NATIONAL ITS PROGRAM PLAN

INTELLIGENT TRANSPORTATION SYSTEMS

VOLUME II

EDITED BY
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Abstract

The purpose of the National ***ITS Program Plan*** is to guide the development and deployment of Intelligent Transportation Systems (ITS) in the United States. This, the First Edition of the Plan was a joint effort of ITS America and the United States Department of Transportation. The plan was developed through a consensus building process which sought the involvement of the entire ITS community. The ***National ITS Program Plan*** consists of four documents: an Executive Summary, a Synopsis, and two Volumes. The Executive Summary provides a very brief overview of the goals, objectives, and recommendations presented in the National ***ITS Program Plan.*** The Synopsis provides a fifty page encapsulation of the major subject areas within the document, with special emphasis on the area of deployment. Volume I focuses on the issues of goals, compatibility, deployment, and program assessment, and Volume II contains detailed descriptions and plans for each of the twenty-nine user services.

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PREFACE

This, the First Edition of the ***National ITS Program Plan*** was a joint effort between ITS America and the United States Department of Transportation. The plan was developed through a consensus building process which sought the involvement of the entire ITS community. Over 36 individuals participated actively as authors, and well over two hundred individuals from a wide range of organizations critiqued, commented, and otherwise contributed substantially to the material presented here.

The ***National ITS Program Plan*** consists of four documents: an Executive Summary, a Synopsis, and two Volumes. The Executive Summary provides a very brief overview of the goals, objectives, and recommendations presented in the ***National ITS Program Plan.*** The Synopsis provides a fifty page encapsulation of the major subject areas within the document. Volume I focuses on the goals of ITS, compatibility, deployment, and program assessment. Volume II contains detailed descriptions and plans for each of the twenty-nine user services.

Work on the ***Nationul ITS Program Plan*** formally commenced in June of 1993. The Second and Final Drafts of the Plan, completed in May 1994 and November 1994 respectively, incorporated the comments and contributions of a substantial number of individuals and organizations. In total, more than 4,000 draft copies of the plan were distributed to ITS America members, U.S. DOT staff, and the general public through the Federal Register process. Over 200 individuals and organizations commented on one or more of the drafts.

The process of developing the ***National ITS Program*** Plan was, in itself, a valuable exercise. The focus of the first draft was upon the creation of the user service development plans now contained in Volume II. A Joint Writing Team (JWT) was formed and given the responsibility of drafting the Plan. In the second draft, the deployment and deployment considerations chapters took shape, and with the third draft, deployment scenarios emerged. Each draft represented significant advances in our thinking about ITS technology, systems, deployments, and impacts.

Overall guidance to the JWT on the direction and structure of the Plan was provided by U.S. DOT officials and the ITS Planning Committee of ITS America. The Joint Writing Team, co-chaired by Doug Robertson (ITS America) and Gary Euler (U.S. DOT ITS Joint Program Office), consisted of ITS America and U.S. DOT staff and ITS America members. The JWT members, acknowledged in Volume I, worked extensively with ITS America members, U.S. DOT staff, and the general public with a goal of insuring balanced representation of the goals, objectives, concerns, and needs of a diverse ITS community.

The field of ITS is advancing rapidly on many fronts; keeping abreast of it will require a continuing effort. This document will serve as the basis for periodic updates, which will provide information on current activities and projections for the future. Prior to the publication of this plan, the U.S. DOT undertook an initiative to study the role of government in all aspects of transportation. The results of this initiative may affect the plan.

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USER SERVICE DEVELOPMENT PLANS

1.0 INTRODUCTION

ITS systems and technologies can be described in a variety of ways. The National ***ITS*** Program ***Plan*** (NPP) was developed around the concept of "user services", e.g. the specific "services" and benefits that can be offered to users. This "user service" approach is intended to place the emphasis of discussions about ITS on the development and deployment of useful ITS products and services for a range of defined users to meet specified needs. So far, twenty-nine user services have been defined and developed through the program planning process. These User Services are a major component of the National ***ITS Program Plan*** and have formed the basis of the "user requirement" employed in the development of the National System Architecture.

This volume contains detailed User Service Development Plans for each of the twenty-nine user services. These plans address the research and development, testing and other activities needed to bring each service to the point of deployment.

2.0 THE USER SERVICES

The user services presented in this volume are defined, not along lines of common technologies, but to meet the safety, mobility, comfort and other transportation-related needs of transportation users and providers. The User Services are closely related to achieving the goals and objectives for ITS as presented in the Intermodal Surface Transportation Efficiency Act of 1991 and the strategic plans for ITS developed by ITS America and the United States Department of Transportation. The relationship of these user services to these goals and objectives is discussed in detail in Volume I, Chapter II.

The discussions of user services in both volumes of the plan assume the following:

User services are in various stages of development and will be deployed according to different schedules.

Some of the technologies required by various user services are currently available in the market place; others will require significant research and development before they can deployed. The development and deployment of an individual service will be guided by the policies and priorities established by both the public and private sector players. These policies and priorities will change over time based on changing technologies, economic factors, and market conditions.

Individual user services are building blocks that may be combined for deployment in a variety of fashions.

The combination of services deployed will vary depending upon local priorities, needs, and market forces. Within the National Program Plan, user services have been grouped into "bundles" based on likely deployment scenarios as described in Volume I, Chapter II, User Services, and Chapter III, User Services Integration.

Many user services can be deployed in rural, suburban or urban settings.

The user services are not defined as specific to a particular location; rather, it is expected that the functions and characteristics of individual services will be adapted to meet local needs and conditions. Some services are better suited to urban environments (for example, Traffic Control); some are more likely to be deployed in rural environments (for example, Emergency Notification). Other services such as advanced traveler information, have applications in both urban and rural environments.

User services may be comprised of multiple technological elements.

A single user service may require several technologies such as advanced communications, mapping, and surveillance; which may be shared with other user services. These requirements may overlap among services, and suggest services that may be deployed simultaneously.

Costs and benefits of user services depend upon deployment scenarios.

The costs and benefits of ITS user services depend, in part, on the combinations in which they are deployed. Deployment of the basic technological functions required for one service, such as communications or surveillance, may allow additional services to be deployed for a relatively small incremental cost. Conversely, the combinations of services deployed will also affect the impacts of those services.

3.0 USER SERVICE DEVELOPMENT PLANS

The User Service Development Plans in this volume follow a common structure. Each plan:

- provides a link to the IVHS goals and objectives described in Volume II,
- identifies the needs the user service is designed to meet,
- presents an operational concept for how the service might function in its fully deployed state,
- describes the technologies that the service might use,
- discusses potential costs and benefits,

- provides an assessment of the roles of the public and private sector in developing and deploying the service,
- identifies major issues or barriers that might impact development and ultimate deployment of the service, and
- lists the activities and milestones that must be accomplished to fully develop the service to a point where it is ready to be deployed.

These user service plans are expected to evolve as technology and experience change our perceptions of the possibilities. The services listed may evolve in ways we have not yet foreseen. As our understanding of user needs and technologies change, new user services may be added and others may be dropped from the list.

The user service plans do not define development or deployment policies. The decision to undertake the necessary activities to develop a user service rests with the individual public or private sector entities involved. Similarly, deployment priorities and decisions rest with the responsible deploying entity, private or public sector provider, and the consumer.

The user service plans are intended to be illustrative, without defining or implying a specific system architecture. The operational concepts and technologies described in the Plans present of vision of how the service might be deployed, rather than dictating a deployment scenario. Thus the plans do not require the use of specific technologies, but simply present the possibilities as we currently understand them.

4.0 USER SERVICE BUNDLES

As discussed in Volume I, Chapter II, user services have been grouped into ***"bundles."*** Table 1 shows these bundles of user services. The services could have been bundled in any number of ways. Table 1 presents only one of a number of possibilities. The services within these bundles may be related in a number of different ways. In some cases, the institutional perspectives of organizations that will deploy the services provided the rationale for the formation of a specific bundle. In other cases, bundles were organized around common technical functionalities. These twenty-nine user services can be bundled in a variety of configurations for deployment to fit user needs and to achieve local or regional transportation goals and objectives.

Table 1 User Service Bundles

Bundle	User Services
I. Travel and Transportation Management	1. En-Route Driver Inform ation 2. Route Guidance 3. Traveler Services Information 4. Traffic Control 5. Incident Management 6. Emissions Testing and Mitigation
2. Travel Demand Management	1. Demand Management and Operations 2. Pre-Trip Travel Information 3. Ride Matching and Reservation
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. Corn m ercial Vehicle Operations	1. Commercial Vehicle Electronic Clearance 2. Automated Roadside Safety Inspection 3. On-board Safety Monitoring 4. Commercial Vehicle Administrative Processes 5. Hazardous Materials Incident Response 6. Freight Mobility
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 System

5.0 CONCLUSION

The User Service Development Plans in this Volume form the core of the *National **ITS** Program Plan.* They describe the specific activities needed to reach deployment of these user services and achieve the goals envisioned for the program by the Congress, the general public, and the public and private sector participants involved in advancing the national ITS program.

CHAPTER 1.0 - TRAVEL AND TRANSPORTATION MANAGEMENT

1.0 INTRODUCTION

The six user services in this bundle are designed to use advanced systems and technologies to improve the efficiency and operation of the existing surface transportation infrastructure and create safer and better-informed travelers. As discussed in more detail later, these services will help to achieve the ITS program goals of enhancing mobility and productivity, increasing efficiency, and reducing the energy and environmental impacts of surface transportation.

1.0.1 User Services

The Travel and Transportation Management user services are listed in the table below, and, for the purposes of the NPP, have been numbered within the bundle as shown.

Table 1.0-l Travel and Transportation Management User Services

Bundle	User Services
I. Travel and Transportation Management	1. En-Route Driver Inform ation 2. Route Guidance 3. Traveler Services Information 4. Traffic Control 5. Incident Management 6. Emissions Testing and Mitigation

These services are described briefly below:

- The **En-Route Driver Information** service provides driver advisories to convey information about traffic conditions, incidents, construction, transit schedules, and other mode choice options to drivers of personal, commercial, and public transit vehicles. This service also includes in-vehicle signing, which provides the same types of information found on highway signs today but displays it directly in the vehicle. Full deployment of in-vehicle signing would also include customized information, such as warnings of hazardous road conditions (e.g., fog, ice) or the safe speed for a specific type of vehicle (e.g., autos, buses, large trucks).

- The **Route Guidance** service provides travelers with a suggested route to reach a specified destination, along with simple instructions on upcoming turns and other maneuvers. When fully deployed, route guidance systems will provide travelers of all modes with directions to their destinations based on real-time information about the transportation system, including traffic conditions, road closures, and the status and schedule of transit systems.

- The **Traveler Services Information** service provides a business directory, or "yellow pages," of information on travel-related services and facilities, for example the location, operating hours, and availability of food, lodging, parking, auto repair, hospitals, and police facilities. Traveler services information would be accessible in the home, office or other public locations to help plan trips, and it would also be available en-route.

- The **Traffic Control** service provides for the integration and adaptive control of the freeway and surface street systems to improve the flow of traffic, give preference to transit and other high occupancy vehicles, and minimize congestion while maximizing the movement of people and goods. This service gathers data from the transportation system, fuses it into usable information, and uses it to determine the optimum assignment of right-of-way to vehicles and pedestrians. The real-time traffic information collected by the Traffic Control service is also disseminated for use by many other user services.

- The **Incident Management** service uses advanced sensors, data processing, and communications to improve the incident management and response capabilities of transportation and public safety officials, the towing and recovery industry, and others involved in incident response. This service will help these groups to quickly and accurately identify incidents and implement a response which minimizes traffic congestion and the effects of these incidents on environment and the movement of people and goods.

- The **Emissions Testing and Mitigation** service uses advanced vehicle emissions testing systems to identify environmental "hot spots" and implement strategies to reroute traffic around sensitive air quality areas, or control access to such areas. Other technologies provide identification of vehicles that are emitting levels of pollutants that exceed state, local or regional standards, and provides information to drivers or fleet operators to enable them to take corrective action. The service also provides transportation planning and operating agencies with information that can be used to facilitate implementation and evaluation of various pollution control strategies.

1.0.2 Bundling the Travel and Transportation Management User Services

The Travel and Transportation Management user services, while in some respects quite different, share numerous commonalities that lead to their integration into a single "bundle." One of the major inter-relationships between these services is information sharing. The ***transportation*** management services (Traffic Control, Incident Management, and Emissions Testing and Mitigation) collect, process, act upon, and disseminate information about the current status and environmental impacts of the surface transportation system. The ***travel*** management services (En-Route Driver Information, Route Guidance, Ride Matching and Reservation, and Traveler Services Information), receive this information, process it, and deliver it as a service to the user. When deployed in concert, these services complement and enhance each other, creating a comprehensive system to improve the safety, efficiency, and environmental soundness of the surface transportation system, while enhancing the productivity and mobility of all modes of travelers.

From a deployment perspective, the Travel and Transportation Management services share numerous functional subsystems which also influenced their bundling. All, or most, of the services in the bundle require the basic functions of surveillance, communications, user interfaces, and data base processing. Once these basic functionalities are in place, adding another functionality, for example interagency coordination, would allow one or more additional services in this bundle to be deployed at a relatively small incremental cost. Thus deployment of some or all of these services as a bundle, or package, presents a practical and cost-effective option to deploying entities.

1.0.3 Relationship to ITS Goals and Objectives

The Travel and Transportation Management services contribute, either directly or indirectly, to achieving almost all of the goals identified for the national ITS program.

- **Increasing Efficiency**. All of the user services in the Travel and Transportation Management bundle have either a direct or indirect impact on improving transportation efficiency and alleviating congestion-related problems. The travel management services provide information that enables travelers to adjust their routes or change modes to avoid congested areas. The Traffic Control service will help to smooth flows and increase the volume of people and goods that can be moved on existing facilities. By providing improved response to, and management of, incidents, the Incident Management service will also help to reduce delays caused by congestion.

- **Reducing Energy and Environmental Impacts**. These services also have a direct impact on achieving energy, environmental, and Clean Air Act goals by allowing travelers to select routes that enable them to avoid congested areas, thus reducing unnecessary fuel consumption and emissions. Route guidance, better driver information, improved traffic control, and more efficient incident management and response will reduce the emissions and wasted fuel caused by congestion and navigational inefficiency. Emissions testing technologies can enable control strategies to reduce the number of vehicles emitting high levels of pollutants, and reroute vehicles or control access to sensitive air quality areas.

- **Enhancing Productivity**. The productivity of individuals, the commercial vehicle industry, and the economy as a whole will be enhanced by the Travel and Transportation

Management services. These services will reduce congestion and improve the efficiency of the surface transportation system, thus reducing the cost that congestion adds to both personal and business travel. In conjunction with the Electronic Payment service, these services will also reduce the costs and improve the equity associated with collecting fares, tolls, parking fees, and surface transportation taxes. The Traffic Control service will improve the quality of, and reduce the costs associated with, the collection and use of data necessary for transportation planning, operations management, and roadway construction and maintenance.

- **Enhancing Mobility**. The travel and transportation management services will enhance mobility by providing travelers with greater ease and confidence in using different routes and modes, improving travel time predictability, and reducing the stress associated with travel in unfamiliar or congested areas. These services will also help to direct consumers to required services in less congested hours.

1.0.4 Cuss-Cutting Issues

Before the Travel and Transportation Management user services can be deployed on a large scale, a number of technical and institutional issues must be addressed. The major issues which cut across most, if not all, of these services are discussed below:

- **Data Collection and Processing.** The key technical issues potentially affecting deployment of the user services in this bundle are data-oriented, since all of these services rely heavily on data collection and data processing. Technical issues must be resolved to maintain software quality and integrity; obtain and integrate dynamic information from multiple sources; maintain the resulting data bases so that they contain current, accurate and reliable information; transmit desired portions of this information to other services; and present the information to users in a useful form.

- **Interjurisdictional Cooperation**. Traffic Control, Incident Management and Emissions Testing and Mitigation, in particular, require coordination and cooperation among the many public agencies and political jurisdictions that will be involved in deployment of these services. Traditional barriers to interjurisdictional cooperation must be removed, since successful deployment of these services is closely tied to the success of the remaining services in this and other bundles.

- **Transportation Planning.** Consideration of ITS solutions must become a part of the normal transportation planning process. Among the six transportation management systems defined in the Intermodal Surface Transportation Efficiency Act (ISTEA), states are required to develop and implement a congestion management system (CMS). The CMS is a systematic process that provides information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods. ITS provides numerous alternatives to support CMS, as well as intermodal and other management systems, by providing more efficient use of existing and future transportation facilities. Since deployment of ITS will have regional impacts, Metropolitan Planning Organizations (MPO), as well as state and local transportation agencies, must become active participants in the planning, consensus-building, and coordination required for successful ITS deployment.

- **Operations and Maintenance**. Planning for and funding long-term operations and maintenance of deployed systems will be critical to their success. While easy maintenance can be included as a system design requirement, this alone will not alleviate the problem. Both public and private sector deploying entities must ensure that funds are available to operate and maintain the infrastructure and products required by the Travel and Transportation Management services.

- **Public/Private Partnerships**. Many of the Travel and Transportation Management user services have a high potential for private sector involvement in their development and deployment. While many of the end-user products and services will be developed by the private sector, these products and services will often rely on information and infrastructure provided by the public sector. Thus potential barriers to public / private partnerships and cooperation must be addressed to ensure successful deployment of these user services.

- **User Acceptance and Willingness to Pay**. The private sector will play a large role in developing and marketing Travel and Transportation Management user services. In many cases, the customer will be the general public, who must perceive that these services have value, and therefore be willing to pay for them. Thus it is critical that the general public be educated and aware of the benefits that ITS user services can provide.

1.0.5 Technology Development Timeline Charts

The functional commonalities of the Travel and Transportation Management user services provide the basis for the technology development timeline charts shown on Figures 1.0-2 and 1.0-3. For convenience, the services are split between two charts showing the ***travel*** management services and the ***transportation*** management services.

