TASK III

EVALUATE STATE OF THE ART

TRAFFIC MANAGEMENT TECHNIQUES

AND IVHS TECHNOLOGIES

Table of Contents

List of Tables

BACKGROUND

The U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) created the document *IVHS Planning and Project Deployment Process* to serve as a tool for transportation organizations to systematically plan for and implement IVHS technologies as part of an integrated transportation system. In this document FHWA refers to the concept of the "user service" approach to IVHS technology deployment. The deployment of IVHS technologies will produce a set of services to the users of the transportation system. These users may include travelers, drivers, transit operators, commercial fleet operators, regulators, emergency responders, and traffic management personnel. Examples of services could include but are not limited to traveler advisory, trip planning, incident detection, traffic control, vehicle and cargo monitoring, and signal pre-emption.

In order to support FHWA in their efforts towards nationwide deployment of IVHS technologies and services, the MITRE Corporation developed the report *Working Paper on IVHS User Services and Functions*. This report is provided in the appendix of FHWA's document *IVHS Planning and project Deployment Process*. This report provides more details on user services and technologies that support these services.

The Intelligent Transportation Society of America (ITS America) is a nonprofit educational and scientific association incorporated in August 1990. It's mission is to accelerate the deployment of ITS in the United States and is chartered as a utilized Federal Advisory Committee to the U.S. Department of Transportation. In 1992, ITS America identified the development of a national ITS architecture as the program's top research and development priority. Currently, ITS America has identified 29 user services which fall into seven general areas (**Table I-1**). The services that were given as examples in the previous paragraph fit under these seven general areas. ITS America defines these seven general areas as follows:

Travel and Traffic Management services provide an array of information services to help travelers plan trips and avoid delays. These category of services also provides improved surveillance and traffic control procedures and mechanisms to improve transportation system efficiency.

Travel Demand Management services provide information and incentives to manage transportation demand and encourage the use of high occupancy vehicles.

Public Transportation Management services improve the efficiency, safety, and effectiveness of public transportation systems for providers and customers alike. This category of services will make public transportation more attractive to potential customers.

Electronic Payment services automates financial transactions for all modes of surface transportation. This will help reduce delays on fee collection and provide accurate data for systems management.

Commercial Vehicle Operations services streamline administrative procedures, improve safety, and help efficiently manage commercial fleets.

Emergency Management services improve emergency notification and response times and enhance resource allocation.

Advanced Vehicle Control and Safety Systems services provide various forms of collision avoidance and safety precautions. Automated vehicles remain a longer-term objective.

Study User Service Objectives

In Task I, with information provided from survey responders and interviews, the Austin study identified several user service objectives. These services are categorized under the following service areas:

Travel and Traffic Management

- improve incident traffic control
- improve incident communications between agencies
- improve training for incident responders
- improve driver information
- improve communications with other modes

Travel Demand Management

- improve driver information
- improve communication with other modes

Public Transportation Management

- improve automatic vehicle location
- improve communications with other modes

Commercial Vehicle Operations

- improve automatic vehicle location
- improve communications with other modes

Emergency Management

- improve incident communications between agencies
- improve communications with other modes

EVALUATE TECHNIQUES

The Austin study created a matrix (**Table III-1**) in order to identify technologies that would support the desired services. The Austin study identified those technologies users have in use now, have in the planning process, or intend to use within the long term service plan (5-10 years). In addition to the interviews that identified technologies that would support these user services, the Austin study used the MITRE paper to further address technologies that would offer support. To evaluate the performance and reliability of the technologies, the Austin study used the Texas Transportation Institute (TTI*), Evaluation of IVHS Technology for User Services in the Dallas Urban Area*. A draft copy of the report used for the Austin area study has been included in Appendix IIIA.

The Austin Study has identified the "Functional Areas" as follows, in order to categorize the technologies and their support of the user services.

Surveillance Need or Technology - What is the surveillance need or technology.

Traveler Interface - How the traveler will interface with information.

Guidance - What does the user need for guidance.

In-Vehicle Sensors - What in-vehicle sensors does the user need or already have.

Communications, Vehicle and Infrastructure - Communications of vehicle to infrastructure or infrastructure to vehicle.

Communications, Within Infrastructure - Communications from agency to agency.

Communications, Vehicle to Vehicle - Communications from vehicle to vehicle.

Control Strategies - What control strategies can the infrastructure use to provide the service.

Data Processing - What type of data processing is needed to support the service.

