services identified by representatives of the metropolitan area's transit operators as the highest priorities are:

- En-Route Transit Information.

- Public Travel Security.
- Public Transportation Management.

Ride Matching and Personalized Public Transit user services were identified as medium-high priorities.

Several recent studies of public transportation in the Kansas City Metropolitan area have identified a perceived problem among transit users regarding coordination among the three primary operators. Although the KCATA, Johnson County Transit (JCT) and the Kansas City, Kansas, Public Transportation Office have coordinated many aspects of their services, the perception among the public is that it is difficult to travel from Missouri into Kansas, and transfers between buses operated by different service providers are not “user friendly”. This perception was-one of the significant findings of market research performed recently by the KCATA related to a comprehensive service review. As part of the Long Range Public Transit Planning Study being performed by the Mid-America Regional Council (MARC), the consultant assisting with the project held a transit planning workshop involving representatives of transit providers and municipal governments. The need for improved coordination was a theme expressed by a number of participants in the workshop.

The application of ITS Technology can assist with the task of interagency coordination to provide the public a “seamless” public transportation. However, technology alone cannot make up for ineffective communication or inadequate coordination between operators. Effective application of ITS technology in the public transportation sector requires a high degree of interagency cooperation, as is the case with highway related applications. Key agencies are the three public transportation providers, and the private companies providing scheduled service to the Kansas City International (KCI) Airport.

EN-ROUTE TRANSIT INFORMATION

Although the user service identified by transit agency representatives is termed En-Route Transit Information, it appears the need exists to improve and coordinate all forms of transit user information. A deficiency of accurate, readily available, user information appears to exist, especially for passenger trips that involve travel on services provided by more than a single agency.

Currently, each of the operators maintain separate telephone information services focusing primarily on the provision of service information relative to services operated by the agency. Information is available regarding transfers between systems, but the customer is directed to the other agency’s phone information number for specific information. Each of the three public transportation operators distributes printed materials with information on routes, schedules, fares, transfers and other pertinent user information.

An alternative to the current situation would be the establishment of one telephone information system for all transit services in the metropolitan area. Several metropolitan areas served by multiple transit operators have successfully implemented regional telephone information systems. While this approach can be taken without an assist from technology, technology can enhance the operation of the regional transit information center by improving communication among the participating service providers. For example, service data could be made available to information center agents in electronic format for easier retrieval and updating.

Telephone information systems are very labor intensive and represent a significant operating cost. Budget limitations result in limited information services, in terms of the number of agents available to take calls, hours operation and days of operation. Technology is available to automate telephone information systems, making them more efficient and potentially reducing costs. A number of commercially available systems exist, ranging from automated tools to assist information agents, to full automation.

The majority of calls that are made to transit information centers are for simple schedule information, such as the scheduled time of the next bus on a specific route. These calls can be readily answered through a caller select key pad based system, or “audiotext”. Areas that have used automated systems also maintain traditional information systems with agents who can address more complex requests for information involving transfers among routes, and other matters not readily addressed by automated responses.

The KCATA is in the preliminary stage of acquiring a system to automate the telephone information function. This project would include the acquisition of software to automate KCATA’s scheduling and related functions.

An advanced traveler information system (ATIS), such as the one in place in the Boston metropolitan area, would provide information for highways as well as transit. An ATIS would be capable of providing the comprehensive transit user data desired by the public, but such a system would require transit operators to provide information in some type of electronic format for use by the ATIS.

User information can be provided en-route in a number of different ways. Several APTS operational tests have assessed the use of electronic kiosks at transit stops or high activity areas near transit stops. These interactive devices allow access to transit information while the user is making the trip. The results of these tests have been inconclusive. Other operational tests have explored the use of electronic signs and displays at stops with the capability of providing real-time information (e.g., through interconnection with an AVL system) or messages controlled by dispatchers (e.g., in the event of service interruptions or reroutes). These tests have also been inconclusive to date.

KCATA has preliminary plans for installing interactive customer information kiosks at the recently opened transit center at 10th and Main Streets in downtown Kansas City.

For the most part, the need for en-route information can be provided through low-tech solutions. For example, static displays of printed transit schedule materials provided at transfer locations can assist transit customers as they transfer from one route (or system) to another. Public telephones, or dedicated information center phones, located at bus stops and transfer centers can provide the important link between the customer and information needed to complete a trip.

PUBLIC TRAVEL SECURITY

Increasingly, concerns about security appear to be having a negative affect on transit's ability to attract and maintain customers. This concern was highlighted by the market research performed by KCATA.

Public travel security can be addressed through technology applications in several ways. AVL technology allows transit dispatchers to direct supervisory and law enforcement personnel quicker in response to incidents reported by bus drivers, often using a silent alarm feature. KCATA dispatchers estimate that AVL reduces response time by up to half.

Electronic video and audio monitoring is increasingly being used to monitor activity on-board buses. Two-way radio systems used by transit operators can be equipped with covert microphones that are activated when a silent alarm is engaged. Conversations between the bus driver, passengers and persons causing disruptions can be monitored and used by dispatch personnel in responding to an incident. KCATA's communication system does have a silent alarm feature to allow bus drivers to covertly alert dispatchers of trouble on-board buses. It may be possible to modify the communication system's controls to add a covert microphone to provide the on-board audio monitoring feature.

Some transit systems in other metropolitan areas use video cameras mounted in the interior of buses. Typically the video is not monitored. Instead, the video is recorded, saved and can be monitored at a later time if an incident occurred on the bus. The video cameras have been deployed as a deterrent, but have allowed authorities to identify individuals responsible for criminal offenses, as well.

Video monitoring can also be used to monitor activity at transit stations and bus stops, and at facilities such as park-and-ride lots. With the large number of bus stops maintained by urban transit systems (5,000 to 10,000 individual stops) video monitoring is practical only at heavily used bus stops, such as transfer locations and downtown area stops. Video cameras used in this manner usually require monitoring by security personnel, adding to operating expense.

Whether or not ITS applications are used, coordination between transit agency dispatch centers and law enforcement control centers is a requirement for improved public travel security. Coordination including standard operating procedures, mutually accepted agency and individual roles, and improved communications between dispatch personnel.

PUBLIC TRANSPORTATION MANAGEMENT

Public transportation management, a high priority among transit operators in the metropolitan area, can include a large number of applications. Generally, technology applications that have the potential to reduce costs, improve service, and address specific problems or objectives in the Kansas City metropolitan area should be considered.

During the past year the KCATA has been working on a project to restore the capability of the Automatic Vehicle Locator (AVL) system initially installed in 1989. In November, 1995, KCATA's Board of Commissioners approved a contract with a local electronics firm to replace failed hardware. The contractor anticipates completion of the project by September 1996.

This is an important because KCATA's AVL system has been recognized by ITS America **as** one of the best examples of ITS technology applied to transit system management. In addition to producing benefits itself, AVL represents technological infrastructure that can be built upon with other applications to produce even greater benefits.

KCATA has recently acquired an automated system to assist with scheduling and dispatching for KCATA's paratransit service, Share-a-Fare. In addition, KCATA is in the process of acquiring an automated scheduling system for their fixed route services. This system may include the automation of materials for the telephone information system.

Beyond these efforts, a number of other opportunities exist in the general area of public transportation management improvements.

Coordinated Dispatch - Each of the transit operators in the metropolitan area maintain separate dispatch facilities for their operations. All revenue vehicles and service vehicles are radio equipped. However, communication among the four separate dispatch centers is limited to telephone communication on an as needed basis. This contact is initiated at the discretion of dispatch personnel.

KCATA upgraded their dispatch capability in '1989 with the addition of CAD and AVL. KCATA experienced significant benefits from the AVL system, including a 12 percent improvement in on time performance, and productivity improvements in the form of a reduction in the number of buses required to operate a given service level. This resulted in the savings of several hundred thousand dollars annually. AVL and CAD applications may not be warranted for the smaller transit operators due to the relatively high initial cost and the nature of the service currently provided.

It would be possible to include buses operated by JCT and KCK in KCATA's AVL system, however, each bus would have to be equipped with the required communications and location monitoring equipment, and dispatch center equipment would have to be acquired to use the location data for dispatch purposes. A careful evaluation of the costs, benefits, and technological and institutional questions would be required.

However, some benefit may be realized simply by formalizing and improving communications between transit operators using readily available technology. For example, transfer connections between buses operated by the different transit systems could be made more reliable through coordinated dispatch.

Communication among various dispatch centers could be enhanced through the establishment of dedicated phone lines, along with standard operating procedures. Some type of improved communication among transit dispatch centers would be required to insure effective coordination between transit and the highway TOC.

Paratransit Scheduling and Dispatching - Another opportunity to use technology to improve public transportation management is in paratransit scheduling and dispatching. Various forms of paratransit services for elderly and disabled persons are provided by multiple operators in the metropolitan area Little coordination exists among various operators, and overlapping service areas and a diversity of eligibility requirements results in confusion among users and potential users. This lack of coordination has been cited as a problem in recent studies of public transportation in the metropolitan area. Coordination and even consolidation of public information, reservation, scheduling and dispatch functions holds potential for significant improvements in service from the public's perspective.

Paratransit services are much less productive in terms of passengers carried per hour, compared with traditional fixed route transit service. This low productivity is a result of the tailored nature of the service. Typically each passenger trip is individually reserved and scheduled. The number of trips per hour is a key variable in the cost of these demand responsive paratransit services. Currently, tasks associated with accepting trip reservations from the public, scheduling these trips to available vehicles and dispatching the vehicles is performed manually, with little or no automated support. Experience from other metropolitan areas has shown that automation of these tasks can result in significant improvements in the productivity of demand response paratransit systems. For example, one large operator of demand response service in the St. Louis metropolitan area reported a 75 percent increase in productivity, measured in passengers per mile, after implementing a fully automated scheduling and dispatch system.

Political, institutional and operational barriers exist, but the technology exists to assist with the coordination of paratransit services in the metropolitan area. The automated scheduling and dispatching system recently acquired by the KCATA may have the capability to allow multiple paratransit operators access reservation, scheduling and dispatching capabilities. Conceivably, the desired coordination of services and user information could be facilitated through the joint use of the paratransit scheduling and dispatching system.

The Americans with Disabilities Act (ADA) requires greater cooperation among paratransit operators to provide for inter-jurisdictional trips that were previously very difficult due to the limitations placed on paratransit users by services largely confined to a single jurisdiction. Conceivably, these inter-jurisdictional trips can initially be scheduled by the KCATA's automated system, with wider use throughout the metropolitan area in the future.

Personalized Public Transit - KCATA has implemented two MetroFlex routes in recent years, representing limited entry into the provision of alternative transit services tailored to suburban markets. JCT operates one route offering route deviation as a means to better serve dispersed trip origins. The difficulty in providing these types of services is the increased scheduling and dispatching tasks required to support the personalized nature of the service. KCATA's paratransit scheduling and dispatch system should have the capability of supporting MetroFlex-type services for the general public, as well as specialized paratransit service for elderly and disabled persons. Thus, such services could be deployed in more parts of the metropolitan area without the added operating cost for additional dispatch personnel.

Chapter 6
Benefits and Costs

Introduction

This chapter provides estimates of the benefits and costs that would be expected due to deployment of a freeway management system and ITS transit technologies. System benefits due to a freeway management system, discussed in the second section, are presented on an annual basis for each of four deployment phases. Costs associated with a freeway management system, discussed in the third section, include both capital and operating expenses and are provided as the summation of the component costs that comprise the system. The benefit cost ratios for each of the four phases of a freeway management system are presented in the fourth section. The fifth section addresses the benefits and costs associated with deployment of ITS transit technologies.

Estimated Benefits - Freeway Management System

The primary benefits expected to result from the deployment of a freeway monitoring system are travel time savings that would result from a decrease in incident response time. A reduction in the time that elapses before an incident is identified and located would be expected due to the deployment of freeway monitoring equipment, including roadway detectors and closed circuit television (CCTV).

Incident response would also be facilitated by the provision of information to emergency responders. Information from the CCTV would help emergency responders decide what kind of equipment is needed; this would decrease vehicle delay by assuring that equipment that is needed arrives quickly, and by minimizing the transport of unnecessary equipment to the scene (unneeded equipment reduces capacity by further obstructing traffic flow). Information from the CCTV could also be used to determine the best method of access for emergency responders. Sometimes accidents are best accessed from surface streets that are close to the freeway or from the freeway lanes in the opposite direction. Finally, information on current travel speeds could be used to help determine the best route for emergency responders. A representational diagram of the freeway management system is shown in Figure 6-l.

Benefits also accrue as a result of informing motorists about traffic conditions. Variable message signs (VMSs), highway advisory radio (HAR), and the provision of current and accurate traffic information through commercial radio and television are all valuable mechanisms for communication with the public. Although it is difficult to predict the magnitude of the impact of this information, it does have an impact. In addition to reducing driver frustration, it can also affect travel behavior. In fact, almost half of respondents using a traveler advisory telephone service reported that the information they received had a direct effect on their travel behavior.[1]

1Summary of Findings, Massachusetts Highway Department Independent Evaluationof SmarTraveler Operational Test (conducted for the Massachusetts Highway Department and presented in a paper to ITS America)

The benefits expected to result from the deployment of a freeway monitoring system due to a reduction in incident duration are shown in the Figure 6-2. These are the annual benefits that would result if each incident in the peak hour were reduced by eight minutes. Additional information regarding the calculation of the benefits, including the assumptions used, is included in Appendix B.

The annual benefit varies depending on the number of incidents and the volume of vehicles in the peak hour on each segment. The values are calculated on a per mile basis, so segment length does not impact the expected benefits. The calculation of benefits on a per mile basis is also logical from the standpoint that the cost of loop detectors and other monitoring equipment may easily be calculated on a per mile basis.

A number of assumptions were necessary to estimate the annual benefits. While these assumptions affect the absolute magnitude of the benefits, they do not affect the relative magnitude of the benefits. Thus, they are not critical with respect to identifying which segments would be expected to result in the greatest benefit. However, because these assumptions affect the magnitude of the estimated benefit, they do affect the benefit cost ratios (discussed in Section 4.4), and impact the recommended time frame for deployment and the extent and kinds of technologies that appear to be warranted.

Note that benefits are higher on segments with higher volumes and higher accident rates. This is due to the fact that benefits would accrue to a greater number of vehicles where volumes are higher, and would accrue more frequently on facilities where the accident rate is higher. Benefits are highest on the downtown loop, on I-70 east of downtown, on I-35 immediately north of downtown, on I-35 south of downtown, and on the southern portion of I-435.

Based on the estimated benefits, four phases for deployment were identified and are shown in Figure 6-3. Benefits and costs were estimated for each of these phases. Deployment issues related to project phasing are discussed in Chapter 5. Benefits for each phase are shown in Table 6-l. Detailed benefits by state are shown in Tables 6-2 and 6-3.

Table 6-1. Summary of Benefits per Phase for Freeway Management System

Phase	Mileage			Benefit (in Millions)			Average Benefits per Mile[1]
	Kansas	Missouri	Total	Kansas	Missouri	Total[1]	
1	20	28	48	$4.7	$8.9	$13.5	$285,000
2	14	20	34	$1.3	$3.5	$4.7	$141,000
3	15	60	75	$1.3	$4.4	$5.6	$75,000
4	49	52	101	$0.7	$0.6	$1.3	$13,000
All	98	160	258	$7.9	$17.3	$25.2	$98,000

[1]Values may not be the sum or the factor of the values shown due to rounding

Table 6-2. Benefits by Segment in Kansas

Facility	County	Segment Description Beginning	End	Segment Length (Miles)	Average Daily Volume	Average Accident Rate	Annual Benefit per Mile	Phase
I-35	Johnson	K-7	K-150	2.4	43,000	1.13	$40,055	4
		K-150	119th	2.3	67,000	0.93	$79,948	3
		119th	I-435	2.3	86,000	0.93	$131,721	3
		I-435	US 69 cut-off	3.2	80,000	1.44	$176,678	1
		US 69 cut-off	63rd Street	3.0	139,000	1.12	$414,848	1
		63rd Street	US 69/18th St Exp	3.0	106,000	1.10	$236,944	1
		US 69/18th St Exp	MO state line	3.0	78,000	0.93	$108,354	1
I-70	Wyandotte	K-7	I-435	3.6	20,000	1.57	$12,039	4
		I-435	K-32	3.9	35,000	1.25	$29,449	4
		K-32	I-635	3.3	55,000	1.34	$77,709	3
		I-635	I=670	3.1	51,000	1.60	$79,781	2
		I=670	MO state line	2.1	27,000	1.64	$22,920	2
I-435	Johnson	State Line	US 169	3.3	116,000	1.15	$296,657	1
		US 169	US 69	2.0	104,000	1.05	$218,341	1
		US 69	I-35	2.4	85,000	1.20	$166,211	1
		I-35	K-10	1.1	60,000	1.05	$72,673	4
		K-10	Renner Rd	4.3	35,000	1.08	$25,363	4
		Renner Rd	Holliday Dr	4.2	32,000	1.05	$20,671	4
I-435	Wyandotte	Holliday Dr	K-32	1.3	33,000	0.69	$14,489	4
		K-32	I-70	3.3	29,000	0.83	$13,382	4
		I-70	Leavenworth Rd	2.6	25,000	0.69	$8,315	4
		Leavenworth Rd	MO state line	4.8	13,000	0.69	$2,248	4
I-635	Johnson	I-35	Wyandotte Co. line	0.4	60,000	2.66	$183,580	2
I-635	Wyandotte	Johnson Co. line	K-32	2.8	60,000	1.52	$105,179	2
		K-32	I-70	1.0	74,000	1.60	$167,967	2
		I-70	K-5 (south jcn)	3.0	52,000	1.76	$91,235	3
		K-5 (south jcn)	MO state line	1.3	38,000	1.52	$42,188	3
I-670	Wyandotte	MO state line	I-70	1.6	42,000	0.58	$19,580	2
K-7	Wyandotte	Johnson Co. line	I-70	4.3	11,000	2.20	$5,103	4
K-7	Johnson	K-10	Wyandotte Co. line	7.2	10,000	0.65	$1,242	4
K-10	Johnson	I-435	K-7	4.6	27,000	0.70	$9,783	4
US 69	Johnson	K-150	US 169/US 69 merge	1.0	39,000	1.36	$39,569	4
		US 169/US 69 merge	I-435	3.2	44,000	1.56	$57,899	3
		I-435	I-35	3.0	67,000	1.53	$131,669	2