At the top, the charts show an estimate of when basic technical capabilities will be available for each function required by the services within the bundle. Using the traffic surveillance function as an example, in-pavement and video surveillance technologies are available now. It is estimated that aerial surveillance will be available by the end of 1995, and machine vision surveillance techniques will be available by the end of 1996. Further, it is estimated that enough properly-equipped vehicles will be in the traffic stream by the year 1999 to use these vehicles as probes for traffic surveillance.

The bottom half of the charts show a high level view of the major research and development (R&D), operational testing, and non-technical activities needed reach deployment of the Travel and Transportation Management bundle of user services. The services have been numbered within the bundle, and the number(s) following the activities refer to the corresponding service(s). The timeframes provide an estimate of when R&D, operational testing or non-technical activities will be completed and the services will be ready for initial deployment. Detailed descriptions of the activities are contained in the supporting material following the Gantt charts in the User Service Development Plans that follow.

The User Service Development Plans that follow describe the Travel and Transportation Management services in greater detail, and discuss the R&D, testing, and non-technical activities required to reach deployment for each of the user services in this bundle.

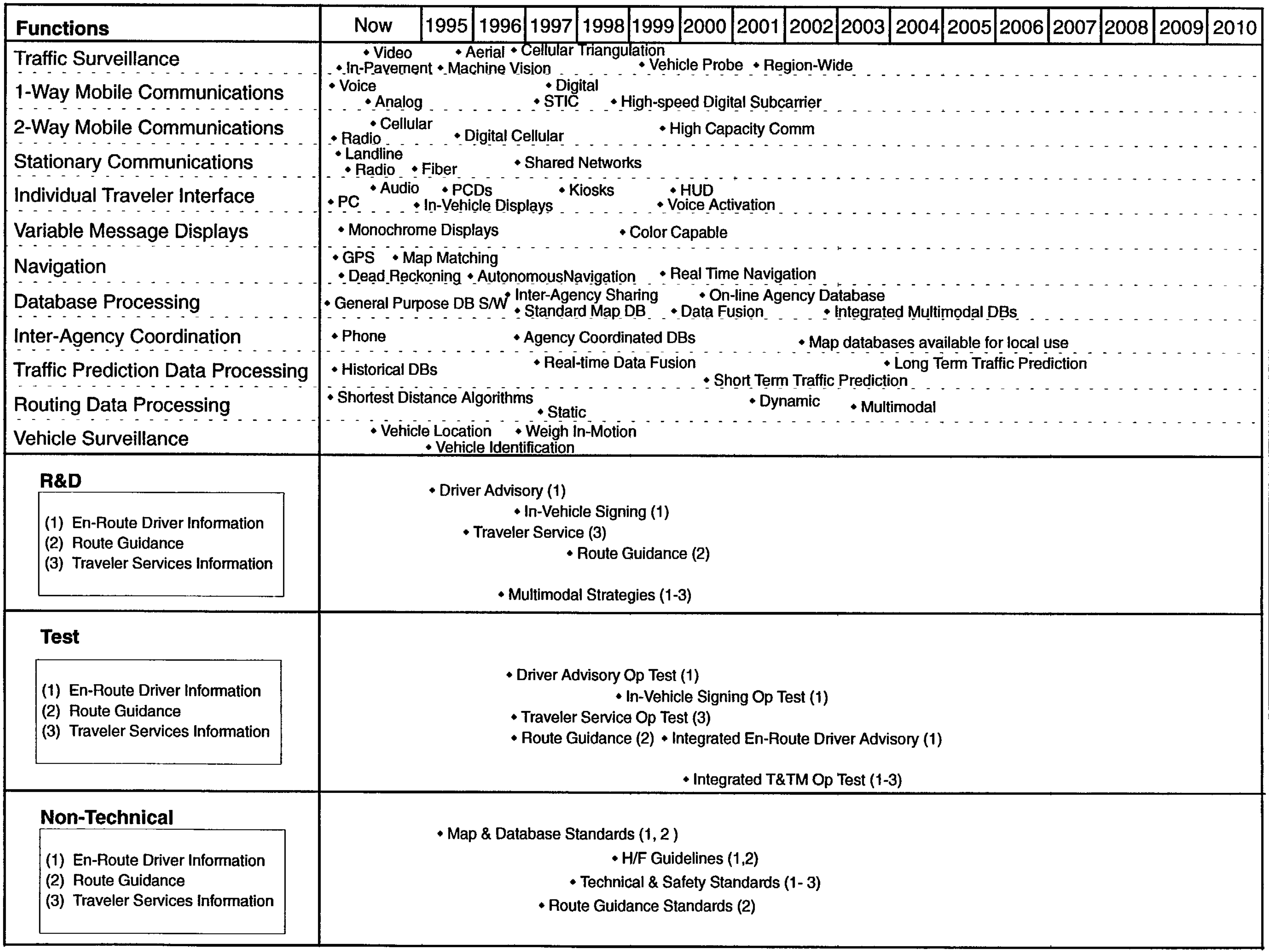

Figure 1.0-2 Travel Management Technology Development Timeline

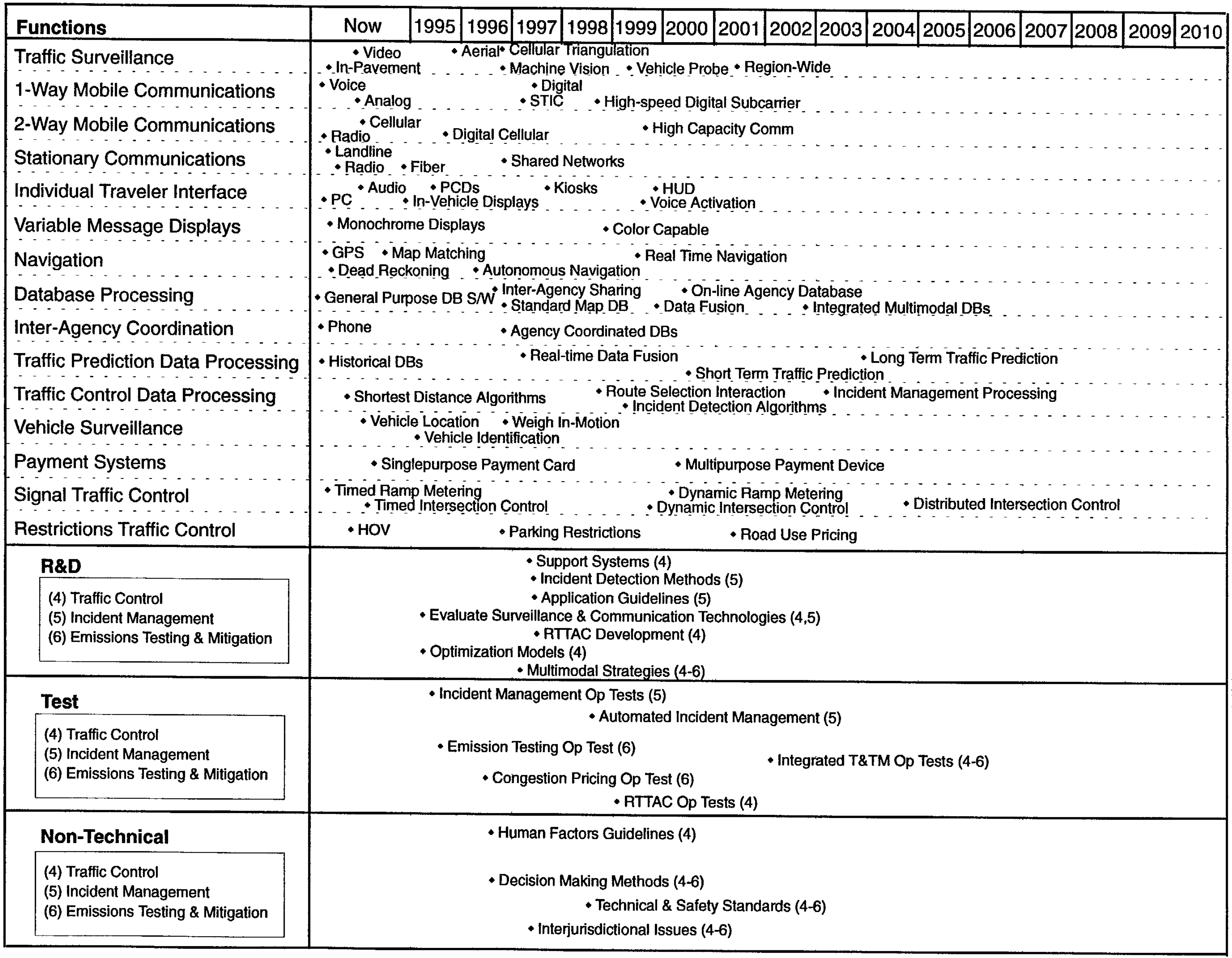

Figure 1.0-3 Transportation Management Technology Development Timeline

1.1 EN-ROUTE DRIVER INFORMATION

1.1.1 Introduction

The En-Route Driver Information user service provides travel-related information to drivers after their trips have begun. This user service includes the Driver Advisory sub-service which provides real-time information on traffic, transit and roadway conditions. The In-vehicle Signing sub-service provides in-vehicle displays of roadway signing and warnings of road hazards, traffic controls or special roadway conditions. Users of the service include drivers of private, commercial and transit vehicles.

Related services include information provided to transit riders during the trip through En-Route Transit Information (User Service No. 3.2). Information received before the start of a trip is covered under Pre-Trip Information (User Service No. 2.1). Travel Services Information (User Service No. 1.3) and Route Guidance (User Service No. 1.2) could be provided in conjunction with the Driver Advisory component of this service.

1.1.2 Needs

The nation's highways are faced with very high levels of congestion. Congestion has become a national issue, with cover stories in national magazines highlighting "gridlock" as a major public policy issue for the 1990s. Projected traffic growth, coupled with the difficulty of providing adequate additional lanes for new capacity, suggests that congestion will continue to be a major issue in many metropolitan areas.

Traffic network efficiency may be increased by permitting drivers with better information about the traffic network to choose routes that are away from congested areas, thus helping to balance the demand on the network through better use of its capacity. Advisory information will be updated dynamically throughout the trip as traffic, weather, or other conditions change. Drivers may be advised to switch to another mode of transportation, and provided with information on transit schedules and parking availability at the nearest transit stop. Currently, some of this information is available through commercial radio broadcasts, changeable message signing, highway advisory radio broadcasts and personal radio (e.g., citizens' band radio) communications. Intelligent Transportation Systems (ITS) technologies hold the promise of providing more timely and reliable information to drivers.

Safety on our nation's highways is an important public health problem. The public's concern has been manifested politically in many geographic areas by seat belt, helmet, and tough drunk driving laws, and in the marketplace by the increased market penetration of such equipment as air bags and anti-lock brakes. Design standards for highways also reflect this emphasis; however, safety is a continuing problem on the nation's highways. Rural accidents are of special concern, since 60.9% of fatal accidents occur in rural areas where collision speeds are likely to be higher. Train-related incidents in rural areas are also a concern. Traffic accidents cost the country an estimated $70 billion in lost wages and other direct costs annually. The economic loss from traffic accidents is 2% of the U.S. gross national product.

Drivers require information related to the roadway and driving environments in order to operate their vehicles in a safe manner. Providing information that more closely reflects the actual conditions of the roadway and driving conditions can enable drivers to operate their vehicles more safely by either avoiding dangerous conditions or driving in a more alert manner.

1.1.3 Service Description

En-Route Driver Information is composed of two sub-services: driver advisory and in-vehicle signing.

Driver advisory information benefits the driver in terms of convenience, cost, time, perceived safety, and reliability when incidents, roadway congestion, construction, or hazardous environmental situations occur on the roadways. Smoother traffic flow resulting from reduced congestion, improved route selection, and trips shifted to public transportation systems can significantly reduce air pollution.

In the short-term (5-10 years), there would be a fairly simple deployment of in-vehicle signing, where only a limited number of roadway signs would be equipped with the in-vehicle signing capability. These would include control signs (stop, yield, etc.) and warning signs (curve, intersection, etc.). Initially in-vehicle signing will be limited to small groups of users with special requirements. Examples of potential users include:

- Individuals who might have difficulty with night vision, in areas where the number of potential users makes the infrastructure investment worthwhile, e.g., older drivers living in areas with a large concentration of senior citizens.

- Rental vehicles that would receive voice or visual prompts at airports giving them directions on how to find the rental agency parking lot or how to exit the airport, e.g., “To head downtown, turn left at this intersection.”

- Rental vehicles in a resort/recreation area that would receive safety warnings for drivers unfamiliar with treacherous terrain or potentially poor visibility.

- Transit or commercial vehicle operators would receive information such as preferred routings or on-time status.

1.1.4 Operational Concepts

In the long term (10 years and beyond), in-vehicle signing could become more prevalent and would probably show a regional preference (i.e., some areas would deploy it and others wouldn't). Local deployment might also be funded by groups of users, such as transit operators, rental car companies, or local delivery fleets.

It is envisioned that, as more vehicles become equipped with other ITS equipment (i.e., video displays, head up displays, voice input/output), stand-alone vehicle signing equipment will become less prevalent and in-vehicle signing will be integrated with other ITS. It is anticipated that existing highway signs will, largely, remain in place. On automated highways, elimination of visual signs may be possible since all vehicles using the system will have automatic control. Many of the same types of data provided to drivers today using physical signs could be provided to automated vehicles via the same technology used to communicate in-vehicle signs. Potential long term in-vehicle signing applications include:

- Providing warnings based on the characteristics of the vehicle (e.g., warning trucks about steep ramps) or the current environmental conditions (e.g., wet pavement, ice, snow, etc.)

- Alerting motorists that they are exceeding the safe speed limit

- Warning motorists of unsafe curves, and providing safe speeds based on vehicle type and road conditions

- Warning motorists of unsafe weather conditions (e.g., ice, snow, fog, dust clouds) based upon roadside environmental sensors.

1.1.5 Technologies

1.1.5.1 <u>Driver Advisory</u>

Driver advisory functions require some equipment for each vehicle. In its simplest form, driver advisories could be provided as auditory messages using FM sideband or other relatively inexpensive communications technologies within the vehicle. Driver advisories might also be provided through a variety of electronic devices that might also be capable of receiving information at home, 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 transportation network requirements.

Communications media and technologies to provide accurate and reliable transportation information to the in-vehicle device are being researched under Federal Highway

Administration (FHWA) programs. FM subcarrier communications techniques that use existing infrastructure, spread spectrum two-way radio, microwave and infrared beacon, and cellular radio, and transponder-based vehicle-to-roadside systems are some of the candidate technologies being evaluated. Information dissemination techniques such as roadside displays, in-vehicle head up displays, video monitors, and other audio or visual presentation methods are also being evaluated.

1.1.5.2 <u>In-Vehicle Signing</u>

In-vehicle signing information would be presented to drivers in various media to accommodate the diverse needs of the driving public. Sign information could be presented to the driver as voice output and/or a head up or other visual display. Such use of audio and visual presentation to overcome hearing and visual impairments will make the surface transportation system more accessible, and increase safety, especially in adverse driving conditions.

There would probably be limited integration of in-vehicle signing with other ITS user services. That is, if the vehicle already has a head-up display or a voice response system, in-vehicle signing could take advantage of it. Otherwise, the in-vehicle signing equipment would be a stand-alone unit. In transit vehicles, where stand-alone equipment is generally not desirable, the signing equipment would conform to applicable SAE J-1708 VAN standards.

Communications media and technologies to provide accurate and reliable signing information to the in-vehicle device are being researched under FHWA programs. Directional microwave and infrared beacon communications techniques, spread spectrum radio, transponder-based vehicle-to-roadside systems, and variations of Highway Advisory Radio (HAR) radio are some of the candidate technologies being evaluated. Information presentation methods are also being evaluated and coordinated with ongoing Human Factors research and development activities to prevent information overload to the driver.

1.1.6 Potential Costs and Benefits

1.1.6.1 <u>Driver Advisory</u>

The benefits of driver advisory information will likely be experienced by all segments of the population. For example, measurable reduction in traffic congestion presents obvious advantages for the traveler, but the indirect consequences are also significant. These include reduction of “secondary” or congestion-related accidents, improved transit service, less fuel wasted from sitting in traffic jams, and fewer emissions from idling engines. Productivity gains result not only from workers who waste less time commuting, but also from lower commercial trucking costs and greater returns on capital investment in public transportation.

Increased collection and creative use of information will assist drivers in making informed decisions to use transit and other ride-sharing arrangements. Less vehicle-miles of travel will result, with associated environmental and energy conservation benefits. Personal mobility will be enhanced by making services better understood and more accessible, especially to the transportation-disadvantaged, including the elderly and disabled, and residents or visitors in geographically remote communities.

1 .1.6.2 In-Vehicle Signing

The benefits of in-vehicle signing information will likely be experienced by all segments of the population. Benefits include reduction of accidents related to "inattentive" conditions caused by driver boredom, poor weather conditions, disruptive situations, and "secondary" or congestion-related accidents. Personal mobility will be enhanced by making traffic and roadway conditions better understood and more accessible, especially to the transportation disadvantaged, including the elderly and disabled.

1.1.6.3 Public Benefit of Entire User Service

The En-Route Driver Information service has potential for high public benefit since the reduction in congestion promises to remove much of the uncertainty, aggravation, frustration, fatigue, and general stress associated with travel that many of us experience today. The potential for increased safety through reduction of traffic accidents is also considered a high public benefit.

1.1.7 Assessment of Roles

Responsibility for development of ITS services generally resides with the private sector; however, there are situations when U.S. Department of Transportation (U.S. DOT) involvement is appropriate. This would include cases with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in the En-Route Driver Information system development.

1.1.7.1 Potential for Private Investment in Develonment

The potential for private investment in driver advisory products appears to be high. These devices may be offered as stand-alone units during the early deployment of ITS, but eventually the in-vehicle units will provide the capabilities to allow the system to incorporate a wide range of user desirable features and options.

There may be less potential for private investment in in-vehicle signing; as it may have a lower degree of demand from potential users compared with other ITS services. Initially, the private market is probably limited to groups with special requirements, although recreational tourists may also represent a potential market. Relatively simple in-vehicle signing, for example a display of the current speed limit, may also attract a consumer market. As the level of sophistication of the service increases, including dynamic warnings of unsafe driving (e.g., approaching stop sign or red light at excess speed), additional demand for the service will probably evolve. Demand will also evolve as geographic coverage of the service is expanded.