The matrix shown on **Table III-1** represents the five identified general areas and the technologies that support them. This matrix is further broken down by general areas and the user services that fit under that area (**Table III-2** thru **Table III-6**). ITS America identifies these user service areas as follows:

Austin ITS Functional Areas									
User Service Area	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
Travel and Traffic Management	Traffic Conditions, Weather, Video Image Processing, Police, Loops,CCTV	VMS, Car Radio, Visual Display, Key Board, Touch Screen	Position Display, Map Database	Odometer, Electronic Compass	Commercial Radio,HAR, Cellular Phones, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Ramp Meter, Lane/Ramp Closings, Signals	Dynamic Database, Static Database, Prediction, Incident Detection
Travel Demand Management	Traffic Conditions, Weather, Video Image Processing, Loops,CCTV	VMS, Visual Display, Key Board, Touch Screen	Position Display, Map Database,	Odometer, Electronic Compass	HAR, Commercial Radio, Cellular Phone	Landlines	Not Yet Determined	Alternate Work Hours,Adjusted Fares,Signals, Ramp Meter, Lane/Ramp Closings	Dynamic Database, Static Database
Public Transportation Operations	Route Information, AVL,Loops, Probes,CCTV Photo Sensors	Visual Display, Key Board, Touch Screen	Position Display, Map Database, GPS	Panic Button, Odometer, Electronic Compass	Beacons, Strobes, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Lane Restriction, Signals	Dynamic Database, Static Database
Commercial Vehicle Operations	Traffic Conditions, AVI,WIM, Weather, Classification	Visual Display, Key Board	Position Display, Map Database, GPS	Odometer, Electronic Compass, Performance Monitoring	Wide Area Two-Way Radio, Celullar Phones	Landlines	Wide Area Two-Way Radio	Lane Restriction, Signals	Dynamic Database, Static Database
Emergency Management	Traffic Conditions, Weather, CCTV, Video Image Processing	Visual Display, Key Board	Position Display, Map Database	Odometer, Electronic Compass	Strobes, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Signals	Dynamic Database, Static Database

Austin ITS Functional Areas_Table III- 1

Travel and Traffic Management

En-Route Driver Information - Driver advisories are given once travel begins. Driver advisories convey information about traffic conditions to drivers of personal, commercial and public transit vehicles. This information allows a driver to select the best route, or shift to another mode mid-trip if desired.

Traffic Control - Integrates and adaptively controls the freeway and surface street systems to improve the flow of traffic, give preference to transit and other high occupancy vehicles, and minimize congestion while maximizing the movement of people and goods. Through appropriate traffic controls, the service will also promote the safety of nonvehicular travelers, such as pedestrians and bicyclists. This service gathers data from the transportation system, fuses it into usable information, and uses it to determine the optimum assignment of right-of-way to vehicles and pedestrians. The real-time traffic information collected by the Traffic Control service also provides the foundation for many other user services.

Incident Management - Enhances existing capabilities for detecting incidents and taking the appropriate actions in response to them. The service will help officials quickly and accurately identify a variety of incidents, and to implement a response which minimizes the effects of these incidents on the movement of people and goods. Traffic movement adjustments over a wide area would be executed through the Traffic Control user service, while decisions at the site of the incident will be made by the police agencies. In addition, the service will help officials to predict traffic or highway conditions so that they can take action in advance to prevent potential incidents or minimize their impacts. While the users of this service are primarily public officials, commercial and transit operators, and the traveling public all benefit from improved incident management capabilities.

Austin ITS Functional Areas									
Travel and Traffic Management User Services	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
En-Route Driver Information	Traffic Conditions, Weather	VMS, Car Radio, Visual Display, Key Board, Touch Screen	Position Display, Map Database	Odometer, Electronic Compass	HAR, Commercial Radio, Cellular Phone	Landlines	Not Yet Determined	Not Yet Determined	Dynamic Database
Traffic Control	Loops, Weather, CCTV, Video Image Processing	VMS	Not Yet Determined	Not Yet Determined	HAR, Commercial Radio	Landlines	Not Yet Determined	Ramp Meter, Lane/Ramp Closings, Signals	Dynamic Database, Static Database, Prediction
Incident Management	Loops, Weather, CCTV, Video Image Processing, Police	VMS, Visual Display, Key Board	Position Display, Map Database	Odometer, Electronic Compass	Cellular Phones, HAR, Commercial Radio, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Lane/Ramp Closings, Signals	Dynamic Database, Static Database, Incident Detection

Travel and Traffic Management Functional Areas_Table III- 2

Travel Demand Management

Pre-Trip Travel Information - Travelers access a complete range of intermodal transportation information at home, work, and other major sites where trips originate. For example, timely information or transit routes, schedule transfers and fares, and ride matching serves are included. Real-time information on accidents, road construction, alternate routes, traffic speeds along given routes, parking conditions, event schedules, and weather information complete the service. Based on this information, the traveler can select the best departure time, route and modes of travel, or decide to postpone or not to make the trip at all. Reducing congestion and improving mobility benefits all potential travelers.