Table 6-3. Benefits by Segment in Missouri

Facility	County	Segment Description Beginning	End	Segment Length (Miles)	Average Daily Volume	Average Accident Rate	Annual Benefit per Mile	Phase
I-29	Platte	N UL KC	I-435	0.7	29,500	1.12	$18,668	4
		I-435 jcn	Rd D	3.6	35,100	1.20	$28,267	3
		Rd D	Rt 152	4.3	43,667	1.44	$52,539	3
		Rt 152	Rt 45	3.3	58,400	2.04	$133,524	3
		Rt 45	Clay Co line	2.7	73,833	0.91	$95,253	3
I-29	Clay	Platte Co. line	Rt 283	1.5	72,750	2.18	$221,357	2
		Rte 283	I-35/I-29	1.0	59,600	0.85	$57,801	2
I-29	Jackson	I-70	End of I-29	1.1	55,400	0.13	$7,936	1
I-35	Clay	Rt 69	I-435	6.5	44,625	1.91	$72,884	3
		I-435	Rt 269	3.4	44,250	1.46	$54,718	3
		Rt 269	I-29	1.4	51,150	2.38	$119,146	3
		I-29	Jackson Co. line	3.2	75,500	2.27	$248,466	1
I-35	Jackson	Clay Co. line	I-670	2.3	75,600	2.47	$270,964	1
		I-670	KS state line	2.3	118,150	1.60	$427,495	1
I-70	Jackson	KS state line	-35 s jcn	2.5	64,940	4.19	$338,365	1
		I-35 s jcn	23rd St	2.4	101,310	1.77	$347,318	1
		23rd St	I-435	3.4	98,555	1.92	$358,249	1
		I-435	Rt 40 E jcn	2.8	105,650	1.55	$332,542	1
		Rt 40 E jcn	I-470	4.4	82,600	1.50	$196,119	2
		I-470	Rt 7	5.0	60,550	1.25	$87,842	3
I-435	Platte	KS State line	Rt 45	2.6	12,300	0.52	$1,508	4
		Rt 45	Rt 152	1.4	15,300	0.12	$558	4
		Rt 152	Rt D	4.7	11,600	0.40	$1,044	4
		Rt D	I-29	2.7	8,000	0.13	$156	4
		I-29	Rt C	3.4	12,500	0.39	$1,166	4
		Rt C	Clay Co Line	2.5	21,800	0.64	$5,842	4
I-435	Clay	Platte Co. line	I-35	12.0	17,875	0.73	$4,462	4
		I-35	Jackson Co line	3.9	52,400	1.15	$60,752	3
I-435	Jackson	Clay Co line	US 24	3.2	76,000	1.13	$125,212	3
		US 24	Truman Rd	1.0	76,000	1.13	$125,212	2
		Truman Rd	I-70	2.4	88,100	0.99	$146,625	2
		I-70	Rt 350	2.8	98,500	1.45	$268,801	2
		Rt 350	Gregory Blvd	1.9	81,450	1.43	$181,699	2
		Gregory Blvd	Bannister Rd	3.4	81,350	1.37	$173,699	2
		Bannister Rd	Holmes Rd	3.5	88,167	2.09	$311,840	1
		Holmes Rd	KS state line	1.4	102,350	2.38	$478,280	1
I-470	Jackson	I-435	Raytown Rd	4.0	54,450	1.01	$57,339	3
		Raytown Rd	Rt 50	3.5	40,600	0.56	$17,623	4
		Rt 50	Colborn Rd	2.5	25,450	0.74	$9,200	4
		Colborn Rd	Woods Chapel Rd	2.6	37,250	0.66	$17,578	4
		Woods Chapel Rd	I-70	4.1	42,700	0.51	$17,920	4
I-635	Platte	I-29 to Rt 9	Rt 9	1.5	235,900	0.08	$81,514	3
		Rt 9	Rt 69	0.5	43,800	0.47	$17,395	3
		Rt 69	Van De Populier	1.0	37,600	0.30	$8,152	3
		Van De Populier	KS State line	0.8	44,500	0.95	$36,004	3
I-670	Jackson	KS State line	I-35	1.2	45,500	1.18	$46,979	2
US 71	Jackson	I-70	63rd St	5.9	28,040	5.39	$81,279	3
		63rd St	I-435	5.0	30,135	4.31	$75,055	3
		I-435	I-470	0.6	95,600	0.29	$50,296	1
		I-470	Blue Ridge Ext	2.1	82,793	3.11	$408,392	1
		Blue Ridge Ext	Main St	1.3	69,800	0.47	$44,137	3
		Main St	Rt 150	2.2	64,500	0.69	$54,945	3
US 169		I-435	I-29	8.9	27,200	2.41	$34,186	4

Estimated Costs - Freeway Management System

The cost estimate for the freeway monitoring system includes both capital and annual operating and maintenance costs. Capital costs reflect the need for freeway monitoring equipment, both CCTV and vehicle detection equipment; VMSs; HAR, both transmitters and advisory signs with flashing lights; power distribution and communications to system components; field data processing equipment; a traffic operations center (TOC); and centralized hardware and software. Additional information regarding costs is provided in Appendix B.

Tables 6-4 through 6-7 show the costs associated with each phase of deployment. Table 6-8 shows the cost for deployment of all phases. All costs indicated are in 1996 dollars. Capital costs were converted to equivalent annual costs, assuming a 15 year life and an interest rate of 6 percent. In general, the quantities shown in Tables 6-4 through 6-8 correspond to the quantities indicated in the deployment plan and shown in the figures in Chapter 7. The exception to this is for closed circuit television cameras, which for cost purposes are estimated for placement every half mile. Only selected (priority) locations for each phase are indicated in the deployment plan.

Also note that Tables 6-4 through 6-8 indicate that shared costs, including the TOC, central hardware, software and systems integration, and personnel costs, are divided between the states based on the proportion of freeway miles included from each state.

The costs shown in Tables 6-4 through 6-8 are based on full deployment of each phase. It is likely that rather than implementing the equipment for an entire phase at one time, key interchanges or freeway segments would be deployed, and additional equipment would incrementally be added to complete the system. Although the cost for equipping a given interchange varies depending on the geometrics, accident and operating characteristics, a range of costs can be estimated.

At the low end, 2 to 3 CCTV cameras could be installed. This would provide substantial benefit, and a minimal investment of approximately $60,000 to $90,000. If automated detection is desired, as many as 8 to 12 detector stations could be added, adding $80,000 to $120,000 to the price tag. Provisions for motorist information would require as many as 4 HAR signs, costing $12,000, and perhaps a HAR transmitter (depending on the location), which would cost $17,000. The greatest cost would be for VMSs. Two to 4 VMSs would incur a cost of $240,000 to $480,000. To summarize, the cost for installing cameras at an interchange, which would provide some monitoring capabilities, would be less than $100,000. The cost for installing full equipment at an interchange could range from just under $400,000 ($392,000) to more than $700,000 ($719,000).

Benefit Cost Ratios - Freeway Management System

Benefit cost ratios were calculated for each phase of the project, as shown in Table 6-9. The benefit cost ratio for Phase 1 is greatest, with annual benefits almost three times the annual costs. The benefit cost ratio decreases for each phase thereafter. Benefit cost ratios must be greater than one in order for the project to be currently justified. Based on this analysis,

Table 6-4. Phase 1 Costs

			Kansas	Missouri	Total
		Number of Miles	20	28	48
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	Cost per site	$30,000	$30,000	$30,000
		Number	40	56	96
		Total cost	$1,200,000	$1,680,000	$2,880,000
	Detection	Cost per site	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Number	40	56	96
		Total cost	$400,000	$560,000	$960,000
	Variable Message Signs	Cost per sign	$120,000	$120,000	$120,000
		Number	12	23	35
		Total cost	$1,440,000	$2,760,000	$4,200,000
	Highway Advisory Radio	Cost per transmitter	$17,000	$17,000	$17,000
		Number	3	3	6
		Cost per sign	$3,000	$3,000	$3,000
		Number	10	12	22
		Total cost	$81,000	$87,000	$168,000
	Power Distribution to System Components				
		Cost per mile	$30,000	$30,000	$30,000
		Total cost	$600,000	$840,000	$1,440,000
	Communications to ITS Elements				
		Cost per mile	$10,000	$10,000	$10,000
		Total cost	$200,000	$280,000	$480,000
	Conduit Installation	Cost per foot	$40	$40	$40
		Total cost	$4,224,000	$5,913,600	$10,137,600
	Field Data Processing Equipment				
		Cost per processor	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Total cost	$400,000	$560,000	$960,000
	Traffic Operations Center	Number of centers[1]	0.38	0.62	1
		Square foot per center	10,000	10,000	10,000
		Cost per square foot	$110	$110	$110
		Total cost	$418,000	$682,000	$1,100,000
	Central Hardware	Base cost[1]	$304,000	$496,000	$800,000
		Cost per mile	$3,333	$3,333	$3,333
		Total cost	$370,660	$589,324	$959,984
	Software and Systems Integration[1]		$380,000	$620,000	$1,000,000
	Subtotal for 15 Year Life		$9,713,660	$14,571,924	$24,285,584
	Construction and Contingency (20%)		$1,942,732	$2,914,385	$4,857,117
	Subtotal		$11,656,392	$17,486,309	$29,142,701
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$1,200,142	$1,800,390	$3,000,532
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel[2]		$147,000	$203,000	$350,000
	Maintenance Personnel[2]		$105,000	$145,000	$250,000
	Replacement Parts and Spare Equipment		$445,783	$663,496	$1,109,279
	Subtotal		$697,783	$1,011,496	$1,709,279
Total Cost per Year			$1,897,925	$2,811,887	$4,709,812

1 Allocation between states based on mileage for all phases.
2 Allocation between states based on Phase 1 mileage.

Table 6-5. Phase 2 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of Miles	14	20	34
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	Cost per site	$30,000	$30,000	$30,000
		Number	28	40	68
		Total cost	$840,000	$1,200,000	$2,040,000
	Detection	Cost per site	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Number	28	40	68
		Total cost	$280,000	$400,000	$680,000
	Variable Message Signs	Cost per sign	$120,000	$120,000	$120,000
		Number	4	6	10
		Total cost	$480,000	$720,000	$1,200,000
	Highway Advisory Radio	Cost per transmitter	$17,000	$17,000	$17,000
		Number	1	1	2
		Cost per sign	$3,000	$3,000	$3,000
		Number	4	3	7
		Total cost	$29,000	$26,000	$55,000
	Power Distribution to System Components				
		Cost per mile	$30,000	$30,000	$30,000
		Total cost	$420,000	$600,000	$1,020,000
	Communications to ITS Elements				
		Cost per mile	$10,000	$10,000	$10,000
		Total cost	$140,000	$200,000	$340,000
	Conduit Installation	Cost per foot	$30	$30	$30
		Total cost	$2,217,600	$3,168,000	$5,385,600
	Field Data Processing Equipment				
		Cost per processor	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Total cost	$280,000	$400,000	$680,000
	Traffic Operations Center	Number of centers[1]	0	0	0
		Total cost	$0	$0	$0
	Central Hardware	Base cost[1]			
		Cost per mile	$3,333	$3,333	$3,333
		Total cost	$46,662	$66,660	$113,322
	Software and Systems Integration[1]		$102,500	$147,500	$250,000
	Subtotal for 15 Year Life		$4,835,762	$6,928,160	$11,763,922
	Construction and Contingency (20%)		$967,152	$1,385,632	$2,352,784
	Subtotal		$5,802,914	$8,313,792	$14,116,706
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$597,468	$855,988	$1,453,456
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel[2]		$143,500	$206,500	$350,000
	Maintenance Personnel[2]		$61,500	$88,500	$150,000
	Replacement Parts and Spare Equipment		$236,663	$339,033	$575,696
	Subtotal		$441,663	$634,033	$1,075,696
Total Cost per Year			$1,039,131	$1,490,021	$2,529,152

Table 6-6. Phase 3 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of Miles	15	60	75
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	Cost per site	$30,000	$30,000	$30,000
		Number	30	120	150
		Total cost	$900,000	$3,600,000	$4,500,000
	Detection	Cost per site	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Number	30	120	150
		Total cost	$300,000	$1,200,000	$1,500,000
	Variable Message Signs	Cost per sign	$120,000	$120,000	$120,000
		Number	2	12	14
		Total cost	$240,000	$1,440,000	$1,680,000
	Highway Advisory Radio	Cost per transmitter	$17,000	$17,000	$17,000
		Number	0	2	2
		Cost per sign	$3,000	$3,000	$3,000
		Number	0	7	7
		Total cost	$0	$55,000	$55,000
	Power Distribution to System Components				
		Cost per mile	$30,000	$30,000	$30,000
		Total cost	$450,000	$1,800,000	$2,250,000
	Communications to ITS Elements				
		Cost per mile	$10,000	$10,000	$10,000
		Total cost	$150,000	$600,000	$750,000
	Conduit Installation	Cost per foot	$20	$20	$20
		Total cost	$1,584,000	$6,336,000	$7,920,000
	Field Data Processing Equipment				
		Cost per processor	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Total cost	$300,000	$1,200,000	$1,500,000
	Traffic Operations Center	Number of centers[1]	0	0	0
		Total cost	$0	$0	$0
	Central Hardware	Base cost[1]			
		Cost per mile	$3,333	$3,333	$3,333
		Total cost	$49,995	$199,980	$249,975
	Software and Systems Integration[1]		$25,000	$100,000	$125,000
	Subtotal for 15 Year Life		$3,998,995	$16,530,980	$20,529,975
	Construction and Contingency (20%)		$799,799	$3,306,196	$4,105,995
	Subtotal		$4,798,794	$19,837,176	$24,635,970
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$494,084	$2,042,436	$2,536,519
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel[2]		$105,000	$420,000	$525,000
	Maintenance Personnel[2]		$70,000	$280,000	$350,000
	Replacement Parts and Spare Equipment		$198,700	$821,549	$1,020,249
	Subtotal		$373,700	$1,521,549	$1,895,249
Total Cost per Year			$867,784	$3,563,985	$4,431,768

Table 6-7. Phase 4 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of Miles	49	52	101
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	Cost per site	$30,000	$30,000	$30,000
		Number	98	104	202
		Total cost	$2,940,000	$3,120,000	$6,060,000
	Detection	Cost per site	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Number	98	104	202
		Total cost	$980,000	$1,040,000	$2,020,000
	Variable Message Signs	Cost per sign	$120,000	$120,000	$120,000
		Number	9	11	20
		Total cost	$1,080,000	$1,320,000	$2,400,000
	Highway Advisory Radio	Cost per transmitter	$17,000	$17,000	$17,000
		Number	2	4	6
		Cost per sign	$3,000	$3,000	$3,000
		Number	6	12	18
		Total cost	$52,000	$104,000	$156,000
	Power Distribution to System Components				
		Cost per mile	$30,000	$30,000	$30,000
		Total cost	$1,470,000	$1,560,000	$3,030,000
	Communications to ITS Elements				
		Cost per mile	$10,000	$10,000	$10,000
		Total cost	$490,000	$520,000	$1,010,000
	Conduit Installation	Cost per foot	$20	$20	$20
		Total cost	$5,174,400	$5,491,200	$10,665,600
	Field Data Processing Equipment				
		Cost per processor	$10,000	$10,000	$10,000
		Frequency per mile	2.0	2.0	2.0
		Total cost	$980,000	$1,040,000	$2,020,000
	Traffic Operations Center	Number of centers[1]	0	0	0
		Total cost	$0	$0	$0
	Central Hardware	Base cost[1]			
		Cost per mile	$3,333	$3,333	$3,333
		Total cost	$163,317	$173,316	$336,633
	Software and Systems Integration[1]		$61,250	$63,750	$125,000
	Subtotal for 15 Year Life		$13,390,967	$14,432,266	$27,823,233
	Construction and Contingency (20%)		$2,678,193	$2,886,453	$5,564,647
	Subtotal		$16,069,160	$17,318,719	$33,387,880
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$1,654,481	$1,783,135	$3,437,616
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel[2]		$257,250	$267,750	$525,000
	Maintenance Personnel[2]		$171,500	$178,500	$350,000
	Replacement Parts and Spare Equipment		$666,486	$718,426	$1,384,912
	Subtotal		$1,095,236	$1,164,676	$2,259,912
Total Cost per Year			$2,749,717	$2,947,811	$5,697,528

Table 6-8. Cost for All Phases

			Kansas	Missouri	Total
		Number of miles	98	160	258
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	196	320	516
		total cost	$5,880,000	$9,600,000	$15,480,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	196	320	516
		total cost	$1,960,000	$3,200,000	$5,160,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	27	52	79
		total cost	$3,240,000	$6,240,000	$9,480,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	6	10	16
		cost per sign	$3,000	$3,000	$3,000
		number	20	34	54
		total cost	$162,000	$272,000	$434,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$2,940,000	$4,800,000	$7,740,000
	Communications to ITS Elements				
		cost per element	$10,000	$10,000	$10,000
		total cost	$980,000	$1,600,000	$2,580,000
	Conduit Installation	cost per foot	$25	$25	$25
		total cost	$13,018,133	$21,254,095	$34,272,229
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$1,960,000	$3,200,000	$5,160,000
	Traffic Operations Center	number of centers	0.38	0.62	1
		square feet per center	10,000	10,000	10,000
		cost per square foot	$110	$110	$110
		total cost	$418,000	$682,000	$1,100,000
	Central Hardware	base cost	$304,000	$496,000	$800,000
		cost per mile	$3,333	$3,333	$3,333
		total cost	$630,634	$1,029,280	$1,659,914
	Software and Systems Integration		$568,750	$931,250	$1,500,000
	Subtotal for 15 Year Life		$31,757,517	$52,808,625	$84,566,143
	Construction and Contingency (20%)		$6,351,503	$10,561,725	$16,913,229
	Subtotal		$38,109,021	$63,370,350	$101,479,371
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$3,923,705	$6,524,611	$10,448,316
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel		$665,000	$1,085,000	$1,750,000
	Maintenance Personnel		$418,000	$682,000	$1,100,000
	Replacement Parts and Spare Equipment		$1,538,538	$2,559,769	$4,098,307
	Subtotal		$2,621,538	$4,326,769	$6,948,307
Total Cost per Year			$6,545,243	$10,851,380	$17,396,623

Table 6-9. Benefit Cost Ratio for Each Phase

Phase		1	2	3	4	All
Annual Benefits (in Millions)'		$13.5	$4.7	$5.6	$1.3	$25.2
Kansas		$4.7	$1.3	$1.3	$0.7	$7.9
Missouri		$8.9	$3.5	$4.4	$0.6	$17.3
Annualized Cost (in Millions)		$4.7	$2.5	$4.4	$5.7	$17.4
Kansas	Capital	$1.2	$0.6	$0.5	$1.7	$3.9
	Operating and Maintenance	$0.7	$0.4	$0.4	$1.1	$2.6
	Total	$1.9	$1.0	$0.9	$2.7	$6.5
Missouri	Capital	$1.8	$0.9	$2.0	$1.8	$6.5
	Operating and Maintenance	$1.0	$0.6	$1.5	$1.2	$4.3
	Total	$2.8	$1.5	$3.5	$2.9	$10.9
Cumulative Capital Investment (in Millions)		$29	$43	$68	$101	$101
Benefit Cost Ratio		2.9	1.9	1.3	0.2	1.4

Total values may not be the sum of the values shown for Kansas and Missouri due to rounding.

Phases 1 and 2 are currently justified, Phase 3 is marginally justified, and Phase 4 is not justified for deployment based on existing conditions.

PROVISION OF FIBER OPTICS CABLE IN KANSAS

The costs shown in Tables 6-4 through 6-9 do not include the cost for the installation of fiber optics cable, which is recommended to serve as the communications backbone for the metropolitan Kansas City ITS system. The cost of fiber is omitted based on the assumption that it will be provided through a public/private partnership at no cost to the Kansas Department of Transportation (KDOT). A similar agreement was reached in Missouri, where fiber is being installed on all interstates and on selected freeways. This agreement, which allows a private firm to use the Missouri Highway and Transportation Department's (MHTD) right-of-way, provides MHTD with a fiber optics backbone at no cost. It is recommended that KDOT pursue a similar agreement, and the costs shown in Tables 6-4 through 6-9 reflect an assumption that such an agreement can be obtained.

The value of such an agreement is substantial, as demonstrated by the costs shown in Table 6-10. The top half of Table 6-10 documents the costs associated with the installation of fiber, including conduit, fiber, and associated equipment (manholes, splice enclosure, pull boxes and fiber hub equipment). If an agreement similar to MHTD's is reached, benefits would be realized due to the value of annual maintenance, as well as due to the capital cost.

The second portion of Table 6-10 shows the total cost for an ITS freeway management system, including the cost of a fiber optics backbone, and all field, communications and data processing equipment. As can be seen in the table, the capital cost of the fiber optics backbone is almost half of capital cost for the entire freeway management system.

The last two rows of Table 6-10 show the benefit cost ratio first, if KDOT must bear the cost of the installation of fiber, and finally, if the fiber is provided by a private entity. Table 6-10 demonstrates the fact that substantial savings can be realized if KDOT can work out an agreement with a private entity for the provision of fiber optic cable.

