HNTB

Ohio Department of Transportation-District12

ITS STRATEGIC DEPLOYMENT PLAN

Final Report

April, 1996

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EXECUTIVE SUMMARY

Purpose of the Project

The purpose of this Intelligent Transportation System (ITS) Deployment Study is to identify where and how ITS technologies can be applied to improve the safety, efficiency and capacity of the Cleveland regional transportation network. The generally accepted concept of ITS primarily considers the hardware and software that is used to manage traffic and inform motorists. But deployment of an ITS system involves more than installing the latest technology. It demands an overall strategy which reaches beyond vehicles and highways, and is aimed at increasing the efficiency of the *entire* transportation system. It requires improved cooperation and coordination among the agencies providing transportation services. It also requires the application of effective management techniques to improve operations, real-time monitoring of traffic conditions, and effective communication with the system users.

In addition to dealing with the "what?" and "where?", this study investigates the "who?" It attempts to define possible solutions to the issues that will inevitably accompany new, non-traditional approaches to solving the area's transportation problems.

The Cleveland metropolitan area's transportation network will continue to serve the needs of the community well into the future. But even as planned improvements are completed, they will not be adequate to satisfy the capacity demands. Through the use of advanced surveillance and communication technology, the ITS Strategic Deployment Plan will offer non-pavement alternatives to improve the carrying capacity and efficiency of the transportation network.

Location of the Project

The Intelligent Transportation System (ITS) Early Deployment Study of the Cleveland/Lorain metropolitan area focuses on the expressway system in the region, as well as the US 42/Pearl Road Corridor. By inclusion of the arterial US 42/Pearl Road corridor, the study was improved in two ways. First, the study addresses the interface between the expressway and arterial street system. Secondly, it also allowed the study to better address the role of transit in serving the transportation needs of northeast Ohio.

Existing and Future Conditions

No plan will be effective unless it addresses the actual needs specific to the area where it is to be implemented. An accurate inventory of the existing transportation system therefore forms the foundation for determining how, when, and where ITS technologies can be applied to improve the safety, efficiency, and capacity of the Cleveland regional transportation network.

A data base was created for this study. All the primary routes evaluated for this study were broken down into sections containing information used to assess existing conditions, as well as estimates of future conditions. The end points of the sections match the end points used by the

State of Ohio Department of Transportation in the Annual Traffic Survey Report, allowing traffic counts to be easily updated as new values become available.

Most of the information on traffic volumes for this study was provided by the Northeast Ohio Areawide Coordinating Agency (NOACA), in the form of their Freeway Accessibility Studies for Cuyahoga, Lorain, and Medina Counties, conducted between 1990 and 1993. In addition, their Highway Management Database proved invaluable in updating traffic volumes as new information became available during the course of this study. Information for segments of road not covered by the NOACA Freeway Accessibility Studies or the Highway Management Database came from the Ohio Department of Transportation 1992 Traffic Survey Report and the State of Ohio Route Straight Line Diagram Sections. Existing levels of service (LOS) were calculated for each segment, taking into account local variations in the peaking characteristics of traffic, the effect of trucks, the directional distribution, and the number of lanes in each segment.

All segments of the roads studied were also evaluated for future traffic volumes. Based on year 2010 projections by NOACA and a review by District 12 personnel, computations were performed to extrapolate traffic volumes another ten years into the future, to the year 2020. Volume to capacity ratios, directional design hour volumes, and levels of service were estimated, assuming no further physical construction would take place beyond what has already been programmed.

Accident statistics were then evaluated. Accidents per lane-mile of freeway were computed. A weighted average that factored fatalities and injury accidents was developed (severity index) to rate various roadway segments.

Existing ITS Initiatives

Transportation users of the Cleveland metropolitan area transportation network now enjoy some of the benefits of "ITS-type" services. Radio traffic reporters provide motorists with information about congested location over the air. Drivers can presently obtain local road construction information by calling a toll-free number (1-800-FYI-ROAD). This service is provided by NOACA. An Ohio Department of Transportation (ODOT) interchange improvement project currently under construction at IR-71 and SR-82 (Royalton Road) will have ramp metering equipment installed for the on-ramps. However, the equipment will not be turned on until traffic volumes increase enough to justify its use.

The City of Cleveland has recently completed the installation of a large "closed loop" traffic signal control network in the central business district. The network encompasses 88 traffic signals, divided into six groups of fifteen to eighteen signals per on-street master. Communication from the central monitoring and control computer to each on-street master is by telephone drop, and from each master to the intersection controller by twisted pair cable in new or existing ductwork. The communication network is configured with cross-connecting ductwork and cable, allowing reconfiguration with minimal field work. Local intersection controllers can therefore be easily switched from one sub-system to another should the need arise.

The system allows traffic signal operation in downtown Cleveland to be adjusted from a central location. The City currently uses this feature to adjust traffic signal operation for special events such as baseball games at the Gateway complex. Loop detectors have been installed on some streets around this facility, and additional detectors will be placed throughout the downtown area as funding permits. Hardware upgrades to the traffic signals themselves are scheduled for fiscal year 1997 (July, 1996 through June, 1997).

Many of the smaller municipalities in the study area also have closed loop traffic signal control systems. Others have such systems under construction or in the design stage. Functioning closed loop systems are in operation in Willowick, Wickliffe, Willoughby, Mentor, and Cleveland Heights. Traffic signals along Mayfield Road in Lyndhurst; Chagrin Boulevard, Richmond Road, and Cedar Road in Beachwood; and Mayfield Road, Lander Road, and S.O.M. Center Road in Mayfield Heights are coordinated using closed loop systems. Closed loop systems are under construction in Eastlake, North Olmsted and Rocky River. Painesville, Euclid, Maple Heights, Garfield Heights, Bedford, Parma, Parma Heights, Brook Park, Bay Village, and Westlake have closed loop systems under design. Brooklyn, Independence and Brecksville are considering installing closed loop systems as well.

Of particular interest to this study, funds have been committed in NOACA's FY 1996 Transportation Improvement Program to upgrade traffic signals on US-42 (Pearl Road) during 1997 (between IR-71 and Snow Road in Middleburg Heights and Parma Heights), and in 1998 (from the Cuyahoga County line north to SR-82 in Strongsville). This will include the installation of closed loop systems to improve traffic flow.

As part of the Gateway Sports Complex improvements in Cleveland, changeable message signs were installed on major freeways approaching the downtown area. These signs provide directions to travelers for special events, and can be programmed by ODOT or the City of Cleveland via cellular and dedicated telephone lines. The signs can also be used to display information about incidents with the cooperation of the local police agency.

The Greater Cleveland Regional Transit Authority (GCRTA) and Laketran are also actively exploring ITS technologies to improve transit service in the area. Other local transit agencies may seek to similarly explore ITS technologies as well.

Institutional Issues

In order to make effective ITS deployment a reality within the study area, interagency coordination and cooperation is necessary. This is especially true in a "home-rule" state like Ohio. If cooperation is lacking, this fragmentation will inhibit chances for the successful implementation of ITS services. Many of the officials interviewed for this report believe that cooperation and coordination can be achieved among agencies and political jurisdictions without far-reaching changes to established laws, regulations, or policies.

Extensive legal research supports the above position: most of the policy issues related to freeway operations can be settled within the existing legal framework under Section 5501.44 (B) of the Ohio Revised Code, which covers intergovernmental agreements. The language allows " . . . the design, construction, operation, maintenance and repair of regional traffic management systems" by the State of Ohio through the mechanism of cooperative agreements with " . . . other states, subdivisions thereof, MPO's, or the United States."

User Services and Needs

The National Intelligent Transportation Systems (ITS) program has defined twenty-nine (29) user services as part of the national program planning process. These user services are defined based upon the services or benefits that various users of the transportation system might use or obtain. Users have been defined to include travelers using all transportation modes, transportation operators including DOT's and transit operators, commercial vehicle owners, state and local government agencies as well as many others involved with ITS deployment.

Regional Goals and Objectives

A questionnaire survey was distributed to local, county, regional and state agencies. Questions dealt with perceived user transportation needs, and the priority placed on meeting these needs. The surveys showed that agencies are looking for ITS to:

- Improve travel times
- Increase service through efficient use of resources
- Reduce capital investment in construction
- Promote smooth traffic flow
- Provide a safe and efficient transportation system
- Improve communications to users
- Reduce traffic congestion on a cost-effective basis
- Provide dependable information to the traveling public
- Respond quickly and professionally to emergencies and incidents
- Decrease delay due to incidents
- Promote more efficient modal utilization
- Increase efficiency in providing transit service
- Provide priorities to HOVs.

It is obvious that a common base is indicated by the agencies' suggestions. The project goals were thus defined as:

- *Reduce both recurring and non-recurring traffic congestion by improving the efficiency of the existing transportation system.*

- *Improve the overall safety of the transportation network.*
- *Improve communications to the general public and between transportation providers.*
- *Improve the response time and clearance of emergencies and incidents on the transportation's network.*
- *Promote more efficient modal utilization.*

The questionnaire completed by area agencies also requested the respondents to indicate a priority in funding for meeting the needs of transportation users. The results are:

User Services Implementation Time Frame

User Service	**Implementation Time Frame**		
	Short (0 - 5 yrs)	Medium (5 - 10 yrs)	Long (>10 yrs)
Traffic Control	X		
Incident Management	X		
En-Route Drive Information	X	X	
Traveler Information Services	X	X	
Pre-Trip Travel Information	X		
Demand Management and Operations	X	X	
Emergency Vehicle Management	X		
Public Transportation Management	X	X	
Emergency Notification and Personal Security	X	X	X
Route Guidance		X	X
Hazardous Material Incident Response		X	
Personalized Public Transit	X	X	
Ride Matching and Reservation		X	
Electronic Payment Services		X	
En-Route Transit Information		X	
Public Travel Security			X
On-Board Safety Monitoring			X
Emissions Testing and Mitigation			X
Automated Roadside Safety Inspection			X
Freight Mobility			X
Commercial Vehicle Electronic Clearance			X
Commercial Vehicle Administrative Process			X

Functional Requirements

The Federal ITS Program has defined seven technical functional areas: surveillance, communications, traveler interface, control strategies, navigation/guidance, data processing, and in-vehicle sensors. ITS technologies have each been classified into one of these seven functional areas. While some technologies may be applicable in more than one functional area, each technology is categorized in the functional area in which it is most relevant. Note that all of the user services are provided through technologies from more than one functional area. User services shown in the following table include all of the user services identified as appropriate for implementation in the short and medium time frame in the Cleveland/Lorain metropolitan area.

User Service	Surveillance	Communications	Traveler Interface	Control Strategies	Navigation /Guidance	Data Processing	In-Vehicle Sensors
Traffic Control	X	X		X		X	
Incident Management	X	X	X	X	X	X	X
En-Route Driver Information	X	X	X		X	X	X
Travel Information Services	X	X	X		X	X	X
Pre-Trip Travel Information	X	X	X		X	X	
Demand Management and Operations	X	X	X		X	X	X
Public Transportation Management	X	X		X	X	X	X
Emergency Vehicle Management	X	X			X	X	
Emergency Notification and Personal Security		X					X

System Architecture

The Federal Highway Administration's (FHWA) ITS National Architecture Program is now yielding documents that can be used to engineer a system architecture for the Cleveland/Lorain metropolitan area. As such, in preparing analysis for this metropolitan area's ITS Early Deployment Plan, the FHWA's June 1995 *ITS Architecture, Physical Architecture* document has been referenced extensively. This is important because adhering to the National Architecture when developing an Early Deployment Plan provides a level of confidence that future incremental growth of user services, including growth via the geographic enlargement of metropolitan areas, can be accomplished efficiently, effectively, and in a manner that is compatible with other regional efforts.

The basic system architecture for the early deployment of Intelligent Transportation Systems technologies and processes in the Cleveland/Lorain metropolitan area was evaluated. This architecture provides the framework for an incremental and logical evolution of ITS since it is evident that funding is not currently available for a comprehensive implementation.

Three system design alternatives were developed, i.e. a centralized-, a distributed-, or a hybrid-type architecture. These systems are characterized by:

- the level of coordination between traffic management, emergency service providers, and transit
- type of control logic
- type of data processing
- operations impact
- type of arterial signal control
- communications network complexity.

In addition, estimates of each design alternatives' initial capital costs and annual operating and maintenance costs were estimated based upon staged implementation in both the short-term (0 to 5 years), medium-term (5 to 10 years), and long-term (greater than 10 years) time frames.

Each design alternative was evaluated using a Utility/Cost analysis procedure that simultaneously incorporates cost, system availability, flexibility, expandability, potential for staged deployment, potential for arterial diversion, and institutional considerations. It should be noted that all evaluation criteria were assigned weighting factors based upon a survey of the members of the Cleveland/Lorain Intelligent Transportation System Deployment Study Joint Policy and Technical Committee so as to reflect local needs, institutional concerns, and fiscal realities.

Even though each of the three design alternatives are equivalent from the perspective of satisfying User Service requirements, it is still necessary to determine which one of them implements the User Service requirements most efficiently and most effectively. To do this, the design alternatives were analyzed for cost, system availability, flexibility, expandability, potential for staged deployment, potential for arterial diversion, and institutional considerations.

The results of this analysis are summarized in the following table. The reader is referred to Chapter V of the final report for a detailed explanation of the analysis methodology.

Utility/Cost Analysis Results

UTILITY & COSTS VALUES	Short Term			Medium Term			Long Term		
	A	B	C	A	B	C	A	B	C
Weighted Utility	508	776	745	466	737	703	417	699	661
Annualized Costs	$2.39	$2.10	$2.17	$4.91	$4.62	$4.69	$7.38	$7.08	$7.16
Utility/Cost Factor	213	370	343	95	159	150	57	99	92

A = Centralized; B = Decentralized; C = Hybrid

A distributed system implemented in the short-term time-frame has both the highest utility and the lowest system costs of all alternatives identified in this analysis. Using this as a starting point provides the Cleveland/Lorain Metropolitan area with a high-return baseline system that can evolve over time into a hybrid system or eventually into a centralized system, if deemed institutionally desirable, in order to take advantage of increased economies of scale and additional opportunities for agency coordination that can become available as both personnel and activities are consolidated.

A " model deployment" corridor was selected for the initial evaluation. It consists of the Traffic Control Center, and the IR-71/US-42 corridor. This is the minimum size of deployment that can be expected to produce favorable results. The construction cost of this project were estimated at $22.7 million, with an annual operating cost of about $930,000. The benefit/cost ratio was estimated at 2.73, with a savings of 811,000 vehicle hours of travel and 721,000 gallons of gasoline annually. Emissions would be reduced by 3,026 tons of carbon monoxide, 27 tons of nitrous oxides and 32 tons of hydrocarbons annually.

Technology Assessment

The various technologies that may be used for ITS applications are identified and discussed with respect to their merits and limitations for both near-term and later-term implementations. All technologies are organized into the following categories that parallel four of the main components of any comprehensive ITS package:

- *Vehicle Detection* details both pavement intrusive and non-intrusive installation technologies (i.e. inductive loops or magnetometers vs. overhead sonic or machine vision systems vs. side-mounted microwave systems, etc.), as well as discussions related to advanced in-vehicle technology systems such as automatic vehicle identification and automatic vehicle location / global positioning systems.

- *Incident Verification* details issues related to successfully implementing closed-circuit television camera systems, including physical issues (e.g. camera type, control, and location/mounting), image transmission issues (e.g. fiber-optic vs. coaxial cable, and digital vs. analog signals), and image display issues (e.g. geographically distributed control, video switching, and large screen video).
- *System Communication* details both commercially owned facility options (i.e. dial-up service, dedicated service, packet radio service, cellular service, etc.), and agency owned cable-based and wireless communication options (e.g. twisted-pair cable, coaxial cable, fiber-optic cable, microwave, wireless video, and spread-spectrum radio).
- *Traveler Information* details a variety of issues ranging from the availability and operation of different types of message signs (i.e. changeable message signs vs. various types of variable message signs), to issues regarding highway advisory radio (e.g. operations, transmitters, and antennas), to discussions about successfully implementing kiosks and dial-in systems.

Each of these components can be deployed and utilized jointly, as well as separately. However, their complementary interaction improves overall system operations by providing synergistic information that enables informed traffic management decisions to be made in a manner that could not be provided by any single component operating alone.

As with any technologies, nobody knows for sure what the future holds. However, as described in this technical memoranda, mature, off-the-shelf technologies are available for implementation in each of the above categories such that when combined with competent systems integration and a comprehensive vision for future ITS user-services goals and desires, today's technologies can form the building blocks for the realizing of successful and cost-effective long-term ITS realities.

Incident Management

Many studies document that incidents can have serious impacts on traffic, manifested in terms of congestion (delay) and safety (secondary accidents). A Michigan study estimates that over fifty percent (50%) of all motorist delay on the freeway system is incident related. A California study estimates that under current operations, by the year 2000 approximately 70% of all urban freeway congestion will be due to incidents. A Texas study reports that it is generally recognized that each minute of blockage on a freeway results in five minutes of motorists delay during non-peak commuter hours. However, during peak hours, each minute of blockage results in up to fifteen minutes of delay and queuing delay can be as high as fifty minutes for each minute of blockage.

The Incident Management Program is the foundation from which the Intelligent Transportation System (ITS) is built. The primary function of any Incident Management Program is to protect the safety of persons and property using the roadway and to lessen the likelihood of an incident increasing in severity by restoring the facility to its normal operation and capacity as rapidly as possible.
A successful Incident Management Program consists of six key elements:

- **Detection** - reducing the time required to detect an incident.
- **Verification** - reducing the time required to verify the incident, determine exact location, determine the type of incident and determine the proper response.
- **Response** - reducing the time required to notify the necessary response agencies and offering suggested routes for response units to reach the scene.
- **Traffic Control** - maximizing traffic control to the extent possible under prevailing conditions to reduce the likelihood of additional incidents occurring.
- **Incident Clearance** - clearing the roadway of offending materials as rapidly as possible and restoring the facility to full free-flow capacity as soon as possible.
- **Traveler Information** - providing traveler information throughout the process to assist the traveler in safely passing the scene of the incident or through avoidance of the scene.

Response time is critical to Incident Management. These elements combine to substantially reduce the elapsed time from occurrence to clearance and a return to normal traffic flow.

A committee was formed to assist in the review of current methods and procedures. The committee membership included Police, Fire, 911, EMS, and ODOT personnel. Each committee member is a trained professional involved in incident response and familiar with the local geography.

An incident response questionnaire was developed and answered by committee members. The questionnaire was also mailed to the Police Chiefs' of communities that abut the freeway. The purpose of the questionnaire was to develop a greater understanding of existing practices, identify issues and to solicit suggestions for improvement. This process was not intended to produce statistically valid results or to invite comparison between responders, such as response times.

The questionnaires and subsequent discussions by committee members provided the necessary understanding of existing conditions and the foundation upon which the Deployment Plan was formulated.

Strategic Deployment Plan

The process of deploying high technology equipment on the regions transportation network is a complex one, requiring capital funding for installation, and a stable revenue stream for operation and maintenance expenditures. It also requires extensive interagency coordination and cooperation. No one expects to implement the entire system as a single project. Rather, the system will grow into the final configuration over time as funding becomes available. However, there are certain definitive stages that should occur in sequence, so that the deployment will be successful and cost-effective. It is recommended that Cleveland/Lorain ITS deployment be implemented in stages.

Immediate Action

- Dedicated Service Patrols

The existing *CREWZer* program has demonstrated the value of this service. Based on the assumption that this program will continue, the only action necessary may be route adjustment. The estimated cost for each additional vehicle is $100,000.

- Cellular Telephone Incident Reporting

Cellular telephone incident reporting is important and should be continued. However, the 911 operator must be able to screen calls that are true emergencies (accidents, injuries, spills, lanes blocked, etc.). An educational program with media assistance and roadside signs should emphasize proper use of this system. Estimated costs for the educational program and signs is $25,000.

- Incident Management Task Force

Appointment of an Incident Management Task Force would have many advantages. The Task Force would be responsible for incident response planning, training, development of personnel, equipment and materials resource list, communications, after action reviews of major incidents, etc.

A policy is also needed to ensure cooperation by all responding agencies to block no more lanes than absolutely necessary while responding to an incident. This can be accomplished by developing a uniform policy that would properly define parking of emergency response vehicles. This policy should be developed from within the incident response agencies, with consensus by all involved in incident response. There are no additional costs associated with this recommendation.

- Diversion Route Planning

Diversion route planning should be completed at an early date. Rerouting via surface streets creates many problems and should be examined very carefully before inclusion in any diversion plan.

- Commercial Radio and Television

Commercial radio and television is used to provide traffic condition reports to large numbers of drivers. The incident Management Team should work closely with the media to enhance the accuracy and timeliness of the media reports. There are no additional costs associated with this recommendation.

- Portable Changeable Message Signs

Portable Changeable Message Signs should be considered for use during major incidents, special events, and advance notifications of dates scheduled for full or partial closures of a freeway for construction or maintenance purposes. Recommend purchase of three signs at $45,000.00 each for a total cost of $135,000.00.

- Highway Advisory Radio

Highway Advisory Radio is a cost effective means of reaching large numbers of motorists with traffic and roadway condition reports that can be updated on a continual basis. A detailed site location study should be conducted to determine the optimum location(s) in terms of area coverage and compatibility with the expanded system. The estimated cost of each transmitter is $20,000.

- Reference Markers

Reference markers will permit the person providing incident notification to provide an exact location of the incident. This will result in significantly reduced response times. Signs installed at 1/10 mile spacing and on all ramps would have an estimated cost of $125,000.

Initial System

An initial system can be deployed over those portions of the roadway network identified as having a favorable benefit/cost ratio. An analysis of costs and benefits suggests the following limits (with some flexibility) for the initial system, taking into account: the segments with the highest benefit/cost ratios; the need to maintain continuity of the communications links; and the need to accommodate for diversion routes.

Route	From	To	Distance (miles)	B/C Ratio* (within limits)
IR-71	US-42	Route end at IR-90	13.6	12.06 (4.07)

IR-77	I-480	Route end at IR-90	5.8	23.48 (4.04)
IR-90	Woodward Avenue	SR-175	19.3	12.00 (4.92)
IR-480	0.3 mi W of IR-77	Warrensville Center Road	6.3	1.55 (0.29)
US-42	Drake Road	Route end at Public Square	17.9	3.80 (1.29)
		Total	**62.9**	**10.20 (3.07)**

* The B/C ratio in parentheses reflects the impact of distributing the entire capital cost of the "centers" over a substantially reduced roadway network, albeit with lower "center" operating and maintenance costs associated with reduced staffing.

The estimated construction, and annual operating and maintenance cost of this proposal is $32.12 million and $1.24 million respectively.
The system would be composed of the following elements:

- Automated Detection System

Automated detection is achieved by placing sensors along the roadway. The sensors are programmed to detect speed, occupancy and volume. The data collected by the sensors is sent through a communications network from the sensor to a roadside processor and then to a control computer equipped with incident detection software at the Traffic Operations Center. Typical sensor spacing is 1/2 mile.

- Closed Circuit Television Cameras (CCTV)

Closed Circuit Television Cameras should be installed at approximately one mile spacing (dependent upon view obstructions). The images are transmitted through the communications network to the Traffic Operations Center. Strategic placement of the cameras will also permit viewing of interchanges and surface roadways. Color cameras and monitors are recommended for added clarity.

- Traffic Operations Center (TOC)

Development of the Traffic Operations Center is recommended in the initial system stage. However, this facility must be capable of expansion to meet the added requirements in personnel and equipment necessary to accommodate expansion for both the extended and full systems.

While the system architecture recommended is a distributed system with eventual transition to a centralized system, the potential exists to build the initial traffic operations center under the combined sponsorship of emergency response, transit management and traffic management agencies. The Cuyahoga County Emergency Management Center, the GCRTA and ODOT are actively discussing the possibility of a combined TOC which would incorporate emergency response, transit management and traffic management all in one location. This represents the optimum ITS deployment scenario for the Cleveland/Lorain area, while also having very positive impacts on the operations of the three entities. Laketran is also interested in establishing remote feeds of video and/or sign messages to their dispatch center or directly to their buses via GPS links.

- Changeable Message Signs (CMS)

Changeable Message Signs are recommended at strategic positions within the system. The number and location of the signs will be determined at the design stage. Signs are normally placed a minimum of ¾ mile in advance of decision points. There are several technologies available with multiple choices for the number of lines, the number of characters and the height of the characters. The appropriate devices should be determined as a part of the design phase.

- Highway Advisory Radio (HAR)

The Highway Advisory Radio system may require additional transmitters under this or future stages. Strategic placement of the equipment proposed under the early action phase may avoid additional equipment under this stage. This decision will again be made at the design stage.

Extended System and Full System

The extended and full systems represent extensions and/or expansion of the personnel, materials, and equipment deployed under the early action and initial system stages. Care must be taken during the design of the Initial System to specify equipment and materials that will permit orderly and efficient expansion.

The full system covering all of the freeways studied in Lorain, Medina, Cuyahoga and Lake Counties exhibits a favorable benefit/cost ratio of 2.23. However, it does not make economic sense to build out the entire freeway deployment, especially the segments with lower benefit/cost ratios, without considering the arterial street network that feeds the expressways. While this study considered only a single arterial due to funding and time constraints (US-42, Pearl Road), other major arterials need to be similarly evaluated for suitability of deployment of ITS technology. Candidates to consider are:

- Broadway Avenue
- Brookpark Road
- Carnegie Avenue
- Cedar Road
- Chagrin Boulevard
- Chester Avenue
- Clifton Boulevard
- Euclid Avenue
- Lorain Avenue
- Mayfield Road
- Richmond Road

Installing ITS equipment on arterials will accomplish two goals that will enhance traffic flow on the freeways. With information on current traffic conditions on arterials, it will be possible to more effectively utilize the non-freeway capacity of the balance of the transportation network, allowing short trips to bypass the freeways entirely. Should traffic diversion from freeways become necessary, traffic flow along the planned routes can be favored to alleviate temporary freeway congestion due to incidents or construction. Secondly, providing current traffic conditions on local streets to the public transit operators will allow more exact scheduling that would serve to encourage better utilization of this efficient means of moving people between destinations.

Therefore, it is recommended that the arterial streets be examined for potential ITS deployment, and that the Extended and Full Systems be composed of the highest ranking combination of freeway and arterial streets in Lorain, Medina, Cuyahoga and Lake Counties.

Estimated Benefits

The estimated benefits realized from the implementation of ITS include reductions in travel delay time, fuel consumption, and air quality benefits. Annual benefits of full deployment are compared to the annual benefits of the proposed initial system in the following table. Note that the initial system realizes 93% of the benefits on 31% of the roadways at approximately 40% of the cost of full deployment.

Annual Costs and Benefits

Index	Full Deployment	Initial System
Travel delay benefits, assuming the value of time at $10/hr	$23,088,000	$21,573,000
Fuel use benefits, assuming cost of fuel at $1.20/gallon	$2,463,000	$2,301,000
Miles of coverage	199.4	62.9
Emissions reductions	8,612 tons/year CO 92 tons/year HC 78 tons/year NOx	8,047 tons/year CO 86 tons/year HC 73 tons/year NOx
Annualized Capital Cost (Total capital cost)	$11.4 million ($80.8 million)	$7.8 million ($32.1 million)
Benefit/Cost ratio	2.23	3.07

Contracting Alternatives

There are three primary approaches for contracting ITS-related system design and implementation projects: Consultant/Contractor, System Manager, and Design/Build. The following sections describe each of these types and some of the major advantages and disadvantages of using them to implement Intelligent Transportation Systems.

- Consultant/Contractor Method

The Consultant/Contractor procurement method is the one typically used for highway projects. It is based on the concept that almost all potential construction options are defined in Federal, state, and local *Standard Specifications for Construction* manuals, that critical system parameters can be fully specified and documented in a single set of contract documents (i.e. Plans, Specifications, and Estimate (PS & E) package), that a single contractor is best suited to implement the project, and that the only criterion of significance for selecting the contractor is the initial bid price. For Intelligent Transportation System projects, this approach uses a consultant to perform the feasibility study and system design.

The only advantage to the Consultant/Contractor approach in Intelligent Transportation System projects is that an agency's basic procurement principles are maintained. Thus, ODOT's contracting office would not have to "learn" a new system for ITS-related project implementations.

Disadvantages are numerous. Any and all design "gaps", "buildability" issues, and system integration during project implementation must be addressed by the DOT or another consultant without assistance from the original consultant (i.e. the first consultant's contractual obligations are over at this point). Furthermore, the extensive experience with this process for highway construction has resulted in a very rigid set of procedures and rules within most highway agencies that severely restrict the flexibility of system designers and implementers, and prove to be "...unduly cumbersome and counterproductive when applied to traffic control systems projects involving advanced technologies" [USDOT, FHWA, *Traffic Control Systems, Operations and Maintenance -- Expert Panel Report*, March 10, 1992, p. 21].

- System Manager Method

The System Manager procurement method divides the project into several sub-projects for each of the various sub-systems with the work overseen by a systems manager (consultant) who administers (with the amount of responsibility determined by ODOT) each contract in conjunction with ODOT, and who is responsible for integrating the several hardware and software sub-systems into an overall operating system. The System Manager converts the project plan into preliminary designs and defines sub-systems, develops PS&E packages for sub-systems, helps ODOT oversee the bidding and award of construction contracts, checks the work of implementation contractors, supervises construction, selects and procures computer and communications hardware components, manages the installation of equipment, develops and furnishes the system software, integrates and tests the sub-systems, provides necessary software documentation, and supervises the provision of operator training.

As with the Consultant/Contractor approach, the System Manager approach maintains the basic procurement principles that an agency is accustomed to working with. However, the System Manager approach has the additional advantage of focusing on a single organization and defined source of accountability that is responsible for both detailed design and subsequent software/hardware integration, thus avoiding controversies over responsibility for design problems that may arise. The involvement of agency personnel as part of the design team also results in improved coordination and tighter cost controls. Furthermore, because the agreement between the agency and the system manager is a negotiated professional services contract, which can more easily be adapted as project needs are refined, increased flexibility is provided to meet the specific project requirements. This approach also provides for the selection of contractors with specific sets of skills for each of the sub-systems. For example, one contractor can be hired

to do the earthwork and install the conduit, while another contractor can be hired to integrate and test the electronics within the communications subsystem, etc.
A potential disadvantage to the System Manager approach, however, is that detailed specifications must be developed to define each subsystem in order that an agency can receive bids and let contracts for each of the major subsystems.

- Design/Build Method

In the Design/Build approach, the DOT issues a single contract with a Design/Build team who is selected to handle all of the work associated with implementing the system. Any and all other necessary contracts with subcontractors are administered and paid for by this single entity, which maintains the ultimate responsibility for subcontractor performance and any cost overruns. For example, the Design/Builder is responsible for all aspects of the system, including detail system design, procurement of all equipment, construction of all system elements, integration of the various sub-systems, and final system checking, tweaking, and operational transfer of a fully functional system to the client. Except for the Design/Build feature of transferring all responsibility from a procuring agency to the Design/Build team, it is in practice very similar to the System Manager approach. It should be noted, however, that even though the "...the [State of Ohio] Director of Transportation may establish a pilot program to expedite the sale and construction of no more than six special projects by combining the design and construction elements of a highway or bridge project into a single contract" [Ohio Revised Code Section 5517.011], the use of this approach in the State of Ohio may not be available for ITS-related projects because the Design/Build concept is still in the experimental stage for traditional Ohio Department of Transportation (ODOT) construction projects.

Since the Design/Build approach combines both the design and construction of an ITS-related project into a single contract, it can result in a better understanding of the designer's intent by the builder, can eliminate the schedule overruns that result from potential conflicts and communication gaps between engineers and contractors, can potentially decrease the number of after-bid changes, and can reduce completion times by streamlining the equipment procurement process via allowing critical components to be ordered and sub-contracts let as soon as engineering details are completed (e.g. Design/Build eliminates the step-by-step procedure of traditional contracting methods whereby one entity must complete their phase before the next entity can proceed with the project). Design/Build also eliminates time consumed in bid preparation and contract award analysis for separate architectural, engineering, and/or contractor entities while at the same time retaining competition through one unified Design/Build price proposal.

A disadvantage to the Design/Build approach, however, is that it places a significant burden on the procuring agency to oversee the design and implementation activities and to ensure conformance to the design concept -- activities that many traditional transportation agencies may not have the in-house expertise to accomplish.

Recommendation

The **System Manager** approach to ITS-related procurement and project implementation is recommended because it provides the most flexibility, enables the greatest degree of control over technical features and system cost, and allows for the ability to obtain an optimum mix of contracting resources for each segment of the project. In addition, the System Manger concept has been successfully used on several major traffic management and incident management systems around the country because it is an approach that recognizes the complexity of these systems, especially when viewed from the context of traditional highway construction projects. Furthermore, other major industry segments in both the public- and private-sector use it to successfully implement projects with similar elements of multi-discipline and advanced technology challenges.

Financing Alternatives

Intelligent Transportation Systems (ITS) projects are of such diverse scope that many unique combinations of existing Federal, State, local, and private financing opportunities are available to help build and operate these systems.

Sources of federal funding include, but are not limited to:

PROGRAM	ELIGIBILITY		
	Routes / Areas	Capital Costs	Operating Costs
National Highway System (NHS) program	All Interstates, most urban & rural principal arterials, & the defense strategic highway network & connectors	YES	YES (for unlimited number of years if annually placed in an area's formal TIP)
Surface Transportation Program (STP)	All public roads (including NHS routes) except those classified as local or rural minor collectors	YES	YES (for unlimited number of years if annually placed in an area's formal TIP)
Congestion-Mitigation Air-Quality (CMAQ) program	Public roads in areas the Clean Air Act designated as being in non-attainment for ozone and carbon monoxide as of Federal fiscal year 1994	YES	YES (typically limited to three-years or as long as FHWA/EPA deem operations funding for a particular ITS project helps air quality)
ITS Corridors program	Funding primarily for use in up to ten corridors specifically designated by the USDOT. Limited "left-over" funds may be available for other areas	YES*	YES* (no specific limitations)
Other ITS Activities	Nationally-competitive funding for specific ITS projects. Has	YES*	YES*

PROGRAM	ELIGIBILITY		
	Routes / Areas	Capital Costs	Operating Costs
section of IVHS Act of 1991	traditionally been used to fund “operational field tests” and other “early deployments”		(no specific limitations)

***All** funds made available to states under the *ITS Corridors* program and the *Other ITS Activities* section of the *IVHS Act of 1991* require dollars to be obligated to specific projects within one year after the fiscal year they are made available, or be subject to being sent back to Washington, D.C. for re-allocation to other states for use on their ITS projects.

Additional funding may also be available from State and local sources.

Finally, another potential source of funding for the deployment of ITS in the Cleveland/Lorain metropolitan area comes from the creation of public-private partnerships. However, present legislation covering public-private partnering in the State of Ohio offers very little incentive for private parties. While the law does allow contributions by private entities, it prohibits joint business ventures. The law also requires that the public entity retain sole ownership and full control of the contributed funds and the project. Finally, the public entity benefiting from the contribution cannot show preferential treatment to any private entity, even if the private entity provided the funds. Major new state legislation will be required to broaden the ability to create successful ITS partnerships.

Deployment Plan Adoption Process

The following Deployment Plan adoption process is recommended:

1. ITS Policy Committee recommends plan to ODOT/FHWA.
2. ODOT/FHWA review and endorsement.
3. ODOT Recommends plan to NOACA, for adoption through its committee process.
4. NOACA Board Adopts Plan.

Subsequent to Deployment Plan adoption by NOACA, any project using federal funds would also have to go through a process as follows:

1. A project sponsor would have to identify a project.
2. The project would have to compete for priority with the other projects using federal funds.
3. The project would be placed on the fiscally constrained area wide Transportation Improvement Plan.

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CHAPTER I. EXISTING AND FUTURE CONDITIONS

A. Introduction

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) established new priorities in transportation system policy in the United States. Recognizing that accommodating increased demand by building new roads is not a viable option in an era of limited funding, this legislation emphasizes the need to increase the safety and efficiency of existing transportation facilities through the application of advanced communication and monitoring technology.

Several initiatives were launched under Title VI, Part B of ISTEA, to research, develop, test, and promote Intelligent Transportation Systems (ITS), formerly IVHS (Intelligent Vehicle-Highway Systems) in the United States. In response to this legislation, the FHWA has developed guidelines and support for planning and deployment of ITS technology. Many urban areas now recognize that ITS can be a viable solution to traffic problems.

In the Cleveland metropolitan area, the Ohio Department of Transportation District 12 has taken the lead on developing a Congestion Management System (CMS). The Northeast Ohio Areawide Coordinating Agency (NOACA) is planning the implementation of several other ITS systems: the Safety Management System (SMS), the Public Transportation Management System (PTMS), the Intermodal Transportation Facilities System (ITFS), and the Traffic Monitoring System (TMS). This study provides the framework upon which to base the design of an areawide ITS for the Cleveland metropolitan area.

B. The Role of ITS

The generally accepted concept of ITS primarily considers the hardware and software that is used to manage traffic and inform motorists. But deployment of an ITS system involves more than installing the latest technology. It demands an overall strategy which reaches beyond vehicles and highways, and is aimed at increasing the efficiency of the *entire* transportation system. It requires improved cooperation and coordination among the agencies providing transportation services. It also requires the application of effective management techniques to improve operations, real-time monitoring of traffic conditions, and effective communication with the system users.

Identifying the appropriate user services is basic to the ITS planning process as defined by the FHWA. No plan will be effective unless it addresses the actual needs specific to the area where it is to be implemented. An accurate inventory of the existing transportation system will therefore form the foundation for determining how, when, and where ITS technologies can be applied to improve the safety, efficiency, and capacity of the Cleveland regional transportation network.

C. Study Area

The purpose of this study is to identify where and how ITS technologies can be applied to improve the safety, efficiency and capacity of the Cleveland regional transportation network. Accordingly, the area studied includes all of Cuyahoga County, and selected road segments in Lorain, Medina, Summit, Geauga, and Lake Counties (Figure I-1).

The metropolitan study area contains thousands of miles of roadway, from interstates and expressways down to local distributor roads. The City of Cleveland is further served by a major freshwater port on Lake Erie, an international airport, a downtown lakefront commuter airport, numerous freight rail lines, and an extensive network of public transportation routes serviced by buses and light and heavy rail rapid transit lines. The scope of this study is limited to interstates and freeways, and selected highways. The State of Ohio Department of Transportation has jurisdiction over these roads in unincorporated areas, and by special agreement, within the city limits of Cleveland. In other incorporated areas, due to Ohio's "home rule," the incorporated entity has jurisdiction.

Three freeways pass through the study area in a north-south direction. IR-71 is the westernmost, IR-77 is located centrally, and IR-271 is to the east. All three freeways pass through the southern suburbs of the study area. The two western freeways, IR-71 and IR-77 are about nine miles apart here, converging as they approach Cleveland's central business district. They terminate in downtown Cleveland, where they join IR-90, a major east-west freeway that extends across the State of Ohio. IR-271 passes through the eastern suburbs of Cleveland, and joins IR-90 east of Cleveland at its northern end. South of the IR-480 junction, IR-271 and IR-480 run concurrently to the Summit County border.

Two freeways traverse the study area in an east-west direction. IR-90, which extends through the State of Ohio, approaches Lake Erie from the southwestern part of the study area, passes through the central business district of Cleveland, and continues eastward along the lake toward Erie, Pennsylvania and Buffalo, New York.

IR-480 is located south of IR-90, and serves as a bypass for east and west through traffic. It begins in Lorain County, just west of the Cuyahoga County line, at the Ohio Turnpike (IR-80), continues east through the southern suburbs of Cleveland, and joins IR-271. IR-271 and IR-480 run concurrently in a southerly direction to the border of Cuyahoga County and Summit County. The Ohio Turnpike has not been directly included in this study due to funding constraints. However, any ITS initiatives that may develop on this toll facility will be investigated and incorporated into the final report.

Several other freeway and highway segments have been included in this study, based on traffic volumes. US-6 From Lake Avenue to IR-90 provides access to the central business district from the west lakefront communities. IR-490 connects IR-90 with IR-77 just south of the downtown area. Part of SR-2 in Lorain County, from Baumhart Road in Vermilion to the junction with IR-90 just east of the Ohio Turnpike is included. At the eastern end of the study area, SR-2 from where it splits off from IR-90 to SR-283 (Richmond Street) in Lake County is included. SR-44 between IR-90 and SR-2 is included as well. In Lorain County, US-20 from Parsons Road to SR-57, and SR-10 from SR-57 to IR-480 is included.

In Geauga County, US-422 from IR-271 in Cuyahoga County to SR-306 is included. Another segment that is part of the study is the proposed Jennings Freeway (SR-176F) which will connect IR-71 with IR-480 and Brookpark Road.

Table I-1 lists the roads initially evaluated. Figure I-1, following, graphically depicts the locations of these roads.

Table CHAPTER I. -1. Initial Roads Studied

Road	Start	End	County
IR-71	SR-303	Cuyahoga County line	Medina
	Medina County line	IR-90	Cuyahoga
IR-77	IR-271	Cuyahoga County line	Summit
	Summit County line	IR-90	Cuyahoga
IR-90	SR-2	Cuyahoga County line	Lorain
	Lorain County line	Lake County line	Cuyahoga
	Cuyahoga County line	SR-44	Lake
IR-271	Summit County line	IR-90	Cuyahoga
IR-480	IR-80	Cuyahoga County line	Lorain
	Lorain County line	IR-271	Cuyahoga
IR-480N	IR-480	IR-271	Cuyahoga
IR-490	IR-90	IR-77	Cuyahoga
SR-2	Baumhart Road	IR-90	Lorain
	IR-90	Lake County line	Cuyahoga
	Cuyahoga County line	SR-283 (Richmond St.)	Lake
SR-10	SR-57	IR-480	Lorain
SR-44	IR-90	SR-2	Lake
SR-176F	SR-17	IR-71	Cuyahoga
SR-237	Sheldon Road	SR-17	Cuyahoga
US-6	Lake Avenue	IR-90	Cuyahoga
US-20	Parsons Road	SR-57	Lorain
US-422	IR-271	Geauga County line	Cuyahoga

	Cuyahoga County line	SR-306	Geauga

D. Methodology

Most of the information on traffic volumes for this study was provided by NOACA, in the form of their Freeway Accessibility Studies for Cuyahoga, Lorain, and Medina Counties, conducted between 1990 and 1993. NOACA staff performed detailed calculations to determine existing levels of service (LOS) on the freeways, taking into account local variations in the peaking characteristics of traffic, the effect of trucks, the directional distribution, and the number of lanes in each segment. Additional information came from NOACA's "Highway Management System" database.

Information for segments of road not covered by the NOACA Freeway Accessibility Studies came from the Ohio Department of Transportation 1992 Traffic Survey Report and the State of Ohio Route Straight Line Diagram Sections. Similar calculations were performed to determine levels of service.

The level of service (LOS) is an indication of how much of the theoretical capacity per lane of the freeway (generally accepted at 2,200 to 2,300 vehicles per hour) is being used in the peak direction. Level of service "A" is indicative of free flow conditions, with traffic volume low relative to capacity. Federal and State guidelines list LOS "C" as the minimum desired condition on freeways, since traffic flow is smooth and stable at this level, and traffic volumes are high without excess restrictions on freedom to maneuver. Level of service "D" represents a traffic stream that has little space to absorb disruptions. Level of service "E" indicates the density at which capacity occurs for different free-flow speeds and different widths of freeway. LOS "F" indicates congested operation, with forced flows and stop-and-go operation. At this level, the road acts as a storage area.

Accident statistics were evaluated. Several statistics were calculated to provide insight into trends. Accidents per lane-mile of freeway were computed. A weighted average that factored fatalities and injury accidents was also developed (severity index) to rate various roadway segments.

All segments of the roads studied were also evaluated for future traffic volumes. Based on year 2010 projections by NOACA, computations were performed to extrapolate another ten years into the future, to the year 2020. Volume to capacity ratios, directional design hour volumes, and levels of service were estimated, assuming no further physical construction would take place beyond what has already been programmed. (Programmed improvements are described in Section I-M).

E. Study Area Revision

After evaluating the future levels of service, it became apparent that some freeway segments maintained an acceptable level of service through the end of the study period. These segments were selectively removed from further study, while maintaining route continuity. In their place a parallel arterial route was selected (US-42, Pearl Road). This route was then evaluated for levels of service and accident trends, and included in the study to broaden the scope, and provide for a sample deployment which would demonstrate the architecture's flexibility. The revised study area is shown in Figure I-2.

Figure CHAPTER I. -1. Original Study Area

Figure CHAPTER I. -2. Revised Study Area

F. Existing Traffic Volumes

According to the Northeast Ohio Areawide Coordinating Agency (NOACA) 1991 Average Daily Traffic (ADT) maps, and their Freeway Accessibility Study Update for Lake and Cuyahoga County (May, 1993), one of the most heavily traveled section in the metropolitan area is the Innerbelt, where IR-71 and IR-77 end at IR-90, just south of the Cleveland central business district. Since these reports used data from 1988 through 1990, more recent (1992) information was obtained and evaluated.

Between the termini of IR-71 and IR-77, the Innerbelt carries an estimated 135,000 vehicles per day. To the east and southeast, IR-90 and IR-77 carry in excess of 125,000 vehicles per day on their busiest links. Further west, IR-90 carries approximately 100,000 vehicles per day, and IR-71 about 109,000 vehicles per day. Traffic volumes on the Outerbelt reach levels of 119,000 vehicles per day on IR-271, and 129,000 vehicles per day on IR-480.

A data base was created for this study using Microsoft's Excel (Version 5.0) spreadsheet. All the primary routes evaluated for this study were broken down into sections containing information used to assess existing conditions (such as traffic volume, number of lanes, percent of trucks, directional peak hour volume/capacity ratio and level of service), as well as estimates of future conditions. A summary listing is contained in Appendix A. The Appendix also contains a summary of the calculation methodology.

Figure I-3 depicts current traffic volumes, and Figure I-4 the associated Level of Service (LOS) during peak periods. Figure I-5 depicts truck volumes.

1. IR-71

Interstate Route 71 is a north-south highway traversing Cuyahoga County in the southwest quadrant. The portion of the highway from State Route 303 to the Cuyahoga County line in Medina County is also included in this study. The study segment ends at the junction with IR-90 and IR-490 near the Cleveland central business district.

Average daily traffic (ADT) in 1992 ranged from a low of 47,400 on the segment between SR-303 in Medina County and the Cuyahoga County line, to a high of 108,690 between Snow Road and IR-480. The road section varies from four to eight lanes. There are four lanes from SR-303 in Medina County up to US-42 (Pearl Road) in Cuyahoga County. All other segments have six lanes, except for a stretch from IR-480 to Fulton Road, which has eight lanes. Right at IR-480, where the Airport Freeway (SR-237) junction is located, the road section narrows to four lanes, creating a bottleneck.

Most of the freeway in the study area operates at or below level of service (LOS) D, indicating congestion exists during peak periods. The highest volume to capacity (V/C) ratio has been calculated for the segment between US-42 (Pearl Road) and the Ohio Turnpike, where there are only four lanes, and an ADT of 74,400, yielding a value of 1.02. Uncongested (LOS C) operation occurs only between Denison Avenue and US-42 (West 25th Street), where there are eight lanes.

2. IR-77

Interstate Route 77 is a north-south highway traversing central Cuyahoga County. The portion of the highway from IR-271 to the southerly Cuyahoga County line in Summit County is also included in this study. In Independence, IR-77 connects with IR-480. This connection, along with the IR-71 connection to IR-480, provide good access to the central business district not only from the southern communities, but from those far to the west and east as well. IR-77 continues north to the southern edge of the Cleveland central business district, and ends at the junction with IR-90, at the Innerbelt.

Average daily traffic (ADT) in 1992 ranged from a low of 28,200 on the segment south of Miller Road in Summit County to a high of 126,200 between SR-21 (Brecksville Road) and Grant Avenue in Cuyahoga County. The road section varies from four to six lanes. There are four lanes from IR-271 in Summit County up to Pleasant Valley Road in Cuyahoga County. All other segments have six lanes, except for short stretches of four lane sections between Rockside Road and Brecksville Road around IR-480, and between IR-490 and East 30th Street.

South of SR-82 (Royalton Road), the freeway in the study area operates LOS C or better. North of this point, the level of service deteriorates. From IR-480 all the way north of IR-490, the level of service is at F, with the segment at SR-21 (Brecksville Road) operating at a volume/capacity ratio of 1.28. The highest volume to capacity (V/C) ratio has been calculated for the segment between IR-490 and US-422 (Woodland Avenue), where there are only four lanes, significant truck volumes (12.3%) and an ADT of 87,250, yielding a value of 1.39.

3. IR-90 and IR-490

The IR-90 freeway passes through the study area in an east-west direction. The study segment starts to the west of Cleveland, in Lorain County, where SR-2 joins IR-90 shortly after it splits off from the Ohio Turnpike (IR-80). It continues through Cuyahoga County, through SR-44 in Lake County. The study segment ends in Concord Township, Lake County, at SR-44. There are multiple access points along this freeway, to local arterials and other freeways. IR-490 is a short connector that allows traffic from IR-90 access to the southeast via IR-77.

Average daily traffic (ADT) on IR-90 in 1992 ranged from a low of 37,800 at SR-306 (Broadmoor Road) in Lake County to a high of 134,600 between Fairfield Avenue and Broadway Avenue (US-422) in southern Cleveland. Volumes here have decreased with the opening of I-490 in September of 1990. I-490 bypasses downtown Cleveland, and runs easterly from the IR-71/IR-90 junction to IR-77. The road section for IR-90 varies from four to eight lanes. IR-490 is mainly eight lanes, with six lanes between Broadway Avenue and the IR-77 east junction. Most of IR-90 is eight lanes within the study area. There are four lanes in Lorain County and western Cuyahoga County. In Lake County, the road section changes from six to four lanes in Willoughby, east of SR-174.

In Lorain County, IR-90 operates at LOS C, except within the corporate limits of Elyria, where it operates at LOS D. Most of IR-90 in Cuyahoga County operates at or below LOS D. The highest volume to capacity (V/C) ratio has been calculated for the segment at the IR-71/IR-90 junction, where IR-90 traffic negotiates ramps to make a right angle turn to the north. The ADT is 123,600 over a four lane section, yielding a value of 1.88.

There was no mainline congestion on IR-490 in 1992. Volumes were from 20,200 to 45,800, with corresponding LOS B. The busiest segment was between the IR-71/Jennings Freeway junction and West 7th Street. A follow-up study in 1994 by NOACA confirmed that main-line traffic on IR-490 was uncongested. However, at the IR-77 junction, volumes were high enough to result in congested operation during the AM peak on the IR-490 eastbound to IR-77 southbound ramp.

4. IR-271

Part of the Outerbelt, IR-271 runs north and south through eastern Summit, Cuyahoga, and Lake Counties. The segment included in this study begins at the Cuyahoga/Summit County line, where IR-271 runs concurrently with IR-480, continues through eastern Cuyahoga County, intersecting with IR-480 and US-422, and ends in southwestern Lake County, where it joins IR-90. IR-271, along with IR-480 serves as a circumferential freeway in Cuyahoga County. These route bypass the City of Cleveland, and facilitate access from Lorain County to points south and east of Cleveland.

Average daily traffic (ADT) in 1992 ranged from a low of 45,200 on the segment from the Summit County line to the south corporate limits of Oakwood, to a high of 118,600 between SR-175 (Richmond Road) and the south corporate limits of Beachwood (Harvard Road). The road section for IR-271 varies from four to six lanes.

Most of IR-271 in the study area operates at or below LOS D. The highest volume to capacity (V/C) ratio has been calculated for the segment between the IR-271/IR-480/US-422 junction and SR-175 (Richmond Road) where there are only four lanes, and an ADT of 107,860, yielding a value of 1.49.

5. IR-480 and IR-480N

Interstate Route 480 begins at its junction with the Ohio Turnpike (IR-80) in western Lorain County. It also forms a junction with SR-10 about 1.3 miles to the east. The freeway continues east through the central part of Cuyahoga County, forming part of the Outerbelt, to Bedford

Heights, where it joins IR-271. A short segment, IR-480N, provides a freeway to freeway junction with IR-271 and US-422. Other freeway to freeway junctions at IR-71 and IR-77 provide connections to Cleveland and the southern suburbs of Cuyahoga County. IR-480 runs concurrently with IR-271 from the IR-480N/US-422 junction in a southerly direction to the Summit County line.

Traffic volumes in 1992 ranged from 22,500 to 129,300. The lowest volume was found on the segment just east of the IR-480/IR-480N junction in northern Bedford Heights, from Northfield Road to the Frontage Road Ramps. The highest volume was on the segment from Lee Road to Warrensville Center Road. Most of IR-480 has eight lanes, but there are segments of six lane sections, and short stretches of four lane segments as well.

Most of IR-480 operates at LOC D or E. Level of service F occurs at the Airport Freeway junction (SR-237), the IR-77 junction, and between Warrensville Road and the IR-480N junction. The highest volume to capacity (V/C) ratio has been calculated for the segment at SR-237 (Rocky River Drive), with an ADT of 97,800 traveling over a four lane section, yielding a value of 1.50.

Average daily traffic on IR-480N was approximately 67,500, with LOS E for the entire roadway. IR-480N has four lanes.

6. SR-2

State Route 2 is an east-west urban radial freeway along Lake Erie. Two segments are included in this study. The first starts at Baumhart Road in Lorain County, and continues eastward to IR-90. The second starts at IR-90 in eastern Cuyahoga County, just before the Lake County line. In Lake County, SR-2 runs parallel to IR-90, between that freeway and the shore of Lake Erie. The study segment ends in Painesville Township at SR-283 (Richmond Street). SR-2 runs concurrently with IR-90 and US-6/20 between the two segments just described, and traffic characteristics on this stretch are described in Section III-A-3 and III-A-11.

In Lorain County, traffic volumes in the study area in 1992 ranged from 25,000 to 44,900. The lowest volume was found on the segment from Baumhart Road to Oak Point Road. The highest volume was on the segment from Middle Ridge Road to the SR-2/IR-90 junction. All segments of SR-2 in Lorain County consist of four lanes.

All of SR-2 in Lorain County operates at LOC B, except the segments at SR-58 (Leavitt Road) and Middle Ridge Road, which operate at LOS C (V/C ratio of 0.51 and 0.58, respectively).

In Lake County, traffic volumes in the study area in 1992 ranged from 42,200 to 87,600. The lowest volume was found on the segment from Heisley Road to SR-44, at the eastern limit of the study area. The highest volume was on the segment just east of the IR-90 junction to SR-633 (Lloyd Road). SR-2 has six lanes up to SR-640 (Vine Street), where it drops down to four lanes.

Most of SR-2 within the study area in Lake County operates at LOC C. Exceptions are from the Cuyahoga County line to SR-91 (LOS D), and from SR-640 (Vine Street) to SR-306 (Reynolds Road), where it operates at LOS E. Past Reynolds Road, the LOS returns to C as volumes decrease.

The highest volume to capacity (V/C) ratio has been calculated for the segment in Mentor, between SR-640 (Vine Street) and Lost Nation Road with an ADT of 70,500 traveling over a four lane section, yielding a value of 0.96.

7. SR-10 and US-20

A portion of SR-10 in Lorain County was initially included in this study, since this road, along with US-20, feeds traffic from the southwestern quadrant of the study area into IR-480, which starts just north of the Ohio Turnpike. The western limit of the study area was Parsons road, where SR-10 and US-20 run concurrently. US-20 breaks off to the north at SR-57, but SR-10 continues in a northeasterly direction past the Ohio Turnpike, where it ends at IR-480.

In Lorain County, traffic volumes in the study area in 1992 ranged from 11,000 to 25,400. The lowest volume was found on the segment between Parsons Road and SR-301. The highest volume was on the segment at SR-57. All segments of the highway in the study area consist of four lanes.

This road operates at LOS B or better. The highest volume to capacity (V/C) ratio has been calculated for the segment of SR-10/US-20 at the SR-57 junction with an ADT of 25,400 traveling over a four lane section, yielding a value of 0.34.

8. SR-44

State Route 44 serves as a north-south connector between IR-90 and SR-2 in central Lake County, at the eastern limit of the study area.

In Lake County, traffic volumes in the study area in 1992 ranged from 12,500 to 24,300. The lowest volume was found on the segment from SR-84 (Ridge Road) to US-20 (Mentor Avenue). The highest volume was on the segment from Jackson Street to the SR-2 junction. All segments of SR-44 in the study area consist of four lanes.

All of SR-44 in Lake County operates at LOC A, except between Jackson Street and the northern end of the study segment at SR-2 in Painesville, where the level of service is B. The highest volume to capacity (V/C) ratio has been calculated for this same segment of SR-44, with an ADT of 24,300 traveling over a four lane section, yielding a value of 0.34.

9. SR-176F

This road is also known as the Jennings Freeway. It is an expressway that will connect IR-71 and IR-480, and also provide a connection with SR-17 (Brookpark Road). Although plans are ready for the entire three mile length, only a short segment at the north end is actually complete and open to traffic. A short southern segment from SR-17 to Schaaf Road is under construction. Current fiscal constraints have delayed letting of the final construction contract.

When completed, traffic volumes are projected at 46,800 ADT, with level of service C operation.

10. SR-237

Also included in this study is a short segment of SR-237, by Hopkins International Airport, from Sheldon Road to SR-17 (Brookpark Road). It provides access to the airport from east and west bound IR-480, as well as from the south. The part of SR-237 included in this study varies in cross section. Part of it is an arterial, and part is a six lane freeway, with ramps connecting to IR-480.

Traffic volumes in 1992 ranged from 28,300 to 53,200. The lowest volume was found between Sheldon Road and Kolthoff Road. The highest volume was on the segment from the airport entrance to IR-480.

This roadway operates at LOS C or better. The highest volume to capacity (V/C) ratio has been calculated for the segment of SR-237 at the entrance to the airport with an ADT of 53,200, yielding a value of 0.52.

11. US-6

Part of US-6, along the Cleveland lakefront, was also evaluated. It is better known as the Cleveland Memorial Shoreway. The freeway is also designated SR-2. It starts at Lake Avenue and Clifton Boulevard in western Cleveland, and continues eastward, to approximately West 28th Street at Burke Lakefront Airport, where it joins IR-90 east of the Innerbelt curve in the northeast part of downtown. The freeway provides direct access to downtown via the West Third and East Ninth Street interchanges. It also provides direct access to IR-90 east of the Innerbelt, allowing traffic from Lakewood and northwestern Cleveland to bypass the Innerbelt through downtown Cleveland. This route also provides access to Edgewater Park and the Yacht Club from the east and west sides of Cleveland.

In 1992, the ADT ranged from 11,700 to 41,900. The lower value was found at Lake Avenue, and the higher value was at the eastern end of the freeway, east of the Cuyahoga River in the northern outskirts of the central business district. The road section varies from four to six lanes, with most of the roadway containing six lanes.

The freeway in the study area operates at or LOS B or better. The highest volume to capacity (V/C) ratio has been calculated for the segment between Clifton Boulevard and Baltic Road, where there is an ADT of 25,000 traveling over four lanes, yielding a value of 0.37.

12. US-422

US-422 provides access to the southeast corner of Cuyahoga County and the southwest corner of Geauga County. The freeway provides an alternate route to Bainbridge Road for the summer recreational traffic to Sea World and Geauga Lake Park. This study evaluated the roadway from its western terminal at the junction of IR-271 and IR-480N, to SR-306 in Geauga County.

In 1992, the ADT ranged from 20,900 to 49,200. The road section is four lanes. The freeway in the study area operates at LOS B east of SOM Center Road, while between the IR-271/IR-480 junction and Harper Road, the LOS is D, improving to C between Harper Road and SOM Center Road. The highest volume to capacity (V/C) ratio has been calculated for US-422 between IR-271/IR-480 and Harper Road, with an ADT of 49,200, yielding a value of 0.68.

Figure CHAPTER I. -3. Current Traffic Volumes

Figure CHAPTER I. -4. Current Level of Service

Figure CHAPTER I. -5. Current Truck Volumes

G. Existing Accident Data

A comprehensive accident analysis was not feasible given the time and budget constraints of this study. A high level analysis of accidents on the major freeways and selected highways within the study area was conducted using accident data supplied in electronic form by ODOT Bureau of Technical Services. This information was processed by NOACA and documented in their 1991, 1992, and 1993 Motor Vehicle Accident Reports.

In terms of gross numbers, IR-90 in Lakewood/Cleveland experienced the most accidents, averaging 1200 accidents per year from 1991 to 1993. Of these, 557 (46.4%) were injury accidents, and fatal accidents for this stretch of roadway averaged 3.33 (0.3%) per year. IR-71 in Cleveland/Brooklyn/Linndale averaged 639 accidents during the same analysis period, with 303 (47.4%) injury accidents and 1.33 (0.2%) fatalities. IR-77 in Newburg Heights/Cleveland averaged 391 accidents per year, with 182 (46.8%) injury accidents and 0.67 (0.2%) fatality. IR-480 in Cleveland averaged 337 accidents per year, with 153 (45.4%) injury accidents and 0.33 (0.1%) fatality. Other locations had averages of anywhere from 221 to 16 accidents per year.

Using 1991 - 1993 data revealed several segments with statistics significantly higher than the rest of the roadways evaluated in this study (Figure I-6). IR-77 in Newburg Heights/Cleveland averaged 16.44 accidents per lane-mile. This same interstate averaged 13.12 accidents per lane-mile in Cuyahoga Heights. The levels of service in these sections are at F, correlating with the high rates. IR-71 in Middleburg Heights (10.20), IR-90 in Lakewood and Cleveland (9.13), IR-71 in Cleveland/Brooklyn/Linndale (8.72), IR-480 in Garfield Heights, Maple Heights (7.95), IR-480 in Independence and Valley View (7.59) also show a high number of accidents per lane-mile, again correlating with reduced levels of service. US-6 from Lake Avenue to the Shoreway (5.98) and SR-44 between SR-2 and IR-90 in Lake County (4.89) also show higher rates than other similar facilities in the area.

Accidents per lane mile were found to be weakly correlated to ADT volumes (correlation coefficient of 0.589). Applying this finding to the values calculated revealed that in addition to the higher than expected rates described above, parts of IR-480 exhibited *lower* than expected accident rates. Between mile markers 11.19 and 13.06 (west corporate limits of Brooklyn to Ridge Road), the expected rate was 7.64 accidents per lane-mile, while the actual rate was 3.51. Similarly, between mile markers 15.81 and 17.59 (west corporate limits of Brooklyn Heights to west corporate limits of Independence) the expected rate was 7.48 accidents per lane-mile, while the actual rate was 2.36.

A severity index (Figure I-7) was used to evaluate segments of highway, weighting for fatalities and injuries. With this factoring, IR-480 in Brooklyn had the highest index at 2.30. IR-90 in Bratenahl was next at 2.29, followed by IR-480 in Brooklyn Heights at 2.13. Note that even though segments of IR-480 had a lower than expected accident rate, as just described above, the accidents that did occur tended to be more serious.

Other segments with a severity index greater than 2.00 included IR-77 in Brecksville at 2.12, IR-480 in Warrensville Heights/North Randall also at 2.12, IR-77 on Independence at 2.03, and IR-490 in Cleveland at 2.01. For US-6 (Memorial Shoreway), the severity index was computed at 2.00, while the SR-237 (Airport Freeway) had an index of 1.94.

Figure I-7 (severity index) does not reveal any significant correlation to ADT volume, number of trucks in the traffic stream, or level of service. There is one noteworthy anomaly: on IR-90 in Bratenahl, east of Cleveland, the index is 2.29 due to one fatality in the three year evaluation period, and an average of 79 injury accidents out of a total of 125 accidents. Looking at the accidents in this area another way, almost two out of three accidents (63.2%) here result in injuries.

Because the roadways presented in Figures I-6 and I-7 vary in classification and functionality, caution must be used in drawing conclusions about accident trends. Many factors contribute to accidents, among them roadway geometrics, traffic volumes, prevailing speeds, and weather. Interstate routes, having limited access and high geometric standards, tend to have more favorable accident statistics than freeways and highways. The interstates in the study area also vary considerably in character due to the prevailing design standards at the time they were built. One possible explanation for the lower than expected accident rates on IR-480 could be that it was built relatively recently, to higher design standards than other portions of the area's interstate routes.

While it is beyond the scope of this study to conduct a detailed analysis of accident trends, it is possible to resolve an "order of magnitude" relationship, and use this information to determine areas that may require special attention to provide the needed communications and surveillance equipment to expedite emergency response.

After evaluating the future levels of service, it became apparent that some freeway segments maintained an acceptable level of service through the end of the study period. These segments were selectively removed from further study, while maintaining route continuity. A parallel arterial route (US-42) was selected in their place. This route was then evaluated for levels of service and accident trends, and included in the study to broaden the scope.

Accident per lane mile on these arterial segments are substantially higher than for the freeway segments. This is not unexpected, since exposure to conditions conducive to collisions is much higher on an arterial, with multiple conflict points due to crossing and merging traffic. Note, however, that the arterial severity index compares favorably with the freeway values, falling below 2.00, except for that part of US-42 within Cleveland's city limits, which is just above, at 2.02. This can be attributed to the lower speeds found in an urban environment, which result in less damaging collisions.

The arterial accident trends are summarized in Tables I-3 and I-5, while Tables I-2 and I-4 summarize these statistics for the freeway segments. These tables provide insights into the locations with unusual accident trends. Figures I-6 and I-7 illustrate these accident trends.