1 .1.7.2 Public and Private Sector Roles in Deployment

The deployment of the En-Route Driver Information service will be a public/private partnership. While the information infrastructure that carries transportation information will likely be privately developed, the public sector will probably have a role in ensuring that mode choice and other information to encourage ride-sharing and public transportation is included. The overall public sector role in deploying driver advisory products will be medium, although the implementation of infrastructure elements will be somewhat higher. The operation and maintenance of the infrastructure (roadside) components is expected to be a public sector role, but some innovative technologies may be implemented by the private sector. The willingness of private, commercial, and transit drivers to pay for en-route driver advisories will determine the market for products and services provided by the private sector.

The public sector will implement the infrastructure elements for in-vehicle signing, while the in-vehicle components will be consumer items provided by the private sector. The operation of the infrastructure (roadside) components is expected to be a public sector role, with costs borne by the public sector.

1.1.7.3 U.S. DOT Role in Developing Service

The U.S. DOT will have both a direct and supporting role in the development of the En-Route Driver Information service.

1.1.7.3.1 ***Research and Development:*** The U.S. DOT role in research and development is high for addressing communications, database, human factors and safety issues that might impact development and deployment of the service. The private sector will be responsible largely for developing prototype products for operational testing of this service.

1.1.7.3.2 ***Operational Testing:*** The U.S. DOT role will be high in fostering public/private partnerships to operationally test this service. This service will likely be tested as part of an integrated system encompassing other services, and the U.S. DOT role will be to ensure careful evaluations of the safety and operational impacts of the service are performed. In addition, the U.S. DOT will ensure that sites are chosen to provide sufficient operational testing to accommodate a variety of final deployments.

1.1.7.3.3 ***Institutional and Legal:*** The U.S. DOT role in addressing institutional or legal barriers to deployment is medium. It is expected that many of the perceived problems will be resolved through the initiative of the private sector.

1.1.7.3.4 ***Deployment:*** The U.S. DOT will promote the development of the necessary standards and guidelines, some of which are needed to ensure interoperability, while others may be needed to ensure safety. The U.S. DOT will foster the public portion of deployment, which, for this service, might be roadside infrastructure needed to collect and disseminate real-time information about the transportation system. The U.S. DOT will also foster and encourage the inclusion of travel-related information in privately-provided information systems.

1.1.8 Milestones and Activities

Figure 1.1-l presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

1.1.8.1 Driver Advisorv Sub-Service

Issues:

The key issues are data-oriented on what technologies can be used to achieve the following: collect the data, process the data into information, maintain accurate databases and keep them current, and disseminate the information to drivers in an effective and safe manner. Non-technical issues such as product liability may also have to be addressed.

Activities:

1. Driver Advisory R&D, including studies on System Concept, Communications, Map Databases, and Human Factors.

   Questions to be addressed:

   - What methods can be used to provide driver advisories to drivers?
   - How do drivers react to and use this information?

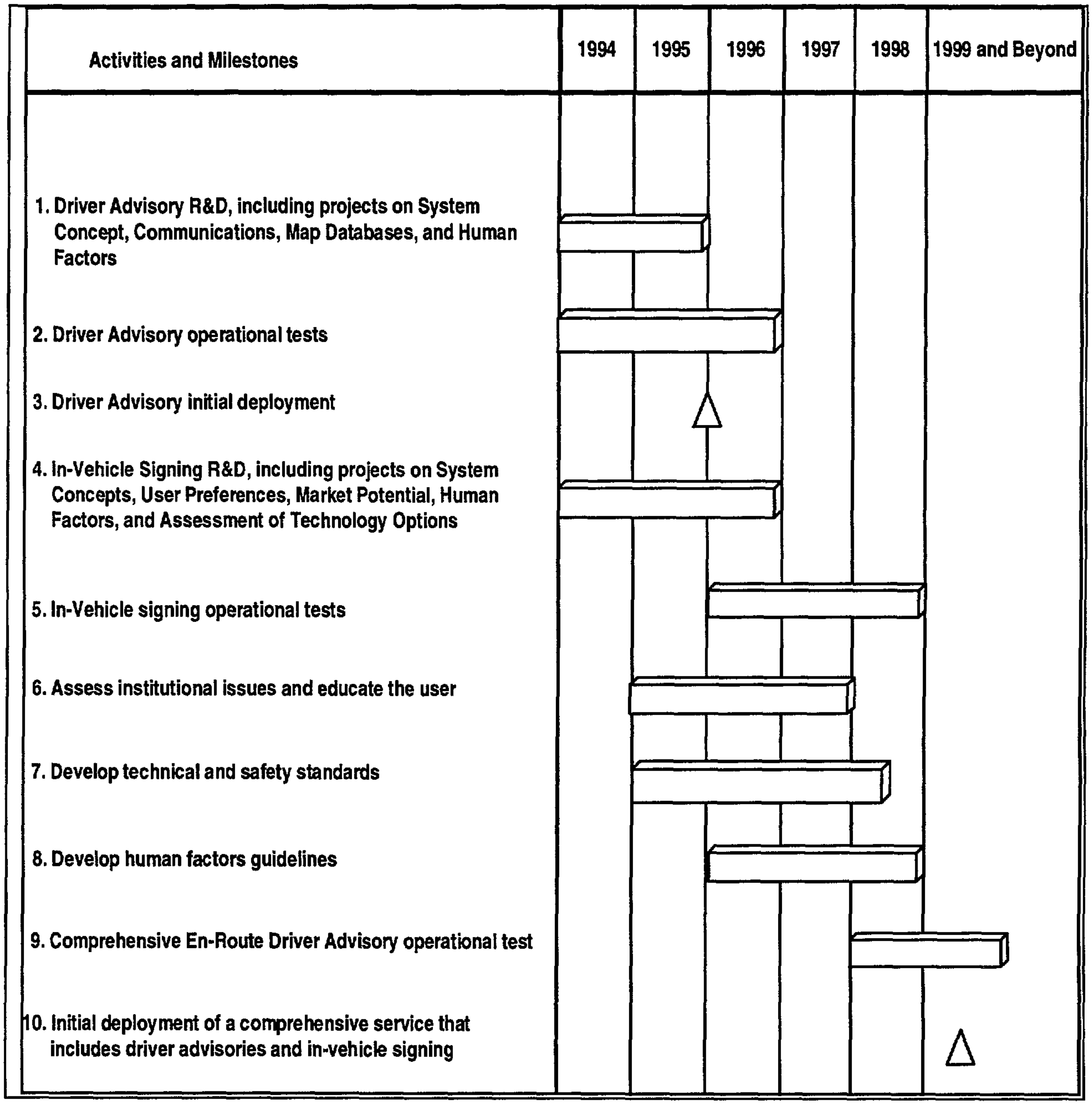

Figure 1.1-1 En-Route Driver Information Activities

- How much will drivers be willing to pay for the in-vehicle technologies that provide this service?

- What are the safety implications of these technologies?

- What are the costs/benefits associated with the technologies for providing driver advisories?

- How can information reliability be ensured?

- What are the technical constraints to using these technologies?

- What are the non-technical constraints to using these technologies?

The following R&D projects have been initiated by FHWA:

- ITS Communications Alternatives Test & Evaluation will identify and analyze communications technologies for ITS functions, and recommend preferred communications alternatives for specific ITS functions.

- ITS Radio Frequency Spectrum Planning will identify emerging RF needs of ITS, ensure spectrum is available when needed, and ensure electromagnetic compatibility with other communications systems.

- FM Subsidiary Carrier Authorizations (FM/SCA) Prototype for Traffic Information Broadcast will design, develop, and pilot test a Subcarrier Traffic Information Channel (STIC) prototype system for broadcast of traffic information to mobile receivers.

- Analysis of Traveler's Preference for Routing will analyze the criteria and decision processes used by drivers for selecting routes, choosing departure time, and rerouting when encountering congestion.

- FHWA is sponsoring a study to assess user requirements and feasibility of rural applications for advanced traveler information systems. A follow-up study will pursue development and prototype testing of the most promising concepts.

2. Driver Advisory Operational Tests (Many of these tests are also evaluating other services used in conjunction with driver advisories.)

   - Pathfinder--A control center transmitted congestion information to equipped vehicles. The information was presented to the driver in two ways: on an electronic map on a display screen, or by digital voice.

- TravelAid--Information on hazardous weather and driving conditions through the Snoqualmie Pass in Washington State will be provided to drivers.

- TravTek--A Traffic Management Center obtained traffic congestion information from various sources and used digital data radio broadcasts to broadcast this information to 100 equipped vehicles. Routes were developed based on driver-selected criteria and presented to the driver by synthesized voice and map display.

- *ADVANCE*--Up to 5000 vehicles will be equipped with in-vehicle navigation and route guidance systems to evaluate their use by local commuters in a typical urban setting. This project will also evaluate the use of equipped vehicles as “traffic probes.”

- Genesis--Portable digital Personal Communications Devices (PCDs) will be designed to receive various real-time traffic and transit information. Project is being conducted by Minnesota as part of Guidestar.

- The Washington, D.C. metro area surveillance test is evaluating the use of digital cellular packet data transmission for providing in-vehicle traveler information.

- The TravInfo project in the San Francisco Bay area is evaluating a broad array of devices for providing information to travelers both before and during their trips.

- The Idaho Storm Warning System is evaluating three environment sensors to detect hazardous visibility conditions and automatically activate messages on overhead variable message signs.

- The Herald project is evaluating the use of a subcarrier on AM as a low-cost medium for transmitting traffic messages over a wide geographic area. The test is also assessing the suitability of the International Traveler Information Interchange Standard (ITIS).

- The TransCal project is evaluating inter-regional traveler information and assessing the ability to integrate information from multiple regions, and to integrate traveler services and transit information with real-time regional congestion and incident data.

- The Atlanta en-route traveler advisory project is evaluating the use of FM subcarrier wide area communications systems and applications of 220 MHz frequency pairs.

- The Northstar project is building on an existing privately-developed traveler information service called Traveler Assurance Services (TAS). The project is evaluating the use of FM subcarrier combined with speech synthesis and cellular telephones to provided personalized incident reports and route guidance.

- Based upon results of R&D tasks, additional operational tests will be conducted on in-vehicle use of PCDs,

3. Driver Advisory Initial Deployment

- Initial deployment will be the broadcast of advisory messages to all vehicles over commercially available radio; more sophisticated deployment capabilities, including messages tailored to a specific route, will evolve.

1 .1.8.2 In-Vehicle Signing: Sub-Service

Issues:

The Driver Advisory Sub-Service issues are relevant here. In addition, a determination is needed as to which types of signs are amenable to for in-vehicle signing, and how to output them to drivers in a safe and effective manner.

Activities:

4. In-Vehicle Signing R&D

Questions to be addressed:

- What methods can be used to provide In-Vehicle Signing information to drivers?

- How do drivers react to and use this information?

- What are the safety implications of these technologies?

- What are the costs/benefits associated with the technologies for providing in-vehicle signing?

- What are the technical constraints to using these technologies?

- What are the non-technical constraints to using these technologies?

The following R&D projects will be conducted by FHWA:

- In-Vehicle Signing (IVS) R&D (1994 and beyond) will investigate technologies and issues associated with IVS systems, including a benefits analysis, definition of functional requirements, and system/concept analysis.

- If the benefits warrant continuation, a consortium will be formed to further develop, test, and make available for deployment an operational IVS system.

- Human Factors R&D will determine how in-vehicle signing can be safely deployed.

5. In-Vehicle Signing Operational Tests

- Tests will be conducted on a limited set of in-vehicle signs in order to determine how they may best displayed and merged with other types of information.

6. In-Vehicle Signing Initial Deployment

- Selected target populations of drivers are candidate users for early deployment of in-vehicle signing by the states. These populations might include elderly drivers or drivers of rental cars. Initially, only a limited number of signs (e.g., stop, yield, warnings of poor visibility, and other signs directly impacting safe operation of the vehicle) will be used.

- In-vehicle signing capability will evolve over time to provide more signs and to provide signs tailored to the driver’s needs (e.g., speed limits appropriate to vehicle class, appropriate exit signs for tourists).

1.1.8.3 Comurehensive En-Route Driver Information Service

Issues:

The In-Vehicle Signing Sub-Service must be integrated with the previously developed Driver Advisory Sub-Service to provide a comprehensive service.

Activities:

7. Assess institutional issues and educate the users

Questions to be addressed:

- What are the perceived issues related to deploying En-Route Driver Information?

- What actions are needed to address these perceived issues?

- How can users be educated to the “reality” of these institutional issues?
- When will radios be available for providing driver advisories and In-Vehicle Signing information?

8. Develop Technical and Safety Standards

- Information interchange, FM Subcarrier, map database and Human Interface standards will be developed. Safety standards will be developed by NHTSA to ensure that map or other information displays and in-vehicle signs do not distract drivers or adversely affect safety.

Questions to be addressed:

- What terminology conventions need to be developed?
- What communication standards are needed to facilitate deployment of En-Route Driver Information?

Projects:

- Map Database R&D will develop a referencing system to establish unique traffic link identity and determine database accuracy, reliability, and compatibility requirements.
- FHWA is funding the Link Identification Format and Map Database Requirements project. Recommendations will be developed for standardizing the information format, content, and accuracy of a nation-wide map database. A format for uniquely denoting links for any part of the country/North America will be recommended.
- Based on the system architecture work, in fiscal year 1995 FHWA will begin development of wireless communications protocols and driver interface standards to support traveler information user services.

9. Develop Human Factors Guidelines.

Questions to be addressed:

- How can driver advisories and In-Vehicle Signing information be presented to users in an understandable and safe fashion?
- How much information is “too much” for a user to reasonably comprehend and react to?

Projects:

- FHWA is sponsoring a contract with Battelle on Human Factors in Advanced Traveler Information Systems. This project will address the impacts of driver interfaces, information type, behavioral factors, and user demographics on the development of specific information subsystems, including In-Vehicle Signing. Human factors guidelines will be developed so that safety can be maintained.

- NHTSA will develop Federal regulations or guidelines on the safety aspects of the driver advisory and in-vehicle signing systems.

- FHWA will develop Federal guidelines on the terminology used in providing information to drivers.

- FHWA will develop human factors guidelines for enhanced display of the highway environment.

10. Comprehensive En-Route Driver Advisory Operational Test.

- FHWA will conduct a comprehensive operational test that integrates the two sub services. The test will use Federal standards and guidelines developed under activities 8 and 9.

11. Initial deployment of a comprehensive service that includes driver advisories and in-vehicle signing.

- States will deploy infrastructure to support the service.

- Integrated in-vehicle displays will be developed to provide travel advisories, routing instructions, and signing. Available information will become more sophisticated and will be tailored to the driver’s needs, the type of vehicle, and the road conditions.

1.2 ROUTE GUIDANCE

1.2.1 Introduction

The Route Guidance user service provides travelers with instructions on turns and other maneuvers to reach their destinations. These directions could be based upon static information (e.g., the road network, transit schedules). As the service matures, static information about the transportation system will be supplemented by real-time information. Thus a fully deployed Route Guidance service will rely heavily on real-time information provided by the following user services: Traveler Services Information (User Service 1.3), Traffic Control (User Service 1.4), Incident Management (User Service 1.5), Emissions Testing and Mitigation (User Service 1.6), Demand Management and Operations (User Service 2.3), Public Transportation Management (User Service 3.1), and En-route Transit Information (User Service 3.2).

This service is closely related to En-Route Driver Information (User Service No. 1.1). In many implementations, the two services could rely on the same information. However, Route Guidance also processes that information into directions for the traveler. Thus a map display (possibly supplemented by indications of roadway congestion) is considered En-Route Driver Information; Route Guidance would use this information to derive a suggested route and instructions.

Users of Route Guidance include drivers of private automobiles, High Occupancy Vehicles (HOV) and van pools, commercial operators, and public transit drivers, especially for non-route specific services such as paratransit and demand responsive transit. Thus Route Guidance is also closely related to Ride Matching and Reservation (User Service No. 2.2), Personalized Public Transit (User Service No. 3.3), and Commercial Fleet Management (User Service 5.6), especially for time-sensitive commercial deliveries. In addition to in-vehicle devices, Route Guidance would be available through hand-held or other personal portable units, to non-vehicular travelers such as pedestrians or bicyclists.

1.2.2 Needs

When travelers are in familiar surroundings and the conditions of the transportation systems remain somewhat constant, generally the maneuvers required to travel to desired locations are well-known. However, as conditions change, better routes usually exist. Being able to determine what these better routes are is a challenge to the traveler. It is also very discomforting not knowing how to maneuver through unfamiliar areas. Traveler safety can also be increased by alerting a driver, pedestrian or bicyclist to unknown route impediments, such as dangerous alignments or unusual geometries.

Real-time route guidance information can also assist commercial vehicle operators in locating delivery points and in facilitating "'just-in-time" pick-up and delivery services. Commercial productivity can be improved with better routing information.

This service will also facilitate carpooling, ride matching and flexibly routed paratransit services by providing routing instructions to passenger pick-up points based on real-time traffic information.

Providing travelers with improved routing instructions and better routes can improve the quality of travel for the entire transportation network. Overall delay can be decreased by allowing informed travelers to avoid unnecessary delays. Travel delay, wasted fuel, and subsequent environmental pollutants can be reduced by reducing wasted travel time due to navigational error and lost travelers. Traveler stress is decreased by providing additional confidence and comfort in traveling to desired destinations.

1.2.3 Service Description

When fully deployed, Route Guidance systems will provide travelers with directions to selected destinations. These directions will be based on information about current conditions of the transportation systems. This will include current traffic conditions and information on events that are taking place that influence travel routes, such as street closures or construction. Route guidance systems will also have access to status and schedules of transit, rail and other transportation systems to facilitate intermodal connections. Portable devices for use by pedestrians or bicyclists will provide directions that avoid unsafe or inaccessible routes. Directions will generally consist of simple instructions, such as arrow displays or simple voice messages instructing which way to turn onto particular streets, roads, walkways, or transit facilities.