Table 6-10. Estimated Value of Fiber Optic Cable on KDOT Freeways In Kansas City Metropolitan Area

	Phase 1	Phase 2	Phase 3	Phase 4	All Phases
Number of Miles	20	14	15	49	98
Cost of Fiber Optics Cable					
Conduit[1]					
Cost per foot	$40	$30	$20	$20	
Total cost	$4,224,000	$2,217,600	$1,584,000	$5,174,400	$13,200,000
Fiber optic cable					
Cost per mile (12 fiber cable)	$7,920	$7,920	$7,920	$7,920	
Total Cost	$158,400	$110,880	$118,800	$388,080	$776,160
Manholes					
$3,000 each, 1 per 4 miles					
Cost per mile	$750	$750	$750	$750	
Total cost	$15,000	$10,500	$36,750	$36,750	$73,500
Splice enclosure					
$850 each, 1 per 4 miles					
Cost per mile	$213	$213	$213	$213	
Total cost	$4,250	$2,975	$10,413	$10,413	$20,825
Pull Boxes					
$1,000 each, 1 per 500 feet					
Cost per mile	$10,560	$10,560	$10,560	$10,560	
Total Cost	$211,200	$147,840	$517,440	$517,440	$1,034,880
Fiber hub equipment[2]					
$25,000 every 5 miles					
Cost per mile	$5,000	$5,000	$5,000	$5,000	
Total Cost	$100,000	$70,000	$75,000	$245,000	$490,000
Total Cost of Fiber and Equipment	$4,712,850	$2,559,795	$1,950,638	$6,372,083	$15,595,365
Expected Annual Maintenance Cost	$235,643	$127,990	$97,532	$318,604	$779,768
Total Cost for ITS Freeway Management System					
Total Cost of Fiber and Equipment	$4,712,850	$2,559,795	$1,950,638	$6,372,083	$15,595,365
Fiber Annual Maintenance Cost	$235,643	$127,990	$97,532	$318,604	$779,768
Other Capital Costs[3]	$5,489,660	$2,618,162	$2,414,995	$8,216,567	$18,557,517
Other Annual Maintenance Costs[3]	$486,583	$330,783	$294,500	$836,516	$1,961,538
Total Capital Cost	$10,202,510	$5,177,957	$4,365,633	$14,588,650	$34,152,882
Capital Recovery Factor	.10296	.10296	.10296	.10296	.10296
Annualized Capital Cost	$1,050,450	$533,122	$449,486	$1,502,047	$3,516,381
Total Maintenance Cost	$722,226	$458,773	$392,032	$1,155,120	$2,741,306
Total Annualized Cost for Kansas	$1,772,676	$991,895	$841,517	$2,657,167	$6,257,687
Total Annual Benefits (in Millions)	$4.7	$1.3	$1.3	$.7	$7.9
Benefit Cost Ratio for Freeway Management System					
B/C if KDOT Funds Fiber Installation	2.65	1.31	1.54	0.26	1.26
B/C if Fiber Provided by Private Entity[4]	4.47	2.17	2.39	0.42	2.04

1 Cost for conduit also included in ITS infrastructure estimates shown in Tables 6-4 through 6-9.
2 Includes SONET hub, air conditioned cabinet, transformer, and back up power.
3 "Other" costs include the costs estimated in Tables 6-4 through 6-8 (except the cost for conduit installation which is subtracted because it is included in this table) Capital cost does not include construction and contingency.

Future Prioritization for Freeway Management System

The deployment phases shown in Figure 6-3 reflect current priorities, which are based on current operating characteristics. In the future, these priorities may change due to changes in operating characteristics. The purpose of this section is to review the methodology that could be used to prioritize freeway segments in the future.

Since the benefits of a freeway management system are calculated as a function of the freeway volume and the accident rate, a change in either of these factors would affect the expected benefits and the resulting priorities. Changes in operating characteristics would be expected to result from a variety of factors, as demonstrated by the following examples.

- Construction and reconstruction activities may result in increased volumes due to latent demand that can be served by an increase in capacity.

- Additional capacity that results from construction and reconstruction activities may reduce demand on parallel facilities. For example, congestion may be relieved on the southeast leg of I-435 due to the completion of Bruce Watkins Drive.

- Geometric improvements may reduce accidents at the affected locations or on the affected segments.

- Increased development or changing demographics may affect travel volumes on facilities that serve the affected areas.

Prioritization of facilities for deployment was based on two factors. The first factor was the benefit cost ratio that would be expected to result from deployment of a freeway management system. If the system were designed based only on benefit cost ratios, a seamless, integrated system may be slow to evolve. Thus, the second factor considered was system continuity. Although system continuity is an important factor that should be considered, it cannot be easily quantified. For this reason, this section will primarily address the calculation of the benefit cost ratio.

CALCULATION OF BENEFITS

The benefits of a freeway management system are calculated based on the time savings that accrue to drivers as a result of the elimination or reduction of incident related delay. For this analysis, time savings are initially calculated separately for the peak and off-peak directions.

Equation 6-l can be used to calculate the time saved in the peak direction in the peak hour for each minute of incident related delay eliminated.

(Eqn 6-7) $$T_P = V_P * [I_P * (1 \text{ minute}) + I_O * (0.25 \text{ minutes})]$$

where: T_P = Time saved in peak hour in peak direction for each minute of incident related delay eliminated (in minutes)
V_P = Peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction

I_O = Number of incidents in peak hour in off-peak direction

Similarly, the time saved in the off-peak direction in the peak hour for each minute of incident related delay eliminated can be estimated as follows.

(Eqn 6-2) $$T_0 = V_O * [I_O * (1 \text{ minute}) + I_P * (0.25 \text{ minutes})]$$

where: T_0 = Time saved in peak hour in off-peak direction for each minute of incident related delay eliminated (in minutes)
V_O = Off-peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction
I_O = Number of incidents in peak hour in off-peak direction

Equations 6-l and 6-2 reflect the assumption that an accident in one direction affects flow in the other direction due to rubbernecking. It is assumed that for every minute of delay in the direction of the accident, 0.25 minutes of delay result in the opposite direction. This value can be verified or revised, using data collected through the freeway management system. In both cases, the number of incidents in the peak hour (I_P and I_O) can be estimated based on the accident rate and peak hour volume for the segment as follows.

(Eqn 6-3) $$I_P = k * V_P * (\text{accident rate})$$

(Eqn 6-4) $$I_O = k * V_O * (\text{accident rate})$$

where: I_P = Number of incidents in peak hour in peak direction
V_P = Peak direction peak hour volume
I_O = Number of incidents in peak hour in off-peak direction
V_O = Off-peak direction peak hour volume
k = Constant, representing the incident to accident ratio

Equations 6-3 and 6-4 utilize a constant to represent the incident to accident ratio. This multiplier is used to account for the fact that not every incident that disrupts traffic and results in delay is represented in an accident log. A value of 5 was used to represent the incident to accident ratio in the analysis of current conditions. This means that for every accident recorded in the state accident statistics, there are 5 incidents (such as flat tires, stalled cars) that are not recorded. This value can be verified or modified based on data collected using the freeway management system.

The total time saved in the peak hour is then calculated using Equation 6-5. The total time saved is the sum of the time saved in each direction per minute of delay eliminated, times the average reduction in incident duration.

(Eqn 6-5) $$T_{TOT} = d * (T_P + T_O)$$

where: T_{TOT} = Time saved in both directions in peak hour (in minutes)
T_P = Time saved in peak hour in peak direction for each minute of incident related delay eliminated (in minutes)
T_O = Time saved in peak hour in off-peak direction for each minute of incident related delay eliminated (in minutes)

d = Constant, representing the average reduction in incident delay

Equation 6-5 utilizes a constant to represent the average reduction in incident duration. A value of 8 minutes was used in the analysis of current conditions. This value can be verified or modified based on data collected using the freeway management system.

The value of time (T_O and T_P) is then converted to an annual dollar value using the following equation:

(Eqn 6-6)

$$\text{Annual benefit} = T_{TOT} * \frac{1\text{ hour}}{60\text{ min}} * [(.95)\frac{\$10}{\text{hour}} + (.05)\frac{\$25}{\text{hour}}] * \frac{2\text{ peak hours}}{\text{day}} * \frac{250\text{ days}}{\text{year}}$$

This calculation is based on a num ber of assumptions, as follows.

- Passenger vehicles comprise 95 percent of the traffic and are valued at $10 per hour
- Commercial vehicles comprise 5 percent of the traffic and are valued at $25 per hour
- Daily benefits are based on 2 peak hours per day (a.m. and p.m.)
- Annual benefits are based on 250 days per year (5 days per week, 50 weeks per year)

These assumptions can be verified or modified based on data collected using the freeway management system. The resulting annual benefit is used as the numerator in the benefit cost ratio. It is recommended that all benefits be stated on a per mile basis, to facilitate comparisons between segments.

Note that the benefits calculated above reflect only the benefits that would be expected to accrue as a result of a reduction in incident related congestion. A decrease in recurring congestion may be expected due to the deployment of ramp metering or other demand management strategies. While cities such as Minneapolis and Seattle have documented increases in freeway capacity and average speed as a result of ramp metering, it is recommended that data collected in conjunction with the ramp demonstration project on I-35 be used as a basis for estimating benefits in the Kansas City metropolitan area.

CALCULATION OF COSTS

Annual costs are calculated as the annualized capital cost plus operating and maintenance costs, as shown in Tables 6-4 through 6-8. Although technologies may change, the basic functions of the freeway management system are expected to remain the same and include monitoring, data processing and motorist information. In support of these activities, operating and maintenance costs will be incurred and must be considered. In the future, technologies to facilitate traffic control, such as ramp meters, may be included in the freeway management system, although these technologies were not evaluated as part of the costs shown in Tables 6-4 through 6-9.

As technologies advance, different kinds of technologies may be incorporated into the system, replacing existing technologies or enhancing system capabilities. The costs associated with the various technologies will need to be updated, due to the rapid changes in technology cost and capability. Although costs cannot be accurately forecasted, the following discussion identifies the kind of issues that may be relevant.

Monitoring - Roadway monitoring equipment used for incident detection and verification currently includes CCTV and detection equipment such as induction loops or radar. Although current technologies are recommended for placement every half mile, this distance may increase as technologies become more advanced.

Data Processing - Data processing requirements due to system expansion will be defined to some extent by the initial system and its capabilities. The current recommendation for field equipment is a Type 170 controller (or comparable equipment) to be placed every half mile. As the components become more sophisticated, additional processing may be needed.

Provision will also need to be made for expansion of central hardware (video monitors and switching equipment, workstation, console, etc.) and software. The costs associated with expansion will vary depending on the configuration and excess capacity built into the central hardware and the adaptability of the software.

Motorist Information - Motorist information may be provided through a variety of means. Current technologies include VMSs, HAR, highway advisory telephone, teletext, personal pager, information kiosk, commercial radio, commercial television and the Internet. The provision of motorist information is often identified as an activity appropriate for cooperative efforts with private entities. Coordination with private entities and the potential for revenue and/or cost sharing should be considered when evaluating costs and mechanisms for providing motorist information.

Operating and Maintenance Costs - Operating and maintenance costs include operators at the TOC, maintenance personnel, and supervision of both activities. These expenses can best be estimated by evaluating the costs associated with operating and maintaining the portions of the freeway management system already deployed. In terms of the cost for replacement parts and spare equipment, five percent of the initial hardware cost is often used as an estimate. This value may be modified based on the experience gained through deployment of the first phase.

Amortization - Capital costs for equipment should be converted to an annualized cost based on the expected life of the equipment and the current interest rate. It is necessary to convert the costs to an annual basis to allow comparison with the benefits which are calculated on an annual basis. The capital recovery factor used in the analysis of current conditions was 0.10296, which represents a capital recovery factor for 15 years at 6 percent interest. The capital recovery factor for other amortization periods and interest rates can be found in an accounting or engineering economics reference book. The total annual cost, to be used as the denominator in the benefit cost ratio, is the annualized capital cost, plus all annual operating and maintenance costs.

BENEFIT COST RATIO

The benefit cost ratio is calculated as the annual benefit divided by the total annualized cost. The benefit cost ratio, which must be calculated for all candidate segments, can then be used in conjunction with a qualitative assessment for the determination of priorities for the system. Qualitative objectives might include system continuity (discussed previously) and coordination with other ITS applications, such as transit and commercial vehicle operations.

Estimated Benefits and Costs - ITS Transit Applications

This section discusses the benefits and costs associated with ITS applications related to transit. The specific technologies were discussed in greater detail in Chapter 5.

BENEFITS

The benefits attributable to ITS transit projects are difficult to estimate, in many cases because the benefits are intangible. For example, video monitoring of bus stops may have a positive effect of the *perception* of security among transit users, but quantifying the benefit is very difficult. Similarly, improvements in the availability of transit service information is obviously beneficial, but estimating the effect on ridership and revenues is very difficult,

Instead of attempting to quantify the benefits of these projects, it is suggested that the value of the applications be assessed by the extent they address specific objectives. These objectives are based on inputs from transit agency representatives. The objectives are as follows.

1. Reduce operating costs. With anticipated reductions in federal operating assistance, and continued competition for local funding, this objective is a clear priority.

2. Employ proven technology to improve methods, increase productivity and enhance service delivery.

3. Improve the timeliness and reliability of transit service.

4. Improve the integration of services provided by different operators. Coordination among the three primary fixed operators has been identified as an important objective. Coordination among the multitude of paratransit operators is perhaps the highest priority with respect to paratransit.

5. Improve the fact and perception of security for transit customers.

6. Improve the availability of transit system information to current and potential transit users.

7. Meet the requirements of the Americans with Disabilities Act (ADA) with respect to complementary paratransit services for disabled persons.

Table 6-11 is an assessment of ITS applications and whether each addresses the stated objectives. All of the applications suggested for consideration employ proven technology that has been applied successfully in other areas. In addition, the projects shown as addressing objective #1 have the potential to reduce operating costs and/or increase productivity. The projects addressing objective #4 have value in helping to achieve a “seamless” regional transit system.

Table 6-11. Benefit Assessment of Transit Applications

Project	Objectives						
	#1	#2	#3	#4	#5	#6	#7
Telephone Information Center Automation	yes	yes		yes		yes	
On Bus Video Monitoring		yes			yes		
On Bus Audio Monitoring		yes			yes		
Bus Stop Video Monitoring		yes			yes		
Park & Ride Lot Video Monitoring		yes			yes		
AVL Expansion	yes	yes	yes	yes	yes		
Consolidated Paratransit Scheduling	yes	yes	yes	yes		yes	yes
Personalized Public Transit	yes	yes	yes			yes	

COSTS

The costs associated with deploying ITS transit projects depend upon the scope of the project and the specific technology employed. For example, the cost of video monitoring all buses or a large number of bus stops would be prohibitive. However, the strategic deployment of video monitoring hardware at select locations can be achieved at a reasonable cost. New technology tends to be more expensive than applications that have been on the market a longer time and have become production standards. Technology involving software applications have a high initial cost, often due to the need to customize the application, but can be expected to perform and produce for a long period of time.

Table 6-12 shows estimated initial costs for ITS technology applications suggested for consideration in the Kansas City metropolitan area. As previously stated, some of these applications are currently being pursued by the KCATA. Because of the integration among projects and components, the cost estimates are valid only in the context of related systems. For example, the telephone information system automation requires an automated scheduling system. The estimate includes the entire cost of both systems. Conversely, the cost estimates for consolidated paratransit scheduling and personalized public transit assumes that the paratransit scheduling and dispatching system recently acquired by the KCATA is in place. The estimates reflect the cost of expanding the use of this system.

Table 6-I 2. Estimated Costs for Transit Applications

Project	Priority	Unit Cost	Units	Total Cost
Telephone Information Center Automation	High	$500,000	1	$500,000
On Bus Video Monitoring	High	$3,500	30	$105,000
On Bus Audio Monitoring	High	$400	250	$100,000
Bus Stop Video Monitoring	High	$5,000	10	$50,000
Park & Ride Lot Video Monitoring	High	$5,000	5	$25,000
AVL Expansion	High	$350,000	1	$350,000
Consolidated Paratransit Scheduling	High	$25,000	2	$50,000
Personalized Public Transit	High	$10,000	1	$10,000

Chapter 7
Deployment

Freeway Management Applications

This section focuses on the deployment of components of a freeway management system. This deployment plan is based on the system architecture developed and described in Chapter 4, the technologies discussed in Chapter 5, and the benefits and costs evaluated in Chapter 6.

SHORT, MEDIUM, AND LONG TERM PRIORITIES

The short, medium, and long term priorities for the transportation system in the Kansas City area correspond closely to the short, medium, and long term intelligent transportation system (ITS) user services discussed in Chapter 3. These priorities are reflected in the deployment schedule, which is discussed in the next section. Short term priorities include priorities that should be addressed in the next five years. Medium term priorities should be addressed in five to ten years. Long term priorities should be addressed in ten years or more.

Short Term Priorities - Priorities for the short term focus on existing problems and identified needs. Thus, priorities include the need to respond to incidents, which account for a significant amount of congestion in the Kansas City area, and the need to identify and respond to locations of recurring congestion.

Short term priorities are met by a number of activities including deployment of a freeway monitoring and management system in selected corridors in the Kansas City area and coordination of the freeway management system with the use of arterials for diversion. A ramp metering project is recommended for implementation as a demonstration project on I-35 in Kansas from I-435 to the state line. This will require close cooperation between the Kansas Department of Transportation (KDOT) and local jurisdictions.

It is also recommended that local jurisdictions, in cooperation with KDOT and the Missouri Highway and Transportation Department (MHTD), initiate activities that would support the use of local arterials as alternate routes to the freeway. Activities include determination of appropriate timing plans for arterials that already have signal control systems that can support diversion activities, identification of priority arterials for equipment upgrade, and the initiation of activities to obtain funding for equipment upgrades, where necessary.

A final short term priority is enhanced institutional coordination, which will be necessary for a coordinated and comprehensive approach to transportation management, and will also be a critical component for the success of future activities. More detailed information about activities and projects to support short term priorities are discussed in the next section, Deployment Schedule.

Medium Term Priorities - Priorities for the medium term focus on expanding the framework that has been laid out in the short term and addressing conditions that might be expected in the foreseeable future. Medium term priorities include expanding the geographic extent of the freeway management system, expanding the freeway traffic management system to include ramp metering where appropriate (analysis will be based on findings of the demonstration project on I-35 in Kansas), broadening the scope of incident management activities to better address the special requirements posed by hazardous materials incidents, and expanding the kind of information provided to travelers, in an effort not only to inform, but also in an effort to have a greater influence on travel behavior.

Another medium term priority is to further integrate the freeway system with the arterial and transit systems in the metropolitan area. This priority implies additional coordination with local jurisdictions for the installation of advanced signal control systems on arterial routes that will be used for diversion from the freeway. This also implies the provision of transit information in addition to freeway information for trip planning purposes.

Long Term Priorities - Long term priorities generally address issues that are not currently critical problems, and may include taking a proactive approach to potential problems. Long term priorities include expanding the freeway management system to encompass the entire metropolitan area, deployment of technologies related to emissions testing, coordinating with activities related to commercial vehicle applications, and the deployment of programs, technologies and facilities which would provide alternatives to the single occupancy vehicle. High occupancy vehicle (HOV) facilities and advanced ride matching programs are just a couple of ways to encourage alternatives to the single occupancy vehicle.

DEPLOYMENT SCHEDULE

The primary focus of the deployment plan is a freeway management system. System components have been identified for a freeway management system that provides coverage of the entire metropolitan area. Conceptual layouts for the placement of closed circuit television (CCTV) cameras, highway advisory radio (HAR) transmitters and signs, and variable message signs (VMSs) are shown in Figures 7-1, 7-2 and 7-3. Deployment of the components is recommended to be staged over four phases, which are shown in Figure 6-3. The locations identified in Figures 7-1, 7-2 and 7-3 are color coded to reflect the recommended staged deployment. Following a brief discussion of the basics of a freeway management system, each phase is addressed as it relates to deployment in the short, medium, and long term.

Freeway Management **System** - The proposed freeway management system and its components address short term priorities by meeting the need for incident detection, verification, and response.

Incident detection is provided by detector stations located every half mile. Computer algorithms automatically process the data from these detectors, displaying real-time travel speeds and providing notification of unusual traffic characteristics that might indicate an accident or incident. Incident detection may also be provided by other means, such as motorist assistance patrols (MAP) and cellular phone calls; the limitation of these mechanisms is that they do not provide continuous monitoring of conditions, and thus they cannot always be relied upon.