Table CHAPTER I. -2. Accidents per Lane-mile, Freeway Segments

ROUTE	SECTION LOCATION	COUNTY	SECT. LEN.	NO. OF LANES	AVG. ANNUAL ACC.	ACC. PER LANE-MILE
IR-77	Newburg Heights/Cleveland	Cuyahoga	3.96	6	390.67	16.44
IR-77	Cuyahoga Heights	Cuyahoga	2.07	6	163.00	13.12
IR-71	Middleburg Heights	Cuyahoga	2.67	6	163.33	10.20
IR-90	Lakewood/Cleveland	Cuyahoga	16.42	8	1199.33	9.13
IR-71	Cleveland/Brooklyn/Linndale	Cuyahoga	9.16	8	639.33	8.72
IR-480	Garfield Heights/Maple Heights	Cuyahoga	3.48	8	221.33	7.95
IR-480	Independence/Valley View	Cuyahoga	1.63	8	99.00	7.59
IR-271	Lyndhurst/Mayfield Heights	Cuyahoga	3.23	6	128.00	6.60
IR-71	Strongsville	Cuyahoga	5.21	4	134.33	6.45
IR-480	Warrensville Hts/North Randall	Cuyahoga	2.90	4	74.00	6.38
IR-271	Pepper Pike/Beechwood	Cuyahoga	3.14	6	120.00	6.37
IR-90	Euclid	Cuyahoga	3.44	8	172.00	6.25
IR-90	Wickliffe	Lake	1.34	6	50.00	6.22
US-6	Lake Avenue to IR-90 (Shoreway)	Cuyahoga	4.03	4	96.33	5.98
IR-90	Bratenahl	Cuyahoga	2.66	8	124.67	5.86
IR-480	Fairview Park	Cuyahoga	1.05	6	34.67	5.50
IR-271	Bedford/Bedford Heights	Cuyahoga	3.60	6	114.33	5.29
IR-480	Cleveland	Cuyahoga	8.06	8	337.00	5.23
IR-271	Warrensvile Heights/Orange	Cuyahoga	2.51	4	50.33	5.01
IR-71	Brook Park	Cuyahoga	2.08	6	61.00	4.89
SR-44	IR-90 to SR-2	Lake	4.45	4	87.00	4.89
IR-77	Independence	Cuyahoga	4.71	6	131.00	4.64
IR-480	Bedford Heights/Oakwood	Cuyahoga	2.59	4	46.67	4.50
IR-271	Oakwood	Cuyahoga	1.61	4	29.00	4.50
IR-90	Waite Hill/Willoughby	Lake	2.27	4	38.00	4.19
SR-237	SR-17 to Sheldon (Airport Xwy)	Cuyahoga	3.59	4	58.00	4.04
SR-2	Cuyahoga County Line To SR-44	Lake	13.54	6	323.67	3.98
IR-480	North Olmsted	Cuyahoga	5.55	6	127.33	3.82
IR-90	Avon	Lorain	5.47	4	81.33	3.72
IR-480	Brooklyn	Cuyahoga	1.87	6	39.33	3.51
SR-2	Baumhart To IR-90	Lorain	7.81	4	108.67	3.48
IR-271	Mayfield/Highland Heights	Cuyahoga	2.56	6	52.00	3.39
IR-90	Rocky River	Cuyahoga	2.63	6	52.33	3.32
IR-90	Concord Township	Lake	6.49	4	86.00	3.31
IR-90	Sheffield	Lorain	2.68	4	34.33	3.20
IR-90	Westlake	Cuyahoga	5.05	6	97.00	3.20
IR-490	Cleveland	Cuyahoga	2.39	8	56.00	2.93
IR-90	Willoughby Hills	Lake	4.13	6	71.00	2.87
IR-77	Broadview Heights	Cuyahoga	2.58	4	28.67	2.78
IR-71	Brunswick Hills Twp/Brunswick	Medina	5.18	4	55.00	2.65
US-422	County Line to SR-306	Geauga	7.15	4	73.33	2.56
IR-90	Mentor	Lake	1.97	4	20.00	2.54

ROUTE	SECTION LOCATION	COUNTY	SECT. LEN.	NO. OF LANES	AVG. ANNUAL ACC.	ACC. PER LANE-MILE
US-422	IR-271 to County Line	Cuyahoga	7.42	4	75.00	2.53
IR-271	Willoughby Hills	Cuyahoga	1.75	6	25.33	2.41
IR-90	Elyria Twp/Elyria	Lorain	5.70	4	54.67	2.40
IR-480	Brooklyn Heights	Cuyahoga	1.78	8	33.67	2.36
IR-480	North Ridgeville	Lorain	2.17	4	19.67	2.27
IR-90	Kirtland Hills	Lake	2.15	4	17.33	2.02
IR-77	Brecksville	Cuyahoga	2.65	4	16.33	1.54
SR-10	SR-57 to Cuyahoga County Line	Lorain	6.25	4	37.33	1.49
US-20	Parsons Road to SR-57	Lorain	7.66	4	36.33	1.19

Table CHAPTER I. -3. Accidents per Lane-mile, Arterial Segments

ROUTE	SECTION LOCATION	COUNTY	SECT. LEN.	NO. OF LANES	AVG. ANNUAL ACC.	ACC. PER LANE-MILE
US-42	Cleveland (Pearl)	Cuyahoga	1.78	4	166.33	23.36
US-42	Brunswick	Medina	2.65	2	95.33	17.99
US-42	Cleveland (West 25th)	Cuyahoga	4.79	2	169.00	17.64
US-42	Parma	Cuyahoga	1.34	4	58.00	10.82
US-42	Middleburg Heights	Cuyahoga	2.87	4	121.33	10.57
US-42	Parma Heights	Cuyahoga	2.68	4	111.00	10.35
US-42	Strongsville	Cuyahoga	5.46	4	221.67	10.15

Table CHAPTER I. -4. Accident Severity Index, Freeway Segments

ROUTE	SECTION LOCATION	COUNTY	SECT. LNGT.	NO. OF LANES	FATAL	INJURY	P. D.	TOTAL	SEVERITY INDEX
IR-71	Brunswick Hills Twp/Brunswick	Medina	5.18	4	0.67	15.33	39.00	55.00	**1.69**
IR-71	Strongsville	Cuyahoga	5.21	4	0.33	40.00	94.00	134.33	**1.62**
IR-71	Middleburg Heights	Cuyahoga	2.67	6	0.33	56.33	106.67	163.33	**1.71**
IR-71	Brook Park	Cuyahoga	2.08	6	0.00	29.67	31.33	61.00	**1.97**
IR-71	Cleveland/Brooklyn/Linndale	Cuyahoga	9.16	8	1.33	302.67	335.33	639.33	**1.97**
IR-77	Brecksville	Cuyahoga	2.65	4	0.33	7.33	8.67	16.33	**2.12**
IR-77	Broadview Heights	Cuyahoga	2.58	4	0.33	9.00	19.33	28.67	**1.76**
IR-77	Independence	Cuyahoga	4.71	6	1.33	60.00	69.67	131.00	**2.03**
IR-77	Cuyahoga Heights	Cuyahoga	2.07	6	1.00	67.00	95.00	163.00	**1.89**
IR-77	Newburgh Heights/Cleveland	Cuyahoga	3.96	6	0.67	182.33	207.67	390.67	**1.95**
IR-90	Elyria Twp/Elyria	Lorain	5.70	4	0.67	18.00	36.00	54.67	**1.79**
IR-90	Sheffield	Lorain	2.68	4	0.33	15.33	18.67	34.33	**2.00**
IR-90	Avon	Lorain	5.47	4	0.33	24.00	57.00	81.33	**1.64**
IR-90	Westlake	Cuyahoga	5.05	6	0.33	39.33	57.33	97.00	**1.85**
IR-90	Rocky River	Cuyahoga	2.63	6	0.33	23.67	28.33	52.33	**1.97**
IR-90	Lakewood/Cleveland	Cuyahoga	16.42	8	3.33	557.00	639.00	1199.33	**1.96**
IR-90	Bratenahl	Cuyahoga	2.66	8	0.33	78.67	45.67	124.67	**2.29**
IR-90	Euclid	Cuyahoga	3.44	8	0.00	63.33	108.67	172.00	**1.74**
IR-90	Wickliffe	Lake	1.34	6	0.00	14.67	35.33	50.00	**1.59**
IR-90	Willoughby Hills	Lake	4.13	6	0.33	17.00	53.67	71.00	**1.53**
IR-90	Waite Hill/Willoughby	Lake	2.27	4	0.00	10.67	27.33	38.00	**1.56**
IR-90	Mentor	Lake	1.97	4	0.00	4.67	15.33	20.00	**1.47**
IR-90	Kirtland Hills	Lake	2.15	4	0.00	3.67	13.67	17.33	**1.42**
IR-90	Concord Township	Lake	6.49	4	0.00	18.00	68.00	86.00	**1.42**
IR-271	Oakwood	Cuyahoga	1.61	4	0.00	10.67	18.33	29.00	**1.74**
IR-271	Bedford/Bedford Heights	Cuyahoga	3.60	6	0.33	46.67	67.33	114.33	**1.85**
IR-271	Warrensvile Heights/Orange	Cuyahoga	2.51	4	0.33	21.33	28.67	50.33	**1.92**
IR-271	Pepper Pike/Beechwood	Cuyahoga	3.14	6	0.00	39.33	80.67	120.00	**1.66**
IR-271	Lyndhurst/Mayfield Heights	Cuyahoga	3.23	6	1.00	40.00	87.00	128.00	**1.71**
IR-271	Mayfield/Highland Heights	Cuyahoga	2.56	6	0.00	14.00	38.00	52.00	**1.54**

ROUTE	SECTION LOCATION	COUNTY	SECT. LNGT.	NO. OF LANES	FATAL	INJURY	P. D.	TOTAL	SEVERITY INDEX
IR-271	Willoughby Hills	Cuyahoga	1.75	6	0.33	8.67	16.33	25.33	**1.83**
IR-480	North Ridgeville	Lorain	2.17	4	0.00	6.33	13.33	19.67	**1.64**
IR-480	North Olmsted	Cuyahoga	5.55	6	0.00	36.33	91.00	127.33	**1.57**
IR-480	Fairview Park	Cuyahoga	1.05	6	0.00	17.33	17.33	34.67	**2.00**
IR-480	Brooklyn	Cuyahoga	1.87	6	0.33	23.67	15.33	39.33	**2.30**
IR-480	Cleveland	Cuyahoga	8.06	8	0.33	152.67	184.00	337.00	**1.92**
IR-480	Brooklyn Heights	Cuyahoga	1.78	8	0.00	19.00	14.67	33.67	**2.13**
IR-480	Independence/Valley View	Cuyahoga	1.63	8	0.33	47.67	51.00	99.00	**2.00**
IR-480	Garfield Heights/Maple Heights	Cuyahoga	3.48	8	0.00	67.33	154.00	221.33	**1.61**
IR-480	Warrensville Hts/North Randall	Cuyahoga	2.90	4	0.67	37.67	35.67	74.00	**2.12**
IR-480	Bedford Heights/Oakwood	Cuyahoga	2.59	4	0.00	16.00	30.67	46.67	**1.69**
IR-490	Cleveland	Cuyahoga	2.39	8	0.00	28.33	27.67	56.00	**2.01**
SR-2	Baumhart to IR-90	Lorain	7.81	4	0.00	29.67	79.00	108.67	**1.55**
US-6	Lake Avenue to IR-90 (Shoreway)	Cuyahoga	4.03	4	0.33	46.33	49.67	96.33	**2.00**
SR-2	Cuyahoga County Line to SR-44	Lake	13.54	6	0.33	99.33	224.00	323.67	**1.63**
SR-10	SR-57 to Cuyahoga County Line	Lorain	6.25	4	0.00	12.67	24.67	37.33	**1.68**
US-20	Parsons Road to SR-57	Lorain	7.66	4	0.67	9.67	26.00	36.33	**1.73**
SR-44	IR-90 to SR-2	Lake	4.45	4	0.33	26.33	60.33	87.00	**1.65**
SR-237	SR-17 to Sheldon (Airport Xwy)	Cuyahoga	3.59	4	0.00	27.33	30.67	58.00	**1.94**
US-422	IR-271 to County Line	Cuyahoga	7.42	4	0.00	29.00	46.00	75.00	**1.77**
US-422	County Line to SR-306	Geauga	7.15	4	0.33	23.67	49.33	73.33	**1.70**

Table CHAPTER I. -5. Accident Severity Index, Arterial Segments

ROUTE	SECTION LOCATION	COUNTY	SECT. LNGT.	NO. OF LANES	FATAL	INJURY	P. D.	TOTAL	SEVERITY INDEX
US-42	Brunswick	Medina	2.65	2	0.00	39.67	55.67	95.33	**1.83**
US-42	Strongsville	Cuyahoga	5.46	4	0.67	78.33	142.67	221.67	**1.74**
US-42	Middleburg Heights	Cuyahoga	2.87	4	0.33	42.00	79.00	121.33	**1.72**
US-42	Parma Heights	Cuyahoga	2.68	4	0.00	37.33	73.67	111.00	**1.67**
US-42	Parma	Cuyahoga	1.34	4	0.00	23.33	34.67	58.00	**1.80**
US-42	Cleveland (Pearl)	Cuyahoga	1.78	4	0.00	71.67	94.67	166.33	**1.86**
US-42	Cleveland (West 25th)	Cuyahoga	4.79	2	0.33	84.67	84.00	169.00	**2.02**

Figure CHAPTER I. -6. Accident Trends, Accidents per Lane-mile

Figure CHAPTER I. -7. Accident Trends, Severity Index

H. Public Transportation

Public transportation in the metro area is provided by the Greater Cleveland Regional Transit Authority (GCRTA). The GCRTA employs 2700 people and maintains a fleet of 700 buses that operate over a network of 1100 miles of routes, providing both express and local service. Recently, ridership has been rising on several links due to improvements linking the Gateway Sports complex with the Tower City Terminal in downtown Cleveland. Park-n-Ride facilities allow customers in outlying areas to reach the central business district using public transportation. Overall, ridership has followed the national trend: downward.

Present elements of the rail transit system include the Shaker Rapid (Green Line), built in 1914; and the Windemere Rapid (Blue Line) and Airport Rapid (Red Line) built between 1954 and 1968. The Red Line is a heavy rail line that runs from Hopkins International Airport through the central business district to East Cleveland (Red Line; 19 miles of track, 18 stations), making connections with the other two light rail lines that provide service to the east (the Blue Line to Warrensville and the Green Line to Shaker Heights; 13 miles of track, 29 stations). Current expansion plans for the Rapid include an extension into the "Flats," and to the North Coast Harbor Development Area: the Rock and Roll Hall of Fame and Museum; the Great Lakes Museum of Science, Environment, and Technology; and the Great Waters Aquarium.

Priority projects currently in the early stages of development include a Transit Center to be built at Cleveland State University, where multiple bus routes intersect, and service is timed to make transferring quick and easy. Other Transit Centers are planned near Parmatown Mall, Westgate Mall, and in the City of Euclid. Another project is the Community Circulator Service, which will use small vehicles that operate like the downtown Loop buses to provide transportation to neighborhood shopping centers, hospitals, businesses and other locations. They will also connect residents to main line bus service.

RTA is working with NOACA, municipalities, and other stakeholders to develop commuter rail service on existing right-of-way to the Akron/Canton area. Service is planned to begin in 1997. The role of Tower City will expand as an intermodal hub, including not only commuter rail, but inter-city rail as well. The facility would also serve four lines of the State's proposed high-speed rail network.

I. Existing ITS Initiatives

The users of the Cleveland metropolitan area transportation network already enjoy some of the benefits of "ITS-type" services. Radio traffic reporters provide motorists with information about congested location over the air. The usefulness of this information is directly related to its timeliness. Television, whether cable or local broadcast, also provides this information. Again, the usefulness of this information, and the drivers' reliance on it, are related to its accuracy and timeliness.

Drivers can already obtain local road construction information by calling a toll-free number (1-800-FYI-ROAD). This service is provided by NOACA. One of the attributes of having ITS technology will be the increased accuracy and timeliness of such information and its availability to a large number of users, who can use it to make informed choices about their trips.

An interchange improvement project currently under construction at IR-71 and SR-82 (Royalton Road) will have ramp metering equipment installed for the on-ramps. However, the equipment will not be turned on until traffic volumes increase enough to justify its use.

The City of Cleveland has recently completed the installation of a large "closed loop" traffic signal control network in the central business district. The network encompasses 88 traffic signals, divided into six groups of fifteen to eighteen signals per on-street master. Communication from the central monitoring and control computer to each on-street master is by telephone drop, and from each master to the intersection controller by twisted pair cable in new or existing ductwork. The communication network is configured with cross-connecting ductwork and cable, allowing reconfiguration with minimal field work. Local intersection controllers can therefore be easily switched from one sub-system to another should the need arise.

The system allows traffic signal operation in downtown Cleveland to be adjusted from a central location. The City currently uses this feature to adjust traffic signal operation for special events such as baseball games at the Gateway complex. Loop detectors have been installed on some streets around this facility, and additional detectors will be placed throughout the downtown area as funding permits. Hardware upgrades to the traffic signals themselves are scheduled for fiscal year 1997 (July, 1996 through June, 1997).

Many of the smaller municipalities in the study area also have closed loop traffic signal control systems. Others have such systems under construction or in the design stage. Functioning closed loop systems are in operation in Willowick, Wickliffe, Willoughby, Mentor, and Cleveland Heights. Traffic signals along Mayfield Road in Lyndhurst; Chagrin Boulevard, Richmond Road, and Cedar Road in Beachwood; and Mayfield Road, Lander Road, and Som Center Road in Mayfield Heights are coordinated using closed loop systems. Closed loop systems are under construction in Eastlake, North Olmsted and Rocky River. Painesville, Euclid, Maple Heights, Garfield Heights, Bedford, Parma, Parma Heights, Brook Park, Bay Village, and Westlake have closed loop systems under design. Brooklyn, Independence and Brecksville are considering installing closed loop systems as well.

Of particular interest to this study, funds have been committed in NOACA's SFY 1996 Transportation Improvement Program to upgrade traffic signals on US-42 (Pearl Road) during 1997 (between IR-71 and Snow Road in Middleburg Heights and Parma Heights), and in 1998 (from the Cuyahoga County line north to SR-82 in Strongsville). This will include the installation of closed loop systems to improve traffic flow.

As part of the Gateway Sports Complex improvements in Cleveland, changeable message signs were installed on major arteries approaching the downtown area. These signs provide directions to travelers for special events, and can be programmed by ODOT or the City of Cleveland via cellular and dedicated telephone lines. The signs can also be used to display information about incidents with the cooperation of the local police agency. In addition, there are several permanently mounted portable changeable message signs on IR-77 south of downtown and IR-90 west of the central business district. The City of Cleveland uses them during special events. These signs can also be programmed by cellular telephone.

The Ohio Department of Transportation maintains a number of traffic count stations throughout the area. Some are seasonal, others are permanent. Presently, data accumulation and processing is handled by the Central Office in Columbus. The potential to tie in to these locations to utilize them for local purposes should be considered.

The Regional Transit Authority uses Community Responsive Transit (CRT) vehicles to provide "door-to-door" service for some passengers. Advance reservations are required, and the service is only available to physically disabled patrons. With appropriate ITS technology, such services can be expanded to include general users, making using public transportation more convenient and quicker. As more people turn to alternative means of transportation, there will be fewer single occupant vehicles on the road, alleviating congestion.

J. Critical Locations

Recurring congestion accounts for a significant portion of delay experienced by motorists. This congestion can be attributed to inadequate capacity and geometric transitions that change the vehicle flow abruptly, among other things. Motorists compensate for the presence of recurring congestion when making their trip by allowing additional time to get through the slow moving sections. Like any large metropolitan area, Cleveland has its share of "bottlenecks."

Motorists heading for downtown Cleveland in the morning via IR-90 usually experiences a slowdown as they approach the IR-71/IR-490 junction. Weaving maneuvers and high volumes, as well as congestion on the Innerbelt cause traffic to slow down. While the opening of IR-490 reduced traffic volumes on the inbound Innerbelt, congestion still exists due to close ramp spacing.

Approaching downtown via IR-71, motorists run into congested operation from the Jennings Freeway junction, where only two inbound lanes are open, through the junction with IR-90/490, where traffic from IR-90 gets on IR-71. The congestion worsens further north as traffic from West 14th Street gets on the expressway also.

On northbound IR-77 north of the IR-480 junction, heavy merging volumes from IR-480, an uphill grade, and the close proximity of the Brecksville Road entrance ramp all combine to produce a bottleneck during the morning peak. Further north, approaching downtown, IR-77 is a three lane roadway, but only two lanes are available over IR-490, creating another bottleneck. The ramp from IR-490 to southbound IR-77 is only one lane wide, creating yet another bottleneck as almost 3,000 vehicles per hour attempt to merge from IR-490.

During the evening (outbound) peak, the mainline sections from the Innerbelt to the IR-71/Jennings freeway are at capacity. At the junction with IR-90/490, the westbound section of IR-90 just east of West 25th Street operates at full capacity across its three lanes. Approaching the junction with the Jennings Freeway, traffic on IR-71 increases due to merging vehicles from IR-90 and IR-490. Weaving maneuvers in this area contribute to slowdowns. Leaving downtown via IR-77, motorists encounter delays over IR-490, where only two lanes are available. Merging traffic from IR-490 compounds the congestion, and the presence of trucks bypassing the Innerbelt creates further speed reductions.

Other bottlenecks can be found on IR-480, out by the airport, where only two through lanes are available in each direction, and at the IR-71 interchange with IR-480, where eight lanes on IR-71 are reduced to four lanes through the interchange. To the east, at the IR-271/US-422 junction with IR-480, ramp capacity is exceeded during peak periods.

K. Special Facilities

Any large metropolitan area has a number of facilities that serve various public and private interests. An efficient transportation network allows these facilities to function with maximum effectiveness.

Transportation hubs such as airports need good access to function effectively. Hospitals depend on good access to get help to people in a timely manner. Industrial and commercial facilities depend on a good transportation network to receive raw materials and ship their products. Recreation facilities also rely on good transportation facilities to provide access for their patrons, as do educational institutions.

Some of these facilities found in the Cleveland metropolitan area include:

- Cleveland Hopkins International Airport and IX Center
- Burke Lakefront Airport
- Port of Cleveland
- University Circle
- Cleveland Clinic
- Metropolitan General Hospital
- Southwest General Hospital
- Gateway Complex (baseball and basketball)
- Rock and Roll Hall of Fame
- Case Western Reserve University
- John Carroll University

- Cleveland State University

Figure I-8 depicts the location of various facilities which depend on a good transportation network for their efficient operation, as well as highlights areas of recurring congestion.

Figure CHAPTER I. -8. Special Facilities and Critical Locations

L. Future Conditions

Because deployment of ITS technology will take place over a long period of time, future conditions have a major role in determining the method of such deployment. Not only do traffic volumes have to be estimated for twenty years into the future, but future capacity has to estimated as well, based on short range and long range planned improvements. While it is beyond the scope of this study to predict traffic growth in detail, a simplified method of estimating future traffic volumes was developed and applied.

M. Programmed Construction

The Cleveland Metropolitan Area Expressway and Interstate System is expected to be completed or under construction by 1998. New construction planned includes (Figure I-9):

- IR-71 widening from Pearl Road to SR-303
- IR-90 widening from SR-83 to SR-252
- IR-90 widening from SR-174 to SR-615
- completion of SR-176F (Jennings Freeway)
- IR-271 dual express lane from IR-90 to IR-480
- new interchange construction
- various interchange modifications
- signal improvements on US-42 (Pearl Road)

Although east-west access across the city is provided by IR-90 and SR-2, only the extreme north and south portions of the east side have good access to these freeways. The remainder of the east side of Cleveland is poorly served due to cancellation of planned segments of the freeway system. According to the Cleveland Civic Vision 2000 Citywide Plan, ". . . the absence of freeways has overburdened arterial roads, particularly in southeast Cleveland, and has forced traffic onto residential side streets."

The existing freeway system also fails to provide for north-south movements through the City of Cleveland, with the exception of areas served by IR-77 along the east side of the Cuyahoga River. Completion of the Jennings Freeway will remedy this deficiency on the near west side. However, lack of available land makes development of a north-south freeway on the east side unlikely. The next freeway providing for north-south movement is IR-271, well to the east of city limits.

Figure CHAPTER I. -9. Programmed Improvements

N. Future Traffic Volumes

Traffic volumes for the year 2020 were projected using a straight line extrapolation of existing traffic counts and year 2010 volumes provided by NOACA. Programmed improvements (Figure I-9) were included in calculations to determine future volume to capacity ratios and levels of service.

1. IR-71

Based on projections of the NOACA year 2010 forecasts into the year 2020, traffic volumes for this interstate will range from a low of 59,600 ADT at Fulton Road to a high of 150,800 ADT between the south corporate limits of Brookpark and Snow Road.

From Medina County all the way to its termination at IR-90 in Cleveland, the level of service will be F or E, with isolated segments at LOS D. The highest volume to capacity ratio of 1.55 is predicted between Snow Road and IR-480, where the ADT is expected to increase to 112,100 with no additional capacity in the bottleneck four lane section at IR-480. In spite of programmed widening to six lanes from SR-303 to Bagley Road, the level of service on IR-71 is predicted to continue to deteriorate due to rapid increases in volume.

2. IR-77

Based on projections of the NOACA year 2010 forecasts into the year 2020, traffic volumes for IR-77 will range from a low of 29,600 ADT between SR-21 and the Ohio Turnpike to a high of 131,800 ADT between SR-21 and Grant Avenue.

From IR-271 in Summit County to Miller Road, the level of service will be C or better. North of Miller Road, the LOS quickly goes from D to E or F north of Rockside. The level of service remains at F past IR-490, where 2020 volumes are predicted to increase more slowly because of the impact of the Jennings Freeway, resulting in level of service E operation.

The highest V/C ratio of 1.49 is predicted to occur over IR-490, where the four lane section will remain, followed closely by a V/C ratio of 1.34, predicted between IR-480 and SR-21, where merging traffic from IR-480 combines to swell the ADT to 131,800 over the present six lane section.

South of Miller Road, the predicted LOS at the end of the planning period will not exceed C, therefore this segment was deleted from the study in exchange for the addition of an arterial segment (US-42, Pearl Road).

3. IR-90 and IR-490

Based on projections of the NOACA year 2010 forecasts into the year 2020, traffic volumes for IR-90 will range from a low of 44,300 ADT in Lorain County between SR-57 and SR-254 (Detroit Road) to a high of 146,300 ADT in the City of Cleveland between Fairfield Avenue and Broadway Avenue.

The LOS in Lorain County will be C or worse. Programmed construction between SR-83 and SR-252 will improve the level of service to C in this stretch of roadway. In Cuyahoga County, the LOS will generally be D or worse. Level of service F operation will occur between the IR-71 junction and Fairfield Avenue, and again from IR-77 to Chester Avenue. The level of service will improve to E to the Lake County line. In Lake County, the LOS deteriorates to F at US-20 (Euclid Avenue), improves to E between Euclid and IR-271, goes to C until SR-91 due to the additional capacity of the express lanes, then drops back to F until re-entering Willoughby west of SR-306, where it improves to D due to additional capacity.

The highest V/C ratio for the IR-90/490 route in the year 2020 is 2.11, predicted to occur on IR-90 at the IR-77 junction, where the existing four-lane section will continue to create a severe bottleneck.

Interstate Route 490 level of service will deteriorate to C, as traffic shifts from IR-71 and IR-77. Average daily traffic volumes are predicted to range from 38,000 to 63,600.

4. IR-271

In the year 2020, traffic on IR-271 is predicted to range from a low of 52,700 ADT at the Summit County line to a high of 133,300 ADT between SR-175 (Richmond Road) and US-422 (Chagrin Boulevard).

Level of service on IR-271 between Rockside Road and IR-90 is expected to improve to C or D due to the addition of four more lanes, currently under construction (Dual/dual projects).

The highest V/C ratio for IR-271 in the year 2020 is 1.07, predicted to occur between IR-480N and SR-175 (Richmond Road).

5. IR-480 and IR-480N

Based on projections of the NOACA year 2010 forecasts into the year 2020, traffic volumes for this interstate will range from a low of 46,000 ADT in Lorain County where the freeway begins near the Ohio Turnpike to a high of 157,500 ADT between Lee Road and Warrensville Road. On IR-480N, the ADT volume is predicted at 87,500 at the point of divergence from IR-480, dropping down to 87,200 past Miles Road.

Levels of service on this facility are expected to be at D or E. Some segments will operate at LOS F: at the Airport Freeway junction, between Tiedeman Road and State Road, and between the Bedford Freeway and Warrensville Road. Levels of service on IR-480N are predicted to improve from current values to LOS D due to programmed improvements that will be completed well before the year 2020.

The highest V/C ratio for IR-480 in the year 2020 is 1.60, predicted to occur between SR-237 (Rocky River Road) and the Airport Freeway due to increased volume and lack of additional capacity.

6. SR-2

In the year 2020, traffic on SR-2 is predicted to range from a low of 30,100 ADT in Lorain County at Baumhart Road to a high of 98,500 ADT between the IR-90 junction and SR-633 (Lloyd Road).

In Lorain County, year 2020 traffic volumes in the study area are estimated to range from 30,100 to 54,000. The lowest volume is expected on the segment from Baumhart Road to Oak Point Road. The highest volume is expected on the segment from Middle Ridge Road to the SR-2/IR-90 junction.

SR-2 in Lorain County will operate at LOC C or better.

In Lake County, traffic volumes on SR-2 are predicted to range from 54,000 to 98,500. The lowest volume is expected on the segment from Heisley Road to SR-44, at the eastern limit of the study area. The highest volume will be on the segment just east of the IR-90 junction to SR-633 (Lloyd Road).

Most of SR-2 within the study area in Lake County will operate at or below LOC D in the year 2020. The LOS is predicted at F between SR-640 (Vine Street) and SR-306 (Reynolds Road). Past Reynolds Road, the LOS returns to D, and improves to C at the east corporate limits of Mentor as volumes decrease.

The highest volume to capacity (V/C) ratio has been calculated for the segment between SR-640 (Vine Street) and Lost Nation Road, with an ADT of 90,200 traveling on a four lane section, yielding a value of 1.22.

West of SR-58, the predicted LOS at the end of the planning period will not exceed C, therefore this segment was deleted from the study in exchange for the addition of an arterial segment (US-42, Pearl Road).

7. SR-10 and US-20

In the year 2020, traffic on SR-10/US-20 is predicted to range from a low of 12,700 ADT west of SR-301 to a high of 29,300 ADT approaching the SR-57 junction.

The LOS will generally be A, with LOS B only at SR-57. The highest V/C ratio on this roadway in the year 2020 is 0.39, predicted to occur at SR-57.

Since the predicted LOS at the end of the planning period will not exceed C, this roadway was deleted from the study in exchange for the addition of an arterial segment (US-42, Pearl Road).

8. SR-44

Based on projections of the NOACA year 2010 forecasts into the year 2020, traffic volumes for this roadway will range from a low of 21,400 ADT between SR-84 (Johnny Cake Road) and Jackson Street to a high of 41,500 ADT at the north end, by SR-2.

Levels of service on this facility are expected to range from A to C. The worst segment, with a V/C ratio of 0.58, will be from Jackson Street to SR-2 at the north end, where the highest ADT will also be found.

9. SR-176F

Traffic volumes on this yet to be completed facility are projected to rise to 46,800 ADT by the year 2020, with level of service C or D operation.

10. SR-237

Traffic volumes in 2020 are expected to range from 18,400 to 63,900. The lowest volume is predicted at IR-480. The highest volume will occur on the segment from the airport entrance to IR-480. The highest volume to capacity (V/C) ratio has been estimated for the segment of SR-237 at the entrance to the airport with an ADT of 63,900, yielding a value of 0.62.

Since the predicted LOS at the end of the planning period will not exceed C anywhere on this roadway with the single exception of the airport segment, it was deleted from the study in exchange for the addition of an arterial segment (US-42, Pearl Road).

11. US-6

In the year 2020, traffic on US-6 is predicted to range from a low of 14,000 ADT at Lake Avenue to a high of 50,300 ADT between East Ninth Street and the IR-90 junction.

The LOS on US-6 will generally be A or B, with LOS C occurring between Clifton Boulevard and the Baltic Road entrance to the Memorial Shoreway.

The highest V/C ratio for US-6 in the year 2020 is 0.44, predicted to occur between Clifton Boulevard and the Baltic Road entrance to the Memorial Shoreway.

12. US-422

In the year 2020, traffic on US-422 is predicted to range from a low of 25,300 ADT to a high of 59,500 ADT. The low number will occur at the eastern end of the freeway, at SR-306. The high value is predicted for western end, between the IR-271/IR-480 junction and Harper Road.

The LOS will be unchanged from 1992 values. The highest V/C ratio for US-422 in the year 2020 is 0.82, predicted to occur at the western end, between the IR-271/IR-480 junction and Harper Road.

East of Harper Road, the predicted LOS at the end of the planning period will not exceed C, therefore this segment was deleted from the study in exchange for the addition of an arterial segment (US-42, Pearl Road).

13. US-42

After the initial evaluation of the study area, it was determined that some segments of freeways could be dropped from further consideration, since the predicted LOS at the end of the planning period did not exceed C. In their place, segments of US-42 (Pearl Road), an arterial roadway paralleling IR-71, were included. The revised study area is shown in Figure I-2.

Arterial capacity analysis differs from the methodology used to evaluate the freeway segments. Levels of service are determined based on delay and distance, rather than on density. Accordingly, for equal traffic volumes, there is a direct correlation between the number of traffic signals per segment and the associated delay.

Evaluating existing conditions shows that US-42 experiences poor levels of service north of the Cuyahoga County line (D through F).

The predicted traffic conditions for year 2020 traffic on US-42 show a further decline in the poor level of service at the southern end of the study area. South of Shurmer Road, the LOS declines from D and E to F.

Figure CHAPTER I. -10. Future Traffic Volumes

Figure CHAPTER I. -11. Future Level of Service

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CHAPTER II. EXISTING INSTITUTIONAL FRAMEWORK

A. Introduction

This Chapter presents an assessment of the "institutional" (also known as "non-technical") issues. In addition, this investigation aims to define possible solutions to the issues that will inevitably accompany new, non-traditional approaches to solving the area's transportation problems, transforming the Ohio Department of Transportation from being simply a builder of highways to an agency that plays a more comprehensive role which includes becoming an efficient and informed operator/manager of these vital facilities.

Some issues relevant to this transformation that have been identified in ITS literature include:

- Political barriers to public/private arrangements.
- Access to state highway rights-of-way.
- Revenue generation and its allocation.
- Participation of other governments, agencies, or firms in regionally coordinated efforts.
- Anti-trust legislation.
- Intellectual property and proprietary technology.
- Invasion of individuals' privacy.
- Information discrimination.
- Potential liability.

Each of these issues is examined. In addition, specifically addressed are:

1. Procedures for future adoption of the ITS Deployment Plan.

2. Procedures for future ITS project identification, prioritization and implementation.
    - Prioritization process
    - Operation options
    - Maintenance options

Institutional change is often preceded by policy change, and typically generates regulations and mandates that force change. One of the keys in making this transition a smooth one is to foster cooperation without violating the individual agencies' sense of autonomy. In this Chapter, we examine the existing institutions, explore their interactions, propose alternative methods for adopting a regional ITS Plan. Chapter X, "Contractual and Financing Alternatives," explores the topic of funding and building an Intelligent Transportation System.

B. Methodology

An extensive review of data from seminars, articles, reports, and information from other states was used to produce this Chapter. In order to produce a better understanding of the various agencies' perspectives, roles and priorities related to the implementation of ITS in the study area, questionnaires were mailed out to various public agencies. A sample questionnaire can be found in Appendix B. To gain additional insight for the ITS Deployment Plan, a committee structure was established to help all the stakeholders participate in the process.

Three committees were established: an Incident Management Committee, to include the public safety forces of the affected municipalities in the process; a Policy Committee, to begin developing the required cooperation and coordination that a successful deployment of ITS technology in an area requires; and a Technical Committee, to oversee the technology issues. Tables II-1 through II-3 break out the Committee membership.

Table CHAPTER II. -1. Incident Management Committee

Name	Job Title	Representing
Mr. Jack Callaghan	Director of Operations	Metro Traffic
Mr. Thomas Dease	Police Chief	City of Brook Park
Mr. Greg Dixon	911 Operations Manager	Lorain County
Mr. Edward Eckart	EMC CO	EMS
Mr. Charles W. Goss	Police Chief	City of Strongsville
Mr. Mitchell Guyton	Police Chief	City of East Cleveland
Mr. Paul Haney	Fire Chief	City of Strongsville
Mr. Michael J. Herceg	P.E.	ODOT - District 12
Mr. Melvin R. House, Jr.	Fire Chief	City of Willoughby
Mr. David Jersan	Supervisor	ODOT - District 12
Mr. John Kalavsky	Police Chief	City of Warrrensville Heights
Mr. Dale A. Kraus	Fire Chief	City of Rocky River
Mr. David Mohr	Fire Chief	Village of Mayfield
Mr. John D. Preuer	Fire Chief	City of Mentor
Lt. C.C. Robinson		Ohio State Highway Patrol
Mr. Don Stevens	Police Chief	Village of Mayfield
Mr. William Taylor	Fire Chief	City of Warrensville Heights
Mr. Frank Viola	Police Chief	City of North Olmsted
Mr. Murray Withrow	911 Operations Manager	Cuyahoga County
Mr. Fred Wright	Police Chief	City of Independence

Table CHAPTER II. -2. Policy Committee

Name	Job Title	Representing
Mr. James E. Buckson	Operations Engineer	FHWA
Mr. Kenneth Carney	County Engineer	Lorain County
Mr. Tom Gilles	County Engineer	Lake County
Mr. Bryan T. Groden	District Deputy Director	ODOT - District 12
Mr. Stan Hunt	Transportation Engineer	ODOT - District 3
Hon. Michael Keys	Mayor	City of Elyria
Mr. Dale Madison	Director of Development	Lake Tran
Mr. Howard Maier	Executive Director	NOACA
Mr. James Mawhoor	Acting Deputy Director	ODOT - District 3
Mr. Thomas Neff	County Engineer	Cuyahoga County
Mr. Robert Phillips	County Engineer	Geauga County
Mr. Frank Polivka	General Manager	Lake Tran
Mr. Julian Suso	City Manager	City of Mentor
Mr. Ronald Tober	Gen. Mgr./Sec. Treasurer	GCRTA
Hon. Michael White	Mayor	City of Cleveland

Table CHAPTER II. -3. Technical Committee

Name	Job Title	Representing
Mr. Gary Bammerlin	District Traffic Engineer	ODOT - District 12
Mr. Joseph Cole	Technical Support Mgr.	NOACA
Mr. Ron Eckner	Director of Transportation	NOACA
Mr. Donald Elewski	City Engineer	City of Independence
Mr. John Konrad	City Engineer	City of Mentor
Mr. Thomas Kreczko	City Engineer	City of Wickliffe
Mr. Henning Eichler	Planning and Research	GCRTA
Mr. Frank Orlando	City Engineer	City of Willoughby
Mr. David Ritz	Commissioner, Traffic	City of Cleveland
Mr. George Saylor	Transportation Engineer	ODOT - Central
Mr. Lonny Shippy	City Engineer	City of Elyria
Mr. Michael Stinehelfer	Traffic Engineer	City of Solon
Mr. Homer Suter	Traffic Control Engineer	ODOT - Central
Mr. Thomas M. Weidinger	District Traffic Engineer	ODOT - District 3

C. Home Rule

The field of ITS is growing rapidly in response to the public's increased demand and need for improved transportation efficiency. Many of the changes that the deployment of ITS technology will generate have political implications. Accordingly, some of these issues could have widespread impact on governmental agencies at all levels, on private companies, and ultimately, on the traveling public.

The deployment of an ITS system requires improved cooperation and coordination among all the agencies providing transportation services. This includes not only the public sector at the state and local level, but also private agencies. This cooperation and coordination within the public sector presents a challenge for ITS deployment in the Cleveland/Lorain study area due to the fragmentation of authority created by Ohio's Home Rule legislation.

Prior to 1912, Ohio state government had complete authority in dispensing power to local communities. All power to govern the population of Ohio was vested in either the federal or the state government. Local communities only had such authority as the state legislature gave them, in contrast to the State, which had all power not specifically denied to it. Over time, large communities like Cleveland and Cincinnati criticized the system, complaining that rural legislators assembled in Columbus had little knowledge of or regard for large metropolitan areas, and were dictating policy that was ignoring the needs of citizens living in cities.

The matter was resolved at the 1912 state constitutional convention, when Home Rule was implemented in Ohio. The purpose of Home Rule was to give cities control of those things peculiar to cities, and which concerned the cities as distinct from rural communities. Home Rule was to draw the line separating the general affairs of the State from those which concerned the municipality only.

Under Home Rule, municipalities receive and derive their power and authority directly from the State Constitution, and not from statutes passed by the General Assembly. Section 3 of Article XVIII of the State Constitution states:

Municipalities shall have authority to exercise all powers of local self-government and to adopt and enforce within their limits such local police, sanitary and other similar regulations, as are not in conflict with general laws.

Home Rule is the legal authority exercised by a municipal corporation within its own boundaries. A municipal corporation is a specific legal entity, as defined by the Ohio State Constitution, and by the Revised Code of Ohio. Cities and villages are municipal corporations. Counties, townships, school districts, boards of education, and road districts are not municipal corporations. Article XVIII, Section 1 of the Ohio Constitution further defines a city as having a population of 5,000 or more people. A village has a population of less than 5,000 people.

Not every territorial subdivision of the State whose boundaries coincide with those of a community constitutes a municipal corporation. Only when the community is granted the power of self-government and is created as a separate entity with power to act in a private and proprietary capacity as well as in a government capacity, can it be considered a municipal corporation.

Home Rule relates to streets and highways, because municipal corporations possess authority to regulate traffic within their territorial boundaries. This authority comes directly from the State Constitution, not from state statute. Therefore, municipalities have broad powers to regulate streets and highways within their limits. For example, they may erect barricades at their borders to regulate vehicular traffic as long as these actions are not clearly unreasonable, arbitrary or capricious, or pursued in bad faith. Municipal corporations have the authority to determine which streets may be used by trucks, even though more convenient routes could be used to gain access to the state highway system. They may regulate the number, type, and location of traffic control devices, right-of-way at intersections, prohibit turns, and create one way streets.

However, municipalities may not adopt ordinances which are in conflict with the general laws of the state. Traffic control devices must comply with the State Manual of Uniform Traffic Control Devices.

The fact that a state highway is routed into and through a municipality does not limit the right of that municipality to regulate the use of that highway. Conversely, the Revised Code also provides that the State is under no duty to construct or improve highways within a municipality, although it may do so after obtaining the consent of the legal authority of the municipality. However, if the state determines there is an urgent need to install or improve a highway within a municipality, it may do so without first obtaining the municipality's consent.

Ohio courts have repeatedly held that a municipality's power of local self-government cannot thwart state power with respect to matters that go beyond local self-government. For example, the State Supreme Court has held that the Ohio Turnpike Commission did not have to obtain the consent of municipalities through which the turnpikes would pass since the construction of a turnpike across the state could hardly be considered a matter of local self-government. Similarly, the Supreme Court rejected the City of Lakewood's challenge to the relocation of a federal aid primary highway, stating that a federal highway is of more than local interest and of local regulation.

Of interest in this study is Section 5501.44(B) of the Revised Code, which provides that the State Director of Transportation, when he considers it in the interest of the welfare and safety of the citizens of Ohio, may enter into agreements with other states, subdivisions thereof, metropolitan planning organizations, or the United States, relative to the design, construction, operation, maintenance and repair of a regional traffic management system, and may expend federal and state highway funds for such purposes. A "regional traffic management system" is defined as "*an integrated, high-technology system to provide remote control center surveillance and monitoring of the regional freeways and main arterial routes in order to reduce and eliminate major backups and delays to motorists in the area*."

D. Existing Agencies - Public

There are four distinct highway systems in Ohio. The Ohio Department of Transportation is responsible for the 19,000 mile State Highway System. The Township Trustees collectively oversee the Township Highway System with its 39,000 miles of roadways. Municipalities maintain the streets and alleys within their boundaries, which together span over 21,000 miles. The 30,000 mile County Highway System is the responsibility of the State's 88 County Engineers.

Transportation projects in the study area typically are evaluated and prioritized by the metropolitan planning organization, the Northeast Ohio Areawide Coordinating Agency (NOACA), which has advisory committees with representation from various local agencies. Projects, once approved, are usually funded and administered by the regional office of the Ohio Department of Transportation.

1. State of Ohio

Most transportation projects in the state receive their funding through the regional districts of the Ohio Department of Transportation. Two districts cover the Cleveland/Lorain study area: ODOT District 3 includes Lorain and Medina Counties, and ODOT District 12 includes Cuyahoga, Geauga, Lake and Summit Counties. Recent organizational changes have decentralized the management structure, allowing regional districts more autonomy.

As described above, due to "Home Rule," the State of Ohio Department of Transportation has jurisdiction over State highways in unincorporated areas, and by special agreements, for the Interstate System within the city limits of municipalities. In other incorporated areas where such agreements have not been negotiated, the incorporated entity has jurisdiction and maintenace responsibilities for State highways.

The State Highway Patrol is charged with enforcing traffic laws and is responsible for protecting the public on roadways in unincorporated areas. Accurate and timely communication is a key factor in reducing response time. The Highway Patrol will therefore also be involved with the operation of the ITS technology on the area's highways. Within municipal boundaries, the local police agencies are charged with enforcing traffic laws, and will also need to interact with ITS technology. The interaction could be as simple as maintaining telephone contact with a traffic control center, or as complex as operating a local control center. The degree of involvement will be determined by local needs.

The Ohio Department of Transportation may be involved with the planning, funding, design, and construction of any ITS projects. The DOT could also be involved in the operation and maintenance of ITS equipment, directly or indirectly, through contractors and vendors. At this stage in the planning process, it is too soon to make that decision.

A recent ODOT District 12 innovation in the field of incident management has been received favorably by the public. Realizing the benefits of early detection and verification towards the management of all incidents, ODOT researched the efforts of other states, investigated available resources, and instituted a highway patrol incident management program. Beginning in June 1995, ODOT District 12, with the cooperation of the Northeast Ohio Areawide Coordinating Agency's (NOACA) "Way To Go" congestion management program, Metro Traffic Control, and Cellular One, began patrolling the interstate system in areas where traffic volumes exceed 80,000 ADT within Cuyahoga County (Figure II-1):

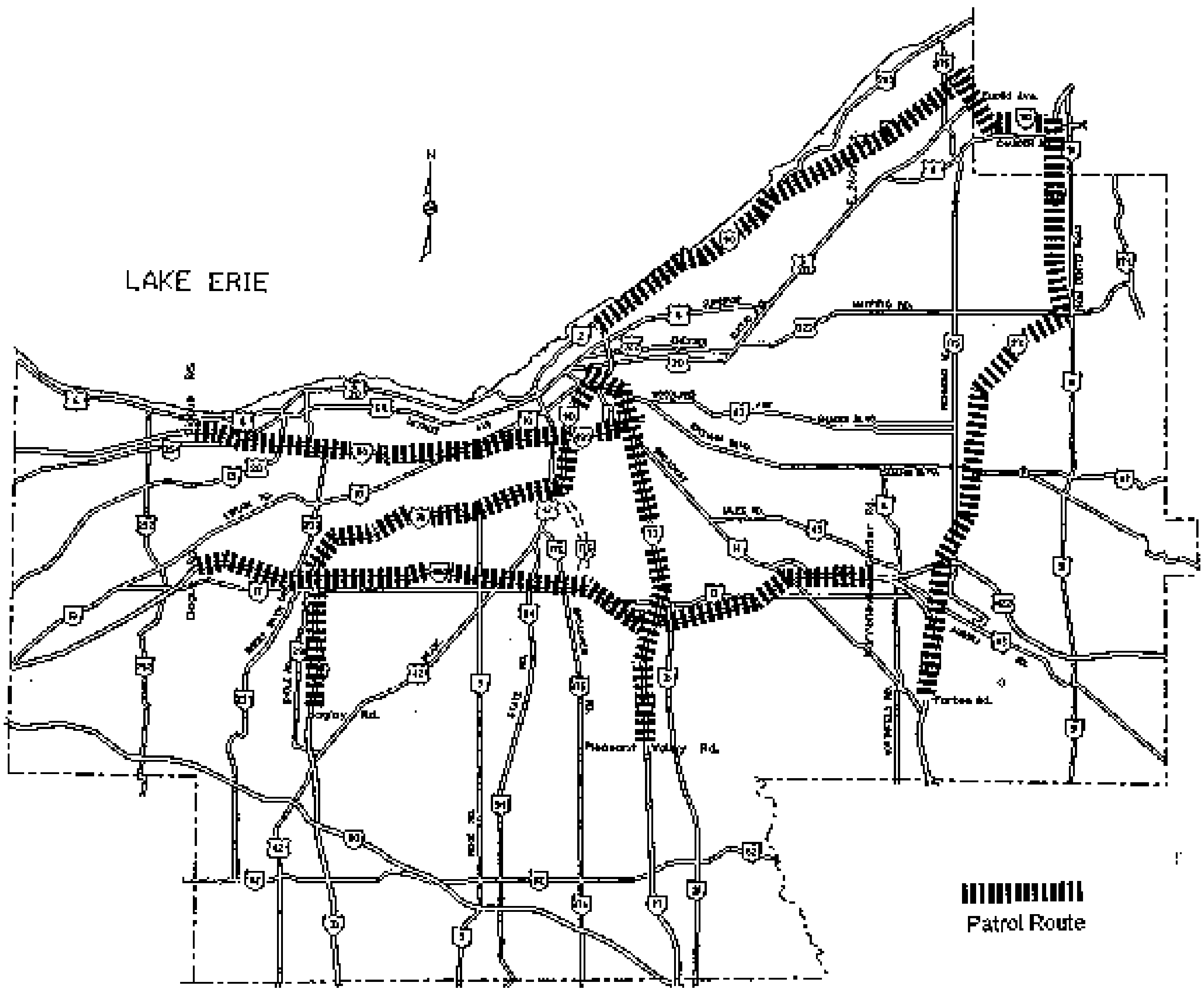
- IR-71 from Bagley Road to West 14th Street
- IR-77 from Pleasant Valley Road to IR-90
- IR-90 from Clague Road to IR-77, including IR-490
- IR-90 from Superior Street to IR-271
- IR-271 from Forbes Road to IR-90
- IR-480 from Clague Road to Warrensville Center Road

Initial patrols were limited to the afternoon weekday peak period (3:00 PM to 7:00 PM. The service was expanded to include the morning peak period (6:00 AM to 9:00 AM) on August 7, 1995. Five specially equipped pickup trucks ("Road Crewzers") manned by trained ODOT employees provide assistance to stranded motorists. The mission is to quickly detect and remove disabled vehicles in order to keep rush hour traffic flowing. The drivers evaluate the nature of the problem, get the disabled vehicle running or arrange for backup support. NOACA provides communication support, while Cellular One provides the communication equipment. Metro Traffic Control provides a vital link in making the Road Crewzer program successful by broadcasting congestion information relayed by NOACA's "Way To Go" staff.

This public-private partnership has assisted almost 350 motorists in the first month of operation. Predominant incident types were flat tires, running out of fuel, and repairs requiring a tow. Access to a cellular telephone expedited the removal or repair of vehicles significantly. An unexpected benefit of this free public service has been the response by private towing companies, who now patrol the freeways more aggressively in response to the competition, providing more opportunities to clear incidents quickly. ODOT has successfully conveyed the message that during congested travel, every minute of delay has far-reaching consequences, and the sooner a blockage is removed, the less severe the congestion that will develop.

While not "high-tech," the Road Crewzers program is an important first step in providing Intelligent Transportation System services in the Cleveland metropolitan area, since it demonstrates that a public-private partnership can be successful locally. The success of this program therefore establishes the groundwork for future partnerships that will build upon this first effort.

Figure Error! No text of specified style in document.**-1. ODOT Service Vehicle Patrol Area**



2. Northeast Ohio Areawide Coordinating Agency (NOACA)

The Northeast Ohio Areawide Coordinating Agency (NOACA) is the region's metropolitan planning organization (MPO). It was formed in 1968 for the purpose of coordinating planning and development activities in northeastern Ohio. The legal authority for this organization comes from the Demonstration Cities and Metropolitan Development Act of 1966, and the Intergovernmental Cooperation Act of 1968. In 1969, NOACA merged with the Cleveland Seven County Transportation Land Use Study (SCOTS), which had been established in 1964 in response to the requirements of the 1962 Federal Aid Highway Act. This Act required that metropolitan areas prepare comprehensive transportation and land use plans to qualify for federal highway funds. As the MPO for the area, NOACA prepares the federally mandated comprehensive long-range transportation plans, covering five counties: Cuyahoga, Geauga, Lake, Lorain, and Medina.

Over time, NOACA became designated for coordination and review of many federal and state funded planning and development activities in the area. NOACA is the areawide coordinator for certain programs of the following agencies:

- US Department of Transportation (DOT)
- Federal Transit Administration (FTA)
- Federal Highway Administration (FHWA) in conjunction with the Ohio Department of Transportation (ODOT)
- U.S. Environmental Protection Agency (EPA)
- Ohio Environmental Protection Agency (OEPA)

NOACA works closely with other agencies to assure that a multi-dimensional and mutually supportive planning consortium is realized. Examples of successful implementations of this operating principle include agreements with the three regional transit operations in the area, as well as the maintenance and emphasis on the continuing multi-county certification and coordination requirements with various federal, state, and local agencies.

After nearly two years of strategic planning, a revised Code of Regulations was adopted on January 9, 1991 by the NOACA Governing Board. Under the new Code, the NOACA Governing Board is composed of 37 local public officials. As provided in the Code of Regulations, it is the responsibility of the Board of County Commissioners to assure appropriate representation on the NOACA Governing Board.

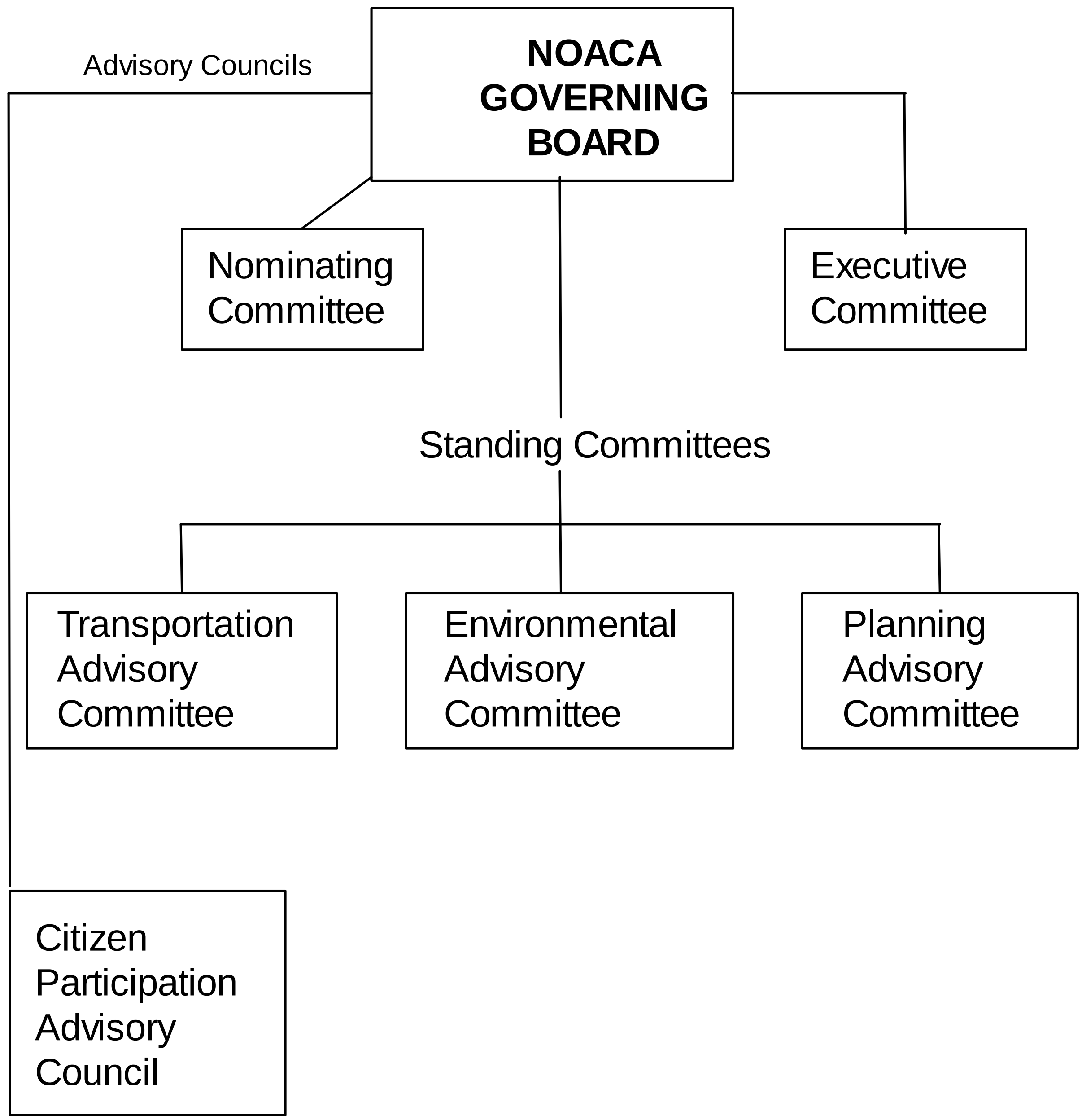
Current membership includes representatives from counties, cities, villages, and townships within the five county area, as well as representatives of County Engineers, the Greater Cleveland Regional Transit Authority, and the Northeast Ohio Regional Sewer District. The 37 members exercise a weighted voting procedure designed to meet requirements of proportional representation by county population. In addition, the Ohio Department of Transportation, Districts 3 and 12, and the Ohio Environmental Protection Agency, Northeast District Office, are non-voting ex-officio members of the NOACA Governing Board.

The Board's prime responsibility is to determine and establish areawide policies which guide transportation development throughout the region. Additionally, certain water and air quality policies are defined and used in the agencies work. The Overall Work Program (OWP) is prepared from these policies. The OWP provides overall direction to the Agency. The Governing Board carries out its responsibility by evaluating information, suggestions, and comments from Agency staff, citizens' groups, business groups, professionals and other individuals, and especially NOACA's standing and ad hoc committees. Standing committees include:

- Executive Committee
- Nominating Committee
- Environmental Advisory Committee
- Transportation Advisory Committee
- Planning Advisory Committee
- Citizen Participation Advisory Council

These committees are responsible for providing the Board with analyses of plans and programs, and making recommendations to the Board on the most appropriate policies and directions for the Agency. The functions of each committee are clearly stated in the NOACA Code of Regulation. Figure II-2 is a schematic diagram of the NOACA Board and Committee structure. A brief description of the responsibilities of each standing committee follows.

Figure CHAPTER II. -2. NOACA Organization Chart



Executive Committee

This Committee is responsible for providing interim advice to the Executive Director and staff between Board meetings. It is also responsible for carrying out directives or responsibilities as delegated to it by the Governing Board. The Executive Board consists of the President, Vice President, Assistant Vice President, Secretary, Treasurer, the immediate past President of the Governing Board, and the mayor of the largest City in the five county region. The Executive Committee also includes a member of the County Board of Commissioners of any county which is not otherwise represented on the Executive Committee.

Nominating Committee

With the advice and consent of the Governing Board, the NOACA Board President, by November 15 of each year, designates members of a Nominating Committee. This Committee consists of one representative of each of the five counties, and a representative of the largest city in the region. The Committee nominates the officers of the Governing Board for the next year.

Standing Committees

Standing Committees provide advice and policy recommendations to the NOACA Governing Board in specific functional areas. They also provide a forum for in-depth discussion and analysis of relevant issues and agenda items prior to Board consideration. Unless otherwise set forth, Committee members are appointed by the Board President with the advice and consent of a majority of Board members present and voting. The Agency Executive Director or his representative serves as an ex-officio member (without vote in that capacity) of all committees and sub-committees. Each standing committee has a Board Member appointed as Chairman by the NOACA Board President, with the advice and consent of the Board.

The Standing Committees participate in the Intergovernmental Review Process as vehicles for the Area Clearinghouse by review of federal grant applications pertaining to each Committee's functional purpose, and by submitting policy recommendations on such matters to the Board.

There are three standing committees: the Environmental Advisory Committee, the Planning Advisory Committee, and the Transportation Advisory Committee.

The Environmental Advisory Committee consists of a minimum of five members of the Governing Board with at least one Board member from jurisdictions within each county. It also includes: one representative elected annually by the Environmental Health Directors of the County Health Agencies; at least one of the Sanitary Engineers of the five counties, and one elected annually by the local air pollution agencies within the NOACA area; a representative of the Northeast Ohio Regional Sewer District; the City of Cleveland Health Director or Environmental Health Commissioner; the Chairman; the chairmen of any established sub-committees; the Ohio EPA Northeast District Office chief; all are non-voting members.

The principal functions of the Environmental Advisory Committee include the following:

1. Provide advice and policy recommendations on environmental issues or projects within the powers of the Agency;
2. Assist the Governing Board and Agency staff in identifying significant environmental problems, priorities, and concerns with the development of a comprehensive regional approach to environmental concerns within powers of the Agency;
3. Assist the Governing Board and Agency staff in environmental work program development;
4. Serve in other capacities, as determined by the Governing Board. Two standing subcommittees have been established: 1) a Water Quality Subcommittee consisting of Board members and water quality management agencies which provides advice and frames policy issues concerning the areawide water quality management plan and program; and 2) an Air Quality Subcommittee consisting of Board members and air quality management and planning agencies which provides advice and frames policy issues concerning ozone and carbon monoxide State Implementation Plan development and the NOACA Air Quality Program.

The Transportation Advisory Committee consists of a minimum of eight members of the Governing Board with at least one Board member from each county and at least three other Governing Board members, appointed by the President of the Governing Board with the advice and consent of a majority of Board members present and voting at a meeting at which a quorum is present. It also includes: the County Engineer and Planning Director of each county; the Commissioner of Traffic Engineering and Parking of the City of Cleveland; the Commissioner of Engineering and Construction of the City of Cleveland; a member of Cleveland City Council; the General Managers of the Regional Transit Authorities; the District Deputy Directors of Districts 3 and 12 of the Ohio Department of Transportation; additional non-voting members as may be appointed to ensure inclusion of elected officials and public administrators concerned with transportation planning; the Division Engineer of the Federal Highway Administration and the Area Manager of the Federal Aviation Administration, both of whom are non-voting members.

The Transportation Advisory Committee is responsible for the following functions:

1. Assist the Governing Board and Agency staff in developing short and long range transportation plans for the area;
2. Assist the Governing Board and Agency staff in identifying local objectives, community values, and regional goals and policies to guide regional transportation planning activities;
3. Assist the Governing Board and Agency staff in environmental work program development;
4. Serve in other capacities, as determined by the Governing Board.

The Planning Advisory Committee consists of the Executive Directors of the Regional or County Planning Commissions, and the City Planning Director of Cleveland.

The Planning Advisory Committee is responsible for the following functions:

1. Provide technical advice and recommendations to the Agency on comprehensive planning issues or projects, and provide for appropriate exchange of information on planning issues and data;
2. Assist the Agency in the operation of the Area Clearinghouse by reviewing federal grant applications and by preparing recommendations on such matters;
3. Assist the Agency and its members in the development of comprehensive, areawide plans in the areas of transportation and wastewater management by providing review and comment at appropriate stages of the planning process;
4. Cooperate and assist the Governing Board and Agency staff in the investigation of special topic areas for regional impact;
5. Assist the Agency in conducting local, countywide or areawide public meetings on projects or studies being conducted by the Agency.

3. City of Cleveland

As the largest city in the study area, Cleveland enjoys the benefits of a large tax base that supports both planning and design staff. The planning staff have developed two documents: the Cleveland Civic Vision 2000 Citywide Plan, and the Cleveland Civic Vision 2000 Downtown Plan, which are designed to serve as guides to future land use and development decision making. As such, they necessarily address transportation needs within the city. The Plan recommends specific improvements to the road system, and describes improvements to the public transportation network.

Traffic engineering services for the City are performed by the Division of Traffic Engineering, part of the Department of Public Safety. The Division of Public Works performs routine road maintenance operations. Emergency medical services are provided by the EMS unit of the Department of Public Safety. The 911 Center is operated by the Cleveland Police Department, with ties to Cuyahoga County's 911 Center (CCOM). Fire protection is by the City's Fire Department. Any towing of disabled vehicles is by contract with private vendors, as ordered by the Police Department.

As already noted, the Ohio DOT maintains the Interstate Highway System within the city limits of Cleveland by special agreements.

4. Counties

The six counties in the study area, Cuyahoga, Geauga, Lake, Lorain, Medina, and Summit, each have their own departments responsible for transportation projects. The staffing levels vary, depending on the county. Transportation projects at the county level can be initiated locally, although the preferred method is to go through the MPO process.

The County Engineer in Ohio is responsible for all maintenance, repair, widening, resurfacing, construction, and reconstruction of pavements and bridges in the County Highway System. Maintenance duties include traffic control, safety projects, mowing and snow removal.

In Cuyahoga County, due to the large number of incorporated areas, including Cleveland, the County has virtually no roads under its direct control. However, many municipalities, lacking the resources, rely on the County for engineering advice. Lake County is similarly urbanized, and the same situation prevails. Lorain County is somewhat less urbanized, and Geauga, Medina and Summit Counties are more rural in character.

Each County maintains an emergency communications center. This fragmentation of 911 services at present seems to pose no difficulties in coordination, since working arrangements allow calls to be routed to the appropriate agency. However, in the interest of expediting response when ITS services are added, the communication protocols and chain of command should be formalized and documented.