Demand Management and Operations (Renamed from Travel Demand Management) -Generates and communicates management and control strategies that support the implementation of programs to (1) reduce the number of individuals who choose to drive alone, especially to work, (2) increase the use of high occupancy vehicle and transit, (3) reduce the impacts of high polluting vehicles, and (4) provide a variety of mobility options for those who wish to travel in a more efficient manner, for example in non-peak periods. The service allows for employers to better accommodate the needs and lifestyles of employees by encouraging alternative work hours, compressed work weeks, and telecommuting. Travel demand management strategies could ultimately be applied dynamically when congestion or pollution conditions warrant. For example, disincentives such as increased tolls and parking fees could by applied during pollution alerts or when major incidents occur. while transit fares would be lowered to accommodate the increased number of travelers changing modes from driving alone. Such strategies will reduce negative impacts of traffic congestion on the environment and overall quality of life.

Austin ITS Functional Areas									
Travel Demand Management User Services	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
Pre-Trip Travel Information	Traffic Conditions, Weather	Visual Display, Key Board, Touch Screen	Position Display, Map Database	Not Yet Determined	HAR, Commercial Radio, Cellular Phone	Landlines	Not Yet Determined	Not Yet Determined	Dynamic Database
Demand Management and Operations	Loops, Weather, CCTV, Video Image Processing	VMS, Visual Display, Key Board, Touch Screen	Position Display, Map Database,	Odometer, Electronic Compass	HAR, Commercial Radio, Cellular Phone	Landlines	Not Yet Determined	Alternate Work Hours, Adjusted Fares, Ramp Meter, Lane/Ramp Closings , Signals	Dynamic Database, Static Database

Travel Demand Management Functional Areas_Table III- 3

Public Transportation Operations

En-Route Transit Information - Provides the same type if information as pre-trip planning services once public transportation travel begins. Real-time, accurate transit service information on board the vehicle helps travelers make effective transfer decisions and itinerary modifications as needed while a trip is underway.

Public Travel Security - Systems monitor the environment in transit stations, parking lots, bus stops, and transit vehicles and generates alarms either automatically or manually as necessary. This improves security for both transit riders and operators. Transportation agencies and authorities integrate this user service with other anti-crime plans.

Public Transportation Management - Computer analysis of real-time vehicle and facility status will improve operations and maintenance. The analysis identifies deviations from schedule and provides potential solutions to dispatchers and drivers. Integrating this capability with the Traffic Control Service can help maintain transportation schedules and assure transfer connections in intermodal transportation, Information regarding passenger loading, bus running times, and mileage accumulated will help improve service and facilitate administrative reporting. Automatically recording and verifying performed tasks will enhance transit personnel management. Improved efficiency benefits transit providers and customers alike.

Austin ITS Functional Areas									
Public Transportation Operations User Services	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
En-Route Transit Information	Route Information	Visual Display, Key Board, Touch Screen	Position Display, Map Database, GPS	Not Yet Determined	Beacons	Landlines	Not Yet Determined	Not Yet Determined	Dynamic Database, Static Database
Public Travel Security	CCTV, AVL	Not Yet Determined	Position Display, Map Database, GPS	Panic Button	Beacons, Wide Area Two-Way Radio	Landlines	Not Yet Determined	Not Yet Determined	Dynamic Database
Public Transportation Management	Loops, Probes, AVL, Photo Sensors	Not Yet Determined	Position Display, Map Database, GPS	Odometer, Electronic Compass	Strobes, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Lane Restriction, Signals	Dynamic Database, Static Database

Public Transportation Operations Functional Areas_Table III- 4

Commercial Vehicle Operations

Commercial Fleet Management - The availability of real-time traffic information and vehicle location for commercial vehicles would help dispatchers to better manage fleet operations by helping their drivers to avoid congested areas and would also improve the reliability and efficiency of carriers pickup-and-delivery operations. The benefits from this service would be substantial for those intermodal and time-sensitive fleets that can use these ITS technologies to make their operations more efficient and reliable.