Incident verification is provided by CCTV. This visual verification provides not only information about the nature of the accident and the kind of equipment needed, but it also allows positive identification of incident location. Visual image detection (VID), which consists of CCTV and computer algorithms that analyze the visual image to determine operating characteristics, also provides incident detection capabilities and may be a viable alternative in the near future. While some systems use VID in conjunction with other means of detection, no system relies solely upon VID.

Incident response includes any action taken as a consequence of the situation on the freeway. It might include contacting emergency responders through 911 or the dispatch of MAP, as well as all resulting communications with motorists, such as messages on HAR and VMSs, and information provided to traffic reporting agencies.

Short Term - Activities identified for deployment in the short term include all activities and projects to be implemented within five years. In addition to short term activities, priority "early winner" activities have been identified for deployment within two years.

The primary activity in the short term is the deployment of a freeway management system on Phase 1 facilities. Phase 1 encompasses the high priority corridors, including the downtown loop, I-70 east of downtown, I-35 just north of downtown, I-35 south of downtown, and the south leg of I-435. These facilities all carry high traffic volumes, and consequently, any breakdown in traffic flow, for instance due to an incident, can have significant impacts in terms of delay. Additional and more specific activities to be implemented in the short term are as follows.

- Permanent CCTV cameras, HAR, and VMSs should be installed as noted for Phase 1 in Figures 7-1, 7-2, and 7-3. Priority locations for CCTV cameras are shown in Figure 7-1, cost estimates include additional cameras (one every half mile) for complete coverage of the freeways. Detector stations should be located every half mile.

  While the technologies identified for deployment are primarily on the freeways, they include arterial VMSs on Metcalf and downtown to inform motorists in the two major employment centers of congestion before entering the freeway. A VMS is also specified for deployment on US 40, which serves as an alternate route for I-70. This VMS should be used to provide additional information for diversion, which may be particularly useful for motorists unaccustomed to leaving the freeway. Additional information on the installation of CCTV cameras, HAR and VMSs is provided in the next section, *Guide to Deployment.*

- A demonstration ramp metering project should be implemented on I-35 in Kansas from I-435 to the state line. Ramp metering will need to be closely coordinated with the local jurisdictions in the corridor to assure that arterial operations are not unduly affected. Additional information on ramp metering is provided in the next section, Guide to *Deployment.*

- Reference markers and overpass signing should be installed on all facilities in the metropolitan area, with priority corresponding to deployment phase. Reference markers should include route and directional information and should be placed every one-tenth of a mile on facilities with a high accident rate or high volume, and every half-mile on less traveled freeways. Location identifiers should be placed on all ramps.

Cellular telephone users can be educated about the system through informational inserts in cellular telephone bills and public service announcements. Dispatchers at 911 answer points will also need to be instructed as to how to interpret the information and solicit the information needed from callers.

- A permanent traffic operations center (TOC) should be established for the metropolitan area. This center may be located in the new MHTD District 4 office. Additional information on the TOC is provided in a later section, *Operations Plan.*

- Weather information should be available at the TOC. This information can be accessed via a modem from the existing weather center in Kansas City, Missouri.

- Traffic conditions should be provided to traffic reporting agencies and to television and radio stations. The provision of traveler information directly to motorists via telephone and/or the Internet should also be explored. It might be possible to partner with a private entity for the provision of a highway advisory telephone service, which could be similar to the existing “time and temperature” phone number.

- A radio link should be provided for communication between the TOC and emergency responders after incident response has been initiated. Initial contact between the TOC and emergency responders should be made through the existing 911 system. The TOC should be connected to the 911 tandem computer, so calls can automatically be placed to the appropriate agency. TOC personnel would need to identify the location (possibly via a touchscreen map of the metropolitan area), and the kind of emergency response needed (fire, police, or medical), and the call would automatically be directed to the appropriate agency.

- The TOC should work with interested local public works agencies and emergency responders to establish video feed from the CCTV cameras controlled by the TOC to the local agencies and dispatch centers.

- Activities conducted by the TOC that are related to incident management should be in accordance with the guidelines established in the *Incident Management Program* for the Bi-State Kansas City area.

Early Winners: Short term efforts include “early winners”, priority activities which are recommended for deployment within the next two years. These projects represent activities that are relatively low cost with a short development time, relatively high priority, and address the core infrastructure elements. These “early winner” projects are expected to be successful, and will enhance the public image of ITS, setting the stage for future projects.

- Freeway reference markers and signs on overpasses, marking the cross street, are recommended for deployment on all Phase 1 and Phase 2 freeway facilities. Reference markers are currently provided on some facilities, but are recommended for installation at one-tenth mile intervals on all Phase 1 and Phase 2 freeway facilities, and on all entrance and exit ramps to these facilities.

- Additional portable VMSs are recommended for procurement by both MHTD and KDOT. These signs can be used to provide en-route driver information and to facilitate incident management during severe incidents of significant duration. These signs can also be used to enhance traffic management during construction and other pre-planned events. These signs can also be placed at locations where permanent VMSs are proposed. This will allow an inexpensive "trial run" prior to installation of a permanent sign, which requires significant capital investment.

- Legislation and regulations to facilitate the prompt removal of disabled and abandoned vehicles and freight from the freeway main lanes and shoulders are recommended in both Missouri and Kansas. The clearance times specified should vary depending on incident location (urban vs. rural), time of day (peak vs. off-peak), and day of week (weekend vs. weekday). While Kansas currently has legislation that allows KDOT and enforcement agencies to remove a vehicle left on a public highway after 48 hours or when the vehicle interferes with highway operations, this legislation could be enhanced by regulations that iterate specific and more stringent clearance times for facilities in urban areas. Removal times for commercial vehicles and freight should also be iterated, allowing the agency having jurisdiction to initiate clean up activities at the expense of the trucking firm or the entity responsible for the incident. Prompt removal of disabled vehicles and freight in the right-of-way would facilitate incident management and reduce vehicle delay.

- Expansion of the motorist assistance patrol (MAP) to provide full coverage of Phase 1 segments of I-35 and I-435 during the peak hours is recommended in Kansas. The recently implemented program in Kansas has been successful, but it could have a more significant impact on incident management in the peak periods if additional equipment and personnel were provided. Expansion of MAP is also recommended in Missouri, for example, service could be restored on the south leg of I-435. The continued coordination of MAP activities with other activities in terms of incident response and traffic control, and the sharing of information with traffic reporting agencies and any other entities that can enhance communications with the public is strongly recommended.

- Coordination of arterial signals into arterial signal systems is recommended on major arterials that may serve as alternate routes for freeway diversion and that currently have the hardware to support a diversion timing scheme. For example, coordination of the signals on 103rd and College Boulevard in Overland Park, Kansas, could be accomplished at a relatively low cost, because all of the intersections currently use type 170 microprocessor controllers. Coordination of arterial signals would enhance incident management activities by facilitating route diversion.

  Furthermore, traffic signal timing plans appropriate for freeway diversion should be developed for these alternate routes that have signal control hardware to support deployment. In Missouri, these systems would generally be developed and implemented by MHTD. In Kansas, these timing plans would need to be determined jointly with Overland Park and Lenexa. Although Kansas City, Kansas, has solid state equipment on State Avenue, which would function as an alternate route to I-70, they have expressed reservations about having anyone manually adjust the signal timing (via a PC), and they prefer to use adaptive signal control for changes in timing. Adaptive signal control would require additional hardware.

  Increased coordination among neighboring jurisdictions is also recommended, not only for signal timing, but also for construction activities. Currently, arterials that traverse multiple jurisdictions may not have their signals coordinated, this results in increased delay and driver frustration. Similarly, neighboring jurisdictions do not always coordinate construction activities, thus alternate routes are sometimes under construction at the same time that the major route is, limiting the number of routes available.

- Standards for construction and reconstruction projects should be developed to reflect the needs of an intelligent transportation system. These standards would accommodate future needs that could easily be accommodated during roadway and/or shoulder construction and reconstruction activities. Standards should include design considerations for interchanges to accommodate ramp metering, provisions for conduit for power distribution and communications to ITS elements, and provisions for pull boxes. With respect to conduit for fiber optics, appropriate applications would include freeways and arterial diversion routes that do not have fiber optics, as well as connections from field equipment to the fiber optic backbone.

  Similarly, construction and reconstruction activities should consider the needs of emergency responders during incident management activities. For example, it is recommended that provisions for fire hoses be included in all noise walls that are being constructed or renovated in the metropolitan area. These holes should be located so that they correspond with fire hydrant locations, and should be marked clearly. These holes would allow fire fighters to more easily access the fire hydrants, facilitating response to freeway incidents involving a potential fire hazard. Efforts to provide for fire hoses in noise walls are already underway. KDOT recently coordinated with the Overland Park Fire Department to provide holes for fire hoses in the noise walls erected in conjunction with the reconstruction on the southern portion of I-435 in Johnson County.

- KDOT should pursue activities for the procurement of a fiber optics communications backbone on all interstates and major freeways in the Kansas City area. The possibility for a public/private partnership, such as the one that resulted in the deployment of fiber on all interstates in Missouri, and the possibility of coordinating with local businesses should be examined as a mechanism for reducing costs.

- A policy regarding the provision of traveler information should be developed. This policy would initially address issues such as whether alternate routes should be provided to motorists, and should evolve to address related issues in the future, as needed. This policy should also address price issues, for example whether all information should be provided without charge, or whether some users should pay a price for specialized information (for example, in the future, it might be appropriate to charge private entities who request the information in a certain format and then, in turn, provide the information to customers for a fee).

- CCTV cameras should be established in priority locations (indicated in Figure 7-l). In Missouri, these cameras would be monitored from the existing MHTD District Office. In Kansas, KDOT should work in coordination with the Cities of Lenexa and Overland Park for the placement of a CCTV camera at the interchange of I-35, US 169 and 87th Street or at another high priority interchange. Both Lenexa and Overland Park are considering installation of a CCTV camera for interchange/intersection monitoring. Cameras could be monitored by both the KDOT Kansas City Metro Office and the affected city.

- A partnership with a private entity (as discussed in a later section, *Public/Private Partnerships)* should be considered as an option for the provision of traveler information, especially in the short term. This kind of partnership would allow a system to be “up and running” in less than a year, and would not require that KDOT and MHTD dedicate staff or space to an interim TOC.

- Efforts should be made to coordinate with planning agencies to assure that local and regional plans incorporate ITS concepts. Coordination activities should be initiated with Mid-America Regional Council (MARC) to assure that ITS projects are incorporated into the *Transportation Improvement Plan,* and with local planning agencies to assure that they understand ITS and how local applications can work together with ITS applications in the Kansas City area.

- With respect to the TOC, design activities for MHTD’s new District Facility should consider inclusion of a TOC to serve the entire Kansas City metropolitan area. Thus, coordination will be required not only with MHTD but also with KDOT. Ideally the facility would be sized to be large enough to serve the entire metropolitan area. At the very least, the proposed facility should be constructed to accommodate the needs of the deployment of Phase 1 and Phase 2, with the capability for expansion to serve the entire metropolitan area (Phase 3 and 4). More information about the TOC is provided in a later section, *Operations P/an.*

- Total station equipment, which facilitates and speeds up accident investigations, should be purchased for use on interstates. It is not necessary for each jurisdiction to purchase their own system, but a responding agency in each state should have access to this equipment. Because Kansas Highway Patrol (KHP) is involved in the investigation of all fatality accidents on the interstates in Kansas, they are a logical agency for procurement in Kansas. Similarly, procurement of a system by Kansas City, Missouri, would cover most of the interstate system in Phases 1 and 2 in Missouri.

Medium Term - Activities identified for deployment in the medium term include all activities and projects to be implemented within five to ten years.

One primary activity in the medium term is the deployment of a freeway management system on Phase 2 facilities. This would extend coverage north on I-29, west on I-70 and I-670, on a portion of I-635, on US 69 between I-35 and I-435 in Kansas, on I-70 east to I-470, and on I-435 north to Independence Avenue and south to Bannister Road. Deployment of Phase 2 would extend the coverage of the system on primary facilities, would provide information on alternate routes, and would complete several more loops, providing additional redundancy. Additional and more specific activities to be implemented in the medium term are as follows:

- Permanent CCTV cameras, HAR, and VMSs should be installed as noted for Phase 2 in Figures 7-1, 7-2, and 7-3. Additional CCTV cameras may be needed for complete coverage. Although not shown in Figure 7-1, these additional cameras were included in the cost estimate. Detector stations should be located every half mile.

- Ramp metering should be evaluated as a possible strategy to address recurring congestion and to break up platoons of vehicles and force single vehicle entry. Analysis should consider the results of the I-35 demonstration project in Kansas (to be conducted in the short term) as well as the operating and geometric characteristics of potential corridors.

Additional information related to ramp metering is provided later in this section under *General Deployment Guidelines.*

- The TOC hardware (monitors and switching equipment) and software should be expanded, as needed, to accommodate additional Phase 2 freeway coverage.

- Continued use of the 911 system should be evaluated to determine if there is a need for a separate phone number for non-emergency freeway situations. Some emergency responders have expressed concern that the 911 line has and will become increasingly busy with non-emergency freeway related calls. Proponents of separate systems state that non-emergency traffic related calls are not the purpose of the 911 system, and the high volume of non-emergency calls may compromise the service to emergency calls. A non-emergency freeway service number could be used to allow motorists to provide information about vehicle disablements and other non-injury situations that require action but no emergency response. This number would be answered at the TOC. This information would then be disseminated by the TOC, and MAP or maintenance personnel could be dispatched as appropriate. A disadvantage of this system is that it would require motorists to make a decision as to which number to call.

- Incident data should be compiled and examined to determine if there are any patterns with respect to hazardous material incidents (whether hazardous materials are more prevalent at certain locations - such as near manufacturing plants, railway junctions or freeway sections with limited geometrics), and whether any particular kinds of hazardous material warrant greater tracking. If analysis indicates that some locations or types of hazardous material are disproportionately affected, appropriate action may be action. Such action may entail increased monitoring of "problem" sites, or increased tracking of "problem" substances. Activities related to hazardous material incident response and planning should be conducted with input from local hazardous material incident response agencies.

- Efforts should be made to provide transit information (such as information on transit routes and schedules) in conjunction with traffic information. This information may be provided via Internet or telephone, depending on the methods by which highway information is provided. The TOC need not directly be involved in the provision of this information, however, it will need to coordinate with transit entities so that this information may be provided through the central information server and/or other means of information dissemination.

Long Term - Activities identified for deployment in the long term include all activities and projects to be implemented in ten years or more.

One activity for deployment in the long term is complete coverage of the metropolitan area with a freeway management system. Extension of the freeway management system to all major freeways in the urban area would allow re-routing of through traffic around congested areas, and would allow traffic management on a systemwide basis. However, relatively low volumes on many of the Phase 3 and 4 facilities imply a relatively low benefit cost ratio at the present time and in the near future. Eventually, however, growth in traffic volumes, as well as decreasing prices for technologies, would be expected to result in more favorable benefit cost ratios. Additional and more specific activities to be implemented in the long term are as follows.

- Permanent CCTV cameras, HAR, and VMSs should be installed as noted for Phase 3 and 4 in Figures 7-1, 7-2, and 7-3. Additional CCTV cameras may be needed for complete coverage. Although not shown in Figure 7-1, these additional cameras were included in the cost estimate. Detector stations should be located every half mile.

  Benefit cost ratios should be used to guide the priority of deployment for Phases 3 and 4. These ratios should be re-calculated in the future to reflect volume increases, changes in accident rates, and changes in the price of equipment. Installation of equipment for freeway monitoring and verification on all facilities will result in complete coverage of the metropolitan area.

  Efforts should be made to coordinate the provision of information from the TOC with the provision of traveler services and other tourist information. This may include information kiosks at the airport and convention centers. This may also include integrating current traffic information into a computer "yellow page" system. Under this scenario, travelers could obtain information about all local barbecue restaurants, for example, as well as current travel times to each restaurant. It would even be possible to allow tourists to make "real-time" dinner reservations, so the restaurant could know they are coming and have their table ready when they arrive.

- Efforts should be made to coordinate the provision of information from the TOC with the provision of in-vehicle information, including en-route driver information and route guidance information. Although the TOC may not directly interface with in-vehicle devices, they should coordinate with private or other entities to provide this information. Under this scenario, current travel speeds could be used to determine the route with the shortest travel time.

- Technologies to facilitate commercial vehicle operations should be considered for deployment. Although many of these would be implemented by enforcement and administrative agencies, the TOC may benefit from interaction with commercial vehicle entities. In Minneapolis, the traffic management center provides information to commercial vehicles, who in turn serve as spotters, notifying the traffic management center of accidents or unusual travel conditions.

- Technologies to enhance compliance with clean air mandates should be considered for deployment. Such technologies might include emissions testing equipment and other means for point source pollution detection.

- Deployment of technologies to encourage alternatives to single occupancy vehicle commuting should be considered for deployment. The provision of real-time carpool matching and flexible transit routing and scheduling are just two examples of possible activities. The provision of high occupancy vehicle (HOV) facilities should also be considered. Although these activities may be primarily conducted by local transit agencies and the MARC, information about these activities should be available through the information server.

On-Going - There are a number of activities that should be on-going in the short, medium and long term. These activities reflect the need for institutional coordination as well as system evaluation.

- It will be necessary for the TOC to coordinate with local public works agencies and emergency response entities. In the future, it may also be necessary for the TOC to coordinate with transit providers and the Kansas Turnpike Authority (KTA), primarily for the exchange of information.

- As local jurisdictions acquire more sophisticated equipment, the need for the exchange of information will increase. For example, the TOC might want video feed for CCTV cameras operated by the city on arterials that serve as freeway diversion routes.

- The TOC will need to coordinate with emergency responders on an on-going basis. As more emergency response agencies acquire automatic vehicle location (AVL) systems, the TOC may wish to use these systems as probes to indicate travel speeds, especially on segments of the system without detectors or monitoring equipment. On the other hand, emergency responders may wish to use travel time information from the TOC to determine which vehicle and route should be used in response to a call.

- Although few transit vehicles regularly use the freeway, the TOC should coordinate with local transit agencies nonetheless. For example, the Kansas City Area Transportation Authority's (KCATA) AVL system may be used to provide information to the TOC about alternate routes in their jurisdiction. Furthermore, in the future, the TOC's information server may serve as a point source for information on all modes in the greater Kansas City area. Thus, coordination will be even more important.

- Local jurisdictions should initiate and continue efforts to upgrade signal control hardware on arterial routes, especially those appropriate for freeway diversion. As development spreads and volumes increase on freeway segments that are currently under capacity, the TOC will need to coordinate with additional cities for arterial diversion.

- Once cities have implemented signal control systems that can accommodate timing plans for freeway diversion, the TOC must work with the local agency to develop signal timing plans and policies. These plans and policies must be evaluated and modified, as necessary.

- Local agencies must notify the TOC of any construction or maintenance activities that would interfere with the use of an arterial as a diversion route.

- The TOC should coordinate with the KTA regarding current and planned ITS applications. For example, the TOC could use the K-tags as probes by installing readers on I-70. Future applications include exchanging information and providing information about traffic conditions on I-70 in Kansas City to travelers on the eastbound tollway, and vice versa.

- The detectors installed as part of the freeway management system should be used to gather information on "before" and "after" conditions. This information can be used for decision making for later study phases, to verify estimated benefits and increase the accuracy of projected benefits and benefit cost ratios.

- Data gathered by the freeway monitoring system can be used to identify the location, severity and duration of recurring congestion. This detailed data can be sued to assess the need for and project the effectiveness of strategies such as ramp metering.

- The impact of the provision of traveler information, including information about recurring congestion, incident related congestion, and alternate routes, may be evaluated using freeway data gathered by the freeway monitoring system.

GUIDE TO DEPLOYMENT

This is intended to be a guide for locating Intelligent Transportation System equipment along roadways in the Kansas City metropolitan area. This section addresses a number of issues, including diversion routes, variable message signs, CCTV cameras, detection equipment, arterial traffic control systems, HAR, and ramp metering.