5. Other Municipalities

Various cities and townships in the study area can initiate transportation projects independently if they can pay for them. However, since most municipalities rely on Federal aid for their road improvement projects, the preferred procedure is to identify a project and then go through the MPO process to secure funding for implementation. While this approach provides maximum leveraging of local funds, it tends to delay needed improvements due to competing priorities from other municipalities.

Each incorporated entity within the study area provides police services within its boundaries, as well as fire protection. Emergency calls are routed to local 911 centers.

6. Public Transit

Public transportation in the metropolitan area is provided by the Greater Cleveland Regional Transit Authority (GCRTA). Operating and capital funds come from farebox revenues and a one percent Cuyahoga County sales tax. Federal grants supplement the capital and operating budgets (approximately 5%), with another 3% of the operating budget coming from the State of Ohio through "formula" funds. Specific projects also receive funding from the state in the form of grants.

Public transit outside of Cuyahoga County is provided by subsidiary agencies, with GCRTA acting in a coordinating role. The other counties reimburse GCRTA. Laketran provides public transportation on a smaller scale to the east of Cleveland, in Lake County. Lorain County operates a small transit agency in the City of Oberland, Geauga County has a Community Responsive Transit service, and Medina County operates a small transit service in the City of Brunswick. None of the outlying transit service providers offer rail transportation.

The GCRTA employs 2700 people and maintains a fleet of 700 buses that operate over a network of 1100 miles of routes, providing both express and local service for a 500 square mile area. Park-n-Ride facilities allow customers in outlying areas to reach the central business district using public transportation. Both light and heavy rail lines provide service between downtown, the airport, and the east side.

The GCRTA has developed a Long Range Plan, Transit 2010, as a blueprint for specifying the kinds of services that GCRTA should put into place over the next 25 years. This plan was developed with the assistance of NOACA, and has been incorporated into the NOACA long range plan. As part of the plan, GCRTA is investing in commuter rail operations on existing right-of-way between Cleveland and Akron, and planning commuter rail operations to Lorain, Medina, Aurora and Mentor.

GCRTA has initiated two planning studies for intelligent transportation system applications to their operations. They are investigating the use of automated vehicle location technology to improve their vehicle performance, scheduling, and rerouting. In addition, they are exploring the use of “Smart Card” technology by their customers to automate fare collection and collect service data. Another project in the design phase is the implementation of a microcomputer based GIS (geographic information system) software package to plan dispatching of paratransit vehicles.

E. Existing Agencies - Private

There are a number of private agencies in the study area that have a direct interest in improving the efficiency of the transportation network. Couriers, such as Federal Express, national package delivery companies, such as United Parcel Service, local delivery companies, and regional and local freight trucking companies stand to make gains in productivity if they have the latest road conditions and are aware of planned construction detours. It should be noted that several local delivery companies already work with Metro Traffic (radio traffic reports) to supply near real time feedback on traffic conditions.

As the ITS deployment proceeds, feedback from these agencies will need to be solicited. Private emergency response agencies throughout the study area will also need to be involved: emergency medical services (ambulances, paramedics) and road service providers (tow truck operators). In addition, travel service providers such as the AAA, and existing traffic monitoring companies such as Metro Traffic Control should be kept informed.

F. Coordination and Cooperation

Chapter 2 of the "Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems" report to Congress by the U.S. Department of Transportation points out that state and local agencies will have to cooperate better if they are going to take advantage of ITS technologies. The responsibility for managing traffic in most metropolitan areas has evolved over time in response to public needs, resources, and prevailing institutional and political arrangements. Within each political jurisdiction these managerial responsibilities are often dispersed among separate public agencies. If cooperation is lacking, this fragmentation will inhibit chances for the successful implementation of certain elements of the national ITS program.

A recent US DOT sponsored report ("Institutional Impediments to Metro Traffic Management Coordination," September, 1993) concluded that public transportation agencies and political jurisdictions generally worked together effectively to introduce and operate traffic management systems. Many of the transportation officials interviewed for this report believe that cooperation and coordination can be achieved among agencies and political jurisdictions without far-reaching changes to established laws, regulations, or policies. Local transportation managers expressed the need for cost-benefit analyses that would allow them to generate the level of public and political support necessary to make large investments in these advanced technologies and to pay for these investments with taxes and user fees.

G. Relationship with Emergency Response Agencies

The local perception of freeway operations in the Cleveland area is one of a practical mixture of various authorities and operating agencies. Most police, fire and highway agencies will readily cooperate with one another when the need arises. The opinion seems to be that things work pretty well already, so that "high-tech" solutions are not needed, or may not be worth the price.

For ITS to succeed in the Cleveland/Lorain region, there must be consensus that this new technology fills a genuine need. Experience in other regions has shown benefits, and the local emergency response agencies need to understand how advanced surveillance and communication can help them carry out their responsibilities more efficiently. This issue will be explored in greater detail in the "Incident Management Plan" Working Paper.

The key to a successful "buy-in" of local emergency response agencies will be to foster regional cooperation without violating their sense of autonomy. In order to maintain a conflict free working relationship among the various participants, it should be stressed that each agency maintains autonomy over their own traffic management operations, while benefiting from the flow of information from a variety of sources. Chapter VII, "Incident Management Plan," explores this further.

H. Political and Legal Concerns

All of the issues discussed in this Chapter have political and legal consequences or implications at some point in their resolution. The following discussion, however, focuses on those issues with particularly sensitive or prominent political considerations or obvious legal issues.

Political barriers to public/private partnership arrangements

Forming partnerships between public and private agencies will require the resolution of legal, regulatory, technical, and user application issues. If such partnerships involve private agencies in fields where there is strong competition, such as telecommunication networks, then the executive and legislative branches of state government are likely to come under lobbying pressures. This will be especially true if large sums of money, whether capital and/or operating, are involved, as is likely to be the case.

In private/public relations, there are many varying opinions on the types of partnerships that should be formed. There are frequently culture clashes, since private companies are mostly market driven, while the public sector is driven by a multitude of Federal, State and local jurisdictions' specifications and regulations.

By examining how other states handle public/private partnerships, ODOT will be better able to determine the best course for its own policies and procedures.

In North Carolina, three telephone companies (Southern Bell, GTE South, and Carolina Telephone Company) will build their own network, the North Carolina Information Highway. The state will then become their biggest customer, utilizing the network for interagency communication.

The Oklahoma State Regents for Higher Education Telecommunications Network provides voice, data, and video communications within and outside of the state. The Office of State Finance has secured an agreement with U.S. Sprint to lease the partial use of a fiber optic cable. This system amounts to a small private telephone or communications company that is owned and operated by the State of Oklahoma. It is not subject to many of the restrictions and tariffs that govern public utilities and private carriers.

The Massachusetts Executive Office of Transportation and Construction is interested in leasing telephone lines. This agency is also working with private companies to jointly fund a motorist assistance program and to provide Advanced Traveler Information, which is managed by a private company and evaluated by consultants.

The New York Department of Transportation is on a number of public/private teams, but only one (NYNEX) requires public funding. It has partnered with the private sector for data services and offered its expressways as a test site for infrared technology. It also volunteered a rest area to be a test site for electronic highway projects.

The Virginia DOT is working with private partnerships for safety service. For example, People's Drug Store operates the service vehicles, and VDOT underwrites the State Police for safety service.

The Minnesota Department of Transportation is involved with several private partnerships for such projects as transit and traveler information projects. The Department has a range of partnerships from simple agreements and traditional traffic engineering projects to partnerships with detailed, sophisticated contracts. In addition Minnesota DOT is installing its own fiber optic cable, and is considering allowing private telephone companies to invest in or lease its fiber. An unsatisfactory experience with one cable company has compelled the Department to proceed with caution.

The Minnesota DOT has also encountered the issue of revenue and royalties, which could become an issue for ODOT as well. The project produces royalties from a product. Superficially, the extra revenue appears invaluable; however, royalties can create a bias for public agencies to issue contracts based on how much money it can net. Ideally, public agencies should not be biased by such financial enticements.

The Ohio Department of Transportation does have private, public, and quasi-public partnerships through ITS Ohio (formerly IVHS-Ohio), public agencies, private consulting firms, and quasi-public/not-for-profit companies like Battelle (which also worked on the Minnesota Guidestar project) and the Transportation Research Center, Inc. (which has a test track and skid pad for automobile manufacturers' test purposes).

<u>Access to state highway rights-of-way</u>

The legality of granting access to others for the use of state highway rights-of-way is still open. Application of existing laws to this issue is subject to differing interpretation. There is a precedent in the area, since a private fiber optic communication trunk does make use of the Ohio Turnpike right-of-way.

Several other state DOTs that have granted access to highway rights-of-way have experienced some negative results. Therefore, the Department should proceed with caution to minimize the risks, and develop well-defined contracts to grant access to its rights-of-way in accordance with the laws of supply and demand.

<u>Revenue generation and its allocation</u>

In addition to the question of whether ODOT can charge other public agencies and/or private agencies for the use of its rights-of-way, there will be substantial issues and potential political implications regarding how such revenue would be allocated and to whom.

Operating and maintaining ITS facilities will require a continuous stream of revenue. It is therefore necessary to accept new annual operating costs that did not exist previously, or to find a way to fund these operations.

Participation of other governments, agencies, or firms in regionally coordinated efforts

Efforts along these lines are just now getting under way, and the establishment of linkages with local and other state agencies and the private sector for deployment of ITS initiatives is still being developed.

Anti-trust legislation

There is still disagreement as to whether anti-trust concern are a real obstacle or just a perceived one. Some resolution is forthcoming through such channels as the National Cooperative Research Act, which provides protection for collaborations in the name of research.

There is concern in the business community that particular cooperative agreements between actual or potential competitors in the field of ITS may lead to violations of anti-trust laws (e.g., in joint ventures, mergers, and aquisitions). For ITS, the most relevant anti-trust statutes are the Sherman Act of 1890, which prohibits monopolization and contracts in restraint of trade; and the National Cooperative Research and Production Act of 1993 (NCRPA), which allows certain joint ventures engaged in research and production to limit their potential anti-trust liability. NCRPA "encourages" parties to engage in joint ventures in the ITS field. According to the U.S. Department of Justice and the U.S. DOT, it is too early to recommend any changes to the anti-trust laws at this time.

The risk of creating a monopoly has to be balanced against the resources that will be available to address the issue. Smaller companies may not be able to compete with the resources and funding of national conglomerates. Any government agency must be cautious of setting up a potentially inequitable arrangement that could hurt not only corporate competitors, but ultimately the taxpaying public by locking ODOT into sole-source arrangements.

Intellectual property and proprietary technology

Proprietary technology and its associated intellectual property rights serve as motivation for private investment. It will require careful planning and negotiation for both sides to foster a successful implementation.

The Bayh-Dole Act is generally applicable to federally funded grants, contracts, cooperative agreements and experimental work. Under this act, the Federal Government retains certain rights to inventions made under Federal funding. It has "march-in" and unlimited rights to data produced under Federal procurement contracts. Private parties may face a problem in offsetting research and development costs through sales if public sector agencies demand a greater share of intellectual property rights to an ITS technology or service. The private sector is concerned that retention of intellectual property rights by a public agency will result in their release into the public domain.

A private party may avoid losing rights to pre-existing or independently developed work by registering copyrights before participating in a federally funded project. For example, new inventions and services can be protected via legal counsel and the creation of programs for in-house documentation of conception and development of inventions.

Invasion of individuals' privacy

This is another category where opinion is divided regarding the perception of this issue as a real concern or something that will resolve itself over time. Current consensus seems to be leaning toward the latter interpretation. However, since ITS technology will collect information on individual's travel, some applications could affect national and/or state right to privacy provisions.

Successful ITS applications require political support. Political support is very sensitive to public opinion. If the public perceives that ITS technology invades their privacy, there could then be a backlash against ITS. This poses a dilemma, because certain ITS deployments will create data bases identifying individuals' travel patterns and account balances. For example, ATM cards can register information on the time and place of the transaction, as well as the amount. Therefore it is important to deploy the types of ITS services and technologies for which there is a genuine need. However, it must be realized that these needs will change over time, and allow for these changing needs to be accommodated.

Information discrimination

Related to privacy issues is the matter of information discrimination. Information needs to be disseminated fairly among all interested users. Depending on the pricing structure and accessibility, travel information may not be equitably available. This potential for inequity comes in many forms: social, economic, regional, or demographic. For example, if private companies become involved in distributing travel information, they can create inequities by charging fees or providing location specific information.

As public agencies get into the information business, a need to establish checks and balances arises. The need for verification of information accuracy is necessary not only for customer satisfaction, but also for the agency's credibility and liability.

Potential liability

The dissemination of travel information entails possible liabilities related to the accuracy and timeliness of that information. Traffic diversion by the suggestion of alternate routes is another area with potential liability aspects. Other technical advances, such as automated highways, could also introduce significant exposure. Liabilities arising out of defective manufacture, incorrect information, reliance on systems that fail to avoid accidents and defective design liability claims are important issues. If public agencies assume responsibility for operations and maintenance of ITS technologies, then the status quo persists. Since private firms may also operate and maintain these technologies under contracts, apportionment of liability responsibilities should be negotiated and incorporated in the contract.

I. Public Involvement

The key to integration and coordination is communication, not only among the agencies carrying out the work, but with the customers as well. In this case, the customers can be broadly defined as anyone who uses the public highways. Thus, communication will include direct and indirect links to the public.

The process of reaching out to the traveling public should start immediately, to inform them of the benefits that can be realized from ITS. All forms of media should be used to gain the public's support. When the public better understands the issues, they will be better prepared to provide feedback. For ITS to succeed in the Cleveland/Lorain region, it must have support from a broad range of stakeholders: the traveling public, all levels of local government, and various private agencies. All must be informed of the issues and need to participate in brainstorming and decision making whenever feasible. Public and legislative input should be solicited and the responses incorporated into the action plan.

Once ITS is a reality in the region, traffic and construction information should be provided to the media, or to the public directly, as is already being done through the MPO, with a toll free number. Weekly construction advisories should be sent to regional trucking firms. Travel information could be faxed to selected businesses during major incidents (like snowstorms or emergency maintenance/construction).

Accurate and timely information will serve to reinforce public support for ITS and will help encourage participation by a variety of private agencies as they realize the benefits of advanced surveillance and communication technology applied to surface transportation.

J. Adopting the ITS Deployment Plan

Unlike previous large-scale transportation undertakings such as the Interstate Highway Program, the ITS program is not envisioned to be funded primarily by the federal government. In fact, 80 to 90 percent of ITS deployment costs over the next twenty years are expected to be borne by the private sector and individuals. The federal ITS program is directed more toward nurturing the emergence of an American ITS industry, instead of using public funds to rebuild the highway infrastructure into an information age transportation system.

At the same time, transportation decision making is shifting from the federal level to state and local governments. Local leaders will make decisions that will affect transportation services in

their own regions. Recent changes in the political climate have created competing priorities and budget pressures. There is intense competition for limited transportation funds. Consensus building across jurisdictional boundaries is difficult, but the ultimate success of ITS may lie not in the technology itself, but in the people who put it together and operate it on a daily basis. Solutions to area-wide transportation problems will only be found through cooperation.
ITS Policy Decisions

ITS projects differ from more traditional engineering projects in process, content, and participants. Ohio, like most other states, has not yet standardized the development process for ITS projects. Because deployment of ITS technology will take place over a long period of time, future conditions have a major role in determining the method of such deployment. Therefore, major elements of this plan will have to be in place before funding sources are identified. Consequently, the plan will need to be iterative as these sources are identified and refined.

The proposed Cleveland/Lorain ITS Deployment Plan will require capital funds, as well as operation and maintenance funds. There are temporary provisions in the ISTEA legislation that allow funds to be used for operation expenses for a period of two years. Beyond that time, other sources of revenue will have to take over. Chapter X, "Contractual and Financing Alternatives," takes a detailed look at the traditional as well as non-traditional methods of funding and constructing a high-technology system in the Cleveland/Lorain metropolitan area.

K. Policy Adoption Requirements

The feedback provided from the questionnaires distributed to public agencies within the study area primarily focused on the lack of funding, followed closely by concerns that local agencies need to cooperate and coordinate their efforts more closely. Of the two, the more critical issue in making the deployment of ITS technology in the Cleveland/Lorain study area successful is interagency coordination and cooperation, since this process needs to start as soon as possible, while funding sources can be developed at a different rate.

Even in the presence of adequate funding, lack of cooperation and coordination can hinder the deployment of ITS technology. With the reality of limited funding, interagency cooperation and coordination is vital to successful deployment, since competing for limited funds would be counterproductive. It is therefore important to define a methodology for funding allocation and project prioritization that is acceptable to all interested parties, so that deployment can proceed unhindered by interagency "turf battles."

The initial deployment will most likely take place on the most heavily traveled roadways first, expanding over time to other parts of the transportation network as resources become available. It is therefore of paramount importance to gain regionwide support, both public and private, up front, before actual deployment begins. It is necessary to get commitments in advance, because once deployment starts, inevitably some areas and agencies will realize benefits earlier in the process than others. If all parties agree in advance that ITS technology can contribute to system-wide improvements (even if not immediately in their particular area of interest), future improvements will build upon past successes and accelerate the deployment as more people realize the advantages provided by up-to-the-minute travel information, and demand access to these services.

Therefore, a policy-setting body that determines funding allocation and project priority cannot be a single agency. Decisions issued by a single agency would always be viewed as autocratic or self-serving. Instead, the authority for setting ITS policy should rest with a group that has the consensus of all interested parties to act for the interests of the entire region.

L. Recommendations

This report cannot recommend an optimal ITS operating environment. The industry's collective experience and knowledge of existing and planned technology are not yet sufficient to specify the optimal set of institutional and organizational arrangements that would guarantee the successful deployment of ITS products and services, whether in the Cleveland/Lorain study area, or anywhere else. Advanced transportation technologies are currently being operated under a multitude of different institutional arrangements and operating environments. What works in one area may not necessarily work in another.

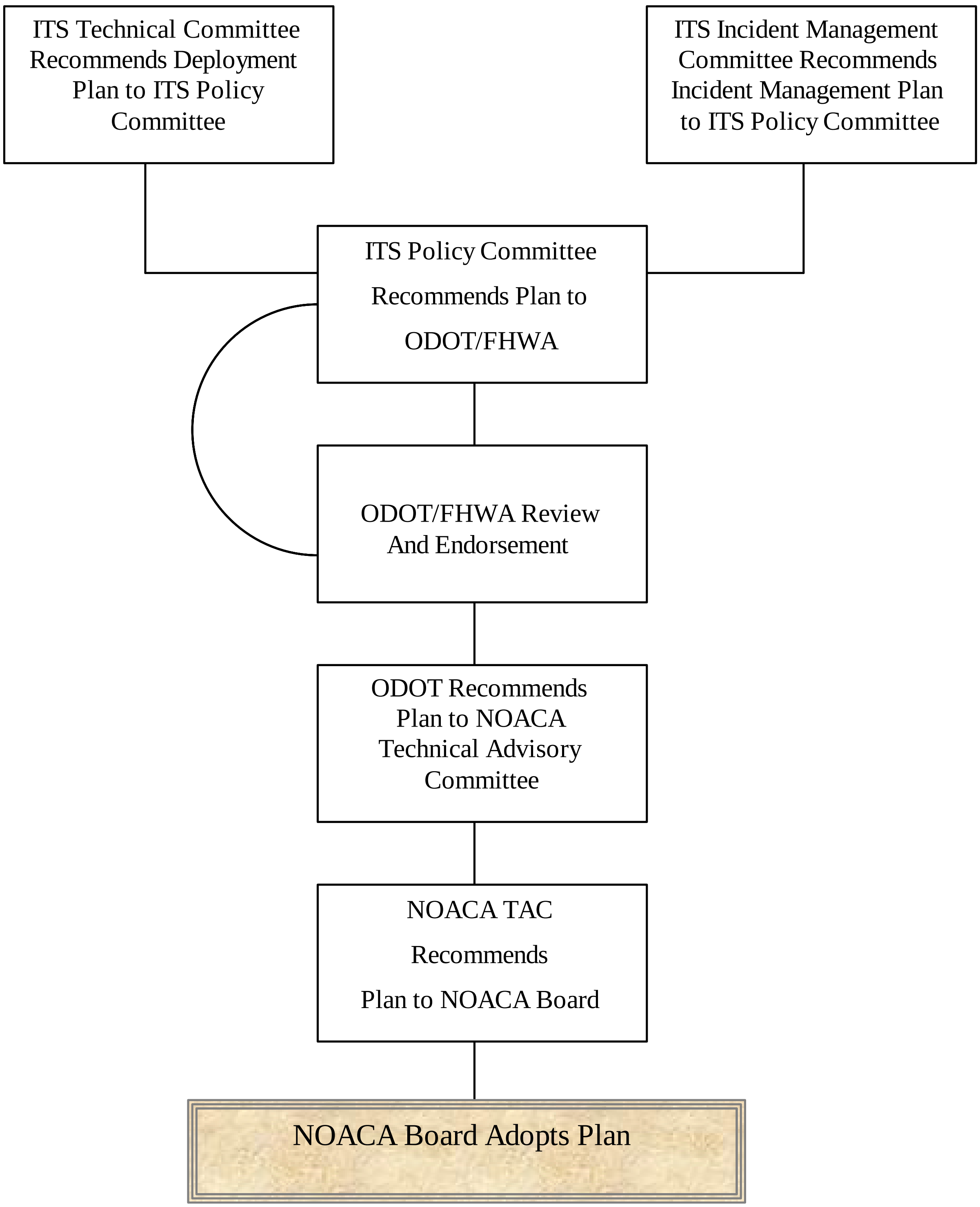
There are two approaches to solving this conundrum: starting from the ground up, or modifying an existing structure. Starting fresh provides the opportunity to avoid past mistakes, but also poses the risk of committing new ones. Modifying an existing structure takes advantage of its good aspects while providing the opportunity to improve the parts that do not work well. However, it poses the risk of harming the working relationships established over the years.

A completely new organization could be set up that would be charged with coordinating local ITS interests. An example of such an entity is the TRANSCOM (Transportation Operations Coordinating Committee) organization in New York/New Jersey, a consortium of public and private entities all contributing staffing, funding, and equipment to facilitate transportation in the area.

Another option would be to use the existing metropolitan planning organization (NOACA) and enhance its structure, forming a subcommittee of the Transportation Advisory Committee, with Ohio Department of Transportation as the lead agency with full voting rights. This approach also takes advantage of existing cooperative networks, and builds upon them. In addition, NOACA has been making acceptable policy decisions regarding transportation projects, which would be conducive to the process of making acceptable policy decisions in ITS matters.

However, given the fragmentation of authority within the study area, and taking advantage of the existing working relationships, the best approach would be to use the bodies set up for this project (the Technical, Incident Management, and Policy Committees), and, with ODOT review and approval, approach the MPO (NOACA) for formal adoption of the Deployment Plan as is current practice for regular transportation improvement projects. The following flow chart outlines the process (Figure II-3).

Figure CHAPTER II. –3. Deployment Plan Adoption Process



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CHAPTER III. USER SERVICES

A. Introduction

This Chapter summarizes the efforts involved in identifying the nationally-defined user services that would be appropriate for implementation in the Cleveland/Lorain Metropolitan Area. The National Intelligent Transportation Systems (ITS) program has defined twenty-nine (29) user services as part of the national program planning process. These user services are defined based upon the services or benefits that various users of the transportation system might use or obtain. Users have been defined to include travelers using all transportation modes, transportation operators including DOT's and transit operators, commercial vehicle owners, state and local government agencies as well as many others involved with ITS deployment.

As described in Chapter I, the major focus of this study is the freeway system in the Metropolitan area. Transit and commercial vehicle operations will also be considered as part of the overall plan, especially where they impact freeway operations and where freeway operations impact upon their operations. Arterial operations are also addressed, since the addition of US-42 (Pearl Road) broadened the scope of this study.

Identifying the appropriate user services is basic to the ITS planning process as defined by the FHWA. No plan will be effective unless it addresses the actual needs specific to the area where it is to be implemented. An accurate inventory of the existing transportation system therefore forms the foundation for determining how, when, and where ITS technologies can be applied to improve the safety, efficiency, and capacity of the Cleveland/Lorain regional transportation network.

B. Transportation System Characteristics

The existing and future transportation characteristics were described in detail in Chapter I. Recurring congestion accounts for a significant portion of delay experienced by motorists. This congestion can be attributed to inadequate capacity and geometric transitions that change the vehicle flow abruptly, among other things. Non-recurring congestion is also a major factor in the Cleveland/Lorain Metropolitan area. Reviewing 1991 - 1993 accident statistics revealed several segments with accident statistics significantly higher than the rest of the roadways evaluated in this study, as described in Chapter I. Overall, nearly 220 centerlane miles of roadway were evaluated in the freeway network.

Over 30% of the network experiences recurring congestion while over 11% would be significantly impacted by an incident resulting in extensive non-recurring congestion. Nearly 20% of the network experiences this recurring congestion for several hours a day. In the future, despite constructions program that will provide additional capacity in the system the situation is expected to deteriorate. Table III-1 summarizes the statistics.

Table CHAPTER III. -1. Recurring/Non-Recurring Congestion Summaries

Characteristics	Existing		Future	
	Miles	% of Study Area	Miles	% of Study Area
Recurring Congestion	66.5	30.3%	85.3	38.9%
ADT Exceeding 15,000 veh/lane	41.9	19.1%	64.9	29.6%
Non-Recurring Congestion	25.25	11.5%	Unknown	Unknown

C. Description of User Services

The national ITS program has defined twenty-nine interrelated user services. These user services are defined by their ability to meet the transportation-related needs of the users in a given metropolitan area. They are not necessarily related along lines of common technology. The users include the entire spectrum of transportation providers, operators and travelers as well as other fringe groups involved in these transportation services or who may benefit from improved transportation services. Figure III-1 shows the cross section of all potential users in a metropolitan area and how the national program defines their interrelationships.

The actual user services are comprised of multiple technological elements and functions. They serve as building blocks that can be combined in many ways for deployment in the Cleveland/Lorain area. The combination of user services should be selected to meet local priorities, needs, institutional frameworks and regional market forces. The user services should be combined in deployable systems and services that will meet the goals for the region. The user services have been grouped into bundles based on those services that are likely to be deployed in a region or corridor scenario. The bundles also typically take into account the commonality of the technological functions for the services. Table III-2 lists the bundles and services and is followed by a brief description of each of these services and bundles.

Figure CHAPTER III. -1. National User Services Relationships

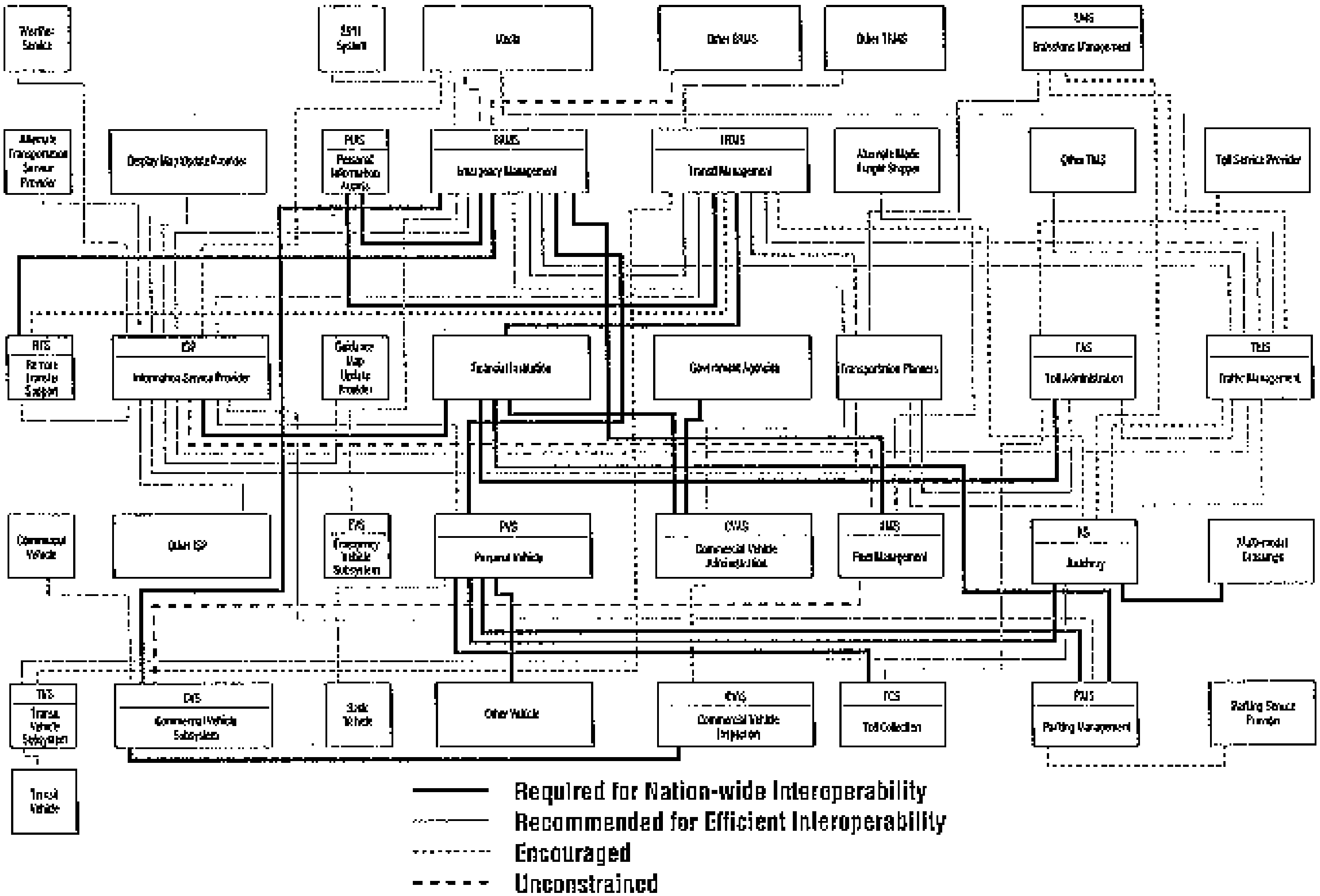


Table CHAPTER III. -2. National User Services

Bundle	User Services
1. Travel and Transportation Management	1. En-Route Driver Information 2. Route Guidance 3. Traveler Services Information 4. Traffic Control 5. Incident Management 6. Emissions Testing and Mitigation
2. Travel Demand Management	1. Pre-Trip Travel Information 2. Ride Matching and Reservation 3. Demand Management and Operations
3. Public Transportation Operations	1. Public Transportation Management 2. En-Route Transit Information 3. Personalized Public Transit 4. Public Travel Security
4. Electronic Payment	1. Electronic Payment Services
5. Commercial Vehicle Operations	1. Commercial Vehicle Electronic Clearance 2. Automated Roadside Safety Inspection 3. On-Board Safety Monitoring 4. Commercial Vehicle Administrative Processes 5. Hazardous Material Incident Response 6. Commercial Fleet Management
6. Emergency Management	1. Emergency Notification and Personal Security 2. Emergency Vehicle Management
7. Advanced Vehicle Control and Safety Systems	1. Longitudinal Collision Avoidance 2. Lateral Collision Avoidance 3. Intersection Collision Avoidance 4. Vision Enhancement for Crash Avoidance 5. Safety Readiness 6. Pre-Crash Restraint Deployment 7. Automated Highway Systems

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.

- **En-Route Drive Information**: Provides driver advisories and in-vehicle signing for convenience and safety.
- **Route Guidance**: provides travelers with simple instructions on how to best reach their destinations.
- **Travel Services Information** : Provides a business directory, or "yellow pages," of service information.
- **Traffic Control**: Manages the movement of traffic on streets and highways.
- **Incident Management**: Helps public and private organizations quickly identify incidents and implement a response to minimize their effects on traffic.
- **Emissions Testing and Mitigation** : Provides information for monitoring air quality and developing air quality improvement strategies.

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 other will be required to do so in response to the mandates of the 1990 Clean Air Amendment.

- **Pre-Trip Travel Information** : Provides information for selecting the best transportation mode, departure time, and route.
- **Ride Matching and Reservation**: Makes ride sharing easier and more convenient.
- **Demand Management and Operations**: Supports policies and regulations designated to mitigate the environmental and social impacts of traffic congestion.

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.

- **Public Transportation Management**: Automates operations, planning, and management functions of public transit systems.
- **En-Route Transit Information**: Provides information to travelers using public transportation after they begin their trips.
- **Personalized Public Transit** : Provides flexibly-route transit vehicles to offer more convenient customer service.
- **Public Travel Security**: Creates a more secure environmental for public transit patrons and operators.

Electronic Payment

The Electronic Payment bundle includes one user service, electronic payment services.

- **Electronic Payment Services**: Allow travelers to pay for transportation services electronically.

Commercial Vehicle Operations

The Commercial Vehicle Operations 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.

- **Commercial Vehicle Electronic Clearance**: Facilitates domestic and international border clearance, minimizing stops.
- **Automated Roadside Safety Inspection**: Facilitates roadside inspections.
- **On-Board Safety Monitoring**: Senses the safety status of a commercial vehicle, cargo and driver.
- **Commercial Vehicle Administrative Processes** : Provide electronic purchasing of credentials and automated mileage and fuel reporting and auditing.
- **Hazardous Materials Incident Response** : Provides immediate description of hazardous materials to emergency responders.
- **Freight Mobility**: Provides communications between drivers, dispatchers, and intermodal transportation providers.

Emergency Management

The Emergency Management bundle includes two user services that relate directly to the detection, modification, 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.

- **Emergency Notification and Personal Security**: Provides immediate notification of an incident and an immediate request for assistance.
- **Emergency Vehicle Management**: Reduces the time it takes for emergency vehicles to respond to an incident.

Advanced Vehicle Safety Systems

The Advance Vehicle Safety Systems bundle includes seven user services that are related primarily to the safety goals of "ITS". The implementation of these user services would diminish the number of severity of crashes. The technologies necessary for user services in the Advanced Vehicle Safety System bundle are currently in the research and development stages. Because these user services are currently being researched at the national level and are not appropriate for local application during the planning horizon considered in this study, they will not be included in future evaluations for the Cleveland/Lorain project. Definitions are provided here for information only.

- **Longitudinal Collision Avoidance**: Helps prevent head-on, rear-end or backing collisions between vehicles, or between vehicles and other objects or pedestrians.
- **Lateral Collision Avoidance**: Helps prevent collision when vehicles leave their lane of travel.
- **Intersection Collision Avoidance**: Helps prevent collisions at intersections.
- **Vision Enhancement for Collision Avoidance**: Improves the driver's ability to see the roadway and objects that are on or along the roadway.
- **Safety Readiness**: Provides warnings about the condition of the driver, the vehicles, and the roadway.
- **Pre-Collision Restraint Deployment**: Anticipates an imminent collision and activates passenger safety systems before the collision occurs, or much earlier in the crash event than is currently feasible.
- **Automated Highway Systems**: Provides a fully automated, "hands-off," operating environment.

D. Regional Goals and Objectives

The national ITS program has defined a series of strategic goals that include:

- Improve Safety
- Increase Efficiency
- Reduce Energy and Environmental Impacts
- Enhance Productivity
- Enhance Mobility

From the local perspective, the survey of regional agencies that was conducted (Appendix B) showed that locally agencies are looking for ITS to:

- Improve travel times
- Increase service through efficient use of resources
- Reduce capital investment in construction
- Promote smooth traffic flow
- Provide a safe and efficient transportation system

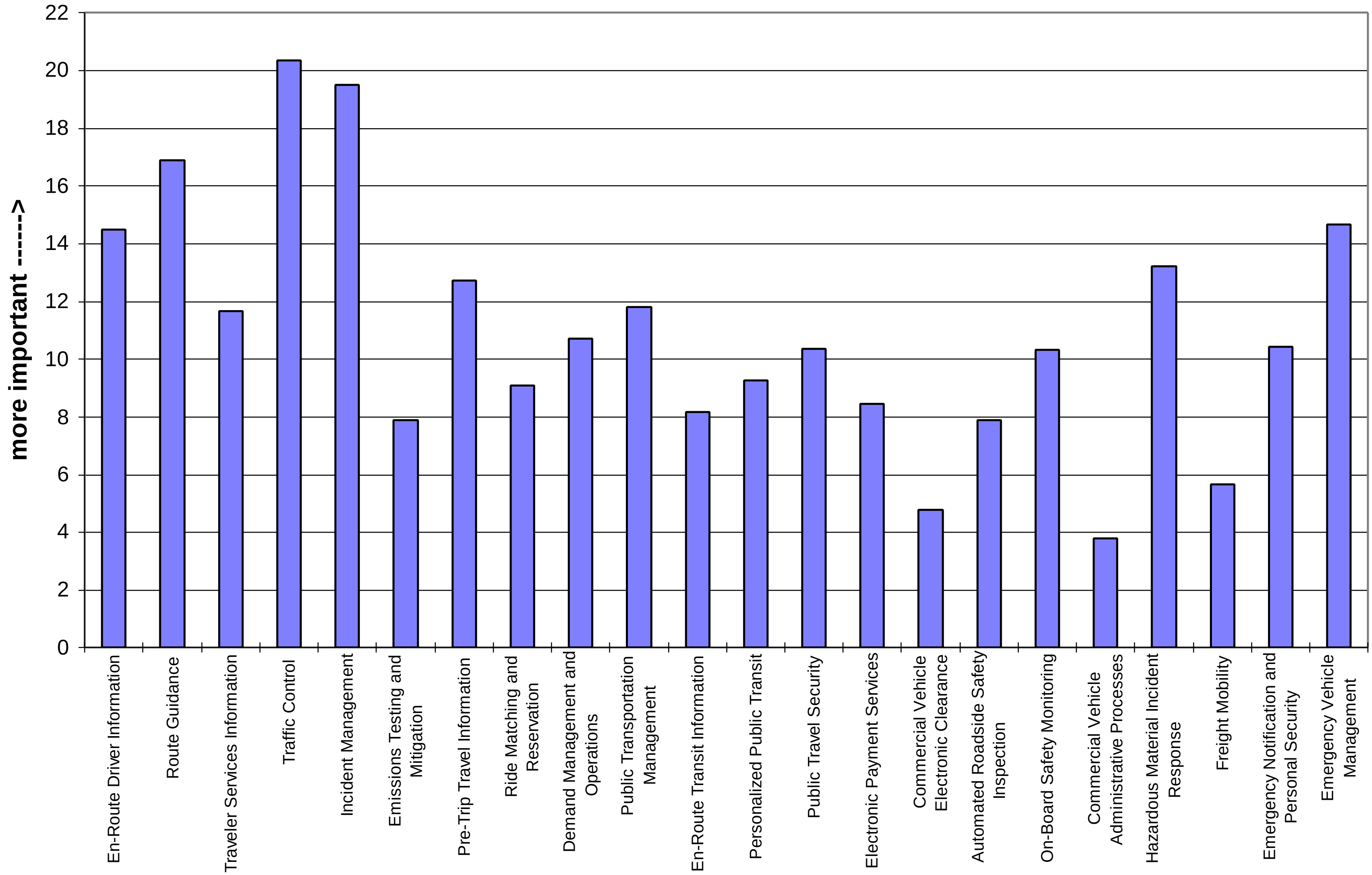
- Improve communications to users
- Reduce traffic congestion on a cost-effective basis
- Provide dependable information to the traveling public
- Respond quickly and professionally to emergencies and incidents
- Decrease delay due to incidents
- Promote more efficient modal utilization
- Increase efficiency in providing transit service
- Provide priorities to HOVs.

The survey of agencies asked each of them to rank the importance of the primary twenty-two user services. Table III-3 and Figure III-2 summarize the results of this ranking process.

Table CHAPTER III. -3. Agency Composite Ranking of User Services

User Services	Composite Rank
Traffic Control	1.64
Incident Management	2.50
Route Guidance	5.11
Emergency Vehicle Management	7.33
En-Route Driver Information	7.50
Hazardous Material Incident Response	8.78
Pre-Trip Travel Information	9.27
Public Transportation Management	10.18
Traveler Services Information	10.33
Demand Management and Operations	11.27
Emergency Notification and Personal Security	11.56
Public Travel Security	11.64
On-Board Safety Monitoring	11.67
Personalized Public Transit	12.73
Ride Matching and Reservation	12.89
Electronic Payment Services	13.55
En-Route Transit Information	13.82
Emissions Testing and Mitigation	14.11
Automated Roadside Safety Inspection	14.11
Freight Mobility	16.33
Commercial Vehicle Electronic Clearance	17.22
Commercial Vehicle Administrative Processes	18.22

Figure CHAPTER III. -2. User Services Composite Ranking



It is clear that the user services contained within the Travel and Transportation Management and Emergencies Management bundles were the local priority of the local agencies. Figure III-2 illustrates this most clearly. The highest ranks representing the most important user services were in those two bundles. It is obvious that a common base is indicated by the agencies' suggestions. The project goals should thus be defined as:

1. *Reduce both recurring and non-recurring traffic congestion by improving the efficiency of the existing transportation system.*
2. *Improve the overall safety of the transportation network.*
3. *Improve communications to the general public and between transportation providers.*
4. *Improve the response time and clearance of emergencies and incidents on the transportation's network.*
5. *Promote more efficient modal utilization.*

In order to evaluate the potential success of any future plans and recommendations, measures of effectiveness (MOE's) can be used to define the success or failure of a strategy or system component. These MOE's must be related to the goals and objectives of the project. For the Cleveland/Lorain project it is suggested that the following MOE's be used in the evaluation process:

- Average vehicle speeds
- Average duration of congestion
- Vehicle hours of delay
- Response and clearance times for incidents
- Number of accidents
- Modal volumes

E. Selected User Services

Matching the user services to local priorities, transportation problems and needs, regional goals and the defined network results in several user services being given the highest priorities. Some services such as Route Guidance and part of the En-Route Driver Information user service rely on the development of in-vehicle computer devices and thus were not given a high priority in the Cleveland/Lorain plan. Over the longer term any systems developed in the Cleveland/Lorain area must recognize the desirability of these services and be capable of integrating them. Others, such as the Hazardous Materials Incident Response user service relies heavily on national efforts to register hazardous material-carrying trucks and should be implemented when these efforts become regionally implemented. The highest priority user services thus are:

- **Travel and Transportation Management Bundle**
  - Traffic Control
  - Incident Management

- En-Route Driver Information (only external Driver Advisory is included)
- Traveler Information Services

- **Travel Demand Management Bundle**
  - Pre-Trip Travel Information
  - Demand Management and Operations

- **Public Transportation Operations Bundle**
  - Public Transportation Management

- **Emergency Management Bundle**
  - Emergency Vehicle Management
  - Emergency Notification and Personal Security

Below is a summary of how each of the services is expected to be used in the Cleveland/Lorain area.

1. Traffic Control

The Traffic Control user service should be used to manage the movement of traffic on streets and highways. It could include surface street controls such as adaptive signal systems and freeway control techniques such as ramp metering and lane controls. Since the focus of this study is the freeway network the emphasis of the user service will be on control aspects of the freeway network as well as future integration needs to allow the surface streets and freeways to work together. Traffic Control will help to improve the efficient movement of all users of the surface transportation system.

Traffic Control can also improve the people moving capacity of the roadway system through preferential treatment for mass transit and other types of high occupancy vehicles (HOVs). One of the long range goals of the Traffic Control user service in the Cleveland/Lorain area will be the integration of the control of freeways and the regional network signal systems to promote areawide optimization of traffic movement. Many areas such as Los Angeles and Boston have already investigated this option. Obviously new institutional arrangements and increased interjurisdictional cooperation would be necessary to allow for this type of unified operation of systems owned and operated by multiple jurisdictions.

The appropriate type of traffic control will be implemented by devices such as traffic signals, information signs, freeway ramp meters, and devices for the dynamic control of the transportation infrastructure such as reversible lanes, rush hour turn restrictions, and HOV signals. The Traffic Control user service will manage these control mechanisms so that control can be provided on an area-wide basis, thereby avoiding fragmented or conflicting control strategies. For example, in the Cleveland/Lorain area metered ramps implemented will not allow traffic queues to overflow the ramp and disrupt the operation of adjacent intersections. The implementation of Traffic Control will require the use of many supporting technologies. These technologies will generally fall into the functional areas of traffic surveillance, data and voice communications, data processing and automation, and human interface.

2. Incident Management

The Incident Management user service will develop the capabilities for detecting incidents and taking the appropriate actions in response to them. Both unpredicted incidents and predicted incidents such as construction or planned lane closures would be included. Incidents such as accidents, construction and maintenance activities, adverse weather conditions, parades, sporting events, tourist attractions, or other events can cause congestion by temporarily increasing demand or reducing the capacity of the transportation network. "Rubbernecking" by those not directly affected by the incident can also lead to congestion and delays. Even minor incidents, such as a disabled or abandoned vehicle on the shoulder, will create a potential safety hazard and potentially cause rubbernecking delays.

In the Cleveland/Lorain area the Incident Management user service will be developed to use advanced sensors, data processing, and communications to improve the detection and response capabilities of transportation and public agencies. The service will help to quickly and accurately identify a variety of incidents, and to implement a set of actions to minimize the effects of these incidents on the movement of traffic. The service can also help to identify or forecast hazardous weather, traffic, and facility conditions so that agencies can take action in advance to prevent incidents or minimize their impacts.

A major focus of the Incident Management user service will be to improve the response to unpredicted incidents, such as accidents, vehicle breakdowns, and loss of cargo situations. There is generally little or no advanced warning for these types of events so that the speed of detecting the incident and implementing the proper response is critical. Detection systems will likely use advanced sensor technology, data generated by numerous other sources, such as freeway service patrol and cellular telephones and sophisticated software to quickly verify the location, characteristics, and potential impacts of an incident. Advanced computer-based decision support systems can also be developed to help all appropriate agencies to cooperatively decide on the best set of actions to minimize the effects of an incident and determine who is responsible for implementing each action. These actions may involve dispatching emergency or service vehicles to the incident scene, providing information and routing instructions to travelers, and/or altering existing traffic control. The user service will also provide the capability to coordinate the scheduling of many predictable incidents, to minimize their traffic flow impacts.

With "Home Rule" in Ohio, an effective response to any incident will require extensive communication and institutional coordination. Due to the dynamic nature of incidents and their impacts, contact among all agencies must be maintained throughout the life of an incident. This will require the use of advanced data management and communications technologies to help ensure that the best possible information on the nature of an incident, and the associated response effort, is available at all times. A determination will have to be made of the best way to respond to all verified incidents, including which organizations, resources, and procedures to use. This response plan must be developed as part of the development of this user service. Response plans for both unpredicted and predicted incidents should be developed in advance.

3. En-Route Driver Information

The En-Route Driver Information user service will provide travel-related information to drivers after their trips have begun. This user service includes the provision of real-time information on traffic, transit and roadway conditions. En-Route Driver Information is composed of two sub-services: driver advisory and in-vehicle signing. For the Cleveland/Lorain Metropolitan area the plan will focus on the driver advisory aspects. Smoother traffic flow should result from reduced congestion by improved route selection, and trips shifted to public transportation systems.

Driver advisory will require some electronic equipment for each vehicle, perhaps something as simple as a radio. It could consist of a variety of electronic devices which might also be capable of receiving information at home, at the office, and at convenient public locations through a variety of technological means and media. These devices will require advanced communications and microprocessor techniques to accommodate a variety of driver and traffic network requirements. FM subcarrier communications techniques that use the existing communications infrastructure, spread spectrum two-way radio, microwave and infrared beacon, cellular radio, variations of Highway Advisory Radio, and transponder-based vehicle-to-roadside systems are some of the technologies. Information dissemination techniques, such as variable message signs, roadside displays, video monitors, as well as audio/visual presentation methods may also be included.

4. Traveler Services Information

The Traveler Services Information user service provides the traveler with access to information regarding a variety of travel related services and facilities. In general this information will be of the "yellow pages" types, organized to provide quick access to services in the local vicinity of the traveler. The information will be accessible to the traveler in his home or office to support pre-trip planning, and while en-route, either in a vehicle or at public facilities such as public transit terminals or highway rest stops to help the traveler locate critical local services or determine regional transportation conditions. Information would be available regarding the location and status of transportation services, food, parking, hospitals and police stations or other related services.

Travel Service Information would be provided to travelers in several ways. In some areas a limited amount of information would be provided as pre-recorded verbal information that is broadcast on a special radio channel via Highway Advisory Radio or accessed through dial-up telephone lines, such as a Highway Advisory Telephone.

Another mechanism for providing this information would be through the use of "yellow pages"-like directories accessed by computers at home or in the office, or at information kiosks at major generators. Kiosks could be located in public areas such as at rest areas along the interstates, near major activity centers, or at tourist attractions. They could also be located at service plazas. Airline travelers at Cleveland Hopkins Airport looking for traffic conditions, alternatives modes and routes for local points of interest and special events could access such a system through kiosks located at the airport.

5. Pre-Trip Travel Information

The Pre-trip Travel Information user service will provide travelers with information prior to their departure and before a mode choice decision is made. The Pre-trip Travel Information service integrates information from various transportation modes and presents it to the user through electronic communications or public information centers. Users of the service will include all travelers, as well as agencies who will develop pre-trip information services. The Pre-trip Travel Information user service will eventually allow travelers to access a complete range of multimodal transportation information at home, work, and other major sites where trips originate.

These systems will provide timely information on traffic and highway conditions; transit routes, schedules, transfers, and fares; intermodal connections to rail services; real-time information on incidents, accidents, road construction, alternate routes, traffic regulations and tolls; predicted congestion and traffic speeds along specific routes; parking conditions and fees; availability of park-and-ride facilities; tolls; special event information; and weather information. To provide travelers with a common information medium for all transportation modes, integration of intermodal information should occur. Traffic control systems generating data on highway conditions should be integrated with public transportation systems providing transit location and route information. Paratransit services and access to ridematching services could also be included.

Real-time public transportation data should include information gathered by an automated vehicle location (AVL) system, while route and schedule data can come from the transit operators. Highway condition information will eventually be collected through the Traffic Control and Incident Management user service using closed-circuit television, roadway sensors, and image processing. Additional highway condition information can also be made available through Electronic Toll and Traffic Management (ETTM) systems, and equipped vehicles acting as traffic probes.

In the initial systems, information will be presented on a standard or cellular telephone, which will ask the listener to push the number corresponding to the desired service, and then provides continually updated information. The Pre-Trip Travel Information User Service can also be presented through personal computers with modems, cable television, and Personal Communications Devices (PCDs).

The ultimate system will include elaborate interactive map presentations requiring larger amounts of computer memory, and will be provided at major generators and public locations in kiosks.

6. Demand Management and Operations

The Demand Management and Operations user service is intended to reduce roadway vehicle demand by developing and encouraging modes other than single occupant vehicles, and to decrease congestion by altering the timing or locations of trips, or eliminating vehicle trips altogether. The Travel Demand Management user service uses ITS technologies and systems to facilitate the implementation and operation of TDM strategies.

The user service will generally operate and function through interactive computer operations and communications centers that implement the TDM management and control strategies, by:

- Receiving information and data from transportation operators and/or users, on the current status, need, and level of activity and;
- Sending or disseminating operational information and commands to operators and/or users on how to control or manage activity so as to conform and comply with a program, policy, or regulation.

For the Cleveland/Lorain area this user service might include:

<u>HOV Facility management and control</u>: HOV Lanes can be operated and enforced to responded to current conditions and situations. Occupancy requirements could be adjusted by time of day or to reflect current demand and congestion levels and incidents. Another example of this operational concept is for traffic management systems to give priority to the movement of carpools, vanpools, and buses at ramp-meters and signalized intersections.

<u>Parking Management and Control</u>: The allocation, price, and availability of parking spaces could be managed and controlled to effect a mode change to HOVs. Working form a traffic operations center, variable message signs, and detection equipment could be used to respond to events by implementing strategies by time of day or in a dynamic manner.

<u>Mode Change Support</u>: This aspect supports the ride matching and reservation options similar to the proposed system being designed by GCRTA. It will provide the public with greater flexibility when using public transportation.

7. Public Transportation Management

The Public Transportation Management user service will apply advanced vehicle electronic systems to public transportation modes by using the data generated by these modes to improve service to the public. For the Cleveland/Lorain ITS plan this user service will focus on the operational aspects of public transportation. Real-time data from individual vehicles can be communicated via a data link and compared with schedule information and other predetermined parameters. A computer can identify deviations, can display them to the dispatcher and determine the optimum scenario for returning the vehicle to its schedule. Corrective instructions can be transmitted to the driver to adjust. Integrating this service with the Traffic Control user service can maintain transportation schedules and minimize varied impacts on traffic congestion.

In addition, using a vehicle location system, a computer will calculate the arrival times of two buses at a transfer point. The bus that arrives first will be instructed to remain at the transfer point and wait for the second arriving bus. This will permit transferring passengers to wait and make their connects. In addition accurate arrival and travel times can be given to the customer.

Public Transportation Management will depend upon the vehicle's communication system. The communication system will provide voice communication and data transfer among the various devices installed on the vehicle, including location equipment and other sensors, and components. On-board sensors can automatically monitor such elements as vehicle location, vehicle passenger loading, fare collection, and vehicle operating conditions. These data must be transferred between the vehicle and the control center.

In addition, smart card use under a distance based fare scheme can be used for automatic passenger counters. Many cities are now using inputs from on board electronic sensors such as an Automated Vehicle Location (AVL) systems, electronic fareboxes, passenger counters, electronic destination signs and automated bus stop announcement equipment.

8. Emergency Vehicle Management

The Emergency Vehicle Management User Service is oriented towards reducing the time from the receipt of notification of an incident to the arrival of the emergency vehicles on the scene. The most common of this service is the ability to access, process, and exchange real-time information on the location and nature, of incidents on roadways, enabling appropriate responses to be promptly programmed and implemented at all potential response sites. This service has three primary users: law enforcement services, emergency medical services (EMS), and fire services. These primary users may need assistance by rescue services, hazardous materials clean up services, and other secondary responders. In many areas this effort is being coordinated through existing 911 operations.

ITS technologies will allow emergency responders receiving notification of response requirements, to immediately identify the appropriate, closest, available responder or mix of responders, and to transfer complete, accurate information regarding the nature and location of the response need. A working model for this ITS function already exists in the Enhanced 9-1-1 (E-9-1-1) function know as selective routing. Selective routing automatically routes a 9-1-1 call to the agency responsible for public safety in the region where the call originated.

Several technologies will need to be integrated to allow the user service to be fully achieved. Most important will be real-time reliable transportation information that is essential to responding to traffic incidents. It requires use of current traffic information, locations of the incident and navigational alternatives to arrive at the proper location.

9. Emergency Notification and Personal Security

This user service is closely related to the previous one as it sends immediate notification of an incident to response personnel. The users of this service are drivers who will benefit from more timely responses in emergency situations. Primary service providers include telecommunications carriers, emergency response centers, police departments, highway patrols, fire and rescue units, emergency medical service providers and those providing towing and other motorist assistance services. This service directly addresses the goal of improving safety by improving EMS/roadway services responses, reducing the number of pedestrian and vehicle collisions secondary to an incident, and reducing the number of fatalities and the severity of injuries resulting from a collision. Driving stress is reduced by providing a means of summoning assistance in the event of an emergency.

The user service can provide manually initiated notification of emergency and non-emergency incidents such as mechanical breakdowns, fire, non-injury accidents, or injury accidents where a person on the scene is able to manually initiate the notification. Request for assistance can be directed to emergency and non-emergency response personnel including emergency medical, fire, law enforcement, as well as towing or repair assistance to deal with a disabled vehicle. Systems would include the capability to automatically transmit the vehicle's location with notification message. Initially this service will provide for manually initiated notifications through service patrols, cellular 911 or call boxes. Primary service providers include telecommunications carriers.

The responding agency would received the incident notification and location coordinates and manage the response. Information would be sent to a centralized dispatch center. Ideally, a focal point, such as an existing dispatch center, would be used as the primary unit to receive calls, determine response requirements and route distress calls to predesignated responding agencies.

A network of these points has been established throughout most states to deal with emergency 9-1-1 calls. These communications centers operate as an agency of a government entity such as the counties or the City of Cleveland. They are responsible for answering 9-1-1 calls. These centers either dispatch a response or transfer the call to another center for dispatch. Agencies and response services typically involved include: state and/or local transportation officials, police department, highway patrol, fire and rescue, emergency medical service providers, and towing and other "courtesy" services. Driver Roadside Assistance Services such as the Road Crewzers in Cleveland could be notified directly, or through an similar emergency response center.

F. Core Infrastructure

The ITS "core infrastructure" will be the focal point for implementing and deploying the user services in the Cleveland/Lorain Metropolitan area. FHWA has defined seven elements that contribute to the deployment of Intelligent Transportation Systems (ITS) and establish a foundation for the deployment of future ITS user service. This core infrastructure focuses on metropolitan Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS), but does not directly address the user services in the Commercial Vehicle bundle and the Advance Vehicle Safety Systems bundle. The seven elements included in the core infrastructure are:

- *Regional Multimodal Travel 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.
- *Traffic Signal Control System(s):* Signal control systems increase transportation efficiency by coordinating arterial signals and adjusting signal timing to maximize vehicle and person throughput and minimize delay.
- *Freeway Management System(s):* Freeway management systems monitor freeway traffic conditions, identify recurring and non-recurring congestion, and allow implementation of control and management strategies such as route diversion and traveler information via variable message signs and highway advisory radio.
- *Transit Management System(s):* Transit management systems include fleet management systems, and advanced computer and communications equipment on vehicles. These systems increase the efficiency of operations and maintenance.
- *Incident Management Program:* Incident management programs facilitate the rapid identification and removal of incidents on freeways and arterials, reducing delay and driver frustration.
- *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.
- *Electronic Toll Collection*: Electronic toll collection allows drivers to pay tolls without stopping, decreasing delays and enhancing transportation efficiency.

The identification of the core infrastructure elements should guide metropolitan areas like Cleveland/Lorain in near-term deployment decisions, and at the same time facilitate opportunities in the future for the implementation of the full range ITS user services. The implementation of as many of the core elements as possible in the Cleveland/Lorain area is expected to provide a foundation for future successful implementation of a full range of ITS user services.

A number of principles were considered by FHWA in the defining these core infrastructure elements and suggesting that they become the focus of initial deployment, including:

- Deployment of elements will enable implementation of ATMS/ATIS user services, and facilitate implementation of other ITS user services.
- Each element can be deployed independently, although concurrent implementation would provide economies of scale.
- Elements can be deployed in the near term using state-of-the-art concepts and technologies.
- Elements can be deployed using varying technologies, from low-tech to high-tech.
- Elements are appropriate for implementation 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.

As the Cleveland/Lorain plan evolves key considerations for the deployment of the core infrastructure elements must recognize the fact that multiple elements utilize common hardware and software components, and face similar institutional issues. The key considerations for deployment will include:

- Capability to distribute multimodal traveler information to the general public.
- Capability for surveillance 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, without any implied change in control and/or responsibility.
- Proactive management of resources, both roadway and transit, to achieve the transportation objectives.
- Continuing support for system operations and maintenance needs.

G. Implementation Time Frame

A time frame for implementation needs to be identified for each of the ITS user service. The time frame associated with each user service is based on a number of things, including input from local agencies, agency rankings of priority, 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 core infrastructure. In general, the specified implementation time frame corresponds to the priority indicated by the local agencies unless there are other limiting factors, such as available technology. User services identified as highest priority are considered appropriate for application in the short term unless technology limitations would constrain implementation in this time frame. User services are identified for implementation 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 projects, some of which require minimal technology and thus could be implemented in the short term, and other 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 indicate milepost 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. It is also important to note 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 changeable 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.

In summary, the priority and implementation time frame noted for each user service (Table III-4) should be considered a general, rather than an absolute, guideline. Actual implementation time frames would also 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 implementation of these user services appropriate, even though they might not otherwise be.

Table CHAPTER III. -4. User Services Implementation Time Frame

User Service	Implementation Time Frame		
	Short (0 - 5 yrs)	Medium (5 - 10 yrs)	Long (>10 yrs)
Traffic Control	X		
Incident Management	X		
En-Route Drive Information	X	X	
Traveler Information Services	X	X	
Pre-Trip Travel Information	X		
Demand Management and Operations	X	X	
Emergency Vehicle Management	X		
Public Transportation Management	X	X	
Emergency Notification and Personal Security	X	X	X
Route Guidance		X	X
Hazardous Material Incident Response		X	
Personalized Public Transit	X	X	
Ride Matching and Reservation		X	
Electronic Payment Services		X	
En-Route Transit Information		X	
Public Travel Security			X
On-Board Safety Monitoring			X
Emissions Testing and Mitigation			X
Automated Roadside Safety Inspection			X
Freight Mobility			X
Commercial Vehicle Electronic Clearance			X
Commercial Vehicle Administrative Process			X

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CHAPTER IV. FUNCTIONAL REQUIREMENTS

A. Introduction

The Federal ITS Program has defined seven technical functional areas: surveillance, communications, traveler interface, control strategies, navigation/guidance, data processing, and in-vehicle sensors. ITS technologies have each been classified into one of these seven functional areas. While some technologies may be applicable in more than one functional area, each technology is categorized in the functional area in which it is most relevant. Table IV-1 provides information regarding the technical functional areas that are utilized by the highest priority ITS user services previously defined in Chapter III (User Service Plan).

B. Functional Areas

The following sections describe the various functional areas pertinent to the successful application of the required User Services in an area. Note that all of the user services are provided through technologies from more than one functional area. User services shown in Table IV-1 include all of the user services previously identified as appropriate for implementation in the short and medium time frame in the Cleveland/Lorain metropolitan area.

1. Surveillance

Surveillance is the mechanism that permits the collection of a range of transportation data including speed, volume, density, travel time, queue length, and, in some cases, vehicle positions for buses and transit. Control strategies that may need to be implemented, incident management plans, responses and procedures, and motorist information are selected on the basis of this collected information. The data are used for making transportation management decisions and stored to provide a historical record of transportation conditions. Surveillance can also be used to obtain information on vehicle classification, length, speed, acceleration characteristics, and cargo (hazardous materials). Specific technologies in the surveillance technical functional area are shown in Table IV-2.

2. User Services That Utilize Surveillance Technologies

Surveillance is one of the most important technical functional areas, because it provides the data necessary for many of the user services to work properly and to be integrated together. Without surveillance capabilities, however primitive or sophisticated, there is no knowledge of the current operating conditions, there is no information for operational decisions, and ultimately there is no information to provide to the users.

Table CHAPTER IV. -1. Technical Functional Areas For Selected User Services

User Service	Surveillance	Communi-cations	Traveler Interface	Control Strategies	Navigation/ Guidance	Data Process-ing	In-Vehicle Sensors
Traffic Control	X	X		X		X	
Incident Management	X	X	X	X	X	X	X
En-Route Driver Information	X	X	X		X	X	X
Travel Information Services	X	X	X		X	X	X
Pre-Trip Travel Information	X	X	X		X	X	
Demand Management and Operations	X	X	X		X	X	X
Public Transportation Management	X	X		X	X	X	X
Emergency Vehicle Management	X	X			X	X	
Emergency Notification and Personal Security		X					X

In the proposed plan all of the user services except the Emergency Notification and Personal Security user service would be expected to utilize technologies in the surveillance technical functional area. The Emergency Notification and Personal Security user service provides direct notification to the traffic management center (TMC) or emergency responder, and thus does not require surveillance.

Many of the user services would utilize surveillance technologies that provide general information about traffic flow, such as detectors, vehicle probes, and video surveillance. This information may be augmented by information provided by Automated Vehicle Identification (AVI) and Automated Vehicle Location (AVL) systems that work with buses, commercial vehicles and emergency response vehicles. This information would be utilized for routing purposes for Emergency Vehicle Management, Public Transportation Management, En-Route Driver Information, and as general information to be provided to the public and operating agencies. The user services focusing on transit, namely Public Transportation Management, would also utilize surveillance technologies that provide more specific information, such as an AVL system for transit vehicles, and audio or video surveillance of transit vehicles and facilities.

Table CHAPTER IV. -2. Surveillance Technologies

Technology	Explanation, Examples or Characteristics
Vehicle probes	Examples includes vehicles with an on-board computer, two-way communications link, or AVI transponder.
Loop detectors	Detect vehicle through a change in the magnetic field (embedded in the pavement).
Infrared sensors	Detect vehicles when infrared beam is broken (located above the pavement).
Microwave and radar sensors	Detect vehicle motion through Doppler phase shift (located above the pavement).
Acoustical sensors	Detect vehicle presence by identifying characteristic sounds.
Machine vision	Examples include videocameras, which may or may not include a microprocessor for image interpretation.
Aerial surveillance	Uses helicopter or light airplanes to monitor traffic flow, detect incidents, and identify alternate routes.
Automatic vehicle identification (AVI)	Uses vehicles-based transponders and readers at fixed locations
Weigh-in-motion	Uses road-mounted sensors and processors to

Technology	Explanation, Examples or Characteristics
	determine vehicle weight.
Automatic vehicle classification	Uses vehicle sensors, detectors (which receive information from sensors), data processing, and a recorder (to store data).
Automatic vehicle location (AVL)	Uses transmitters, dead-reckoning, global positioning systems (GPS), or LORAN, and map matching to identify vehicle location.
Police/emergency medical/other traveler information	Information based on human observation and transmitted via two-way information link.
Weather and other environmental information	Includes information based on weather monitors (roadway monitors, National Weather Service Monitoring, etc.), as well as pollution and emissions monitors.