Austin ITS Functional Areas									
Commercial Vehicle Operations User Services	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
Commercial Fleet Management	Traffic Conditions, Weather, WIM, AVI, Classification	Visual Display, Key Board	Position Display, Map Database, GPS	Odometer, Electronic Compass, Performance Monitoring	Wide Area Two-Way Radio, Cellular Phones	Landlines	Wide Area Two-Way Radio	Lane Restriction, Signals	Dynamic Database, Static Database

Commercial Vehicle Operations Functional Areas_Table III- 5

Emergency Management

Emergency Vehicle Management - This user service includes three capabilities: fleet management, route guidance, and signal priority. Fleet management will improve the display of emergency vehicle locations and help dispatchers efficiently task the units that can most quickly reach and incident site. Route guidance directs emergency vehicles to and incident location. Signal priority clears traffic signals in an emergency vehicle route. Primary users include police, fire,and medical units.

Austin ITS Functional Areas									
Emergency Management User Services	**Surveillance Need or Technology**	**Traveler Interface**	**Guidance**	**In-Vehicle Sensors**	**Communications**			**Control Strategies**	**Data Processing**
					Vehicle and Infrastructure	**Within Infrastructure**	**Vehicle to Vehicle**		
Emergency Vehicle Management	Traffic Conditions, Weather, CCTV, Video Image Processing	Visual Display, Key Board	Position Display, Map Database	Odometer, Electronic Compass	Strobes, Wide Area Two-Way Radio	Landlines	Wide Area Two-Way Radio	Signals	Dynamic Database, Static Database

Emergency Management Functional Areas_Table III- 6

TECHNOLOGIES

The matrices that have been presented address technologies that will support the user services that have been identified. These technologies and how they will offer support to these services are defined as follows:

Surveillance Need or Technology

Traffic Conditions - Prior to departing travelers, commercial, and emergency vehicle operators could access real-time information on traffic conditions in order to select the best route to get to their destination in order to avoid congested areas. This also provides the option for the travelers to change their mode of transportation or decide to postpone unnecessary trips.

Commercial vehicle dispatchers scheduling delivery routes could access real-time information on traffic conditions in order to aid them. Traffic conditions that report the beginnings of congestion may warn emergency response personnel to be on the alert for possible incidents occurring. While en-route travelers, commercial, emergency vehicle operators can access information on traffic conditions in order to determine if they need to alter the route they are on in order to get to their destination.

Weather - The user services that weather surveillance is listed under would provide them the same information. Prior to departure travelers or commercial vehicle dispatchers could plan their trip or routes based on the weather reports and what effect it would have on roadways condition. If the driver access's this information while en-route he or she could alter their route or change their mode of transportation. Along with weather conditions environmental sensors in the roadways or bridges would monitor the ice conditions of that facility in order for traffic operators to manage and control traffic. Along with traffic operators, emergency response personnel could prepare for incidents and the management of them.

Loops - Inductive loops are the most common form of detection used for traffic management. Loops can provide volume counts, presence detection, and lane occupancy measurements. Loops can be used to detect vehicle speeds by placing two loops a short distance apart. The distance between the loops divided by the time required for a vehicle to travel between the loops provides the speed of the vehicle. Information on the speeds at which vehicles are traveling would aid traffic operators in the detection of congestion, peak demand, or incidents. From this information traffic operators can control and manage traffic. Public transportation agencies would use the information provided from the loops on congestion or incidents to schedule or reroute their transit vehicles.

Closed Circuit Television (CCTV) - This technology has been used for many years for providing visual surveillance on the freeway system. It aids traffic operators in the detection of traffic conditions and conformation of incidents. CCTV systems allow for traffic operators to visually monitor sections of roadway in real-time, and to react directly to the actual conditions on the roadway. CCTV would aid emergency response agencies in the proper dispatch of emergency personnel and vehicles. CCTV systems would also aid in public travel security at transit transfer stations.

Video Image Processing - Video image processing detects vehicles by monitoring specific points in the video image of a traffic scene to determine changes between successive frames. For traffic management these systems can be used for visual surveillance, to obtain measurements of speed, vehicle classification counts, and potentially travel times in detection zones. Traffic operators and emergency response agencies could use this type of technology in place of loops and CCTV in order to detect congestion or incidents. This type of technology would aid emergency response agencies in the proper dispatch of emergency personnel and vehicles.