1.2.4 Operational Concepts

Route Guidance systems have essentially two modes of operation: static and real-time. Static systems rely upon unchanging transportation network information to provide travelers with routing instructions to specific destinations. This static information includes mapping information about the roadways and scheduling information for transit, rail or other systems. Real-time systems enhance the information of static systems by providing current travel condition information, such as traffic conditions or dynamic transit schedule information. Further developments in areas such as dynamic traffic assignment, will allow routing instructions to be based on predictions of the traffic conditions that will occur as the trip progresses.

Route Guidance systems operate in two different configurations, depending on the location of the route selection process. Route determination can either be done onboard a vehicle (or other mobile device) or by processors installed in the transportation system infrastructure. The location of this process determines whether the system is mobile-based or infrastructure-based. Mobile-based static systems are autonomous guidance systems that can operate independent of any infrastructure. Mobile-based real-time systems can operate as autonomous systems, but when available, receive information about the transportation network from the infrastructure and use this real-time information to determine routing. Infrastructure-based static systems use communications between route guidance devices and the infrastructure to receive information on the traveler's desired destination, calculate a route and then provide directions back to the traveler. If current, real-time information is included in the route determination, these systems become infrastructure-based real-time systems.

There are a number of ways that the route guidance device can exchange information with the traveler. Visual displays, keypads, and other touch-sensitive devices can be used by the traveler to enter information and view routing instructions. Audible instructions also may be provided to travelers through computer-generated voice. The traveler may also be able to enter information into the device through a voice-recognition system.

There are a number of different procedures that can be used to determine the traveler's routing. Mobile-based systems will use programs that use the best information available to provide routing instructions to the traveler based upon certain parameters provided by the traveler. These parameters might include avoiding expressway-type highways or areas inaccessible or unsafe for bicyclists. These parameters enable a traveler to customize the routing selection process. Likewise, infrastructure-based systems can permit a traveler to customize a routing, but they can also use the destination of the traveler to provide a routing that is "customized" for the entire transportation network. With this destination information, an infrastructure-based system can determine the extra demand on a transportation system and provide routing information to travelers that is based upon this predicted demand.

1.2.5 Technologies

Route Guidance systems require a navigable digital map database that provides accurate, current, and complete information on the roadway network and its attributes. Navigable attributes include the identification of one-way streets, the location of traffic signals, stop signs or turn prohibitions, and other characteristics which affect the provision of accurate route guidance information.

Route Guidance systems also require a position determination function to permit a route guidance device to locate itself on a map. A number of technologies exist to perform this function. The most sophisticated of these are triangulation techniques, or using trigonometric functions and known reference sites to calculate a location. The known reference locations may be terrestrial, such as those used in the LORAN-C system (land-based radio navigation system operated by the U.S. Coast Guard), or satellite-based, such as used for the Global Positioning System (GPS) or the GLONASS (former Soviet, now Russian, version of GPS) System. To provide the accuracy required by Route Guidance applications, these systems are usually supplemented by dead reckoning and map-matching, described below, to more precisely place the vehicle on the road network.

A simpler locating system consists of reference sites that send their location to devices that are very near. This system may be thought of as a system of “sign-posts” that can transmit location information to route guidance devices as they pass nearby. Either of these systems may be used by any route guidance device, whether mounted in a vehicle or hand-held. Another technique that may be used by vehicle-based devices is known as dead-reckoning. Dead-reckoning uses very accurate sensors to measure how far and in what direction a device or vehicle traveled and keeps track of these measured differences from a starting location to determine a device’s location. Dead-reckoning devices in vehicles may also use map-matching techniques whereby the determined location is checked against a map of roadways. This technique assumes that the vehicle will generally remain on roadways and will correct the determined location to position the vehicle on a known roadway.

The means for getting information from and providing routing instructions to travelers may involve many technologies. Visual displays for showing travelers which way to turn, how far to their destinations and other information may be computer screens that can be carried by the traveler, such as personal portable devices. These may also be “touch-screen” displays, enabling travelers to enter information about desired destinations. Displays similar to these can also be used in vehicles to provide information to travelers. Driving instructions may also be given through head-up displays, where the instructions are projected onto the windshield. Therefore, the driver does not need to look away from the roadway to get the routing information. Voice instructions are another means of providing information that does not require the traveler to divert his/her gaze. Similarly, voice recognition technology can permit the traveler to enter information into the route guidance system without requiring any diversion of sight or additional movements by the traveler.

1.2.6 Potential Costs and Benefits

Perhaps the greatest direct benefit to the route guidance system user is the reduction of navigational waste for both personal and business travel. In other words, travelers will not waste as much time selecting a route and subsequently following the route. In systems with real-time traffic information, drivers will be provided with the least-congested route, further reducing travel time. In addition to reduced overall travel time, personal stress can be reduced by not having to search for landmarks or signs for routing directions. From a transportation system and general society point of view, this reduced time will result in reduced environmental impacts from vehicles.

1.2.7 Assessment of Roles

The responsibility for development of Intelligent Transportation Systems (ITS) services generally resides with the private sector; however, there are situations when the U.S. Department of Transportation (U.S. DOT) involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and evaluation of systems with high public benefit but low commercial potential.

Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in Route Guidance development.

1.2.7.1 Potential for Private Sector Investment in Development

The potential for private investment in the route guidance service, including development of routing algorithms, route data bases, and hardware, appears to be high. While there can be significant benefits derived from autonomous route guidance systems, unless the route guidance system can provide instructions based on current information, the market will probably remain low.

1.2.7.2 Public and Private Sector Roles in Deployment

Deployment of dynamic route guidance systems will be a public/private partnership, because of the interdependency between the end-user route guidance device and the supplier of current transportation-related information. It is likely that the public sector, at least initially, will be responsible for deploying the infrastructure that is required to provide real-time communications between the supplier and processor of current transportation-related information and end-user route guidance systems. However, the private sector may also provide the real-time information since it will increase user benefits and thus increase the market potential for route guidance systems. The public sector will likely be the accumulator and processor of real-time information, primarily through the Traffic Control service, although the information networks necessary to collect and disseminate information for dynamic route guidance systems might be provided by either the public or private sectors.

1.2.7.3 U.S. DOT Role in Developing Service

The U.S. DOT will have both a direct and supporting role in the development of the Route Guidance service.

1.2.7.3.1 ***Research and Development:*** The U.S. DOT role in research and development is high for addressing technical issues such as communications and map database requirements, that might impact development and deployment of the service. The U.S. DOT role will also be to support research in human factors related to the display and provision of route guidance information to travelers. The private sector will be responsible largely for developing prototype products for operational testing of this service.

1.2.7.3.2 ***Operational Tests:*** The U.S. DOT role will be high in fostering public/private partnerships to test this service operationally. This service will likely be tested as part of an integrated system encompassing other services, and the U.S. DOT will ensure careful evaluations of potential safety and operational impacts of the service. Other issues to be examined through operational testing include how current information impacts the use of route guidance systems, and how users perceive the value of route guidance systems. In addition, the U.S. DOT will ensure that sites are chosen to provide sufficient operational testing to accommodate a variety of final deployments.

1.2.7.3.3 ***Institutional and Legal:*** The U.S. DOT role in addressing institutional or legal barriers to deployment is medium. It is expected that many of the perceived problems will be resolved through the initiative of the private sector.

1.2.7.3.4 ***Deployment:*** The U.S. DOT will promote the development of necessary standards and guidelines, some of which are needed to ensure interoperability, while others may be needed to ensure safety. The U.S. DOT will also foster the public portion of deployment, which, for this service, is the roadside infrastructure required for the collection and dissemination of information about the transportation system.

1.2.8 Milestones and Activities

Figure 1.2-1 presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

1.2.8.1 Issues:

1. What technologies and techniques are currently available for collecting, processing, and disseminating route guidance information?

2. What technologies and techniques need to be developed for collecting, processing, and disseminating route guidance information?

3. What are the safety implications of the various techniques for presenting route guidance information?

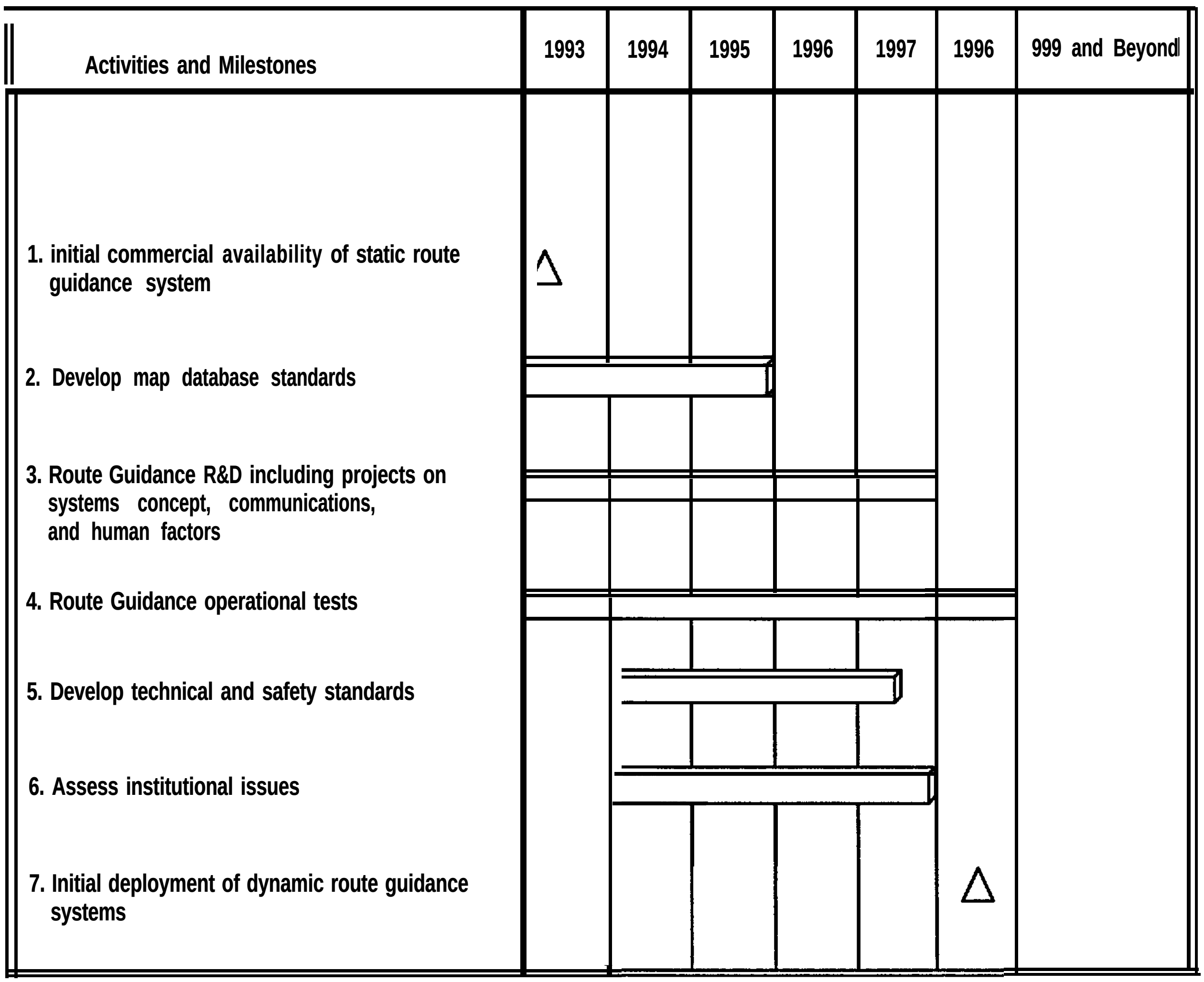

Figure **1.2-1** Route Guidance Activities

4. What are the liability issues associated with providing incorrect route guidance information?

5. How do users react to and use route guidance information?

6. What technical difficulties must be overcome to ensure that the map database is accurate and up to date?

7. What issues must be resolved concerning individual vs. system optimization and cross-jurisdictional optimization of vehicle routes?

8. How large are the actual time benefits to the user, after taking into account the time to initialize the system, download information, etc.? Is the gain in travel time significant enough to justify the use of the route guidance system by the driver?

9. How can route guidance best be integrated with other user services, such as Traffic Control (User Service No. 1.4) and Incident Management (User Service No. 1.5)?

1.2.8.2 Activities and Milestones:

1. Initial commercial availability of static route guidance systems

2. Develop map database standards

   - The Society of Automotive Engineers (SAE) Map Database Committee is developing standards so that a common referencing system for identifying traffic link I.D.s can be established.

   - The Federal Highway Administration (FHWA) is funding the Link Identification Format and Map Database Requirements project. Recommendations will be developed for standardizing the information format, content, and accuracy of a nationwide map database. A format for uniquely denoting links for any part of the country/North America will be recommended.

3. Route Guidance R&D including projects on system concept, communications, and human factors

   - FHWA is sponsoring a contract with Battelle on Human Factors in Advanced Traveler Information Systems. This project will address the impacts of driver interfaces, information type, behavioral factors, and user demographics on the development of specific information subsystems, including In-Vehicle Routing and Navigation Systems (IRANS). Human factors guidelines will be developed so that safety can be maintained.

- An FHWA study, "Analysis of Travelers' Preferences for Routing," will analyze the criteria and decision processes used by drivers for selecting routes, choosing departure time, and rerouting when encountering traffic congestion.

- An FHWA study, "ITS Communications Alternatives," will investigate various communications issues and validate particular technologies for ITS functions.

4. Route Guidance Operational Tests (Note that these tests are also evaluating other services used in conjunction with route guidance)

   - Pathfinder and TravTek are recently completed operational tests that included a route guidance component.

   - The *ADVANCE* project is a cooperative effort among FHWA, the Illinois Department of Transportation, Motorola, Inc., and the Illinois Universities Transportation Research Consortium (IUTRC) in the northwest suburbs of Chicago. Vehicles will serve as probes, providing travel time data to a Traffic Information Center (TIC). The TIC will fuse the probe and other real-time data and transmit the information to the equipped vehicles. The vehicles will then generate and present dynamic route guidance instructions to the drivers.

   - FAST-TRAC is a public/private cooperative effort in Oakland County, Michigan. For the route guidance portion of the test, vehicles will be equipped with the Siemens Ali-Scout system. Infrared beacons will be installed at critical locations to provide a continuous exchange of real-time traffic and route guidance information.

   - Project Northstar in New York is evaluating the effectiveness of FM subcarrier, combined with speech synthesis and cellular technology, to provide personalized incident reports and route guidance.

5. Develop technical and safety standards

   - Information Interchange, FM Subcarrier Protocol, and Human Interface standards developed under the En Route Driver Information user service are applicable here and will accommodate route guidance.

   - Based on the system architecture development effort, in fiscal year 1995, FHWA will begin development of wireless communication protocols and driver interface standards needed for advanced traveler information systems.

   - The FHWA will develop and test a multi-modal spatial data transfer standard.

6. Assess institutional issues

- Legal issues must be addressed. These include the impact of the recommended routes on neighborhoods (e.g., routing through residential streets or in front of a hospital) and on drivers (e.g., routing through unsafe areas).

- There are institutional issues in keeping map databases current (e.g., assigning responsibility for disseminating information about new streets) and in the implications of errors in the databases.

- Long-term coordination will be needed to address the potential institutional problems of developing, and then maintaining, accurate, compatible map databases nationwide.

7. Initial deployment of route guidance systems

- Initial deployment of route guidance systems will be static systems which do not rely on real-time information. Such systems are being test-marketed by the automobile industry in limited areas.

- Deployment of dynamic route guidance systems will probably occur initially in limited areas of the country as real-time traffic information becomes available.

1.3 TRAVELER SERVICES INFORMATION

1.3.1 Introduction

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" type, organized to provide quick access to services in the local vicinity of the traveler.

The information will be accessible to the traveler in the 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. Information would be available regarding the location and status (e.g., operating hours, etc.) for a variety of services, such as food, lodging, parking, car service/repair facilities, hospitals, and police stations. This service could be particularly useful to the commercial vehicle operator traveling in unfamiliar areas. An additional feature of this service would allow the traveler to communicate with service providers interactively to make and confirm reservations, and possibly, to purchase tickets, or guarantee payments for reservations.

The type of information that will be available to the traveler and the nature of the presentation will vary depending upon whether the service is accessed by the traveler in fixed locations, while riding in a transit vehicle, or while driving a private or commercial vehicle. Safety considerations will tend to restrict the type and amount of visual information that will be provided to a driver while the vehicle is in motion. When the vehicle is parked, the driver will be free to access all available information and to conduct transactions in an interactive manner.

1.3.2 Needs

This service addresses several traveler needs, including the safety-related need **to** quickly locate nearby support facilities such as car service/repair stations, hospitals or police stations, etc. The ability to identify nearby facilities and to determine the traveler's location will reduce traveler anxiety, add to the feeling of security, and also reduce the possibility of the driver becoming lost while searching for them. Additionally, travelers in remote areas would be advised of the unavailability of certain services which also reduces time spent searching for them.

Another need that will be partially satisfied by this service will be the ability to inform the traveler of the status and location of facilities such as parking or other concessions in highly congested commercial/tourist areas, thereby helping to reduce congestion levels caused by drivers searching for a business establishment or for available parking nearby.

1.3.3 Service Description

The Traveler Services Information user service will provide up-to-the-minute information related to the conditions, status, and availability of traveler services, including motorist services, tourist services and other travel-related items, regardless of the traveler's mode. When fully deployed, this service will connect users, sponsors, and providers in an interactive manner to request and provide needed information. Travelers may request general information about an area or specific information about a desired service, e.g., lodging, food, parking, or special events. This would be analogous to yellow pages directory that is available on-demand. A further capability that could be supported would permit the traveler to request actions of the service provider, for example, making lodging or dining reservations. Also, more specific information may be requested, such as hours of operation, parking, tourist activities, daily events, etc.

1.3.4 Operational Concepts

Traveler 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 or accessed through dial-up telephone lines, similar to the recorded weather information currently provided in most metropolitan areas. As personal portable advanced traveler information systems (PPATIS) become more prevalent, traveler service information could easily be provided as an additional capability on these devices.