3. Communications

Communications include all transmissions (including voice, video, and data transmissions) between the elements of the transportation system, both the vehicles and the infrastructure. Communications technologies provide the TMC with information about traffic and roadway conditions; transit vehicle locations and schedule adherence and allow system users to be better informed about network conditions which in turn allows for more efficient utilization of the system. Communications services include:

- Communications between traffic management infrastructure and vehicles;
- Communications between elements of the infrastructure and supporting organizations and agencies; and
- Communications between vehicles.

Specific technologies in the communications technical functional area are shown in Tables IV-3 and IV-4.

4. User Services That Utilize Communications Technologies

Communications is another one of the most important technical functional areas, because it is necessary to transmit data for surveillance, and to transmit information to operating agencies and transportation consumers. Without communications capabilities, there is no mechanism to transmit roadway data to the TMC, and there is no mechanism to communicate conditions to either incident responders or roadway users. The importance of communications is exemplified by the fact that all of the user services shown in Table IV-1 would be expected to utilize technologies from the communications technical functional area.

Table CHAPTER IV. -3. Technologies For Communications Between Vehicle and Infrastructure

Technology	Explanation, Examples or Characteristics
Local-area broadcasts	Examples include highway advisory radio (HAR) and automatic HAR (AHAR), which will automatically tune to the AHAR frequency for the duration of the message.
FM subcarrier (one-way)	Utilities spare bandwidth in the guard bands of conventional FM radio stations (vehicles must be equipped to receive and decode the data).
Infrared and microwave beacons (two-way)	Transfer data at high rates, but coverage range is limited (less than 100 feet).
Wide-area radio system (two-way)	Transmits common information to all vehicles, to be stored by a device in the vehicle.
Cellular radio services (two-way)	Can selectively access vehicles within specific cells of the system (message could vary depending on driver location).
Satellite communications (two-way)	Provide nationwide coverage of voice or data transmission.

Table CHAPTER IV. -4. Technologies For Communications Between Elements of the Traffic Management System[1]

Technology	Explanation, Examples or Characteristics
Landlines	Examples include twisted pair wire (for data from detectors), and coaxial or fiber optic cable (for unprocessed video). Lines needed depend on transmission rates required.
Microwave	Transmits images and data from roadside video cameras, or controls variable message signs; used where landlines are not cost effective (such as in rural and mountainous areas).
Wide-area radio	Connects variable message signs to the TMC where land lines are not cost effective.
Satellite communications (two-way)	Used where land lines are not appropriate due to cost or other factors.

[1] Technologies that facilitate communications between the elements of the traffic management system address: communications between traffic sensors, signals, signs and ramp meters and the traffic management center (TMC); communications between the TMC and vehicles (for examples, via communications base stations or beacons); and communications between the TMC and other TMC’s, organizations, and/or agencies (for example, emergency response or enforcement agencies).

5. Traveler Interface

The traveler interface allows the traveler to interact with the ITS system to obtain traffic management center updates or information from the database. The traveler may interact with the system:

- At home or work via telephone, computer, television, or radio;
- At bus stops or transit kiosks; and
- In-vehicle through a computer, car radio, cellular telephone, or roadside variable message sign.

This functional area includes all the technologies with which the traveler interfaces. Traveler interface technologies must be easy to understand, without ambiguity, and designed to provide a level of detail appropriate to the needs of the user and the task at hand. Specific technologies in the traveler interface technical functional area are shown in Table IV-5.

6. User Services That Utilize Traveler Interface Technologies

Technologies in the traveler interface technical functional area are utilized by five of the user services shown in Table IV-1. With applications for the Incident Management, En-Route Driver Information, Traveler Information Services, Pre-Trip Travel Information and Demand Management and Operations user services, traveler interface technologies are needed for communication with transportation consumers. In general, the traveler interface technologies vary from the communications technologies in that they can allow interaction with the user. For example, traveler interface technologies allow motorists to query about conditions on specific routes, and provide preference information for input into route selection algorithms.

Note that other user services, such as Public Transportation Management and Emergency Vehicle Management, might utilize some of the technologies included in the traveler interface technical functional area (such as a keyboard). However, the use of the traveler interface technologies in these cases would not be for "traveler interface," or communications with transportation consumers, and thus they are not indicated in Table IV-1.

The kind of technology used for traveler interface varies, depending on the user service. While a kiosk at a transit station might utilize a touch screen to provide En-Route Transit Information, a variable message sign might be used to provide information regarding alternate routes for Incident Management.

Table CHAPTER IV. -5. Traveler Interface Technologies

Technology	Explanation, Examples or Characteristics
Touch Screen	When user points to an item on the display screen, an infrared light grid overlaying the display screen is broken.
Key pad or key board	Used to input destination or reference data, or request traveler services information (when vehicle is not in motion).
Variable message sign	Displays information regarding current traffic or roadway conditions, or alternate routes.
Voice recognition	Allows user to give voice commands to on-board computer without looking away from the roadway.
Voice output	Computerized voice may provide audio warning and advisory information (including route guidance) to augment graphic information
Visual display	Displays route guidance information (via simplified street diagrams and turn arrows), traveler services information, and safety and incident advisories. More detailed graphics are displayed when vehicle is stopped.
Heads up display	Projects route guidance visual display information onto a two-dimensional laser holograph that the motorist can view without looking away from the roadway.

7. Control Strategies

Control strategies include those strategies that the TMC can implement to help control demand on the infrastructure, smooth traffic flow, or help to improve traveler safety. Control strategies may focus on either the freeway or the surface streets, or they may manage traffic on the entire system.

The control function involves the operation of traffic control measures such as signals, freeway ramp meters and HOV lane restrictions. Control strategies allow the TMC to respond to incidents and other special events by changing signal control to accommodate additional traffic loads on specific links of facilities. Control strategies attempt to increase the efficiency in the roadway network, and generally involve demand reduction techniques. Specific technologies in the control strategies technical functional area are shown in Table IV-6.

8. User Services That Utilize Control Strategies Technologies

As shown in Table IV-1, technologies in the control strategies technical functional area may be utilized in conjunction with the Traffic Control, Incident Management and Public Transportation Management user services. Signal control and ramp metering technologies may be used to directly influence vehicle volumes on certain links, which may be important for the Incident Management and the Traffic Control user services. Signal pre-emption may be provided for transit vehicles, contributing to the Public Transportation Management user services.

Table CHAPTER IV. -6. Control Strategies Technologies

Technology	Explanation, Examples or Characteristics
Ramp metering	Traffic signals at freeway entrance ramps help maintain an acceptable level of service (LOS) on the freeway. Traffic flow improves because vehicles merge onto freeway one at a time rather than in platoons.
HOV restrictions	Limit use of a lane to certain kinds of vehicles (such as buses and/or registered vanpools) or vehicles that meet the minimum occupancy requirement (such as two or three person carpools).
Signal control	Allows for orderly and efficient movement of vehicles on arterials and through networks. May improve traffic flow and reduce vehicle delay and incidents.
Parking restrictions	Include limits on on-street parking (especially near intersections). May increase capacity.
Ramp/lane closures	Closure of the freeway entrance ramp or freeway lane segment prior to entrance point may help maintain LOS on the freeway.
Road use pricing	Also called congestion pricing, this demand management technique allows variable pricing for peak and off-peak periods.
Reversible lanes	Lane capacity is assigned based on directional distribution of traffic. Examples include reversible HOV lanes.
Lane control	Lanes can be closed off during incidents through the use of overhead signals in advance of the scene, reducing the impact of temporary loss of capacity.

9. Navigation/Guidance

On-board navigation systems assist the traveler in route planning and route following. Information may be provided via a video display terminal in the vehicle, a heads-up display, voice output, or dashboard signals. While this functional area does not necessarily include information on real-time conditions, more advanced systems will integrate this information. Specific technologies in the navigation/guidance technical functional area are shown in Table IV-7.

10. User Services That Utilize Navigation/Guidance Technologies

Technologies in the Navigation/Guidance technical functional area may be used in conjunction with the provision of the Incident Management Emergency Vehicle Management, Public Transportation Management, En-Route Driver Information, Pre-Trip Travel Information, and Demand Management user services. For the Pre-Trip Travel Information and Incident Management user services, the navigation/guidance technologies provide information about the local transportation infrastructure, including a map and possible routes. In all other cases, the technologies in the Navigation/Guidance technical functional area would also provide information regarding current vehicle location, and its relationship to the final destination. For the transit user services, this information would not only be of interest to the patrons on-board (as well as the drivers and managers), but it would also be of interest to patrons waiting for the next bus.

Table CHAPTER IV. -7. Navigation/Guidance Technologies

Technology	Explanation, Examples or Characteristics
Position display	Indicates current vehicle position on road network.
Guidance display	Simplified street diagrams and turn arrows guide vehicle while it is in motion. Include information on lane changes, turns, freeway exits, etc.
Map database	Includes road network, and parking facilities; may include speed limits and traffic control information (such as turn restrictions that vary depending on the time of day).
Dead reckoning	Determines vehicle location and orientation based on distance and direction traveled.
LORAN (long range radio navigation system)	Identified vehicle location using multiple transmitters. System initially developed for maritime use, thus most transmitters are located along the coast.
Global positioning system (GPS)	Provides vehicle location based on satellite-based radio triangulation system.
Map matching	Provides vehicle location using dead reckoning and map database, requires extensive database for high accuracy.

11. Data Processing

Data processing includes the management and quality control of all data pertaining to ITS. The data processing function includes all in-vehicle, roadside, and central computer processing. This functional area also includes the algorithms that are used for navigation and for making traffic management decisions. Specific technologies in the data processing technical functional are shown in Table IV-8.

12. User Services That Utilize Data Processing Technologies

Many of the technologies in the data processing technical functional area provide the "intelligence" in the ITS systems. These technologies are often algorithms that sort through extensive data regarding current and historical conditions, and identify not only the current operation characteristics (and identify them as typical or unusual), but also may provide an optimal management strategy, if action needs to be taken. The recommended action might be a suggested route for a specific emergency vehicle, or a traffic management plan for implementation of all but one of the user services shown in Table IV-1. Data processing becomes increasingly critical as the volume of data (provided by the surveillance technologies) increases.

Table CHAPTER IV. -8. Data Processing Technologies

Technology	Explanation, Examples or Characteristics
Coupled route selection and traffic control	Algorithms that adjust route guidance recommendations and signal settings based on demand levels.
Database -- static	Contains historical time of day and day of week traffic data. Useful for predicting traffic conditions and identifying unusual conditions.
Database -- dynamic	Contains real-time data describing current traffic conditions. Useful for traffic management decisions.
Route selection algorithms	Estimates optimal routing for individual vehicles based on destinations and route preferences.
Driver, vehicle, and cargo scheduling	Matches available drivers and vehicles to cargo delivery needs, facilitates just-in-time delivery.
Real-time traffic prediction	Calculates current traffic flows, queue lengths, and delays based on volume and speed information indicated by detectors.
Traffic assignment algorithms	Predict traffic loads and link travel times on network based on current traffic data. Estimate routes that individual vehicles will take based on trip and network characteristics.
Route guidance algorithms	Translate route information into simple directions displayed in the vehicle.
Data fusion techniques	Integrate historical and current data from a variety of sources to provide estimates of traffic characteristics.
Optimal control strategies	Uses algorithms to optimize settings of traffic control devices at central or subarea TMCs.
Incident detection algorithms	Uses algorithms (such as pattern recognition and time series) to detect anomalies or disruptions in traffic flow due to an incident.

13. In-Vehicle Sensors

In-Vehicle sensors include all in-vehicle devices that monitor the individual vehicle and driver. In-vehicle sensors also include sensors that monitor elements of the driving environment that pertain to individual vehicle operation. Specific technologies in the in-vehicle sensors technical functional area are shown in Table IV-9.

14. User Services That Utilize In-Vehicle Sensor Technologies

Technologies in the in-vehicle sensors technical functional area may address a variety of user services, including Emergency Notification and Personal Security, En-Route Driver Information, Public Transportation Management, Traveler Information Services and Demand Management and Operation. For the Emergency Notification and Personal Security user service, in-vehicle sensors would check the status of vehicle operating systems, and provided notification of malfunction, collision, or other dangerous situations. For the En-Route Driver Information, Demand Management and Public Transportation user services, in-vehicle sensors would be used for identification of vehicle location.

Table CHAPTER IV. -9. In-Vehicle Sensor Technologies

Technology	Explanation, Examples or Characteristics
Equipment status sensors	In-vehicle systems programmed to store and/or display engine diagnostics; may also record operating information (speed, acceleration, fuel consumption, etc.).
Vehicle headway sensors	Monitor front and rear headway, as well as side distances and lane position indicators (may use gap radar or other technology).
Odometers	Electronic odometers used in navigation can measure distance traveled in increments of less than one inch.
Electronic compasses	Superimposition of the earth's magnetic field produces a phase shift in the induced voltages of the electronic compass when orientation of compass changes due to a change in vehicle orientation.
Driver fatigue and performance monitoring	Sensors monitor driver conditions, which may include drowsiness, and slow or excessive reactions (sensors may also include breathalyzer, etc.)

C. Technical Functional Area Priorities

The technical functional areas that appear most important in the short and medium term are for the Cleveland/Lorain metropolitan area are:

- Surveillance, which is needed to monitor traffic flow and detect incidents;
- Communications, which are needed to convey traffic information to the appropriate operating agencies as well as to the public;
- Control Strategies, which are needed to optimize the efficiency of freeways and arterials, during typical conditions and in response to incidents;
- Traveler Interface, which is need to communicate with the public; and
- Data Processing, which becomes increasingly important as the amount of data to be processed increases.

The technical functional areas that appear less important in the short and medium term are:

- Navigation/Guidance.
- In-Vehicles Sensors.

The technologies in both of these technical functional areas depend heavily on in-vehicle devices and thus may be more appropriate for implementation by vehicle manufactures, rather than local transportation providers.

D. Selection Of Individual Functional Elements

The importance of the elements of the technical functional areas vary, depending on the objectives and extent of the ITS system. Furthermore, it is difficult to identify the most appropriate technologies without having examined the benefit cost ratios, and other data that will be developed in later stages of the study. However, preliminary examination of the technical function areas and specific technologies does result in expectations regarding the most important technical functional areas and technologies.

Based on local priorities and examination of the technologies that have been successfully implemented in other cities, the specific technologies that appear most important in the short and medium term are:

- Surveillance
  - Loop detectors and/or sensors (infrared, microwave, sonar and/or radar)
  - Machine vision (cameras)
  - Automated Vehicle Location (AVL)
  - Information provided by police, emergency medical providers, motorist assistance patrol, etc.
  - Weather monitors

- Communications
  - Local area broadcast (HAR)
  - Commercial radio
  - Landlines
  - Cellular/wireless services
  - Satellite communications

- Control Strategies
  - Signal control
  - Ramp metering

- Traveler Interface
  - Variable message signs

- Data Processing (data processing capabilities become increasingly important as the amount of data to be processed increases)
  - Static and dynamic databases
  - Data fusion
  - Optimal control strategies
  - Incident detection and route guidance algorithms
  - Coupled route selection and traffic control
  - Real-time traffic prediction

It is more difficult to identify the technologies that may be appropriate in the long term, due to the fact that technology advancements are expected to have a significant effect on the capabilities and relative costs of the options available.

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CHAPTER V. SYSTEM ARCHITECTURE

1. INTRODUCTION

The Federal Highway Administration's (FHWA) ITS National Architecture Program is now yielding documents that can be used to engineer a system architecture for the Cleveland/Lorain metropolitan area. As such, in preparing analysis for this metropolitan area's ITS Early Deployment Plan, the FHWA's June 1995 *ITS Architecture, Physical Architecture* document has been referenced extensively. This is important because adhering to the National Architecture when developing an Early Deployment Plan provides a level of confidence that future incremental growth of user services, including growth via the geographic enlargement of metropolitan areas, can be accomplished efficiently, effectively, and in a manner that is compatible with other regional efforts. It must be emphasized, however, that not all elements of the National Architecture are clearly defined nor available for implementation at this time.

This chapter examines the basic system architecture for the early deployment of Intelligent Transportation Systems technologies and processes in the Cleveland/Lorain metropolitan area. Since it has been discussed that funding limitations may require a phased- vs. a one-time comprehensive ITS implementation, the Cleveland/Lorain metropolitan area's ITS system architecture is presented as a framework that can be utilized for incremental and logical evolutions of ITS. More specifically, it is described in the context of the ten relevant subsystems of the national ITS system architecture (see Table V-1-1) that are necessary to implement the fourteen priority ITS User Service objectives that have been identified as part of this study for implementation in the Cleveland/Lorain metropolitan area (see Table V-4-1).

Table V-1-1. Cleveland/Lorain Architecture "Class" Categories and Subsystems

ARCHITECTURE "CLASS" CATEGORY	ARCHITECTURE SUBSYSTEM
Center-Class Subsystems:	Traffic Management Emergency Management Information Service Provider Transit Management
Roadside-Class Subsystem:	Roadway
Vehicle-Class Subsystems:	Personal Vehicle Emergency Vehicle Transit Vehicle
Traveler-Class Subsystems:	Personal Information Access Remote Traveler Support

In this chapter, three system design alternatives that meet the above objectives are described as per characteristics of level of coordination (i.e. a centralized-, a distributed-, or a hybrid-type of coordination between traffic management, emergency service providers, and transit), type of control logic, type of data processing, operations impact, type of arterial signal control, and communications network complexity (see Section 5). In addition, estimates of each design alternatives' initial capital costs and annual operating and maintenance costs are estimated based upon staged implementation in both the short-term, medium-term, and long-term time frames (see Appendix A).

Finally, this chapter presents the results of each design alternatives' system evaluation based-upon a Utility/Cost analysis procedure that simultaneously incorporates cost, system availability, flexibility, expandability, potential for staged deployment, potential for arterial diversion, and institutional considerations. It should be noted that all evaluation criteria were assigned weighting factors based-upon a survey of the members of the Cleveland/Lorain Intelligent Transportation System Deployment Study Joint Policy and Technical Committee so as to reflect local needs, institutional concerns, and fiscal realities (see Section 6).

2. REFERENCES

In the preparation of this chapter, the following publications have been referenced:

- HNTB Corporation, et. al. *I.T.S. System and Project Performance Criteria*. October 1995.
- HNTB Corporation. *I.T.S. System Architecture for the Kansas City Metropolitan Area*. 1995.
- HNTB Corporation, et. al. *I.T.S. Technical Functional Areas*. November 1995.
- HNTB Corporation, et. al. *I.T.S. User Services Objectives for the Cleveland Metropolitan Area*. August 1995.
- United States Department of Transportation, Federal Highway Administration. *Computerized Signal Systems -- A Student Handbook*. June 1979.
- United States Department of Transportation, Federal Highway Administration. *Intelligent Transportation Systems (I.T.S.) Architecture -- Physical Architecture*. June 1995
- United States Department of Transportation, Federal Highway Administration. *Traffic Control Systems Handbook*. June 1976.

3. NATIONAL ARCHITECTURE OVERVIEW

The emergence of an ITS National Architecture now provides a definitive roadmap for geographically diverse areas to implement ITS designs and deployment strategies in a consistent manner. While the National Architecture is not totally defined, it is sufficiently developed to provide general direction and guidance in formulating solutions to transportation issues and the provision of core user services. The Physical Architecture volume (referenced in Section 2, above) forms the basis for the architecture definitions presented herein.

There are four basic elements of the architecture:

- Users: The class of people who interface with architecture implementation as travelers or operators. The capabilities and services of ITS would be utilized for improved travel, enhanced service, streamlined operations, and increased profits.

- External Systems: The computer systems outside of ITS that interface with the architecture.

- System Environment: The physical world of roadway, air, obstacles, etc.

- Internal Subsystems: The key elements of the Architecture that interact to provide ITS services and functionality.

These four basic elements provide a top level architecture (see Figure V-3-1) for the eighteen subsystems that are defined in the National Architecture. To show completeness of the system, Figure V-3-2 presents a comprehensive view of the information flows for all subsystems. This detail will be simplified in the next section as per this chapter’s focus on developing the appropriate subsystems necessary and sufficient to meet the user services and priorities established in previous tasks of this project. It should be emphasized, though, that adhering to this model should provide for the reintroduction of additional detail sufficient to accommodate growth as conditions change and it becomes necessary to implement new/evolving user requirements within the project area.

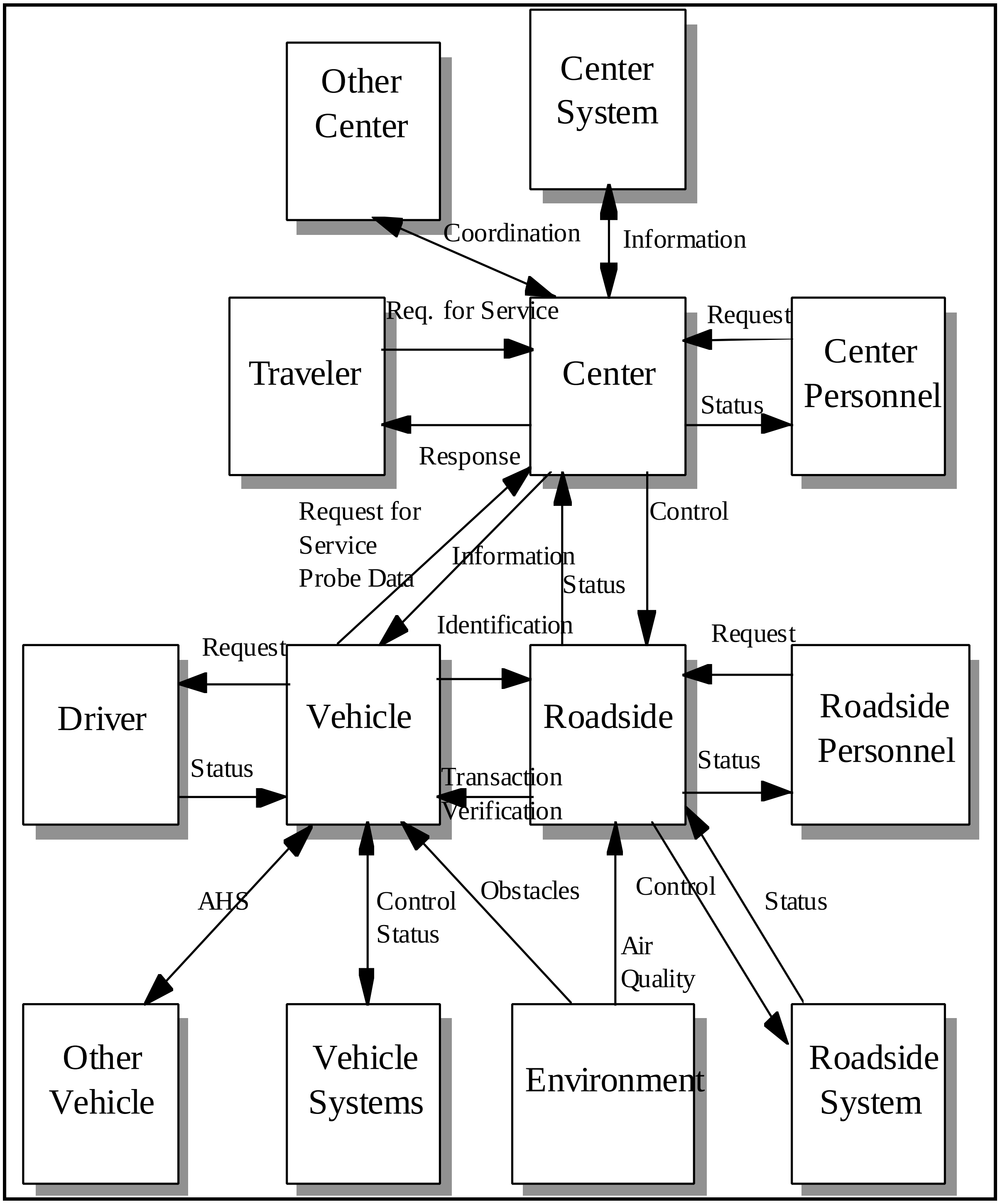

Figure V-3-1 Very Top Level Architecture Flow Diagram

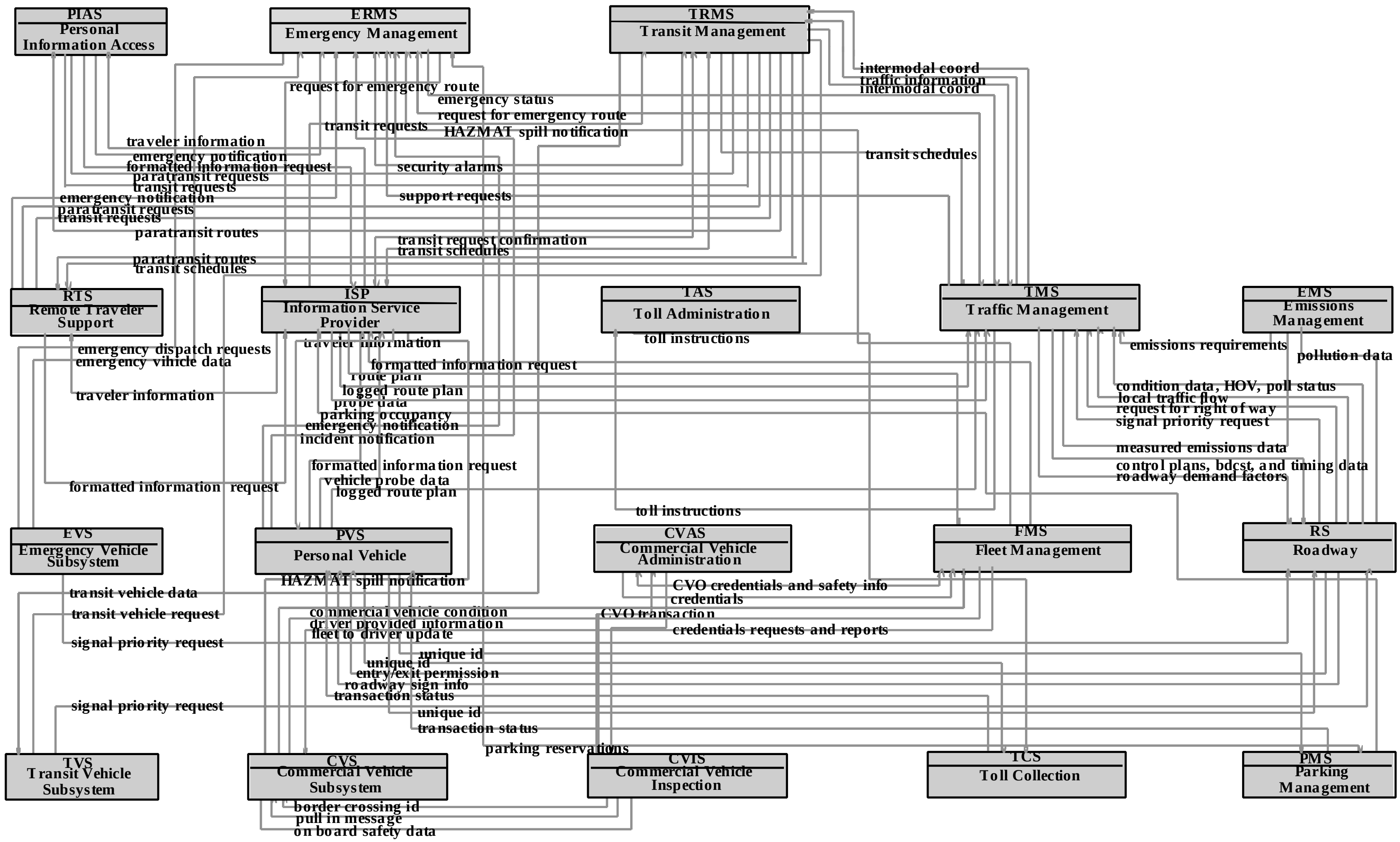

Figure V-3-2. Top Level Architecture Flow Diagram (Subsystems Only)

4. CLEVELAND ARCHITECTURE

4.1 User Services Requirements

From discussions with the Steering Committee and results of the user surveys, the following User Services have been defined in terms of priority and implementation time frame. This has allowed the scope of this Early Deployment Study to focus on "early winners" that can provide for near term pay-backs to the area. Table V-4-1 summarizes the User Services that the Architecture must address.

Table V-4-1. User Services Priority and Time Frame

USER SERVICE	PRIORITY	TIME FRAME
Traffic Control	High	Short
Incident Management	High	Short
Hazardous Material Incident Response	High	Short
Public Transportation Management	High	Short
En-Route Driver Information	Medium-High	Short
Pre-Trip Travel Information	Medium-High	Medium
Demand Management and Operations	Medium-High	Medium
Route Guidance	Medium-High	Medium
On-Board Safety Monitoring	Medium	Medium
Traveler Services Information	Medium	Medium
Ride Matching and Reservation	Medium	Medium
En-Route Transit Information	Medium	Medium
Personalized Public Transit	Medium	Medium
Emissions Testing and Mitigation	Medium	Medium

Analysis of these User Services in terms of the Architecture's subsystems allows the ITS National Architecture to be descoped to specific Cleveland priorities. Figure V-4-1 is presented to show the subsystems, interfaces, and information flows necessary to address these services. It must be emphasized, however, that the Architecture shows what the system does, (i.e. the allocation of responsibilities), but not necessarily the how of implementation. The selection of technologies to enable the "how" is a topic of a seperate chapter. In this chapter, the "how" will be addressed in terms of potential designs. This approach facilitates an implementation strategy that coincides with local priorities, technological evolution, and funding availability.

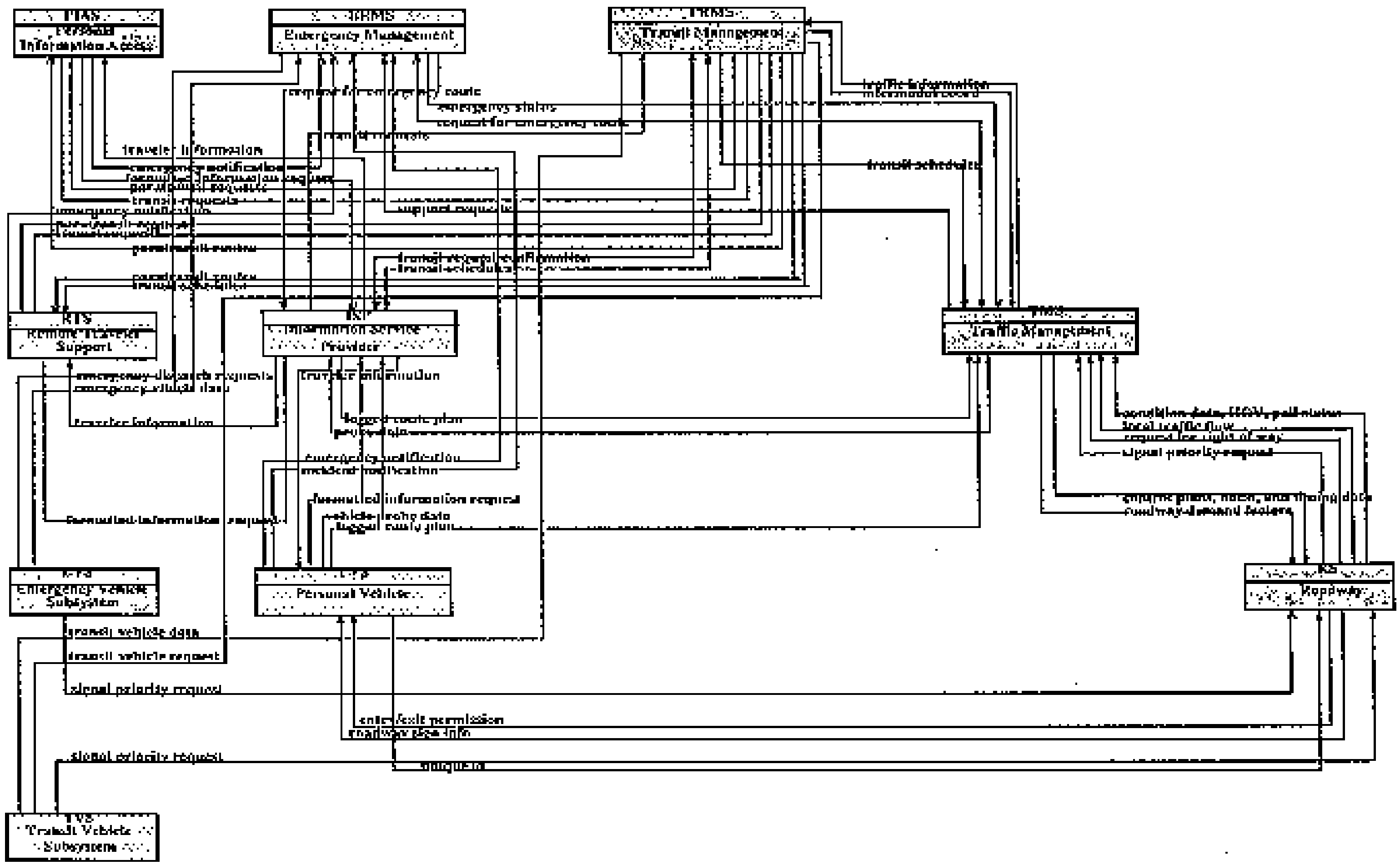

Figure V-4-1. Cleveland Subsystems and Data Flows

4.2 ITS Subsystem Definitions

ITS subsystems are categorized into four functional perspectives known as "classes". These include:

- "Centers", which collect, process, and store information
- "Roadsides", which encompasses elements deployed along the "roadway" regardless of the type of "road" (e.g. rail, air, sea)
- "Vehicles", which travel the "roadways"
- "Travelers Remote Access", which represents ITS users with transportation needs.

The following briefly defines these system classes and their appropriate Architecture subsystems as necessitated by the above User Services requirements. ITS National Architecture information has been derived from the *ITS Architecture, Physical Architecture* document (referenced in Section 1, above).

4.2.1 Center-Class Subsystems

The "center"-class subsystems provide management, administration, and support functions for the transportation system. By communicating to other center-subsystems any relevant information gathered from center-controlled roadside- and vehicle-subsystems, they enable regional coordination across jurisdictional boundaries and between transport modes.

4.2.1.1 Traffic Management Subsystem

The Traffic Management Subsystem, usually operating within a traffic management center or other fixed location, monitors and manages traffic flow via communications with the Roadway Subsystem and other Traveler Subsystems. It can coordinate traffic information and control strategies in neighboring jurisdictions, monitor and manage maintenance work, disseminate maintenance work schedules and road closures, manage reversible lane facilities, and process probe vehicle information. This subsystem also supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. When incidents are detected and verified, appropriate incident information is provided to the Emergency Management Subsystem, to travelers (through Roadway Subsystem Highway Advisory Radio and Variable Message Signs), and to third party providers. Finally, the Traffic Management Subsystem provides capabilities necessary to exercise control over those devices utilized for AHS traffic and vehicle control.

4.2.1.2 Emergency Management Subsystem

The Emergency Management Subsystem, operating in various emergency centers that support public safety (including police and fire departments, search and rescue special detachments, and HAZMAT response teams), interfaces with other Emergency Management Subsystems to support coordinated emergency response involving multiple agencies. The subsystem creates, stores, and utilizes emergency response plans to facilitate coordinated response, and tracks and manages emergency vehicle fleets using automated vehicle location technology and two way communications with the vehicle fleets. Interfaces with the Traffic Management Subsystem allows strategic coordination in tailoring traffic control to support en-route emergency vehicles, and interfaces with the Transit Management Subsystem allows coordinated use of transit vehicles to facilitate response to major emergencies. In addition, real-time traffic information received from the other center subsystems is used to further aide the emergency dispatcher in selecting the appropriate emergency vehicle(s) and routes that will provide the most timely response.

4.2.1.3 Information Service Provider Subsystem

This subsystem provides the capabilities to collect, process, store, and disseminate traveler information such as basic advisories, real time traffic condition and transit schedule information, yellow pages information, ride matching information, and parking information to subscribers and the public at large. The subsystem also provides the capability to provide specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, and returning the calculated plans to the users. In advanced implementations, reservation services are also provided. The subsystem provides the capability for an informational infrastructure to connect providers and consumers, and gather needed market information to assist in service improvement planning and operations maintenance. Available communications links, such as basic one-way (broadcast) and personalized two-way links, provide information to the traveler via the Personal Information Access Subsystem, the Remote Traveler Support Subsystem, and various Vehicle Subsystems

4.2.1.4 Transit Management Subsystem

The Transit Management Subsystem provides the capability for determining accurate ridership levels, implementing corresponding fare structures, supporting travelers using a fare medium applicable for all surface transportation services, providing for optimized vehicle and driver assignments, and providing for vehicle routing for fixed and flexibly routed transit services. An interface with traffic control can allow for integration with traffic signal prioritization for transit schedule adjustments, and the transit vehicle maintenance management can be automated with schedule tracking. The Transit Management Subsystem also provides the capability for automated planning and scheduling of public transit operations; and can provide the capabilities to furnish travelers with real-time travel information, continuously updated schedules, schedule adherence information, transfer options, and transit routes and fares. In addition, the capability to monitor key transit locations with both video systems, audio systems, and traveler activated alarms, can be provided such that system operators and police are automatically alerted regarding any potential incidents.

4.2.2 Roadside-Class Subsystems

These infrastructure subsystems, governed by and connected to one or more of the center subsystems, provide interfaces to support operations and other functions that require data distribution to the roadside for direct surveillance, information provision, and control plan execution. Direct user interfaces to drivers and transit users, and short range interfaces to the vehicle subsystems are also generally included.

4.2.2.1 Roadway Subsystem

This subsystem includes traffic control and monitoring equipment that are distributed along roadways, such as highway advisory radios, variable message signs, cellular call boxes, vehicle loop detectors, signals, freeway ramp metering systems, and CCTV cameras and video image processing systems for incident detections and verification. Also provided are capabilities for emissions and environmental condition monitoring, and HOV and reversible lane management functions. In advanced implementations, this subsystem supports the monitoring and communications functions of automated vehicle safety systems that control access and egress to and from an Automated Highway System. This includes systems such as intersection collision avoidance that determine the probability of a collision in the intersection and then send appropriate warnings and/or control actions to the approaching AHS-equipped vehicles.

4.2.3 Vehicle-Class Subsystems

These vehicle-based subsystems communicate with the roadside subsystems and center subsystems to provide general driver information, vehicle navigation, and advanced safety system functionalities. It should be noted that general traveler information and vehicle safety functions, as detailed in the Personal Vehicle Subsystem section below, are also applicable to the three fleet vehicle subsystems (Commercial Vehicle Subsystem, Emergency Vehicle Subsystem, and Transit Vehicle Subsystem). The fleet vehicle subsystems also include vehicle location and two-way communications functions that support efficient fleet operations, in addition to various special functionalities that support their specific service areas

4.2.3.1 Personal Vehicle Subsystem

Residing in a personal automobile and providing the sensory, processing, storage, and communications functions necessary to support efficient, safe, and convenient travel by personal automobile, the Personal Vehicle Subsystem uses both one-way communications options (i.e. low-cost broadcast facilities) and two-way communications options (i.e. advanced pay for use personalized information systems) to support a spectrum of information services that provide drivers with current travel conditions and the availability of services along a given route and at a particular destination. Route guidance capabilities assist in formulating both an optimal travel route and step by step guidance along that route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services so that in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. Furthermore, initial collision avoidance functions can provide “vigilant co-pilot" driver warning capabilities. When unavoidable collisions do occur, precrash safety systems can be deployed and emergency notification messages can be issued. In the future, more advanced functions may assume limited control of the vehicle to maintain safe headway. Ultimately, this subsystem supports completely automated vehicle operation through advanced communications with other vehicles in the vicinity and in coordination with the supporting Automated Highway System infrastructure subsystems.

4.2.3.2 Emergency Vehicle Subsystem

Residing in an emergency vehicle and providing the sensory, processing, storage, and communications functions necessary to support safe and efficient emergency response, the Emergency Vehicle Subsystem interacts with the Emergency Management Subsystem to support coordinated responses to emergencies. Using two-way communications and automated vehicle location equipment, appropriately equipped emergency vehicles are able to be monitored by vehicle tracking and fleet management functions in the Emergency Management Subsystem so that the proper emergency response vehicle can be determined. In addition, route guidance and traffic signal preemption capabilities can be added to further enable safe and efficient routing to an emergency via communications with the roadside subsystem.

4.2.3.3 Transit Vehicle Subsystem

Residing in a transit vehicle and providing the sensory, processing, storage, and communications functions necessary to support the safe and efficient movement of passengers, the Transit Vehicle Subsystem interacts with the Transit Management Subsystem to collect accurate ridership levels, support electronic fare collection, relay transit vehicle maintenance data, and integrate automated vehicle location functions that enable more efficient operations. The Transit Vehicle Subsystem also furnishes travelers with real-time travel information, continuously updated transit schedules, transfer options, routes, and fares. In addition, an optional traffic signal prioritization function can communicate with the roadside subsystem to improve transit on-schedule performance.

4.2.4 Traveler-Class Subsystems

The traveler subsystems include general purpose equipment that is typically owned and operated by the traveler, such as personal computers, telephones, personal digital assistants (PDAs), televisions, and any other communications-capable consumer products that can be used for gaining access to information that can be supplied to a traveler within the scope of the ITS architecture. These subsystems interface to the information provider, usually one of the center subsystems (most commonly the Information Service Provider Subsystem), in order to access the traveler information. A range of service options and levels of equipment sophistication are considered and supported.

4.2.4.1 Personal Information Access Subsystem

This subsystem provides the capabilities for travelers to receive formatted traffic advisories from the infrastructure at fixed locations such as homes, workplaces, and other major trip generation sites; and via multiple types of electronic media at mobile locations such as mobile information centers or within individual vehicles. Included is basic route-planning information that allows users to select those transportation modes that avoid congestion, and in more advanced systems, travel information that allows users to specify those transportation parameters that are unique to their individual needs. Also provided are capabilities to initiate a distress signal, and to cancel a prior issued manual request for help.

4.2.4.2 Remote Traveler Support Subsystem

This subsystem uses kiosks and other informational displays that support varied levels of interaction and information access to provide traveler information at transit stations, transit stops, other fixed sites along travel routes, and at major trip generation locations such as special event centers, hotels, office complexes, amusement parks, and theaters. For example, at transit stops, simple displays providing schedule information and imminent arrival signals can be provided. This basic information may be extended to include yellow pages information, and multi-modal information regarding traffic conditions and transit schedules to support mode and route selection at major trip generation sites -- including personalized route planning and route guidance information based on criteria supplied by the traveler. In addition, this subsystem supports fare card maintenance, public safety monitoring using CCTV cameras or other surveillance equipment for emergency notification within these public areas, and other features to enhance traveler convenience that may be provided at the discretion of the deploying agency.

5. DESIGN ALTERNATIVES

5.1 Introduction

With the National Architecture defining what information is processed and where the information flows, we may now proceed to evaluate various designs that are bounded by the architecture. The three design alternatives provided in this chapter are based on operational scenarios that are viable for the Greater Cleveland area. The basic premise of the all three designs is that sensor information (volume, speed, occupancy, video, device status, etc.) from the roadway will be gathered and analyzed either manually or via computer algorithms in order to assess current roadway status and/or determine if there is an incident. In addition to just being of value to the traffic management function, this information is also valuable to emergency management, transit management, commercial vehicle operations, and the traveling public. Looking at the "how" of information flows and processing are the focus of these design alternatives.

5.2 Characteristics

The design alternatives are best described by looking at distinguishing characteristics, since all three provide the same basic functionality. These characteristics are detailed in the following text, and summarized in Table V-5-1, below.

5.2.1 Levels of Coordination

Levels of Coordination are characterized by the inherent synergy of the three key management functions: traffic, emergency, and transit.

- Alternative A consolidates all three functions under a common umbrella or operations center.
- Alternative B provides a very high degree of independence among the three functions, assuming they are geographically dispersed.
- Alternative C couples traffic and emergency, while allowing transit to stay independent.

It should be noted that in Alternative C, emergency services, rather than transit, was selected to be coupled with traffic because there is a common "hours of operation" factor between the two of them. Traffic on the roadway is continuous, and emergency personnel are available twenty-four hours a day in call-answering and dispatch facilities Transit, on the other hand, normally has a specific operational period that is a subset of a day, and even more limited on the weekends and holidays -- times when travelers are still on the roadways.

Table V-5-1. Design Alternatives

DESIGN CHARACTERISTIC	ALTERNATE-A: CENTRALIZED	ALTERNATE-B: DISTRIBUTED	ALTERNATE-C: HYBRID
Level of Coordination:	Tightly Coupled; Traffic, Emergency, & Transit Management	Decoupled; Independent Traffic, Emergency, & Transit Management	Tightly Coupled Traffic & Emergency Management; Independent Transit;
Control Logic:	Centralized	Distributed	Distributed
Data Processing:	Centralized; Tightly coupled computer system	Distributed; Very loosely coupled computer systems	Distributed; Tightly coupled for Majority of Processing and Data; Loosely coupled with Transit
Operations Impact:	Common staff to handle multiple functions	Independent staffs specialized for specific functions	Traffic and Emergency functions shared but Transit staff separate
Arterial Signal Control:	Centralized	Distributed to each Jurisdiction	Centralized for Key Corridors
Communications Network Complexity:	Simplified: Data flows to a Central Point for All	Complex: Data delivered to multiple locations; Information shared to multiple locations	Medium Complexity: Key Incident and roadway status centralized; Information shared with Transit

5.2.2 Control Logic

Control Logic focuses on where the responsibility and capability to control the functions exist.

- Alternative A centralizes the control of traffic, emergency, and transit resources.
- Alternative B maintains the independence of each function to control its own assets.
- Alternative C couples Traffic and Emergency to a single point of control, and maintains a sharing of information with Transit, while it continues to control its own.

5.2.3 Data Processing

Options considered include centralized data processing, where most of the data is processed at the central server in the operations center, or distributed data processing, where much data is processed in the field, some control decisions are automatically made in the field based on the results of field-processed data, and mostly processed data is returned to the operations center.

Advantages of decentralized data processing are that it reduces the amount of data required to be communicated to the functional centers, and decreases the processing loads on the central server(s). Distributed processing may also imply increased reliability, because the system is less dependent on the central server. Disadvantages of distributed data processing are that any increases in reliability due to increased redundancy with respect to data processing, communications, and control capabilities usually result in an associated cost increase. Furthermore, there may be increased maintenance requirements due to the equipment not being located in a single location.

5.2.4 Operations Impact

Centralizing transit, traffic, and emergency operations has impacts on the facilities required and the integration of existing operations. As laid out in Alternative A, all agencies must be in agreement in funding initial startup and continued operating costs. Economies should be realized in the staffing and operations personnel required to run the system. Alternative B maintains the existing "stovepipe" operations and does not derive any economies from overlapping tasks and responsibilities. Alternative C provides the synergy between traffic and emergency for incident detection, verification, response, and management. The close working relationship should expedite the response to incidents and effect control measures to minimize the impacts of the incident by notifying travelers via highway advisory radio or changeable message signs. Transit would be provided information on incidents and dispatchers would evaluate contingency plans if routes are affected.

5.2.5 Arterial Signal Control

Signal system management is of particular importance on arterials that might be used for traffic diversion away from freeways following an incident. Cleveland does have a number of freeways that may serve as primary alternate routes, but arterials are normally impacted by any significant incident requiring re-routing of traffic. Since the scope of the Cleveland Metropolitan area freeway system consists of routes crossing multiple jurisdictions with a variety of arterial signal control systems, it presents a significant problem in providing control or control information (e.g. expected demand) and having the timing plans updated if at all possible.

5.2.6 Communications Network Complexity

While the three designs are independent of the communications transmission system, there are levels of complexity associated with each.

- In Alternative A, all data and information flows into a centralized system and the sharing of information is very collapsed into this single location.
- Alternative B is more complex since each function requires and maintains its own communications network to its assets, and an additional network is required to support the sharing of information.
- In Alternative C, the traffic and emergency data share a common network with limited amounts of information (incident information) being shared with transit. This minimizes the complexity and capacity aspects of the communications network.

Fiber optics was selected because it provides adequate capacity for most ITS applications, and has been proven in applications in other urban areas. While it does represent a major initial investment, it provides needed infrastructure into the foreseeable future for roadside subsystems such as detection and surveillance. Also, since most municipalities are located along the freeway system, any communication network would be a candidate for providing high-speed, high-capacity connections to them.

A star/ring configuration was selected because the topology of the metropolitan Cleveland freeway system most represents multiple loops from I-480 north into the city and to the east of the city. Branches from the ring would emanate from I-480 south along I-71, I-77 and US 42 and west (of I-71) along I-480 and SR 2. The ring configuration provides a physical security in facilitating alternate routing in case of a failure. Rings could be implemented on the branches by routing cable on both sides of the road. This philosophy, while increasing communications reliability, does double the cost of material and installation. What is normally done is running a "collapsed" ring within a single cable bundle. This is usually acceptable since there are no "life support" functions within the system and the areas are usually on the outer fringes of the system.

6. ALTERNATIVES EVALUATION

6.1 Introduction

Each of the three design alternatives presented in Section 5 will accommodate the implementation of all User Services that have been identified by representatives of the agencies participating in this study for priority implementation in the Cleveland metropolitan area (see Section 4). These User Services include: Traffic Control, Incident Management, Hazardous Material Incident Response, Public Transportation Management, En-Route Driver Information, Pre-Trip Travel Information, Demand Management and Operations, Route Guidance, On-Board Safety Monitoring, Traveler Services Information, Ride Matching and Reservation, En-Route Transit Information, and Personalized Public Transit. In addition, because each design incorporates features compatible with the National ITS Architecture (see Section 3), all alternatives will be able to accommodate the implementation of any combination of the other fifteen non-priority User Services when, and if, they are ever deemed appropriate for implementation in the Cleveland metropolitan area.

6.2 Evaluation Criteria

Even though each of the three design alternatives are equivalent from the perspective of satisfying User Service requirements, it is still necessary to determine which one of them implements the User Service requirements most efficiently, and most effectively. To do this, the design alternatives were analyzed for cost, system availability, flexibility, expandability, potential for staged deployment, potential for arterial diversion, and institutional considerations. Additional detail regarding these seven evaluation categories are discussed in the following subsections. Table V-6-1 summarizes these details into a list of sixteen specific evaluation criteria.

6.2.1 Cost

Included were consideration of capital costs, including initial equipment and software costs; the cost for later enhancements to a system; and ongoing costs, namely system maintenance and operating costs.

6.2.2 System Availability

Included were consideration of the reliability of the field equipment, the communications equipment, and the data processing equipment (i.e. expected failure rates); the impacts that result from equipment failures; and the capability of a system to accommodate equipment failures based on a system’s level of redundancy.

Table V-6-1. Evaluation Criteria

EVALUATION CATEGORY	SPECIFIC DETAILS
Cost:	Initial cost for equipment, installation, and software
	Maintenance cost
	Operating cost
System Availability:	Reliability of field equipment
	Reliability of communications network
	Reliability of data processing equipment
	Reliability of operations center 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 operations center
	Capability of one agency/jurisdiction to proceed independently of another
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
Potential for Staged Deployment:	Ease of incremental implementation with respect to technology, functions, or funding
Potential for Arterial Diversion:	Ease with which an arterial diversion scheme could be implemented, for example, the number of agencies and Traffic Operations Centers that would need to be involved to change signal timing along an alternate route
Institutional Considerations:	Whether design is compatible with existing institutional framework, or whether new institutional agreements would be necessary

6.2.3 Flexibility

Included were consideration of both the capability of system functions to be operated independently of the center, and for one agency/jurisdiction to proceed independently of another agency/jurisdiction.

6.2.4 Expandability

Included were consideration of technological expandability for the inclusion of still-to-be-developed components in the future, as well as geographic expandability to encompass additional corridors or extensions of existing corridors.

6.2.5 Potential for Staged Deployment

Included were the ease with which a proposed design could be implemented in discrete but operable segments over a period of time, including the ability to add additional ITS functions (i.e. automatic vehicle location and automatic vehicle identification, etc.) at a later date. For example, a 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 justified by changes in operating conditions, or as additional funding becomes available.

6.2.6 Potential for Arterial Diversion

Included were a system's ability to facilitate the implementation of an arterial diversion scheme, the ease with which an arterial diversion scheme could be implemented, and the effectiveness of such an arterial diversion response. For example, capabilities for arterial diversion will usually depend on the operating agreements with local jurisdictions, as well as the sophistication of the signal control equipment on the affected arterials.

6.2.7 Institutional Considerations

Included was the feasibility of a system to be implemented with respect to non-technical/ jurisdictional considerations. For example, a system that is technically satisfactory will be of no benefit if it cannot be implemented due to institutional obstacles.

6.3 Evaluation Methodology

6.3.1 Introduction

Evaluating alternatives based on a single evaluation criteria is usually a straightforward process. For example, comparing:

- The cost of Product-A vs. the cost of Product-B
- The reliability of Product-C vs. the reliability of Product-D
- The expandability of Product-E vs. the expandability of Product-F

However, when needing to evaluate alternatives based on multiple evaluation criteria, such as is the case in this study, an additional item must be taken into consideration: What is the relative importance of each individual evaluation criteria with respect to each of the other evaluation criteria?. For example:

- Should more emphasis be placed on system availability, even if it might mean choosing a more costly alternative?
- Should twice as much emphasis be placed on expandability, as is placed on cost or reliability?
- Should all evaluation criteria be weighted equally?

6.3.2 Utility/Cost Analysis Method[1]

6.3.2.1 Introduction

Utility/Cost analysis is a procedure commonly used in situations such as this where it is necessary to evaluate alternatives based on multiple evaluation criteria; especially, when evaluations must simultaneously include both qualitative and quantitative criteria (i.e. monetary and non-monetary items). In this context:

- A "utility" is a measure of value, much like either the concepts "benefit" or "effectiveness". However, unlike those concepts, it is considered as a proxy measure of value because it is simply a dimensionless number scaled between zero (lowest or least effective) and ten (highest or most effective) that has meaning only when compared to a competing system's utility.

- A "cost" is an actual monetary value, usually defined as the annualized cash flow for the capital, operating, and maintenance costs of a project throughout its entire design life. It should be noted that costs can also be incorporated as an additional qualitative "utility" value (see Section 6.4.1).

6.3.2.2 Procedure Overview

Essentially, the procedures for a Utility/Cost analysis consist of the following:

- Identify the alternatives to be evaluated (see Section 5)
- Identify the goals/criteria that will be used to evaluate the identified alternatives (see Section 6.2)
- Assign "utility" values on a scale of one (lowest) to ten (highest) that reflect the extent to which each alternate design achieves each of the above-identified evaluation goals/criteria
- Determine the relative weighting values to be assigned to each criteria as compared to each of the other criteria in the analysis
- Calculate the total weighted utility value for each alternative (see below)

The resultant weighted utilities for each alternative to be considered are then divided by the cost of that particular alternative (usually consisting of annualized capital costs plus any annual operating and maintenance costs). The resulting value is then considered the "Utility/Cost Factor" (UCF). The higher this value, the more likely the associated alternative better satisfies the various multiple evaluation criteria, and thus should more likely be chosen as the preferred alternative.

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[1] Discussion of Utility-Cost analysis is based on a methodology described in Chapter 17 of *Traffic Control Systems Handbook*, a June 1976 FHWA-published book; and *Computerized Signal Systems*, a June 1979 FHWA student workbook.

6.4 Utility Factor Development

To represent the extent to which design alternatives were expected to satisfy each of this study's sixteen specific evaluation criteria (see Table V-6-1), the study team calculated 16 Utility Factors (u_{ij}) for each of the three design alternatives, and for each of the three implementation time-frames under consideration: short-term, medium-term, and long-term. Utility values range from zero to ten. Zero is indicative of the least utility or benefit, five is indicative of an average utility or benefit, and ten is indicative of the highest utility or benefit. With the exception of utility factors for cost (described in additional detail below), all utility factors were qualitatively determined. The following subsections discuss methodologies used to assign utility values to each alternative, and highlight design characteristics that affected what utility values were actually assigned to each design. Table V-6-2 summarizes the utility values assigned to each of the design alternatives.

6.4.1 Cost

The utility factors representing cost are scaled values based on the estimated dollar costs for each alternative (see Appendix A). Cost utilities were calculated by first expressing the dollar cost of each alternative as a percentage of the dollar cost of the most expensive alternative for the particular cost evaluation criteria being considered. These proportions were then subtracted from one, with the resultant values multiplied by ten in order that they may be scaled to values between zero (lowest utility) and ten (highest utility).

For example, given three alternatives that may cost $5 (Alternate X), $10 (Alternate Y), and $20 (Alternate Z), they would be scaled as follows:

- Alternate X: { [1 - ($5/$20)] *10 } = 7.5 (high utility since cheapest)
- Alternate Y: { [1 - ($10/$20)] * 10 } = 5
- Alternate Z: { [1 - ($20/$20)] * 10 } = 0 (low utility since expensive)

6.4.2 System Availability

The utility factor representing system availability varies depending on the control logic, the data processing, the number of operations centers, and the geographic extent of the system (interim or ultimate). Multiple server control logic and multiple operations centers are considered more reliable, because if one server or operation center goes down, the remaining server or operations center might be able to assume some of the functions of the server or operations center that is unavailable. Even if this redundancy does not exist, only the portion of the system that relied on the single server or operations center would be down, rather than the entire system. With respect to data processing, distributed 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 communications configuration would provide more possible routes for information flow which would provide additional redundancy and minimize the impact of an equipment malfunction or break in communications. Overall, system availability of a given design alternative tends to increase as component redundancy increases, and as the number of alternate communications routes increases.

6.4.3 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 agency/jurisdictions' ability to proceed independently). The level of centralization is defined not only by the number of activities and agencies included in the operations center (transit, emergency responders, etc.,), but also by the number of operations centers, and the control logic.

6.4.4 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, distributed data processing would facilitate expandability because data processing capacity can be added as needed when additional field equipment is implemented.

6.4.5 Potential for Staged Deployment

The utility representing staged deployment varies depending on the degree of centralization of 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 since data processing equipment can be installed concurrent with the staged expansion.

6.4.6 Potential for 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 a traffic operations center.

Table V-6-2. Utility values assigned to each alternate design

EVALUATION CRITERIA		Near-Term			Medium-Term			Long-Term		
	Design Alternatives:	A	B	C	A	B	C	A	B	C
COST										
u_1	Capital cost	6.8	7.2	7.1	3.3	3.7	3.6	0.0	0.4	0.3
u_2	Maintenance cost	6.3	8.8	7.5	3.8	6.9	5.0	0.0	5.0	2.5
u_3	Operating cost	7.1	7.6	7.5	3.5	4.7	4.5	0.0	1.8	1.6
SYSTEM AVAILABILITY										
u_4	Field equpment reliability	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
u_5	Comm. network reliability	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
u_6	Data processing equipment reliability	5.0	7.0	7.0	5.0	7.0	7.0	5.0	7.0	7.0
u_7	Operations center software/ hardware reliability	7.0	8.0	7.5	7.0	8.0	7.5	7.0	8.0	7.5
u_8	Capability to monitor & control operations in the event of a break in comm. capability	3.0	8.0	7.0	4.5	8.5	7.5	6.0	9.0	8.0
u_9	Extent of loss in capability due to a single break in communications capability	3.0	7.0	7.0	4.5	7.5	7.5	6.0	8.0	8.0
FLEXIBILITY										
u_{10}	Capability for equipment to operate independently or be controlled by the ops. center	3.0	8.0	8.0	3.0	8.0	8.0	3.0	8.0	8.0
u_{11}	Capability of one agency/ jurisdiction to proceed independently of another	4.0	10.0	9.0	4.0	10.0	9.0	4.0	10.0	9.0
EXPANDABILITY										
u_{12}	Extent to which the system can be modified to provide additional capabilities at a later time (e.g. equipment)	5.0	8.0	8.0	5.0	8.0	8.0	5.0	8.0	8.0
u_{13}	Ease with which system can be modified to encompass additional geographic areas	5.0	7.0	7.0	5.0	7.0	7.0	5.0	7.0	7.0
STAGED DEPLOYMENT										
u_{14}	Potential for staged deployment	4.0	8.0	8.0	4.0	8.0	8.0	4.0	8.0	8.0
ARTERIAL DIVERSION										
u_{15}	Potential for arterial diversion	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
INSTITUTIONAL CONSIDERATIONS										
u_{16}	Potential for implementation w/min. institutional barriers	3.0	8.0	7.0	3.0	8.0	7.0	3.0	8.0	7.0

6.4.7 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 operations centers, and the control logic. With respect to the level of centralization, in a more distributed design, institutional issues tend to be related to who "owns" various pieces of data, what data will be shared, and how often that data will be shared; whereas, in a more centralized design, potential institutional issues tend to relate to how responsibilities are ultimately shared, since agency personnel can often do multiple functions. Ultimately, though, institutional considerations relate to the extent to which a design is compatible with the existing institutional frameworks, or if new ones need to be created.

6.5 Weighting Factor Development

To determine the appropriate weighting factors (k-values) to apply when performing the Utility/Cost analysis, a short survey and cover letter with background information was sent to all members of the Cleveland/Lorain Intelligent Transportation System Deployment Study Joint Policy and Technical Committee. Their task was to "spend" a total of 100 points on the above seven evaluation criteria categories, such that the number of points "spent" on each category reflected the relative value that they placed on each particular category. This exercise was also repeated to weight the relative value of each of the specific evaluation criteria that were within each of the more general evaluation categories originally weighted above. Table V-6-3 summarizes the Mean values of these committee responses, and the k-values that the study-team used to perform this analysis (calculated as the mean value of a specific evaluation criteria, multiplied by the mean value of its associated evaluation category, then all divided by 100). Note that the sum of all k-values must be equal to 100 percent.

6.6 Calculations and Results

The overall Utility (U_i) of each alternative is calculated as the sum of each designs' sub-utilities relative to each of the sixteen individual evaluation criteria (u_{ij}-factors), weighted to reflect the appropriate priorities that have been assigned to them by the Steering Committee (k_j-factors). Thus, for each design alternative in this study ($_I$):

$$U_i = k_1u_{i1} + k_2u_{i2} + k_3u_{i3} + ... + k_{15}u_{i15} + k_{16}u_{i16}$$

Next, the Utility-Cost Factor (UCF_i) for each design alternative was computed as the overall Utility for a design (U_i), divided by the annualized cost for that design (C_i).

$$UCF_i = U_i \ / \ C_i$$

Table V-6-3. k-Values Used for Each Evaluation Criteria

EVALUATION CATEGORY WEIGHTINGS	MEAN	EVALUATION CRITERIA WEIGHTINGS	MEAN	**k**-FACTOR WEIGHTING	VALUE
Cost:	15.1	Initial cost for equipment, installation, and software	27.3	k_1	4.1
		Maintenance cost	36.3	k_2	5.5
		Operating cost	36.3	k_3	5.5
		TOTAL:	100.0		
System Availability:	18.3	Field equipment reliability	21.0	k_4	3.9
		Communications network reliability	21.0	k_5	3.9
		Data processing equip. reliability	19.7	k_6	3.6
		Operations center software/ hardware reliability	20.3	k_7	3.7
		Capability to monitor and control operations in the event of a break in communications capability	18.0	k_8	3.3
		Extent of capability loss due to a single break in comm. capability	0.0	k_9	0.0
		TOTAL:	100.0		
Flexibility:	13.1	Capability for equipment to operate independently or be controlled by the operations center	59.3	k_{10}	7.8
		Capability of one agency to proceed independently of another	40.7	k_{11}	5.3
		TOTAL:	100.0		
Expandability:	15.7	Extent to which system can be modified to provide additional capabilities at a later time	55.7	k_{12}	8.7
		Ease of system expandability to additional geographic areas	44.3	k_{13}	6.9
		TOTAL:	100.0		
Potential for Staged Deployment:	12.2	Incremental implementation ease r.e. technologies, functions, or cost	100.0	K_{14}	12.2
		TOTAL:	100.0		
Potential for Arterial Diversion:	13.3	Implementation ease & # of TOCs/ agencies needed to change signal timings along an alternate route	100.0	K_{15}	13.3
		TOTAL:	100.0		
Institutional Issues:	12.3	Is design compatible w/institutional framework or are new ones needed	100.0	K_{16}	12.3
		TOTAL:	100.0		
TOTAL:	100.0			TOTAL:	100.0

Results for both of these calculations are summarized in Table V-6-4. It should be noted that in addition to the cost of each design alternative entering the analysis as the above formula's denominator, the cost of each design alternative was also taken into account as a utility criteria in this formula's numerator (with lower cost resulting in higher utility).

Table V-6-4. Summary of Utility/Cost Analysis Results for Each Alternative

UTILITY & COST VALUES	SHORT-TERM			MEDIUM-TERM			LONG-TERM		
	A	B	C	A	B	C	A	B	C
Weighted Utility:	508	776	745	466	737	703	417	699	661
Annualized Costs:	$ 2.39	$ 2.10	$ 2.17	$ 4.91	$ 4.62	$ 4.69	$ 7.38	$ 7.08	$ 7.16
Utility/Cost Factor:	213	370	343	95	159	150	57	99	92

Note: All costs are in millions of dollars

As presented in Figure V-6-1, a Distributed-type system implemented in the short-term time-frame has both the highest utility and the lowest system costs of all alternatives identified in this analysis. Using this as a starting point provides the Cleveland/Lorain Metropolitan area with a high-return baseline system that can evolve over time into a Hybrid-type system or eventually into a Centralized-type system, if deemed institutionally desirable, in order to take advantage of increased economies of scale and additional opportunities for agency coordination that can become available as both personnel and activities are consolidated. It must be noted, though, that even though Figure 6-1 indicates declining incremental system utility as more miles are added to the system in later time-frames, it should be remembered that since this initial analysis was focused on agency costs, the increased user-benefits that tend to accompany the implementation of increased system coverage and additional user-services were not included. When area-specific user-benefits quantified from the implementation of a baseline system become available, their incorporation into a similar analysis can make increasing incremental system utility more readily apparent such that it could indicate needs to implement later-term features.