Police - Mobile police units are sometimes the first to detect or report an incident. Traffic operators could scan the police radio transmissions to become aware of incidents that might or might not be in view of the traffic management area.

Route Information - On board real-time information on traffic conditions and transit routes, schedules and transfers would allow for travelers to make transfer decisions and itinerary modifications.

Automatic Vehicle Location (AVL) - This technology determines a vehicles location relative to a map database. Approximate location of a vehicle can be determined and tracked as it traverses the transportation network. Transit vehicles equipped with an AVL system can be tracked and have their travel speeds monitored in order to determine if they will meet their arrival schedules.

Dispatchers that receive a distress or emergency call from a transit vehicle equipped with an AVL system, could monitor the location or movement of that vehicle.

Probes - Transit vehicles equipped with an on-board computer, and a two-way communications to a control center, or with no on-board computer, but properly equipped for AVI readers, can serve as roving sensors (or probes) to provide travel conditions in the transportation system. These vehicles will provide speed, travel time, and delay along links. This information provided would help in the detection (sensing) of incidents.

Automatic Vehicle Identification, (AVI) - AVI systems use vehicle-based transponders (radio or microwave-based) that can be read by equipment at fixed points to identify the vehicle. A roadside communication unit broadcasts an interrogation signal from its antenna. When an AVI-equipped vehicle comes within range of the antenna, a transponder (or tag) in the vehicle returns that vehicles identification number to the antenna. This technology could be used for identifying commercial vehicles at weight monitoring stations. Dispatchers could use this technology in identifying their vehicles that are overweight.

Photo Sensors - Photo sensors detect the presence of transit or emergency vehicles. It receives the light emitted from the strobe on the vehicle and causes (pre-empts) the traffic signal controller to advance to and/or hold a desired traffic signal display selected from signal phases normally available. The photo sensors internal circuitry transforms the optical energy form the strobes (optical emitter) into electrical signals for delivery via an optical detector cable to the phase selection equipment which in turn sends the signal to the traffic signal controller. Photo sensors have the capability of recognizing the different levels of light to distinguish between transit or emergency vehicles.

Weigh-In-Motion (WIM) - Pavement installed sensors an road mounted processors determine vehicle weight by taking into account axle weights, vehicle length, and vehicle speed. By calculating vehicle characteristics such as length, number of axles, and axle spacing, WIM devices can classify vehicles and determine their compliance with weight standards without requiring commercial fleet operators to stop. This type of technology and the information it provides could also aid transportation engineers in pavement design and management.

Classification - Automatic Vehicle Classification systems are installed in the highway to collect vehicle classification data. These systems can be used in conjunction with weigh-in-motion stations. Automatic vehicle classification systems include sensors which detect the presence or passage of vehicles and detectors which receive the signals from the sensors. They also include a processor which calculates the vehicle length, number of axles, and axle spacing from which the vehicle class is determined and the recorder stores this data.

Traveler Interface

Variable Message Signs (VMS) - (Also referred to as changeable message signs)

VMS's communicate real-time information directly to motorists for warning, regulation, routing, and traffic management purposes. VMS could provide information to motorist on congestion ahead and suggest alternate routes, ride sharing, or alternate modes of transportation. For incident management traffic operators have the capability of not only warning motorist of an incident ahead but also provide which lanes are closed or suggest an alternate route.

Car Radio - Travelers en-route in their personal vehicle will tune to a radio station looking for traffic reports on traffic conditions or incidents, in order to select the best route.

Visual Display - In-vehicle visual displays would provide en-route real-time information to motorists while driving. In the case of congestion or incidents, it would provide the location of the situation and suggest an alternate route. A visual display system would show the location of congestion or an incident. From this the system would provide an alternate route for motorists or commercial fleet operators. These displays also aid emergency vehicle operators in providing the best response route to an incident. Visual displays can also provide pre-trip travel information in the home or office.

Key Board - A key board is a way in which the driver can enter or access information to a computer in the home, office, or vehicle. This device could be used for en-route or pre-trip travel information to access traffic conditions, incidents, navigation, or route selections. Emergency responders would use keyboards in order to access information on incidents they are responding to. Traffic operators would use this device in order to access information on traffic conditions and to output information to motorist on congestion or incident management. Commercial fleet dispatchers would not only use a keyboard to access information on traffic conditions, they would also use a keyboard to determine their pickup and delivery schedules.