Another mechanism for providing this information would be through the use of "yellow pages"-like directories of traveler services information that could be stored on CD-ROM and read/accessed by properly equipped computers at the home or office, or at information kiosks. Kiosks could be located in key public areas such as at rest areas along the interstates or near major cities, activity centers, or tourist attractions. They could also be located at service plazas. A motorist could access the system while in the vehicle, requesting information on service facilities or lodging, although, for safety reasons, this service may only be available when the car is stopped and the transmission is set in park.

Airline travelers looking for local points of interest and/or special events could access the system through kiosks located at the airport. This capability could be closely integrated with the services provided by the Pre-Trip Travel Information user service.

Traveler Services Information may overlap with other electronic traveler services such as banking, shopping, ticket purchase, etc. A more comprehensive, integrated service could include the ability to support financial transactions where the traveler could be billed automatically for the purchase of tickets or reservations.

1.3.5 Technologies

The following is a list of technology areas that could play key roles in the provision of this user service area:

- CD-ROM Directory databases (static databases of "yellow page" information both for vehicles and at information kiosks)

- Two-way communications for: 1) interactive request/access to databases, 2) reservation request/confirmation, 3) providing the location of the traveler for location-specific information, and 4) financial transaction support

- Query language and procedures for efficient, user-friendly access to databases

- User interface for presentation/display of services information

1.3.6 Potential Costs and Benefits

The potential costs and benefits of Traveler Services Information have been broken into public and private sector discussions.

1.3.6.1 Public Sector Costs

The major costs for the public sector would be administrative and regulatory primarily . The public sector would be responsible for establishing the regulations that would govern the development, implementation, and operation of the traveler information services in urban and rural areas. Once the services are in place, the public sector would have the responsibility for any administration and enforcement functions required. Decisions would need to be made as to whether this function would best be done by a State level agency or by local agencies, especially within a major urban area.

1.3.6.2 Private Sector Costs

The major private sector costs would be in the development, implementation, and operation of the infrastructure that is needed in order to provide the services. The infrastructure costs would include both the hardware and software systems needed to support the provision of the service. These costs are expected to be significant, especially in dense, congested urban areas.

1.3.6.3 Potential Benefits

Traveler Services Information has moderately high potential benefits, These benefits include the following:

- Reduction in the amount of wasted travel. By having easily accessible and usable traveler services information (including type of services available and instructions for locating the service provider), motorists could easily find the needed services without getting lost or making extra trips to locate specialty services.

- Savings of energy and reduced air pollution. By reducing wasted travel, energy and pollution savings would be realized.

- Reduction in accidents. By having information that is accurate and reliable, motorists would not be distracted while searching for services. Instead they would be able to concentrate on driving rather than looking for the required services.

- Increased convenience for the traveler. Accurate information would be available regarding the location of needed services (e.g., fuel and/or repair facilities).

- Improved marketing and service exposure. Having a readily accessible medium for the public and private sector providers of services (including tourist attractions and special events) can improve service marketability and exposure.

- Safety. By having quick, accurate access to service information, emergency services and facilities can be located by the traveler.

1.3.7 Assessment of Roles

Private/public sector roles for development, deployment, and operations will be variable from one region or area to another, depending upon the state and local views of the service and on the initiatives from private sector organizations. Patterns will develop that must be evaluated over time to identify those approaches that add to the safety of the traveler and efficiency of the traffic network and serve the overall needs of both the public and private sector organizations participating in the provision of this user service.

1.3.7.1 Potential for Private Investment in Development

The private sector role in the development and deployment of this user service will be high. With the exception of the development of information transfer and safety standards, which must be developed jointly by the public and private sectors, most of the actual deployment of this service will be a private sector endeavor.

The types of private sector organizations that are expected to play major roles in the development and deployment of this service are the phone companies and other providers of "yellow pages" information, local business organizations in the regional or local area covered by the service including providers of traveler/motorist/tourist services, and providers of traveler information (i.e., motor clubs and travel map providers). In addition, groups of local businesses may develop special focus information kiosks for resort/tourist areas. These kiosks may be located at rest stops along interstates/access roads in coordination with other public sector facilities.

1.3.7.2 Private and Public Sector Roles in Deplovment

The role of the public sector for deployment of this service will be low. This user service will in all likelihood "piggyback" on other user services that may be provided by the public sector (i.e., Pre-Trip Travel Information, Route Guidance, and the En-Route Driver Information services). This user service will have very little direct impact on public sector efforts to deploy other ITS services. In fact, this service may provide additional incentives to the private sector to become involved in public/private ventures and to provide a means for sharing costs of deploying an ITS infrastructure to support other user services.

The following is a list of potential areas of public sector involvement and/or interest areas within this user service:

- Public Service Information
  - Event-related traffic information
  - Event-related routing and schedules
- Safety Standards
  - Displays (Graphic/Auditory)
  - Information Content/Presentation
- Common Information Channel (potentially sharing of a common traffic information channel in rural or small metropolitan areas, or use of a private communications network).
- Outreach -- Common to all initiatives
- Information Kiosks -- public sector agencies may approve the co-location of private sector kiosks in public rest facilities or may permit private sector organizations to operate a combined traffic information and traveler services information channel as a franchisee.

- Public Sector role in resolving Institutional Issues and deployment options
  - Should (and how should) public/private information be combined?
  - Merge and pay for public information carried on private channels.
  - Private information and transactions included on Public channels.
  - Authorize private sector (franchisee) to use Public channels but require inclusion of public information.

1.3.7.3 U.S. DOT Role in Developing Service

The U.S. DOT will have a very limited role in developing this service.

1.3.7.3.1 *Research and Development:* The U.S. DOT has no direct role in research and development for this service. However, R&D activities for other services, such as addressing communications, safety, human factors, or other issues, might be applicable and of interest to private sector developers of this service.

1.3.7.3.2 *Operational Tests:* The U.S. DOT role in operational testing of this service is low, except where it is provided by the private sector as an additional service in an operational test of an integrated system. The U.S. DOT would participate in these tests, since the value added by this service might make other user services more appealing to the consumer, thus increasing user acceptance and willingness to pay for ITS.

1.3.7.3.3 *Institutional and Legal:* The U.S. DOT has no direct role in addressing institutional or legal issues, except as they relate to how this service might impact, or be deployed with, other ITS user services.

1.3.7.3.4 Deployment: The only U.S. DOT role in deploying this service is to ensure safety.

1.3.8 Milestones and Activities

The following section describes the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The supporting text identifies probable issues and describes activities, with associated projects, to address these issues. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

1.3.8.1 Issues

From a Federal perspective, the key issue is how this service can be provided while safety is maintained (e.g., providing the service while vehicles are in motion.)

From the perspective of a private sector provider, issues might include:

- Maintenance and updating of the business directory data.

- Advertizing aspects - Will advertisers pay extra to be first in the list? What about unsolicited advertising, e.g. while driving down the freeway, will the driver be bombarded with "specials of the day" at various exits?

- Additional services, e.g., special directories for special interest groups. Does there need to be a standard to allow others to add these specialty databases to the business data? Would this be something along the lines of the Japanese CD-CRAFT standard?

1.3.8.2 Activities

1. The only role for the U.S. DOT in this service is to ensure safety. Otherwise, the provision of this service is a private industry/free marketplace responsibility. Other Federal agencies, for example the National Park Service and the National Forest Service, could provide information which would make this service more useful in rural areas and near tourist attractions.

2. Evaluations of operational tests such as TravTek, which was aimed at rental car drivers, and *ADVANCE*, which is aimed at local commuters, could provide information on user response and acceptance of Travel Service Information.

3. Examine the feasibility, or operationally test the concept, of a nationally interlinked information system (e.g., a telephone or kiosk-based system) that contains traveler services information. Such a system could be accessed from any location and provide information about any other location in the country.

4. Explore transportation opportunities presented by expected telecommunication industry market initiatives. Initial activity could include technology/market assessments.

Since this service will be developed and deployed primarily by the private sector, ITS AMERICA inputs are actively solicited for the additional milestones and activities associated with this user service. The following are suggested private sector initiatives to date:

1. Investigate methods of distribution and the nature of the revenue stream for in-vehicle business directories.

2. Evaluate field operational tests that include business/travel listings (i.e. TravTek, *ADVANCE*, etc.)

3. Develop guidelines for the presentation of business directory information to travelers:

   - Basic information, such as location, telephone number, hours of operation, etc.

   - Expanded information, such as products sold, other services provided, charge cards accepted, etc.

   - Narrative, additional advertising material, etc.

4. Develop human factors guidelines

1.4 TRAFFIC CONTROL

1.4.1 Introduction

The Traffic Control user service manages the movement of traffic on streets and highways. It includes surface street controls such as adaptive signal systems and freeway control techniques such as ramp metering and lane control. Traffic Control will help to ensure the safe and efficient movement of all users of the surface transportation system, including private automobiles, commercial and transit vehicles, as well as non-vehicular travelers such as bicyclists and pedestrians. In addition, traffic control will help protect the public's investment in the nation's transportation system by striving for optimum use of these facilities.

Traffic Control is one of the most fundamental of the user services. The surveillance, control, communications, and support system activities covered here form the basic framework upon which many of the other user services depend. Traffic Control provides the real-time transportation network performance information which many of the other Intelligent Transportation Systems (ITS) services use. In particular, the data collected, processed, and used by Traffic Control will be needed by virtually all of the other services in the Travel and Transportation Management bundle, as well as various services in the Public Transportation Operations and Emergency Management bundles.

Traffic Control gathers data from the field, fuses it into usable information, and uses it to assign right-of-way to users of the transportation infrastructure. The goal of this service is to maximize the efficiency with which people and goods move through the roadway network. This often involves the preferential treatment of transit and other high-occupancy vehicles (HOV) to ensure equitable treatment of the multiple travelers they carry. If implemented properly, it will also help to alleviate congestion problems, and improve air quality. Traffic Control information will be disseminated to the general public and other service providers, laying the foundation for many other user services. In order for Traffic Control to operate properly, a sustained commitment to maintenance and operations is required.

System operators including State and City DOT's, transit agencies, toll facility owners, and trucking companies, who are responsible for the development and implementation of control strategies and policies that minimize congestion, will be the initial users of the Traffic Control Service. Adequately sized, trained, and motivated permanent staffs are essential to operate and update the systems. Closely related services that can be used in conjunction with Traffic Control to provide overall traffic management include Incident Management (User Service No. 1.5), Electronic Payment Services (User Service No. 4.1), Public Transportation Management (User Service No. 3.1), Emergency Vehicle Management (User Service No. 6.2), and all of the services in the Travel Demand Management bundle. Although they are not direct users of this service, the traveling public, commercial and transit vehicle operators, employers and shippers of goods will be the ultimate beneficiaries.

1.4.2 Needs

Vehicle miles traveled (VMT) in the U.S. has doubled from 1 trillion to 2 trillion in the past 30 years. Unless actions are taken to reduce demand and increase operational efficiency, VMT is forecasted to double again in the next 30 years, with no substantial increase in physical capacity, such as the construction of the Interstate Highway System. ITS, and particularly Traffic Control, provides the ability to cope with this increase in demand, and utilize the existing capacity in a more efficient manner.

High-level traffic control needs have already been established and documented based on extensive research and development (R&D) and practical experience. These needs have been stated as characteristics or requirements for Advanced Traffic Management Systems (ATMS). *Mobility 2000 (1990),* the *IVHS AMERICA Strategic Plan for Intelligent Vehicle-Highway Systems* (1992), and the "Draft ATMS Committee (of ITS AMERICA) Strategic Plan" (1993) all contain such a listing. However, the locally-defined needs for advanced traffic control systems in cities of various size and congestion levels will be reassessed after more is known about the benefits and costs of such systems.

1.4.3 Service Description

Traffic Control is an array of institutional, human, hardware, and software components used to efficiently manage the movement of people and goods on streets and highways. Traffic Control can contribute significantly to the people movement capacity of the system by giving preferential treatment for mass transit and other types of high occupancy vehicles (HOVs). Traffic Control will also help to ensure the safe movement of non-vehicular travelers, such as bicyclists and pedestrians.

Traffic Control includes the control of network signal systems to achieve specific objectives such as maximizing system throughput while minimizing delay, energy use, and air quality impacts. Freeway control alternatives such as ramp metering and lane usage signals are also included. Integration of the control of freeways and network signal systems will eventually lead to area-wide optimization of traffic movement which will allow this ITS service area to optimize goods and people movement over a large geographic area. New institutional arrangements and increased interjurisdictional cooperation will be necessary in many areas to allow for the unified operation of control systems owned by several jurisdictions.

Improved surveillance techniques, Real-Time Traffic-Adaptive Control (RTTAC), and support systems are needed to implement this service. Surveillance of traffic conditions is an essential first step. The collection and processing of basic traffic data is necessary for the development and implementation of proactive control strategies and feedback **on** the effect of these strategies. Improved surveillance technologies will provide enhanced levels of information on traffic movements, which in turn will allow implementation of more sophisticated control strategies, and dissemination of more accurate and reliable information to other user services. Improvements and new approaches to “localized” surveillance techniques (represented best by the existing magnetic field “loop” detector) should improve the reliability and performance of measuring traffic flow at specific locations. Advanced surveillance techniques may provide a means for automatically determining vehicle occupancy data, which will facilitate maximizing people movement and enhance travel demand management strategies.

“Area-wide” surveillance, which provides speed and flow information on a large number of roadway segments, will measure relative traffic loads throughout the network. This will allow the control system to react and maintain an optimum balance of traffic flow among all parts of the roadway network. The availability of information from area-wide surveillance systems will also greatly improve the operation of other user services that rely on information about the condition of the transportation system.

Given the availability of accurate real-time traffic information describing existing conditions of the road network, real-time traffic-adaptive control can be implemented. Various optimization strategies for the proper mix of speed, people and vehicle flow, fuel consumption, and pollution emission will be deployed. Real-time tactics such as signal priority or pre-emption schemes will be used to allow automobiles, emergency and transit vehicles, bicycles, pedestrians, and other modes to share the traffic right-of-way more safely and efficiently. In addition, these tactics can provide priority to HOVs and other shared-ride vehicles to facilitate implementation of travel demand management strategies.

The appropriate traffic control is implemented by communicating control data to such devices as traffic signals, information signs, freeway ramp meters, and devices for the dynamic control of infrastructure, e.g., reversible lanes, rush hour turn restrictions, and HOV signals. The Traffic Control service will manage these control mechanisms such that control functions are provided on an area-wide basis, thus avoiding fragmented or conflicting control strategies. For example, metered ramps will not allow traffic queues to fill the ramp and disrupt the operation of adjacent intersections. It is likely that there will be some form of a hierarchical control system that allows local controllers to function independently within constraints set by the optimization plan. There is also the possibility of coordinating traffic control optimization with route guidance strategies in the future. Accurate and reliable feedback mechanisms are a key element of the Traffic Control service. These provide information on the network performance that results from the implemented control decisions, and adjusts control strategies as needed.

1.4.4 Operational Concepts

Traffic Control will depend upon various support systems. Sophisticated traffic prediction models that use dynamic assignment and statistical analysis techniques will anticipate demand characteristics throughout the network. Incident reports and historical time-of-day patterns will also be factored into the traffic prediction process. Data fusion algorithms are needed to integrate incoming surveillance data as well as data from numerous other sources, including public safety or police reports, cellular telephone calls, or other sources of traffic information.

Operator support systems will provide the Transportation Managment Center (TMC) operator with accurate, readily-understood depictions of current conditions on the transportation system. User input capabilities that enable the human operator to override automated control strategies will also be available. This human interface will be especially important in coordinating traffic control strategies with other TMCs in response to incidents.

Regional Traffic Control could be provided by a single TMC or by multiple TMCs that serve the area. In the decentralized approach, local TMCs would be linked through a communications network and a regional coordinating group might be formed to compile and disseminate multi-modal system data. Communications networking with other transportation operating agencies and jurisdictions would provide access to information on transit or paratransit schedules and routes, rail schedules and intermodal connections.

In a more centralized approach, a single regional TMC could be the central data collection and dissemination point for real-time multimodal information. Data from multimodal sources would be collected, processed, and any contradictions resolved to create an accurate picture of the transportation system that can be used for signal control and be disseminated for use by other user services.

1.4.5 Technologies

The implementation of Traffic Control requires the use of many supporting technologies. These technologies generally fall into the functional areas of traffic surveillance, data and voice communications, data processing and automation, and human interface.

Many technologies can be used for traffic surveillance, and a combination of these is likely to evolve in any given area. These include inductive loop detectors, infrared sensors, microwave sensors, radar, magnetic, ultrasonic, machine vision (video cameras and video image processing systems), aerial surveillance, police and citizen reports, and environmental (climate) sensors.

In addition, equipped vehicles themselves may act as probes to determine traffic conditions. These vehicles might be equipped, for example, with sophisticated GPS-based route guidance systems, or with cellular telephones which could provide vehicle position and movement through triangulation techniques.

Electronic toll and traffic management (ETTM) systems use automatic vehicle identification

(AVI) technologies installed primarily for toll collection purposes to also provide information on traffic flow. Readers placed on toll facilities and at other strategic locations throughout a region can provide information on congestion and assist in incident detection.

Data, voice, and video communications for traffic control information within the infrastructure can also employ several technologies. These include landlines (twisted pair wire, coaxial, or fiber optic cable), microwave, wide-area radio frequencies, cellular radio, and satellite communications. Wide area communications will also be required to disseminate information that can be used by other services. Short range communications by means of localized beacons might also be used in transit priority schemes.

The data processing technologies required for Traffic Control include real-time database processing, data fusion techniques, traffic prediction and assignment algorithms, graphic user interfaces, and optimal control strategy algorithms. Major advances must be made in the areas of software integration, automation, and quality in order to support RTTAC systems.

The TMC operator will make use of human interface technologies such as touch screen, key boards, voice recognition, voice output, and visual display.

1.4.6 Potential Costs and Benefits

Implementation costs for Traffic Control vary greatly depending on numerous factors such as size, type, and location of the installation. This makes generating an accurate estimate difficult. The full-scale implementation of adaptive traffic control systems is expected be a costly investment, but is also expected to yield high rates of return. Important capital cost considerations include the traffic surveillance equipment, traffic controller modifications / upgrades, computer hardware and software, variable message signs (VMS), communication equipment, staff, building space needed for the TMC, etc. In addition, finance charges associated with bond issues or other deficit spending must be factored into the total cost.