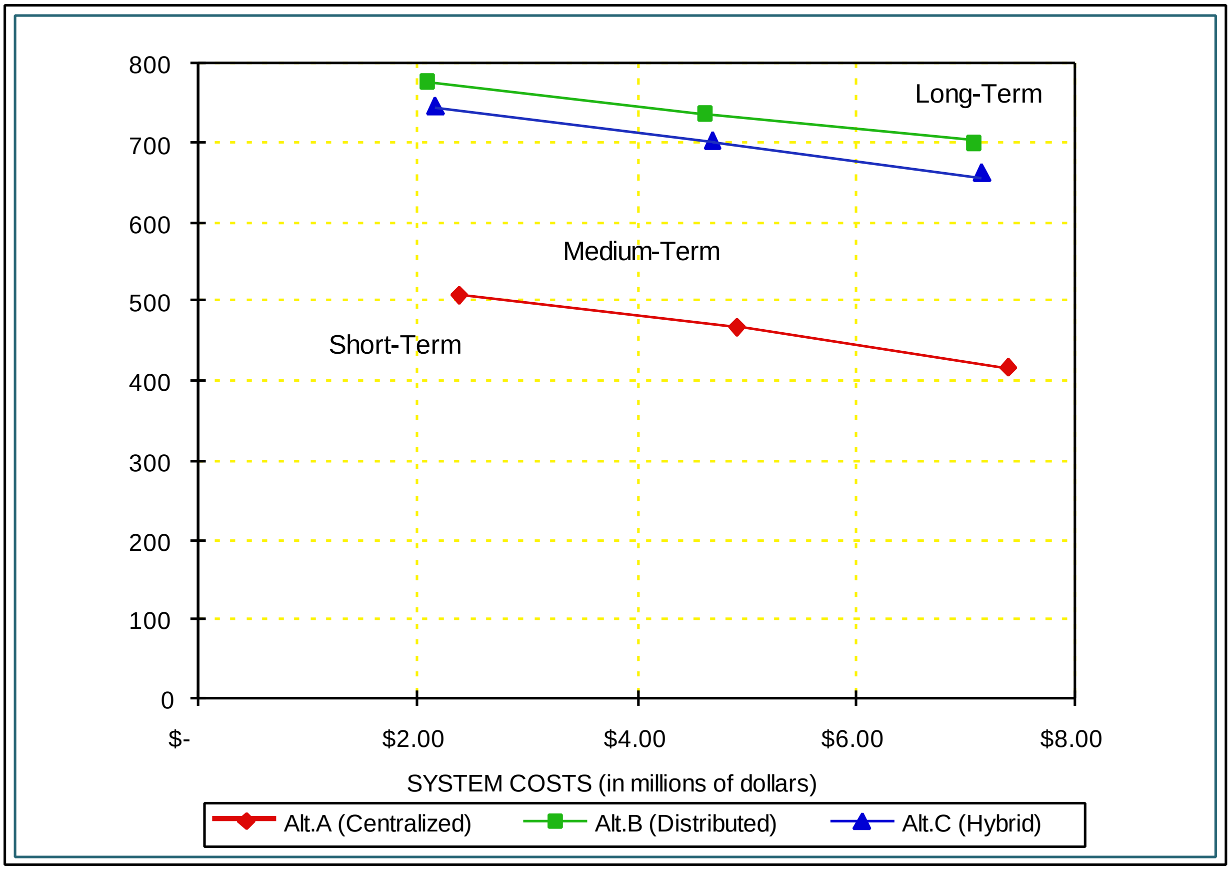

Figure V-6-1. System Costs vs. System Utility for Each Design Alternative

APPENDIX A

COST CALCULATIONS FOR EACH DESIGN ALTERNATIVE

A.1 Calculation of Alternate Systems' Dollar Costs

The dollar costs to implement, operate, and maintain each of the three alternate architectures were calculated for each of the three time-frames / level of deployment under consideration: Near-term (50 miles -- i.e. 100 directional miles); Medium-term (125 miles -- i.e. 250 directional miles); and Long-term (200 miles -- i.e. 400 directional miles). These costs are summarized in Table V-A-1 (capital costs) and Table V-A-2 (operating and maintenance costs), and itemized in the following text. It should be noted that for evaluation purposes, a uniform equivalent annual cash flow was calculated for each design alternative ($\mathbf{C}_{\mathbf{annualized}}$). As formulated below, this consisted of each design's capital costs ($\mathbf{C}_{\mathbf{capital}}$), annualized over a time period of fifteen years (assumed interest rate = 6%), and then added to each design's estimated annual operating costs ($\mathbf{C}_{\mathbf{operating}}$) and estimated annual maintenance costs ($\mathbf{C}_{\mathbf{maintenance}}$).

$$\mathbf{C}_{\mathbf{annualized}} = (\mathbf{C}_{\mathbf{capital}} \times \mathbf{CRF}_{\mathbf{15,6\%}}) + \mathbf{C}_{\mathbf{operating}} + \mathbf{C}_{\mathbf{maintenance}}$$

Where, $\mathbf{CRF}_{\mathbf{15,6\%}}$ (= 0.103) is the Capital Recovery Factor of a cost that is annualized at 6% interest over a time period of fifteen years.

A.1.1 Estimated Capital Costs

A.1.1.1 Roadway Surveillance Equipment

For each alternate design (including poles, conduit, wires, and field data-processing equipment):

- CCTV: $26,000 per site; To be located every mile (bi-directional coverage):
  Near-term = 50 sites; Medium-term = 125 sites; Long-term = 200 sites

- Detection: $22,000 per site; To be located every one-half mile (directional):
  Near-term = 200 sites; Medium-term = 500 sites; Long-term = 800 sites

A.1.1.2 Variable Message Signs

For each alternate design:

- Large fiber-optic type (3 rows, 18 characters/row, 18" characters): $171,000/sign
  - * Near-term = 13 VMS; Medium-term = 26 VMS; Long-term = 36 VMS

A.1.1.3 Communications

For each alternate design:

- $138,000/mile; Including, fiber optic cable, conduit, pull boxes, installation, and termination

Table V-A-1. Estimated Capital Costs for Each Alternative Design

CAPITAL COST ITEMS		NEAR-TERM			MEDIUM-TERM			LONG-TERM		
		A	B	C	A	B	C	A	B	C
	# of miles:	50	50	50	125	125	125	200	200	200
#of directional miles:		100	100	100	250	250	250	400	400	400
ROADWAY SURVEILLANCE EQUIP.										
C.C.T.V.:	cost / site	$0.026	$0.026	$0.026	$0.026	$0.026	$0.026	$0.026	$0.026	$0.026
	freq./mile	1	1	1	1	1	1	1	1	1
	Total Cost:	$1.300	$1.300	$1.300	$3.250	$3.250	$3.250	$5.200	$5.200	$5.200
Detection:	cost / site	$0.022	$0.022	$0.022	$0.022	$0.022	$0.022	$0.022	$0.022	$0.022
	freq./dir.mile	2	2	2	2	2	2	2	2	2
	Total Cost:	$4.400	$4.400	$4.400	$11.000	$11.000	$11.000	$17.600	$17.600	$17.600
VARIABLE MESSAGE SIGNS										
	cost / site	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171
	#of sites	13	13	13	26	26	26	36	36	36
	Total Cost:	$2.223	$2.223	$2.223	$4.446	$4.446	$4.446	$6.156	$6.156	$6.156
COMMUNICATIONS										
	cost/mile	$0.138	$0.138	$0.138	$0.138	$0.138	$0.138	$0.138	$0.138	$0.138
	Total Cost:	$6.900	$6.900	$6.900	$17.250	$17.250	$17.250	$27.600	$27.600	$27.600
HIGHWAY ADVISORY RADIO										
	cost / site	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122	$0.122
	# of sites	5	5	5	8	8	8	11	11	11
	Total Cost:	$0.610	$0.610	$0.610	$0.976	$0.976	$0.976	$1.342	$1.342	$1.342
OPERATIONS CENTER BUILDING										
	cost / sq.ft	$180	$180	$180	$180	$180	$180	$180	$180	$180
	sq.ft./center	25,000	12,000	15,000	25,000	12,000	15,000	25,000	12,000	15,000
	Total Cost:	$4.500	$2.160	$2.700	$4.500	$2.160	$2.700	$4.500	$2.160	$2.700
CENTRAL HARDWARE										
Centralized:	base cost	$0.650			$0.650			$0.650		
	cost / mile	$0.002			$0.002			$0.002		
	Total Cost:	$0.750			$0.900			$1.050		
Distributed/	base cost		$0.440	$0.500		$0.440	$0.500		$0.440	$0.500
Hybrid:	cost / mile		$0.002	$0.002		$0.002	$0.002		$0.002	$0.002
	Total Cost:		$0.540	$0.600		$0.690	$0.750		$0.840	$0.900
SOFTWARE										
	Total Cost:	$0.750	$0.500	$0.600	$1.000	$0.750	$0.850	$1.250	$0.900	$1.000
MISC.(Mobilization, Maint. Traffic, etc.)										
	cost / mile	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035	$0.035
	Total Cost:	$1.750	$1.750	$1.750	$4.375	$4.375	$4.375	$7.000	$7.000	$7.000
Subtotals for 15-Yr. Life:		$23.183	$20.383	$21.083	$47.697	$44.897	$45.597	$71.698	$68.798	$69.498
Cptl. Rcvry. Fctr.(@6%):		0.10296	0.10296	0.10296	0.10296	0.10296	0.10296	0.10296	0.10296	0.10296
Annualized Cap.Costs:		$2.387	$2.099	$2.171	$4.911	$4.623	$4.695	$7.382	$7.083	$7.156

Note: All costs except for operations center building costs per square foot are in millions of dollars.

Table V-A-2. Estimated Operating and Maintenance Costs for Each Alternative Design

Design Alternatives: COST ITEMS	NEAR-TERM			MEDIUM-TERM			LONG-TERM		
	A	B	C	A	B	C	A	B	C
OPERATIONS CENTER PERSONNEL									
cost/operator	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050
# of operators	6	2	4	10	5	8	16	8	12
Ttl. Category Costs:	$0.300	$0.100	$0.200	$0.500	$0.250	$0.400	$0.800	$0.400	$0.600
MAINTENANCE PERSONNEL									
cost/maintainer	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050	$0.050
# of maintainers	7	3	4	14	5	6	21	7	8
Ttl. Category Costs:	$0.350	$0.150	$0.200	$0.700	$0.250	$0.300	$1.050	$0.350	$0.400
REPLACEMENT PARTS & SPARE EQUIP.									
(Calculated as percent of hardware costs -- i.e. all capital costs less those for ops. center bldg., software, & misc.)									
hardware percentage	5%	5%	5%	5%	5%	5%	5%	5%	5%
hardware cap. costs	$16.183	$15.973	$16.033	$37.822	$37.612	$37.672	$58.948	$58.738	$58.798
Ttl. Category Costs:	$0.809	$0.799	$0.802	$1.891	$1.881	$1.884	$2.947	$2.937	$2.940
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS:	$1.459	$1.049	$1.202	$3.091	$2.381	$2.584	$4.797	$3.687	$3.940

Note: All costs are in millions of dollars.

A.1.1.4 Highway Advisory Radio

For each alternate design:

- Permanent AM Radio installation: $122,000 per site
  - * Near-term = 5 sites
  - * Medium-term = 8 sites
  - * Long-term = 11 sites

A.1.1.5 Operations Center

All alternate designs are for a new facility to be built on DOT property. All building sizes assume enough space to accommodate the long-term system (400 directional miles of coverage).

For Alternate A:

- Centralized facility with room for traffic operations, emergency management, and transit operators: 25,000 ft^2 facility at $180 / ft^2

For Alternate B:

- Decentralized facility to handle traffic operations only: 12,000 ft^2 facility at $180/$ft^2$

For Alternate C:

- Hybrid facility with room for traffic operations and emergency personnel: 15,000 ft^2 facility at $110 / ft^2

A.1.1.6 Central Hardware

Each alternative includes the following costs, plus the costs at the base (see below)

- $50,000/25 miles of controlled freeway; Including $5,000 for a console, $10,000 for two video monitors, $10,000 for one computer workstation, and $25,000 for miscellaneous items.

For Alternate A (Centralized):

- $650,000 at base; This consists of $300,000 for video displays, $250,000 for the central computer, and $100,000 for miscellaneous items.

For Alternate B (Decentralized):

- $440,000 at base; This consists of $300,000 for video displays, $40,000 for central servers, and $100,000 for miscellaneous items.

For Alternate C (Hybrid):

- $500,000 at base; This consists of $300,000 for video displays, $40,000 for central servers, and $100,000 for miscellaneous items.

A.1.1.7 Software

For Alternative A:

- Near-term = $750,000; Medium-term = $1,000,000; Long-term = $1,250,000

For Alternate B:

- Near-term = $500,000; Medium-term = $750,000; Long-term = $900,000

For Alternate C:

- Near-term = $600,000; Medium-term = $850,000; Long-term = $1,000,000

A.1.2 Estimated Annual Operating Costs

For each alternative design, annual operating costs were estimated to be $50,000 per year per operator (fully burdened). Assuming three and one-half shifts (3 shifts, plus 1/2 shift coverage) each for traffic and emergency services, and two shifts for transit, the total number of operators estimated to be needed for each alternative and for each time-frame are:

For Alternate A (with traffic, emergency, and transit):

- Short-term = 6 operators needed; Medium-term = 10 operators needed; Long-term = 16 operators needed

For Alternate B (traffic only):

- Short-term = 2 operator needed; Medium-term = 5 operators needed; Long-term = 8 operators needed

For Alternate C (traffic and some emergency):

- Short-term = 4 operators needed; Medium-term = 8 operators needed; Long-term = 12 operators needed

A.1.3 Estimated Annual Maintenance Costs

A.1.3.1 Maintenance Personnel

For each alternative design, annual maintenance personnel costs were estimated to be $50,000 per year per maintainer (fully burdened). Assuming adequate field maintainers and control center maintainers for one shift, the total number of maintainers estimated to be needed for each alternative and for each time frame are:

For Alternate A (with traffic, emergency, and transit):

- Short-term = 7 maintainers; Medium-term = 14 maintainers needed; Long-term = 21 maintainers needed

For Alternate B (traffic only):

- Short-term = 3 maintainers needed; Medium-term = 5 maintainers needed; Long-term = 7 maintainers needed

For Alternate C (traffic and some emergency):

- Short-term = 4 maintainers needed; Medium-term = 6 maintainers needed; Long-term = 8 maintainers needed

A.1.3.2 Replacement Parts and Spare Equipment

For each alternative design, the annual costs for replacement parts and spare equipment were assumed to be approximately 5% of hardware costs (i.e. all capital costs except for the cost of the operations center, and the cost of software).

A.2 Calculation of Alternate Systems' Cost Utilities

Section 6.4.1 summaries the basic methodology used to convert the above dollar costs into utility factors. Actual values used are summarized in Table V-A-3, below.

Table V-A-3. Summary of Calculations for Alternate Systems' Cost Utilities

COST CATEGORY	NEAR-TERM			MEDIUM-TERM			LONG-TERM		
	A	B	C	A	B	C	A	B	C
CAPITAL:	$23.18	$20.38	$21.08	$47.70	$44.90	$45.60	$71.70	$68.80	$69.50
% of greatest	0.32	0.28	0.29	0.67	0.63	0.64	1.00	0.96	0.97
Utility Factor:	6.8	7.2	7.1	3.3	3.7	3.6	0.0	0.4	0.3
OPERATING:	$ 0.30	$ 0.10	$ 0.20	$ 0.50	$ 0.25	$ 0.40	$ 0.80	$ 0.40	$ 0.60
% of greatest	0.38	0.13	0.25	0.63	0.31	0.50	1.00	0.50	0.75
Utility Factor:	6.3	8.8	7.5	3.8	6.9	5.0	0.0	5.0	2.5
MAINTENANCE:	$ 1.16	$ 0.95	$ 1.00	$ 2.59	$ 2.13	$ 2.18	$ 4.00	$ 3.29	$ 3.34
% of greatest	0.29	0.24	0.25	0.65	0.53	0.55	1.00	0.82	0.84
Utility Factor:	7.1	7.6	7.5	3.5	4.7	4.5	0.0	1.8	1.6

Note: All costs are in millions of dollars

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CHAPTER VI. TECHNOLOGY ASSESSMENT

A. Introduction

This Chapter identifies and discusses the various technologies that may be used for ITS applications with respect to their merits and limitations for both near-term and later-term implementations. Furthermore, the text is organized in a manner that parallels four of the main components of any comprehensive ITS package: vehicle detection, incident verification, system communication, and traveler information.

The *Vehicle Detection* section details both pavement intrusive and non-intrusive installation technologies (i.e. inductive loops or magnetometers vs. overhead sonic or machine vision systems vs. side-mounted microwave systems, etc.), as well as discussions related to advanced in-vehicle technology systems such as automatic vehicle identification and automatic vehicle location / global positioning systems.

The *Incident Verification* section details issues related to successfully implementing closed-circuit television camera systems, including physical issues (e.g. camera type, control, and location/mounting), image transmission issues (e.g. fiber-optic vs. coaxial cable, and digital vs. analog signals), and image display issues (e.g. geographically distributed control, video switching, and large screen video).

The *System Communication* section details both commercially owned facility options (i.e. dial-up service, dedicated service, packet radio service, cellular service, etc.), and agency owned cable-based and wireless communication options (e.g. twisted-pair cable, coaxial cable, fiber-optic cable, microwave, wireless video, and spread-spectrum radio).

The *Traveler Information* section details a variety of issues ranging from the availability and operation of different types of message signs (i.e. changeable message signs vs. various types of variable message signs), to issues regarding highway advisory radio (e.g. operations, transmitters, and antennas), to discussions about successfully implementing kiosks and dial-in systems.

Each of these components can be deployed and utilized jointly, as well as separately. However, their complementary interaction improves overall system operations by providing synergistic information that enables informed traffic management decisions to be made in a manner that no component could provide alone.

For example, even though the vehicle detection component electronically monitors the flow of traffic on the roadways and transmits this information in "real time" to a traffic operations center (TOC) for analysis and status displays, without the closed-circuit television component to provide system operators with a visual means for incident verification and human interpretation/evaluation of the traffic conditions, false alarm rates could be higher than desired, thus causing system operators to possibly dispatch too few or too many emergency personnel in response to an incident that was reported by the vehicle detection component alone.

Similarly, the vehicle detection component could theoretically be used in a stand-alone configuration to only provide data to engineers in a TOC for the updating of signal timing plans; however, the addition of a traveler information component increases overall system effectiveness by allowing user understandable summaries of this information (i.e. automobile travel times on specific roadways or mode-specific travel times from major origins to major destinations) to be shared with the traveling public so that they too can make informed transportation choices.

As with any technologies, no one knows for sure what the future holds. However, as described in this working paper, mature, off-the-shelf technologies are available for implementation in each of the above categories such that when combined with competent systems integration and a comprehensive vision for future ITS user services goals and desires, today's technologies can form the building blocks for the realizing of successful and cost effective long term ITS realities.

B. Vehicle Detection

1. Overview

Vehicle detection technologies form the foundation of the ITS surveillance sub-system. Control strategies, incident management procedures, and motorist information displays are selected based upon real time data collected by the vehicle detection system. In addition, data summaries are often collected for storage into electronic databases that provide the needed historical information for future traffic condition planning purposes.

There are two separate approaches to vehicle detection: those that involve no electronics in the vehicle (i.e. roadway pavement intrusive and non-intrusive detection technologies), and those that cooperatively utilize in-vehicle and roadside electronics (i.e. advanced technology systems). Technologies that do not require any in-vehicle devices are the basis for most current vehicle detection systems because they allow all vehicles in the vicinity of a sensor to be detected and monitored -- adequate for near-term ITS user services implementations; however, as more advanced user services are desired to be implemented, these detection systems will need to be augmented with in-vehicle devices in order to provide the two-way information exchange that will ultimately be necessary for route guidance, electronic toll collection (where appropriate), and other advanced technology systems.

As such, detector types appropriate for any given application are dependent on the data requirements specific to each ITS purpose. For example, to meet the needs of automated incident detection and response, real time data is needed to ascertain vehicle speed, traffic counts, lane occupancy, vehicle classification, and changes in vehicle motion and position. Depending on the technology chosen, obtainable data can also include traffic density, travel time, vehicle length, acceleration characteristics, and in some cases, vehicle location and hazardous materials status. In addition, operational environment and maintenance requirements such as the extent to which traffic lanes may need to be closed for detector installation, maintenance, and replacement can be some of the most critical factors in determining the types of detectors to be used in an ITS application.

The following sections, which are summarized in Table V-1 in terms of the primary parameter that is most directly measured by a given detector in its preferred mounting position(s), describe various off-the-shelf vehicle detection technologies that are applicable for implementation in the Cleveland metropolitan area. In addition to those listed, there are also numerous other technologies that have been experimented with and tested by various departments of transportation (DOTs) and the Federal Highway Administration (FHWA). Although many of these other technologies show promise, they have not yet progressed to reliable field operations and are therefore not included in this study so as to limit system complexity and the resultant increased operations and maintenance costs that can be associated with the use of experimental technologies.

While keeping this in mind, however, a significant and related point must be made. As with all areas of electronic technologies, changes do occur regularly, and changes will occur regularly. Therefore, discussions in the following sections should not be considered as a complete set of technological options for the provision of all mid-term and long-term ITS user services implementations. Minds must always be open to those non-listed devices that are experimental today, but that may be tomorrow's standard devices for the provision of new solutions to existing problems. As such, even though it is considered appropriate to limit near-term system *components* to off-the-shelf technologies, it is important that *the actual system* that is considered for implementation be looked at with an eye to tomorrow such that there is always enough flexibility to accommodate change on a regular basis.

2. Intrusive Installation Technologies -- Passive-Type Devices

Technologies that involve cutting existing road surfaces and pavements, such as inductive loops, are known as intrusive installations. They can typically create installation and maintenance problems due to the need to close traffic lanes, and can compromise the structural integrity of the roadway; especially, on bridges and other structures.

a) *Inductive Loops*

The most commonly used vehicle detection technology is the inductive loop. Typically configured as a 6 x 6 ft square formed by two or three turns of a 12-gauge or 14-gauge wire that is placed in slots cut into a pavement, it can provide "point" (i.e. presence) detection when connected to an amplifier/detector in the control cabinet, or speed information when used in conjunction with a second inductive loop that is placed just downstream of the first. As such, it is extensively used for arterial signal control, and has a long history of successful field deployment.

The advantages of inductive loops are their well known performance characteristics, maturity, application flexibility, and multiple vendor availability. Disadvantages of inductive loops arise from the need to embed them in the pavement surface, and the resultant problems associated with pavement deterioration and freeze-thaw damage that happens when heaving pavements break the loop wires. Further difficulties include damage to loop conductors during resurfacing operations or construction, and the reduced effectiveness of loops when in close proximity to reinforcing steel -- especially in concrete pavements.

Over the years, however, the manufacturers have enhanced and refined their equipment, providing numerous options and alternatives to meet a wide range of application needs. One new development is the manufacture of pre-formed loops. Available from a number of suppliers, this type of loop is pre-assembled with the wires encased in a filled conduit. When a roadway is constructed, this assembly is embedded in the pavement, typically several inches below the surface, and offers improved reliability and life expectancy. A similar approach is also being utilized in some areas as part of roadway reconstruction projects. After the old pavement is removed by milling, an inductive loop is saw cut into the milled surface. Therefore, once the new pavement is applied, the inductive loop (now buried several inches below the road surface) is less subject to damage from either traffic, construction, or weather.

Further improvements have also been made regarding the signal output of inductive loops. Since sophisticated computer systems were unable to gain access to any information contained in the magnetic or inductive signal collected by the detector amplifier, new products have been made available with on-board microprocessors that are able to monitor the “signature” of the detected field in order to allow for more accurate speed measurement and some capability for vehicle classification. In addition, serial data ports with RS-232 communication, now allow systems to access a detector amplifier’s internal database to perform remote sensitivity adjustments and compensate for weather conditions.

While inductive loop detectors are often maligned; especially, in cold weather climates due to the problems noted previously (i.e. roadway cut installation life of approximately three years, etc.), they are still the primary source of vehicle detection in most systems around the country due to their high accuracy when functioning properly. As indicated by verification studies in Los Angeles that compared traffic counts obtained from inductive loops with traffic counts obtained from manual counts of time stamped vehicles on video tapes from the same traffic streams, inductive loop detectors were accurate to within +/- 0.6% with respect to actual vehicle counts.

Table CHAPTER VI. -1. Major Features of Common Off-The-Shelf Vehicle Detectors

DETECTOR TYPE	PRIMARY DATA TYPE	MOUNTING OPTIONS	COMMENTS
Inductive Loop:	Presence	In Roadway (Per Lane)	Roadway cut installation life of approx. 3 years
Piezoelectric Strip:	Axle Count, Weight	In Roadway (Per Lane)	Installation involves a roadway cut
Radar (Continuous Wave):	Speed	Overhead (Per Lane)	Poor results at low speeds
Radar (Multi-Zone):	Presence	Overhead or Side-Fired (Multi-Lane)	Some tests show difficult calibration
Active Infrared (Non-Image):	Presence	Overhead (Per Lane)	Few installations
Passive Infrared (Non-Image):	Presence	Overhead (Per Lane)	Few installations
Passive Infrared (Image):	Presence	Overhead or Side-Fired (Multi-Lane)	Few installations
Acoustic (Passive):	Presence	Overhead (Per Lane)	Some tests show reliable ops.; Few installations
Ultrasonic (Pulsed):	Presence	Overhead (Per Lane)	Poor sample rate for high speed flow statistics
Ultrasonic (Continuous Wave):	Presence	Overhead (Per Lane)	Poor results at low speeds
Magnetometer or Microloop:	Presence	In Roadway (Per Lane)	Manufacturer claims good results on bridge decks
Video Image Detection:	Tracking	Overhead or Side-Fired (Multi-Lane)	Forty foot mounting height suggested
Automatic Vehicle Identification:	Travel time, Location	Overhead or Side-Fired (Limited Range)	Proven benefits for transit fleet management

b) *Magnetometers*

In locations such as bridges, where loop installations in the existing pavement area could affect structural integrity, magnetometers and their related micro-loop technologies are often suggested for deployment. Shaped like small cylinders, and installed in a hole that is cored into the pavement and sealed with sealing compound, magnetometers have had spotty operational success. Preliminary results from "Detection Technology for ITS", an FHWA sponsored project that is evaluating a wide range of equipment under laboratory and field conditions, indicate that magnetometers have an accuracy in the +/- 5% range. This has resulted in other technologies often being considered for these particular needs. However, the use of new digital processing technology has the potential to significantly improve their performance. A re-evaluation of their role will be appropriate after sufficient field experience is gathered.

c) *Axle Counters*

Commonly referring to a bending beam piezoelectric strip that is embedded in the roadway surface, axle counters are used to obtain the number of axles on a vehicle in order to help satisfy Federal Highway Administration (FHWA) requirements for thirteen bin vehicle classification on certain roadways. When combined with inductive loops, vehicle length and speed can also be determined.

3. Non-Intrusive Installation Technologies - Active

Technologies that are mounted either above a roadway on existing structures, or in a “side-fire” position on poles along the side of a roadway are termed non-intrusive installations. Since they do not disturb the pavement, lane closures and the associated traffic diversion and control problems that often arise whenever intrusive detectors are installed and maintained can be minimized.

Technologies that detect vehicles by emitting some type of energy signal, such as microwaves, are known as active-type devices.

a) *Microwave*

Microwave detectors are currently in limited use for incident detection on freeway management projects, and for the gathering of necessary data for computerized arterial signal systems. They operate by emitting a signal in the microwave portion of the electromagnetic spectrum, such that when the returned signal is analyzed, various traffic characteristics can be determined (Note: the specific traffic characteristics that can be determined depend on the type of microwave detector that is used). Except for the newly available side-fired sweep frequency microwave vehicle detector described below, a separate detector unit is required for each lane that is to be monitored by each of the various types of radar detectors described below. In addition, except for the above mentioned case, each detector unit is required to be mounted on some type of cantilever structure or sign bridge that is located over each lane to be monitored. Finally, early results from the FHWA’s IVHS Detection Technology project indicate that the microwave radar detectors described below have accuracies that range from +/-0.5% to +/-6%.

Microwave detectors can usually be configured with two types of interfaces: an RS-232 serial data interface, and a dual pulse-type contact interface. The serial output provides data (volume, speed, etc.) in an ASCII text string, and can be modified to incorporate a standard error checking communications protocol to allow for a multi-lane unit to be installed without a local field microcomputer. The dual pulse-type interface provides for the emulation of a paired inductive loop speed trap. To emulate this type of configuration, the first contact closure occurs when a vehicle enters the detection zone, and the second contact closure is timed by the detector to occur relative to the first closure such that it provides the correct travel time based upon a calibrated "loop spacing".

Advantages of radar and microwave devices include ease of use, requiring no cutting of pavement and/or 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 (described), direct speed measurement is a significant benefit. Furthermore, for all radar type systems, if traffic lanes are shifted, radar antennas can be easily re-aimed. The disadvantages of radar are: the overhead mounting requirement for most of the detectors, limited field operational experience for many of the new units, a small number of vendors in the market, and difficulties in accurately sensing lane occupancy and slow moving or stopped vehicles with the Doppler-type units.

Doppler

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 cannot readily obtain lane occupancy and vehicle lengths. Detection of stopped or very slowly moving vehicles is not possible.

Pulsed

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 reflections, pulsed radar units utilized for traffic detection typically limit their filed of view to a portion of a lane, such that only a single vehicle is ever 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 of a sample rate that must be frequent enough to provide accurate presence calculations to determine other traffic parameters.

Sweep Frequency

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

A new technology subcategory of the traditional sweep frequency microwave detector has recently become available. When mounted at the side of the roadway, this device is able to scan up to twelve lanes. Since side mounting facilities are often available, or can be readily installed, the device is more cost effective. The device can also detect vehicle presence, and is thus able to determine occupancy and the existence of stopped vehicles. However, in a side-fire position, it does not measure speed directly, relying instead upon "single loop" speed estimation techniques based upon average vehicle length. The accuracy of this device, as stated in the early results from the FHWA's Detection Technology project, is in the +/- 5% range for volumes. For the particular mounting height used in this test, results indicated missed and duplicated counts across multiple roadway lanes upon the passage of large vehicles.

b) *Active Infrared*

Using a strategy similar to that used in a pulsed radar detector, active infrared detectors operate by illuminating a vehicle detection zone with infrared energy supplied either by light emitting diodes (LEDs) or lasers (used to provide a higher level of output energy). Since it is known that a portion of the energy will be reflected back if a vehicle is in a detection zone, these detectors consist of optical elements to focus the returned signal onto a matrix of infrared sensors. By measuring the two way travel time of this infrared pulse from the source to the sensors, distance to a vehicle can be measured such that when all data is processed, active infrared detectors can provide vehicle counts, occupancy, presence, speed, and classification information. A significant disadvantage, however, is that because infrared energy (i.e. electromagnetic energy in the band above the visible spectrum) is attenuated and scattered by rain, snow, fog, smoke, dust, and mist in the air, active infrared detectors are vulnerable to significantly reduced effectiveness during these types of atmospheric conditions.

c) *Sonar*

Several techniques have been explored to use sound for vehicle detection. One such device, known as a sonar system, utilizes concepts similar to those found in radar systems such that when sent out sound waves (instead of microwaves) are echoed back to a sending device, these echoes can be analyzed so that they represent detected vehicles. Early results for these detectors that were included in the FHWA's ITS Detector Technology test have shown accuracies in the +/- 2% range. However, when similar units were tested by the Arizona DOT, they were found to only have an accuracy in the +/- 5% range.

4. Non-Intrusive Installation Technologies - Passive Devices

Technologies that detect vehicles by either "looking" at them or "hearing" them without emitting any type of energy signal are known as passive-type devices.

a) *Passive Infrared*

Without emitting any energy themselves, passive infrared detectors are able to determine the presence and passage of vehicles by utilizing the characteristic that all objects emit both heat and other infrared radiation as a function of their surface temperature and their actual object characteristics. By focusing this infrared energy through an optical system and then onto infrared sensors, vehicle counts and "detector" occupancy can be determined via the detection of differences between the temperature and energy emitted by vehicles, and by the temperature and energy emitted by the roadway surface itself. A disadvantage of these devices, however, is that because passive infrared detectors are dependent upon the sun and other infrared sources for their input energy, and that because infrared energy is obscured by atmospheric effects, any periodic changes such as cloud cover, glare from bright objects that are reflecting sunlight, etc. can create confusing and unwanted signals in passive infrared devices.

It should be noted, though, that by increasing the number of sensors in a passive infrared detector, an "image" of the scene of interest can be generated such that this increase in detail allows additional information from the "scene" to be discerned and analyzed. Therefore, as the number of individual sensors becomes large enough, the boundary between this type of infrared detector and an infrared sensitive CCTV camera becomes blurred such that for all practical applications, an infrared imaging system has essentially all of the same characteristics as the Video Image Detections systems discussed below.

b) *Sonic*

A second type of audio based vehicle detection device is the overhead mounted sonic detector. By passively "listening" to the noise generated by vehicles, and then analyzing this resulting noise energy, these devices are able to emulate inductive loops and detect individual vehicles and their resultant location and speeds. Since these types of sonic detectors have not yet been used extensively in surface transportation applications, field experience is limited. However, they are considered to hold significant promise as a valid tool for vehicle detection because they are based on well proven defense technologies that have been used to detect and classify submarines via their noise signatures. It has also been reported that future versions of this device are being developed that will use vehicle noise signatures to implement FHWA's thirteen bin classification for surface vehicles, without the need for any costly piezoelectric devices.

c) *Machine Vision -- Video Image Detection (VID)*

Machine vision systems, often referred to as Video Image Detection (VID) systems, were originally used for various industrial, manufacturing, military, and aerospace applications before being applied to traffic management. They are composed of two components: fixed orientation CCTV cameras that are strategically located to provide views of specific areas or long sections of roadway, and a computer that analyzes the video image in real time (e.g. 30 times/second). VID systems have experienced growing success in recent years; especially, since early system troubles due to shadows, adverse/changing lighting conditions, harsh environments, differing vehicle shapes, and sometimes difficult operating conditions, have essentially been solved by extensive field testing, actual deployment, and increasingly sophisticated software on more powerful computers.

Currently, two fundamentally different strategies are available to analyze the video images: fixed analysis zones that detect vehicles moving through them, and vehicle identification / subsequent tracking systems. The technique utilizing fixed analysis zones, analogous to a "loop" in the video image, is the most stable and best tested approach, and will therefore be discussed here. Equipment based on this approach can provide vehicle counts, lane occupancy, vehicle speeds, and vehicle lengths. In addition, software in the VID processor can collect this standard information (i.e. volume, occupancy, and speed, etc.) to provide limited data analysis and processing features that include automated statistics accumulation, data smoothing, and level-of-service calculations. It should also be mentioned that a third video analysis strategy is available that involves reading license plates "on-the-fly"; however, it is not directly applicable to this Early Deployment Study since it is usually only appropriate for toll violation enforcement and other related applications.

While the promise of VID systems is significant, it is still a young technology that will evolve and grow for many years. Disadvantages are that in spite of the advances that have been made with these systems, there are still some operational problems under adverse lighting, and during the transitions between daylight and darkness (including storm conditions) that will require more refinement. In addition, camera placement must be carefully considered since shadows from objects outside of the detection area may affect performance. Finally, early results from the FHWA's Detector Technology project report VID accuracies ranging from +/- 0.3% to +/- 2.3%, with accuracy decreasing under dark or adverse weather conditions.

However, as this is a quickly evolving technology, its most promising usage cannot be overlooked -- e.g. the detection of stopped or stalled vehicles either in a travel lane or on the shoulder; thus, providing direct detection of an incident. Furthermore, because of the ability of a VID-connected CCTV camera to be oriented such that it can monitor large areas of roadway up to 1/4-mile in length from a single equipment location, significantly more roadway and a greater number of vehicles can be monitored. As such, this capability, coupled with individual vehicle detection, is expected to provide significantly more information than is currently available with existing point-source technologies such as inductive loops or radar, etc.

5. Cost / Mounting Comparisons

Two different categories of vehicle detectors are discussed above: those that are embedded in the road surface (i.e. inductive loops, etc.), and those that are mounted overhead (i.e. a radar detector or a video image detector, etc.).

As discussed, embedding detectors in the roadway necessitates significant traffic disruptions since it requires that the road surface be cut or drilled, and subjects the detector to failure due to pavement deterioration, etc.; thus, creating ongoing maintenance problems, or poor detector reliability. As noted, though, newer construction techniques that embed the detector several inches below the pavement surface are being used to solve some of these problems.

Conversely, detectors that are mounted above each lane, such as most radar detectors and ultrasonic detectors, claim an advantage of minimal traffic disruption during installation and maintenance; however, these mounting locations require some form of support structure.

Mounting on an existing over-crossing is an option, but can create aesthetic concerns, and often results in limited accessibility requiring that at least one traffic lane be closed to service the unit. The use of signal head mast arms is another option, but has the drawback of motion under high wind loading and the need to block traffic for installation and servicing. Sign bridges are a third option, and are excellent choices where they already exist, especially if they include a catwalk 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.

a) ***Overhead Installation Example***

Many of the overhead detectors that monitor a single lane cost between $750 and $1000 per unit. However, sign bridges and associated foundation and installation costs range from $66,000 to $84,000 depending on the distance that needs to be spanned, resulting in a cost of roughly $19,000 per lane -- approximately 20 times the cost of the detector itself (assuming an average span of four traveled lanes plus two shoulders and any necessary clear distance to the supports).

For comparison purposes, the installed cost of an inductive loop is about $5,500 per lane. This cost, though, does not include additional life cycle costs related to needs to periodically re-cut/re-install inductive loops due to loop failures -- a rate that depends on the quality of the initial installation, the area’s climate, and the location’s initial pavement condition. This above inductive loop cost also does not include the more difficult to determine lane closure costs and life-cycle costs associated with a decrease in the remaining service life of an existing pavement that has had inductive loops saw cut into it, thus reducing its structural integrity.

Therefore, overhead mounted detectors that must be positioned over each lane can be significantly more expensive than inductive loops when the costs of a mast arm and pole, or the cost of a new sign bridge must be included. However, in those situations where an existing structure or sign bridge is available, overhead mounted detectors can be cost effective, even though they may also require limited traffic disruptions for installation and servicing.

b) ***“Side-Fired” Installation Example***

Another category of overhead devices -- side-fired radar and/or video image detectors (VIDs) -- can be mounted on a pole off the side of a road or in its median. Since installed poles and necessary foundation costs are approximately $6,500 per pole, this can significantly reduce the total cost of a mounting while having the advantage of being able to monitor several lanes from a single unit (thus spreading the cost of each unit and its mounting pole across several lanes). Furthermore, side-fired mounting typically does not require the stopping of traffic for access to the units.

A disadvantage of side mounting or an oblique camera view is the fact that trucks and larger vehicles in the near lanes may sometimes obscure smaller cars in the farther out lanes through disruption of a detectors’ line of sight (known as occlusion), thus resulting in missed counts. In addition, with VIDs, the ability to discriminate between two closely following vehicles is a function of its mounting height and angle of view; however, even though increased height improves its discrimination ability, it results in a more costly pole and foundation. Furthermore, a problem noted with VIDs in this configuration (though not necessarily noted with side-fired radar), is that the motion of the mounting pole under wind loading, or the twisting of the mounting pole due to differential solar heating can result in the camera's field of view changing, thus "moving" the fixed analysis zones to another portion of the image. However, as detailed in the following comparisons for a typical four lane single-direction freeway scenario, side-fired detection is very cost competitive with installed inductive loops.

c) *Freeway Scenario Comparisons*

For comparison purposes, a four lane, single direction freeway cross-section has been utilized to evaluate the following six different detection equipment configurations:

- *Presence-Type Inductive Loops,* including four loops and lead-in wires sawcut into a pavement surface, necessary conduit and pullboxes, a processor cabinet on one shoulder, a field-controller, and appropriate interface cards;
- *Speed-Pair Inductive Loops with Piezoelectric Strip,* including eight loops and lead-in wires sawcut into a pavement surface, necessary conduit and pullboxes, a processor cabinet on one shoulder, a field controller, and appropriate interface cards;
- *Side-Fired Sweep-Frequency Microwave Radar,* including one unit mounted on a pole located on one shoulder, pole and foundation installation costs, necessary conduit and pullboxes, and appropriate processor interfaces;
- *Overhead Mounted Sensors on a Sign Bridge,* including four units mounted on an overhead sign bridge, sign bridge and foundation installation costs, necessary conduit and pullboxes, and appropriate processor interfaces;
- *Overhead Mounted Sensors on Mast-Arms,* including four units mounted on two poles/mastarms, pole and foundation installation costs, necessary conduit and pullboxes, and appropriate processor interfaces; and
- *Machine-Vision Video Image Detector,* including one camera mounted on a pole located on one shoulder, pole and foundation installation costs, necessary conduit and pullboxes, and a pro-rated allocation of appropriate processor interfaces (at least two cameras are usually connected to a single field-processor and cabinet).

With the exception of the video image detector that includes a pro-rated allocation of field processor and cabinet costs, a Model 170 processor and installed cabinet is included in all configurations. In addition, conduit, cable, installation, and testing costs are included for all cases. It is also assumed that necessary power and a communications "backbone" are available. However, since a fiber-optic communications "backbone" is usually only placed on one side of a freeway, a pro-rated allocation of all costs associated with jacking conduit under the pavement is included to account for the need to connect devices located on one side of a freeway with the assumed communications "backbone" that may be on the "other" side of a freeway. Table VI-2 summarizes the results of these cost scenarios. It should also be mentioned that maintenance costs were not included in this analysis. For some applications, maintenance costs can usually be calculated as 10% of equipment costs; however, for devices like inductive loops that typically need to be re-cut every three years in northern climates, maintenance costs may be higher, as indicated by each jurisdictions' local experience.

Table CHAPTER VI. -2. Estimated Vehicle Detection Costs

CONFIGURATION EXAMINED	Detection Cost Per 4-Lane Site (directional)		
	Equipment	Construction	Total
Presence Type Inductive Loops:	$8,800	$11,200	$20,000
Side-Fired Sweep-frequency Microwave Radar:	$9,500	$10,800	$20,300
Speed Trap Inductive Loop Pair with Piezoelectric Strip	$9,000	$14,200	$23,200
Pole mounted Machine vision Video Image Detector:	$13,200	$10,800	$24,000
Overhead Mounted Sensors on Mast Arms:	$8,500	$21,500	$30,000
Overhead Mounted Sensors on a Sign Bridge:	$8,500	$78,200	$86,700

6. Advanced Technology Systems

Technologies that include in-vehicle electronics that interact with the roadside infrastructure and/or other vehicles in their immediate vicinity are currently being used for specific applications around the country, such as electronic toll collection, transit and commercial fleet management, route guidance assistance, and vehicle emergency notification (Mayday) systems. In addition to these applications, advanced technology systems appear to be taking the first steps toward further vehicle guidance and other types of automation in highway systems. Though, it is expected to be at least two decades before any truly automated highway systems become widely available.

a) *Automatic Vehicle Identification (AVI)*

<u>Vehicle Probe Data</u>

The recent addition of electronic toll tag capabilities, also referred to as automatic vehicle identification (AVI) transponder capabilities, to many toll facilities creates the potential to monitor the passage of individual AVI equipped vehicles past various AVI antennas such that these vehicles may be used as active "probes" for the direct determination of link travel times. However, this technology can be successful in areas where AVI tags are in use for toll roads, and therefore may be of limited applicability elsewhere.

Transit Fixed-Position Timing

Another vehicle detection application of AVI technology has found a receptive audience in those who see its implementation on transit vehicles as a way to determine when a particular bus passes a fixed timing mark position. By deploying an AVI reading antenna coupled with an inductive loop at specific locations, transit officials can have a method of tracking fixed route bus fleets for control and dispatch. Some even feel that this could be a more cost effective method this type of application rather than systems that utilize the Global Positioning System (GPS) discussed below; especially since there is no error in location with AVI (i.e. the timing point is a fixed location).

b) *Automatic Vehicle Location (AVL)*

Global Positioning Systems (GPS)

GPS equipment, coupled with a data channel link to an operations center, is being used by various emergency services providers (police, ambulance, etc.) and fleet transportation organizations (transit/trucking) to permit continuous tracking of vehicle locations, and are an important component of vehicle navigation systems that are currently being tested. GPS is even included as a specific component of the in-vehicle navigations systems and vehicle emergency notification (Mayday) systems in the National ITS System Architecture that is currently being developed in conjunction with the FHWA. Furthermore, since 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, certain metropolitan areas around the United States are using this vehicle location technology in conjunction with a data channel in order to link public service vehicles (police, fire, transit, etc.) to a traffic operations center (TOC) as a component of their incident response systems.

The accuracies of GPS receivers 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. As such, 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. However, as sales volumes increase, prices should continue to decrease; especially, if the additional hardware and software features that are being added to these devices open up additional markets for even greater volume sales of GPS equipment.

Map-Matching / Position Correction

A variation of the GPS strategy is the use of an on-board computer that is connected to an electronic odometer and compass such that it is able to estimate a vehicle's location by monitoring its movement in comparison against known information about a route to be followed. Furthermore, this strategy can be refined by the addition of roadside beacons at fixed locations along a route in order that they can then be monitored by a vehicle, such as a bus, in order to provide "check points" that permit the on-board computer to update and correct its location estimates. The periodic transmission of vehicle location to a central computer allows a central dispatcher to track the vehicle such that this tracking can then be matched to a bus schedule in order to alert the driver and the dispatcher if the bus is ahead of schedule or behind schedule.

This automated vehicle monitoring system can also be input to a traffic management system, such that these vehicles also become active probes in the vehicle stream (similar to the AVI system discussed above). However, 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. Although monitoring transit vehicles through an AVL system would be possible in the Cleveland Metropolitan area, it might be of limited benefit for freeway monitoring purposes due to the lack of significant numbers of transit vehicles using the freeway. This, though, does not minimize the potential benefits of integrating this type of tracking with existing voice communications between a transit driver and their base command center; especially, since it could be a very useful tool in locating incidents, and determining their nature and severity.

C. Incident Verification - Closed Circuit Television (CCTV)

1. Overview

Closed circuit television (CCTV) has proven to be one of the most valuable elements of an advanced traffic management system because it provides the eyes for traffic operations center (TOC) personnel to verify reported incidents and/or other traffic conditions, evaluate their severity, and determine the appropriate response vehicles and personnel that should be dispatched to an incident scene. The typical cost of an installed and tested color CCTV camera with field controller and cabinet, necessary conduit, housing and pole mount, one-half mile viewing radius zoom lens, pan/tilt unit, and a pro-rated allocation of associated central hardware costs is approximately $26,000 dollars per site.

CCTV cameras can also be used to:

- Monitor the operation of critical signalized intersections that are in a CCTV camera's vicinity in order to evaluate signal timing and the related functions of a controller. For example, one agency has reported the placement of spare fiber-optic cable to each of their critical intersections so that they can install CCTV cameras on an as needed basis when trying to correct intermittent failures and eliminate unnecessary trips to a site for trouble shooting and problem isolation.

- Monitor a freeway's adjacent parallel streets prior to implementing a freeway diversion plan in order to determine an arterial's operating conditions, verify whether or not it has adequate capacity to handle diverted traffic, and observe its operation during a diversion to ensure successful implementation.

- Monitor traffic movements on mainline freeway entrance and exit ramps, and observe motorist responses to messages posted on a variable message signs (VMS) or transmitted on highway advisory radio stations (HAR). For example, some cities are using CCTV to verify compliance with ramp metering and HOV restrictions.

For routine operations, however, it must be noted that experience has shown that CCTV cameras should not be used as the primary means for incident detection because constant and long term monitoring of these images by TOC personnel quickly renders them ineffective due to the operators becoming "numbed" by the constant repetition of vehicles moving across their screens.

2. CCTV Physical Issues

a) *Camera Type (Color vs. Black-and-White)*

Color CCTV cameras provide the greatest amount of visual information under favorable lighting conditions and are the preferred choice of most traffic operations centers; however, they rapidly lose their sensitivity under night or other dim lighting conditions. Black and white CCTV cameras do not provide as much visual information under favorable lighting conditions; however, they are able to produce a usable image with only 1/10 or less of the light level that is required for a color camera -- i.e. they are able to produce usable images even when it is too dark for a person to see.

Some vendors have solved this dilemma by packaging both a color camera and a black and white camera in the same housing; however, this increases the price of the assembly such that this added cost may only be acceptable for certain critical locations. As with any technology installation, actual field testing should be performed and/or the performance of cameras at existing traffic operations centers should be verified before committing to any specific equipment selection.

b) *Camera Control (Pan/Tilt/Zoom/Focus)*

CCTV cameras must be moveable to the left, to the right, and in the up and down directions in order to permit them to monitor the greatest possible area; must include a zoom lens and associated focus control in order to allow the viewing of vehicles at varying distances; and must be capable of being controlled by all authorized operators who have access to the CCTV images. This functionality is implemented by placing a microcomputer in each CCTV location that receives commands from a traffic operator such that this microcomputer can turn on and turn off the appropriate motors in each camera's pan/tilt and motorized lens units. Unfortunately, each CCTV system vendor currently has its own proprietary system for this type of control. Therefore, both short and long term system control requirements must be addressed during the design of the initial system architecture in order to maintain compatibility such that an operator is not faced with several different camera control systems as coverage grows and expands over time.

c) *Camera Location / Mounting*

Since the selection of specific CCTV camera locations is controlled by the desire to monitor high incident locations and other areas of interest, such as parallel surface streets and ramps, CCTV cameras are typically mounted 40 to 50 feet above a roadway surface in order to allow for the monitoring of a distance of approximately one-half mile in each direction from a camera's location. However, the constraints imposed by site access issues, available communications links, and suitable locations for cabinets and pole foundations can often limit the optimum selections for these camera placements. For example, in order to provide larger coverage areas via the minimization of topographic, roadway geometric, and vegetation related constraints, some jurisdictions have mounted their CCTV cameras on high mast poles or towers more than 100 feet above their roadways. Therefore, each perspective site must be thoroughly investigated to establish the mounting height and lens combination required for the camera range and field of view that is desired.

3. CCTV Image Transmission Issues

The standard for CCTV pictures is a "broadcast" quality, full motion, real time image of thirty frames per second. Since this type of direct video requires a communications channel that is equivalent to more than 1,500 voice grade audio channels, the transmission of CCTV images from a camera location to a control center has become the biggest issue to overcome with CCTV. Thus, most efforts to optimize CCTV systems are directed toward reducing the bandwidth of the CCTV communications channel. For example, these efforts range from not updating an image in real time, to digitally compressing an image via image analyzers that only transmit an image's moving elements.

a) *Fiber-Optic vs. Coaxial Cable*

Except for very short coaxial cable runs of less than 500 feet, the use of fiber-optic cable for CCTV video transmissions has almost completely replaced the use of coaxial cable. This is because coaxial cable transmissions need to be amplified every few thousand feet to compensate for signal attenuation and the susceptibility it has to cable induced noise; whereas, fiber-optic transceivers with ranges of up to five miles for multi-mode fiber and ranges of over 20 miles for single-mode fiber are now available in prices ranging from less than $300 for short range units, to over $2,000 for long range units. Currently, a fiber-optic communications system with a separate full bandwidth fiber allocated between each CCTV camera and a multiplexing hub is often the least costly and best performing method to transmit CCTV video images; especially, due to the tremendous bandwidth available on fiber-optic systems. However, when this direct approach is not cost effective, alternate solutions must be utilized.

b) *Digital vs. Analog Signals*

The technology used to date for most long haul, "broadcast quality" CCTV systems has been analog transmission. Within the past five years, however, significant progress has been made in developing cost effective digital transmission equipment. This is advantageous because once video is converted to the appropriate digital format, it can be transmitted long distances over a fiber-optic link with no further conversion and without image quality degradation by using a digital protocol, such as a Synchronous Optical Network (SONET) communications system. In addition, since digital video switches are smaller and less expensive than their analog counterparts, further cost savings can be realized.

However, a major benefit of digital video is the ability to compress video images prior to their transmission to other facilities, thus enabling the utilization of less expensive data communications channels because compressed video requires less bandwidth. This compression/decompression (codec) equipment can typically compress data at a 40:1 ratio and currently costs about $20,000 per unit; however, new products are being discussed which may bring their prices down into the $5,000 range. Furthermore, given normal price/performance curves in the digital electronics industry, this price drop could probably happen over the next three years. However, if the price/performance ratio of digital systems does not progress as rapidly as desired, analog systems can provide fully satisfactory results at their greater bandwidths.

4. CCTV Image Display Issues

a) *Geographically Distributed Control*

To facilitate joint and coordinated responses to incidents, the distribution of video images, camera selection, and pan/tilt/zoom control to other agencies that can utilize them, even if they may be at multiple locations, is an effective and needed strategy in modern incident/traffic management systems. Geographic distribution of these control functions, however, must be considered in the basic design of a CCTV system, since adding these capabilities to a simpler system is often difficult and costly.

b) *Video Switching*

Since most CCTV systems have more cameras than monitors, with typical ratios being in the 3:1 to 10:1 range, a key component of any CCTV system is the video switch that allows any CCTV camera to be viewed on any monitor, and at any location that has authorized access to the CCTV system. A variety of switch architectures are currently available, from fully centralized to fully distributed, with each having its own advantages, disadvantages, and associated costs.

The cost of an analog video switch 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 number of switching options grows. For example, for a relatively small video switch of 30 camera inputs and 10 monitor outputs (e.g. 300 switching points), the installed cost is about $20,000. However, if coverage is doubled to 60 camera inputs and 20 monitor outputs (i.e. 1200 switching points), the installed cost increases to approximately $75,000 because the number of switching options has quadrupled. It must be remembered that these costs are in addition to the costs for video monitors, operator controls, system integration, and interconnection to the monitors and video transmission system.

Digital video switches, similar in concept to a local area network (LAN) and strategies commonly used in the telephone industry for switching voice conversations, are also being utilized to transmit and switch video images. With these techniques, a video image is digitized, divided into small segments called packets, and then distributed on a very high speed transmission system, such that those users who need to view a particular image only have to copy the packets for that image and reassemble it for viewing. 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 video switches. With the typical decline in costs for all digital based systems, though, digital switching of video images is expected to become a cost effective alternative in the future.

c) *Large Screen Video*

Even though personnel in traffic operations centers (TOCs) with 3’ x 4’ or larger video screens report that they seldom use these enlarged images during normal operations, they are still frequently included in TOCs because the ability to project either an enlarged video image or an enlarged computer-generated graphic can be useful for decision support during incident response and for public relations during tours or other system demonstrations. The following are the two fundamental technologies available to create these enlarged images: video projection, and video wall.

Video projection utilizes either a CRT (cathode ray tube) or an LCD (liquid crystal display) system to optically enlarge an image and display it on a screen using either front- or rear-projection techniques. Care, however, must be exercised with respect to room lighting since these projected images are easily washed out by typically available light. A video wall overcomes this problem by using electronic circuitry to divide an image into smaller parts that are then displayed on a number of separate, moderately sized video monitors that have been combined into an array. For example, a typically sized video wall of four 21-inch monitors high by four 21-inch monitors across would utilize each monitor to display 1/16th of an enlarged image. However, video walls often cost more than $50,000; whereas, large screen projectors are typically in the $20,000 cost range.

D. SYSTEM COMMUNICATION

1. Overview

Commercial circuits and agency owned circuits are the two primary alternatives available for system communications. Typical ITS use both of these alternatives, with the chosen mix of types being driven by cost constraints and other technical and system specific requirements. However, irrespective of the choices to use private or publicly owned systems, it is of utmost importance that the communications system architecture be designed around common and commercially supported standards so that it has sufficient flexibility to respond to the rapid changes in communications technology. This will enable agencies to utilize emerging lower cost, faster, and higher capacity circuits, in addition to many of the new wireless communications options that are being spurred by growth in both portable computers and personal communications.

The following sections summarize selected communication options. Additional detail and extensive discussions are provided in much of the published literature. Especially valuable is a 1993 FHWA publication, "Communications Handbook for Traffic Control Systems".

2. Commercially-Owned Facilities

The local telephone company, cable television provider, cellular carriers, and other communications service suppliers provide a variety of circuits operating at a wide range of speeds. They are typically priced with both a one time installation charge and a recurring monthly charge, and can be obtained on either a month-to-month basis or on various contractual terms that range from one year to ten years. Month-to-month service provides the most flexibility since service can be terminated when required. However, this flexibility also makes it the most expensive option. Multi-year contracts provide lower monthly costs, but do include penalties for cancellation prior to the end of a contract period.

Commercial communications circuits are available as either switched (dial-up) or dedicated (private line) facilities. In addition, each of these basic types can be configured as point-to-point circuits (2 parties) or multi-point circuits (three or more parties). On dial-up facilities, a multi-point circuit is usually referred to as a "conference call"; whereas, on dedicated facilities, a multi-point circuit is usually refereed to as a "multi-drop" circuit. A further distinction is in the transmission technique used (i.e. analog or digital). It should be known that the original telephone network was designed as an analog system for transmitting voice. However, 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 that are resulting in better quality and performance.

Since initial installation costs and short term monthly costs for low speed data circuits are relatively low, they are advantageous for vehicle detection and variable message sign circuits. In addition, since maintenance and repair is provided by the commercial service provider, many agency requirements for special training or equipment are eliminated. This advantage, however, can also be a potential drawback due to the "finger pointing" that often occurs when multiple parties are involved in maintenance disputes; especially, those involving repairs at locations where the commercial infrastructure ties into agency equipment. A second disadvantage of leasing commercial circuits are the expense of high speed circuits, when necessary, and the reality of long term costs (i.e. recurring monthly billings) that an agency must pay. This is because monthly costs are considered operational expenses, and therefore must be budgeted from annual operations budgets -- dollars that are often more difficult to obtain than initial capital funds.

a) *Dial-Up Analog Service*

This is the basic, universally accessible, dial-up voice-grade business and residential telephone service that is used extensively with widely available/inexpensive modems (about $250) and personal computers for data and fax transmissions at transfer speeds of up to 28.8 Kbps. Dial-up telephone service is a useful alternative for occasional and relatively short term data transmission only. This is because the dialing and connect time is of such length (approximately fifteen to thirty seconds) that it does not realistically permit data collection or control of devices more frequently than every five minutes. In addition, since the dial-up telephone network was designed and configured for human calling patterns and call holding periods in order to allow the service provider to share their expensive central office equipment among many subscribers, use of dial-up circuits for frequent data calls of long holding times throughout many hours of the day can result in the local telephone company complaining about inappropriate usage due to the tie up effects this has on their central office equipment.

Disadvantages, as with any dial-up configuration, are primarily security related. The ability of "hackers" to break into computer systems has been widely reported, and documented cases have included the display of inappropriate or unsafe messages on variable message signs. Additional system security via the use of dial-up/dial-back verification, data encryption, lengthy security passwords, and/or other safeguards reduces the risk for these cases, but at the expense of increased system complexity and additional "hassle" for the authorized personnel who must support and maintain the system.

b) *Dedicated Voice-Grade Analog Circuits*

Even though these circuits were designed for voice transmissions and therefore not optimized for data transmissions, they have been the backbone of many traffic management and arterial control systems over the past twenty years due to their wide spread availability and low cost for low speed applications. They can be configured as either point-to-point or multi-point circuits, and can support data transfer speeds of up to 9600 bps. Furthermore, modems to utilize these circuits are included in the designs of both NEMA and 170-Type controllers, in addition to the availability of other wide ranging interface equipment. It should be noted, though, that there are reports of telephone companies changing their tariff and pricing policies in order to discourage the long term use of these analog circuits in an attempt to move customers to digital circuits.

c) *Digital Carrier Circuits*

In the mid-1960s, the telephone companies began converting their long haul trunk circuits from analog technology to digital technology. Called either DS-1 (Digital Service 1) or T-1 circuits, they operate at 1.544 Mbps and are configured to support 24 voice grade channels with each channel having 64 Kbps of digital bandwidth. The primary interest in T-1 for traffic/incident management systems is in its capability to digitally transmitting video signals; especially, since within the past few years, T-1 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. It is possible that T-1 may provide a reasonable option to agency owned fiber-optic cable for a few circuits used over a limited period of time; however, if large numbers of circuits are involved, T-1 can quickly become quite expensive.

It should be noted that there is a hierarchy of faster digital circuits, each built upon various combinations of T-1 circuits. For example, a typical combination known as DS-3 (T-3) operates at 43.232 Mbps, which is equivalent to 672 voice grade channels. The emerging Synchronous Optical Network (SONET) standard further builds upon DS-3 and is defined in various combinations of up to OC-48 (Optical Carrier 48), which operates at 2,488 Mbps -- the equivalent of 32,256 voice grade channels.

d) *Dataphone Digital Service (DDS)*

The telephone companies offer an additional category of digital circuits, often referred to as DDS (DATAPHONE Digital Service) circuits, that range in data transmission rates from 2.4 Kbps to 64 Kbps. Primarily available as dedicated circuits, but occasionally available in a switched configuration, since they were specifically deigned for data transmission, they have very good reliability and operational characteristics. However, a difficulty with these circuits is that they often require adapters at each end of them because they are usually configured as "synchronous" data channels; whereas, most communications for incident/traffic management systems are configured for "asynchronous" data transmissions. Finally, since the telephone companies have a limited availability of the Data/Channel Service Units (DSU/CSU) that are needed to connect to these DDS circuits, DDS may not be a viable option in all areas for incident/traffic management system communications.

e) *Integrated Services Digital Network (ISDN)*

The technology for Integrated Services Digital Network (ISDN) was specifically developed by the telephone industry during the early 1980s as a digital service with appropriate operational parameters and error characteristics to yield excellent performance. However, up until the last few years, its implementation has been very slow. Since then, ISDN has experienced significant market penetration increases in many areas due to its key claimed benefit of allowing 144 Kbps of switched digital data to be transmitted over two pairs of wires that are configured as two 64 Kbps data channels and one 16 Kbps control channel. Another benefit is its reduced switching/interconnect time, thus making it feasible to support additional field devices on dial-up connections. ISDN interface boards (their equivalent to modems) for certain types of computers are currently priced in the $1,000 to $2,000 price range, with costs expected to decrease as equipment availability continues to increase.

ISDN is currently offered in two user configurations: the Basic Rate Interface (BRI), and the Primary Rate Interface (PRI). Basic rate ISDN is the digital equivalent of dial-up analog service; whereas, primary rate ISDN is the equivalent of T-1 service -- providing the user with 23 channels of 64 Kbps data and one control channel also operating at 64 Kbps. The bandwidth available on a single BRI circuit is probably not enough for most applications to show traffic motion; however, some manufacturers are providing inverse multiplexing capabilities in their equipment such that they can obtain the required bandwidth from the inclusion of additional BRI data channels. Since it has been reported that video devices are coming on the market with ISDN-compliant interfaces that may be able to feasibly utilize this technology to access remote cameras for transmitting video images to a TOC, the next generation of traffic equipment may well be able to take advantage of some aspects of ISDN.

Still, though, utilization of ISDN circuits for the current generation of traffic/incident management system projects is probably not feasible due to the lack of appropriate interface boards for the field equipment, and the limited number of ISDN circuits that are available for use, even if enough of the appropriate equipment existed. 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.

f) *Packet Radio*

Packet radio is a wireless technique that was designed specifically for transmitting data. When operated by commercial suppliers, radio base stations are utilized to communicate with multiple field transceivers via time synchronized data bursts known as "packets". Since many field transceivers share the same frequency pair for transmitting and receiving data, a "cooperation strategy" known as a communications protocol is utilized to coordinate this sharing. Because of this sharing, however, there can be several second delays whenever data packets are delivered.

Since the basic architecture of packet radio yields a pricing structure that is based upon the amount of data that is transmitted (measured in either bytes or "packets"), packet radio is most effective when transmitting short messages rather than large quantities of data. For example, at typical prices of $0.03 per 100 bytes transmitted, real time communications with a traffic monitoring processor would cost about $5.00 per hour. This cost is probably prohibitive for continuous communications ($120 per day), but may be attractive for occasional use to communicate with a remote VMS and/or isolated weather station controller that may have previously been reached by another method such as cellular telephone. It should be mentioned, however, that considerable development may be required to convert currently configured remote devices and central processors in such ways that they would be able to communicate in a packet network protocol environment.

g) *Cellular Service*

The use of cellular telephones by field personnel has simplified many maintenance and incident response procedures by eliminating the need to connect to a telephone company service point. In addition, convenience and declining prices have rapidly expanded the market penetration of cellular telephones over the past five years such that the cellular network now covers an area that can serve over 93 percent of the United States population. This has introduced a high degree of flexibility and enables equipment to be located anywhere within the coverage area -- especially valuable for temporary installations of portable or mobile equipment where the capability of establishing circuits on an as needed basis may prove cost effective for infrequent communications. However, for many incident/traffic management systems' more lengthy data transmission needs, the primary disadvantages of cellular service -- cost and its current limitations for the transmission of data -- become readily apparent.

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. Increased competition and the economies of scale from increased call volumes made by greater numbers of cellular users are decreasing prices via unit cost reductions and "innovative" cellular service plans; however, even if costs got as low as ten cents per minute, airtime would still cost $144 dollars per day -- prohibitively expensive for full time cellular communications. In addition, since a cellular system's operating efficiency is based on the principle of dynamically reallocating each cell's limited frequency resources among all users, even if a traffic control system wanted to use a cellular system for continuous communication between field master controllers and intersection controllers, there could be no dynamic reallocation of the channels to other subscribers -- thereby, eliminating cellular telephone as a viable alternative.