Touch Screen - A device that is used for the same purposes as a key board. A touch screen is a convenient means for a user to select on-board system options since the position of the user's finger indicates the function which he or she wishes to invoke. When the user points to an item on the display screen, an infrared light grid overlaying the display screen is broken. Users en-route would access information on traffic conditions, incidents, navigation, or route selections. Users would also use this at home and in the office to access information on pre-trip travel.

Guidance

Position Display - Position displays provide information on the driver's current position in the transportation network. The vehicles position is overlaid on a map to the surrounding street network. For en-route or pre-trip driver information, position display will show where the drivers location is in relation to their intended destination. It will also show where congestion or an incident is located. Transit operators and dispatchers would also use this technology not only for locating their transit vehicles position in order to evaluate the arrival schedules, but also in the event of an emergency they can track their vehicles. Commercial vehicle operators can use position display the same as drivers in order to determine their location in relation to their destination. Commercial vehicle dispatchers would use this technology not only to determine if drivers are on schedule, but also to access information on traffic conditions to determine pickup and delivery schedules. Emergency vehicle operators and traffic operators would use position display to determine location of congestion or incidents. Emergency responders would then use position display to determine their location in relation to the incident.

Map Database - The map database includes the coordinates or other descriptors of the road network for the metropolitan or regional area. This system will include the location of parking lots and other traffic related facilities. The database contains street names including alternate names, speed limits, normal travel times, turn and other time-of-day restrictions. It will also include pertinent traffic control information as a result of maintenance, congestion, or an incident that will support vehicle route selection and guidance. A map database would aid motorists in routing them to their destination prior to trip travel or en-route. It would also aid commercial and transit vehicles in determining their schedule times to their destination. Transit vehicles could also be tracked on a map database when ever a distress call comes in. Guidance from this technology would aid emergency response vehicles to the shortest route to an incident.

Global Positioning Systems (GPS) - The GPS system locates a vehicles position using radio signals broadcast from satellites orbiting the earth. These systems can locate a vehicle in the transportation network with a high degree of accuracy. In order to get an accurate reading on the vehicles, the receiver in the vehicle must receive transmissions from three satellites. This is called a triangulation technique. Travelers, transit, and commercial fleet agencies could use this technology not only for tracking their vehicle location or routes but also for security to ensure their fleets do not wander from designated routes.

In Vehicle Sensors

Odometer - Odometers for the automobile are usually driven by flexible shafts attached to the drive train, and display distances to the nearest 0.1 mile. However, these types of odometers are not accurate enough for navigation and vehicle location. New electronic odometers can accurately measure travel distance in increment smaller than one inch and are used in navigation. Route guidance and navigation systems, especially those systems that use dead-reckoning/map-matching techniques, rely on the odometer to provide accurate distance measurements. Travelers, transit, commercial fleet, and emergency response agencies could all use the vehicles odometers to track their distance to their point of interest, of destination. An electronic odometer would provide an accurate means of distance measurement for a route guidance or navigational system.

Electronic Compass - The electronic compass consists of two electric coils wound around a highly permeable core material. A third coil carries an alternating current which induces an alternating voltage in the coils. The magnitude of the phase shift in the induces voltages depends upon the orientation of the vehicle in the earth's magnetic field. For dead-reckoning and map-matching electronic compass are critical for these systems. They rely on compass readings to accurately determine the heading of the vehicle. The heading in combination with the cumulative distance traveled since the last heading change are used to determine the position of the vehicle in the transportation network. Travelers, transit, commercial fleet, and emergency response agencies that rely on systems for determining their heading would require that they have an electronic compass.

Panic Button - A panic button on transit vehicles provide direct warning to the dispatcher that there is an emergency on the vehicle. If the dispatcher has vehicle tracking or locating capabilities they can automatically start monitoring the location of that vehicle while emergency responders are being sent for assistance.

Performance Monitoring - In-vehicle systems for commercial vehicles would monitor driver fatigue and performance. Driver condition sensors would monitor drowsiness, slow or excessive reactions and take corrective measures. Sensors may include a breathalyzer system which would not allow the vehicle to be started if the driver is intoxicated. Vehicle monitoring systems and enhanced vision systems can aid drivers in perceiving and reacting to hazardous and low visibility conditions.