With respect to equipment, in general, currently available and acceptable, state of the art technology should be employed whenever possible. However, value engineering should be used to determine the most cost effective equipment to be used. The cost of training, maintenance and operations are also important criteria that should be considered.

Closed Circuit Television Cameras (CCTV) - On interstates and freeways, CCTV cameras should be placed to allow complete coverage of the roadway, this may require spacing as frequent as one every half mile. Selected priority locations for CCTV cameras are shown for each phase in Figure 7-l. The cost estimate includes provisions for additional cameras, and is based on a frequency of one camera every half mile.

CCTV camera priority locations include high accident locations, freeway to freeway interchanges, and interchanges with major arterials. More than one CCTV camera may be needed at some interchanges. These CCTV cameras will be used to verify the conditions of diversion routes before, during and after a diversion plan. In some cases, the capacity of an interchange may be unable to accept additional traffic volume, especially at peak traffic times. The CCTV images could be used to determine whether diversions should be continued or discontinued.

On diversion routes that are major arterial roadways with at least two lanes per direction, CCTV cameras should be considered for placement. These CCTV cameras would be used to verify the condition of the diversion routes before, during and after implementation of a diversion plan deployment. CCTV cameras located on arterial diversion routes may be implemented in conjunction with cities, providing an opportunity for shared costs and benefits.

Highway Advisory Radio Transmission (HAR) - It is recommended that a system of individual HAR transmitters be deployed to cover the entire metropolitan area. A conceptual layout of HAR coverage is provided in Figure 7-2 (approximate radius shown is 2.5 miles).

The transmission ranges should be set and the transmitters should be located such that they do not overlap or interfere with one another. There are two approaches to accomplish this, the first and recommended approach is to use a single frequency for the entire metropolitan area, in this case it would be 1610 AM. Under this scenario, drivers would be able to access information anywhere in the metropolitan area on the same frequency, minimizing confusion. A disadvantage of this is that there can be no overlap in coverage areas, or the message will become garbled. A second approach is to use different frequencies for adjacent transmitters. This approach allows more complete coverage, but requires drivers to know where they are and know the associated frequency, changing the radio station as they enter a new HAR coverage area.

Local HAR should be coordinated with any future HAR along the Kansas Turnpike. Some degree of cooperation, coordination and shared use of the messages on HAR between the Kansas Turnpike, KDOT and MHTD should be developed based on the location, severity and impact of an incident on the adjacent agencies roadway.

Variable Message Signs (VMSs) - The kind of VMS required, and the recommended placement of the sign varies, depending on the type of facility. Possible locations for VMSs for each phase are shown in Figure 7-3.

On interstates and freeways, VMSs should be placed prior to interchanges with other interstates and freeways for route diversion information. VMSs should be placed approximately three-fourths of a mile prior to the alternative route decision point, keeping in mind the sight distance necessary to read a three-panel message at the prevailing speed of the facility. Special attention should be given to vertical and horizontal curves.

On major arterial roadways that are two lanes per direction (such as Metcalf Avenue), VMSs should be placed prior to interchanges with interstate and freeways. VMSs should be placed approximately one-half mile prior to the decision point, keeping in mind the sight distance necessary to read a message at the prevailing speed of the facility. Special attention should be given to vertical and horizontal curves.

On minor arterial roadways that are two lanes total (such as the two lane, one-way streets downtown), the option of smaller, less sophisticated and less expensive changeable message signs (CMSs) should be considered. Options include rotating drum signs, blank-out signs, or electromechanical flip panel signs. These CMSs should be used because they are less expensive and because fewer motorists will see the information displayed on the CMS. The lower cost and the fact that fewer motorists will be impacted should be considered when determining the number of locations for deployment. The use of CMSs is less obtrusive and provides information to the motorist as to the condition of the adjacent facility (for example, normal conditions ahead are indicated by the absence of a message; congested conditions are indicated with an appropriate message).

In general, VMSs should not be located prior to interchanges with roadways that have little or no capacity to accept the diverted traffic.

Diversion Routes - Possible diversion routes are shown in Figure 7-3. Although ideally diversion routes are on freeways, many of the Phase 1 and 2 alternate routes are on arterials. For Phases 3 and 4, particularly for through trips, freeway alternate routes are recommended, although they are not shown in Figure 7-3.

In general, choices for traffic diversion routes should be prioritized as follows:

- First: Freeway to Freeway.
- Second: Freeway to Major Arterial Roadway.

The key to mitigating the impact of diverted traffic on any one roadway is to provide the information as wide spread as possible to the motorists. This allows the motorist to choose the diversion route well in advance of the incident. Providing information to the motorist about the extent of the queue developed by the incident may help motorists decide whether to stay on their route to reach their destination.

If the alternate route has not been instrumented, then manual means of monitoring the alternate route should be deployed until the alternate route has been instrumented. This can be accomplished through roaming service patrols and cellular call-in by motorists to the TOC.

An analysis of the capacity of the available adjacent alternative roadways should be performed. A list of criteria which might eliminate a roadway from consideration as a diversion route is as follows:

- Single lane in each direction.
- School located along the route.
- Hospital located along the route.
- No traffic signals to control traffic or increase capacity for diverted traffic.
- Limited overhead clearance for large vehicles.
- Limited turning radii for large vehicles.
- Substandard roadway alignment or geometrics.
- Lack of shoulders.
- Residential areas.
- Heavy pedestrian traffic.
- Active railroad crossings.
- Substantial change in speed limits.
- Circuitous routes.
- Roads which require resurfacing and/or reconstruction.

Traffic Volume, Travel Speed and Traffic Density Detection Systems - Detection equipment should be deployed along interstates and freeways. Detection equipment may also be deployed along segments of roadways that act as links between diversion routes. These detection systems would provide valuable information about travel speeds and traffic volumes, information which can be used to determine the usefulness of a link for diversion purposes.

Detection Systems should be deployed on interstates and other freeways at half mile intervals or between interchanges. Whenever possible, detection equipment should be employed that is non-intrusive to the flow of traffic. This provides detection equipment that can be installed, operated and maintained with minimal disruption to traffic flow.

On diversion routes that are major arterial roadways with at least two lanes per direction, detection systems can be used to evaluate the capability of the arterial to handle the additional volume resulting from freeway diversion. Such systems may be appropriate for deployment in the future by cities or other agencies with jurisdiction, however, such systems are not currently recommended.

Coordinated Arterial Traffic Signal Systems - Traffic signal control should be coordinated along all signalized arterials that may be used as diversion routes. These routes should be designated mutually by the city or agency with jurisdiction and by MHTD or KDOT. Possible alternate routes are shown in Figure 7-3. Key arterial diversion routes for Phase 1 and 2 include Truman Road, US 40, US 24 and Bannister Road in Missouri, and State Avenue, Metcalf Avenue, 103rd Street, and College Boulevard in Kansas.

Management of the coordinated arterial traffic signal system will depend on agreements worked out with each jurisdiction. For example, Kansas City, Kansas, prefers that adaptive signal control be used, so no agency will manually change the timing plan upon implementation of a diversion scheme.

On the other hand, Kansas City, Missouri, would be willing to allow the TOC to implement a pre-determined (and agreed upon) timing plan on a diversion route such as Truman Road. At other times, during typical operations, control would be maintained by Kansas City. Similarly, Overland Park, Kansas, would allow the TOC to implement a pre-determined timing plan when Overland Park engineers are not available. During office hours, however, the TOC would notify the city, and city engineers would implement the pre-determined timing plan.

In all cases, the affected city and MHTD and/or KDOT should work together to determine an appropriate timing plan prior to the incident. These timing plans should then be evaluated and modified, as necessary.

It is also important that issues related to liability be addressed prior to deployment. Records of all changes in signal timing will need to be kept, and issues related to agency liability will need to be addressed thoroughly.

Ramp Metering Demonstration Project - Ramp metering is recommended for implementation in the short term as a demonstration project on I-35 in Kansas from I-435 to the state line. Ramp metering is recommended for consideration in the medium term on other congested facilities in the Kansas City area.

Ramp metering is a tool used to reduce recurring traffic congestion on a freeway facility by managing vehicle flow from on-ramps. The on-ramp is equipped with a traffic signal that allows vehicles to enter the freeway at an interval. Ramp metering has a number of potential benefits including[1]:

- Reduction of freeway mainline congestion.
- Decrease in freeway mainline delay.
- Protection of freeway level of service.
- Reduction in ramp merging accidents.

This section provides an analysis of the potential for ramp metering on I-35 from I-435 to Southwest Trafficway. This section will examine the necessary elements in developing the

1Transportation Research Board, *Highway Capacity* Manual. 1994 standards for planning, operation, design and implementation of a ramp metering program study.

Ramp Metering Planning: Ramp metering is a transportation system management (TSM) approach to solving freeway congestion problems. An effective ramp metering program utilizes a series of entrance ramps within a specified corridor and treats them within a "system" configuration. The installation of ramp control signals should be preceded by an engineering and planning study of the physical and traffic conditions on the highway and surrounding arterials likely to be affected. After implementation of a ramp metering program, planning analysis should be maintained to observe the impacts of the system and to make program changes.

An I-35 ramp metering program study should include analysis of the ramps and ramp connections as well as the freeway itself and surface streets affected by the ramp control. Types of traffic data which should be obtained for the study include, but are not limited to, traffic volumes, traffic accidents, operating speeds, travel time, and delay on I-35 and on alternate surface routes.

Analyzing the potential for a ramp metering program involves developing a set of criteria to determine whether freeway and ramp sections are a good candidate for a ramp meter. Each ramp meter should be individually planned to accommodate the surrounding traffic demand. Analysis should be made as to the desirable ramp metering rates, probable reductions in delay of freeway traffic, likely increases in delay to traffic on ramps and potential impact on surface streets'. Ramps are usually timed so that on-ramp demand will not exceed downstream freeway capacity. Additional analysis should include level of service, storage capacities on the ramp and whether suitable alternate surface routes have adequate capacity to accommodate additional traffic volume.

After the ramp metering program has been implemented, analysis should continue to follow the performance of the system. Adjustments to the system can be made as a result of this analysis. Because ramp metering imposes delay on vehicles wishing to enter the freeway, this disbenefit must be outweighed by the time savings and accident reduction for overall freeway travel.

Ramp Metering Operations: The primary objective of a ramp metering program is to improve the operating efficiency and safety of the existing freeway mainline. While freeway operations are improved, ramp operating efficiency is compromised. Ramp metering must be closely coordinated with arterial signal timing on nearby streets to assure that arterial operation is not unduly affected.

There are a number of basic strategies for inserting vehicles into the mainline freeway traffic. Each of the following metering operations provides a different level of sophistication of control. The best ramp metering operation is one that is tailored to the individual ramp characteristics and goals and objectives of the ramp metering program'.

1Federal Highway Administration, *Manual of Uniform Traffic Control Devices, 1988*
2Discussion on ramp metering operation is based on Information provided in W McShane and R Roess. *Traffic Engineering, 1990*

Primary ramp metering operations include:

- *Simple Metering* - uses a fixed metering rate with an optional detector for sensing the presence of a vehicle. The green indication is generally 2 to 3 seconds long, sufficient to pass one vehicle.

- *Demand-Responsive Metering* - uses freeway mainline information so that the ramp metering rate is computed in real-time to respond to current demand levels and freeway conditions.

Secondary ramp metering operations include:

- *Gap-Acceptance Metering* - uses a series of detectors in the shoulder lane of the upstream traffic to identify "acceptable gaps" and match a ramp vehicle to maximize the likelihood of a smooth merge. This method has special advantages for ramps with poor sight distance.

- *Pacer* and *Greenband Systems* - use a series of lights along the ramp to lead the vehicle along with the pace of the lights matched to the gap sensed on the mainline. The Greenband system uses a band of acrylic panels backed by floodlights every two feet to provide an image of a moving band.

Ramp metering operations include five types of vehicle throughput. The type of throughput that is best suited for a particular ramp depends on the goals and objectives of the individual ramp, the entire ramp metering system and the existing ramp configurations. Five types of vehicle throughput include:

- Single vehicle throughput, single lane.
- Multiple vehicle throughput, single lane.
- Single vehicle throughput, dual lane.
- Multiple vehicle throughput, dual lane.
- Single vehicle lane metering with HOV bypass lane.

Ramp Metering Design: Design of the ramp metering facility includes all physical elements of the project, including upstream warning signs, ramp configuration and the ramp metering site. The on-ramp metering system should meet all of the standard design specifications for ramps and traffic control signals including the following design criteria from the *Manual of Uniform Traffic Control Devices.*

- The standard signal face for freeway entrance ramp control signals should be either a two-lens signal face containing red and green lenses or a standard three-lens signal face containing red, yellow and green lenses.

- Entrance ramps having more than one lane should have a signal head mounted on both the left and right side.

- The required signal faces should be mounted such that the height to the bottom of the housing of the lowest signal face is between 4.5 and 6 feet.

- All ramp control signals should utilize vertically aligned lenses with a minimum nominal diameter of 8 inches.

- Ramp control signals need not be illuminated when not in use.

- Ramp control signals should be mounted close to the driver level.

Figure 7-4 illustrates a typical installation of the principle hardware components of a pretimed ramp control.

On-ramp vehicle storage should be adequate so as not to adversely impact adjacent streets. The metered on-ramp should be able to store between 5 percent (minimum) and 10 percent (desirable) of the peak hour ramp traffic volume with the assumption of 20 feet per vehicle. On-ramp vehicle storage can be adjusted with the location of the ramp meter signal and the timing of the signal. Examples of single and double lane ramp metering placement are shown in Figure 7-5.

A standard estimated cost to implement the ramp metering program ranges from $25,000 - $35,000 per on-ramp or $50,000 - $70,000 per interchange[1]. This estimate includes the signal head, controller and the detectors. Any geometric improvements to the ramp would be an additional cost.

Ramp Metering Implementation: It is important to develop an Implementation Plan when planning a ramp metering program. Consideration should be given to public acceptance potential and enforcement requirements of ramp control, as well as alternative means of increasing capacity, reducing demand or improving characteristics of the freeway[2].

The following is a step approach to implementing a ramp metering program.

STEP 1- Collect data and analyze existing conditions of freeway, ramp and arterial segments.
STEP 2 - Develop goals, objectives and policies regarding program.
STEP 3 - Prepare design layout.
STEP 4 - Implement public awareness campaign.
STEP 5 - Follow-up with program monitoring and improvement.

There are 12 arterial to freeway interchanges on I-35 from I-435 to the state line . All of these would be potential ramp metering candidates within the I-35 corridor system. Each location would be coordinated with the system-wide ramp metering program to facilitate improved traffic operation on I-35. It would also be possible to include the Southwest Trafficway entrance ramp in Missouri in the system. At this location, ramp metering could be implemented by using the existing traffic signals on northbound Southwest Trafficway and Broadway. It would also be possible to include freeway to freeway interchanges in a ramp metering system. All of these candidate ramp metering sites on I-35 are shown in Figure 7-6.

1 Final Report, Bi-State St. Louis Area Intelligent Vehicle Highway System Planning Study, April 1994
2 Federal Highway Administration, *Manual of Uniform Traffic Control Devices, 1988*

Arterial to Freeway:

1. 95th Street
2. 87th Street
3. 75th Street
4. 67th Street
5. 63rd Street (Shawnee Mission Parkway)
6. Johnson Drive
7. Antioch Road
8. Lamar Avenue
9. Roe Avenue (18th Street Expressway)
10. Mission Road
11. 7th Street (Rainbow Boulevard)
12. Cambridge Circle
13. Southwest Trafficway

Freeway to Freeway:

14. I-435
15. U.S. 69
16. I-635

These 16 ramp interchange locations, together, make up a ramp metering system that can provide increased operating efficiency to the I-35 corridor. The ramp metering system provides a low cost TSM solution to a congested freeway corridor.

OPERATIONS PLAN

The key to success of the Kansas City freeway management system will be an effective program of operations and maintenance. This will require personnel located at the TOC, individuals responsible for field maintenance, and a management structure to coordinate and administer the overall operation. Training of staff, both initially and on a continuing basis as new equipment and functions are added, is critical to insure that the staff can provide maximum effectiveness. Complete and thorough system documentation is also necessary to effective operation. This section presents a review of actions and issues related to the operation and deployment of the future system. Procurement methods, staffing, TOC sizing, system start-up plan requirements, and operations plan requirements are also addressed.

Agreements and Memorandums of Understanding - In order to be effective, the proposed freeway management system must be conceived and operated in a cooperative effort by multiple state and municipal agencies. Generally, its purpose is to be responsive to traffic and incident conditions without regard to jurisdictional boundaries. The system will be designed as a unit, but it must operate in the context of decentralized functions and responsibilities. Since it will support and enhance current functions, the cooperative relationships established for its operation will extend beyond its functions of roadway monitoring, incident detection, incident response, and motorist information. The system will serve as an effective catalyst for communication among agencies involved in incident response.

A series of agreements and memorandums of understanding will be necessary to establish and support the freeway management system. These will need to be developed over a period of time as an ordinary part of system design and development. Multiple agreements or memorandums are advisable in lieu of a single document to provide flexibility for responding to future needs.

Potential needs for cooperative agreements or memorandums of understanding would likely include four categories:

- Agency Support.
- System Construction, Operations, and Maintenance.
- Emergency Response.
- Specialized Control Plans.

Agency Support: One of the first documents to be executed should be a joint statement of support for improved incident management systems and operations within the metropolitan Kansas City area. This should be a statement of policy, with specific roles and responsibilities to be identified in follow-up documents. This agreement should provide a statement of goals and objectives in support of a cooperative policy. The agency support statement should be signed by the state, county and city authorities. This document will serve to inform the public of intent and commitment to the system, and will provide general guidance (through goals, objectives, and policies) for further system development.

To best serve its intended purpose, execution of the agency support agreement should be well publicized. This could include signing ceremonies by county, city and state officials and may include media coverage. In addition to indicating support and cooperation of involved jurisdictions, this will provide an early opportunity for public education regarding the character and intent of the system.

System Design, Construction, Maintenance, and *Operations:* Agreements will be necessary among participating jurisdictions and agencies to establish and operate the system. These will address the following categories: funding, system operation and maintenance, and functional roles and responsibilities. Among the topics which may need to be addressed for each category are the following:

- Funding
  - Engineering
  - Construction
  - Start-up
  - Operations
  - Maintenance

- System Operation and Maintenance
  - Traffic operations center
  - Field equipment
  - Administration and management
  - Staffing

- Functional Roles and Responsibilities
  - Communication responsibilities of traffic operations center
  - On site coordination (incident manager, call for tow trucks, etc.)
  - Role and limitations of motorist assistance patrols
  - Identification and management of diversion route systems
  - Operation of variable message signs and motorist information systems
  - Data links (CCTV, traffic counts, operating speeds, etc.)

Emergency Response - Agreements, legislation, and cooperative understandings should be developed for the coordination of incident response. Activities toward this end are currently underway. Changes may be needed as emergency response personnel interact and as the system design evolves but the system will not supplant or modify most established relationships. Some potential new emergency response policies may require enabling legislation, including:

- Vehicle removal policies.
- Lane closure policies.
- Tow truck notification policies.

Specialized Control Plans - In addition to agreements and/or memorandums of understanding for day-to-day system operations and emergency response, it may be useful to establish roles, responsibilities, and relationships for special conditions. These include the following, as a minimum:

- Recurring special events (such as a Chiefs game)
- Unique special events (such as a presidential visit)
- Maintenance of traffic during construction
- Special incidents, such as hazardous material spills

#ours of Operation - Although cost estimates provided for 24 hour weekday operation, it would be reasonable to initiate monitoring on a more limited basis. Experience from other freeway management systems indicates that, at a minimum, the TOC needs to be staffed from the beginning of the morning rush hour to the end of the evening rush hour. One alternative would be 15 hour (generally 5:30 am to 8:30 p.m.) operation. Weekend staffing may not occur initially, but eventually it may be needed, especially during special events or adverse weather. Since the TOC will be located with the MHTD district office, it may be possible for TOC staff to perform other duties during the off-peak hours.