Additional cellular service limitations can also be found in the context of relatively short length data transmissions. Even though off-the-shelf cellular modems permit data to be transmitted over a cellular network, because cellular modems utilize different techniques for error correction and circuit initialization, they are often not compatible with landline modems. Furthermore, since the existing cellular network utilizes analog transmission, it is somewhat noisy; thus, limiting data transmission speeds. It should be noted, though, that cellular networks may be moving toward digital transmissions that would increase data transmission speeds. The first steps in the development of this system can be seen in the offering by some systems of a service called Cellular Digital Packet Data (CDPD). The National ITS System Architecture program is currently investigating this possibility; however, only time will tell if this eventually becomes a viable alternative.

h) *Satellite Communications*

Even though satellite communications services have been available for many years and have proven cost effective for both long distance point-to-point circuits and wide area broadcast applications, their use in "local" applications such as traffic management systems are not considered cost effective because of the prohibitive costs of ground station and satellite transponder rentals, and the reality that costs are essentially distance independent. For example, a 56 Kbps satellite-based communications circuit will typically cost $10,000 per month, irrespective of whether or not the circuit is to be used for either a 200 mile or a 2,000 mile transmission.

The one case, however, where satellite communications may prove useful for traffic management purposes is for incident response in rural areas. The ability to deploy an incident response vehicle with capabilities to communicate live voice, data, and limited motion video to a central control facility has proven effective in field trials; nevertheless, the long term costs vs. overall benefits to be derived from this approach's flexibility must still be weighed against other communications channel options.

3. Agency-Owned Facilities

In an effort to reduce monthly operating costs and to provide the communications bandwidth necessary to support large numbers of video cameras, many agencies install their own communications facilities.

a) *Cable-Based Techniques*

Various cable-based land line systems are available and summarized in the following sections. For these systems, the costs for cable, installation, splicing, and electronics termination equipment are relatively moderate, ranging from $5 to $15 per foot, depending upon the installation specifics. However, the costs for trenching, installing conduits and ducts, backfilling, and patching are significant. Depending upon the construction conditions, these conduit installation costs alone can range from $20 to $40 per foot -- translating into capital costs of over $100,000 to $200,000 per mile, or even higher if structures need to be crossed or roads need to be bored under, etc.

To minimize these ITS-charged installation expenses and to provide for future needs, some agencies have found it reasonable to install conduit during all major roadway reconstruction activities since it can be placed at reduced costs during these times -- provided that a means of record keeping can be utilized to locate this conduit when it is needed. To further save in trenching costs, conduit may also be stacked on top of each other or buried side by side. For example, the New Jersey DOT stacks two 4-inch rigid non-metallic conduit on top of each other in a six inch wide trench. Similarly, the Washington State DOT has installed two conduits buried side by side in a 1-foot 7-inch wide trench, and has even installed four conduits in a similar sized trench by placing them simultaneously side by side and stacked. Finally, several agencies add a type of innerduct to their conduit in order to provide extra non-obtrusive space for additional cable to be pulled through at a later time. This is accomplished by either using fiberglass conduit that already has four chambers molded right into the conduit, or by pulling "innerduct" material through standard rigid metallic or non-metallic conduit in order to provide separate raceways for the cables.

Twisted-Pair Cable

Twisted-pair cable, usually installed in combination with a fiber-optic long haul system for interconnecting field equipment to a communications hub, provides a simple, straightforward, and low cost method to handle the short haul circuits that provide connections between the termination of high capacity backbone circuits, and individual vehicle detector cabinets or variable message signs. As such, twisted-pair cable has been referred to for decades as the backbone of "the last mile" of communications systems. It works well for data transmissions of several miles at speeds up to 28,800 bits per second (bps). However, if the system connects numerous nodes, a slower/ "practical" baud rate limitation of approximately 12,000 bps is often utilized in order to achieve faster data synchronization.

Coaxial Cable

Coaxial cable has been used in the past for the transmission of video images from CCTV cameras into a control center. However, due to the need for active amplification every 1/2 mile, image degradation over long cables, and maintenance problems, coaxial cable is no longer recommended for ITS applications.

Fiber-Optic Cable

Fiber-optic cables utilize pulses of light instead of electrical signals to transmit information. They are either being proposed or installed in virtually all new communications systems for incident/traffic management because it provides very high data rates (up to 2.5 Gbps) over long distances (over 25 miles) without amplification. In addition, these fibers are small (a 0.5 inch cable can contain 72 fibers), have high immunity to electrical interference, and can avoid the ground loop and lightening strike problems that are often encountered with metallic conducting cables such as copper wire.

Fiber-optic cable is commonly manufactured with two internal structures: those fibers that support single-mode transmissions, and those that support multi-mode transmissions. Single-mode fibers are used for long haul circuits (longer than five miles) and require more expensive transmission and receiving equipment to utilize their higher performance characteristics. Multi-mode fibers, on the other hand, can utilize lower cost transmission and receiving equipment because they are typically used for short distance transmissions (i.e. video images from a CCTV camera to a communications hub), which are then combined (or multiplexed) onto a long haul single-mode fiber for transmission to a control center.

It should be noted that since many telephone and cable television companies are upgrading their systems to fiber-optic cable, opportunities do exist for public/private partnerships that could reduce each organizations' fiber-optic installation and maintenance costs.

Network Configurations

Star, Bus, and Ring are the three basic network configurations, or topologies, that are used to design fiber-optic systems. Since all topologies assign unique addresses to each communications node in order that data retrieval and control information can be sent/received to/from the proper field devices, the major differences between any network configurations are usually related to system coverage and degree of redundancy. It should be noted that additional configurations are available via hybrids of these topologies. For example, Star-Ring is a frequently used hybrid that maximizes the advantages of both the Star- and the Ring-type configurations such that a system can have high speed trunkline communications and a significant number of alternate data routings in the case of any breaks in the fiber.

Star-Type

In a star configuration, separate fiber-optic trunks are used to connect the central facility to each communications hub. Additional connections are then made from each communications hub to the field devices via a local distribution network that can consist of various media types such as additional fiber-optic cable, twisted-pair cable, or radio based communications, etc. Finally, all data to and from the central facility is multiplexed and demultiplexed at the communications hub.

Even though this is a proven configuration that has been successfully used in many traffic management systems, a star topology has disadvantages in that separate "home run" links are required from each hub to the central facility, and that star topologies are typically not configured with redundant, automatic switch over fibers or equipment.

Bus-Type

In a bus configuration, each communications unit (i.e. any device that is located at a node or communications hub, or any field device such as a 170 controller, etc.) is assigned a channel and an address, and is connected to either a fiber-optic link or series of fibers that carry data in two directions (i.e. full-duplex). Devices are then accessed by polling them on their assigned channel, using their specified address.

This configuration is commonly used in local area networks (LANs) to link together personal computers, and is advantageous in that it uses a single communications facility to reach from the central location to each field device. However, since bus configurations have not been utilized in operational traffic management systems, there is very limited experience with them in this environment. Additional disadvantages are that low cost fiber-optic modems that are directly compatible with 170 controllers, variable message signs, and other traffic related equipment are not yet readily available.

Ring-Type

In a ring configuration, each communications unit is connected in series ("daisy-chained") to the communications units that are located immediately upstream and downstream of this first unit in order to create a single ring closed loop. If significantly increased system reliability is desired, a second set of transmitters and receivers can be added to each communication unit such that a double ring closed loop is created. In fact, most ring configurations that are being installed today utilize this redundant double ring concept in order to implement a concept known as automatic reconfiguration that takes advantage of this configuration's "self-healing" capabilities to re-route data transmissions in the event of a break in the fiber.

Dual ring configurations can be disadvantageous because of the requirements for additional fibers between communications nodes and equipment redundancy at each communications node; however, the operational advantages of self-healing rings are clear. Especially, when compared to the life cycle costs of system failures, the incremental costs of both redundant equipment and additional fibers within the same cable are very small (approximately $150 per fiber per kilometer, plus equipment costs). In addition, because this configuration is being widely implemented and utilized, a full range of equipment is readily available at competitive prices.

<u>Data-Transfer Standards -- SONET</u>

Fiber-optic communications systems were initially developed in the 1960s by the telephone companies for long haul transmission of voice and data. Early implementations replicated the existing systems that were based on twisted-pair cable, coaxial cable, and microwave channels such that these digital carrier systems were only being implemented at DS-I (1.544 Mbps) and DS-3 (43.232 Mbps) transmission rates. Within the past ten years, however, successive refinement of fiber-optic technology has resulted in a new communications standard termed Synchronous Optical Network (SONET). Based upon multiples of 51.84 Mbps, which is known as an Optical Carrier I (OC-I) channel that is capable of carrying a DS-3 data stream plus additional control/status information, SONET systems are typically installed with either OC-3 (155.52 Mbps) or OC-12 (622.08 Mbps) capacity. Some systems are even implementing data transfer rates as high as OC-48 (2488.32 Mbps), with still even faster data streams currently being planned.

SONET systems are implemented to utilize four single-mode optical fibers operating at a wavelength of either 1310 nm or 1550 nm for transmissions on each link, preferably with two separate routings. Devices known as multiplexors/demultiplexors are then utilized to interconnect the low speed data streams (1200 bps to 9600 bps) from field devices (i.e. 170 controllers, variable message signs, etc.) to a "communications hub", which is then able to connect to the much higher data rates of the SONET backbone. This also makes best use of a SONET system's capacity by allowing data originating at several field devices to be combined together in a "time slice" format for transmission to the central facility. Similarly, in the reverse direction, data coming from the central facility is extracted, or demultiplexed, from a combined data stream for routing to individual field devices. An equivalent set of multiplexors/demultiplexors also exists at the central facility to perform these same functions of combining and separating the data.

Another of SONET's key design concepts is known as "self-healing", and refers to the redundancy that is achieved by using dual counter-rotating ring circuits that provide for automatic re-routing of data traffic onto a secondary ring in the event of failure in the primary ring. Since a SONET's secondary ring transmits data in the opposite direction from the primary ring, a cable break at one location does not result in a total system failure. Furthermore, except for a momentary loss of real time voice or video traffic information, this switch over from the primary ring to the secondary ring occurs rapidly enough such that most data communications can recover without any loss of data. In the event of a cable break, however, restoration of full system functionality occurs as soon as the broken cables are field repaired. Equipment failures are also contained by the inclusion of redundant components at all key locations.

SONET's advantage of supporting a very wide bandwidth is also its greatest drawback since this communications capacity results in higher costs when compared to lower bandwidth solutions. In addition, wide bandwidth systems have the potential to be more affected by system failures since these failures would impact a greater number of field devices and communications channels than would probably be affected if they were served by lower bandwidth systems. In spite of this, SONET's self-healing capability and designed-in redundancy typically results in a more reliable overall system than could otherwise be obtained.

While alternate configurations may be considered, it should be remembered that SONET has been the preferred choice of all new communications systems; especially, since it can also be used for voice communications when voice is represented in digital format. In fact, some agencies often utilize this voice capability to implement PBX-to-PBX links between their various locations in order to bypass the telephone companies and reduce their long distance charges. Furthermore, SONET's digital voice ability has resulted in its extensive use by local telephone companies and long distance carriers, which has been a major driving force behind much of the competition to develop additional digital carrier and SONET technologies. As such, a wide range of manufacturers and equipment vendors have developed highly cost effective, very reliable, and feature rich SONET systems. Overall, other alternatives do not have SONET's range of options and features, and are typically more expensive when compared to SONET on a functionality basis.

b) *Wireless Techniques*

Microwave

Point-to-point microwave is an attractive alternative for the initial stages of ITS implementation, or for periodic transmission of video images from CCTV cameras; especially, in those cases where it is neither technically feasible nor cost effective to install conduit and fiber-optic cable. Depending on performance, prices for a video transmission microwave system can range from $20,000 to $40,000, including transmitter, receiver, and reverse direction control channel. If a fiber-optic system is eventually installed, the microwave equipment can then be re-used to extend CCTV coverage beyond the end of the fiber-optic network. A key limitation, though, is that microwave requires a line-of-sight transmission, and signal quality does degrade under adverse weather conditions. Finally, all microwave installations must receive a site specific Federal Communications Commission (FCC) license.

Wireless Video

A recent video transmission development 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 that microwave has (i.e. it does not require an FCC license because the equipment is class licensed by the manufacturer). A potential disadvantage, however, is that wireless video requires a line-of-sight transmission. Its antennas, though, are much less sensitive to alignment errors.

Spread Spectrum Radio

Spread spectrum radio was developed nearly fifty years ago by the military as a secure communications technology, and was commercialized in 1985 when the FCC assigned it to the 902-928 MHz frequency bands. It operates by having a transmitter unit spread a message’s signal bandwidth over a wide range of frequencies such that when this transmission is recovered by a receiver unit that knows the coding technique utilized, the original message can be reconstructed.

The technique of spreading a signal over multiple frequencies results in high noise immunity. In addition, since each communications circuit within a given band utilizes a different coding technique, multiple and simultaneous circuits can co-exist. This introduces significant potential for traffic management applications. Further advantages related to increased equipment availability and decreased price could also be realized if the many efforts currently underway to evaluate spread spectrum radio for the next generation of digital cellular telephones results in that industry’s wide application of the spread spectrum radio technology. This could, though, result in increased personnel training requirements and specialization, and technological complications

Potential disadvantages are that spread spectrum radio generally requires line of sight transmissions, which limits its range to about six miles, and that its signal is attenuated by vegetation, so a site survey is recommended before committing to this technology. In addition, even though there are no FCC facilities license requirements, spread spectrum equipment operating in the 902-928 MHz band cannot interfere with licensed equipment, and must accept interference from licensed services. Finally, as with any new sophisticated equipment, its implementation will increased agency personnel training and specialization -- especially related to maintenance issues.

E. Traveler Information Dissemination

1. Message Signs

Message signs, both fixed and portable, are widely used as part of successful strategies to minimize incident impacts by quickly alerting motorists of any problems ahead, and by providing them with appropriate alternate routes of potential traffic diversions around long term incidents.

Different agencies also use various display philosophies to operate the message signs. Some feel that they 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 may become numbed. Conversely, some agencies always display a routine or safety-type message in order to confirm operability. Still, other agencies use their message signs to advertise events during non-incidents.

a) *Changeable Message Signs (CMS)*

Rotating Drum

The simplest form of CMS is the rotating drum sign, in which several faces of a rotating drum (or several drums) can be used to display one of several fixed messages. They are typically used where a fixed message such as "LANE OPEN" or "LANE CLOSED" needs to be displayed for portions of a day, and can be configured with the same size, shape, and letter fonts as traditional static signs. The advantages of rotating drum signs are derived from their mechanical simplicity, which results in lower costs and higher reliability when compared to "dot matrix"-type variable message signs (VMS). Their prime disadvantage, however, is the limited number of messages that can be displayed on a single sign. Furthermore, their use for incident response is limited.

Seven-Segment Numerical Display

A related type of sign is the changeable seven segment numerical display. Typically used to display variable speed limits, they can be fabricated according to MUTCD (Manual of Uniform Traffic Control Devices) specifications for speed limit signs, with the space traditionally used for painted numerical digits replaced by remotely controlled displays. Compared to a full VMS, this technique produces an easily recognized, relatively low cost variable speed limit sign.

b) *Variable Message Signs (VMS)*

Individual characters on a VMS are composed of individually controllable dots that are grouped into "character cell" matrices such that the greater the number of dots per character cell, the "sharper" each character will appear to the human eye as it fuses together adjacent dots and recognizes characters as whole images. In general, the legibility of a minimum sized VMS character cell of at least five dots wide and seven dots high is very acceptable for typical roadway applications; especially, if only upper-case letters are used. However, when lower-case letters, "double-stroke" characters, or other effects are desired, the larger character cells that are required for improved resolution can increase the number of surface dots needed, and thus increase costs. If a VMS is intended for text messages only, though, adjacent character cells can be separated by a blank space to minimize the cost of the sign.

Signs in which this separating blank space has been eliminated are known as "continuous matrix signs" since all of a sign's surface locations become controllable. Because a VMS can display a wide variety of characters in each character cell, dynamic messages can then be created by manipulating the timing of when individual characters and/or groups of characters are displayed. This permits the implementation of moving text, "exploding" and "collapsing" images, roller blind, horizontal shutter, and other types of special effects. Even though these special effects are more commonly used in commercial displays, continuous matrix signs are used in roadway applications to display proportional fonts for improved readability, special graphics, or the following quite effective simple effects: blinking text, moving arrows, and cyclic displays of message sequences with delays between them (i.e. safety messages such as "BUCKLE UP", "DRIVE 55 FOR SAFETY", and "USE YOUR SEAT BELT"). It should be noted, however, that message complexity, information acceptance rates, and driver attention spans must all be considered when utilizing these features on high speed roads.

The following sections summarize the two fundamental technology categories that are used to create the individual dots that form the letters in messages: light reflectance, and light emission. A third technology category, known as hybrid techniques, is also described.

<u>Light-Reflecting (Flip-Disc)</u>

Light-reflecting VMSs typically consist of a matrix of mechanically changeable dots on the surface of a sign, such that when rotated, the dots form letters. This technology is also easily scaleable, with character sizes ranging from 2 inches to 18 inches in height. Typically, individual dots can either be flat disks that are black on one side and colored on the other, or balls or cubes that are colored on half of their surface and integrated with a split-flap cover such that the colored surface is exposed when opened. Still, other implementations consist of a multi-part flap that is used to implement "white" characters for standard visibility during daytime use, and a "fluorescent color" for improved visibility during night time use. A wide range of colors can be used on the "bright" side of a dot, with white or yellow being most common. However green, red, orange, gold, and other colors are becoming available. One vendor has even extended this technique to allow one of up to six different colors to be displayed on each dot. A variety of techniques have also been used to improve the visibility of these signs, including internal illumination and the use of retro-reflective surfaces.

Because the dots are mechanically moved, a finite amount of time is required to change a message displayed on a sign. Character change rates of 30 characters per second are typical, which equates to over two seconds required to change a message on a sign with three rows of twenty two characters per row. However, if one is willing to tradeoff various implementation dynamics such as power consumption, dot inertia, overshoot, and flutter, different vendors are able to implement a range of faster character write rates, including some that are even capable of changing an entire message in parallel.

Light-reflective signs have a proven field track record with generally high reliability rates in the range of 100 million operations for each dot. However, it is still not uncommon to find individual dots stuck in either a "dark" or "bright" position as a sign ages. As such, the signs are fabricated for easy repair, with individual dots being repairable and/or each character cell being quickly replaceable. Furthermore, to reduce power consumption and to provide stability during periods of power outages so that dots do not randomly change position and display "garbage" on a sign's face, light-reflective signs are designed with a method of latching the dots into a fixed position. A common technique is magnetic, whereby 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 face of a sign.

Finally, the cost of these signs are in the medium to expensive range, and are a direct function of the number of characters on a sign's face, the mounting style, the enclosure type (required to be weatherproof because of this technology's mechanical nature), the options desired, and the manufacturer's level of quality and attention to detail. In addition, since these are electro-mechanical type signs, long term reliability is impacted by operational experience and the degree to which a manufacturer has emphasized product refinement. Large signs (3 rows by 20 characters/row) range in cost from $50,000 to $90,000 including installation and commissioning, whereas small signs (3 rows by 8 characters/row) range in cost from $25,000 to $50,000. It should be noted that all support structure costs (i.e. sign bridge, attachment to overpass, or roadside poles, etc.) are in addition to the above basic costs of a sign.

For many agencies, light-reflective signs have been the "mainstay" of their VMS implementations, with their key advantages being the maturity of their technology, their long experience of use, and their ability for continued message display 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. As described above, though, disadvantages include their limited visibility under some lighting conditions, their fading of color contrast over time, and their mechanical failures that result in "stuck" dots.

Light-Emitting Signs

The use of an active light source at each dot (or pixel) of a VMS produces a light emitting sign. They are currently available in two varieties (listed in order of their evolutionary development): incandescent bulb matrix and light emitting diode (LED). Key advantages are their enhanced visibility vs. light reflecting signs, and their ability to mix various color light sources to produce different colored messages. The biggest disadvantage of light emitting signs, however, is their requirement for continuous power (i.e. they are non-operable during power failures). Therefore, if power failures are common in an area where an installed light emitting sign is critical to continued operations, some sort of back-up power is required.

Incandescent Bulb Matrix

The original light emitting sign is the incandescent bulb matrix. This type of sign provides good visibility at various angles and is currently used in commercial applications; however, it has fallen into disfavor for roadway applications and is generally not recommended for highway use because of its low reliability, its high maintenance costs due to bulbs burning out, and its major problems with high power consumption and excessive heat as a result of the high wattage bulbs that are required. For example, some agencies in warm climates have found that they have to limit the number of bulbs that are simultaneously turned on in these types of VMSs due to the excessive heat that is generated within their sign enclosures.

Light-Emitting-Diode (LED)

Technology developments over the past several years have produced VMSs with high brightness, simple control, and long life through the use of "solid state" lamps known as light emitting diodes (LEDs). Good reliability should also result from the inherent simplicity of this design concept, with other benefits being that the small size of the LED, coupled with computer-type integrated circuits, can produce sign displays with large numbers of individually controllable dots for special effect applications. Furthermore, these signs have a very fast turn on and turn off time; thus, removing the message changing problems noted above with the flipped/rotating disk type of message signs. However, because of the physics of the LED semiconductor junction and the wavelength of their emitted photons, LEDs do have a limited range of colors. Red and green are the most commonly available colors; though, combinations of different colored LEDs are being used to implement other colored signs (e.g. yellow -- the color preferred for most roadway signing applications).

In the past, LED signs suffered from problems with LED brightness not being fully adequate for bright daylight conditions, variability in light output between "identical" LEDs located on different parts of the sign (likely, due to each pixel having differing power-on times), and aging effects of the light emitting active elements such that it reduced their brightness (often, non-uniformly) on the order of 50% after approximately 30,000 hours of operation (i.e. less than 3 1/2 years of continuous operation). In particular, the "amber" LED, which is preferred for roadway usage, had been difficult to manufacture with the desired characteristics. However, about three years ago, these problems appear to have been solved by utilizing a group of LEDs (on the order of 15) to form each individual pixel. In addition to increasing the brightness of each pixel, this averaged any small differences between the brightness of adjacent LEDs. Still, other solutions are the implementation of newer type LEDs that are becoming available with increased intensities. Since preliminary reports are indicating either no intensity loss, or even a slight intensity gain over time with these newer type LEDs, their use should allow signs to be fabricated with fewer LEDs per pixel, resulting in a lower fabrication cost; or allow for brighter signs with the same number of LEDs; or allow for the same number of LEDs to operate at lower power, thus prolonging their life and reducing their aging effects. As such, the LED sign is currently finding acceptance in the transportation field, and is now being fabricated by a number of major manufacturers. However, since long term field results are not yet available, the above is based on initial testing only. As these signs are deployed in large numbers, actual field experience must be gathered in order to verify these expectations.

Finally, the costs of LED signs are moderately expensive and controlled by a sign's size (e.g. the number of characters on the sign's face), the type of LED used, and the quality/reliability focus of the sign's manufacturer. For example, large signs (3 rows by 20 characters per row) range in cost from $60,000 to $130,000, including installation and commissioning; whereas, small signs (3 rows by 8 characters per row) cost from $40,000 to $60,000 each. Furthermore, the newer, high output amber LEDs are also more expensive than their older standard LED counterparts because of limited manufacturing yield and the need for suppliers to recover development costs. As with all semiconductor devices, however, component prices should decline fairly rapidly -- especially as their usage increases sales volumes. It should also be noted that all support structure costs (i.e. sign bridge, attachment to overpass, or roadside poles, etc.) are in addition to the above basic costs of a sign.

Hybrid Technology

Hybrid technology message signs are those in which either rotating disks or shutters are placed in front of a light source in order to produce a hybrid of mechanical motion and light emission. The following are the two basic types of hybrid signs that are currently available: the lighted rotating disk sign, and the fiber-optic/shutter sign.

Lighted Rotating Disk

Lighted Rotating Disk signs are those in which a light source is placed behind the rotating disks that comprise each pixel of a message sign. The theory is that if the rotating disk is colored on one side, the light source "enhances" the message on the sign by providing additional visibility and "punch" for longer distance viewing. Some vendors consider this an enhancement of the basic rotating disk/shutter sign, while other explain their product as a totally different technology.

Different vendors implement this same basic idea with a range of schemes, all effectively performing the same task. For example, a LED is often used as the light source (mounted behind each disk), with each disk serving as a shutter to permit the LED to be seen when the disk is in the "bright" position, and masking the LED when the disk is in the "dark" position. Other implementations mount the LEDs off-center with a hole through the disk such that when the "bright" side of the disk is visible, the hole is positioned over the LED. Conversely, 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. Still, another 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 each disk is exposed. However, this technique requires a location within each pixel that is constantly visible, and usually only works well with circular dots since the LEDs can be located in a "corner" of each pixel. Therefore, with split-flap pixels that are square or rectangular in shape, the locations for mounting each LED are limited.

The approach of combining a light source with a light reflecting sign is an effective way to increase the visibility of the basic VMS, thus producing a good combination of daytime and night time usage. However, the prime reliability concerns of this hybrid sign are still the same as with the basic "flip-disk" sign -- i.e. "stuck" disks. Furthermore, the LED light source enhancements that make this type of hybrid sign can add as much as 15% or 20% to the cost of a "basic" flip-disk message sign. Thus, for a large sign (3 rows by 20 characters) the cost will be in the $60,000 to $105,000 range. Similarly, a small sign (3 rows by 8 characters) can cost from $30,000 to $60,000. As with any cost increases to a basic sign, any performance enhancements must be considered within the specific needs and constraints of each individual ITS project.

Fiber-Optic / Shutter

A message sign consisting of a matrix of shuttered pixels such that each pixel contains a fiber-optic bundle illuminated by a high intensity light source is the second type of technology combination to be considered in the "hybrid sign" category. This concept, available in two different configurations, utilizes a light source for several characters (on the order of three or more), and separate bundles of optical fibers to "pipe" the light to each individual dot on the face of a sign. One of these configurations utilizes a rotating-disk as the shutter; whereas, in another configuration, the shutter is assembled with its rotational shaft perpendicular to the sign's face such that this shutter functions in a manner similar to that of a camera (i.e. alternately blocking or uncovering the light source). The mechanical orientation and motion of this second type of shutter, however, seems to result in enhanced reliability. It should also be noted that some manufacturers even include a feature that utilizes a motor-driven colored filter between the light source and the fiber-optic bundle in order to produce different colored characters on the face of these signs.

In all cases of this type of sign, though, the light source is a high intensity light bulb similar to that used in a slide projector. This creates a brightness for each individual dot that is several times brighter than what can be obtained with the hybrid LED sign. In addition, a useful design "trick" that is available with this type of sign is the utilization of two separate bulbs for each bundle of fiber (each fiber bundle usually handles at least three characters), such that by monitoring the current flow through the small number of bulbs involved in this design, circuits can be implemented that will automatically switch the light source to a secondary bulb whenever a primary bulb fails. Furthermore, this configuration can also send an alarm signal to a central control station in order to report the failure of a primary bulb such that the proper personnel can schedule its prompt replacement. Finally, these secondary bulbs can also be used to produce an "over-bright" condition for extra intensity during poor visibility conditions, such as fog.

The combination of a fiber-optic type light source and mechanically-shuttered pixels cause these signs to carry a price tag of about 20% over their "basic" light emitting counterparts; thus, making them the "cadillac" of VMS applications. For example, a three row by 18-character/row configuration can cost approximately $135,000, including installation and commissioning, However, these signs' prime selling features are their brightness, resulting high visibility, and vendor emphasis on high reliability; which, might be more a result of high quality manufacturing and engineering rather than anything due to the fundamental technology of these signs. Over time, though, competition, other market forces (e.g. realization of more sharply focused merits gained from experiences from more field installations of them), additional manufacturing efficiencies, and related factors may eventually push their price down to be more competitive with other technologies. As with all signs, their cost is dependent upon their size (i.e. number of characters on the face of each sign), and the design/quality approach taken by the manufacturer. Furthermore, it should be noted that all support structure costs (i.e. sign bridge, attachment to overpass, or roadside poles, etc.) are in addition to the above mentioned basic costs of this hybrid-type message sign.

c) *Operations*

System Control

Due to the increased complexity of system control requirements as the number of individually controllable elements on a sign face increases, some sort of computer-based central control and operator interface is required for virtually all message signs, except for those capable of displaying only a few fixed messages such as is found in the case of simple rotating-drum signs. To meet these needs, manufacturers have selected a variety of microcomputers for "central" control and monitoring. Many are "PC"-based with vendor-specific hardware enhancements such as unique serial communications boards; whereas, others use special purpose microcomputers that are only able to control the signs that they manufacture. Still, others use Model 170 intersection controllers to utilize any potential advantages that they may have due to their being a standard hardware item familiar to highway agencies.

Similarly, command sets (e.g. "communications protocols") and software packages that are used to communicate between a sign and its control location are also often unique to each vendors' systems -- ranging from "convenient" to "obtuse" in their user interfaces. Furthermore, 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; which, if not properly addressed, can contribute to implementation difficulties and resultant costs. Especially, since as the overall scope of traffic information systems increase, the selection of message signs on the basis of their ease of integration into larger systems is usually even more important for future benefits. It should be mentioned that a soon-to-be available option for alleviating some of these compatibility issues is the NEMA/FHWA development of a National Transportation Communications/ITS Protocol (NTCIP) specification. Even though work is currently focused on NEMA/170 controllers only, protocol development is scheduled to be extended to VMSs once this initial controller work is completed.

The challenges associated with a control system can be addressed by carefully understanding the a system's current operational needs, while simultaneously considering its growth requirements and future needs. For an agency getting started with VMSs, a fully packaged system from a single supplier can be more simple because the vendor can be assigned total responsibility for the system; however, because of the "proprietary" nature of each vendors' implementations due to the current lack of defined standards, many difficulties can appear when it comes time to integrate equipment from several vendors into an overall system. In addition, agencies can easily get "locked into" a single supplier, thus preventing the use of other superior or more cost effective products whenever they are made available; they can suffer from poor support; and/or their original products can become "orphaned" whenever a new model is introduced or when a VMS supply company is bought out.

Finally, prices for the central system range from little more than the cost of the PC itself, to many times that, depending upon the included features, the total system size, and each particular vendors' perception of the value of the central control system. In all cases, however, the vendor must be required to supply full documentation of all system components. Especially, the important details of the communications protocol, so that existing signs can be integrated into larger systems as agency needs evolve.

Communications Needs

Since VMS systems are often implemented with a library of pre-composed messages that are simply selected by a system operator for implementation, thus only producing very small communications loads, connections between VMSs and a central processor can usually be provided by a standard serial data communications link. Even if a completely new message is typed by an operator (slightly increasing the communications load), or if a complex message with graphics is desired to be displayed on a VMS (requiring a somewhat larger amount of data to be communicated), communication links to message signs will generally not need to operate above 1200 bps (which allows for roughly 120 characters per second to be transmitted).

Security

Since the public switched telephone network is an "open" system, unless security measures are added, agency-owned or dedicated type leased communications links are required if an agency desires a truly secure / "closed" communications system to prevent unauthorized access to message sign control capabilities. These security measures can include the use of encryption devices, which involve transmitting messages in a code that cannot easily be reproduced with a personal computer, or can include "call-back" security, which involves placing a call to a VMS, entering an identification code, and then waiting for the VMS to call-back a pre-entered/pre-authorized control point phone number before any access is allowed to change sign messages.

2. Highway Advisory Radio (HAR)

Highway advisory radio (HAR) is widely used to provide motorist information to travelers in a limited geographic area. Non-commercial information services include construction, traffic congestion, and safety information, possible alternate routes, traveler advisories, parking information at major destinations, lodging and rest stop availability, and details about local points of interest. Typical HAR utilize low power level equipment to provide this information over either the 530 KHz or the 1610 KHz frequencies of the AM broadcast band. However, any standard AM broadcast frequency between 530 KHz and 1700 KHz (in 10 KHz increments) can be used, provided that there is no interference with existing stations. The following sections describe the various elements that make up a HAR: system control, transmitters, and antennas.

a) *Operations*

Message Record / Playback

Traffic Information System (TIS) messages have typically been recorded on audio tape recorders; however, digital memory systems are now becoming the preferred recording technique because their lack of moving parts has eliminated virtually all periodic cleaning and other maintenance requirements. Furthermore, when TIS messages are composed and digitized at a PC before transmission to the HAR, the use of a digital transmission reduces the amount of noise that might have otherwise been introduced into the signal by the actual transmission, thus resulting in a broadcast that is clearer and more easily understood. The following features are usually available with typical TIS devices:

- Message capacity of nearly half an hour
- Ability to retain messages during power failures
- Ability to provide concatenation of various stared message sequences in any order to form the broadcast message
- Double-buffering to allow the playing of one message while recording another message

In addition, digital memory is available in several varieties, including:

- EEPROM (Electrically Erasable Programmable Read-Only Memory)
- DRAM (Dynamic Random Access Memory) -- a low-cost but inefficient system that is sensitive to power fluctuations
- SRAM (Static Random Access Memory) -- a good candidate for digital memory due to its low power-consumption, its ability to be back-up-protected with an on-board lithium battery, and its recent price drops.

Finally, it should be noted that most HAR systems are able to operate in a mode that provides for live message broadcasts should the need arise.

Notification Signs

Static signs advising drivers to tune their radios to the frequency required to receive a HAR broadcast are usually placed near the edges of a HAR signal reception area. Some jurisdictions also add remote activated flashing attention lights to these signs in order to alert motorists when especially important messages are being broadcast (i.e. details about a major freeway closing incident, etc.).

System Control

Communications links between a control point and HAR sites are typically provided either via radio, standard telephone, cellular telephone, conventional cable, or fiber-optics. Most HAR systems also allow for remote controlled operations via either a touch-tone telephone or a personal computer. For example, telephone control can be accomplished by the interpretation of Dual Tone Multi-Frequency (DTMF) tone commands that are operator input in response to various system voice prompts for each of the remote controllable features and status messages. Under computer control, all functions and diagnostics can be controlled from a PC. Finally, control software that incorporates a graphical user interface (GUI) is often also included in order to make system operation more clear and intuitive.

b) *Transmitters*

The function of a transmitter is to convert the audio signal from the message record/playback subsystem into a modulated AM radio signal that can be transmitted by an antenna. They are available in various classifications, characterized by an alphabetic letter "A" through "D" that describes the linearity and efficiency of the operations of their power amplification stage. For example, Class-A transmitters are the least efficient and most linear type of transmitter, while Class-D transmitters are the most efficient (at about 75%) due to their ability to switch on and off for various parts of the output signal. Since greater efficiency results in less heat loss, and hence better operation, highly efficient transmitters will be more conservative in their use of battery power during power outages. Finally, efficient transmitters can be kept in sealed enclosures to protect them from dirt and moisture, thereby further extending their useful life. It should also be noted that in order for a HAR transmission's voice quality to be much like telephone transmissions (between 3 KHz and 20 KHz), signals from a transmitter must be low-pass filtered in the audio range to about 4 KHz, and filter attenuated at 60 log (f/3)dB, where "f" is the audio frequency in KHz.

c) *Antennas*

The following sections highlight the three different antenna configurations used for highway advisory radio (HAR) systems: a vertical-type antenna, a "leaky-cable" type antenna, and a micro-transmitter type antenna. Further details regarding the specific regulations that govern these types of HAR system operations are defined in Part 90.242 of the FCC regulations.

Vertical Antenna

The vertical-type antenna, termed a Traveler Information System (TIS), is the most commonly utilized HAR broadcast configuration and must be appropriately licensed by the FCC. These systems consist of a single vertical antenna that, provided there are no geographical obstructions, produce an omni-directional (circular) signal pattern that diminishes uniformly as the square of the distance from the antenna increases. Table V-3 summarizes some of the key FCC regulations that apply to vertical antenna HAR/TIS stations.

Since it is desirable to place a vertical-type highway advisory radio antenna in an area that has few obstructions to radio signals, areas with either large buildings, geographic obstructions, trees, metal towers, and/or overhead power lines should be avoided. An ideal vertical antenna site would be a flat and open field that is several hundred feet across with good soil conductivity. If this is not available, special chemical systems are available to provide a ground plane in areas where available space may be as small as ten feet in diameter. A radio ground plane can also be improved with radials composed of heavy gauge copper wire with end-attached ground rods buried about 12 inches below the surface, and extending about one hundred feet in all directions from the base of the antenna. Finally, when tuning a vertical antenna to its proper operating frequency and providing for the maximum allowable signal output, both electrical and mechanical means are usually used to adjust both the antenna and its lead-in cable from the transmitter output.

"Leaky Cable" Antenna

The "leaky cable"-type antenna is used when multiple HAR/TIS systems are desired to be operated along a roadway in order that different messages can given to each direction of traffic. Its antenna consists of a specially designed and lightly shielded coaxial cable that is run through conduit and either suspended near the roadway or directly buried beneath it. This enables strong signals to be transmitted near the antenna, while allowing signal strength to rapidly dissipate as the distance from the antenna increases. As such, there is much more control of the emission field strength as compared to a vertical-type antenna system, and therefore less chance of interference with other radio services. These advantages, however, do make "leaky cable" antenna systems generally more expensive to install; especially, since a buried antenna can be easily damaged by roadway construction, installations of roadside guardrail, signs and/or delineator posts, as well as be susceptible to attack from rodents. Table V-3 summarizes some of the key FCC regulations for "leaky cable"-type antenna HAR stations.

Micro-Transmitter Antenna

This special type of very low power HAR transmission is permitted by Part 15 of the FCC regulations to be used without any FCC license requirements. Coverage is usually defined by a radius of 0.15 to 0.4 kilometers, although some manufacturers claim acceptable operational distances of twice that much.

All micro-transmitter-type antenna systems must meet the following requirements of Part 15 of the FCC code:

- The length of antenna and ground may not exceed ten feet
- Only standard AM frequencies between 530 KHz and 1705 KHz may be used
- The transmitter's RF output must not exceed 100 milliwatts

Finally, multiple HAR micro-transmitters can be utilized on an identical frequency to transmit the same message over larger areas, provided that they are carefully synchronized. Fiber-optic interconnect can be utilized to provide for this needed means of synchronization.

F. Kiosks

Another medium for traveler information is the use of kiosks -- interactive video screens that display maps and/or text information regarding traffic, incident, and transit information. When placed strategically at shopping malls, schools, factories, or large places of business, pre-trip information can be provided so that motorists can plan alternate routes around congested areas or incidents, and transit users can plan their routes with information provided on the time/location status of transit vehicles in relation to their desired trip-ends. As such, successful and highly utilized kiosks can place significant burdens on the communications systems emanating from a Traffic Operations Center; especially, if appropriately timed information is to be consistently provided.

Table CHAPTER VI. -3. Comparison of FCC Regulations for Vertical-Type and "Leaky Cable"-Type Highway Advisory Radio (HAR) Antenna Configurations

F.C.C. REGULATION CRITERIA	VERTICAL-TYPE ANTENNA CONFIGURATION SPECIFICATION	"LEAKY CABLE"-TYPE ANTENNA CONFIGURATION SPECIFICATION
Minimum separation from the 0.5 milli-volt/meter daytime contour of any AM broadcast station operating on an adjacent frequency:	15 kilometers	15 kilometers
Minimum separation from the 0.5 milli-volt/meter daytime contour of any AM broadcast station operating on the same frequency:	130 kilometers	130 kilometers
Maximum height (length) of antenna:	15 meters above ground level	3 kilometers
Maximum RF output of the transmitter:	10 watts	50 watts
Minimum separation from other Vertical-type antenna HAR/TIS stations:	15 kilometers to any other station	7.5 kilometers to those stations at the same frequency
Minimum separation from other "Leaky Cable"-type antenna HAR/TIS stations:	7.5 kilometers to those stations at the same frequency	0.5 kilometers to any other station
Required Frequency Stability:	+/- 20 Hz	+/- 20 Hz
Distance from HAR antenna that the antenna emission's signal field strength at the operating frequency must not exceed 2.0 milli-volts/meter:	1.5 kilometers	60 meters

G. Dial-In Systems

Dial-in systems can be useful tools for pre-trip travel information; especially, for those who are at locations that do not have easy access to on-site kiosks that are linked to a region's Advanced Traffic Management System (ATMS). With dial-in systems, a local or toll-free telephone number is established for the public to call and obtain current traffic conditions, which are usually prerecorded with a time stamp so that the caller knows the age of the traffic information. Sophisticated systems can even allow for users to enter a specific highway route number, an interchange location, or in the case of transit, a bus line number for more specific information. As such, it is extremely important that information from a traffic operations center (TOC) be fed to a dial-in system operator on a regular basis so that all recordings can be updated in a timely manner.

H. Internet Access

The World Wide Web (WWW) portion of the Internet computer network has become the latest medium that some agencies are using to provide real time traffic information to the public. By utilizing links between an agency's traffic computer and an Internet feature known as a "home page", users are typically able to view a regional map that is color coded to reflect various levels of congestion that may exist at the present time (usually updated every minute), may view a list of estimated travel times from various origins to various destinations within an area under traffic surveillance, may obtain construction delay information, and/or may allow users to directly link to other related WWW sites, including those for transit, weather, and/or tourist information. For example, visitors to the Illinois Department of Transportation's home page for the Chicago area may obtain a color coded map of freeway congestion, may obtain travel times to and from the downtown Chicago "loop" and various major freeway interchanges or traffic generators (i.e. O'Hare International Airport), and may obtain the actual traffic speeds at specific locations on any of the region's freeways that have been instrumented with an appropriate number of traffic "detectors". Real time traffic information for the following cities is currently available at the following Internet addresses on the World Wide Web:

Chicago:	http://www.ai.eecs.uic.edu/GCM
Houston:	http://herman.tamu.edu/houston-real.html
Seattle:	http://www.wsdot.wa.gov/regions/northwest/NWFLOW/
Southern California:	http://www.scubed.com/caltrans/

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CHAPTER VII. INCIDENT MANAGEMENT PLAN

A. Introduction

Traffic problems are growing at an unprecedented rate today, not only in urban areas but also in suburban and rural areas. Congestion, with the resulting delays and accidents, is imposing enormous costs on society in terms of dollars, human suffering and frustration. Many cities are being seriously affected by congestion on both freeways and surface streets. Indicators point to worsening conditions as development continues to take place, traffic volumes continue to build, and roadways become more congested.

Many studies document that incidents can have serious impacts on traffic, manifested in terms of congestion (delay) and safety (secondary accidents). A Michigan study estimates that over half of all motorist delay on the freeway system is incident related. A California study estimates that under current operations, by the year 2000 approximately 70% of all urban freeway congestion will be due to incidents. A Texas study reports that it is generally recognized that each minute of blockage on a freeway results in five minutes of motorist delay during non-peak commuter hours. However, during peak hours, each minute of blockage results in up to fifteen minutes of delay and queuing delay can be as high as fifty minutes for each minute of blockage.

These problems, coupled with a slowdown in the construction of new highways, have placed greater emphasis on improving the operation of existing facilities. With this emphasis there has come a greater understanding of congestion; its causes and effect on the operation of facilities. Moreover, The Incident Management Program is the foundation from which the Intelligent Transportation System (ITS) is built.

The primary function of any Incident Management Program is to protect the safety of persons and property using the roadway and to lessen the likelihood of an incident increasing in severity by restoring the facility to its normal operation and capacity as rapidly as possible.

A successful Incident Management Program consists of six key elements:

1. Detection
   - Objective; reducing the time required to detect an incident.

2. Verification
   - Objective; reducing the time required to verify the incident, determine exact location, determine the type of incident and determine the proper response.

3. Response
   - Objective; reducing the time required to notify the necessary response agencies and offering suggested routes for response units to reach the scene.

4. Traffic Control
   - Objective; maximizing traffic control to the extent possible under prevailing conditions to reduce the likelihood of additional incidents occurring.

5. Incident Clearance
   - Objective; clearing the roadway of offending materials as rapidly as possible and restoring the facility to full free-flow capacity as soon as possible.

6. Providing Traveler Information
   - Objective; providing traveler information throughout the process. To assist the traveler in safely passing the scene of the incident or through avoidance of the scene.

Response time is critical to Incident Management. These elements combine to substantially reduce the elapsed time from occurrence to clearance and a return to normal traffic flow.

A committee was formed to assist in the review of current methods and procedures. The committee membership included Police, Fire, 911, EMS, and ODOT personnel. Each committee member is a trained professional involved in incident response and familiar with the local geography. Table VII-1 lists the committee members.

An incident response questionnaire (Appendix B) was developed and answered by committee members. The questionnaire was also mailed to the Police Chiefs of communities that abut the freeway system. The purpose of the questionnaire was to develop a greater understanding of existing practices, identify issues and to solicit suggestions for improvement. This process was not intended to produce statistically valid results or to invite comparison between responders, such as response times.

The results of the incident response questionnaire are summarized in tabular form in Table VII-2 and in narrative form in Table VII-3.

The questionnaires and subsequent discussions by committee members provided the necessary understanding of existing conditions and the foundation for the incident response improvements recommended in this report.

The following identifies existing incident response procedures, emergency response procedures, and constraints to effective incident management. Suggestions made by incident response personnel for improved response methods are also discussed.

Table CHAPTER VII. -1. Incident Committee Members

Greg Dixon	911 Operations	Lorain County	322 N Gateway Blvd	Elyria OH	44035	329-5444
Charles Goss	Police Chief	Strongsville	18688 Royalton Road	Strongsville OH	44136	238-1048
David Jersan	Supervisor, ODOT	Garfield Heights	5500 Transportation Blvd	Garfield Heights OH	44125	521-2100
John Preuer	Fire Chief	Mentor	8467 Civic Center Drive	Mentor OH	44060	974-5765
Lt. C.C. Robinson	Highway Patrol	Garfield Heights	12323 Broadway Avenue	Garfield Heights OH	44125	587-4305
Fred Wright	Police Chief	Independence	6800 Brecksville Road	Independence OH	44131	524-3033
Michael Herceg	ODOT	Garfield Heights	5500 Transportation Blvd	Garfield Heights OH	44125	581-2100
Edward Eckart	EMS C O	Cleveland	2001 Payne Avenue	Cleveland OH	44114	664-2064
David Mohr	Fire Chief	Mayfield	6621 Wilson Mills Road	Village of Mayfield OH	44143	461-1208
Don Stevens	Police Chief	Mayfield	6621 Wilson Mills Road	Village of Mayfield OH	44143	461-1208
Melvin House, Jr.	Fire Chief	City of Willoughby	36700 Euclid Avenue	Willoughby OH	44094	953-4343
Dale Kraus	Fire Chief	City of Rocky River	21012 Hilliard Blvd	Rocky River OH	44116	356-5642
Paul Haney	Fire Chief	Strongsville	18600 Royalton Road	Strongsville OH	44136	238-3102
William Taylor	Fire Chief	Warrensville Hts.	4301 Warrensville Ctr. Rd.	Warrensville OH	44128	587-6523
John Kalavsky	Police Chief	Warrensville Hts.	4301 Warrensville Ctr. Rd.	Warrensville OH	44125	587-6538
Thomas Dease	Police Chief	Brook Park	17401 Holland Road	Brook Park OH	44142	433-1234
Mitchell Guyton	Police Chief	East Cleveland	14340 Euclid Avenue	East Cleveland OH	44112	681-2379
Frank Viola	Police Chief	North Olmsted	27213 Lorain Avenue	North Olmsted OH	44070	777-3535
Jack Callaghan	Metro Traffic	Cleveland	1700 E 13th St., Suite 3F	Cleveland OH	44114	771-1147
Murray Withrow	911 Operations	Cuyahoga County	1255 Euclid Ave, Ste 102	Cleveland OH	44115	443-3196

Table CHAPTER VII. -2. Incident Response Matrix, Tabular

① TO WHICH FREEWAYS DO YOU RESPOND? (I-NO.'S)	90	480	71	480	77	480	77	71	271	271	ALT	SR2	271	77	90	480	90	271
	-	-	-	271	480	-	-	480	480	-	422	-	-	-	-	271	SR2	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	422	-	-
② HOW DO YOU RECEIVE NOTIFICATION OF FREEWAY INCIDENTS?																		
% CELLULAR PHONE	40	40	60	5	70	5	-	50	15	60	60	4	30	20	5	80	25	30
% GOVERNMENT RADIO	50	10	1	95	5	-	75	50	84	40	30	6	70	80	20	10	3	20
% FLEET RADIO	10	-	1	-	-	-	-	-	1	-	-	-	-	-	-	10	-	-
% FIXED CELLULAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
③ HOW ARE NOTIFICATION OF INCIDENTS RECEIVED?																		
INDEPENDENT COMM. CENTER	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
MULTI-JURISDICTIONAL COMM. CENTER							X	X				X				X		
OTHER																X		
④ % OF CALLS MADE VIA 911?	80	10	70	-	80	20	5	30	50	10	50	2	25	50	10	75	50	20
⑤ WHO IS GENERALLY DISPATCHED FIRST?																		
POLICE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FIRE																X		
PUBLIC WORKS																		
OTHER																		
⑥ HOW MANY FREEWAY INCIDENT NOTIFICATIONS ARE RECEIVED PER MONTH?																		
RECORDED										4								256
AVERAGED		6	15	200		20						1						43
APPROXIMATED	10			300	300		70	30	50		50		30	50	25	10	80	
⑦ WHAT IS YOUR AVERAGE RESPONSE TIME TO AN INCIDENT? (IN MINUTES)																		
OCCURANCE TO NOTIFICATION	3	5	4	2	0-15	-	-	10	2-10	-	4	5-10	1-2	1-5	5	1-5	5-10	5
NOTIFICATION TO DISPATCH	1	1	1	1	0-15	-	1	1	1	-	1/2	1-3	0-1	0-1	1-2	1	0-1	5
ENROUTE AVERAGE	8	4	-	11	2	4	2-3	5	3-5	5-8	3	5	4	1-3	10	3-5	2-3	4
RETURN TO NORMAL	60	30	20	-	30	-	-	30	30	25	15	30	17	-	150	6-10	-	30
⑧ WHAT PROBLEMS INCREASE RESPONSE TIME?	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
⑨ WHAT TYPES OF INCIDENTS CAUSE GREATEST RESPONSE PROBLEMS?	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
⑩ WHAT TYPE OF INCIDENT DO YOU RESPOND TO MOST FREQUENTLY? (%)																		
ACCIDENT	50	28	62	70	30	70	30	30	30	50	25	95	40	50	40	50	35	80
INJURY	40	12	20	15	10	-	-	-	20	25	7	-	5	5	-	35	-	12
FIRE	5	5	5	-	1	2	5	1	10	5	7	-	5	5	1	10	-	1
SPILL	5	5	2	-	1	-	5	1	10	-	1	-	1	1	1	4	-	2
MECHANICAL BREAKDOWN	-	50	20	15	50	10	60	3	30	45	60	2	49	39	60	1	65	5
⑪ IN WHAT % OF INCIDENT RESPONSES MUST A CALL BE MADE FOR ADDITIONAL ASSISTANCE?	30	65	25	10	30	10	20	15	20	20	5	33	30	80	30	10	55	20
⑫ WHO IS IN CHARGE WHEN MULTIPLE AGENCIES ARE INVOLVED IN THE RESPONSE?	◎	◎	◎	◎	◎	◎	◎	–	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
⑬ WHAT PROBLEMS ARE ENCOUNTERED WHEN YOU REQUEST ADDITIONAL ASSISTANCE?	◎	◎	◎	◎	◎	◎	◎	–	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎

LEGEND: ◎ = RESPONSE CONTAINED IN NARRATIVE LIST
M = MEDICAL SUPPORT
IP = IN PLACE
T = TOWING
P = POSSIBLY
HZ = HAZARDOUS MATERIALS
C = CLEAN UP
CR = CRANE
N = NONE

Table VII-2. (continued)

(14) WHO IS RESPONSIBLE FOR COORDINATION BETWEEN RESPONDING AGENCIES?	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
(15) WOULD THE PRESENCE OF AN AREA-WIDE COORDINATING AGENCIES BE BENEFICIAL TO THE RESPONSE PROCESS?		NO	P	YES	NO	-	NO	IP	YES	NO	NO	NO	IP	NO	P	YES	⊙	NO
(16) WHAT % OF RESPONSES REQUIRE MEDICAL TREATMENT AT THE SITE?		20	40	20	10	20	10	25	20	5-10	7	0-15	20	50	25	90	8	5
(17) WHAT TYPES OF AID ARE RECEIVED FROM CONTRACTED PRIVATE COMPANIES?		T	⊙	T	T	T	T HZ	T	T CR C	T	T	T	T C	N	T	T HZ M	T	T
(18) DESCRIBE MAJOR RESPONSE PROBLEM:		⊙	⊙	⊙	⊙	⊙	⊙	-	⊙	⊙	⊙	⊙	⊙	-	⊙	⊙	-	-
(19) HOW IS YOUR AGENCY NOTIFIED OF AN INCIDENT NEEDING A RESPONSE?		⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
(20) DO YOU HAVE A ROTATING LIST FOR TOWING SERVICES?																		
YES																		
NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO
OTHER																		
(21) DO YOU HAVE MUTUAL AIDE AGREEMENT(S) WITH NEARBY GOVERNMENTAL AGENCIES?																		
YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
NO																		
OTHER																		
(22) DO LOCAL RADIO/TELEVISION STATIONS PROVIDE DAILY TRAFFIC REPORTS?	YES	YES	YES	YES	YES	-	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
RADIO CALL LETTERS																		
STATION LOCATION (CITY)																		
TELEVISION CALL LETTERS																		
STATION LOCATION (CITY)																		
(23) DO SAMARITAN VEHICLES OPERATE ON THE FREEWAYS IN YOUR COMMUNITY?																		
YES			YES	YES	YES		YES	YES					YES					YES
NO	NO	NO				NO			NO	NO	NO	NO		NO	NO	NO	NO	
HOURS OF OPERATION:	-	-	-	7AM TO 11PM	-	-	RSH HRS	-	-	-	-	-	-	-	-	-	-	-
(24) HOW WOULD YOU RATE THE ACCURACY OF THE LOCATION PROVIDED BY CALLER REPORTING AN INCIDENT?																		
VERY ACCURATE (LIST %)	20	15	30	-	60	-	95	-	10	20	10	-	20	10	-	25	8	20
FAIRLY ACCURATE (LIST %)	60	70	55	50	20	-	5	-	40	50	70	70	60	70	75	50	85	70
INACCURATE (LIST %)	20	15	15	-	20	-	-	-	50	30	20	-	20	20	-	25	6	10
(25) WHAT INFORMATION IS GENERALLY CONFUSING OR UNRELIABLE?							⊙	⊙										
NAME OF FREEWAY (LIST %)	-	10	5	10	10	-	-	-	40	-	35	-	5	-	-	25	-	-
DIRECTION OF TRAVEL (LIST %)	10	50	25	30	20	-	-	-	50	-	35	40	40	-	-	45	10	20
MILE MARKER (LIST %)	20	20	30	50	50	-	-	-	50	-	20	-	30	-	-	20	-	30
LANDMARK (LIST %)	30	20	40	10	40	-	-	-	50	-	10	-	25	-	25	10	80	30
OTHER	-	-	-	-	-	-	-	-	-	-	-	⊙	-	-	⊙	-	-	-

LEGEND:

⊙ = RESPONSE CONTAINED IN NARRATIVE LIST
M = MEDICAL SUPPORT
IP = IN PLACE
T = TOWING
P = POSSIBLY
HZ = HAZARDOUS MATERIALS
C = CLEAN UP
CR = CRANE
N = NONE

Table CHAPTER VII. -3. Incident Response Matrix, Narrative
(Note: question numbers correspond to the questionnaire, as found in Appendix B.)

8. What problems increase response time?

Weather	Delay in notification	Jurisdictional questions
Time of Day	Construction	Median barriers
Traffic Conditions	Higher priority calls	No direct freeway access
Location of incident	No available units	Incorrect location information

9. What type of incident causes greatest response problems?

Multi-vehicle accidents	Multi-vehicle with injuries	Weather
Congestion	Truck incidents	Accidents
No shoulder due to bridge	Fire	Rush hour accidents
Location relative to ramps	HAZMAT	Incorrect location information

12. Who is in charge when multiple agencies are involved in the response?

Police	Agency with legal jurisdiction	Depends on incident type
Ranking fire officer	Ranking officer at the scene	Fire Incident Commander
State Highway Patrol	Ranking officer of jurisdiction	

13. What problems are encountered when you request additional assistance?

Different radio frequencies	Manpower availability	Logistics
Untrained dispatchers	Coordination	None
Response of assisting units	Making proper notification	Response by ODOT crews
Communications	Major disaster over wide area	

14. Who is responsible for coordination between responding agencies?

Police dispatch	Jurisdiction officer in charge	Fire Incident Commander
Officer in charge of incident	Officer in charge on site	Public Safety dispatch
First responding agency	CEMAC	
Police Department	Senior officer; Fire Chief	

15. Would the presence of an area wide coordinating agency be beneficial to the response process?

Yes, speed up response	Yes, countywide	Must define authority first
CEMAQ fills this need	Very little locally	Yes, would have better idea of what is needed and how to respond
No, very good mutual aid group		

18. Describe major response problems.

Weather	Uncertainty of accident type	Closing of ramps
Congestion	Location	No access across divider
Peak hours	Communication: police to tow co.	Coordination
Poor communications on east side	Availabilitty of tow service	Commitment of manpower by others

19. How is your agency notified of an incident needing response?

911, CECOM	Police telephone	Walk-in citizens
Cellular telephone	Neighbors near roadway	Radio from other agencies
Public telephone	Officer at scene	Direct calls from dispatcher
Fire radio	County communications center	Other government agencies

What information is generally confusing or unreliable?

Responding beyond jurisdiction	Incident type(acc. vs. breakdown)	Is incident within jurisdiction
Location		

B. Existing Conditions and Suggestions for Improvement

1. Incident Detection

a) *Description*

There are two types of congestion on freeways; recurrent and non-recurrent. Although both occur when the amount of traffic wishing to use the freeway (demand) exceeds the traffic-carrying capabilities of the freeways (capacity), they have different causes and solutions. Typically, recurrent congestion occurs during high volume periods (such as during the morning and afternoon peak periods). In most cases, recurrent congestion occurs daily and is predictable in terms of its effect, location, and duration.

Non-recurrent congestion, on the other hand, is caused by incidents that temporarily, and often unexpectedly, reduce the capacity of a freeway. Most incidents (accidents, stalled vehicles, weather, spilled loads, etc.) occur randomly and are unpredictable; both in terms of the time and location. Other incidents (maintenance activities, construction, special events, etc.) are predictable or planned activities. Regardless of whether they are recurrent or non-recurrent, incidents and the congestion they cause create safety hazards and excessive delays for uninformed motorists.

The first step in the Incident Management process is to identify that an incident has occurred and to determine its location. To achieve this step there are two basic methods of detection; manual and automated.

Manual detection requires some form of human involvement. Such reports may be made by cellular phones, radio equipped vehicles, the media, etc.

Automated detection involves the placement of devices in, upon, or over the roadway that have the ability to examine real-time data (volume, speed, and occupancy) and to detect changes in this data which indicates a possible incident and accurately identifies its location.

b) *Current Conditions*

Notification of most incidents is provided by an individual that has witnessed the incident. This is most commonly achieved by a call to 911 via cellular phone, telephone, or by the driver of a radio equipped vehicle to his/her dispatcher who relays the information to the 911 operator or appropriate agency.

The tremendous growth in cellular telephones in recent years has been of great assistance in the notification process. Additionally, many governmental agencies are experimenting with fixed solar powered telephones on freeway systems.

c) *Suggestions for Improvement*

<u>Automated Detection</u>

Develop an automated detection system that will sense a possible incident and accurately identify its location. It is recommended that electronic detection devices be provided on the freeway mainline and all on/off ramps. The detection devices must be designed to monitor all moving traffic lanes There are several technologies available in today's marketplace including inductive loops, radar and video-imaging devices. The detection equipment to be used should be determined at the design stage due to emerging technologies and enhancements to existing technologies.

<u>Manual Detection Enhancements</u>

- Three Digit Phone Numbers

Cellular telephones have grown in popularity and indicators point to a continuation of this trend well into the future. Their use as a manual method of incident detection has resulted in a decrease in incident detection time.

To enhance the use of cellular telephones as an incident detection tool, a special three digit phone number can be established for reporting non-emergency incidents (minor accidents, stalled vehicles, debris, etc.). Such incidents are not appropriate for the 911 system, yet they can be a major cause of congestion.

The establishment of such a number generally requires the placement of signs to advise motorists of its availability and intended use.

Fixed cellular telephones are used in more isolated areas where detection times may be lengthy. The fixed cellular telephones are generally solar powered. They function 24 hours per day and can provide the information directly to the primary response agency.

- Supplemental Signing (Reference Markers)

A common problem with incident notification by cellular phone is inaccuracy of the incident location. Unfamiliar motorists are frequently unable to identify their location in any meaningful way. Also, many people have difficulty with compass direction even if they are familiar with the area. Supplemental signing along the freeway system may be used to minimize the potential of erroneous information from the well intended cellular caller. The ARTIMIS system in Cincinnati was instrumental in having such signs approved for testing by the Ohio Department of Transportation and FHWA. A drawing of the approved signing appears in Figure VII-2. These reference markers are installed at 1/10 mile intervals and on all ramps.

- Dedicated Freeway Service Patrols

Dedicated Freeway Service Patrols play an important role in the timely detection of incidents and ensure timely assistance to motorists who may not have been involved in an accident. The vehicles are equipped with the supplies necessary to clear most incidents caused by vehicle breakdown. The drivers may be certified or trained in vehicle mechanics and many agencies provide them with emergency medical training (EMT) or first aid training. The vehicles should be equipped with push bumpers; however this may require legislative action by local authorities. The service patrols may be privately funded, funded by transportation agencies or jointly by private and government funds. The CREWZERS program provides this service during peak hours of traffic flow.

2. Incident Verification

a) *Description*

Once an incident is reported, it is necessary to verify its presence, location and severity.

b) *Current Conditions*

Typically, the 911 operator or local dispatcher will receive a call reporting an incident. The local police are dispatched to the scene to assess the incident and determine what personnel and/or equipment will be needed to treat and clear the incident.

c) *Suggested Improvements*

Develop a system of verification that would be capable of verifying the location and magnitude immediately following notification.

Closed Circuit Television (CCTV)

It is recommended that a system of closed circuit television cameras be deployed that will permit immediate verification of the presence, location and severity of the incident. Camera technologies can be combined with incident detection algorithms that will automatically direct the cameras to the location of the detection device that is reporting a possible incident.

Closed-circuit Television (CCTV) has proven to be one of the most valuable elements of a freeway management system. In addition to the primary function of incident verification, the CCTV has many other applications, including but not limited to :

- Best route information for response units
- Monitoring of traffic on parts of the freeway system so equipped during incident and normal flow conditions
- Identifying and aiding stranded motorists
- Incident severity assessment
- Weather/hazardous conditions
- Monitoring critical interchanges
- Monitoring key surface streets

The cameras are typically spaced at approximately one mile intervals. Spacing may vary due to obstructions to line of sight such as vertical/horizontal curves, structures and vegetation.

3. Incident Response

a) *Description*

Response units must have timely and accurate information concerning the location and magnitude of the incident. An extremely helpful added ingredient would be notification concerning the availability of access routes.

b) *Current Conditions*

Response units are provided with accurate information concerning the location and magnitude by the police officer at the scene. However, the response units are not dispatched until the police officer that answers the initial call has located and assessed the incident. Additionally, the response units are generally given very little information concerning delays and availability of alternate routes.

c) *Suggested Improvements*

A system that will permit simultaneous notification of response agencies of the location and magnitude of an incident more rapidly and also provide information concerning best available routes for responding units. However, this may result in more "false alarms" if an operator makes an incorrect assessment of the situation.

<u>Dissemination</u>

The data provided by the field devices will be electronically transmitted to a Traffic Operations Center. This information can then be dispersed to response agencies that have been previously identified and agreed upon by those response agencies. The CCTV image may also be sent to a police dispatcher for his/her use in determining the proper response. This may not preclude the occasional need to evaluate the incident at the scene.

Dispatching Procedures

No recommendation for changing the current method of dispatching is included in this report. It is anticipated that items included in the Initial System (electronic detection, closed circuit television, changeable message signs, highway advisory radio, Samaritan vehicles) will greatly aid the existing dispatching system by providing both information to existing dispatchers and in giving emergency service providers new tools to deal with incident situations.

4. Traffic Control

a) *Description*

Traffic control is vital to the safety of the motoring public as well as the personnel responding to the incident. The absence of traffic control can be expected to amplify the severity and increase the likelihood of additional incidents.

b) *Existing Conditions*

Traffic control is generally provided by flashing devices mounted on response vehicles (flash bars) and flares. Occasionally, these devices are supplemented by traffic cones and portable signs which are provided by Public Works personnel.

c) *Suggested Improvements*

Methods of providing the motorist with information in advance which will permit avoidance or safe passage of the incident scene. When provided with accurate information in advance, the motorist can make the decision to avoid the incident or to be in the proper lane traveling at the proper speed when passing the incident thus enhancing the safety of both traveler and response personnel at the scene.

Variable / Changeable Message Signs

Variable / Changeable Message Signs (VMS / CMS) are utilized to provide motorists with upstream notification of incidents and real time delays. These devices are used for traffic warning, regulation, routing and management. They are designed to affect the behavior of the motorist, thus improving the flow of traffic by providing real-time highway related information.

The VMS / CMS provide the motorist with advanced warning of conditions ahead, explain the effects, provide directions, indicate real-time delays, and provide alternate route directions when appropriate.