Equally important will be the required operation and maintenance (O&M) costs to ensure that systems continue to operate at their full potential. Yearly O&M costs vary by type of system and generally have been about 10 percent of capital costs. Budgets for maintenance should include costs for equipment, spare parts, labor and facilities considering preventative, response and design modification maintenance and being consistent with the capabilities of the maintenance agency. Operating budgets will vary with the hours of operations and the staffing required for information processing, documentation, updating software, and operating a center.

In its early stages, the primary benefit from the Traffic Control service will be in the reduction of undue stops and delays. As ITS matures, data processing and communication technologies will make the data within the Traffic Management Center available to other ITS services such as in-vehicle navigation systems, trip planning and routing systems, and public transportation, emergency vehicle and commercial fleet management systems. The ultimate benefits expected to be derived from these user services include increased productivity, savings in travel time, delays, and driver frustration. Traffic Control will also help to mitigate the environmental and energy impacts of surface transportation by reducing harmful vehicle emissions and fuel wasted by congestion and navigational inefficiencies. Because the general public will be the beneficiary of these energy and environmental improvements, the total benefits are expected to be significant.

No detailed estimates are currently available for the overall magnitude of the benefits from the Traffic Control user service, since these benefits will depend to a large degree on the extent of infrastructure improvements made. In addition to benefits derived directly from Traffic Control, additional benefits will be realized from the real-time traffic network data that will be available to other ITS user services.

1.4.7 Assessment of Roles

Responsibility for development of ITS services generally resides with the private sector, however, there are situations when U.S. Department of Transportation (U.S. DOT) involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and evaluation of systems with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in developing the Traffic Control user service.

1.4.7.1 Public Benefit

This service has high potential for public benefit. Traffic Control will identify existing and potential traffic problem locations and implement strategies that minimize their effect or preclude their occurrence. This has a significant benefit in reducing unnecessary travel time delays, accidents, air pollution, and traveler frustration. In addition, the data collected, processed, and disseminated by Traffic Control will provide the foundation for deployment of many other user services, with resulting public benefits.

1.4.7.2 Potential for Private Investment in Development

Provision of the Traffic Control service will primarily be the responsibility of public sector transportation entities. Although private industry will supply products for traffic control systems, these will be developed to meet the requirements of the responsible public entities.

Little private development of Traffic Control service capabilities will take place without public sector incentive.

1.4.7.3 Public and Private Sector Roles in Denlovment

The public sector role for installing, supporting, operating, and maintaining traffic control systems is high, since this service directly affects overall public safety and the publicly-owned roadway network. Local DOTs have the primary role in the day-to-day operation/maintenance of the traffic monitoring and control system. In many cases, private sector firms will have a role as contractors executing the actual design, development, and integration of the technology and equipment to perform traffic control. The use of new technologies for these functions will broaden the market potential for private industry suppliers. Potential new markets for vendors of surveillance, communications, and control systems exist, and the public and private sectors may share rights-of-way for communications or other networks. In addition, private firms may also operate and maintain traffic control systems under contract to public agencies.

1.4.7.4 U.S. DOT Role in Developing Service

The role of the U.S. DOT in developing this service is high.

1.4.7.4.1 *Research and Development:* The U.S. DOT role in research and development activities is to address deployment issues associated with the use of advanced system components, and to develop operational concepts and support systems for advanced traffic management systems. The U.S. DOT will encourage private industry involvement in the development of the necessary technology and equipment to be compatible with the functional specifications of the systems. The U.S. DOT will also work with private industry to develop functional specifications for traffic surveillance and control systems such that system components may be fully integrated in an effective and efficient manner.

1.4.7.4.2 *Operational Tests:* The role of the U.S. DOT in operational tests of the Traffic Control service is high, particularly since it will be a critical component of integrated systems which support numerous services. Careful evaluations will be a critical element of this effort to determine the operational impacts of the test. The U.S. DOT will also ensure that sites are chosen to provide sufficient operational testing to accommodate a variety of final deployments.

1.4.7.4.3 *Institutional and Legal:* The U.S. DOT will take an active role in fostering the necessary institutional arrangements required for deployment of the Traffic Control service.

1.4.7.4.4 *Deployment:* The U.S. DOT role in deployment of this service is high, including conduct training and technology transfer activities to encourage adoption of advanced systems by local government agencies.

1.4.8 Milestones and Activities

Figure 1.4-1 presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

1.4.8.1 Issues

1. Understanding the issues associated with optimizing freeway flow, and integrating freeway and surface street systems most effectively.

2. Developing and integrating Real-Time Traffic Adaptive Control, Surveillance, and Support Systems

3. Integrating Traffic Control with other user services, including issues relating to communications, and collection, processing, and dissemination of information.

4. Overcoming institutional and other non-technical barriers to interjurisdictional and interagency cooperation.

5. Funding long-term operations and maintenance required for deployed systems (See discussion of this issue in Volume I, Chapter VII, Deployment Support).

   O&M costs can be estimated for existing and proposed systems using a multi-task approach that could have the two parallel tracks of maintenance and operations. Both tracks follow the same general path and are described below:

   - Assess Current Traffic Control Programs - This task includes a review and assessment of an area's Traffic Control Program. Operational and maintenance philosophies and technologies should be defined and capabilities should be identified.

   - Analyze Transportation Operating Conditions - Present and future transportation operating conditions on the transportation system should be analyzed. Operational problems and available operational programs to deal with such problems should be identified.

   - Assess Current Traffic Management Operations - Traffic management operations practices should be identified and improvements proposed relative to staffing and hardware/software for the system's Traffic Operations Center(s).

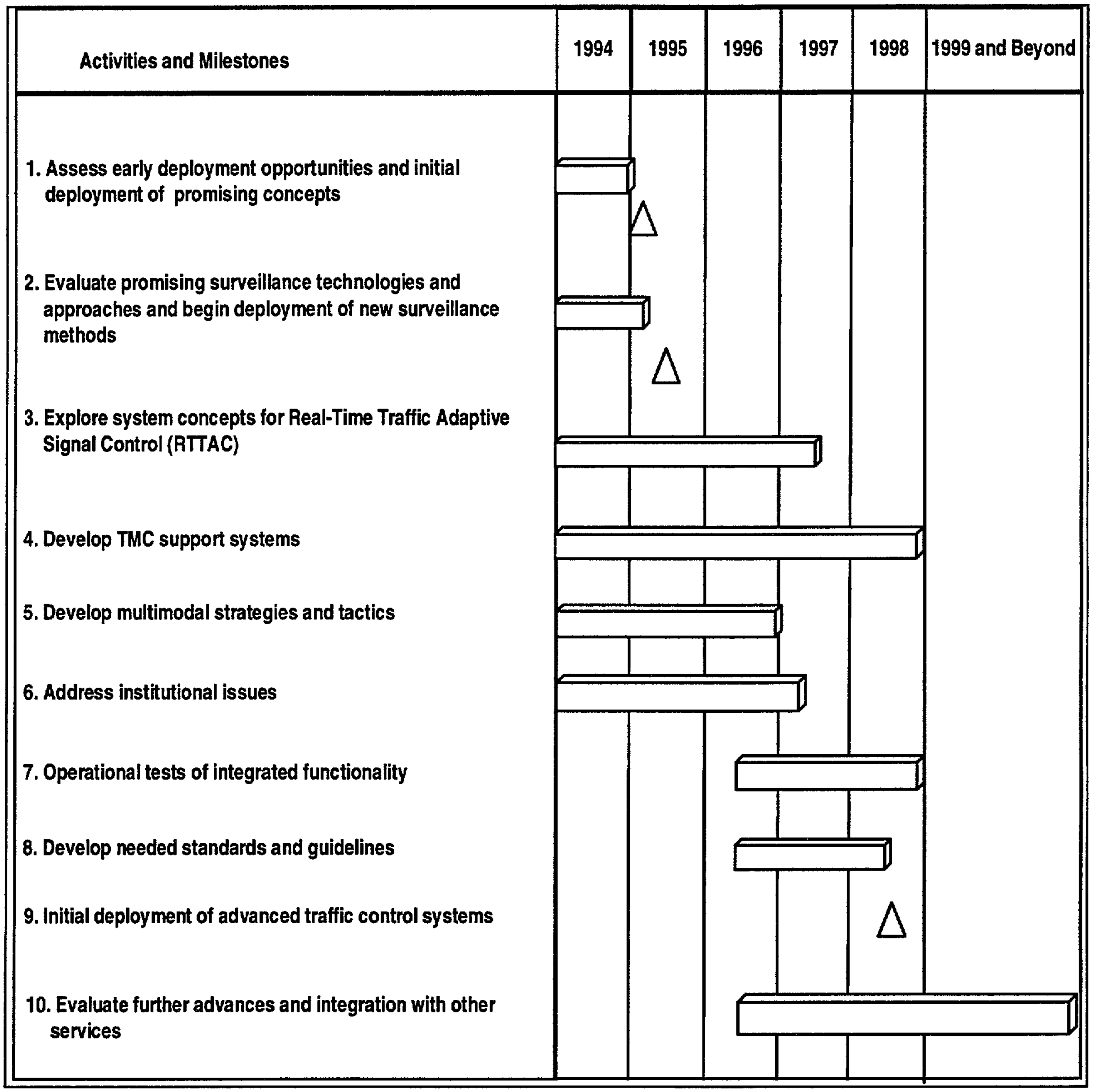

Figure 1.4-1 Traffic Control Activities

- Assess Current Maintenance Practices - Maintenance procedures should be identified and improvements proposed relative to staffing, hardware/software, spare parts requirements, and servicing equipment.

- Develop an Operational Program - Based on previous tasks, prepare an operations program, defining the manner and level of operation of the system to most effectively deal with operations deficiencies on the roadway network. The operations requirements that the Program will address should be determined and should include requirements for staffing, organizational structure, and coordination with other activities.

- Develop a Maintenance Program - Based on previous tasks, prepare a program for efficiently maintaining the traffic control system components. A fact sheet describing basic components and related peripheral equipment should be prepared considering such items as estimated life, running time per year, maintenance costs, spare parts requirements, and special tools and diagnostic equipment. The maintenance function should be divided into preventive and response maintenance.

- Prepare a Coordinated Operations and Maintenance Program - Based on previous tasks, a coordinated program should be developed for strategies and procedures to meet future operational and maintenance requirements including staffing, spare parts, equipment, traffic operations center requirements, and costs by participating agency.

6. Inter-jurisdictional issues associated with coordinating traffic control plans and ensuring compatible control systems

7. Traditional procurement practices which limited flexibility in procuring advanced systems and technologies

1.4.8.2 Activities

1. Assess early deployment opportunities and initial deployment of promising concepts.

   - The Federal Highway Administration (FHWA) is currently sponsoring ITS early deployment planning studies. ITS funds are provided to metropolitan areas for assessment of needs in the current state of the area’s traffic management system and for recommendation of potential ITS-related deployments that would improve the system.

- This activity concludes with a milestone for the initial early deployment of promising concepts. The experiences gained from these initial deployments will influence subsequent activities.

2. Evaluate promising surveillance and communications technologies and approaches and begin deployment of new surveillance communications methods.

This activity will study and evaluate technologies and approaches that hold promise for satisfying ITS data gathering and communications requirements. Key issues to be addressed include the accuracy, reliability, cost, maintainability, and potential coverage area for each communication and surveillance method. This is closely related to Activity 3, since the communications and surveillance requirements for alternative RTTAC prototypes may vary. Non-standard surveillance approaches such as using individual vehicles as sources of travel time data (traffic probes) will also be studied.

- Detection Technology for ITS (1991-1994)--The primary objectives of this study are (1) to determine the types of traffic parameter data and the accuracies required for vehicle detection in ITS applications, and (2) to test and evaluate a variety of detection technologies in diverse climactic conditions.

- Wide Area Surveillance Systems (1993-1994)--This study will provide an initial feasibility assessment of promising technical approaches for wide area surveillance systems for ITS.
- ITS Communications Alternatives Test and Evaluation (1995-1996) This study will identify and analyze communications technologies for ITS functions, and recommend preferred communications alternatives for specific ITS functions

- Development and Lab Testing of New Detection Technologies and Surveillance Concepts (1995-1996) This study will identify and test state-of-the-art industry and defense technologies and concepts for ITS detection, communications and surveillance systems.

- ITS Radio Frequency Spectrum Planning This study will identify emerging RF needs of ITS, ensure spectrum is available when needed, and ensure electromagnetic compatibility with other communications systems

- FM Subsidiary Carrier Authorizations (FM/SCA) Prototype for Traffic Information Broadcast This completed study designed, developed, and pilot tested a Sub-carrier Traffic Information Channel (STIC) prototype system for broadcast of traffic information to mobile receivers.

- Begin Denloyment of New Surveillance and Communications Methods (1995)--The milestone at the end of this activity is for the deployment of new surveillance and communications methods as soon as they are adequately tested, necessary standards and guidelines for their use are produced, and industry products that meet the standards are available. However, before widespread implementation of any new method, the surveillance and communications requirements for RTTAC systems should also be examined (Activity 3).

- Encoding Scheme for ATMS/ATIS Data Fusion (1994) The study will support work underway by the Washington State DOT to expand their data fusion algorithm to have national applicability.

- Technical Design Reviews and Workshops (1995) Focus groups will be formed for real-time signal control, traffic management laboratory, incident detection, and dynamic traffic assignment to provide practitioners with the opportunity to participate in the design and development of ITS technologies.

- Deployment Issues of ITS Surveillance Systems (1995-1996) This study will investigate deployment issues associated with existing and emerging surveillance systems in terms of cost effectiveness, compatibility with existing systems, upgrading flexibility, and malfunction management.

- Low Cost Area-wide Roadway Traffic Sensor (1995) will test low frequency (300-1000 MHz) coherent radar technology for wide area traffic surveillance.

- National Vehicle Detector Test Center This project will provide seed money to establish a self-supporting national test center(s) for evaluating new ITS sensors.

3. Operationally test new surveillance and communications technologies and advanced transportation management techniques.

- The San Antonio, TX Advanced Transportation Management System operational test is evaluating a digital communication network for cost effectiveness and benefits versus “traditional” transportation data communications systems.

- The Washington, D.C. metro area operational test is evaluating the use of passive statistical cellular and cellular geolocation technologies for providing traffic flow information and incident detection through vehicle probes.

- The Mobile Communication System test in California is evaluating the use of portable surveillance and vehicle detection capabilities, using video, image processing, VSAT and spread spectrum technologies, for work zones, incidents, or special events.

- The Smart Call Box operational test in California is evaluating the cost-effectiveness of using the existing control center/field infrastructure communications link provided by cellular-based call boxes to transmit data needed for traffic monitoring, incident detection, hazardous weather detection, changeable message sign control, and CCTV control.

- An operational test in Los Angeles is evaluating the effectiveness of using spread spectrum radio communications in an urban environment for traffic signal control system functions.

4. Explore system concepts for Real-Time Traffic-Adaptive Control (RTTAC).

This activity will research and develop alternative operational concepts for RTTAC systems. Laboratory prototypes will be built to evaluate the potential effectiveness of each approach. The functional requirements (or specifications) of each operational concept will be determined. Limited field tests could be included as part of the evaluation effort. A major R&D study is already underway in support of this activity.

- Real-Time Traffic-Adaptive Signal Control (RT-TRACS) For IVHS (1992-1997)--This study is developing four alternative operational concepts and signal control logic suitable for RT-TRACS systems. It includes the development of system prototypes and the determination of functional requirements (including surveillance, communication, and processing requirements). One of the prototypes will be selected for further development and field evaluation by 1997.

- Traffic Models For Testing Real-Time Traffic-Adaptive Signal Control Logic: Phase I (1992-1996)--This study will enable currently available traffic models to simulate the operation of RTTASC systems prior to their field implementation. These models will also provide a basis for quantifying the operational performance of such systems.

- Evaluation of RT-TRACS Prototypes (1995-1996) . This study will conduct laboratory evaluation of four RT-TRACS prototypes developed by two separate contracts, and field evaluation of the prototype selected for full development.

- Operational Evaluation of SCOOT in Southern California (1995) This study will evaluate the adaptability of SCOOT for U.S. application, including equipment interface, quantification of staffing and cost requirements, and overall performance of the system.

- Ramp Metering for Recurrent and Non-recurrent Congestion (1995-l998) This study will develop and test, through simulation, ramp metering strategies for recurring and non-recurring congestion.

- An operational test in Anaheim, California is comparing the SCOOT adaptive signal control system against 1.5 generation UTCS control.

5. Develop TMC support systems.

The TMC of the future will play an integral part in the day-to-day operation of advanced transportation management systems. This activity will develop support systems intended to assist in the efficient and effective operation of TMCs. It will address data fusion methods, decision support systems, traffic models and algorithms, operator interface, and other human factors issues. It will also address control center design, database needs, functional integration, and hardware platforms.

- Design of Support Systems for Advanced Traffic Management System (ATMS) Control Centers (1992-1997) --The objectives of this study are to develop the functional requirements of the automated support systems for a mature ATMS control center, develop representative functional designs for these systems, and to develop and test support system prototypes.

- Traffic Models For Testing Real-Time Traffic-Adaptive Signal Control Logic: Phase I (1992-1996) -- This study will enable currently available traffic models to simulate the operation of RTTASC systems prior to their field implementation. These models will also provide a basis for quantifying the operational performance of such systems.

- Network-wide Optimization Models (1992-1995)--This study will develop traffic models which optimize the operation of urban networks composed of freeways and surface streets.

- Traffic Modeling to Support Advanced Traveler Information Systems (1990-1993)-- This study is developing a dynamic traffic assignment model suitable for developing real-time diversion strategies.

- Human Factors in Advanced Traffic Management Systems (ATMS) (1992-1996)--The goal of this project is to provide information that focuses on the human factors engineering issues and human resource capability issues for operators in ATMS control centers. Products of this effort include a Human Factors Handbook for TMC operators and maintainers, a Human Factors Handbook for TMC designers, and a stand-alone first generation human factors research TMC simulator.

- Traffic Management Laboratory (1993-1997)--This project will develop, implement, and support the operation of a laboratory configuration to support off-line testing, evaluation, and calibration of newly developed traffic control strategies, support systems, multimodal transportation strategies, and TMC hardware/software configurations.