Communications, Vehicle and Infrastructure

Highway Advisory Radio (HAR) - HAR is a broadcast service provided from low powered transmitters located along the roadway and motorists while en-route would receive it on the vehicle's standard AM radio. The low power of the transmitters allows for a limited range of the broadcast to a few miles. Motorists are instructed to tune to their vehicle radio to a specific frequency through roadside or overhead signs. The information is usually a pre-recorded message, although live messages can also be transmitted. The information being broadcast to motorists is on the traffic conditions ahead. These conditions may involve congestion, accidents, stalled vehicles, traffic or routing patterns caused by construction or special events. Prior to travel travelers within transmission range could access this information through their office or home radios. HAR would aid motorist while en-route to re-evaluate the route their on. It would help on the dissemination of information on traffic control, incident, and demand management.

Commercial Radio - Most commercial radio stations include traffic reports as part of their regular programming during the rush hour periods of the day. The advantage of this approach is that traffic information is reaching a large segment of the driving population with little or no additional cost to the public agency or for specialized in-vehicle equipment. Commercial radio provides information on traffic conditions to travelers prior to travel, and en-route on congestion, accidents, stalled vehicles, and routing patterns. However, the timeliness and accuracy of the information being broadcast is not very reliable.

Cellular Phone - A large number of travelers carry a cellular phone in their vehicles. A majority of incidents that occur out in the transportation network are reported through cellular phones. Motorists or commercial vehicle operators could access a number to call of they want to receive information on traffic conditions in order to plan or make changes to their route prior to travel or while en-route. If they have an on board computer system that provides route selection or guidance they could use a cellular modem to communicate with a control center on real-tome traffic conditions.

Wide Area Two-Way Radio - Wide area radio system offers two-way communication between the traffic management center and a large number of vehicles over a wide geographic region such as a metropolitan area. These systems can be used to broadcast traffic and other travel information to vehicles such as travel times. A control facility can transmit route selection and guidance information to specific vehicles such as emergency response or commercial. This type of communication would greatly aid various emergency response agencies to communicate among each other especially at the site of an incident.

Beacons - Beacons provide localized communications between the infrastructure and vehicles. Data can be transferred to and from the vehicles at high data rates between 400 Kbps and 1 Mbps. To avoid multiple vehicles contending for the same uplink channel to the communication system, the coverage area of a single beacon is limited to less than 100 feet. Therefore, beacons are usually located at intersections or key decision points. Intersection placement allows for specific information to be broadcast to the vehicle. For example, transit vehicles that are coming up to the next stop could receive information on the approaching stopping point. Also, transit vehicles that have an emergency could send out a distress call to the dispatcher via beacons.

Strobes - The strobes or optical energy emitting unit produce precisely timed pulses of high capacity optical energy. Strobes can be programmed to different levels of frequency in order for the photo sensors that tie into the traffic signals to distinguish between emergency response or transit vehicles.

Communication, Within Infrastructure

Landlines - Landlines are the backbone for communication within the infrastructure of a traffic management system and an ITS system. Depending on the required data transmission rates there are three different types of communication mediums that make up the land line system. Those are twisted pair wire, coaxial cable, and fiber optics.

Twisted pair wire are mostly used for traffic signal control and loop detector systems. To minimize interference with information that is being transmitted, two wires are wrapped around each other and covered with a plastic shield. A single twisted pair cable is not used to carry information from several devices to a control center because of the greater capacity requirements of a trunk line system.

Coaxial cable is used to connect numerous traffic control devices to the traffic control center. Coaxial cable is used for transmitting voice, digital, and video data.

Fiber optics use pulsating light wave to transmit data digitally for communication systems. Fiber optic cable provides a high quality transmission of video, data, and voice data. Compared to other mediums, fiber optics allows for transmission of much higher data volumes and video images.

Communications, Vehicle to Vehicle

Wide Area Two-Way Radio - Refer to Vehicle and Infrastructure

Control Strategies

Ramp Metering - Ramp metering uses traffic signals at the freeway entrance ramp to control the demand of traffic entering so that the combined freeway and ramp traffic does not exceed the capacity of the freeway. This promotes a smoother operation on the freeway main lanes by allowing them to adjust their speeds on the outside lane as one vehicle or a small platoon of vehicles are permitted by the traffic signal to enter the freeway.

Lane/Ramp Closings - Closing selected entrance or exit ramps helps to improve traffic flow on freeways that operate at or near capacity. Weaving maneuvers between lanes form vehicles entering and exiting the freeway effectively reduce the capacity of that section of freeway. Ramp closings are used where other control strategies such as ramp metering, have failed to control the demand maintain the desired flow on the freeway. Ramp closings have also been used in the event of an incident in order to control and prevent traffic from the incident site.