These signs provide a tremendous benefit for the motorists and also enhance the safety of the response personnel. Given the proper information sufficiently in advance of the incident will result in a reduction of traffic passing the scene of the incident and in most approaching traffic the opportunity to change to the proper lane thus increasing the safety of the response personnel.

There are two types of VMS / CMS; fixed and portable. The fixed signs are typically mounted on trusses over the roadway. The portable signs can be operated by a generator and are typically moved from site to site as conditions demand.

Highway Advisory Radio (HAR) can also be used to achieve the same results as VMS / CMS. The HAR has the ability to reach the motorist well in advance of the scene thus providing a greater opportunity for the motorist to change routes or to get into the proper lane(s) to pass the scene of the incident.

5. Incident Clearance

a) *Description*

It is extremely important that the roadway be cleared of all materials as rapidly as possible. The more expeditiously the roadway is cleared and full free-flow capacity is restored, the less likelihood of secondary incidents occurring.

b) *Existing Conditions*

The police officer(s) dispatched to the scene determine probable clean-up needs which are then relayed to the appropriate agency, generally Public Works personnel.

c) *Suggested Improvements*

A method of early notification to the agency responsible for clean-up and removal that speed up the clearance of an incident considerably by eliminating the delay currently encountered while waiting for notification by police officer(s) at the scene. Additionally, receipt of accurate information concerning the best available access routes to the scene would further expedite response.

Notification

Early notification can be achieved via the Traffic Operations Center. The verified information can be provided to the agency charged with clean-up and removal responsibilities simultaneously with notification to response agencies. Once again, the agencies to be notified would be predetermined by the agencies responsible for clean-up and removal operation. Information can also be given concerning the best available routes to reach the scene.

Clean-up and removal operations are most frequently performed by Public Works personnel and responding to an incident will generally require considerable time to locate and equip the people necessary to handle the task at hand. Therefore, early notification is extremely important and beneficial in reducing overall vehicle delay associated with this task.

6. Traveler Information/Aid

a) *Description*

Traveler Information

It is highly desirable to provide the traveler with accurate and timely information concerning traffic flow on the freeway system. When provided with such information, the motorist may avoid or pass the scene of the incident with a greater degree of safety.

Traveler Aid

Motorists frequently require assistance in dealing with minor incidents such as mechanical failure, flat tire, out of gas, etc. Such minor incidents do not normally require police assistance.

b) *Existing Conditions*

Traveler Information

Information is transmitted by local media. For the traveler this frequently requires tuning of automobile radios to radio frequencies airing traffic reports. This is done by scanning the dial manually or automatically.

Traveler Aid

Traveler aid generally requires police officer response. However, Cuyahoga County recently introduced the ROAD CREWZERS. The CREWZERS are "samaritan" vehicles equipped to deal with minor incidents. At present, five vehicles patrol the freeways in Cuyahoga County during rush hours, Monday through Friday. These vehicles serviced approximately 1,600 distressed motorists during the PM peak hours alone during the first six months of operation.

c) *Suggested Improvements*

Traveler Information

A system with components that will provide the motorist with traffic flow information as they enter the region and supplemental information as they approach and/or pass incidents along their specific route(s).

- Highway Advisory Radio

  The use of a series of Highway Advisory Radio (HAR) transmitters is recommended. Highway Advisory Radio (HAR) is an excellent instrument to share information with motorists in their automobiles. The HAR system can provide advance notification of conditions ahead (lane closures due to construction or maintenance, incidents, or special events, etc.). The HAR has the ability to reach the motorist well in advance of the scene thus providing a greater opportunity for the motorist to change routes or to get into the proper lane(s) to pass the scene of the incident. For those travelers opting to pass the incident, they will gain additional information displayed by the Changeable Message Signs (CMS).

Signs can be installed throughout the areas of coverage informing motorists of the HAR frequencies. These signs can be equipped with flashing beacons that would be activated when important information was being broadcast.

Traveler Aid

- Dedicated Freeway Service Patrols

For motorists aid, dedicated freeway service patrols (such as the recently implemented CREWZERS) play an important role in the timely detection of incidents and also ensure timely assistance to distressed motorists who may not be involved in an incident. An individual who is involved in an incident is generally unprepared to immediately cope with even the simplest situation. With the passage of time, presence of darkness, or remoteness of setting, motorists may become fearful and behave in an irrational manner. Abandoning their vehicles in search of aid, these motorists increase the probability that they will sustain personal injury. A public education program should be initiated to encourage stranded motorists to remain with their vehicle and await assistance.

By providing timely, reliable service, motorist assistance patrols can improve motorist safety, decrease incident related congestion, and reduce the occurrence of secondary incidents.

Many minor accidents and varied incidents can be cleared by the patrol vehicles entirely without the necessity of response by police, tow trucks, or Public Works. Many jurisdictions provide the service patrol vehicle operators with EMT or first aid training. The operators are familiar with auto mechanics and some are certified.

- Cellular Telephones / Reference Markers

Many vehicle operators have access to cellular telephones. In the event of an emergency, this is their first contact with an emergency response agency. Since present technology cannot provide the originating location of cellular 911 calls, it is up to the caller to provide this information. Accurate information is vital to quick response. The installation of a series of reference markers will enable stranded motorists to pinpoint their location with several hundred feet, allowing accurate dispatching of aid.

- Call Boxes/Telephones

Many governmental agencies have introduced call boxes/telephones on the freeway system. They are generally solar powered and are used most frequently in the more isolated areas where detection times are more lengthy. However, maintenance costs and vandalism concerns need to be addressed.

7. Traffic Operations Center (TOC)

a) *Description*

Traffic Operations Center (TOC) is a central location for the collection and dissemination of incident information and the organization of incident management activities. The TOC database would include all traffic data collected by the congestion monitoring system (speeds, congestion levels, travel times). The database should also include information from all the various incident management entities (incident locations, maintenance/ construction activities).

b) *Existing Conditions*

Each response entity has their own method of incident management. There is no centralized location for the collection and dissemination of incident information.

c) *Suggested Improvement*

Traffic Operations Center

Development of a Traffic Operations Center (TOC) is recommended. The TOC will receive and process the data collected by the field devices via a communications network. The persons monitoring the TOC will have access to all data pertinent to the incident and this data can be provided to all designated recipients including the media, as required. Combining police, emergency, and transit functions will quicken response, improve safety and expedite clean-up and return to normal traffic flow.

C. Alternatives Evaluated

1. Citizen Band (CB) Radio

Citizen Band (CB) Radios function much like the cellular telephone systems however, the CB radio transmissions can be monitored by properly equipped service patrol vehicles, or by remote antennas feeding into the TOC. This results in a more rapid response and will often remove the necessity of dispatching additional response units.

2. Transit/Taxi Vehicles

Transit/Taxi Vehicles offer the advantages of a large fleet of vehicles on the roadways that are operated by professional drivers who are familiar with the roadway system. They can provide detection on the entire city street system in addition to portions of the freeway system. The drivers would report incidents to their dispatcher who would relay the information to the TOC for incident response notification(s). The transit/taxi companies receive the benefits associated with rapid response and clearance of incidents on their routes, and can be provided with information that allows them to adjust their routes to avoid congested areas.

3. Aircraft Patrols

Aircraft patrols currently operate during rush hours and certain special events. They provide commercial radio traffic information in which they identify problem areas and monitor alternate routes. The aircraft patrol could provide timely information directly to an operations center. With the proper equipment, a video link can be established. The operations center in turn could provide the aircraft with the data they have compiled.

4. Kiosks

Kiosks may be utilized to provide traveler information at major trip generators such as industrial centers, commercial centers, special event centers, amusement parks, hotels, etc.

5. Volunteer Watch

Volunteer watch involves citizen observation of the freeway from vantage points in high incident areas or directly in vehicles calling in observation 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. A successful informal program has been established in conjunction with the northern New Jersey Freeway Management System, utilizing cellular telephone technology.

D. Recommendations

Four stages of Implementation for deployment of the Incident Management System are recommended:

1. Early Action
2. Initial System
3. Extended System
4. Full System

The Early Action recommendations include Incident Management activities that can be incorporated expeditiously at minimal cost. The Initial System will provide improved detection, surveillance and communications through the establishment of the Initial Electronic System and construction of a Traffic Operations Center. The Initial System will cover fifty (50) miles of roadway. The Extended System will extend the Electronic System coverage an additional seventy-five (75) miles, thus providing one hundred and twenty-five (125) miles of system coverage. The Full System would entail extending the system coverage an additional seventy-five (75) miles which will result in coverage of the complete study area of two hundred (200) miles.

1. Early Action Recommendations

a) *Dedicated Service Patrols*

The CREWZER program has demonstrated the value of this service. Based on the assumption that this program will continue, the only action necessary may be route adjustment. The estimated cost for each additional vehicle is $100,000.00. Private involvement could reduce these costs substantially.

b) *Cellular Telephone Incident Reporting*

Cellular telephone incident reporting is important and should be continued, however, the 911 operator must be able to screen calls that are true emergencies (accidents, injuries, spills, lanes blocked, etc.). An educational program with media assistance, cellular bill inserts, and roadside signs should emphasize proper use of this system. Estimated costs for educational program $15,000.00 and signs $10,000.00. Total cost $25,000.00

c) *Incident Management Task Force*

Appointment of an Incident Management Task Force would have many advantages. The Task Force would be responsible for incident response planning, training, development of personnel, equipment and materials resource list, communications, after action reviews of major incidents, etc. There are no additional costs associated with this recommendation.

d) ***Legislative***

Legislative concerns expressed in this report should be addressed at an early date. Each one would play an important role if properly concluded.

e) ***Tow Truck Contracts***

Tow truck and crane removal contracts should be reviewed. Major emphasis should be placed on equipment availability and response time.

f) ***Diversion Route Planning***

Diversion route planning should be completed at an early date. Rerouting via surface streets creates many problems and should be examined very carefully before inclusion in any diversion plan.

g) ***Commercial Radio And Television***

Commercial radio and television is used to provide traffic condition reports to large numbers of drivers. The incident Management Team should work closely with the media to enhance the accuracy and timeliness of the media reports. There are no additional costs associated with this recommendation.

h) ***Portable Changeable Message Signs***

Portable Changeable Message Signs should be considered for use during major incidents, special events, and advance notifications of dates scheduled for full or partial closures of a freeway for construction or maintenance purposes. Recommend purchase of three signs at $45,000.00 each for a total cost of $135,000.00.

i) ***Highway Advisory Radio***

Highway Advisory Radio is a cost effective means of reaching large numbers of motorists with traffic and roadway condition reports that can be updated on a continual basis. A detailed site location study should be conducted to determine the optimum location(s) in terms of area coverage and compatibility with the expanded system. Estimated cost of transmitter and associated hardware is $122,000.00 each.

j) ***Reference Markers***

Reference markers similar to that shown in Figure VII-2 will permit the person providing incident notification to provide an exact location of the incident. This will result in significantly reduced response times. Signs installed at 1/10 mile spacing and on all ramps, estimated cost $125,000.00.

2. Initial System

a) *Automated Detection System*

Automated detection is achieved by placing sensors along the roadway. The sensors are programmed to detect speed, occupancy and volume. The data collected by the sensors is sent through a communications network from the sensor to a roadside processor and then to a control computer equipped with incident detection software at the Traffic Operations Center. Typical sensor spacing is 1/3 to 1/2 mile. Estimated cost is $22,000 per direction.

b) *Closed Circuit Television Cameras (CCTV)*

Closed Circuit Television Cameras should be installed at approximately one mile spacing (dependent upon view obstructions). The images are transmitted through the communications network to the Traffic Operations Center. Strategic placement of the cameras will also permit viewing of interchanges and surface roadways. Color cameras and monitors are recommended for added clarity. Estimated cost is $26,000 each plus cost of communications.

c) *Traffic Operations Center (TOC)*

Development of the Traffic Operations Center is recommended in the initial system stage. However, this facility must be capable of expansion to meet the added requirements in personnel and equipment necessary to accommodate expansion for both the extended and full systems. Expected initial cost of $2 to $3 million.

d) *Changeable Message Signs (CMS)*

Changeable Message Signs are recommended at strategic positions within the system. The number and location of the signs will be determined at the design stage. Signs are normally placed a minimum of ¾ mile in advance of decision points. There are several technologies available with multiple choices for the number of lines, the number of characters and the height of the characters. The appropriate devices should be determined as a part of the design phase. Cost, including typical support structure is estimated at $171,000.

e) *Highway Advisory Radio (HAR)*

The Highway Advisory Radio system may require additional transmitters under this or future stages. Strategic placement of the equipment proposed under the early action phase may avoid additional equipment under this stage. This decision will again be made at the design stage.

f) *Dedicated Freeway Patrol Vehicles*

Additional dedicated freeway patrol vehicles will be required as the system is extended. Funding decisions will be necessary as this need develops.

3. Extended System and Full System

The extended and full systems represent extensions and/or expansion of the personnel materials and equipment deployed under the early action and initial system phases. Care must be taken at the design stage to specify equipment and materials that will permit orderly and efficient expansion.

E. Institutional and Legal Issues

1. Abandoned Vehicles

Such vehicles (non-hazardous) are currently permitted 48 hours before they may be removed. Consideration should be given to reducing this time to 4 hours.

2. Removal of Equipment or Materials

A policy is needed which will permit the expeditious removal of such equipment or materials (spilled cargo) from the roadway when they are deemed a hazard to public safety. Liability of agency charged with removal of the offending equipment or materials should be clearly stated. (Does not apply to hazardous materials.)

3. Pushing Vehicles

A policy is needed to permit police and other governmental vehicles, including Road Crewzers, to push vehicles to a safe position. Push bumpers are recommended for samaritan vehicles and any other vehicles routinely assigned to patrol the freeway system.

4. Blocking of Travel Lanes by Emergency Vehicles

A policy is needed to ensure cooperation by all responding agencies to block no more lanes than absolutely necessary while responding to an incident. This can be accomplished by developing a uniform policy that would properly define parking of emergency response vehicles. This policy should be developed from within the incident response agencies, with consensus by all involved in incident response.

Figure CHAPTER VII-1. Incident Management Tasks

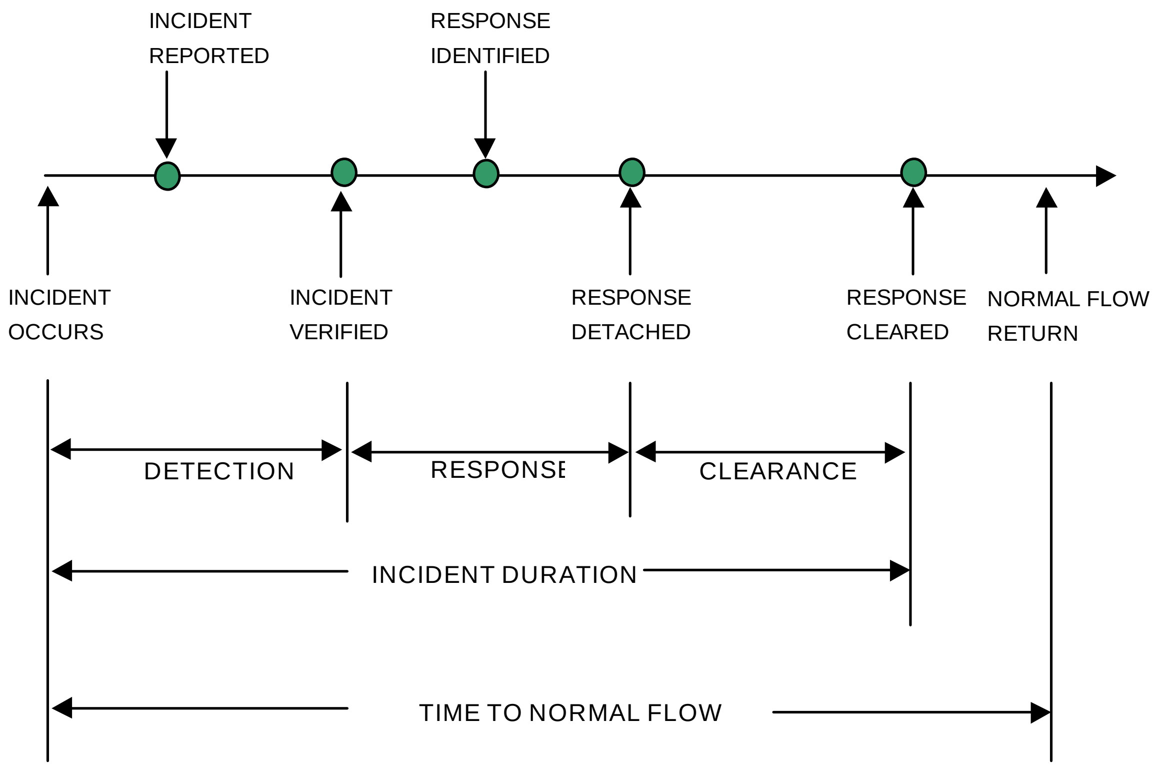
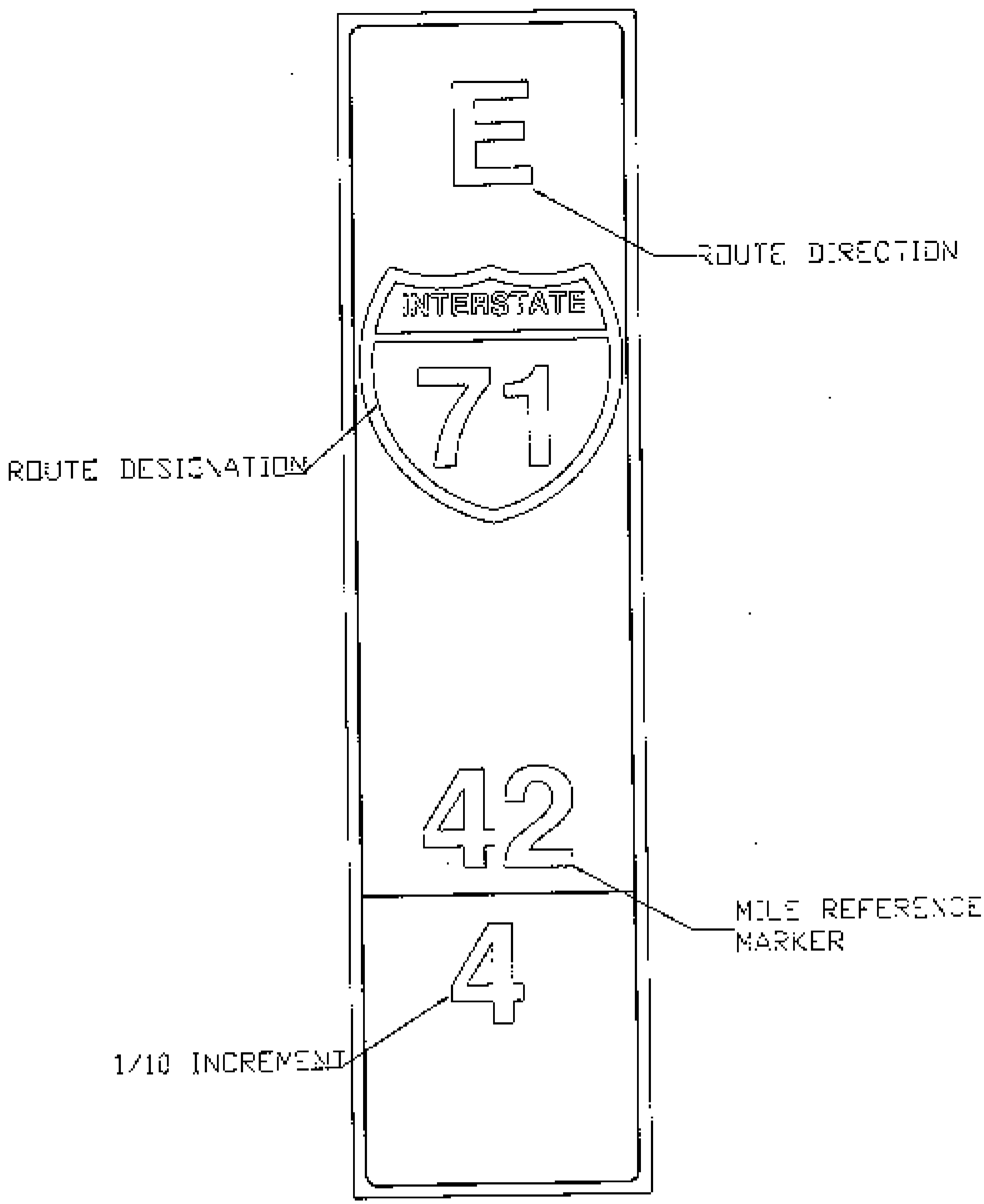


Figure CHAPTER VII. -2. Highway Reference Marker



References

In the preparation of this document, the following publications have been referenced:

Texas Transportation Institute, Federal Highway Administration
Guidelines For Response to Major Freeway Incidents Response Manual
April 1994

Texas Transportation Institute, Federal Highway Administration
Method Of Selecting Among Alternative Incident Detection Strategies
February 1993

Transportation Research Board
Freeway Incident Management
December 1990

Michigan Department of Transportation
Statewide Incident Management Program Including The Detroit Metropolitan Area
March 1995

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CHAPTER VIII. STRATEGIC DEPLOYMENT PLAN

A. Introduction

This chapter brings together the results of the preceding work and presents a methodology for determining the next step toward deployment.

1. Area of Coverage

The primary focus of this study has been the expressway system of the greater Cleveland/Lorain metropolitan area. There were approximately 200 miles of expressways in the original study area. Segments that were found to maintain satisfactory levels of service through the end of the study period (year 2020) were deleted from further consideration, taking into account the need to maintain route continuity. In order to broaden the scope of the study, an equivalent length of arterial roadway (US-42, Pearl Road) was added to the study. Figures I-1 and I-2 in Chapter I depict the original and revised study areas.

2. Agency Involvement

The Incident Management, Policy, and Technical Committees that were formed during the process of this study are comprised of representatives of the Ohio Department of Transportation as well as members of the safety forces of the various affected municipalities, transportation officials, and private sector agencies. In addition, the regional metropolitan planning organization (NOACA) was represented on the Policy and Technical Committees. The three groups met on a regular basis to review the work in progress, and provided valuable insights to the process of identifying the regional transportation needs.

B. Legislative Changes

As described in Chapter VII, "Incident Management Plan," and Chapter X, "Contractual and Financing Alternatives," current Ohio statutes may not adequately address some of the following issues:

- Abandoned vehicles - how soon can the maintaining agency remove an abandoned vehicle from the right-of-way?
- Removal of equipment or materials - what is the liability aspect of cleaning up a spilled load?

- Diversion of expressway traffic to local streets - with "home rule," can freeway traffic be diverted to local streets as an incident management measure?
- Design/build contracts - can ODOT award a contract by any means other than a "low bid" approach?
- Partnerships - can ODOT enter into an agreement with a private agency where in lieu of payment, access to right-of-way is granted?

A review of current state statutes is in its final stages. Based on the results of this review, a policy addressing the above points will be developed. Legislative changes may need to be initiated.

C. Implementation Plan Recommendation

The process of deploying high technology equipment on the regions transportation network is a complex one, requiring capital funding for installation, and a stable revenue stream for operation and maintenance expenditures. It also requires extensive interagency coordination and cooperation. No one expects to implement the entire system as a single project. Rather, the system will grow into the final configuration over time as funding becomes available. However, there are certain definitive stages that should occur in sequence, so that the deployment will be successful and cost-effective.

1. Immediate Implementation Plan

These are actions and/or projects which can be implemented within a year or two from the point when the decision to proceed has been made. These are described in detail in Chapter VII, "Incident Management Plan."

- Maintain and expand Road Crewzers patrol area - both area of coverage and the number of vehicles should be expanded to provide additional benefits to motorists.
- Cellular telephone incident notification - calls to 911 currently need to be screened. An educational program needs to be initiated.
- Incident Management Task Force - detailed planning for response to incidents needs to take place to develop personnel, equipment and materials resource lists; communications; and to resolve jurisdictional and authority issues prior to an event.
- Diversion route planning - rerouting over surface streets involves multiple jurisdictions, and should be planned for in advance.
- Commercial radio and television - the media currently provide traffic information to drivers. The Incident Management Task Force needs to work closely with the media to enhance the timeliness and accuracy of the reports.

- Portable changeable message signs - these would be another useful tool for getting information to the motorists.
- Highway advisory radio - another cost effective means to reach large numbers of drivers with current traffic information. A detailed site study should be conducted to determine appropriate locations for deployment.
- Reference markers - since one of the most frequent causes for delay in responding to an incident is the reporting of an inaccurate location, reference markers (and an educational program on their use) will lead to more accurate location reporting.

2. Short-Term Implementation Plan

These are actions and/or projects which can be implemented within five years from the point when the decision to proceed has been made. As discussed in Chapter III, "User Services," the following should be in place within five years to satisfy the identified transportation needs of the area.

- Incident management
- Emergency vehicle management
- Traveler information, both public and private
- Driver information, both pre-trip and en-route
- Demand management
- Emergency vehicle management
- Traffic control

As the next step in incident management, wide area video monitoring of freeways should be implemented. Due to funding constraints, it would be advisable to deploy video monitoring first on those segments of roadways that have a history of frequent incidents (annual accidents per lane-mile greater than 8.00), and expanding the area of coverage as funds become available.

Automated detection of incidents will require the placement of sensors on roadways to monitor traffic conditions, and the implementation of an incident detection algorithm to identify potential incidents which can then be manually verified using CCTV. As with wide area video monitoring, due to funding constraints, locations will have to be prioritized, keeping in mind route continuity and the requirements of the communications backbone.

Emergency vehicle management will take place under the guidance of the proposed Incident Management Task Force. Issues such as detailed planning for response to incidents; personnel, equipment and materials resource lists; communications; and jurisdictional and authority issues will all have an impact on determining the appropriate steps.

To process the information collected by traffic detectors and wide-area monitoring equipment, a traffic operations center should be established within this time frame. A study of feasible locations should be initiated. The study should also investigate the possibility of incorporating some emergency management elements into the traffic operations center facility.

The traveler information needs can be satisfied by variable message signs (VMS) and highway advisory radio (HAR) transmitters. Since these devices are inexpensive compared to the cost of installing the communications and surveillance network, they can be deployed at the maximum configuration at an early point in the process. They will continue to yield additional benefits as the rest of the system evolves over time and provides additional information. In addition, radio and television organizations need to have access to this information to assist in maximizing the area of coverage.

Demand management can be implemented by the deployment of ramp metering. Again, since these devices are inexpensive compared to other costs, they can be deployed at the maximum configuration at an early point in the process.

Traffic control will need to take place on a local level, since arterial roadways that feed the expressway system are under the control of the municipalities through which they pass. Most municipalities either already have functional closed loop traffic control systems or soon will. The most challenging part of providing traffic control will not be technical, but jurisdictional. Interagency agreements will need to be worked out to maintain continuity of traffic flow across municipal boundaries.

3. Medium-Term Implementation Plan

These are actions and/or projects which can be implemented from five to ten years from beginning of the process. The following user services would need to be implemented within this time frame to satisfy local needs.

- Public transportation management
- Emergency notification and personal security
- Route guidance
- Hazardous material incident response
- Personalized public transit
- Ride matching and reservations
- Electronic payment services
- En-route transit information

Building upon the short-term deployment elements, medium-term actions should continue to expand the installed equipment base. As the area of coverage increases, more and more information will become available to help motorists make travel decisions.

An important aspect of alleviating traffic congestion is mode choice. With the additional information about current travel conditions, motorists will be able to make informed choices about their travel. This same information could also be used by the regional public transportation agencies to make their services more attractive to potential riders.

4. Long-Term Implementation Plan

These are actions and/or projects which can be implemented more than ten years from the point when the decision to proceed has been made.

- Public travel security
- On-board safety monitoring
- Emissions testing and mitigation
- Automated roadside safety inspections
- Freight mobility
- Commercial vehicle electronic clearance
- Commercial vehicle administration

A fully installed system will provide up-to-the-minute information on travel conditions over the entire region, incorporating both private vehicles and public transit. It will also provide a base from which to expand the user services available in the area by the incorporation of state-of-the-art equipment to satisfy the local needs. Looking this far into the future can only provide a general outline of what will occur. However, assuming a progression of technological advances, it is probably safe to speculate that much of the original equipment will be nearing the end of its useful life and can be replaced by more cost-effective components that fulfill the required functions.

The following figures (VIII-1 through VIII-4) depict the full deployment of ITS equipment in the study area. A cost analysis based on this deployment can be found in the next chapter, along with an estimate of the expected benefits.

The cost analysis was refined to determine an initial deployment configuration, presented in Figure VIII-5. The reader is directed to Chapter IX for the underlying assumptions and calculations which determined the recommended limits.

Figure CHAPTER VIII. -1. Communications and Surveillance Network

Figure CHAPTER VIII. -2. Service Patrol Area and Vehicle Detection

Figure CHAPTER VIII. -3. Changeable Message Signs and Ramp Metering

Figure CHAPTER VIII. -4. Highway Advisory Radio and Operations Centers

Figure CHAPTER VIII. -5. Recommended Initial Deployment

D. Guide to Deployment

1. Diversion Routes

Choices for traffic diversion routes should be prioritized as follows:

First:	Limited Access Highway to Limited Access Highway
Second:	Major Arterial Roadway to Limited Access Highway
Third:	Limited Access Highway to Major Arterial Roadway
Fourth:	Major Arterial Roadway to Major Arterial Roadway

When and where appropriate, diversions to mass transportation should be accommodated.

The key to mitigating the impact of diverted traffic on any one roadway is to provide the information to the maximum number of motorists over a wide area. 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 to stay on their original route if their destination is not affected by the congestion.

If the alternate Interstate or Limited Access Highway has not yet 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 agreements with local police agencies, roaming service patrols and cellular call-in by motorists to the areawide 911 center or the available traffic operations center.

An analysis of the capacity of the available adjacent alternative roadways should be performed. A list of criteria which would eliminate a roadway from being an alternative route might include the following:

- Substandard roadway alignment or geometrics
- Lack of shoulders
- Residential areas
- Schools
- Hospitals
- Heavy pedestrian traffic
- Active railroad crossings
- Substantial change in speed limits
- Circuitous routes
- Roads which require resurfacing and/or reconstruction
- No traffic signals to control or use to artificially increase capacity for diverted traffic

2. Variable Message Signs

One of the means to provide motorists with current traffic information is through the use of Variable Message Signs (VMS).

<u>On Interstates and other Limited Access Highways:</u>

VMSs should be placed prior to interchanges with Interstates and other Limited Access Highways and other alternate route diversion which meet the diversion route criteria. VMSs should be placed approximately 3/4 of a mile prior to the alternative route decision point; keeping in mind the sight distance necessary to read the message at the prevailing speed of the roadway. Special attention should be given to vertical and horizontal curves.

<u>On Major Arterial Roadways:</u>

VMSs should be placed prior to interchanges with Interstate and other Limited Access Highways as well as Major Arterial Roadways.

VMSs should be placed approximately one 1/2 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.

<u>On Minor Arterial Roadways:</u>

The option of smaller, less sophisticated and less expensive changeable message signs (CMSs) should be considered (i.e. rotating drum signs, blank-out signs, or electro-mechanical flip panel signs). These CMSs should be used due to their relative cost as compared to the number of motorists that will use the information on the CMS. The magnitude of the number of such locations that would be deployed and the size of the CMSs as compared to the full VMSs should also be a consideration. The use of these CMSs would be less obtrusive and would provide information to the motorist as to the conditions of the adjacent facility (i.e. either normal conditions ahead with no message; or roadway closed ahead using the appropriate message).

VMSs should not be located prior to interchanges with roadways that have little or no capacity to accept the diverted traffic or those that do not meet the criteria for diversion routes.

3. Video Surveillance (CCTV)

Closed circuit television (CCTV) cameras should first be deployed along roadways that meet the criteria for high accident locations (accidents per lane mile greater than 8.00). CCTV cameras should be placed at such intervals as to cover the entire segment of roadway that meets this criteria, given the present technology. CCTV cameras should be placed in conjunction with automated detection equipment (see "Traffic Detection Systems). This reduces the need for an operator to constantly view the CCTV monitors.

On Interstates and other Limited Access Highways:

For all other Interstate and Limited Access Highway segments, CCTV cameras should be considered at interchanges with other Interstate and Limited Access Highways, and interchanges with Major Arterial Roadways and high incident locations. More than one CCTV camera may be needed at major interchanges; each site is distinct. These CCTV cameras would be used to verify the conditions of interchanges to diversion routes before, during and after a diversion plan. In many cases the capacity of the interchange is unable to accept the additional traffic volume, especially at peak traffic times. The CCTV images could be used to determine whether diversions should be used and/or continued or be discontinued.

On Major Arterial Roadways:

CCTV cameras should also be considered at interchanges with Interstate and Limited Access Highways, and interchanges with other Major Arterial Roadways. These CCTV cameras would be used to verify the condition of the arterials before, during and after a diversion plan implementation. In many cases the capacity of the arterial is unable to accept the additional traffic volume, especially at peak traffic times. The CCTV camera images could be used to determine whether diversions should be used and/or continued or be discontinued.

4. Traffic Detection Systems

Detection equipment should be deployed along roadways that meet the criteria for high incident roadways. It also must be considered that detection equipment be deployed along segments of roadways that act as links between alternative route. These detection systems could provide valuable information with regard to travel speeds and traffic volumes to determine the usefulness of a link for diversion purposes.

On Interstates and other Limited Access Highways:

Detection Systems should be deployed on Interstates and other Limited Access Roadways that meet the high accident criteria from the Integrated Transportation Management System Master Plan and should be placed at intervals along the roadway that provide the most cost-effective use of such systems (i.e. 1/2 mile spacing 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. As described in Chapter VI, "Technology Assessment," when all costs are considered, the process of detection is relatively technology insensitive.

On Major Arterial Roadways:

Vehicle detection systems should be deployed on major arterial roadways that meet the high accident criteria (accidents per lane mile greater than 8.00) and should be placed at intervals along the roadway that provide the most cost-effective use of such systems (i.e. 1/2 mile spacing 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. The arterial roadway selected for this study (US-42, Pearl Road) is programmed for the installation of closed-loop traffic signals before the end of the century. The entire length of the facility satisfies the accident criteria, and steps should be taken to coordinate the installation of the closed loop systems so that information from vehicle detectors can be shared.

5. Ramp Metering

Since its first implementation in 1963 along Chicago's Eisenhower Expressway[1], freeway entrance ramp metering has been adopted by many cities as part of their freeway demand management strategies. In its simplest form, freeway entrance ramp metering consists of a two-color (red and green) ramp control traffic signal that is mounted close to driver level and set up to release vehicles at a fixed rate, one or more per green interval, onto the freeway. More advanced versions incorporate freeway mainline detection upstream of a ramp merge area such that ramp-metering signals can be coordinated to release vehicles whenever acceptable gaps are detected on the freeway. Still other systems incorporate on-ramp detectors upstream of the metering stop-bar so that ramp metering rates can be increased whenever excessive ramp queues threaten to spill back onto adjacent surface streets.

In theory, freeway entrance ramp metering has the following advantages[2]:

- The freeway mainline operation can be greatly improved by restricting access and perhaps encouraging drivers to use alternate paths, such as existing frontage roads.
- Arrivals from a nearby surface street signal are "smoothed out" by the metering and do not load onto the freeway as a periodic pulse of vehicles.
- Certain types of accidents can be alleviated, such as ramp/merging accidents and rear-end accidents on a congested freeway mainline.
- Emissions, fuel consumption, and vehicle operating costs can be decreased.

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[1] United States Department of Transportation, Federal Highway Administration. *Traffic Control Systems Handbook*. United States Government Printing Office, Washington, DC, June 1976. p. 344.

[2] McShane, William R. and Roger P. Roess. *Traffic* Engineering. Prentice-Hall, Inc., Englewoods Cliffs, New Jersey, 1990. p. 619.

- Network routings can be beneficially influenced.

In practice, freeway entrance ramp metering has had the following impacts[3]:

- In Chicago, ramp metering was found to reduce peak period congestion by up to 60% and accidents by up to 18% (benefits vary according to the level of congestion prevailing before ramp metering was implemented).

- In Houston, ramp metering reduced travel times by 25% and accidents by 50%, with little adverse effect on adjacent arterials.

- In many other North American cities, similarly favorable experiences have been reported.

However, the following cautions are also reported[4]:

- There is no evidence that ramps with ramp metering have better *capacities*. Indeed, the purpose of the ramp control is generally to assure that the ramp operates below its capacity level in order to give priority to those vehicles already on the expressway.

- Ramps from which alternate paths do not exist are poor candidates for entrance control, due to the formation of large queues awaiting service.

- Likewise, ramps which are "dead ends" due to termination of the frontage road or other such reason are poor candidates.

- The potential effects of alternate routes -- adverse and beneficial -- must be taken into account before implementing any type of freeway entrance ramp metering.

Finally, if freeway entrance ramp metering is decided to be pursued, mode-choice strategies can be implemented by providing separate ramp lanes for transit and/or other appropriate high-occupancy vehicles (HOV) such that they can be given preferential treatment by allowing them to bypass all other vehicles (i.e. single-occupancy vehicles (SOV), etc.) who may be waiting in long queues to enter the freeway.

The criteria for ramp metering include ramp geometry, impact on approach road, ease of enforcement, and pavement conditions. The length and width of the ramp are important for the storage of the queued traffic. An extensive cost estimate must be prepared regarding the possible reconstruction needs of each ramp within the recommended ramp metering system. A test section should be considered where the ramp geometry is supportive of queue storage.

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[3] Davies, P., et. al. *Assessment of Advanced Technologies for Relieving Urban Traffic Congestion* -- *National Cooperative Highway Research Program Report #340*, Transportation Research Board, Washington, D.C.. December 1991. p. 21.

[4] McShane, p. 619.

6. Highway Advisory Radio (HAR)

It is recommended that a system of individual HAR transmitters be deployed to cover the entire area. A detailed radio propagation study should be conducted for the potential sites. The locations, transmission ranges, and frequencies should be set so that the transmitters do not overlap or interfere with one another. This will allow individual transmitters to provide area-specific information. A system of flashing beacons would alert motorists to tune to the appropriate frequency when important traffic information was being broadcast. Since the cost of this equipment is low relative to the cost of the other ITS equipment, the full set of transmitters and beacons should be deployed early in the process.

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CHAPTER IX. COSTS AND BENEFITS

A. Introduction

This chapter provides estimates of the costs and benefits that would be expected due to implementation of a freeway management system in the Cleveland/Lorain metropolitan area. Costs associated with a freeway management system are discussed first, and include both capital and operation and maintenance expenses. These costs are developed in detail, expanding on the numbers introduced in Chapter V, System Architecture. The second section of this chapter provides a background to benefits experienced with other ITS implementations in other areas of the country.

Since the deployment would be staged over time as funds become available, the uncertainty of future funding precluded a definitive direction. System benefits due to a freeway management system, discussed in the third section, are therefore presented for the full implementation of a distributed freeway management system, as described in Chapter V. The benefit cost ratios for the fully deployed freeway management system are presented in the final section.

B. Estimated Costs

The cost estimate for the freeway surveillance system includes capital costs, and annual operating and maintenance costs. Capital costs reflect the need for freeway surveillance equipment, both CCTV and vehicle detection equipment; variable message signs; highway advisory radio, both transmitters and advisory signs with flashing lights; power distribution and communications to system components (fiber optic and twisted pair); field data processing equipment; ramp metering equipment; a traffic operations center; and centralized hardware and software. Included in the capital costs are a 10% engineering component, along with 5% for mobilization and 15% for contingencies. Costs are based on the information provided in Chapter V, System Architecture. A full set of worksheets can be found in Appendix D. Each element is indexed to the Traffic and Accident Data Base found in Appendix A, allowing cross calculations to determine costs and benefits by route or by component. This indexing is also useful for estimating benefits, allowing different levels of benefits to be assigned to different roadway segments, depending on their characteristics.

Table IX-1 shows the estimated capital costs at full deployment, summarized by route. Table IX-2 presents this same information, summarized by equipment type. Figures IX-1 and IX-2 present this information graphically. Note that costs per route (Figure IX-1) are correlated with the distance to be covered. Of more interest is Figure IX-2, which shows that over half of the total capital cost is absorbed by only two physical components: fiber optic communication equipment and spot detection.

Table IX-3 shows the operating and maintenance costs. Figure IX-3 presents this information graphically. All costs indicated are in 1996 dollars.

Table CHAPTER IX. -1. Summary of Capital Costs by Route

Route	**Total Length** (miles)	**Equipment Capital Cost** (millions)	**Engineering (10%)** (millions)	**Mobilization (5%)** (millions)	**Contingency (15%)** (millions)	**Total Capital Cost** (millions)	**Annualized Capital Cost** (millions)
"Central"	0.00	$5.94	$0.59	$0.30	$0.89	$7.73	$0.80
SR-2	20.39	$6.24	$0.62	$0.31	$0.94	$8.11	$0.83
US-6	2.28	$0.52	$0.05	$0.03	$0.08	$0.67	$0.07
SR-44	4.45	$1.12	$0.11	$0.06	$0.17	$1.46	$0.15
IR-71	21.78	$6.63	$0.66	$0.33	$0.99	$8.62	$0.89
IR-77	15.97	$4.81	$0.48	$0.24	$0.72	$6.25	$0.64
IR-90	57.05	$16.99	$1.70	$0.85	$2.55	$22.09	$2.27
SR-176F	3.88	$0.98	$0.10	$0.05	$0.15	$1.27	$0.13
IR-271	18.40	$4.64	$0.46	$0.23	$0.70	$6.03	$0.62
US-422	3.15	$0.79	$0.08	$0.04	$0.12	$1.03	$0.11
IR-480	26.02	$7.44	$0.75	$0.37	$1.12	$9.73	$1.00
IR-480N	2.07	$0.52	$0.05	$0.03	$0.08	$0.68	$0.07
IR-490	2.43	$0.61	$0.06	$0.03	$0.09	$0.80	$0.08
US-42	21.57	$4.87	$0.49	$0.24	$0.73	$6.34	$0.65
Total:	**199.44**	**$62.15**	**$6.21**	**$3.11**	**$9.32**	**$80.79**	**$8.32**

Capital costs were converted to equivalent annual costs, assuming a 15 year life and an interest rate of 6 percent. The quantities shown correspond to the quantities indicated in the deployment plan and shown in the figures in Chapter VIII.

Table CHAPTER IX. -2. Summary of Capital Costs by Equipment

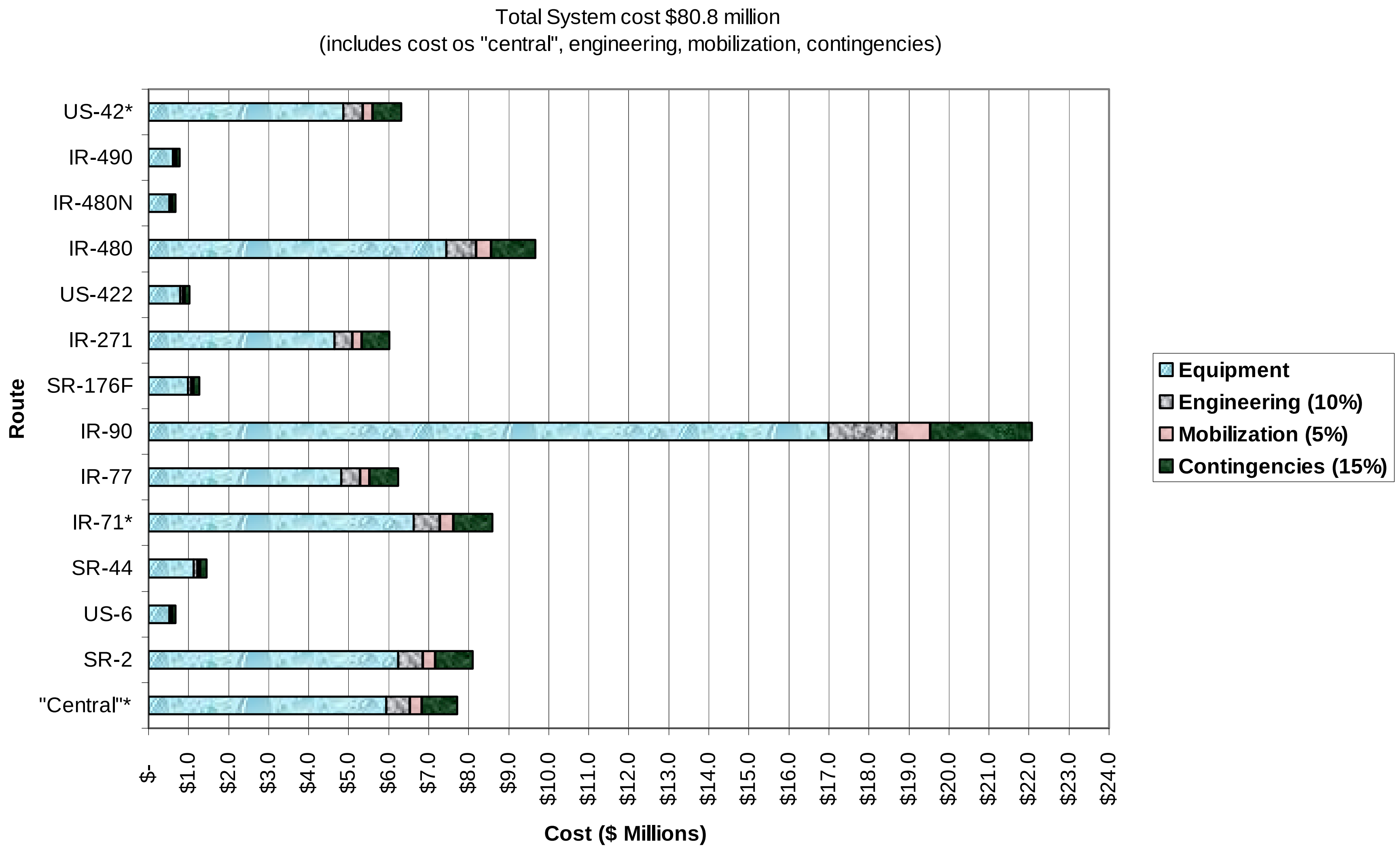
Equipment type	Equipment Capital Cost (millions)	Engineering (10%) (millions)	Mobilization (5%) (millions)	Contingency (15%) (millions)	Total Capital Cost (millions)	Annualized Capital Cost (millions)
"Central"*	$5.94	$0.59	$0.30	$0.89	$7.73	$0.80
Fiber optics	$24.23	$2.42	$1.21	$3.63	$31.50	$3.24
Twisted pair	$3.29	$0.33	$0.16	$0.49	$4.28	$0.44
CCTV	$4.57	$0.46	$0.223	$0.68	$5.93	$0.61
Detection	$17.55	$1.76	$0.88	$2.63	$22.82	$2.35
VMS	$4.62	$0.46	$0.23	$0.69	$6.00	$0.62
HAR	$1.71	$0.17	$0.09	$0.26	$2.22	$0.23
Ramp meter	$0.24	$0.02	$0.01	$0.04	$0.31	$0.03
Total:	**$62.15**	**$6.21**	**$3.11**	**$9.32**	**$80.79**	**$8.32**

Table CHAPTER IX. -3. Estimated Annual Operating and Maintenance Costs

Item	Annual Cost
Fully burdened salary - operators (8 at full deployment @ $50K)	$400,000
Fully burdened salary - maintainers (7 at full deployment @ $50K)	$350,000
Fiber optic maintenance @ 2% of capital cost	$484,600
Twisted pair maintenance @ 5% of capital cost	$164,600
Surveillance cameras @ 5% of capital cost	$228,300
Spot detection @ 5% of capital cost	$877,500
Variable message signs @ 5% of capital cost	$230,800
Highway advisory radio @ 5% of capital cost	$85,400
Ramp metering @ 5% of capital cost	$12,000
Central equipment @ 5% of capital cost	$297,200

Total	**$3,130,400**

Figure Chapter IX-1. Summary of Capital Costs by Route



* IR-71 "Smart Corridor" cost $22.7 million
(includes cost of "central", engineering, mobilization, contingencies)

Figure IX-2. Summary of Capital Costs by Equipment
($80.8 million)

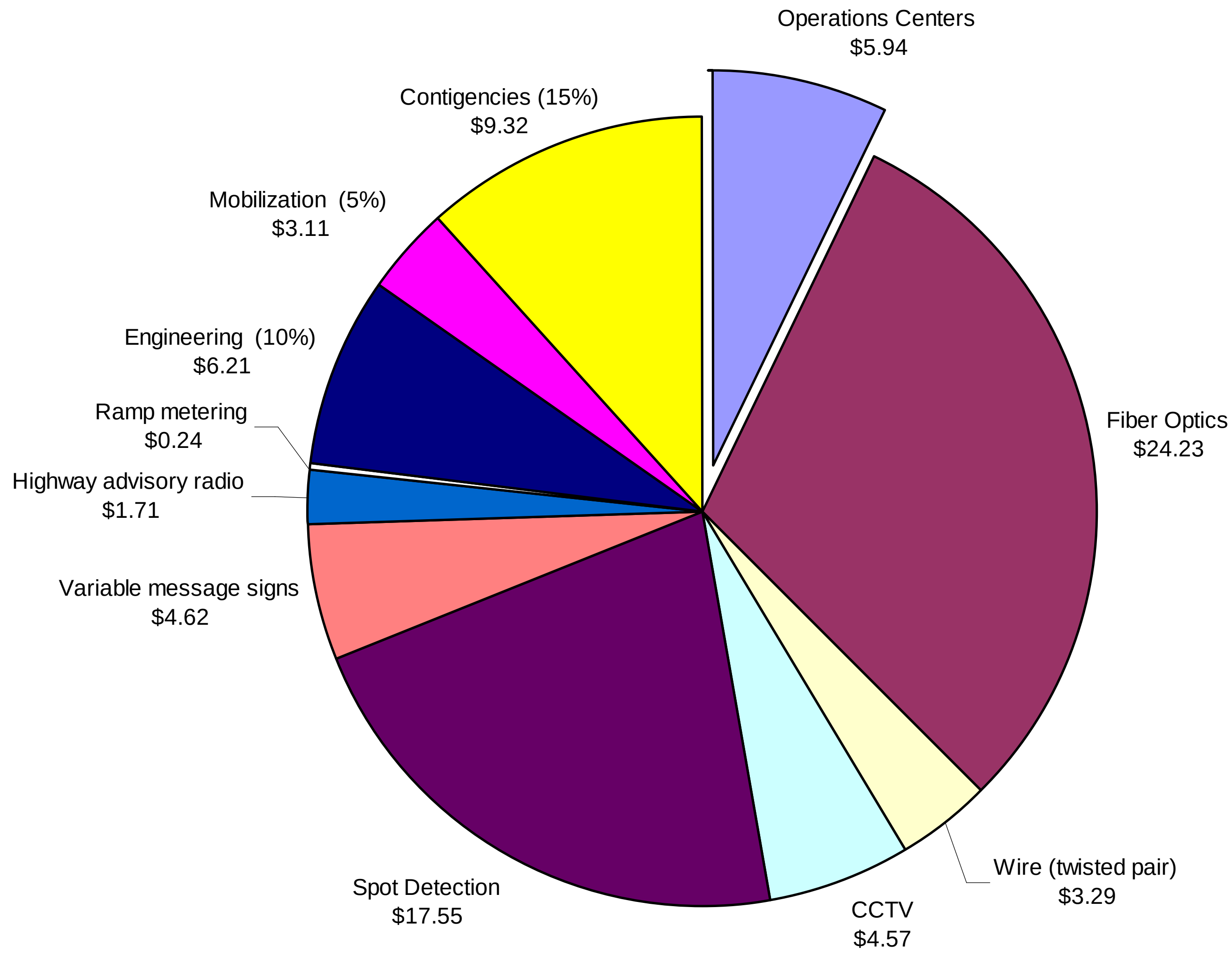
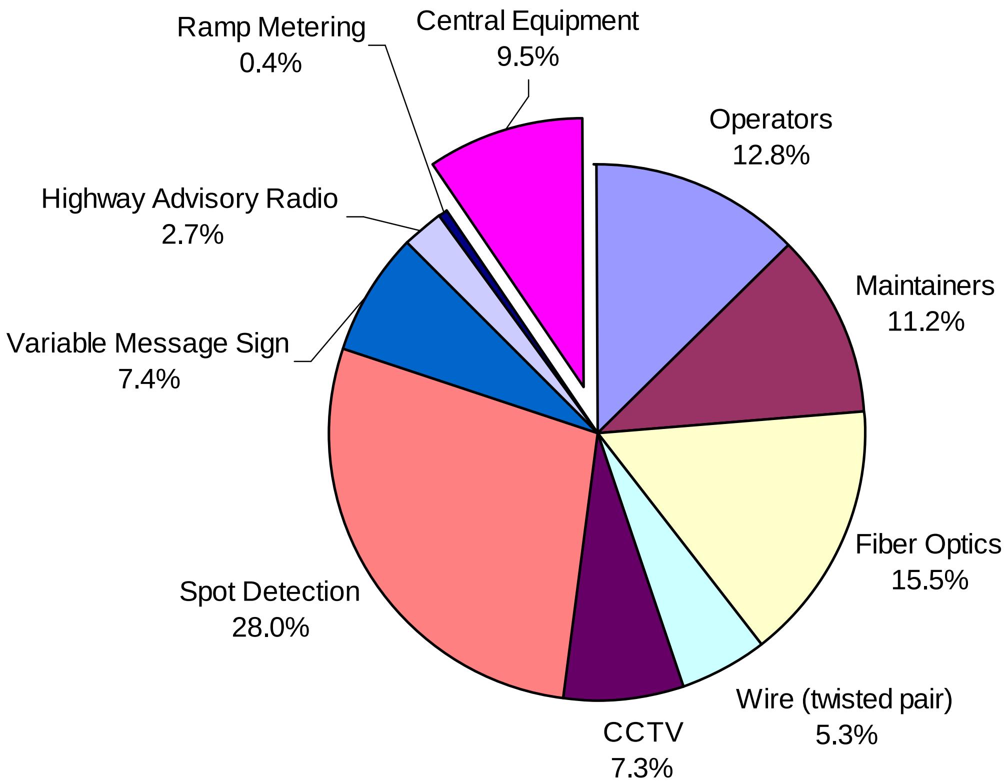


Figure IX-3 - Estimated Annual Opearting and Maintenance Costs
($3.1 million)



C. IR-71 "Smart Corridor"

A "model" deployment corridor was selected by the members of the Policy and Technical Committees. Following the same methodology as above, costs were estimated for this installation. Tables IX-4 and IX-5 enumerate these costs. Since a central location would still be required, the capital costs of the "center" have been included in their entirety. However, less staffing would be required since less lane mileage would be monitored, so the salary costs have been reduced.

Table CHAPTER IX. -4. "Smart Corridor" Summary

Route	Total Length (miles)	Equipment Capital Cost (millions)	Engineering (10%) (millions)	Mobilization (5%) (millions)	Contingency (15%) (millions)	Total Capital Cost (millions)	Annualized Capital Cost (millions)
"Central"	0.00	$5.94	$0.59	$0.30	$0.89	$7.73	$0.80
IR-71	21.78	$6.63	$0.66	$0.33	$0.99	$8.62	$0.89
US-42	21.57	$4.87	$0.49	$0.24	$0.73	$6.34	$0.65
Total:	**43.35**	**$17.45**	**$1.74**	**$0.87**	**$2.62**	**$22.68**	**$2.33**

Table CHAPTER IX. -5. Estimated "Smart Corridor" Annual Operating and Maintenance Costs

Item	Annual Cost
Fully burdened salary - operators (2 at full deployment @ $50K)	$100,000
Fully burdened salary - maintainers (1 at full deployment @ $50K)	$50,000
Fiber optic maintenance @ 2% of capital cost	$60,100
Twisted pair maintenance @ 5% of capital cost	$148,800
Surveillance cameras @ 5% of capital cost	$28,300
Spot detection @ 5% of capital cost	$190,700
Variable message signs @ 5% of capital cost	$34,200
Highway advisory radio @ 5% of capital cost	$18,300
Ramp metering @ 5% of capital cost	$4,500
Central equipment @ 5% of capital cost	$297,200

Total	**$932,200**

D. Estimated Benefits

The estimated benefits for the implementation of a freeway management system in the Cleveland/Lorain metropolitan area include reductions in travel delay time, fuel consumption and automobile emissions. In order to help prioritize areas for improvement, the benefits are also shown on a per route basis, as well as savings per mile on each route. In addition, benefits for the "Smart Corridor" discussed above have been broken out.

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 and will impact the recommended time frame for implementation and the extent and kinds of technologies that would appear to be warranted. Additional information regarding the calculation of the benefits, including the assumptions used, is included in Appendix D.

1. Background[1]

The first implementations to some of the user services included in the current ITS structure began appearing in urban areas in the late 1960's. Implementations since then have become more flexible, more capable, and more integrated. For example, incident management programs that began as courtesy patrols and CB monitoring have incorporated new technologies and are increasingly being integrated into transportation management centers.

Implementations of ITS programs have demonstrated benefits to address the national program goals in the areas of safety, productivity, efficiency, and environmental impact. Benefits are derived from a smoother flow of traffic with less delay from signals, incidents, and traffic queues. Most aspects of the implementations contribute to time savings.

Experience with past ITS program implementations have shown positive results. For example, Incident Management Programs have shown an eight (8) minute decrease in incident clearance time, a 10%-20% decrease in travel time, and a 10% decrease in fatalities in urban areas. According to draft analyses based on data from the Fatal Accident Reporting System, reduction of incident notification times on urban freeways from the current average of 5.2 minutes to 3 minutes would reduce fatalities 10% annually.

Implementations of ITS programs are justified by user benefits and are evaluated against other no-build options. As an approximate comparison, freeway expansion costs $2 million per lane mile while a complete implementation of an urban corridor costs between $300,000 and $500,000 per freeway mile plus the cost of a freeway management center. If the existing freeway is four

[1] Information on the background of ITS benefits was obtained from *Intelligent Transportation Infrastructure Benefits: Expected and Experienced*. USDOT, Operation Timesaver, January 1996.

lanes, installing a traffic management center could add about half the capacity of an additional lane at about 1/8 the cost.

2. Travel Time Delay

The primary benefits expected to result from the implementation of a freeway management 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 implementation of freeway surveillance 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 at the scene. This would decrease vehicle delay by both assuring that the equipment needed arrives quickly and minimizing the transport of unnecessary equipment to the scene which would reduce 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.

Benefits also accrue as a result of informing motorists about traffic conditions. Variable message signs, highway advisory radio, 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.[2]

Studies completed in other areas have reported a 20-50 percent reduction in incident induced travel delay times resulting from the implementation of freeway management systems. For this analysis a conservative approach was taken to estimating the benefits that may be obtained by implementing a freeway management system. It is assumed that during incidents causing delay, a 25 percent reduction in travel time delay would result from the implementation of a freeway management system. It is also assumed that the average queue length during an incident in the Grand Rapids area is three (3) miles, the average speed in the queue is 10 mph. The percentage of the total traffic that will experience delays due to accidents depends on where the accident occurs and at what time it occurs. For accident sensitive areas (where accidents per lane-mile exceeded 8.00 as shown on Figure I-6 in Chapter I), it is assumed that 40 percent of the ADT will encounter 30 percent of the total number of accidents. This is based on the assumption that approximately 10 percent of the ADT occurs during each of the a.m. and p.m. peak hours when accidents are most likely to cause significant delay. It is further assumed that an additional 20

[2] Summary of Findings, Massachusetts Highway Department Independent Evaluation of SmarTraveler Operational Test (conducted for the Massachusetts Highway Department and presented in a paper to ITS America).

percent of the ADT is likely to encounter delay causing incidents, primarily during the midday period.

Another set of assumptions was made concerning the frequency of accidents and the percentage of accidents that are likely to cause delay. The first assumption was that 40 percent of the recorded accidents occurred during the time that 40 percent of the ADT was on the road. The second assumption was that 75 percent of those accidents would cause delay. Taking 75 percent of the 40 percent of the accidents expected to occur during the heavier traveled periods resulted in 30 percent of the total recorded accidents for each segment being used in the calculation of travel time delay. Similarly, for those areas not identified as accident sensitive, it is assumed that only 10 percent of the ADT is likely to encounter delay causing accidents and that 10 percent of the recorded accidents will cause the delay. Table IX-6 summarizes the annual benefits expected from travel delay time savings, assuming the value of time to be $10.00 per hour.

Table CHAPTER IX. -6. Travel Delay Benefits By Route

Route	Distance (miles)	Annual Travel Delay Benefits	Travel delay savings per mile
"Central"*	0	$0	$0
SR-2	20.4	$156,300	$7,700
US-6	2.3	$17,800	$7,800
SR-44	4.5	$12,300	$2,800
IR-71*	21.8	$6,109,000	$280,500
IR-77	16.0	$5,090,500	$318,800
IR-90	57.0	$8,582,800	$150,400
SR-176F	3.9	$10,100	$2,600
IR-271	18.4	$369,100	$20,100
US-422	3.2	$11,700	$3,700
IR-480	26.0	$691,300	$26,600
IR-480N	2.1	$18,800	$9,100
IR-490	2.4	$14,800	$6,100
US-42*	21.6	$2,003,700	$92,900
* "Smart" Corridor Subtotal:	43.4	$8,112,600	$187,100
Total:	**199.4**	**$23,088,100**	**$115,800**

3. Fuel Use and Emissions

Benefits are also expected to result from a decrease in fuel consumption and related automobile emissions due to the implementation of the freeway management system. These benefits correspond to the travel delay time savings in that they are the direct result of improved incident response and management.

The average fuel efficiencies are assumed to be 15 miles per gallon when the speeds are under 35 mph. The cost of fuel is estimated to be $1.20 per gallon. The assumptions regarding the average speed, length of queue and percentage of ADT encountering congestion are the same as mentioned for the travel delay time benefits. Table IX-7 summarizes the annual benefits expected from fuel use savings.

Table CHAPTER IX. -7. Fuel Use Benefits

Route	Distance (miles)	Annual Fuel Use Benefits	Fuel savings per mile
"Central"*	0	$0	$0
SR-2	20.4	$16,700	$800
US-6	2.3	$1,900	$800
SR-44	4.5	$1,300	$300
IR-71*	21.8	$651,600	$29,900
IR-77	16.0	$543,000	$34,000
IR-90	57.0	$915,500	$16,000
SR-176F	3.9	$1,100	$300
IR-271	18.4	$39,400	$2,100
US-422	3.2	$1,300	$400
IR-480	26.0	$73,700	$2,800
IR-480N	2.1	$2,000	$1,000
IR-490	2.4	$1,600	$700
US-42*	21.6	$213,700	$9,900
* “Smart” Corridor Subtotal:	43.4	$865,300	$20,000
Total:	**199.4**	**$2,462,700**	**$12,300**

Vehicle exhaust emissions can be reduced due to the reduction of incident related congestion. Research which was conducted by Partners for Advanced Transit and Highways (PATH) and the South Coast Air Quality Management District shows that vehicles emit various amounts of CO, HC, and NO_x emissions according to their speed. The following emission rates occur at a travel speed of 10 mph:

Emission	**Emission Rate (g/sec)**
CO	0.94
HC	0.01
NO_x	0.0085

Table IX-8 shows the reductions in these emissions. No attempts has been made to assign a monetary value to the emission reductions. This is in keeping with the conservative approach taken in this analysis.

Table CHAPTER IX. -8. Emissions Benefits

Route	CO Reduction (tons/year)	HC Reduction (tons/year)	NOx Reduction (tons/year)
"Central"*	0.0	0.0	0.0
SR-2	58	0.6	0.5
US-6	7	0.1	0.1
SR-44	5	0.0	0.0
IR-71*	2,279	24	21
IR-77	1,899	20	17
IR-90	3,202	34	29
SR-176F	4	0.0	0.0
IR-271	138	2	1
US-422	4	0.0	0.0
IR-480	258	3	2
IR-480N	7	0.1	0.1
IR-490	6	0.1	0.1
US-42*	747	8	7
* "Smart" Corridor Subtotal:	3,026	32	27
Total:	**8,612**	**92**	**78**

4. Total Benefits

The total annual benefits for each roadway are summarized in Table IX-9. Note that the benefits are higher on the routes with higher volumes and accident rates. This is due to the fact that benefits accrue to a greater number of vehicles where both volumes and incidents are higher. Benefits are highest for IR-77, followed closely by IR-71.

Table CHAPTER IX. -9. Total Benefits

Route	Distance (miles)	Total Annual Benefits	Benefits per mile
"Central"*	0	$0	$0
SR-2	20.4	$172,900	$8,500
US-6	2.3	$19,700	$8,600
SR-44	4.5	$13,600	$3,100
IR-71*	21.8	$6,760,600	$310,400
IR-77	16.0	$5,633,500	$352,800
IR-90	57.0	$9,498,200	$166,500
SR-176F	3.9	$11,200	$2,900
IR-271	18.4	$408,400	$22,200
US-422	3.2	$13,000	$4,100
IR-480	26.0	$765,100	$29,400
IR-480N	2.1	$20,800	$10,100
IR-490	2.4	$16,400	$6,800
US-42*	21.6	$2,217,400	$102,800
* "Smart" Corridor Subtotal:	43.4	$8,978,000	$207,100
Total:	**199.4**	**$25,550,900**	**$128,100**

E. Benefit / Cost Ratios

Benefit cost ratios were calculated for each roadway, as shown in Table IX-10. The cost of the "central" equipment and staffing was apportioned over the roadways in proportion to length of instrumented roadway. This was necessary to arrive at a more realistic annual cost for each roadway.