- Advanced Computing Architectures for ATMS (1995-1996) This study will provide technical support for the design and implementation of the architecture for the Traffic Management Laboratory's ATMS simulator.

- Models to Simulate IVHS Operations (1993-1998) --This project will modify existing traffic models to simulate ITS operations such as real-time control strategies, navigation and route guidance, real-time graphics displays, probe vehicles, and user interfaces.

- Dynamic Traffic Assignment and Synthetic Origin and Destination Matrices (1995) will account for different ITS deployment levels in terms of coverage of traffic monitoring and incident detection systems, and the extent of surface street and freeway control integration.

- Traffic Management Center Integration Issues (1992-1998) This study will analyze the technical issues associated with integrating information flow between multi-modal transportation management systems.

- Cal Poly San Luis Obispo has established a traffic management laboratory that will become an intermodal transportation management center prototype.

- The Texas Traffic Responsive Automated Corridor (TxTRAC) operational test is providing a vendor-independent ITS technology test site. The first effort will be an evaluation of digital communications and high resolution video in incident detection and management. The operational test will also evaluate multiple incident detection algorithms. The Texas Department of Transportation is the lead agency, in partnership with Allied Signal, Technical Services Corporation, Texas Transportation Institute, and the Southwest Research Institute.

6. Develop multimodal strategies and tactics.

The multimodal aspects of advanced traffic control systems must be addressed early on so they can be incorporated into the research, development, and operational testing activities. This activity will develop strategies by which automobiles, HOVs, transit, bikes, pedestrians, and other modes will share the traffic right-of-way. Capabilities will be developed to optimize speed, flow of people (people throughput), and flow of vehicles;

minimize pollution and fuel consumption; and implement a mix of these strategies. In addition, real-time tactics such as signal priority (pre-emption) schemes will be developed, which can be incorporated into RTTAC systems. This activity is strongly influenced by transportation policy decisions, some of which may be derived from legislative requirements (Activity 6).

- Responsive Multimodal Transportation Management Strategies (1991-1993)--The objectives of this contract effort are to identify candidate scenarios for demonstration of multimodal transportation management strategies, determine their usefulness and feasibility, develop additional innovative multimodal concepts that can be linked to ITS technologies, and provide recommendations for additional research, development, and operational testing activities.

7. Address institutional issues.

Complex matters of inter-jurisdictional cooperation must be addressed prior to widespread deployment of RTTAC systems. State, regional, and local jurisdictions must work together to achieve the full benefits of such systems. Officials must agree on how the responsibilities for operation of the system will be shared among jurisdictions or how they will cooperate to support a multi-jurisdictional TMC. The responsibilities of transportation agencies, transit authorities, law enforcement agencies, etc., must be agreed upon. Traffic control strategies to be used during active incident management must also be agreed upon.

Additionally, policy and funding issues related to the traffic control system must be addressed. For example, direction will be needed to ensure the multimodal aspects of the system are handled in a manner that is consistent with local policies. Challenging funding issues, including operations and maintenance (O&M) funding, need to be resolved to derive the most public benefit from the expenditures.

Although these issues ultimately will be decided at the local and regional levels, the establishment of federal guidelines may be beneficial in some of these areas. This activity represents the development of such guidelines as well as the decision-making needed at the local level prior to deployment of fully integrated RTTASC systems.

- On May 12, 1993, the FHWA sponsored a Signal Manufacturers' Symposium to formally establish cooperative working relationships. As a result of this symposium, a formal industry/user task group has been formed to: a) set the groundwork for a formal, continuing working relationship among the signal manufacturing industry, end users, and the FHWA; and; b) establish a process to facilitate industry/user/FHWA interaction and information exchange.

8. Operational tests of integrated functionality.

This activity is for operational tests that are focused on advanced traffic control systems, including TMCs that provide integrated functionality and advanced support systems. The most promising of the RTTASC systems from Activity 4 will be operationally tested and evaluated.

Also included would be operational tests of regionwide systems which integrate the operation of multiple jurisdictions and operating agencies into a comprehensive transportation management system.

9. Develop needed standards and guidelines.

This activity includes the development of all standards and guidelines necessary before the deployment of RTTAC systems and new surveillance and communications approaches. It includes any needed human factors standards or guidelines for TMC operators to effectively perform their jobs.

This activity would also focus on development of needed standards, guidelines, and interfaces to allow integration of Traffic Control with other user services which rely on real-time information about the condition of the transportation system.

- An operational test in Anaheim, CA is testing expert system applications for coordinated ramp metering and arterial signal control systems, including distributing demand across the roadway network. The test is also evaluating the OPAC adaptive signal control strategy.

- Modification to Electronic Traffic Control Device Communications Standard Protocol (NTCIP) (1995) will develop a standard, general purpose communications protocol for use throughout the transportation industry.

10. Initial deployment of advanced traffic control systems.

After successful operational tests have been conducted, needed standards and guidelines have been developed, and industry products meeting these standards are available, field deployment of advanced traffic control systems can begin. This deployment is assumed to include RTTAC systems, fully-functional, integrated TMC support systems, and integration with other related user services.

11. Evaluate further advances and integration with other services.

This is a research and development activity that is intended to pursue any additional traffic control advances and look at issues uncovered in previous research, prototyping, and operational testing activities. Additionally, this activity will include efforts to evaluate the integration of advanced traffic control systems with other ITS user services in the Travel and Traffic Management bundle, as well as commercial vehicle services, and public transit and emergency management services. In particular, the feasibility, costs, and benefits of such integration will be evaluated. The degree of integration studied will depend on the specific user service since the Traffic Control service will provide the real-time transportation network performance data that many other ITS services will use.

1.5 INCIDENT MANAGEMENT

1.51 Introduction

The Incident Management user service enhances existing capabilities for detecting incidents and taking the appropriate actions in response to them. Both unpredicted incidents (resulting from accidents, for example) and predicted incidents (planned lane closures, etc.) are covered. Incident Management is closely related to Traffic Control (User Service No. 1.4). The development of response actions is part of Incident Management, while the implementation of appropriate traffic control measures would be executed through the Traffic Control user service. Decisions at the site of the incident are usually made by police agencies.

Incident Management is also closely related to Emergency Notification and Personal Security (User Service No. 6.1) which provides notification of an incident and requests assistance; Emergency Vehicle Management (User Service No. 6.2) which supports the dispatch and routing of emergency vehicles; and Hazardous Materials Incident Response (User Service No. 5.5) which provides a description of hazardous materials to emergency responders. Incident Management is also related to the travel management services, including Pre-Trip Travel Information (User Service No. 2.1), En-Route Driver Information (User Service No. l.l), En-Route Transit Information (User Service No. 3.2) and Route Guidance (User Service No. 1.2).

1 .5.2 Needs

It is estimated that over half of the traffic congestion in the U.S. is caused by incidents. 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 lead to further congestion and delays. Even minor incidents, such as a disabled or abandoned vehicle on the shoulder, can reduce roadway capacity and create a potential safety hazard. Over the past 30 years, Incident Management programs have been implemented in various locations throughout the country as a systematic approach to minimizing the traffic congestion and safety impacts of incidents. These programs have proven that Incident Management is one of the most successful ways to reduce traffic congestion, but the associated commitment of resources and institutional arrangements often appears daunting. The incorporation of new Intelligent Transportation Systems (ITS) technologies and concepts promises to make Incident Management more effective, less resource-intensive, and more feasible for widespread application throughout the United States.

1.53 Service Description

The Incident Management user service will use advanced sensors, data processing, and communications to improve the Incident Management capabilities of transportation and public safety officials. The service will help these officials to quickly and accurately identify a variety of incidents, and to implement a set of actions to minimize the effects of those incidents on the movement of goods and people. In addition, the service will help officials to identify or forecast hazardous weather, traffic, and facility conditions so that they can take action in advance to prevent incidents or minimize their impacts. This may include coordinating the schedules of construction or other planned roadway activities. While the direct users of the Incident Management service are emergency response fleets, enforcement agencies, the private towing and recovery industry, and those that operate and maintain the transportation system, the ultimate beneficiary is the traveling public.

A major focus of the Incident Management user service is improving the response to unpredicted incidents. These include unforeseen occurrences such as accidents, vehicle breakdowns, and loss of cargo situations. Because there is little or no advanced warning, the speed of detecting the incident and implementing the proper response is critical. Detection systems will use advanced sensor technology, fusion of data generated by numerous sources, and sophisticated software analysis to quickly verify the location, characteristics, and potential impacts of incidents. Advanced computer-based decision support systems will help all appropriate organizations to decide cooperatively 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, rerouting or diverting transit vehicles, and/or altering existing traffic control.

The Incident Management user service will also help in scheduling or forecasting predicted incidents so that actions can be taken in advance to minimize their impacts. Predicted incidents include events such as roadway/transit facility construction and maintenance efforts, facility closures, special events, and certain weather conditions that can be anticipated. The Incident Management user service will support the development and implementation of appropriate incident response actions, such as changes in traffic control or provision of information to travelers, before predictable incidents occur. The service will also provide the capability to coordinate the scheduling of many predictable incidents so as to minimize their traffic flow impacts. Predicted incidents often do not occur exactly as predicted, however. Thus, both predicted and unpredicted incidents will require detection, verification, and response activities.

In order to help develop and implement effective response plans, the Incident Management user service must be closely linked to other user services and management systems, including emergency management and public transportation management systems. Transportation system users do not see the direct outputs of the Incident Management service. Instead, they see the traffic control, pre-trip and en-route driver and transit information, route guidance instructions, and response vehicles that are the outputs of other user services. Incident Management must interact with these services to determine what alternative strategies are available and to assure the selected strategies are implemented. In some cases where Incident

Management is closely integrated with other user services, detection, verification, and implementation of a response plan may be partially automated with manual supervision to increase the speed and suitability of the response.

An effective response to any incident also requires extensive communication and institutional coordination. Due to the dynamic nature of incidents and their impacts, ongoing contact among the responders must be maintained throughout the life of an incident. The Incident Management service will use 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 to all participants at all times.

1.5.4 Operational Concepts

An ITS will continuously collect, fuse, and evaluate data from many surveillance sources to identify possible incidents. Conditions corresponding to an incident can be detected by a variety of fixed or mobile electronic sensors that monitor traffic flow and environmental conditions. These sensors will generally support traffic control and other ITS user services as well. Verbal or electronic notification of incidents may also come from public safety sources such as police and fire departments, from media services, from weather services, from other transportation service providers within or outside of the region, or from travelers themselves. Data, such as desired time, location, and characteristics, needed to pre-schedule construction and other events will be supplied by those scheduling the events, but the actual occurrence and impacts of these predicted incidents will be verified and monitored through the surveillance sources, just as for unpredicted incidents.

Integration and analysis of data from the different sources could take place at a single location, often an area-wide traffic management center. In other deployment scenarios, several traffic management centers, transit operating agencies, and other transportation authorities could be connected through a communications network to share information about the transportation system. A regional coordinating committee or other organization could compile and disseminate incident-related information.

Computer-based incident detection algorithms will be used to monitor all incoming data for unusual conditions or reported incidents. The algorithms will determine that an incident has taken place only when supported by sufficient credible data. For each incident, algorithms will verify details regarding location, characteristics, and potential traffic flow and environmental impacts. Verified incidents will also be tracked as they progress to determine whether changing conditions warrant new action. Many of the detection and tracking procedures will be automated to minimize human intervention and effort.

A determination will be made of the best way to respond to all verified incidents, including which organizations, resources, and procedures to use. This response plan will be developed and updated based on the latest information on the status of the incident and the response effort and will be developed in coordination with the responding organizations. Response plans for predicted incidents will be developed in advance based on predicted traffic conditions and other concurrently scheduled incidents. When possible, the schedule for an event will be arranged in order to lessen its impacts on traffic.

Various resources will be available for developing an incident response plan. As is current practice, pre-determined response plans for many incident scenarios will be maintained as part of a decision support system. This will help to speed the response and minimize confusion among the responding organizations.

Although the use of computers for developing and selecting incident response plans is currently limited, this will change in the future. Computer algorithms employing artificial intelligence capabilities will be used to recommend response plans based on input incident characteristics and, in many cases, will "learn" over time which actions work best. Computer simulation modeling may also be used to predict potential incident and incident response impacts ahead of time. Data on each incident response will be stored for future analysis of the effectiveness of the response plan.

When a recommended response plan has been developed, the appropriate organizations are notified to implement it. The Incident Management service will provide the communication capabilities necessary to support a flow of information among all of the potential responders. This not only allows the cooperative development and implementation of response plans, but also enables continued monitoring of each incident and the effectiveness of the corresponding response. This involves communications among all pertinent public and private organizations and information sources, including mobile communications for on-site incident status updates. As conditions warrant, additional response actions may be implemented until the incident is finally cleared from the system.

In the fully developed Incident Management service, incident response plans will be developed and implemented using a single incident status and decision support system that links all potential responding organizations. This computerized system will integrate the communication, dynamic and static database, and data processing capabilities necessary for the Incident Management service. It will simultaneously track the status, response, and impacts of all verified, potential, and predicted incidents. It will access the computerized decision support algorithms discussed above. The system will also contain information such as the current status of all potential responding organizations and their resources, predetermined incident characteristics and response actions, and roadway and transit facility characteristics. The system will allow data on incidents, incident response actions, and traffic conditions to be archived for future analysis. It will also be possible to link ITS emergency vehicle management services and other resource management systems directly to this system to obtain information on the availability and response times of emergency vehicles and other resources. Eventually, this could lead to full automation of the incident detection and response dispatch process under some circumstances.

1.5.5 Technologies

Several alternative technologies exist for detection of incidents. Incident reports might come from roadside call boxes or calls to cellular 911 services. Traffic flow monitoring can be performed by fixed sensors based on inductive loop, infrared, microwave, acoustic, beacon, cellular telephone or video image processing technology. Automatic reporting of travel times by private, commercial or transit vehicles equipped as traffic probes, can also provide information on traffic flow. These sensors will often be used to support the traffic control ITS user service as well, and they are discussed in the documentation for that service. Video, voice, or data transmissions from these traffic flow monitoring sensors will feed into algorithms that detect potential incidents based on disruptions to flow. Potential incidents may also be detected from environmental sensors that measure weather conditions, from the reception of manual or automated traveler distress transmissions, or from roving ground or aerial patrols.

Verification of incidents can be performed using many of the same detection technologies, especially ground and aerial patrols. In addition, video cameras will be used extensively for verifying the location and characteristics of an incident. Verification will often rely on data fusion technologies that will correlate the input from the various surveillance sources.

As the service matures, data processing technologies will also help to automate the selection of response plans, which is now often based on the experience of knowledgeable individuals. To reduce response time, that experience will increasingly be incorporated into computerized decision support tools that use artificial intelligence and traffic modeling algorithms. These support systems will recommend response plans based on the specific incident, network and traffic conditions, and the available resources of the potential responders. Response decisions will be automated to various degrees and may be linked directly or indirectly into participants' dispatch systems. Incorporation of historical data and response evaluations from previous incidents will allow response selection to improve over time.

Dynamic and static databases will allow a common area for the storage and retrieval of all incident management information. These databases will contain up-to-date information on traffic conditions, current and predicted incidents, response status, and available resources. They will also contain information on system characteristics, response policies and guidelines, and anything else necessary for detecting an incident and developing a response plan.

A variety of technologies will be used to communicate video, voice, and data from the traffic flow monitoring locations to the central processing location and to share information among the participating organizations. Dial-up or dedicated land lines will probably serve most of the communication needs between fixed points. Microwave, wide-area or cellular radio, or satellite communications may be used where land lines are not feasible. Radio or satellite technology will also likely be used for communications to and from incident locations. Hand-held geographic information system (GIS) devices will provide highway and local network status and pre-planned response information to police and incident response personnel in the field. These devices, continuously updated via wireless modem, will facilitate decision-making with respect to traffic diversion and related actions.

1.5.6 Potential Costs and Benefits

The costs of current Incident Management systems are highly variable and difficult to determine. A per-mile cost of $1 million to construct and $100 thousand per year to operate and maintain would not be out of line for a traffic management system built today. (Ref: A Toolbox for Alleviating Traffic Congestion, Institute of Transportation Engineers, 1989, p. 20). However, these traffic management systems generally combine various capabilities of incident management, traffic control, and traveler information. Thus it is difficult to say how much of their extensive surveillance and communications equipment costs are attributable specifically to incident management requirements.

The deployment of incident management programs in coordination with traffic control and traveler information systems takes advantage of common functional requirements and is necessary to realize the full capabilities of the Incident Management service. However, several initial measures can provide the bulk of the benefits at a fraction of the cost. Programs such as service patrols, motorist call boxes or cellular hotlines, accident investigation sites, and quick incident clearance policies have proven to be very cost-effective. These types of programs provide the foundation that can later lead to implementation of the ITS technologies that provide the Incident Management user service.

Public agencies have typically reported that incident clearance times decreased by up to 50% due to the implementation of incident management programs. The resulting reduction in congestion is even greater. Studies done on Los Angeles highways by the California Department of Transportation have shown that each additional minute in the time to clear a lane-blocking incident results in an additional four or five minutes of congestion during off-peak periods. The resulting congestion is often much greater during peak periods. (Ref: Roper, D.H., “Incident Management,” California Department of Transportation, date unknown.)

1.5.7 Assessment of Roles

Responsibility for development of ITS services generally resides with the private sector; however, there are situations when U.S. Department of Transportation (U.S. DOT) involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and evaluation of systems with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT’s strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in the development of the Incident Management user service.

1.5.7.1 Public Benefit

Incident Management has a high potential public benefit. Certainly, the ability to identify and respond to incidents quickly is a safety benefit to those injured in accidents. In addition, it improves safety and reduces congestion for other system users by minimizing disruptions to flow. Providing information on all types of incidents will allow travelers to avoid the affected areas, which also serves to improve safety and reduce congestion.

1.5.7.2 Potential for Private Investment in Development

Only limited private development of Incident Management service capabilities is likely without public sector encouragement, although there is potential for the private towing and recovery industry to invest in the development of technologies to improve their response to incidents. The public entities responsible for Incident Management will be the primary market for other products developed by the private sector.