Lane closing on a freeway is also a control strategy for improving capacity. Such as, the lane closure on a freeway segment just before an entrance point improves the merging operations on the freeway segment and prevents overflow onto surface streets. Lane closings are also used for advance warning of an incident or maintenance activity.

Signals - Traffic signals allows for control and the orderly progression of vehicles through the transportation network. When traffic signals are properly maintained and timed, improvements in progression, air quality, and fuel consumption can be achieved. Some traffic signal systems may require equipment upgrade to achieve optimum conditions. Advanced communications between a traffic management center and a fully adaptive traffic signal system allow for control to current changing traffic patterns. Ability to control an adaptive traffic signal system would aid in control of traffic during incidents and when congestion is high. Communication between a strobe and the traffic signals would allow for transit and emergency response vehicles to either activate or extend the green time of the traffic signal when responding to an incident or when behind schedule. Commercial vehicles capable of communication with a traffic management center can have the traffic signal they are approaching green time or clearance interval extended to allow for start up time or for the vehicles inability to stop easily.

Alternate Work Hours - Alternate work hours allows for employees to travel in a more efficient manner during non-peak periods. Employers can better accommodate the needs and lifestyles of employees by encouraging alternative work arrangements such as variable work hours, compressed work weeks, and telecommuting. Alternate work hours would help in the reduction of demand on the transportation network during peak periods.

Adjusted Fares - Adjusted fares could be implemented when congestion or pollution conditions warrant. Disincentives such as increased tolls and parking fees could be applied during pollution alerts or when major incidents occur. During pollution alerts or special city events transit fares could be lowered to accommodate the increased number of travelers changing modes from driving alone.

Lane Restriction - Lane restriction applications would allow for transit and commercial vehicles to park in adjacent lanes restricted only for their us. This would allow for these vehicles to load and unload without impeding the flow of traffic.

Data Processing

Dynamic Database - Dynamic database are constantly updated in response to current conditions in the transportation network. Dynamic data includes real-time data that describes an event as it happens. The following are examples of the type of data provided by a dynamic database.

- Loop detector data from a freeway surveillance system or traffic signal system.
- Current location and travel time of individual transit and commercial vehicles.
- Current location and travel time of probe vehicles.
- Current availability of parking at specific parking facilities.

Dynamic databases permit the real-time management of traffic as it occurs. It provides real-time routing of vehicles, adaptive traffic signal control, and dynamic management of transit vehicles.

Static Database - Static databases provide historical information about traffic conditions throughout the transportation network. The following are examples of the historical information static databases can provide.

- Traffic volume and travel time information throughout the transportation network by time-of-day and day-of-week.
- The type and location of traffic control devices in the network.
- Transit schedules and stop locations.
- The locations and cost for parking facilities.

When real-time information is not available static database can provide alternative information.

Static database provides a measure of comparing real-time data against historical data to determine when conditions are out of the ordinary, suggesting some type of congestion which might be recurrent or the result of an incident.

Prediction - Algorithms are being developed to provide real-time traffic prediction on traffic flows, queue lengths, and delays based on current measurements of volume and speed. These algorithms would use real-time origin-destination data obtained from vehicles equipped with an in-vehicles device and two-way communications capability to predict where and when congestion will occur. Information gathered would then be integrated with traffic management and traffic control to provide accurate information on predicted traffic conditions and develop strategies for the best routes and modes of transportation to avoid areas of congestion.

Incident Detection - For incident detection algorithms have been developed for automatically detecting incidents on a freeway system using detector data. The following are the different types of algorithms that are for incident detection.

- Pattern recognition are comparative algorithms. They compare measured traffic conditions to pre-established thresholds.
- Time series uses statistical procedures to detect significant changes in traffic patterns over time.
- Complex theoretical models predict future traffic conditions using traffic measures and historical data.

REFERENCES

The following documents contain information used as the basis for recommendations made in this task. The reader is encouraged to become familiar with these documents.

IVHS Planning and Project Deployment Process, Federal Highway Administration, Version 1.0 April 1993.

IVHS Architecture Development Program, Interim Status Report, IVHS America, April 1994.

ITS Architecture Development Program, ITS America, Phase I, November 1994.

Working Paper on IVHS User Services and Functions, MITRE, November 1992.

This page intentionally left blank.