Two different strategies for providing staff have been utilized by different agencies: utilizing agency personnel (either existing or new hires), and contracting to a private organization to provide the personnel. In either case, the budgetary impact is essentially identical, although the specific budgetary categories may be different. As such, there is no distinction as to which approach is used.

During mid-day hours, when traffic is lighter, the operational staff can utilize some of their time to perform other activities that can be handled from within the control room. But the operator is still required to be immediately available to monitor and coordinate response to an incident which might occur. During the hours when the control room is not staffed, at night and on weekends, the system design and architecture must allow an auxiliary console to be located at a 24 hours per day facility, such as the emergency medical or police dispatch center. One logical place for this console would be in the Missouri Highway Patrol Office which will be located adjacent to the MHTD district office.

TOC Operators - The specific functions that the operator needs to perform include:

- Utilizing the computer displays and CCTV screens to monitor and verify the traffic conditions and incidents on the freeways.
- Operating the computer systems, through a keyboard or mouse or joystick, to select different displays and to control field devices, such as VMSs and CCTV cameras.
- Responding to status and alarm messages from the computer systems, again with a keyboard and mouse, that are generated when incidents are detected or equipment malfunctions are detected.
- Utilizing telephone and radio equipment to communicate with police, fire personnel, and other personnel responding to an incident.
- Utilizing telephone or FAX equipment to communicate with media and the public regarding the status of an incident or current traffic conditions. This function may also be automated through the central information server, and/or through the provision of information via highway advisory telephone or the Internet.
- Operating recording equipment, such as a VCR, that would be utilized to capture the specifics of a particular incident.
- Troubleshooting and performing simple replacements for malfunctioning equipment in the TOC.
- Maintaining logs and other required records of activities.

Several different strategies, alternatives to the more traditional full-time agency technical or support staff, have been utilized by other TOCs for hiring operators. These include hiring part-time workers, including college students. If additional operators are needed during the peak periods, part-time employment may be a logical option.

The cost estimate includes provision for two operations per shift for Phase 1, two additional operators for Phase 2 (four total for Phases 1 and 2), and three additional operators for Phase 3 and 4 (seven total for Phases 1,2 and 3; ten total for all phases). It was assumed that 3.5 shifts would be used for all phases.

Equipment Maintenance - The maintenance and repair of all equipment must be accomplished in a timely fashion in order to achieve effective system operation. The typical goal for these systems is a four hour response time from the time a failure is reported until the equipment is returned to service. This requires a maintenance technician with adequate spares, appropriate tools and equipment, and up-to-date training.

Although the cost estimate provides for five maintenance people for Phase 1, with three additional people for Phase 2 (eight total for Phases 1 and 2), and seven additional people for

Phase 3 and Phase 4 (15 total for Phases 1, 2 and 3; and 22 total for all phases), it would be possible to initiate the system with fewer personnel. It is recommended that at least one technician be dedicated to ITS equipment. While it is possible to share this individual with other maintenance and support activities, it is important that the technician's first priority be the support of the field equipment, and not arterial signals or other equipment. This individual should be available prior to the start of any construction for the project to allow familiarity with the system design. The technician's input to the design process, to insure that maintainability is built into the system, will yield long-term benefits. The technician should serve as the field inspector during all construction work so that details are retained by an agency employee. Also, since the technician will have to live with or correct any problems created by the construction, there will be a strong incentive to get the system built correctly.

Another important role of the maintenance technician is to coordinate with other roadway maintenance or construction activities to minimize the disruption of field equipment. Because contractors and other organizations do not always recognize the importance of the field equipment and associated power and communications circuits, inadvertent actions can create problems. The maintenance technician, by being available or on-site during these potential disruptions, can minimize or eliminate equipment down-time.

The maintenance technician needs to be well experienced in a wide range of skills, including electronics, communications, power distribution, cable installation and repair, portable generators, and general small scale mechanical repairs. Since the maintenance technician will be faced with diverse equipment and failure conditions, a broad set of general repair capabilities is required. Effective troubleshooting and problem isolation techniques, supported by a systematic and logical approach, is needed to quickly identify and correct problems. Preventive maintenance, locating and repairing small problems before they become major, and conscientious record keeping and documentation are also regular components of the equipment maintenance program.

System Management - A manager of the operators and maintenance technician will be required. It is desirable that this individual also have an engineering background so that broader system support and long-range upgrades can be handled. The role of the manager is to provide day-to-day supervision and scheduling of operations and maintenance activities, to coordinate with other agencies and organizations, to develop plans and policies for incident management and freeway monitoring, and to financially manage the operation by developing budgets and being responsible for operating within these budgets.

The manager will also be available to support the operator during a major incident, to be a higher level liaison with other agencies and the media, and to supervise a back-up person if regular operations personnel are not available. The manager will be responsible for training new operations personnel, and insuring that current staff are trained on new equipment and that refresher training is conducted for all personnel, as necessary.

The manager will be responsible for supervision of maintenance activities, insuring that adequate spares are available and that the maintenance technician has all the tools, equipment, and test devices needed to perform effectively. The manager must make certain that the technician's training is current and up-to-date. When a crises occurs, the manager must expedite support and repair services, and provide a buffer between the maintenance technician and other individuals, so that the technician can work without being disturbed.

When the maintenance technician is on vacation, sick-leave, at training, or otherwise unavailable. The manager must also be able to fill-in and supervise or provide basic levels of equipment support and repair.

Support staff, such as secretarial, clerical and receptionist personnel, may be provided on a shared basis from the MHTD district office. Although the freeway management system and TOC do not require dedicated personnel, a part-time equivalent may need to be included in the budget to account for this labor component.

Implementation Plan - Part 655.409 of Title 23 Code of Federal Regulations requires the development of an Implementation Plan prior to the deployment of monitoring and control elements of an incident management plan. According to current guidelines, the Implementation Plan is to be completed prior to project design completion and must be approved by the Federal Highway Administration (FHWA) prior to authorization of construction funding. The Implementation Plan should finalize needed legislation, system design, procurement methods, construction management procedures, acceptance testing, and system start-up. It will also need to include an Operations Plan and Maintenance Plan which provide specific information regarding the equipment to be installed. The intent of the Operations Plan is to clearly describe all significant system features and the means for installing and operating the system. An important element of the Operations Plan is the commitment of involved agencies to staff the system and fund its operation. Many of these issues must await design activities for an appropriate level of detail.

Traffic Operations Center (TOC) Concept - The Traffic Operations Center will serve as the centerpiece of the Kansas City freeway management system. Most ITS functions will be performed at the TOC. Both technically and visually, the TOC will play a major role in defining the success and public image of the Kansas City system.

The internal functions of the TOC will include items such as incident management, systems operations, freeway and arterial monitoring, congestion management, and other ITS activities. Important to the success of the internal operations of the TOC is the facilities (the building, grounds, utilities, etc.) and location. Adequate floor space, highway access, communication linkage, site security, building construction, and alternate route access all contribute to a successful TOC.

Although the proposed MHTD District 4 facility has been identified as the tentative location for the TOC for the entire metropolitan region, it is worthwhile to iterate the factors that should be considered when locating a TOC. If, for any reason, KDOT or MHTD need to find an alternate location for a TOC, potential sites should be evaluated with respect to these factors.

- Ownership. Ownership of the property is an important location. Whether the property is owned or leased has significant implications in terms of on-going expenses (such as rent) and stability, which would be affected by the lease term.

- Space Availability. Space availability refers to the amount of space available for the TOC. This is given in square feet for existing structures, and acreage for vacant lots.

- Highway Access. Highway access indicates distance to access the nearest highway facility, such as I-35, I-435, I-70, or I-470, for the proposed MHTD District 4 facility.

- Emergency Alternate Access. Alternate access lists alternate routes from the site to the highway system. These routes are in addition to those listed in the highway access category.

- Costs. Costs include approximate site preparation costs, which is the cost of all items necessary to prepare the site for the installation of the TOC. Included in this would be items such as building construction or renovation, utility connections/installations, communication iinkage, property acquisition, etc.

- Communication Link Potential. This category reflects proximity to fiber optic networks, microwave towers, and telephone lines, types of telephone lines, cellular phone usage, short range microwave capabilities, etc. Proximity to the interstate is especially important when one considers the need to connect to the fiber optics communication infrastructure.

- Site Utilities. Site utilities include existence or availability of utilities such as electricity, sewer, HVAC, gas, and water.

- Site Security. Site security includes items such as fences, barriers and adjacent types of development.

A program of minimum space needs for the TOC is shown in Table 7-l. These space needs are based on the assumption that the TOC is co-located with the MHTD District 4 facility. Some facilities in the TOC can be used to support other district functions. Shared space includes two conference rooms, which can be used for other activities when not in use for traffic operations and management. One of these conference rooms will serve as a command center during severe incidents; the other conference room will serve as a media room. Both of these conference rooms should overlook the control room, and can serve as viewing rooms for tours of the facility.

Public Transportation Applications

This section addresses deployment of ITS components related to public transportation. The projects recommended for deployment are based on the user services discussed in Chapter 3, the technologies and applications discussed in Chapter 5, and the benefits and costs evaluated in Chapter 6.

In addition to the applications related to transit identified in the previous Freeway Management Applications section, such as high occupancy vehicle (HOV) facilities, and coordination with the provision of transit information through the TOC, it is recommended that the transit agencies in the Kansas City metropolitan area move forward with the technology applications that are already underway, such as the automation of KCATA's scheduling and telephone information system. Additionally, the other technology applications identified as high priorities and discussed in Chapter 5 should be considered for deployment. All of these applications can be implemented in the short term (within five years). These projects include the following.

- Telephone information center automation.
- On-bus audio and video monitoring.
- Bus stop video monitoring.

Table 7-1. Program of Space Needs for Traffic Operations Center to be Co-Located with New MHTD District Facility

Rm qty.	Description	Size	Sq. ft.	Sq. ft. ext.	Comments
1	Control Room - control console - video display - secured area	25 x 30	750	750	Begin with 4 technicians, but size room for 6.
1	Equipment Room - possible raised floor - possible cooling and UPS requirements - consult with vendors	20 x 20	400	400	Serves control room, locate adjacent to minimize cable runs.
1	Supervisor Office	10 x 10	100	100	Share function with a manager in existing traffic department.
1	Secretary Cubicle	6 x 8	48	48	
1	Computer Storage Room - paper and disk storage	8 x 10	80	80	
1	UPS Equipment	10 x 20	200	200	
1	Communications Room - fiber optics - telephone and switch equipment	8 x 10	80	80	
1	Open office area	8 x 10	80	240	Space for 3 work stations
1	Maintenance Area	-	-	-	Not on site, share with existing maintenance department
1	Break Room - counter/storage - microwave - sink/refrigerator - coffee	10 x 15	150	150	Combine with building break rooms.
2	Toilet Rooms - ADA accessible	6 x 9	54	108	Combine with toilets for building.
2	Locker Areas - coats and personal possessions	3 x 5	15	30	Combine with locker areas in building.
1	Conference/viewing/command center - adjacent to control rool - view windows	20 x 25	500	500	Combine with building conference areas. Use as command center during incidents.
1	Conference/viewing/media - adjacent to control room - view windows	10 x 12	120	120	Combine with building conference areas. Use as media room for press conferences.
	Filing/Storage area	5 x 5	25	25	
	Subtotal sf			2,831	
	Circulation @ 35%			991	
	Total sf			3,822	
	Deduct areas shared with building			(1,426)	
	Total dedicated sf			2,396	

- Park-and-ride lot video monitoring.
- Automatic vehicle location (AVL) expansion.
- Consolidated paratransit scheduling.
- Personalized public transit.

As these projects are implemented, opportunities for sharing systems among transit agencies should be pursued to achieve greater consolidation of transit service in the metropolitan area and to extend the benefits of technology to smaller transit operators. improved institutional and jurisdictional coordination will increase the benefits associated with technological applications.

Other ITS applications should be considered for deployment as medium term priorities in five to ten years. These applications include additional public transportation management projects such as automatic passenger counting and automated bus stop announcements. These applications are examples that build on the AVL capability. Another example for consideration is provision of real-time schedule information through telephone information systems and electronic message signs installed at high activity bus stops.

Other potential activities for medium term deployment are advanced ridesharing applications. The application of ITS technology to multi-modal transportation programs is rapidly developing and is being tested through advanced public transportation systems (APTS) operational field tests throughout the country. Agencies involved with the planning and management of public transportation in the metropolitan area should be alert to new products and applications that can address the specific objectives and problems of the Kansas City metropolitan area.

Interagency Coordination

Issues related to interagency coordination include agency roles and responsibilities, as well as deployment issues related to operations and maintenance. Interagency coordination is a critical factor to the success of the Kansas City ITS system. interagency coordination is also an on-going issue that will require continued efforts, as agency personnel, procedures and policies change.

AGENCY ROLES AND RESPONSIBILITIES

The following is a description of the future roles and responsibilities of the agencies participating in establishing a freeway management system for the Kansas City area:

Kansas Department of Transportation (KDOT) and Missouri Highway and Transportation Department (MHTD) - KDOT and MHTD will oversee the development and operation of a traffic operation center (TOC) which will be the focal point for the freeway management system and the distribution of current traffic information. This system will eventually serve the entire interstate network and selected freeway facilities in the Kansas City metropolitan area, and will consist of the following:

- Control of all field equipment on the interstates and freeways in the system.

- Equipment, primarily covering the interstate and freeway network, includes a variable message sign (VMS) system, a traffic detection system, a closed circuit television (CCTV) monitoring system, and a highway advisory radio (HAR) system. Equipment also includes ramp metering equipment, such as the equipment implemented on I-35 in Kansas for the ramp metering demonstration project.

- A traveler information kiosk system in key generators in the area, highway advisory telephone (HAT), and an electronic bulletin board system for access by citizens and businesses in the area may be incorporated in the future.

- Other future systems, not justified by existing traffic conditions, may include freeway high occupancy vehicle (HOV) facilities. The need for these facilities should be continually evaluated over time.

- Information provided by the Kansas City regional weather information system should be available at the TOC. This system has already been developed and is fully operational. Access to this information will require a modem connection to the main facility in Kansas City, Missouri.

- The Kansas Turnpike has recently implemented K-Tag, a system which utilizes a transponder for electronic toll collection (ETC). In the future, if the population of K-Tag users increases sufficiently, transponder-equipped vehicles may be used as probes, allowing individual vehicle travel times to be measured between instrumented reader stations. With sufficient penetration, this direct measurement may be used to supplement other methods of detecting congestion along interstates and selected freeways.

- MHTD's traffic signal systems should be controlled from the TOC. Signal systems on diversion routes in cities should also be controlled from the TOC during incident diversion activity, when possible. The timing of the signal systems can be modified to accommodate additional demand when the facility is being used as an alternate route during deployment of a freeway diversion scheme.

- The activities of motorist assistance patrols should be coordinated with the TOC to help in the removal of disabled vehicles associated with minor incidents and vehicle disablements.

- These systems, described above, should be operated and maintained by KDOT and MHTD, either directly through increased staffing and training for employees of either or both agencies, or through a contract with an outside company or agency for the provision of the needed services.

- KDOT and MHTD or their contracted designee should have sole control of the operations of the TOC and component systems.

Local Jurisdictions/Public Works Departments - Local jurisdictions should upgrade their signal systems on key arterials, as necessary. Each arterial used for a freeway diversion plan should have a signal control system capable adapting to accommodate the addition demand that would be expected. This may consist of solid state controllers with remote control for the implementation of a variety of pre-determined timing plans, including those appropriate for a freeway diversion scheme. An alternative would be the use of adaptive signal control systems, which would automatically detect the increase in demand on the diversion route and increase capacity as needed. Coordination with the TOC will depend on the method by which signal timing plans are changed, as well as the agreements between the TOC and each local jurisdiction. Ideally, coordination and communication would consist of the following.

- Although local jurisdictions will maintain primary control of the signal systems in their jurisdiction, timing plans to absorb the additional demand resulting from freeway diversion will be implemented by the TOC, by the city upon the recommendation of the TOC, or automatically implemented via adaptive signal control.

- Local jurisdictions will have access to current traffic conditions, including CCTV and additional data as needed, on the freeway facilities in their jurisdiction. Local jurisdictions will be responsible for obtaining the funding and equipment necessary to access this information.

- Local signal systems should be coordinated with ramp metering (controlled by the TOC) to assure that operating conditions on the arterial are not unduly affected.

- KDOT and MHTD should retain primary control of the CCTV cameras on the interstates and freeways. Communications can be established for local agencies to view the CCTV camera images of facilities in their jurisdiction at any time. Local jurisdictions should be able to request selection and movement of the CCTV cameras in their jurisdiction. Requests should be granted by operators at the TOC when possible. It would also be possible to implement CCTV cameras that could be controlled from multiple locations (such by local jurisdictions and the TOC), under this scenario, the TOC would have primary control, and the TOC commands would override the local commands.

- CCTVs cameras located on arterial streets will be controlled by the agency responsible for implementing and operating such cameras, although the images should be available to both local jurisdictions and the TOC.

Law Enforcement - The state and local police should coordinate and communicate with the TOC when responding to incidents on the freeway system. This includes not only response by law enforcement officers, but also the response of Kansas Motorist Assistance Patrol, which is under the jurisdiction of the Kansas Highway Patrol.

- Local and state police should have no direct control of the operations of the freeway/expressway or traffic signal equipment.

- Local and state police should have access to CCTV camera images in their jurisdiction and should be able to request selection and movement of the CCTV cameras. The police desk should be able to view the freeway and arterial status traffic information displays. Law enforcement agencies will be responsible for obtaining the funding and equipment necessary to access this information.

- The TOC will communicate with law enforcement via either telephone or two-way radio.

Kansas Turnpike Authority (KTA) - The KTA should coordinate and communicate with the TOC on an as-needed basis. Of particular interest are incidents on I-70 west of downtown and the potential for use of the K-Tags for vehicle detection and for commercial vehicle applications.

- The KTA should have dial-up remote access to the traffic information and status display.

- The K-Tag system implemented by the KTA may eventually be used as a means for detection of incidents, particularly on I-70 west of Kansas City. This would be accomplished by placing transponder readers on the freeway, and would require an adequate population of K-Tag users.

Public Transportation - Local transit agencies should coordinate and communicate on an as-needed basis with the TOC. Major transit agencies include the Kansas City Area Transportation Authority (KCATA), Johnson County Transit, and Public Transportation Division, Public Works Department, Kansas City, Kansas.

- Transit providers should be able to access current traffic information and any other information that would be valuable for their operations. Transit agencies will be responsible for obtaining the funding and equipment necessary to access this information. Transit agencies may use this information to re-route transit vehicles around congested areas.

- Transit providers should make information from their automatic vehicle location (AVL) systems available to the TOC, if the TOC has a need for this information. The agencies operating the TOC will be responsible for obtaining the funding and equipment necessary to access this information.

- Any freeway HOV facilities developed in the future should be developed in coordination with transit service providers, as well as arterial HOV facilities. HOV bypass facilities should be considered for implementation with ramp metering.

Emergency Response and Coordination - The TOC should utilize the existing 911 system for direct contact with emergency responders in the case of an accident on the freeway. The system should be set up so that the TOC operator will be automatically connected with the appropriate agency upon identification of the location of the incident and the kind of emergency response agency needed.

- The existing 911 system will be maintained as the primary mechanism for responding to emergencies on the freeways.

- The TOC should use two-way radio for communication with emergency responders for on-going coordination once the incident response has been initiated.

- In the future, if conditions warrant, a special number for reporting non-emergency incidents on the freeway should be implemented. This number would be answered by personnel at the TOC, who could then coordinate with the motorist assistance patrol (MAP), or other appropriate agencies, as needed. Implementation of a system such as this one, which requires motorists to make a determination as to the severity of the incident (for example, vehicle disablement versus injury accident) would require significant public education activities. This disadvantage would have to be considered relative to the need to relieve the 911 system of non-emergency calls.

Private Sector Involvement - Wherever possible, the private sector should be involved in developing and expanding the freeway management system and the distribution of traveler information.