Benefit cost ratios must be greater than one in order for the project to be justified. Using this criterion, full deployment of ITS equipment appears justified over the entire area. However, on a per-route basis only four routes qualify: IR-71, IR-77, IR-90, and US-42 (Pearl Road). The "Smart Corridor" model deployment has a favorable benefit/cost ratio as well, in spite of having to absorb the entire capital cost of the operations "center." The reason the entire area has a favorable benefit/cost ratio is due to the exceptionally high ratios of the above four routes, which serve to offset the shorter routes with unfavorable ratios.

However, certain segments may realize greater benefits than other segments (due to volumes and incidents). Further investigation revealed that for those routes with a favorable overall B/C ratio, benefits did not exceed costs for all segments. Conversely, for one of the roadways (IR-480) that did not show a favorable overall B/C ratio, a significant stretch exists where benefits exceed costs. Figure IX-4 graphically depicts those portions of the roadway network where individual segments exhibit favorable B/C ratios. Table IX-11 summarizes the limits. Since route continuity must be maintained, the limits in the table also take into account communication backbone considerations. This table represents the first attempt to prioritze roadways for installation of ITS equipment. However, direct comparisons between costs and benefits may be misleading because certain irreducible fixed costs are inherent in ITS deployment regardless of the area to be instrumented.

Table CHAPTER IX. -10. Benefit / Cost Ratios

Route	Total Annual Cost (with apportioned "center")	Annual Travel Delay Benefits	Annual Fuel Use Benefits	Total Annual Benefits	B/C Ratio
"Central"*	n/a	$0	$0	$0	n/a
SR-2	$1,219,300	$156,300	$16,700	$172,900	0.14
US-6	$115,800	$17,800	$1,900	$19,700	0.17
SR-44	$228,900	$12,300	$1,300	$13,600	0.06
IR-71*	$1,329,700	$6,109,900	$651,600	$6,760,600	5.08
IR-77	$965,700	$5,090,500	$543,000	$5,633,500	5.83
IR-90	$3,414,500	$8,582,800	$915,500	$9,498,200	2.78
SR-176F	$199,600	$10,100	$1,100	$11,200	0.06
IR-271	$946,300	$369,000	$39,400	$408,400	0.43
US-422	$162,000	$11,700	$1,300	$13,000	0.08
IR-480	$1,508,800	$691,300	$73,700	$765,000	0.51
IR-480N	$106,500	$18,800	$2,000	$20,800	0.20
IR-490	$125,000	$14,800	$1,600	$16,400	0.13
US-42*	$1,095,600	$2,003,700	$213,700	$2,217,400	2.02
* "Smart" Corridor Subtotal:	$3,293,600	$8,112,600	$865,300	$8,978,000	2.73
Subtotal:	**$11,449,000**	**$23,088,100**	**$2,462,700**	**$25,550,900**	**2.23**

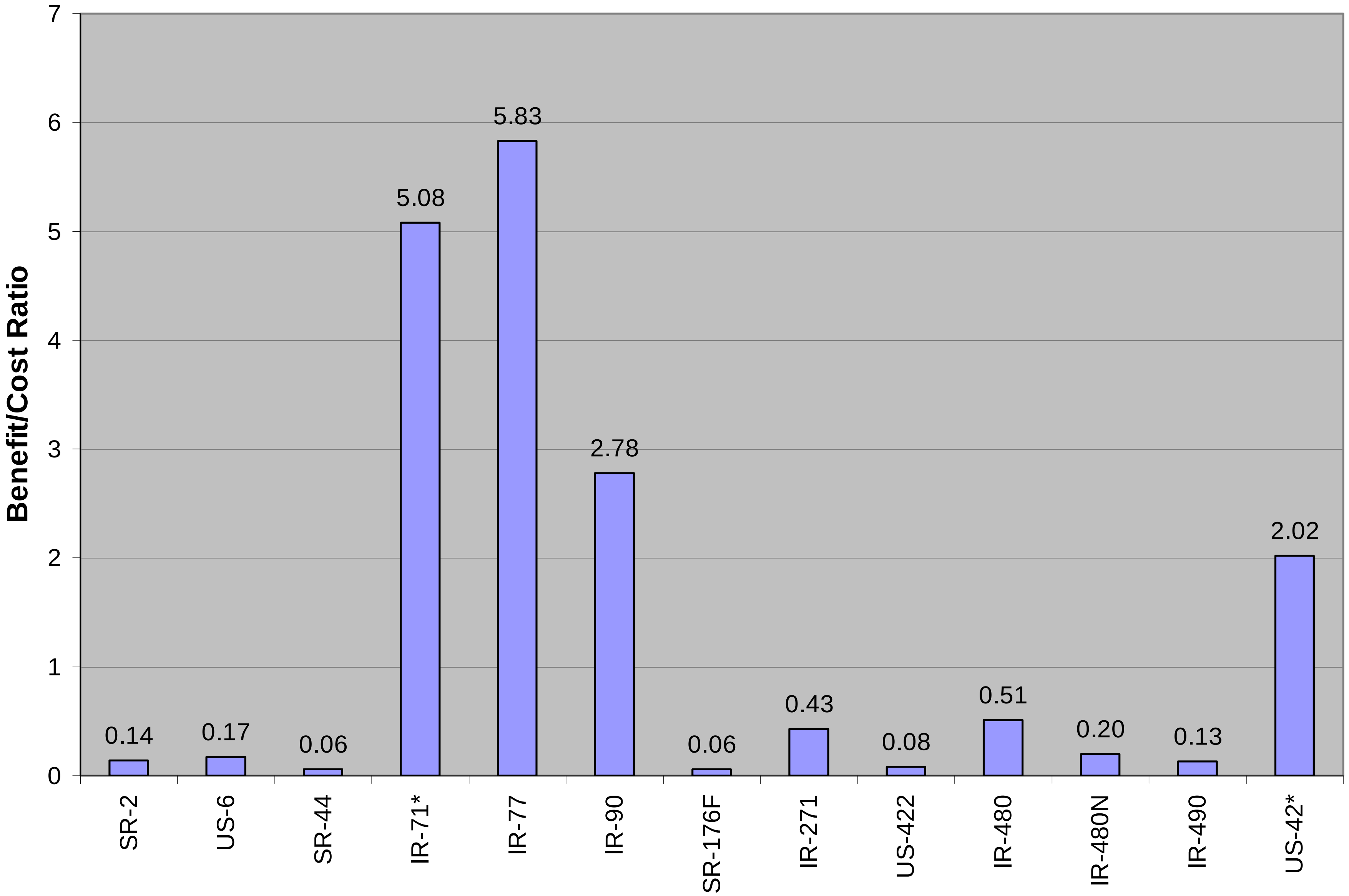
Table CHAPTER IX. -11. Limits of Favorable B/C Ratios, by Route

Route	From	To	Distance (miles)	B/C Ratio (within limits)
IR-71	US-42	Route end at IR-90	13.6	12.06
IR-77	I-480	Route end at IR-90	5.8	23.48
IR-90	Woodward Avenue	SR-175	19.3	12.00

IR-480	0.3 mi. W of IR-77	Warrensville Center Road	6.3	1.55
US-42	Drake Road	Route end at Public Square	17.9	3.80

Figure CHAPTER IX. -4. Benefit / Cost Ratios by Roadway Segment

Figure CHAPTER IX-5. Benefit/Cost Ratios by Facility



An initial system can be deployed over those segments of the roadway network identified in Table IX-11. To derive meaningful benefit/cost ratios for the proposed initial deployment, it is necessary to distribute the entire capital cost of the Traffic Operations Center (TOC) over the selected roadways. Table IX-12 presents the adjusted B/C ratios.

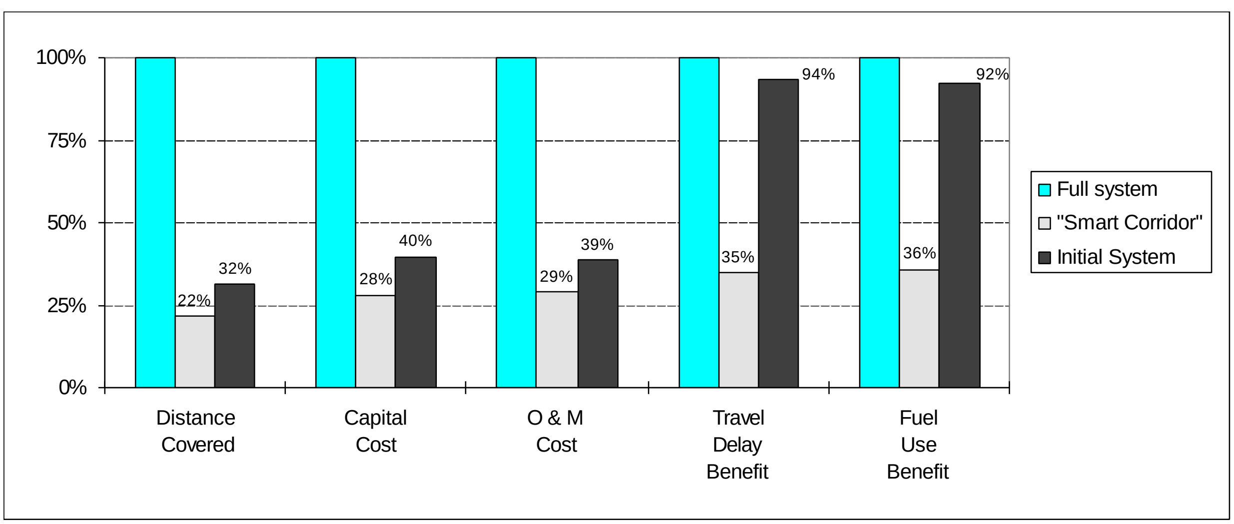
Table CHAPTER IX. -12. Initial System's Adjusted B/C Ratios

Route	From	To	Distance (miles)	Adjusted B/C Ratio
IR-71	US-42	Route end at IR-90	13.6	4.07
IR-77	I-480	Route end at IR-90	5.8	4.04
IR-90	Woodward Avenue	SR-175	19.3	4.92
IR-480	0.3 mi W of IR-77	Warrensville Center Road	6.3	0.29
US-42	Drake Road	Route end at Public Square	17.9	1.29
		Total	**62.9**	**3.07**

The estimated construction cost of this initial deployment is $32.12 million. The estimated annual operating and maintenance cost is $1.24 million. The operating cost reflects reduced staffing levels in the TOC due to reduced area of coverage.

After analyzing the three alternatives (full deployment, the "Smart Corridor" containing IR-71 and US-42 (Pearl Road), and the initial deployment over a limited area), the recommendation is to select the initial deployment alternative. Figure IX-6 presents the alternatives side by side:

Figure CHAPTER IX. -6. Comparison of Deployment Alternatives



For approximately 40% of the total system cost, the initial system can deliver around 93% of the benefits, while being deployed on about 32% of the roadways.

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CHAPTER X. CONTRACTUAL AND FINANCING ALTERNATIVES

A. Introduction

This Chapter provides documentation of the activities conducted to date regarding ITS Contracting Alternatives and Potential Funding Sources.

The first section describes the Consultant/Contractor, System Manager, and Design/Build methods of contracting, discusses their advantages and disadvantages, and assesses their potential for use on ITS projects under current Ohio laws. This section also compares and contrasts traditional transportation agency contracting methodologies and practices with those typically used by the National Aeronautics and Space Administration (NASA) and the United States Department of Defense (DOD) for major projects requiring significant systems integration (i.e. projects requiring implementation expertise similar to what may be experienced with ITS deployment activities).

The second section details both potential public and private sources of ITS financing. This includes actual dollars (i.e. public funding via the Intermodal Surface Transportation Efficiency Act of 1991, the National Highway System Act of 1995, and various State and local user-fee options), and in-kind services (i.e. the trading of a portion of agency-controlled right-of-way to a communication company that wishes to install fiber-optic cables in exchange for that agency's right to use a pre-defined amount of fiber-optic bandwidth for either no fee or at a significantly reduced fee). This section also includes innovative techniques for financing operating costs (i.e. the ability of an agency to sell raw traffic "data" to value-added service providers who specialize in converting this raw data into valuable "information" for later re-selling to the public by the value-added service provider).

B. Contracting Alternatives

1. Overview

Discussions regarding "contracting alternatives" are most easily looked at as discussions regarding the different ways in which various degrees of risk and responsibility can be "traded" amongst the parties participating in a project such that the choosing of the "proper" formalized relationship (i.e. "contracting alternative") might more enable the realization of desired results rather than the possibility of unintended and/or undesirable consequences. For example, the answer to questions such as who or what organization has the authority and/or ultimate responsibility for:

- Determining system goals/objectives;
- Developing system designs;
- Creating system specifications;

- Letting system contracts;
- Making system changes;
- Authorizing/financing system changes; and/or
- Making the system work as intended

can often determine the difference between a project's immediate success or its ultimate failure. In addition, it is important to recognize that these discussions are also inter-twined with discussions that ask, "Does whomever have the above responsibilities actually have the proper technical competence to efficiently and effectively exercise their contractual authority in matters regarding these responsibilities?"

The following sections provide much needed insight into these above issues and provide a recommended course of action regarding the *type* of contract best suited for ITS implementation in the Cleveland/Lorain metropolitan area. Readers, however, should be aware that even though this focus is on a recommended *type* of contract (i.e. Consultant/Contractor, System Manager, or Design/Build), it is important to note that the choosing of any particular contracting *type* does not necessarily require the choosing of any particular contracting *method* (i.e. Time and Materials, Firm-Fixed-Price, Cost Plus Fixed-Fee, etc.). This latter decision can often be made on a contract by contract basis during bid requesting and/or negotiations between an agency and a consultant, a contractor, a system manager, and/or a design/build team.

2. Existing Agency Methodologies

a) *Transportation Agency Practices*

Transportation agencies have much experience and established procedures for procuring equipment and services for highway and bridge construction projects, and for obtaining design assistance for these types of projects. The following sections describe the established relationships between a transportation agency and contractors, and a transportation agency and consultants.

Construction Contracts

To assure open and competitive bidding on government contracts, a process has evolved whereby transportation agencies have traditionally awarded contracts to the lowest bidder. To assure quality, many transportation agencies, including ODOT, have developed well defined processes such as their *Standard Specifications for Construction* manual, and have also developed detailed criteria whereby contractors must first be prequalified in order to even bid on certain projects. Then, contracts are awarded to the lowest qualified (i.e. prequalified) bidder. This may work in theory on "non-complex" projects to prevent unqualified contractors from being awarded a job as the low bidder. However, marginal contractors or sometimes even non-qualified contractors can often be prequalified because DOTs are afraid of potential litigation if they reject a given contractor's prequalification request. Under this scenario, when it comes time to award a contract, a truly unqualified but "prequalified" bidder can end up winning a contract if they are the lowest bidder. It should be mentioned that Ohio law might be interpreted to provide a potential "escape clause" for this scenario in the form of the phrase "competent and responsible" (i.e. ODOT must award a construction contract to the "...lowest competent and responsible bidder qualified to bid" [Ohio Revised Code 5525.01] or must reject all bids). However, the act of an agency awarding a prequalification status to a contractor may in itself imply that the contractor is "competent and responsible" for that particular project.

This can be especially problematic in ITS-related procurements (see *Consultant / Contractor*, below) since transportation agencies do not usually have enough in-house expertise to actually determine those who are qualified or not. Furthermore, because transportation agencies are typically very liberal in approving contractual "change orders", which effectively transform "Firm-Fixed-Price" contracts into "Cost Plus Fixed-Fee" contracts, the potential for cost overruns can be very high because unqualified bidders tend to underestimate the complexity and cost of projects in order to win jobs and later make-up their fee through various types of contractual changes.

Professional Services Contracts

In most ODOT professional services contracts (i.e. consulting contracts), firms are also prequalified, however, projects are not necessarily awarded to the lowest bidder. Instead, contracts are awarded on the basis of who is the most technically competent to do a job, irrespective of price. This process, codified under Title 23 of the United States Code of Laws and required of all contracts in which Federal funds are used, is essentially as follows:

1. An agency identifies the scope of work
2. A selection schedule is established
3. A list of professional firms is compiled (often from a prequalified list)
4. Qualification documents are requested
5. Qualification documents are evaluated
6. A shortlist of firms to be interviewed is composed
7. Interviews are conducted
8. Firms are ranked for selection
9. A contract is negotiated with the top-ranked firm. If an agreement cannot be reached, those negotiations are ended and negotiations are begun with the second-ranked firm, and so on down the line, until agreement is reached and a firm is selected

10. All firms involved receive post-selection communications

However, since ODOT does not yet have a specific prequalification process for ITS-related professional services (i.e. multiple systems *integration*), and the only ITS-subsystem-related prequalification category is for Traffic Signal Design (i.e. signal warrants, data collection, justification; design in detector and controller applications; design of signal support structures; coordination for arterial system; coordination for grid system; traffic adjusted systems-arterial; traffic adjusted systems-network; computer system communications; construction of signals and signal systems; inspection or testing of signals and signal systems; and maintenance of signals and signal systems), ODOT will either have to waive prequalification requirements for ITS systems integration projects, develop prequalification/ranking procedures for these projects, or accept the fact that non-ITS-qualified contractors will be the only ones able to bid for ITS-related systems integration work in the State of Ohio. Furthermore, a lack of numerous ITS-experienced personnel in a DOT's Contracts Office may put the agency at a significant disadvantage when it comes time to negotiate the multiple contracts for ITS design and implementation that may be required by this above selection process.

It should be mentioned that because the creation of prequalification and/or ranking procedures can require expertise that an agency may not readily have on staff, it is possible to hire an independent consultant to develop these procedures and/or even review any incoming proposals, however, that consultant would most likely not be able to bid on the projects in which they had developed the ranking procedures. Thus, potentially depriving a DOT of valuable sources of knowledge from consultants who might have otherwise been able to make significant contributions to the actual implementation of a project.

b) *NASA / Department of Defense Models*

In contrast to the above traditional transportation methodologies of explicit contractual separation between the design and implementation stages of a project, both the National Aeronautics and Space Administration (NASA) and the United States Department of Defense (DOD) typically utilize contractual unity between a project's design and implementation stages, especially on large-scale/complex programs that may consist of multiple sub-systems requiring integrated command, control, and intelligence (i.e. programs with challenges similar to those that are found with Intelligent Transportation Systems).

For example, when the DOD needs a new airplane it does not contract with McDonnell Douglas for the design (i.e. one contractor), and then have it built by a team headed-up by the Lockheed Corporation (i.e. another contractor). A major reason for this is that not all of a designer's knowledge can ever be transferred from their brains into contracting documents -- (i.e. something inevitably always ends-up being left out). Furthermore, when looking at formal contracting arrangements on complex projects like airplanes or ITS, it is important to understand that risk is directly related to cost. In other words, the more a bidder knows about a project or the agency developing a project, the smaller the amount of "risk dollars" that need to be added to a bid by a contractor. Conversely, the less one knows about a project, the greater the amount of "risk dollars" that need to be added to a bid, thus increasing the cost of a project. This is especially evident in either a NASA or a DOD project environment because major change orders are rarely approved. Unlike their DOT counterparts, NASA and DOD "Firm-Fixed-Price" contracts are just what they say they are -- "Firm-Fixed-Price". In light of this discussion of "risk dollars", it is interesting to note that traditional transportation contracting methods (see *Transportation Agency Practices*, above) can actually encourage *distance* relationships between designer and implementor (and thus drive-up costs). This is further encouraged whenever agency-bidder contact and question/answer times are excessively limited upon release of a Request For Proposals.

Similar to what will be described later in the Design/Build section of this Chapter, whereby a single organization handles both the design and the building of a project and thus does not have to deal with the uncertainties of another organization's design (see *Design / Build*, below), the path leading to the successful implementation of ITS projects is very similar to the path that has been used by both NASA and the DOD to put humans on the Moon. This may not yet be that evident to Departments of Transportation who are accustomed to dealing with bridge or highway projects in which concrete, steel reinforcing bars, and traffic signal heads behave a certain way and can be obtained by multiple vendors (i.e. there are established standards). However, many ITS devices do not have established standards and there are a multitude of components that must all work together in order for a project to be successful. Thus, the lesson to be learned is that it is no longer adequate to solicit items on a piece-by-piece basis for complex ITS implementations that require a systems *integrator*. As will be discussed below, the potential is too high for many dollars to be unnecessarily spent if there is too much distance between an agency the design organization, and the implementation organization.

3. Formal Contracting Arrangements

There are three primary approaches for contracting ITS-related system design and implementation projects: Consultant/Contractor, System Manager, and Design/Build (see Figure X-1). The following sections describe each of these types and some of the major advantages and disadvantages of using them to implement Intelligent Transportation Systems. Included, where appropriate, are discussions regarding issues such as implementation schedule, constraints of current procurement laws, availability of qualified contractors, availability of ODOT staff, and number of contracts required.

a) *Consultant / Contractor*

<u>Description</u>

The Consultant/Contractor procurement method is the one typically used for highway projects. It is based on the concept that almost all potential construction options are defined in Federal, state, and local *Standard Specifications for Construction* manuals, that critical system parameters can be fully specified and documented in a single set of contract documents (i.e. Plans, Specifications, and Estimate (PS & E) package), that a single contractor is best suited to implement the project, and that the only criterion of significance for selecting the contractor is the initial bid price. For Intelligent Transportation System projects, this approach uses a consultant to perform the feasibility study and system design.

For example, ODOT would issue one contract with a consulting firm to design the system, and then ODOT would issue multiple contracts with different contractors who would implement each of the subsystems that were designed by the original consultant. The implementation contractor is completely responsible for system installation, checkout, documentation, and training. However, the DOT is responsible for installation monitoring activities and making sure that the system components work together and actually perform the functions that they were originally intended to perform.

Advantages

The only advantage to the Consultant/Contractor approach in Intelligent Transportation System projects is that an agency's basic procurement principles are maintained. Thus, ODOT's contracting office would not have to "learn" a new system for ITS-related project implementations.

Disadvantages

Any and all design "gaps", "buildability" issues, and system integration during project implementation must be addressed by the DOT or another consultant without assistance from the original consultant (i.e. the first consultant's contractual obligations are over at this point). Furthermore, the extensive experience with this process for highway construction has resulted in a very rigid set of procedures and rules within most highway agencies that severely restrict the flexibility of system designers and implementers, and prove to be "...unduly cumbersome and counterproductive when applied to traffic control systems projects involving advanced technologies" [USDOT, FHWA, *Traffic Control Systems, Operations and Maintenance -- Expert Panel Report*, March 10, 1992, p. 21]. It must be remembered that there are no standard specification books for ITS components, and no standard "recipes" that ensure all components will work together as intended. The following paragraphs provide additional detail regarding some of the various reasons that the Consultant/Contractor approach is frequently ineffective for projects such as Intelligent Transportation Systems that involve electronics, computers, and communications equipment. For example:

- Electronics technology is changing too rapidly. A new generation of electronics equipment (computers, communications, software, etc.) is available every eighteen months. With a minimal three-year cycle from start of design to completion of construction, two generations of equipment will have evolved. The equipment can be obsolete before it is put into use.

- Initial low bid is not the most important discriminator of system success and total system cost. Operations costs, maintenance costs, training costs, equipment upgrade and compatibility, and related life-cycle costs are nearly always larger than initial procurement price. Furthermore, software development and system integration, key elements to the success of a complex system, are low bid items.

- The complex nature of these projects is often beyond the experience and capability of traditional highway contractors. However, since a majority of the cost under the Consultant/Contractor approach is generally associated with field construction activities, the prime contractor is often one of these roadway or electrical contractors that has little or no system integration or software capability.

- Departments of Transportation usually have limited ability to understand and fully specify a complex system involving computers, software, and human interactions. Furthermore, many of the human-factor issues that relate to system usability are typically addressed during implementation stages because of the need to meet special and unforeseen site-specific DOT user requirements. For example, the end users of the system must define the operational requirements, but they usually do not have the experience needed to convert their needs into precise and unambiguous system specifications. Conversely, the analysts and software engineers who have to create the system may have limited DOT experience and therefore do not always understand the user's requirements.

Thus, the assumption that enough can be known about a project in order to be able to fully define its characteristics (i.e. the Consultant/Contractor approach) is invalid for ITS. Also, with two or more organizations involved in the process (i.e. Consultant(s) and Contractor(s)), responsibilities of the design and implementation parties can become unclear. For example, due to the numerous parts that would have to be procured by a DOT under separate low-bid contracts, situations such as the possibility of functionally-specified computer cards purchased under one contract not being able to fit into controller cabinets purchased under a separate contract may become commonplace. No matter how well the Consultant/Contractor approach is for traditional highway projects, unless the procuring agency has a detailed and complete knowledge of what they are buying, it does not work well for projects involving advanced electronics, computer, and software technologies.

b) ***System Manager***

Description

The System Manager procurement method divides the project into several sub-projects for each of the various sub-systems with the work overseen by a systems manager (consultant) who administers (with the amount of responsibility determined by ODOT) each contract in conjunction with ODOT, and who is responsible for integrating the several hardware and software sub-systems into an overall operating system. The System Manager converts the project plan into preliminary designs and defines sub-systems, develops PS&E packages for subsystems, helps ODOT oversee the bidding and award of construction contracts, checks the work of implementation contractors, supervises construction, selects and procures computer and communications hardware components, manages the installation of equipment, develops and furnishes the system software, integrates and tests the sub-systems, provides necessary software documentation, and supervises the provision of operator training.

Advantages

As with the Consultant/Contractor approach, the System Manager approach maintains the basic procurement principles that an agency is accustomed to working with. However, the System Manager approach has the additional advantage of focusing on a single organization and defined source of accountability that is responsible for both detailed design and subsequent software/hardware integration, thus avoiding controversies over responsibility for design problems that may arise. The involvement of agency personnel as part of the design team also results in improved coordination and tighter cost controls. Furthermore, because the agreement between the agency and the system manager is a negotiated professional services contract, which can more easily be adapted as project needs are refined, increased flexibility is provided to meet the specific project requirements. This approach also provides for the selection of contractors with specific sets of skills for each of the sub-systems. For example, one contractor can be hired to do the earthwork and install the conduit, while another contractor can be hired to integrate and test the electronics within the communications subsystem, etc.

Disadvantages

A potential disadvantage to the System Manager approach, however, is that detailed specifications must be developed to define each subsystem in order that an agency can receive bids and let contracts for each of the major subsystems. Though, unlike the Consultant/Contractor approach, because all work is coordinated by a System Manager, many potential and costly change orders that may have otherwise appeared from the lack of a clear leader can be avoided. Thus, any potential disadvantages of the System Manager approach may be outweighed by its potential to provide for a more cost effective method of procurement.

c) *Design / Build*

Description

In the Design/Build approach, the DOT issues a single contract with a Design/Build team who is selected to handle all of the work associated with implementing the system. Any and all other necessary contracts with subcontractors are administered and paid for by this single entity, which maintains the ultimate responsibility for subcontractor performance and any cost overruns. For example, the Design/Builder is responsible for all aspects of the system, including detail system design, procurement of all equipment, construction of all system elements, integration of the various sub-systems, and final system checking, tweaking, and operational transfer of a fully functional system to the client. Except for the Design/Build feature of transferring all responsibility from a procuring agency to the Design/Build team, it is in practice very similar to the System Manager approach. It should be noted, however, that even though the "...the [State of Ohio] Director of Transportation may establish a pilot program to expedite the sale and construction of no more than six special projects by combining the design and construction elements of a highway or bridge project into a single contract" [Ohio Revised Code Section 5517.011], the use of this approach in the State of Ohio may not be available for ITS-related projects because the Design/Build concept is still in the experimental stage for traditional Ohio Department of Transportation (ODOT) construction projects. This approach may eventually pave the way for building ITS systems, but is not currently a viable method for project implementation.

Advantages

Since the Design/Build approach combines both the design and construction of an ITS-related project into a single contract, it can result in a better understanding of the designer's intent by the builder, can eliminate the schedule overruns that result from potential conflicts and communication gaps between engineers and contractors, can potentially decrease the number of after-bid changes, and can reduce completion times by streamlining the equipment procurement process via allowing critical components to be ordered and sub-contracts let as soon as engineering details are completed (e.g. Design/Build eliminates the step-by-step procedure of traditional contracting methods whereby one entity must complete their phase before the next entity can proceed with the project). Design/Build also eliminates time consumed in bid preparation and contract award analysis for separate architectural, engineering, and/or contractor entities while at the same time retaining competition through one unified Design/Build price proposal.

Disadvantages

A disadvantage to the Design/Build approach, however, is that it places a significant burden on the procuring agency to oversee the design and implementation activities and to ensure conformance to the design concept -- activities that many traditional transportation agencies may not have the in-house expertise to accomplish. This is best expressed by the following: At their best, design-build procurements can serve to streamline the development process and free the private sector to exercise ingenuity and creativity in packaging and delivering construction solutions. But, at their worst, they can distance the owner and user from design influence and decision-making, marginalize the participation of professional designers, and shift the onus for quality control and public accountability primarily to the customer. It is up to the procuring agency to determine the extent that they wish to be involved in any type of ongoing Design/Build review process. However, it should be mentioned that it can be especially detrimental to results if an agency chooses the "hands-off" approach since the agency personnel with direct operational experience and needs would then not be involved with the detail design, and thus could not provide input and feedback during design and implementation. It is therefore critical for an agency to know exactly what they want, and to establish a framework which effectively ensures its delivery. To support this, it is possible to hire a second, independent, consultant to help develop the necessary scope of work and to help oversee the design and implementation activities of the primary Design/Build consultant.

4. Recommendations

The System Manager approach to ITS-related procurement and project implementation is recommended because it provides the most flexibility, enables the greatest degree of control over technical features and system cost, and allows for the ability to obtain an optimum mix of contracting resources for each segment of the project. In addition, the System Manager concept has been successfully used on several major traffic management and incident management systems around the country because it is an approach that recognizes the complexity of these systems, especially when viewed from the context of traditional highway construction projects. Furthermore, other major industry segments in both the public- and private-sector use it to successfully implement projects with similar elements of multi-discipline and advanced technology challenges.

For this recommendation to work, however, it is strongly recommended that ODOT seek a consultant experienced in ITS systems and software *integration*, rather than a just a general system engineering type of consulting firm. For example, many people "call" themselves systems engineers, however, they usually deal with just one given "system" (i.e. communications, etc.). Not many people or organizations are true systems *integrators* (i.e. those who can combine multiple systems -- surveillance, communications, command, control, intelligence, etc. -- and ensure that all of the pieces work together in a synergistic manner.

Finally, it must be emphasized that the System Manager approach allows a DOT to benefit in multiple ways by capturing the System Manager's expertise both as a designer, and as an entity experienced in ITS-related contract negotiations. For the duration of any contract with a System Manager, the procuring agency will always have the System Manager's assistance for such activities as evaluation of ITS products bid by the contractors, submittal reviews, and contractor change-order analysis. Furthermore, under this scenario, the System Manager is always available to accompany the DOT to construction meetings in which it is felt that their attendance would be beneficial to the procuring agency.

C. Financing Alternatives

1. Overview

Intelligent Transportation Systems (ITS) projects are of such diverse scope that many unique combinations of existing Federal, State, local, and private financing opportunities are available to help build and operate these systems. The following sections highlight a number of specific and proven sources that can be utilized as part of a creative financing package for ITS implementation and operation.

2. Federal/State Sources

a) *Formal Programs*

With the passage of *the Intermodal Surface Transportation Efficiency Act of 1991* (ISTEA) [Public Law 102-240] and the *National Highway System Designation Act of 1995* (NHSDA) [P.L. 104-59, 109 Stat. 588], ITS project costs, generally including those costs related to both capital and operational expenses, are now eligible for 80% Federal funding under the *National Highway System* program (NHS), the *Surface Transportation Program* (STP), and *the Congestion Mitigation Air Quality* program (CMAQ) portions of the above legislations. In addition, limited funding is also available under the *ITS Corridors Program* and the *Other ITS Activities* section of the *Intelligent Vehicle-Highway Systems Act of 1991*. It must be noted, though, that all projects wishing to be considered for funding under any of these programs must compete for limited program dollars with other eligible projects (i.e. non-ITS projects for the NHS, STP, and CMAQ categories), and must be approved by the appropriate committee(s) in each region for inclusion in a metropolitan area's formal three-year Transportation Improvement Plan (TIP).

The following sections highlight key features of the above programs, detail eligible routes, and describe any special provisions that may apply to each of them. Table X-1 summarizes this information as it relates to the length of availability of operating funds, and any time limits as to when projects must be financially obligated after the funds are made available. Finally, as amended by the NHSDA in Section 101(a) of title 23, United States Code, "The term 'operating costs for traffic monitoring, management, and control' includes labor costs, administrative costs, costs of utilities and rent, and other costs associated with the continuous operation of traffic control, such as integrated traffic control systems, incident management programs, and traffic control centers".

Table CHAPTER X. -1. ITS-Eligible Federal Funding Sources For Capital and Operating Costs

PROGRAM	ELIGIBILITY		
	Routes / Areas	Capital Costs	Operating Costs
National Highway System (NHS) program	All Interstates, most urban & rural principal arterials, & the defense strategic highway network & connectors	YES	YES (for unlimited number of years if annually placed in an area's formal TIP)
Surface Transportation Program (STP)	All public roads (including NHS routes) except those classified as local or rural minor collectors	YES	YES (for unlimited number of years if annually placed in an area's formal TIP)
Congestion-Mitigation Air-Quality (CMAQ) program	Public roads in areas the Clean Air Act designated as being in non-attainment for ozone and carbon monoxide as of Federal fiscal year 1994	YES	YES (typically limited to three-years or as long as FHWA/EPA deem operations funding for a particular ITS project helps air quality)
ITS Corridors program	Funding primarily for use in up to ten corridors specifically designated by the USDOT. Limited "left-over" funds may be available for other areas	YES*	YES* (no specific limitations)
Other ITS Activities section of IVHS Act of 1991	Nationally-competitive funding for specific ITS projects. Has traditionally been used to fund "operational field tests" and other "early deployments"	YES*	YES* (no specific limitations)

*****All funds made available to states under the *ITS Corridors* program and the *Other ITS Activities* section of the *IVHS Act of 1991* require dollars to be obligated to specific projects within one year after the fiscal year they are made available, or be subject to being sent back to Washington, D.C. for re-allocation to other states for use on their ITS projects.

National Highway System (NHS) Program

Established in Title I-A, Section 1006(a) of ISTEA, and officially designated in Title I, Section 101(a) of the *National Highway System Designation Act of 1995*, the National Highway System (NHS) consists of major roads in the United States, including all Interstate routes, a large percentage of urban and rural principal arterials, the defense strategic highway network, and strategic highway connectors (see Table 3-2 for specific NHS-designated routes within the Cleveland/Lorain metropolitan area). All routes on the National Highway System are eligible to use these funds for "Capital and operating costs for traffic monitoring, and control management, facilities and programs" [Section 103(i) of title 23, United States Code, as amended by Section 301(a) of title III, NHSDA].

There are no limitations as to the number of years that National Highway System (NHS) operating assistance may be obtained for any given project (Section 301(a) of title III, NHSDA eliminated ISTEA's "startup costs" language that had limited operating assistance funding to a maximum of two-years). However, all requests for NHS operating assistance must be approved for placement in a region's formal Transportation Improvement Plan (TIP) each year.

Surface Transportation Program (STP)

Established in Title I-A, Section 1007(a) of ISTEA, the Surface Transportation Program (STP) is a block grant type program that may be used by States and localities for eligible projects on any roads that are not functionally classified as either local or rural minor collectors, including those roads that are also on the National Highway System (NHS). Projects on all STP-eligible routes may use these funds for "Capital and operating costs for traffic monitoring, management, and control facilities and programs" [Sect. 1007(b-6) of title I-A, ISTEA].

There are no limitations as to the number of years that STP operating assistance may be obtained for any given project. However, all requests for STP operating assistance must be approved for placement in a region's formal Transportation Improvement Program (TIP) each year.

Table CHAPTER X. -2. NHS-Designated Routes Within the Cleveland/Lorain Metropolitan Area

ROUTE NUMBER (NAME)	"FROM" LOCATION	"TO" LOCATION
I-71	Entire Length	
I-77	Entire Length	
I-80	Entire Length	
I-90	Entire Length	
I-271	Entire Length	
I-480	Entire Length	
I-490	Entire Length	
US-6	SR-57	Port of Lorain
	CR-747 ramps in Cleveland	SR-2
	SR-44 in Chardon	West to US-6D
US-6D	US-6	SR-44 in Chardon
US-6A	CR-750	US-42 in Cleveland
US-20	US-6	SR-10 in Lorain County
US-422	I-271 in Cleveland	SR-5 in Youngstown
SR-2	I-280 in Toledo	I-90 in Lorain County
	US-6 in Cleveland	I-90
	I-90	SR-44
SR-8	I-76 in Akron	I-271 in Cleveland
SR-10	US-20	I-480 in Lorain County
	SR-252 in Cleveland	SR-252
SR-18	US-20 in Norwalk	I-76 in Akron
SR-43	US-30 in Canton (Stark Co)	SR-91 in Cleveland
SR-44	US-422 in Geauga County	SR-2
	SR-2 in Lake County	Headlands Beach St. Park
SR-57	CR-202	US-6 in Lorain County
SR-91	SR-43 in Cleveland	US-422
	I-90	SR-2 in Lake County
SR-176F (Jennings Freeway)	I-480	I-71 in Cleveland
SR-237	Cleveland Hopkins Airport	CR-237
SR-252	I-480	SR-10 in Cleveland
	SR-10	I-90

ROUTE NUMBER (NAME)	"FROM" LOCATION	"TO" LOCATION
CR-32 (Middle Ridge Road)	SR-2	CR-202 in Lorain
CR-202 (Broadway)	CR-32 (Middle Ridge Road)	SR-57 in Lorain
CR-237 (Airport Freeway)	SR-237	I-480 in Cleveland
CR-703 (East 9th Street)	I-90	SR-2 in Cleveland
CR-747 (Herman Avenue)	CR-750 (West 49th Street)	US-6 in Cleveland
CR-750 (West 49th Street)	US-6A	CR-747 (Herman Avenue)
CR-779 (Prop. Jennings Fwy.)	I-480	North to I-71 in Cleveland

Congestion Mitigation Air Quality (CMAQ) Program

Established in Title I-A, Section 1008(a) of ISTEA, the Congestion Mitigation Air Quality program (CMAQ) directs funds toward transportation projects in areas that were designated under the *Clean Air Act* (CAA) as being in non-attainment for maximum allowable levels of ozone or carbon monoxide pollutants during Federal fiscal year 1994 (see Table X-3 for more details regarding the Cleveland/Lorain Metropolitan area), and are either still in non-attainment status or were later redesignated by the Administrator of the Environmental Protection Agency (EPA) as being in attainment and therefore subject to maintenance requirements for ambient air quality standards. All public roads within CMAQ-eligible areas, including roads within the Cleveland/Lorain metropolitan area, may use these funds "to establish or operate a traffic monitoring, management, and control facility or program if the [United States] Secretary [of Transportation (i.e. FHWA)], after consultation with the Administrator of the Environmental Protection Agency, determines that the facility or program is likely to contribute to the attainment of a national ambient air quality standard" [Section 319(b-4) of title III, NHSDA].

Table CHAPTER X. -3. *Clean Air Act* Attainment Status for the Cleveland/Lorain Metropolitan Area

POLLUTANT CATEGORY	COMPLIANCE STATUS	NOTES
Ozone: (O_3)	Non-attainment	Awaiting redesignation to an attainment (i.e. "maintenance") area by April 1996
Carbon Monoxide: (CO)	Attainment	
Particulate Matter of Size 10 Microns or Less: (PM-10)	Non-attainment	
Nitrous Oxides: (NO_X)	Attainment	
Sulfur Dioxide: (SO_2)	Attainment	
Lead: (Pb)	Attainment*****	*****Note: One site is still considered non-compliant, however it has been designated as inactive

Neither ISTEA or NHSDA specifically limits the number of years that operating assistance may be obtained for any given project. However, the FHWA's latest CMAQ guidance issued on July

13, 1995 places a typical three-year limitation on CMAQ reimbursements of ITS "start-up" (i.e. operations) costs. Furthermore, "If at some point the FHWA, in consultation with EPA, determines the operation of these new improvements [(i.e. ITS projects)] are no longer contributing to continuing improvements in air quality, further operating costs will become ineligible for CMAQ funds".

ITS Corridors Program

Established in Title VI-B, Section 6056(a) of ISTEA, the ITS Corridors Program is primarily used to finance ITS projects on "not less than three but not more than ten corridors" [ISTEA Title VI-B, Section 6056(b)] that have been specifically designated by the Federal Highway Administration (FHWA) due to their having characteristics such as severe traffic density (i.e. at least 1.5 times the national average for such class of highway), extreme non-attainment for ozone, and significant complexity of traffic patterns, etc. However, any limited left-over funding from these specific corridors may be "...allocated to eligible State and local entities for application of intelligent vehicle-highway systems in corridors and areas where the application of such systems and associated technologies will make a potential contribution to the implementation of the [USDOT] Secretary's plan for the intelligent vehicle-highway systems program ... and demonstrate benefits related to ... improved operational efficiency, reduced regulatory burden, improved commercial productivity, improved safety, [and/or] enhanced motorist and traveler performance" [ISTEA, Title VI-B, Section 6056(c)].

No specific stipulations are given that may limit the use of these funds to capital projects vs. their use as operational assistance. However, it must be noted that all funds made available to states under the ITS Corridors program require dollars to be obligated to specific projects within one year after the Federal fiscal year in which they were made available to a state, or be subject to being sent back to Washington, D.C. for re-allocation to other states for use on their ITS projects [NHSDA, Title III, Section 338(b)]. This is a key difference as compared to the NHS, STP, and CMAQ programs, in which states have up to three years after the year in which these block-grant dollars are made available to them before they are lost if not obligated to specific projects [Title 23, United States Code]. In all cases, though, the FHWA recommends that projects must be ready to be advertised for bidding for construction within a "reasonable" period of time, which is typically three-months to one-year, once they have been obligated after appropriate programming into a State's Transportation Improvement Program (STIP).

Other ITS Activities Program

Established in Title VI-B, Section 6058(b) of ISTEA, the Other ITS Activities section of the *IVHS Act of 1991* is a nationally-competitive funding source for specific ITS projects that the United States Department of Transportation (USDOT) wishes to promote. These dollars have traditionally been used to fund "operational field tests" and other "early deployments" of ITS technologies.

No specific stipulations are given that may limit the use of these funds to capital projects vs. their use as operational assistance. However, it must be noted that all funds made available to states under the Other ITS Activities section of the *IVHS Act of 1991* require dollars to be obligated to specific projects within one year after the Federal fiscal year in which they were made available to a state, or be subject to being sent back to Washington, D.C. for re-allocation to other states for use on their ITS projects [NHSDA, Title III, Section 338(b)]. This is a key difference as compared to the NHS, STP, and CMAQ programs, in which states have up to three years after the year in which these block-grant dollars are made available to them before they are lost if not obligated to specific projects [Title 23, United States Code]. In all cases, though, the FHWA recommends that projects must be ready to be advertised for bidding for construction within a "reasonable" period of time, which is typically three-months to one-year, once they have been obligated after appropriate programming into a State's Transportation Improvement Program (STIP).

b) *Creative Financing*

In addition to the above formal programs, the NHSDA enabled two new financing mechanisms that may be utilized by state and local governments to further leverage these Federal dollars: (1) Flexible matching funds, and (2) State infrastructure banks.

Flexible Matching Funds

A provision in Title III, Section 322 of the NHSDA allows private funds, materials, or services to be donated to specific Federal-aid projects, and permits a State to apply the fair market value of these donations towards the amount of matching funds that need to be provided for projects in which costs are shared with the Federal government (e.g. typically, 80% Federal dollars and 20% State/local dollars). Since ITS projects can often involve unique public/private partnerships for capital and/or operating expenditures (see *Communications Partnerships*, below) this provision can be especially valuable for implementing ITS projects during times when an agency has limited "cash" on hand to match Federal dollars, and/or during times when an agency has enough "cash" on hand to match Federal dollars, however, they wish to leverage additional Federal dollars so that the scope of a project may be expanded without expending any additional State/local matching dollars.

State Infrastructure Banks (SIB)

A provision in Title III, Section 350 of the NHSDA allows the Secretary of Transportation to enter into agreements with a maximum of ten States to establish what will be known as State Infrastructure Banks (SIB) to help finance eligible highway construction[1] and transit capital projects (i.e. no operating assistance is available). Designed to complement the regular Federal-aid program (i.e. no new funds were made available to capitalize or administer this program; though, States may contribute up to 10% of several categories of their Federal-aid highway and Federal transit funds to capitalize their bank), a SIB is an infrastructure investment fund that can

[1] "The term 'construction' means the supervising, inspecting, actual building, and all expenses incidental to the construction or reconstruction of a highway, including ... improvements which directly facilitate and control traffic flow, such as ... traffic control systems..." [23 USC Sec. 101(a), by reference in Title III, Sec. 350(l-2) of NHSDA].

be created at the State or regional (multi-State) level to make project loans (i.e. Federal funds contributed to the SIB cannot be used for traditional "grants"), and to "...provide credit enhancements, serve as a capital reserve for bond or debt instrument financing, subsidize interest rates [at or below market rates], ensure the issuance of letters of credit and credit instruments, finance purchase and lease agreements with respect to transit projects, provide bond or debt financing instrument security, and provide other forms of debt financing and methods of leveraging funds that are approved by the [United States] Secretary [of Transportation] and that relate to the project with respect to which such assistance is being provided" [Section 350(l-3) of title III, NHSDA]. Furthermore, a SIB established under this program may provide this above-described assistance to public or private entities in an amount equal to all or part of the cost of carrying out a SIB-eligible project [Section 350(c) of title III, NHSDA]. Finally, it must be emphasized that even though specific details regarding how this process will actually work are not yet available (i.e. USDOT rules and guidelines are still forthcoming), there is much potential for using SIBs in ITS-related capital projects because these projects can often have a future identifiable revenue stream (see State/Local Sources and Private/Public Sources, below). However, since the United States Secretary of Transportation must report the results of this SIB pilot program to Congress by March 1, 1997, only time will tell if this initiative will truly yield its intended results.

3. State/Local Sources

a) *Transportation User Fees*

Although some State governments have recently found it difficult to increase their state gas tax, it should be carefully examined by local officials for possible implementation on a regional basis for the funding of ITS projects since it is a direct user-paid revenue option that can raise relatively large sums of money with low administrative costs, especially if the state will collect the tax and return local revenues to the local government. Using estimates by the Federal Highway Administration (FHWA) that indicate urban areas consume about 400 gallons of fuel per person per year, a one-cent regional motor fuel tax in an area of 100,000 population could raise $400,000 per year, while only costing the average driver $4 per year. If a one-cent regional motor fuel tax were implemented in the Cleveland/Lorain metropolitan area (1990 U.S. Census population of 2,102,000), as much as $8.4 million dollars could be raised each year. Furthermore, even if this potential revenue amount was calculated based only on those in the 18 to 64 year-old age group (1990 U.S. Census group of 1,278,000 persons), over $5.1 million dollars could be raised each year. However, state legislation may be needed before a local government could levy any such motor-fuel tax.

b) *Billboard Fees*

Some transportation financiers have suggested a "user fee" for off-premise billboard advertising. The logic behind this idea is that since advertising would be useless without streets and highways, advertisers and/or sign owners could be charged a user fee based on the size of their sign and the daily traffic count of the adjoining highway. Although there are no known jurisdictions that currently impose such a fee, it is similar to the currently accepted practice of transit properties receiving small amounts of advertising revenue from messages placed inside or on the outside of buses and subway cars.

c) *State Transportation Improvement Fund*

As part of Ohio's 1989 motor fuel tax increase, a special State Transportation Improvement Fund was created for local governments. Financed by a one cent per gallon set-aside, money from this fund is distributed on a per capita basis to each of the nineteen districts statewide that administer a separate, voter-approved public works construction program.

4. Private/Public Sources

a) *Communications Partnerships*

Intelligent Transportation System (ITS) projects can require significant communication bandwidth capacities depending on the amount of data and/or video that may need to be transmitted. In addition, many telecommunications companies have specific right-of-way needs for the installation of new fiber-optic communications networks to better serve their customers' data-transmission needs. Therefore, a number of synergistic opportunities now exist that can unite private-sector needs with public-sector resources, and public-sector needs with private-sector resources. For example, public-sector resources such as significant "vacant" right-of-way strips along freeways and some major arterials can be exchanged with telecommunications companies in order to satisfy public-sector data/video communication bandwidth capacity needs. Similarly, private-sector resources such as extensive fiber-optic cable networks can be exchanged with transportation agencies in order to satisfy private-sector needs of narrow strips of right-of-way that may be used to install conduit and additional fiber-optic cables.

Some jurisdictions are utilizing this concept to much success by trading a portion of agency-owned right-of-way to a telecommunications company that wishes to install fiber-optic cables in exchange for that agency's right to use a pre-defined amount of fiber-optic bandwidth for either no fee or a significantly reduced fee. Furthermore, because Federal law now allows private donations to be credited towards the matching funds that State/local agencies must provide for Federal-aid projects (see Flexible Matching Funds, above), additional benefits can be derived from these types of partnerships because of the ability to leverage significant amounts of additional Federal transportation dollars. In fact, the Missouri Department of Transportation recently used this concept to obtain an additional $30 million dollar credit towards their portion of future ITS implementation project funding (see Appendix immediately following).

b) *Value-Added Partnerships*

The National Weather Service obtains needed dollars by selling their “raw” weather data to cable television’s *The Weather Channel* ,which repackages it into useable “information” for “re-selling” to the public through advertisements on their network. In a similar manner, some transportation agencies are obtaining needed ITS operational funds by selling their “raw” traffic data to similar “value-added” service providers who specialize in converting and repackaging this data into public-useable “information”. This information is then re-sold to radio/TV stations and/or other interested parties such as digital paging service providers who will, for a fee, provide subscribers with traffic alerts on specific routes that they may have requested as part of their paging plan. It must be noted, though, that the legality of this type of partnering, which amounts to the government selling publicly-obtained information on a for-profit basis, has not formally been approved or disapproved by any state or Federal Attorney Generals’ offices.

c) *Early Deployment Profit-Sharing*

In what may at first seem to be a reverse variation of the above value-added partnerships scenario, Early Deployment Profit-Sharing can be a way for public entities to accelerate the deployment of specific ITS User Services that neither the public sector nor the private sector may be able to do entirely on their own.

For example, as part of the initial phase of the ARTIMIS (Advanced Regional Traffic Interactive Management & Information System) ITS project currently underway in the Cincinnati/Northern Kentucky metropolitan area, it was desired to have a successful, highly visible, easily demonstrable, and publicly accessible ITS User Service that could help to build and sustain additional momentum for full ITS deployment in the region. As such, the public entities involved with this project contracted with an experienced private sector service provider to implement, for a periodic flat fee, a "Smart Traveler" dial-in telephone/cellular phone service that would provide callers with free, up-to-the-minute, route-specific information regarding traffic, transit, and road conditions.

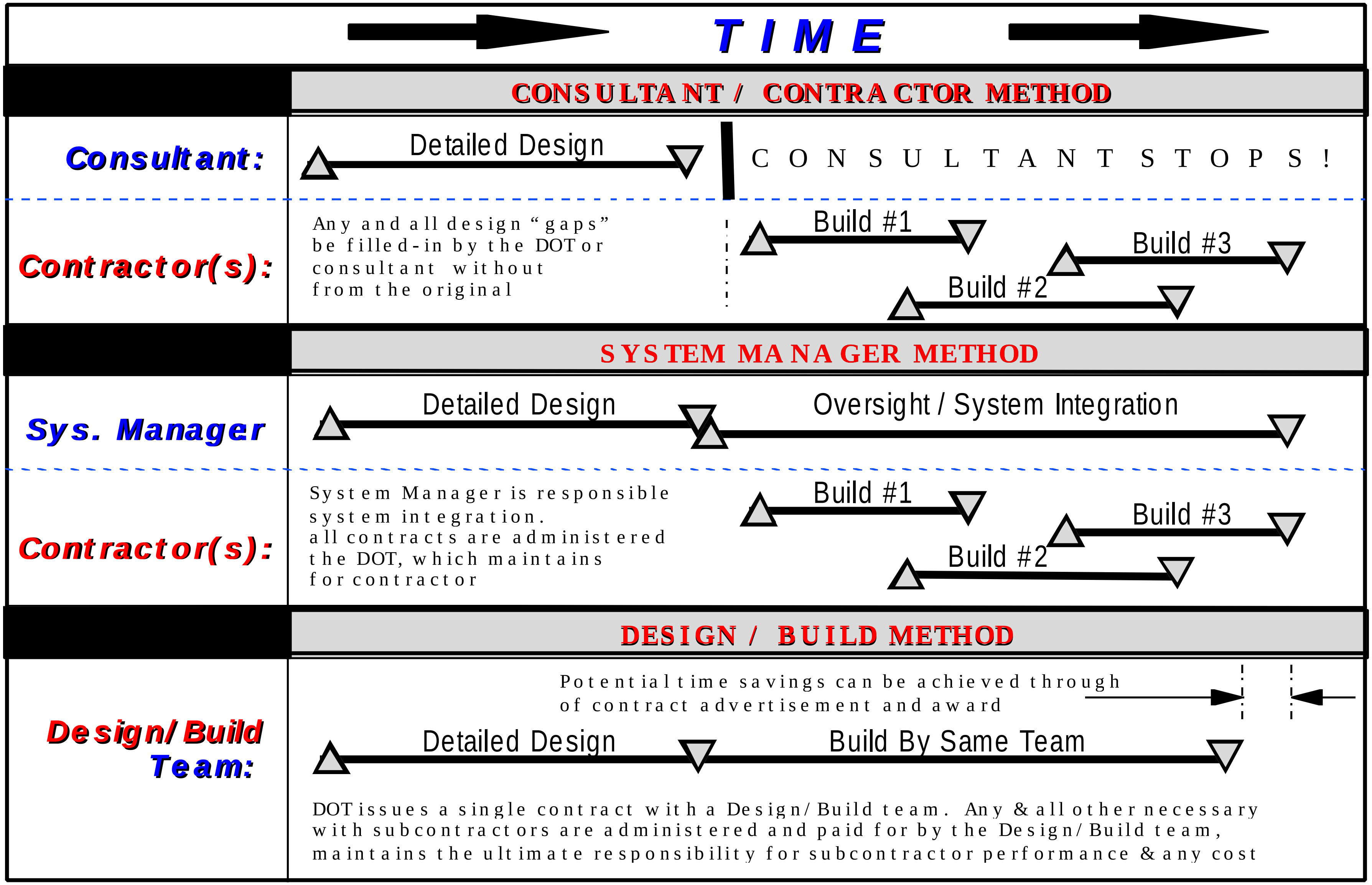
As part of this agreement, the private sector service provider put up all capital that was needed for a limited number of CCTV cameras, a traffic surveillance airplane, a system for pre-selected cellular users to act as probes for calling in traffic information, and for all necessary office space, personnel, and equipment to operate an interim control center. Within six months, this service was fully operational and being aggressively promoted by the private sector service provider.

The unique portion of this partnership, however, is that as the private sector service provider takes information they collect for Smart Traveler and sells it on a for-profit basis to television stations, radio stations, and other communication/information providers, such as those providing traffic information via data pagers and/or interactive cable television, the public sector equally shares in all profits. More specifically, the public entities receive 50% of all net revenues, calculated quarterly, with a stipulation that the private sector service provider may only claim up to 40% of gross revenues as costs associated with selling the data when determining net revenues.

Thus, the public entities are guaranteed at least 30% of all net revenues, which is paid to them monthly.

In addition, as the ARTIMIS project adds full instrumentation to freeways in the Cincinnati/Northern Kentucky metropolitan area, additional profit sharing revenues can be generated because more reliable, and thus more valuable data will be available to the private sector service provider for selling to other interested parties. Furthermore, since this particular agreement has no limit as to the actual dollar amount that the public sector is able to receive via profit sharing, this amount could theoretically exceed the flat-fee dollar amount that the public entities are currently paying to the private sector service provider for the Smart Traveler service. Thus, this particular ITS User Service has the potential to be 100% self-sustaining, and profitable to both the public and private sectors.

Figure CHAPTER X. -1. Summary of Consultant/Contractor, System Manager, and Design/Build Contracting Types



Appendix

INNOVATIVE FINANCING SPEECH BY U.S.D.O.T. SECRETARY PENA

U.S. Dept. of Transportation Speech

REMARKS AS PREPARED FOR DELIVERY
SECRETARY OF TRANSPORTATION FEDERICO PENA
INNOVATIVE FINANCING ANNOUNCEMENT
WASHINGTON D.C.
FEBRUARY 6, 1996

Today, I am happy to announce another $2 billion in creatively financed transportation projects. This is one of the President's favorite programs, because it's common sense government. In 1994, through an Executive Order, he asked all of us in the Cabinet to find better ways to invest in our infrastructure -- and we have.

So, let me get straight to the details.

There are 32 projects in 22 states -- from states on the east coast like Connecticut, Delaware, and Rhode Island to Washington out west; from Texas in the south to Ohio up north; and many, many states in between in the heartland.

For me, what stands out, first, is the creativity of the states in finding partners; and equally important our creativity in throwing out old rules and being flexible.

Many states, because of their own budget challenges, don't have cash, don't have the money to match our 80 percent contribution with their usual 20 percent. But we said: "Give us your best ideas, bring in new partners and approaches, and we'll be equally creative and flexible."

States have teamed up with city governments, metropolitan planning organizations, the private sector -- people rarely in the business of financing transportation projects who are here investing, moving ideas into action at no extra cost to the federal taxpayer.

Second, what stands out is that these projects improve the quality of life for Americans. This is about reducing commute times; it's about making our roads safer; it's about cleaning the air and boosting local economies.

Let me illustrate with four states.
In Missouri, there's a company interested in laying fiber optic cables across Missouri's interstate, in order to sell phone and data lines to businesses. The same cables also could be used as the backbone for a statewide intelligent highway network.

Governor Carnahan wants smart highways. I'm all for them, too. As you know, I've set a national goal: to have 75 cities with high-tech gear on their highways within a decade, so we can reduce the commute time of Americans by 15 percent.

Missouri is letting the telecommunications company lay the cables, and in return its Transportation Department will take strands for themselves, worth $30 million, to build a statewide smart highway system. And instead of the state matching dollars from the Department of Transportation, we'll give Missouri a $30 million credit for future intelligent transportation system projects.

Missouri's the show me state, and I hope this shows the rest of America we can use the information superhighway to finance the building of smart highways.

In Florida, Governor Chiles is constructing $200 million in projects that would normally have had to wait one to three years. He's doing this by using non-federal sources in anticipation of receiving future funds. So not only can construction begin, this allows multiple projects to be done.

In one, the Governor is adding lanes to I-4 in Tampa. This was one of the first sections of the Interstate ever built in Florida. It's often stop-and-go, bumper to bumper; and it's one of the worst spots in the state for accidents. Widening I-4 will be a big help.

Also, near the Georgia border, Governor Chiles is widening I-75. Let me ask you a question: Have you ever headed south in a minivan filled with kids, hit the "Welcome to Florida" sign, and thought the worst is over, it's a quick trip to Orlando? Then I-75 turns from six to four lanes, and it's not so quick. Widening I-75 will be a benefit both to residents and tourists.

Texas, my birth state, has a Texas-sized project: a $600-million turnpike in Dallas. This had been on the drawing boards since Lyndon Johnson was President, but was stalled until we found some flexible ways involving bond proceeds and advanced construction to fund it. I know Governor Bush likes this because he's given it a name -- his father's: the George Bush Turnpike.

Now, in Maine, Governor King has several projects that illustrate how we're making a difference in the lives of small communities.

In Madison, he's extending existing sidewalks to an elderly housing area, so senior citizens can get around.

In Milbridge, which has had economic hard times, a new road the state's putting in will anchor the revitalization of the downtown waterfront.

And in Bethel, ski country, a developer has helped pay to relocate about 1,000 feet of a road, which opens up a large tract of land. On the tract, the developer is building a $40 million hotel and theater complex, bringing jobs to the local economy.

I've focused on highways, but building on these successes, today I'm pleased to also announce $2.7 million in transit funds to support seven projects. They'll leverage $7 million in additional investment value.

In Santa Clara County, California, they're converting a parking lot to a housing development and the lease payments will be returned to the transit authority. In Florida, a statewide transit finance corporation will assure that operators, large and small, can acquire much needed replacement vehicles at a reasonable cost.

So, overall, we have $2 billion today in new highway, rail, and transit projects, and these are on top of the $2 billion the President announced last year. And a dozen states have participated in both years.

Let me update you -- quickly -- on last year's projects. About half are under construction. About half are in the engineering stage. And a few are done and operational.

One, in particular, is by Cincinnati, where four railroads tried to cross the Ohio River using two tracks. Trains were backed up as far as 60 miles; they were delayed as long as two hours. Two months ago, Governor Voinovich finished constructing 3.5 miles of a third track, that was two-thirds paid by private railroads. It's now open for business, working like it's supposed to.

There are great stories about all these projects. On average, the roads and bridges and facilities are being built two to three years sooner than if we hadn't started this program. They have created 25,000 jobs. And it hasn't cost the federal government one extra dollar.

...

And in a bi-partisan way, Congress has supported our efforts in innovative financing and has, with the National Highway System, now put many of our experimental tools into law.

So, if ever there was an example of the end of big government, and the new role Washington and the states and the private sector must play, this is it.

And I'll leave you with a prediction. One day, very soon, all 50 states will be participating.

CAPACITY ANALYSIS METHODOLOGY FOR VOLUME/CAPACITY RATIO AND LEVEL OF SERVICE

Freeway traffic congestion can be estimated in different ways. Volume, speed, and freedom to manuever (a function of density) have all been used to describe freeway operation. Although speed (and its derivative, travel time) is a major indication of service quality to drivers, it is not an adequate measure of service level for engineering purposes.

In practical terms, all recent studies suggest that speed on freeways is insensitive to flow over abroad range of flows (Chapter 3, Highway Capacity Manual, revised October, 1994). Because modern freeway operating characteristics show that speed is nearly constant over a wide range of flow rates, speed alone is not an adequate measure of performance. Freedom to maneuver within the traffic stream and proximity to other vehicles have a major impact. These two qualities are related to the density of the traffic stream. Furthermore, density increases throughout the range of flows from zero to capacity, resulting in a measure of effectiveness that is sensitive to flow throughout the range of useful values.

Density is therefore the parameter of choice for defining the level of service (LOS) for a freeway section. The LOS ranges from A (free-flow operation) through D (traffic stream has little space to absorb disruptions) and E (the density at which capacity occurs for different free-flow speeds and different widths of freeway) to F (congestion, breakdown, queue formation).

Given a volume, it is possible to calculate the service flow rate (SFR) for that volume for a particular freeway segment, and compare it to the maximum flow rate. This ratio of volume to capacity (V/C) can be compared to thresholds based on the collective professional judgement of the members of the Highway Capacity and Quality of Service Committee, as found in the Highway Capacity Manual (HCM).

The thresholds for levels of service used in this database are derived from Table 3.1 of the October 1994 HCM, which takes into account the variation in capacity (C) as a function of number of lanes (2,200 vehicles per hour per lane for four lane freeways, and 2,300 vehicles per hour per lane for six and eight lane freeways). Additional factors affecting traffic flow such as percent of trucks, section restrictions for lane widths and lateral clearance, and free flow speed (urban vs. rural) are also used in the calculation, per the HCM methodology.

The process of determining a section's volume/capacity ratio involves several steps.

1. Directional design hour volume (DDHV) is estimated from the average daily traffic (ADT) downloaded from the Ohio Department of Transportation, by factoring the ADT by the

peak hour factor (D) and percent of ADT during the peak (K). The latest values available are for 1992.

DDHV = Total Section ADT x K x D

where K ranges from 0.10 to 0.09, depending on urban or rural location, and the presence or absence of restrictions;

and where D is assumed to be 0.55 for urban areas and 0.50 for rural areas.

2. Service Flow Rate (SFR) is estimated by dividing DDHV by the peak hour directional flow factor, assumed to be 0.90.

3. A heavy vehicle factor (FHV) is calculated using the percent trucks in the section, and a truck terrain factor (E_t).

$$FHV = 1/(1 + \% \text{ trucks} \times (E_t - 1))$$

using $E_t = 1.7$ for urban areas and

$E_t = 2.8$ for rural areas.

4. The maximum capacity (C at 2200 or 2300 vehicles per hour per lane) is adjusted for the number of lanes in the peak direction, and by a restriction factor (FW) and the truck factor (FHV) determined in the previous step.

$$C_a = C \times (\text{number of lanes}/2) \times FW \times FHV$$

where FW = 1.00 for normal operation, and 0.95 for restricted operation.

5. The V/C ratio is computed by dividing the service flow rate (SFR) by the adjusted capacity (C_a):

$$V/C = SFR/C_a$$

6. The level of service (A through F) is determined from a maximum value table (derived from Table 3-1, HCM), on the following page:

		MAX. V/C RATIO	
LOCATION DESCRIPTION	**L.O.S**	**4 LANES**	**6 + LANES**
Urban & Restricted	**A**	0.250	0.239
	B	0.400	0.383
	C	0.600	0.574
	D	0.800	0.765
	E	1.000	1.000
	F	>1.0	>1.0
Urban & Normal	**A**	0.272	0.261
	B	0.436	0.417
	C	0.655	0.626
	D	0.829	0.793
	E	1.000	1.000
	F	>1.0	>1.0
Rural & Restricted	**A**	0.295	0.283
	B	0.473	0.452
	C	0.704	0.673
	D	0.887	0.849
	E	1.000	1.000
	F	>1.0	>1.0
Rural & Normal	**A**	0.318	0.304
	B	0.509	0.487
	C	0.747	0.715
	D	0.916	0.876
	E	1.000	1.000
	F	>1.0	>1.0