- Private sector should include, but not be limited to, universities and colleges, manufacturing and service companies, the broadcast and print media, communications and entertainment companies, etc.

- Opportunities for public/private ventures should continue to be explored. This avenue resulted in significant benefit for MHTD through the deployment of fiber on all interstates in the State of Missouri, and may result in similar benefits for Kansas. Additional aspects related to public/private activities for the provision of traveler information are discussed in the following section, Funding Issues.

- Other opportunities for private sector participation might include information kiosks, new products testing, and the development of an area wide communications network.

- Information from the TOC should be available to traffic reporting agencies and cellular phone companies. Fees for traffic information (such as data required in a specialized format) should be outlined in a policy developed prior to deployment.

DEPLOYMENT ISSUES

One of the issues most critical to the success of the deployment of ITS in Kansas City is the continued coordination among local agencies. Coordination among agencies will allow a coordinated approach to project and system planning, will facilitate implementation through the cooperation of neighboring jurisdictions, will allow all agencies to benefit from the experiences of a few, and will enhance the effectiveness of the deployment of ITS projects.

Interagency coordination is perhaps one of the least expensive and most effective means of assuring the development of a seamless ITS system for the metropolitan area. It is recommended that all agencies on the Steering Committee continue to meet periodically, as needed. This group may expand to include representatives from cities or other agencies that are stakeholders in the deployment of ITS technologies.

Maintenance Issues - Agencies participating in the freeway management system should develop clear guidelines on the maintenance of the elements of the system. The following are beginning elements of assigning responsibilities for maintenance:

- An agreement between KDOT and MHTD for the maintenance of all aspects of the freeway management system, including the equipment and software at the TOC and in the field, needs to be developed. All maintenance agreements should be formalized and written, whether the work is done in-house by public agencies or by contract with private firms.

- With respect to field equipment, each state should be responsible for the maintenance of equipment in their jurisdiction, which does not preclude a coordinated approach to maintenance that may result in economies of scale.

- Local jurisdictions and agencies should be responsible for maintenance of equipment they have purchased for communications with and for obtaining information from the TOC.

- CCTV cameras and detection placed by the TOC on arterial streets that are primary diversion routes should be maintained by the TOC unless other agreements are made with the local jurisdiction.

- Space at the TOC should be reserved for maintaining, testing and troubleshooting; either on-site or off-site storage should be provided.

Operations Issues - Agencies participating in the freeway management system should develop clear guidelines on the operations of the system. These responsibilities should evolve from the following initial principles of operation including:

- Any future ramp metering signals should be the responsibility of either MHTD or KDOT, unless other arrangements are made with the local jurisdiction.

- Compatibility with TOC software and operations should be considered during selection of new signal system equipment on arterials that may be used as freeway diversion routes.

- Agreements between KDOT, MHTD and local jurisdictions for the operation of signal systems and other equipment on arterial facilities needs to be developed. These agreements would be expected to vary depending on the needs and desires of each local jurisdiction, All operating agreements should be formalized and written, whether the work is done in-house by public agencies or by contract with private firms.

Open Issues - There are several issues that will need to be continually explored as new information becomes available and as technology and circumstances change. These issues include

- Roles for the private sector.

- Funding sources, which vary depending on the kind of expenditure, the agency requesting funds, and changes in legislation and available funding.

- Level of deployment, which will affect the number and variety of affected agencies.

- “Open architecture”, which is still being defined at the national level and which should be a significant consideration with respect to integration with in-vehicle navigation systems and other ITS applications in the future.

- The need to modify the system to incorporate new technologies.

Funding Issues

Funding issues include potential sources of funds, both traditional sources through the various levels of government, as well as newer sources, such as partnerships with private entities.

POTENTIAL FUNDING SOURCES

Potential funding sources for elements of the ITS Strategic Deployment Plan vary, depending on the jurisdiction and the kind of project. Potential funding sources may include: local funding, both city and county, state funding, including funds from KDOT and MHTD, and federal funding.

Federal funding sources include National Highway System (NHS) funds, Surface Transportation Program (STP) funds for projects not eligible for NHS funds, and Congestion Mitigation and Air Quality (CMAQ) funds. New Intermodal Surface Transportation Efficiency Act (ISTEA) legislation is expected for fiscal year 1998, which begins in October 1997. This legislation may designate funding for ITS projects recommended by the early deployment studies funded through the original ISTEA legislation. Opportunities to include ITS equipment as part of reconstruction activities should also be considered.

Additionally, some projects may present the opportunity for funding from private entities, through joint ventures and other public/private partnerships, as well as through consumer driven technologies such as technologies that will be integrated into the automobile. Opportunities for public/private partnerships are discussed in the next section.

PUBLIC/PRIVATE PARTNERSHIPS

Deployment of an intelligent transportation system will likely involve partnerships with private industry, businesses and the academic community. In fact, currently the primary providers of traffic information are private entities that provide radio and television traffic reports. The extent of the partnerships that will be formed depends on several things. First, the need for partnerships must be adequately communicated and understood. Understanding can be enhanced by an intensive program to explain the goals and objectives of ITS and how these goals can be enhanced through partnerships. Second, public technical assistance (for example, to facilitate coordination with local jurisdictions) should be made available where possible, and its availability should be made explicit. Third, resources are limited in all sectors of society, and the benefits of participation for all affected entities should be examined and carefully delineated.

A general outline of the possibilities for ITS partnerships indicates three categories of techniques that can be implemented:

- Privately operated techniques.
- Public/private coordination and joint activities.
- Publicly-led activities.

In each of these categories, there is a need for coordination between private and public sectors to expand understanding and to assure their deployment. In some instances, there may also be a need for technical assistance from either the public or the private sector.

The academic community may be able to play an important role, as well. Academic institutions are not only employers, but are also able to undertake a role in research and training. Coordination with academic institutions may include employment of student interns and participation in cooperative education programs, the provision of data for research and educational efforts, and student tours of the TOC. Bringing the academic community into the ITS programs can significantly broaden the approach to both the technical and institutional arrangements that are essential to the success of the program.

Coordination with area colleges and universities can be pursued. Possible activities include:

- Provision of data and video feed to regional colleges for research and educational activities.
- Research in transportation technology.
- Training in transportation fields, using teaching expertise at the colleges.
- Receiving information about transportation for use by their students.
- Developing kiosks to display information (for example, at University of Missouri, Kansas City, and University of Kansas Medical Center).

The potential for public/private coordination has been realized to some extent by MHTD through the installation of fiber optics cable on all interstates and selected freeways. A similar arrangement is being pursued by KDOT. In addition to these activities, opportunities exist for coordination with private entities for the provision of current traffic information. These activities may include the following.

KDOT and MHTD, working with other agencies, can develop and market the information that can be provided externally as a result of deployment of various ITS components. One of the principal methods of information delivery that has been suggested is the use of on-line technology. This technology can include a home page, with instructions on how to access the information. It can be free of charge or it can include methods of subscription which require payment in return for a password for access to the information. Another method of delivery of transportation information to a distribution source such as Cablevision. Both of these methods make use of existing communication network technology for distribution of transportation information. These alternatives and others should be explored in greater detail.

Tests of information dissemination might be pursued with employer human resource departments, who have an interest in safe and timely travel by employees. CCTV cameras on the freeway would be transmitted to employment centers and would allow people see the traffic conditions on the highways prior to beginning their trips. They could then make decisions about travel path or time of travel based on the information provided. Information might be transmitted to a commuter at home via teletext, telephone, television, or Internet, or to individual desk PCs for display at work. Another possibility is distribution of information via personal pagers.

The kiosk is another technology for distribution of information that is now being explored in several metropolitan areas. KDOT and MHTD may want to know more about its potential for the distribution of information to employment and recreation locations in the future.

Coordination with local trucking agencies, as well as local cab and shuttle services may also be initiated. These entities might be sources of information and also consumers of current traffic information.

A Case Study, The Provision of Traveler Information through a Private Entity - Although many cities, such as San Antonio, Texas, and Seattle, Washington, have developed freeway management systems and traveler information systems solely through public agencies, the use of private agencies for the provision of these services has also become a viable alternative.

While there are a number of ways for a public agency to coordinate with a private entity for the provision of traveler information and other ITS components, one possible concept is easily demonstrated through examination of systems deployed elsewhere. One example, in a city similar in size and character to Kansas City, is the system recently deployed in Cincinnati, Ohio.

The greater Cincinnati area is currently served by SmarTraveler, an advanced traveler information system (ATIS) operated by SmartRoute Systems'. This system, which went on-line in June 1995, provides current transportation information via telephone for the metropolitan Cincinnati area within the I-275 loop, which encompasses urbanized areas in both Ohio and northern Kentucky. The information provided includes current, route specific information on traffic volumes, travel times, and alternate routes, if necessary. Schedule information on transit and airport shuttles, as well as carpools, is also available. Calls for traveler information are free local calls; cellular calls through selected cellular providers are also free of charge. After dialing the seven digit phone number or three digit cellular number, an audio menu is provided, this allows specific information to be selected on any of 16 travel routes in the area.

Current reports about traffic conditions are provided from 6 a.m. to 7 p.m., Monday through Friday. Information regarding special events and construction activities is available 24 hours a day. The information provided is based a variety of sources, including 15 remote-controlled CCTV cameras, two aircraft, a network of "mobile probes" (drivers who report traffic conditions by cellular phone or two-way radio), direct contact with transit agencies and shuttle services, radio contact with law enforcement and emergency responders, and direct communication with key state and local transportation agencies.

Cincinnati's SmarTraveler is the first phase of the Cincinnati/Northern Kentucky area's Advanced Regional Traffic Interactive Management & Information System (ARTIMIS). Funding for the system is provided primarily by the FHWA under the ISTEA legislation. Kentucky and Ohio also provide state funds for the service. The ARTIMIS system operates under the authority of the Kentucky Transportation Cabinet (KYTC), the Ohio Department of Transportation (ODOT), and the OKI Regional Council of Governments. When fully operational in 1996, ARTIMIS will include detectors, VMSs, area-wide HAR coverage, and freeway service patrols in addition to the *SmarTraveler* system. The total cost for ARTIMIS is approximately $35 million.

1Discussion of this system is based on information provided by SmartRoutes Systems

During the first 18 months of the contract, SmartRoutes built and is operating their own facility to provide ATIS for the Cincinnati area. For the remaining 21 months of the 39 month contract, SmartRoutes will operate the facilities currently being built by the Kentucky and Ohio Departments of Transportation. The public sector commits to purchase services for a specified period of time. SmartRoute Systems is also responsible for staffing and operating the center. A center such as the one in Cincinnati can be in operation within six months of the decision to implement. In some cases, negotiated agreements for profit sharing with public agencies of profits from sales of the database to private entities, such as cellular phone companies and paging companies.

The sale of information to private entities does raise the issue of equity. The philosophy generally espoused is that as long as the public has free access to the information (in this case via telephone), information can justifiably be sold to private entities.

Deployment of traffic information through a private entity should be considered in Kansas City, particularly in the short term. The fast implementation time, coupled with the fact that this system would relieve KDOT and MHTD of staffing and operation duties (at least in the short term), makes the option quite attractive. This arrangement would also allow the information to be provided prior to the construction of MHTD's new District 4 facility. One disadvantage is that equipment may not belong to KDOT or MHTD at the end of the contract, and thus expenditures do not contribute to the ITS infrastructure in the metropolitan area.

PROCUREMENT METHODS

Procurement Methods - An important element in the deployment of the Kansas City freeway management system is the method to be used for procurement. Several procurement techniques have been used throughout the country on related projects. These are outlined below:

So/e Source: the basis for a sole source procurement is the documented existence of only one technical or cost-effective solution to the requirements of a particular project. The most common basis for sole-source procurements is the requirement for compatibility with existing equipment, so that system-wide interoperability can be maintained. For initial systemwide procurement, compatibility with existing equipment is not a factor, and sole-source procurement is not advisable or practical.

For later project phases, sole-source procurement will probably be necessary to maintain equipment compatibility for specific devices, such as CCTV camera controllers. Operating and maintenance problems caused by incompatible equipment are design and procurement issues for the initial system. Conversion or replacement of non-interoperable devices before the end of their useful life is an expensive penalty to be paid for lack of foresight. Some of these issues related to compatibility will presumably be resolved by specification of national architecture standards.

Engineering/Contractor: This procurement method is the one typically used for highway projects. It is based on the concept that all critical system parameters can be fully specified and documented in a single set of contract documents (the Plans, Specifications, and

Estimates - PS & E package), that a single contractor is best suited to implement the project, and that the only criteria of significance for selecting the contractor is the initial bid price. The extensive experience with this process for highway construction has resulted in a very standardized set of procedures and rules within most highway agencies, severely restricting the flexibility of system designers and implementers.

Two-Step Approach: This method modifies the engineer/contractor technique by separating the technical evaluation step from the financial step. This approach provides an opportunity to reject proposals that do not meet the technical criteria for the project. This minimizes the risk of selecting a contractor whose bid is low, but who is not technically capable of performing the work. It also insures that the technical merits of each proposal are fully considered prior to award of a contract, instead of during the "material submittal" stage of a traditional highway construction contract.

Design/Build: In this approach, a single entity is selected to handle all the work associated with implementing the system. The design/builder is responsible for detail system design, procurement of all equipment, construction of all system elements, integration of the various sub-systems, and final system turn-on and operation. The fully functional system is then turned over to the operating agency. A design/build concept simplifies the number of contracts and the steps associated with taking a system from concept to operations. This can be beneficial if the designer/builder fully understands the project concept, and has the experience to successfully handle the full scope. Often the design/builder can use streamlined equipment purchase procedures, thereby speeding up the project schedule.

However, this approach limits the agency's role to that of limited oversight and monitoring of the activities of the design/builder. This can be beneficial since the agency personnel with direct operational experience and needs are typically not involved with the detailed design and thus cannot provide input and feedback during design and deployment.

System Manager/System Integrator: This procurement method divides the project into several sub-projects for each of the various sub-systems. The work is overseen by a system manager who administers each contract and is responsible for integrating the several sub-systems into an overall, operating system. The most effective structure for this approach is to use a design team consisting of agency and system manager personnel. The system manager converts the project plan into preliminary designs and defines sub-systems, develops PS&E packages for sub-systems, oversees bidding and award, supervises construction, selects and procures computer and communications hardware components, develops system software, integrates and tests sub-systems, and supervises operator training.

By assigning responsibility for total system success to the system manager, a single source of accountability and responsibility is defined. The involvement of agency personnel as part of the design team results in improved coordination and tighter cost controls. The agreement between the agency and the system manager is a negotiated contract, which can be easily adapted as project needs are refined. This provides increased flexibility to meet the specific project requirements, when compared to the typical fixed price turnkey or design/build contracts.

Conclusions

This document has outlined a plan for the strategic deployment of an ITS system in the Kansas City metropolitan area. In the short term, this plan calls for the deployment of a freeway management system on priority corridors to facilitate incident management and address incident related congestion. In the future, the freeway management system will expand to encompass additional facilities and to coordinate with ITS activities undertaken by transit, local public works, and enforcement agencies.

While this plan identifies priorities for deployment and makes recommendations for activities in the short, medium, and long term, it is important to note the limitations associated with these recommendations. Any plan, such as this one, that incorporates "advanced technologies" as a component must change to reflect and utilize new technologies and applications. The plan must also change to reflect changing circumstances in the metropolitan area. Thus, the recommendations set forth in this document should be considered guidelines, rather than constraints. Recommendations should be re-evaluated in light of future needs, future technologies, and future circumstances.

Regardless of the specific technologies used, or the user services implemented, the overriding focus of the ITS system must be to safely and efficiently meet the transportation needs of the Kansas City metropolitan area and other roadway users.

Appendix A

A.1 Utility Factors

Utility factors for each evaluation criteria are based on a range from 0 to 10, with 0 indicative of the least utility and 10 indicative of the greatest utility. With the exception of the utility factor for cost, the utility factors were qualitatively determined, as discussed below.

COST

The utility factor representing cost is based on the estimated cost for each alternative, as shown in Tables A-l through A-3. The cost for each alternative was expressed as a percentage of the greatest cost for the capital, operating and total cost. The utility was calculated by subtracting this percentage from 10.0. The estimated cost for each alternative was calculated based on the following assumptions.

Roadway Surveillance Equipment - Roadway surveillance equipment includes:

CCTV cameras:

$30,000 each site
1 site each 0.5 miles

Detection:

$10,000 each site
1 site each 0.5 miles

Variable Message Signs - Variable message signs include:

Large fiber optic variable message signs
3 rows, 18 characters per row, 18” characters
$120,000 per sign
Quantities based on locations identified for deployment (Chapter 7)

Highway Advisory Radio - Highway advisory radio includes:

Permanent installations
AM Radio
$17,000 per transmitter
$3,000 per sign
Quantities based on locations identified for deployment (Chapter 7)

Field Processors - Field processors include:

Alternatives A and C: Non-intelligent Processors, $10,000 per processor
(for example, a Type 170 controller)
1 processor per 0.5 miles

Alternative B: Intelligent Processors, $20,000 per processor
1 processor per 0.5 miles

Table A-1. Estimated Cost for Alternative A

		Level 1	Level 2	Level 3
	Number of miles	48	82	258
Capital Costs				
Freeway Surveillance Equipment				
CCTV	cost per site	$30,000	$30,000	$30,000
	frequency per mile	2.0	2.0	2.0
	total cost	$2,880,000	$4,920,000	$15,480,000
Detection	cost per site	$10,000	$10,000	$10,000
	frequency per mile	2.0	2.0	2.0
	total cost	$960,000	$1,640,000	$5,160,000
Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
	number	35	45	79
	total cost	$4,200,000	$5,400,000	$9,480,000
Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
	number	6	8	16
	total cost	$102,000	$136,000	$272,000
	cost per sign	$3,000	$3,000	$3,000
	number	22	29	54
	total cost	$66,000	$87,000	$162,000
Power Distribution to System Components				
	cost per mile	$30,000	$30,000	$30,000
	total cost	1440000.0	2460000.0	7740000.0
Communications to ITS Elements				
	cost per mile	$10,000	$10,000	$10,000
	total cost	$480,000	$820,000	$2,580,000
Conduit Installation	cost per foot	$40	$36	$25
	total cost	$10,137,600	$15,523,200	$34,272,229
Field Data Processing Equipment				
Non-intellilgent	cost per processor	$10,000	$10,000	$10,000
	frequency per mile	2	2	2
	total cost	$960,000	$1,640,000	$5,160,000
Intelligent	cost per processor			
	frequency per mile			
	total cost			
Traffic Operations Center	number of centers	1	1	1
	square feet per center	$12,000	$12,000	$12,000
	cost per square foot	$110	$110	$110
	total cost	$1,320,000	$1,320,000	$1,320,000
Central Hardware				
Centralized	base cost	$650,000	$650,000	$650,000
	cost per mile	$3,333	$3,333	$3,333
	total cost	$809,984	$923,306	$1,509,914
Decentralized	base cost			
	cost per mile			
	total cost			
Software and Systems Integration				
Centralized		$750,000	$1,000,000	$1,250,000
Decentralized				
Subtotal for 15 Year Life		$24,105,584	$35,869,506	$84,386,143
Construction and Contingency		$4,821,117	$7,173,901	$16,877,229
Subtotal		28926700.8	43043407.2	101263371 .1
Caprtal Recovery Factor (15 years, 6%)		0.1	0.1	0.1
Subtotal for Annual Cost		$2,978,293	$4,431,749	$10,426,077
Percentage of Greatest		2.7	4.0	9.5
Utility Factor		7.3	6.0	0.5
Annual Operating and Maintenance (O-M) Costs				
Traffic Operations Center Personnel		$350,000	$700,000	$1,750,000
Maintenance Personnel		$250,000	$400,000	$1,100,000
Replacement Parts and Spare Equipment		$1,101,779	$1,677,475	$4,090,807
Subtotal		$1,701,779	$2,777,475	$6,940,807
Percentage of Greatest		2.33	3.81	9.52
Utility Factor		7.67	6 19	0.48
Total Cost per Year		$4,680,072	$7,209,225	$17,366,884
Percentage of Greatest		2.56	3.94	9.49
Utility Factor		7 44	6.06	0.51

Table A-2. Estimated Cost for Alternative B

			Level 1	Level 2	Level 3
		Number of miles	48	82	258
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		frequency per mile	2	2	2
		total cost	$2,880,000	$4,920,000	$15,480,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2	2	2
		total cost	$960,000	$1,641,000	$5,160,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	35	45	79
		total cost	$4,200,000	$5,400,000	$9,480,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	6	8	16
		total cost	$102,000	$136,000	$272,000
		cost per sign	$3,000	$3,000	$3,000
		number	22	29	54
		total cost	$66,000	$87,000	$162,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$1,440,000	$2,460,000	$7,740,000
	Communications to ITS Elements				
		cost per mile	$10,000	$10,000	$10,000
		total cost	$480,000	$820,000	$2,580,000
	Conduit Installation	cost per foot	$40	$36	$25
		total cost	$10,137,600	$15,523,200	$34,272,229
	Field Data Processing Equipment				
	Non-intellilgent	cost per processor			
		frequency per mile			
		total cost			
	Intelligent	cost per processor	$20,000	$20,000	$20,000
		frequency per mile	2	2	2
		total cost	$1,928,000	$3,280,000	$10,320,000
	Traffic Operations Center	number of centers	2	2	2
		square feet per center	6000	6000	6000
		cost per square foot	$110	$110	$110
		total cost	$1,320,000	$1,320,000	$1,320,000
	Central Hardware				
	Centralized	base cost			
		cost per mile			
		total cost			
	Decentralized	base cost	$440,000	$440,000	$440,000
		cost per mile	$3,333	$3,333	$3.333
		total cost	$599,984	$713,306	$1,299,914
	Software and Systems Integration				
	Centralized				
	Decentralized		$500.000	$750,000	$1 ,000,000
	Subtotal for 15 Year Life		$24,605,584	$37,049.506	$89,086,143
	Construction and Contingency		$4,921,117	$7,409,901	$17617,229
	Subtotal		$29,526,701	$44,459,407	$106,903,371
	Capital Recovery Factor (15 years, 6%)		0.10296	0 10296	0 10296
	Subtotal for Annual Cost		$3,040,069	$4,577,541	$11,006,771
	Percentage of Greatest		2.76	4.16	10.00
	Utility Factor		7.24	5.84	0.00
Annual Operatlng and Maintenance (0-M) Costs					
	Traffic Operations Center Personnel		$700,000	$700,000	$1,750,000
	Maintenance Personnel		$300,000	$450,000	$1,200,000
	Replacement Parts and Spare Equipment		$1,139,279	$1.748,975	$4.338,307
	Subtotal		$2,139,279	$2598,975	$7,288,307
	Percentage of Greatest		2.94	3.98	10.00
	Utility Factor		7.06	6 02	0.00
Total Cost per Year			$5,179,348	$7,476,516	$18.295.078
Percentage of Greatest			2.83	4 09	10.00
Utility Factor			7 17	5 91	000

Table A-3. Estimated Cost for Alternative C

		Level 1	Level 2	Level 3
	Number of miles	48	82	258
apital Costs				
Freeway Surveillance Equipment				
CCTV	**cost per site**	$30,000	$30,000	$30,000
	frequency per mile	2	2	2
	total cost	$2,880,000	$4,920,000	$15,480,000
Detection	**cost per site**	$10,000	$10,000	$10,000
	frequency per mile	2	2	2
	total cost	$960,000	$1,640,000	$5,160,000
Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
	number	35	45	79
	total cost	$4,200,000	$5,400,000	$9,480,000
Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
	number	6	8	16
	total cost	$102,000	$136,000	$272,000
	cost per sign	$3,000	$3,000	$3,000
	number	22	29	54
	total cost	$66,000	$87,000	$162,000
Power Distribution to System Components				
	cost per mile	$30,000	$30,000	$30,000
	total cost	$1,440,000	$2,460,000	$7,740,000
Communications to ITS Elements				
	cost per mile	$10,000	$10,000	$10,000
	total cost	$480,000	$820,000	$2,580,000
Conduit Installation	cost per foot	$40	$36	$25
	total cost	$10,137,600	$15,523,200	$34,272,229
Field Data Processing Equipment				
Non-intellilgent	cost per processor	$10,000	$10,000	$10,000
	frequency per mile	2	2	2
	total cost	$960,000	$1,640,000	$5,160,000
Intelligent	cost per processor			
	frequency per mile			
	total cost			
Traffic Operations Center	number of centers	1	1	1
	square feet per center	$10,000	$10,000	$10,000
	cost per square foot	$110	$110	$110
	total cost	$1,100,000	$1,100,000	$1,100,000
Central Hardware				
Centralized	base cost	$800,000	$800,000	$800,000
	cost per mile	$3,333	$3,333	$3,333
	total cost	$959,984	$1,073,306	$1,659,914
Decentralized	base cost			
	cost per mile			
	total cost			
Software and Systems Integration				
Centralized		$1,000,000	$1,250,000	$1,500,000
Decentralized				
Subtotal for 15 Year Life		$24,285,584	$36,049,506	$84,566,143
Construction and Contingency		$4,857,117	$7,209,901	$16,913,229
Subtotal		$29,142,701	$43,259,407	$101,479,371
Capital Recovery Factor (15 years, 6%)		00.10296	00.10296	00.10296
Subtotal for Annual Cost		$3,000,532	$4,453,989	$10,448,316
Percentage of Greatest		2.73	4.05	9.49
Utility Factor		7.27	5.95	0.51
nnual Operating and Maintenance (O-M) Costs				
Traffic Operations Center Personnel		$350,000	$700,000	$1,750,000
Maintenance Personnel		$250,000	$400,000	$1,100,000
Replacement Parts and Spare Equipment		$1,109,279	$1,684,975	$4,098,307
Subtotal		$1,709,279	$2,784,975	$6,948,307
Percentage of Greatest		2 35	3.82	9.53
Utility Factor		7.65	6.18	0.47
otal Cost per Year		$4,709,812	$7,238,964	$17,396,623
ercentage of Greatest		2.57	3.96	9.51
tility Factor		7 43	6.04	0 49

Traffic Operations Center (TOC) - TOC consists of:

New facility built on DOT property

Building sized for ultimate system size

Alternative A: 12,000 square foot facility (extra room for emergency management and transit operators)
1 facility

Alternative B: 6,000 square foot facility
2 facilities
$110 per square foot

Alternative C: 10,000 square foot facility
1 facility
$110 per square foot

Central Hardware - Central hardware includes:

Alternative A, Centralized:

$50,000 per 15 miles of controlled freeway (Console $5,000, 2 video monitors at $5,000, Computer Workstation $10,000, Miscellaneous $25,000).

$650,000 base (Video displays $300,000, Central Computer $250,000, Miscellaneous $100,000).

Alternative B, Decentralized :

$50,000 per 15 miles of controlled freeway (Console $5,000, 2 video monitors at $5,000, Computer Workstation $10,000, Miscellaneous $25,000).

$440,000 base (Video displays $300,000, Central Servers $40,000, Miscellaneous $100,000).

Alternative C, Centralized:

$50,000 per 15 miles of controlled freeway (Console $5,000, 2 video monitors at $5,000, Computer Workstation $10,000, Miscellaneous $25,000).

$800,000 base (Video displays $300,000, Two Servers plus Information Server, $400,000, Miscellaneous $100,000).

Software and Systems integration - Software and Systems Integration includes:

Alternative A, Centralized: $750,000 Level 1
$1 ,000,000 Level 2
$1,250,000 Level 3

Alternative B, Decentralized: $500,000 Level 1
$750,000 Level 2
$1 ,000,000 Level 3

Alternative C, Centralized: $1,000,000 Level 1
$1,250,000 Level 2
$1,500,000 Level 2

Annual Operating and Maintenance Costs - Annual operating and maintenance costs include:

Traffic Operations Personnel for 1 TOC (Alternatives A and C):

Level 1 System - 2 operators/shift
Level 2 System - 4 operators/shift
Level 3 System - 10 operators/shift
3.5 shifts (3 shifts plus 1/2 shift coverage) for 24 hour coverage
$50,000 per year (fully burdened) per operator

Traffic Operations Personnel for 2 TOCs (Alternative B):

Level 1 System - 2 operators/shift at each TOC (4 total)
Level 2 System - 2 operators/shift at each TOC (4 total)
Level 3 System - 5 operators/shift at each TOC (10 total)
3.5 shifts (3 shifts plus 1/2 shift coverage) for 24 hour coverage
$50,000 per year (fully burdened) per operator

Maintenance Personnel for 1 TOC (Alternatives A and C)
Level 1System - 5 maintenance people /shift
(4 Field maintainers and 1 TOC maintainer)
Level 2 System - 8 maintenance people/shift
(7 Field maintainers and 1 TOC maintainer)
Level 3 System - 22 maintenance people/shift
(20 Field maintainers and 2 TOC maintainers)
1 shift
$50,000 per year (fully burdened) per maintainer

Maintenance Personnel for 2 TOCs (Alternative B)
Level 1 System - 6 maintenance people/shift
(4 Field maintainers and 2 TOC maintainers)
Level 2 System - 9 maintenance people/shift
(7 Field maintainers and 2 TOC maintainers)
Level 3 System - 24 maintenance people/shift
(20 Field maintainers and 4 TOC maintainers)
1 shift
$50,000 per year (fully burdened) per maintainer

Replacement Parts and Spare Equipment:
Approximately 5 percent of Hardware Costs (all capital costs except the software cost and cost for TOC)

RELIABILITY

The utility factor representing reliability varies depending on the control logic, the data processing, the number of traffic operations centers (TOCs) and the geographic extent of the system (interim or ultimate). Multiple server control logic and multiple TOCs are considered more reliable, because if one server or traffic operation center goes down, the remaining server or TOC might be able to assume some of the functions of the server or TOC that is unavailable. Even if this redundancy does not exist, only the portion of the system that relied on the single server or TOC would be down, rather than the entire system. With respect to data processing, decentralized data processing is considered more reliable since field data processing can continue to some extent even when central processing capabilities are restricted. Finally, with respect to the geographic extent of the system, the ultimate system would be more reliable because the loop configuration of the fiber optic cable would provide more possible routes for information flow which would provide additional redundancy and minimize the impact of an equipment malfunction or break in the fiber.

FLEXIBILITY

The utility factor representing flexibility varies depending on the data processing (which impacts the capability to operate the field equipment independently of the central server), and the level of centralization (which impacts each state's ability to proceed independently). The level of centralization is defined not only by the number of activities and agencies included in the TOC (transit, emergency responders, etc.), but also by the number of TOCs and the control logic.

EXPANDABILITY

The utility factor representing expandability is affected by the capacity of central control, as well as the communications network and the data processing. Because all alternatives have fiber optics as the basis for communications, and assuming all systems have similar available capacity with respect to central control, decentralized data processing would facilitate expandability because data processing capacity can be added as needed when additional field equipment is implemented.

STAGED DEPLOYMENT

The utility representing staged deployment varies depending on the degree of centralization and the data processing. A more centralized system would be more difficult to deploy in stages, due to the fact that a larger number of agencies would have to be coordinated. Decentralized data processing is more conducive to staged deployment because data processing equipment can be installed concurrent with the staged expansion.

ARTERIAL DIVERSION

The utility representing the ease with which arterial diversion could be implemented is based on the extent to which arterial signal systems on major alternate routes are controlled by the TOC.

INSTITUTIONAL CONSIDERATIONS

The utility representing the feasibility of each architecture with respect to institutional considerations is affected by the level of centralization, the number of TOCs, and the control logic. With respect to the level of centralization, it is assumed that the fewer agencies involved in the deployment and operation of the TOC, the fewer institutional barriers there will be. Similarly, if multiple TOCs and servers are implemented, then presumably fewer agencies will need to cooperate, and fewer institutional barriers will result.

A.2 Weighting Factors

Table A-4 shows the weighting factors recommended by the Steering Committee members.

Table A-4. Steering Committee Recommendations for Weighting of Evaluation Criteria

Criteria		Response								
		1	2	3	4	5	6	7	8	9
k_1	Cost	25	20	25	20	10	15	20	15	20
k_2	Reliability	15	15	25	15	20	15	20	10	40
k_3	Flexibility	10	15	15	10	20	20	15	15	5
k_4	Expandability	20	20	15	20	15	10	15	10	15
k_5	Staged Deployment	10	10	15	20	5	15	15	20	10
k_6	Arterial Diversion	10	5	3	5	10	10	5	10	5
k_7	Institutional Considerations	10	15	2	10	20	15	10	20	5
Total		100	100	100	100	100	100	100	100	100

Appendix B

B.1 Calculation of Benefits

This appendix documents the calculation of the benefits that would be expected to result due to the deployment of a freeway management system. Benefits calculated reflect the value of time saved due to a reduction in incident detection and clearance time.

ASSUMPTIONS

A number of assumptions were necessary for the calculation of the benefits. The assumptions are as follows:

- Peak hour traffic is 10 percent of average daily traffic.
- The directional distribution is 60 percent in the peak direction, and 40 percent in the off-peak direction.
- The number of accidents in the peak hour is based on the accident rate and the volume on the segment. Thus, as is implied by the previous two assumptions, 10 percent of the accidents each day occur in the peak hour, with 6 percent in the peak direction and 4 percent in the off-peak direction.
- Daily benefits are based on 2 peak hours per day (a.m. and p.m.).
- Annual benefits are based on 250 days per year (5 days per week, 50 weeks per year).
- For every accident recorded in the state accident statistics, there are 5 incidents (such as flat tires, stalled cars) that are not recorded.
- An accident in one direction affects flow in the other direction due to rubbernecking. For every minute of delay in the direction of the accident, 0.25 minutes of delay result in the opposite direction.
- Commercial vehicles comprise 5 percent of the traffic and are valued at $25 per hour.
- Passenger vehicles comprise 95 percent of the traffic and are valued at $10 per hour.
- All vehicles in the peak hour benefit from the eight minute reduction in delay per incident. This assumption is made to simplify the estimation of benefits. It is recognized that in actuality, the number of vehicles benefiting from an eight minute reduction in incident delay would depend on the duration of the incident. On one hand, this assumption overstates the benefits because all of the vehicles in the peak hour would not be expected to benefit from an eight minute reduction in incident delay for many of the shorter incidents. On the other hand, the overstatement with respect to the number of vehicles affected may be offset by the fact that for each minute that capacity is reduced due to an incident, up to five minutes of delay may result due to vehicle queuing effects.

EQUATIONS

The equations that describe the calculation of the benefits are as follows:

for the time saved *in the peak direction in fhe peak hour for each minute of incident related delay eliminated:*

$$T_P = V_P * [I_P * (7\ minute) + I_O * (0.25\ minute)]$$

Where: T_P = Time saved in peak hour in peak direction (in minutes)
V_P = Peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction
I_O = Number of incidents in peak hour in off-peak direction

For the time saved in the off-peak direction in the peak hour for each minute of incident related delay eliminated:

$$T_O = V_O * [I_O * (1\ minute) + I_P * (0.25\ minute)]$$

Where: T_O = Time saved in peak hour in off-peak direction (in minutes)
V_O = Off-peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction
I_O = Number of incidents in peak hour in off-peak direction

Converting this to an annual dollar value:

$$\text{Annual benefit} = [T_P + T_O] * \frac{1\text{ hour}}{60\text{ min}} * [(.95)\frac{\$10}{\text{hour}} + (.05)\frac{\$25}{\text{hour}}] * \frac{2\text{ peak hours}}{\text{day}} * \frac{250\text{ days}}{\text{year}}$$

DATA SOURCES

The benefits calculated for each segment depend on the average volume of the facility segment (the number of vehicles affected), and the accident rate (the probability that an incident will occur). Volumes and accident rates used are based on data provided by Kansas Department of Transportation (KDOT) and Missouri Highway and Transportation Department (MHTD).

Volumes are based on 1994 average annual daily traffic (AADT) values. An average value for the segment was taken, when necessary.

The calculation of accident rates varies slightly between the two states. In Kansas, KDOT accident data was provided for the five year period from 1989 through 1993. Accident data is compiled by KDOT for each facility, by county. High frequency accident spots and high frequency accident segments are also identified. High frequency accidents spots are segments (0.1 mile long in urban areas and 0.3 miles long in rural areas) for which the accident rate exceeds the critical accident rate. The critical accident rate is the 95 percentile accident rate for similar roadways in the state. High frequency accident sections are roadway segments that include a number of high accident spots. The length of high accident sections varies, depending on a variety of things, such as geometric characteristics and jurisdictional boundaries.

For the calculation of the accident rate on a given segment, the weighted average accident rate was calculated. This calculation was based on the length and accident rate in the high frequency accident section, as well as the length and accident rate for portions of the facility not in a high accident section. The average accident rate for the county for a certain facility was assumed to be the accident rate for the portions of the facility not in the high accident section.

In Missouri, data from MHTD's Accident Master database was provided for each facility. This data included information about every accident, by milepost, for a one year period (1994 for Jackson County, 1993 for Cass, Clay and Platte Counties).

RESULTS

Tables 6-2 and 6-3 summarize the estimation of benefits for Kansas and Missouri, respectively.

B.2 Estimation of Costs

The estimated cost for each phase was calculated based on the following assumptions.

Roadway Surveillance Equipment - Roadway surveillance equipment includes:

CCTV:

$30,000 each site

1 site each 0.5 miles

Detection:

$10,000 each site

1 site each 0.5 miles

Variable Message Signs - Variable message signs include:

Large fiber optic variable message signs

3 rows, 18 characters per row, 18" characters

$120,000 **per** sign

Quantities based on locations identified for deployment (Chapter 7)

Highway Advisory Radio - Highway advisory radio includes:

Permanent installations

AM Radio

$17,000 per transmitter

$3,000 per sign

Quantities based on locations identified for deployment (Chapter 7)

Field Processors - Field processors include:

Non-intelligent Processors, $10,000 per processor (for example, a Type 170 controller)

1 processor per 0.5 miles

Traffic Operations Center (TOC) - TOC consists of:

New facility built on DOT property

Building sized for ultimate system size
10,000 square foot facility
1 facility
$110 per square foot

Central Hardware - Central hardware includes:
$50,000 per 15 miles of controlled freeway
(Console $5,000, 2 video monitors at $5,000, Computer Workstation $10,000, Miscellaneous $25,000).
$800,000 base
(Video displays $300,000, Two Servers plus Information Server, $400,000, Miscellaneous $100,000).

Software and Systems Integration - Software and Systems Integration includes:
$1,000,000 Phase 1
$250,000 Phase 2 (incremental cost)
$125,000 Phase 3 (incremental cost)
$125,000 Level 4 (incremental cost)

Annual Operating and Maintenance Costs - Annual operating and maintenance costs include:

Traffic Operations Personnel for 1 TOC:
Phase 1 System - 2 operators/shift
Phase 2 System - 2 operators/shift (incremental), 4 total
Phase 3 System - 3 operators/shift (incremental), 7 total
Phase 4 System - 3 operators/shift (incremental), 10 total
3.5 shifts (3 shifts plus 1/2 shift coverage) for 24 hour coverage
$50,000 per year (fully burdened) per operator

Maintenance Personnel for 1 TOC
Phase 1 System - 5 maintenance people/shift
(4 Field maintainers and 1 **TOC** maintainer)
Phase 2 System - 3 maintenance people/shift (incremental)
Total 8 maintenance people/shift
(7 Field maintainers and 1 TOC maintainer)

Phase 3 System - - 7 maintenance people/shift (incremental)
Total 15 maintenance people/shift
(13 Field maintainers and 2 TOC maintainers)
1 shift
$50,000 per year (fully burdened) per maintainer

Phase 4 System - - 7 maintenance people /shift (incremental)
Total 22 maintenance people/shift
(20 Field maintainers and 2 TOC maintainers)
1 shift
$50,000 per year (fully burdened) per maintainer

Replacement Parts and Spare Equipment:

Approximately 5 percent of Hardware Costs (all capital costs except the software cost and cost for TOC)