1.5.7.3 Public and Private Sector Roles in Deployment

The public sector will be the primary user of the deployed Incident Management service. Public agencies in charge of transportation, emergency response, and law enforcement will purchase and use most of the Incident Management equipment and services. The private sector is expected to supply incident management-related hardware and software systems, generally under contract to specific public agencies. Private towing and recovery companies are usually responsible for incident clearance. Private participation in other Incident Management activities, such as incident detection and service patrols, is expected to continue due to the value of the information collected or the public exposure of these activities. Private firms may also provide portions of the Incident Management service under contract to public sector agencies.

1.5.7.4 U.S. DOT Role in Developing Service

The public benefit of Incident Management will be high, but the private sector market potential is relatively low. In addition the public sector will be primarily responsible for providing incident management. This forms the basis for the U.S. DOT's role in developing this service as discussed below.

1.5.7.4.1 *Research and Development:* The U.S. DOT role in research and development activities for this service is high, including addressing technical issues involved in incident detection, and developing and evaluating incident detection algorithms.

1.5.7.4.2 *Operational Tests:* The U.S. DOT role in operational tests of Incident Management services is high. The U.S. DOT will be responsible for ensuring adequate evaluations of new incident detection technologies, strategies, and algorithms, and for determining that the site chosen provides sufficient operational testing to support a variety of deployment scenarios.

1.5.7.4.3 *Institutional and Legal:* The U.S. DOT role in addressing potential institutional or legal barriers to development and deployment of the Incident Management service is high. Deployment support would include appropriate input to the development of standards, the development of guidelines for equipment purchased with Federal-aid funds, and helping to address the institutional barriers to multi-agency incident management.

1.5.7.4.4 *Deployment:* The role of the U.S. DOT in deployment of Incident Management is expected to be medium, as private sector funds will continue to support towing and recovery efforts, as well service patrols and other activities. The U.S. DOT will provide training and technology transfer activities to assist public agencies in deploying advanced incident management systems.

1.5.8 Milestones and Activities

Figure 1.5-1 presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

1.5.8.1 Issues

1. Develop computer-based algorithms for data fusion and incident detection.

2. Develop guidelines for incident response plans and implement them in decision support systems.

3. Address inter-jurisdictional institutional issues associated with notifying multiple agencies of an incident and having them achieve a coordinated response to it.

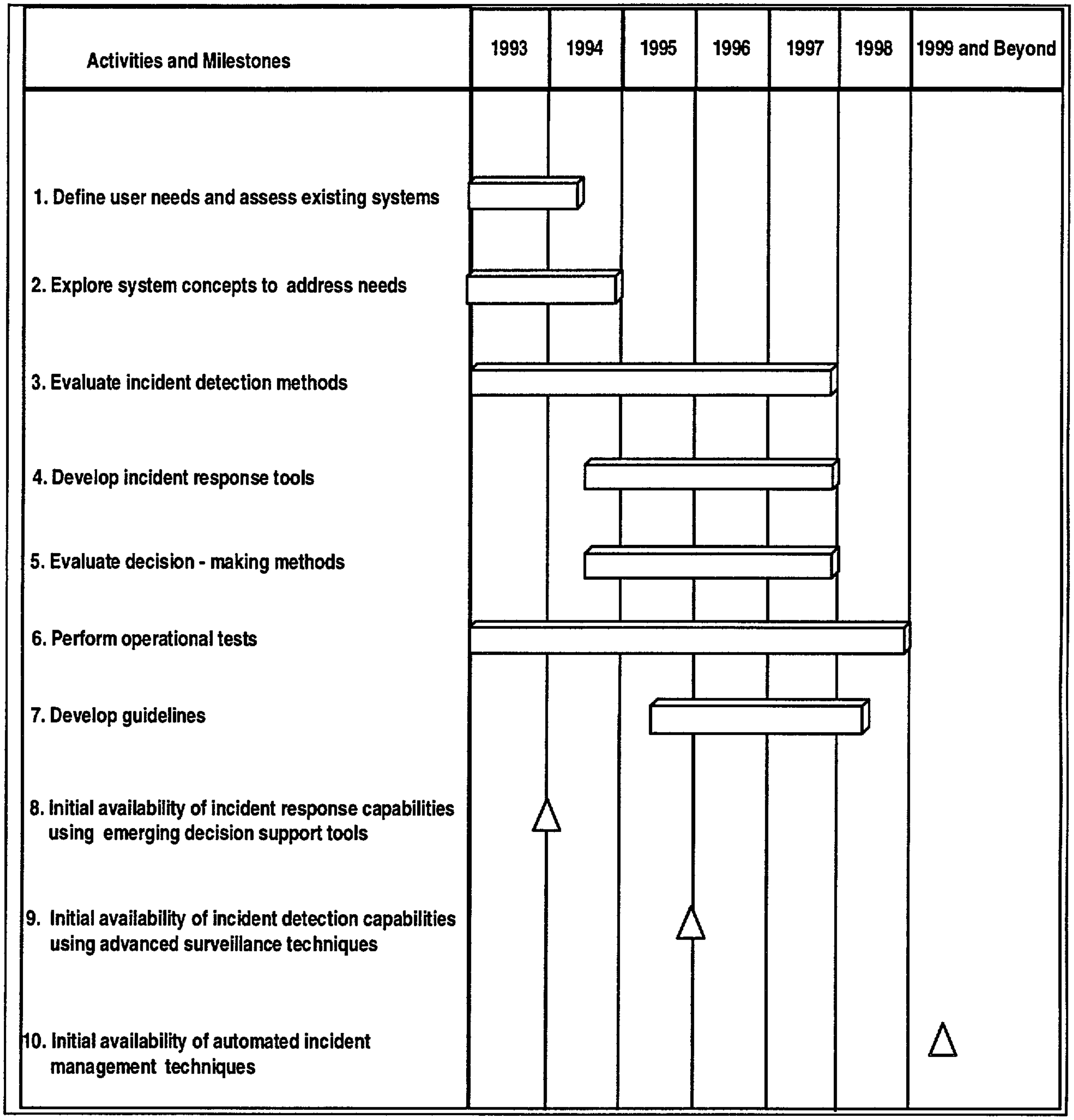

Figure 1.5-1 Incident Management Activities

1.5.8.2 Activities

1. Define user needs and assess existing systems.

Because Incident Management programs have existed for many years, much background documentation on user needs exists. However, further research is desirable on the best type, amount, and timing of incident information to provide to travelers and potential travelers. The type, amount, and timing of incident information that both public and private entities need to carry out Incident Management activities is also evolving as new methods for performing route guidance, traffic control, travel information, and emergency dispatch are introduced. For example, information on the potential impacts of alternative diversion strategies will be needed more quickly to support the increased diversionary capability of real-time traffic adaptive signal control systems. Several activities are already underway and described in the En-Route Driver Information user service, to define traveler information needs.

2. Explore system concepts to address needs.

This activity will identify what data sources and processing activities must take place to provide the information required for incident management and where data processing activities could occur.

- "Design of Support Systems for Advanced Traffic Management Systems (ATMS)," 1992-1997, Project Number DTFH61-92-R-00073. Some of the work in this project has involved defining information sources and possible information flows and processing activities for incident management.

- "Application of Incident Detection Algorithms," 1994~and beyond, proposed project. This project will develop guidelines for analyzing surveillance equipment needs to support incident detection.

- "Technical Design Reviews and Workshops," 1994 and beyond. Focus groups on incident detection will be formed to give practitioners the opportunity to provide input to the U.S. DOT research program.

3. Evaluate incident detection methods.

These activities will determine what methods and algorithms will provide quick, accurate incident detection and verification and what their supporting surveillance and communication requirements are. They will also determine what alternative algorithms can be used in identifying hazardous traffic conditions and their supporting surveillance and communication requirements.

- "Incident Detection Issues - Part I," 1992-1997, Project Number DTFH61-92-C-00122. This study will examine the issue of automatic incident detection on freeways. Its key products include the recommendation of optimal surveillance configurations for available incident detection algorithms and the development of a methodology for the uniform measurement and reporting of the impacts of traffic incidents.

- "Surface Street Incident Detection," 1994~and beyond, proposed project. This project will develop and test algorithms for incident detection on surface streets.

- "Support Systems for ATMS," 1992-1997, Project Number DTFH61-92-R-00073: This study will design and develop several support systems for use in traffic management centers. Among them are expected to be algorithms for use in incident detection and congestion forecasting.

- "A Proactive System for Real-Time Incident Prediction," 1994-1995. This ITS-IDEA project will develop, test and apply models that predict the likelihood of various freeway incidents based on real-time data.

4. Develop incident response tools.

Methods and algorithms that can be used to generate appropriate incident response plans must be developed quickly. Methods for predicting incident impacts and using these predictions to help develop response plans must also be developed. These tools must be easy to install and use. They must also be integrated with other user services such as Pre-Trip Travel Information, En-Route Driver Information, Route Guidance, Traffic Control, and Emergency Vehicle Management to implement incident response plans.

- "Traffic Modeling to Support ATIS," 1990- 1993, Project Number DTFH6 1-90-C-00074 and "Dynamic Traffic Assignment and Synthetic Origin and Destination Matrices," 1994~and beyond, proposed study. These studies will develop and test a dynamic traffic assignment model that will allow the development and implementation of diversion routes in real time. The model could be used to evaluate the impacts of alternative incident response strategies.

- "Support Systems for ATMS," 1992-l 997, Project Number DTFH61-92-R-00073. Among others, this study is expected to develop computer-based support systems for use in incident response plan development.

- "Human Factors in ATMS Design Evolution," 1992- 1996, Project Number DTFH61-92-C-00094. This project focuses on the human factors and human resources issues for traffic control center design, including those that might affect incident management and response.

5. Evaluate decision-making methods.

   These activities will determine what institutional arrangements and processes and what methods of communication will best facilitate the many inter-agency and inter-jurisdictional agreements that must be made to support incident management. Some of the important types of agreements that must be considered are for the provision of surveillance and resource availability data, for the coordination of predicted incidents and, for the acceptance and implementation of incident response plans that are developed.

6. Perform operational tests.

   Operational tests will examine how promising Incident Management tools and methods interact with each other, existing traffic management system components, and other ITS user services under actual traffic conditions. Testing of Incident Management will not be limited to urban scenarios since the service is equally effective in rural areas, for example at tourist attractions or parks.

   - TRANSMIT operational test, New York/New Jersey, 1993-1995. This test will evaluate incident detection based on the use of Automated Vehicle Identification (AVI)-equipped probes. This will include an evaluation of the sufficiency of the surveillance, data processing, and user interface used.

   - Texas Department of Transportation/Texas Transportation Institute, Houston, Texas (1993-1995) This operational system uses the movement of automatic vehicle identification (AVI)-equipped vehicles as probes to evaluate traffic conditions and identify incidents.

   - The Texas Traffic Responsive Automated Corridor (TxTRAC) operational test is providing a vendor-independent ITS technology test site. The first effort will be an evaluation of digital communications and high resolution video in incident detection and management. The operational test will also evaluate multiple incident detection algorithms. The Texas Department of Transportation is the lead agency, in partnership with Allied Signal, Technical Services Corporation, Texas Transportation Institute, and the Southwest Research Institute.

7. Develop guidelines.

   Guidelines for deployment of the Incident Management user service will be developed under this activity. Initial guidelines will concern surveillance and communication requirements to support Incident Management and the deployment of some detection and response tools. Later, guidelines will address all capabilities of the fully integrated user service.

8. Initial availability of incident response capabilities using emerging decision support tools.

- Incident Management capabilities already exist and have been implemented in many areas. These capabilities will continue to evolve and will be deployed as products become available. Initially, decision support tools that implement incident response plans will become available. Manual techniques will evolve into automated tools.

- The SMART Corridor in California is developing a set of standard operating procedures for incident response. Expert systems and the supporting communications tools are being developed to help implement the procedures.

- The Central Artery Project in Boston, scheduled to open in early 1996, will be evaluating various advanced decision-making techniques for detecting, verifying, and responding to incidents, especially in tunnel sections of the project.

9. Initial availability of incident detection capabilities using advanced surveillance techniques.

- The next set of capabilities to become available will be the incident detection techniques that rely on advanced surveillance capabilities developed under other ITS user services. Video surveillance and probe vehicles are possible approaches to be used in detecting incidents.

- A Washington, D.C. metro area operational test is evaluating the use of passive statistical cellular and cellular geolocation technologies for providing traffic flow information and incident detection via vehicle probes.

10. Initial availability of automated Incident Management techniques.

- In the longer-term, more sophisticated computer algorithms will become available. These could automatically detect incidents and then initiate appropriate actions in response to them. Such responses would be in accordance with previously developed response plans.

1.6 EMISSIONS TESTING AND MITIGATION

1.6.1 Introduction

Advanced vehicle emissions testing systems can be utilized on an area-wide basis to assist in improving air quality levels. For example, emissions information can be used to reroute traffic around sensitive air quality areas, or even, under severe conditions, to control access to such areas. Or, emission levels can be monitored at one location under a given set of conditions (e.g., on metered ramps), and then compared with other locations to form a better foundation for developing decisions on traffic system improvements, traffic demand management strategies, etc.

Other emission testing applications involve roadside identification of individual vehicles that are emitting levels of pollutants exceeding state, local or regional vehicular emission standards. Further developments in on-board diagnostic systems might also provide in-vehicle monitoring of emissions levels. These could provide the driver with an alert that the vehicle may not be in compliance with applicable standards, enabling them to take corrective action on a timely basis. Roadside technologies can also be used to continuously monitor the number of vehicles in the traffic stream that are in violation of pollutant emission standards, and provide the monitoring agency with other data that may be helpful in framing pollution control strategies.

1.6.2 Needs

State and local governments, particularly as a result of the Clean Air Act Amendments and ISTEA planning requirements, have been and are now establishing air quality control strategies. Approximately 200 geographic areas of the United States have been identified as non-attainment areas for one or more “criteria” pollutants. These areas must meet a series of deadlines for submitting attainment demonstrations, and states must also submit State Implementation Plans that demonstrate reasonable further progress toward achieving attainment by certain milestone years. For example, by 1996, moderate, serious, severe, and extreme ozone nonattainment areas must demonstrate that emissions of ozone precursors will be reduced by 15% from 1990 baseline levels. These requirements are compelling state and local governments to look for various means by which such reductions can be obtained, including IVHS technologies.

1.6.3 Service Description

Emissions testing equipment can be used to provide area-wide pollution information for use in monitoring air quality conditions and framing air quality improvement strategies. Either mobile systems or sensors installed in the infrastructure could identify problem areas, test results of different control strategies, serve as a foundation for rerouting or access control measures, and monitor changes in air quality conditions over time.

In another form, emissions testing technologies could provide an alert to the owner or operator of a motor vehicle that it is not in compliance with state or regional emissions standards. Such an alert, whether provided through a driver advisory, in-vehicle signing system, or a roadside message, would allow for mitigative action before further degradation occurred. Owners of individual vehicles or fleets, if informed that their vehicles may be out of compliance, may be motivated to quickly correct the problem since excessive emissions often indicates that the vehicle needs a tuneup. This voluntary, low-cost approach can be a part of government efforts to improve air quality.

Systems could be developed that can define and display the specific pollutant involved and the level by which the standards have been exceeded.

1.6.4 Operational Concepts

Roadside emission testing technologies can also be utilized by government agencies to detect those vehicles that do not meet emission standards. Sensors could be installed at particular locations where emissions could be accurately measured and related to specific vehicles. Motorists with automobiles that have high emission levels could be identified and provided with incentives to correct the problem, information on alternative modes of transportation, etc. Enforcement approaches, or pricing strategies based on level of pollutants emitted, could be implemented at the state or local level, if the testing systems proved to have a high degree of accuracy or if followup measurements were taken.

1.6.5 Technologies

Emissions testing and mitigation services rely primarily upon monitoring technologies that collect information about exhaust emissions from specific vehicles, local points, or over a wide area. A primary enabling technology consists of remote sensing devices, by which an active infrared beam crosses the exhaust plume and is received by a signal detector that can communicate with an emissions diagnostic computer. LIDAR (Light Detection and Ranging) is an example. In-vehicle systems might include diagnostic mechanisms that can monitor fuel consumption and exhaust emissions and display a warning to the driver.

Variable message displays may also be used to convey information about the emissions status of vehicles to their drivers, or about local or wide-area emissions problems (with accompanying instructions) to traffic control authorities or the traveling public.

Traffic control technologies could also be involved. If, for example, data collected at a freeway ramp indicated undesirable emission levels, merge controls might be modified to smooth the traffic flow and minimize the problem.

Another example of how these technologies could be utilized to alleviate air quality problems would be to have roadside detectors evaluate passing vehicles for emission levels instantaneously and without inconvenience to the driver. Drivers with high-emitting vehicles could then be notified by in-vehicle or variable message signing and requested to take remedial action.

These applications, as well as their potential benefits and limitations, were among the topics discussed in a report prepared for the U.S. DOT's Volpe National Transportation Systems Center by Jack Faucett Associates in July, 1993. The report is entitled "Qualitative Assessment of IVHS Emission and Air Quality Impacts."

1.6.6 Relationship to IVHS Goals and Objectives

Emissions testing and mitigation applications are primarily related to advancing the environmental goals of the IVHS program. These applications can:

- identify emissions levels of specific vehicles
- identify emission problem areas, and implement traffic control strategies to reroute vehicles or control access
- enable control strategies for reducing the number of vehicles emitting high levels of pollutants and the volume of pollutants emitted
- help bring areas into compliance with Clean Air Act requirements

These applications can also have a favorable effect on energy conservation, since many vehicle owners who correct excessive emission problems will experience collateral benefits in improved gas mileage.

There may be some individual *mobility* disbenefits, however, particularly if detection efforts are accompanied by strong local enforcement programs or road pricing strategies. Some owners of vehicles that prove repeatedly to be excessive emitters may be forced, or given incentives, to dispose of them. Local agencies should be sensitive to possible hardships that might result from any enforcement policies; they could utilize ridesharing advisories, transit benefits, etc. to assist persons who might be adversely affected.

1.6.7 Potential Costs and Benefits

1.6.7.1 Public Sector Costs. The major cost for the public sector of the emission testing user service will be in the purchase and installation of the roadside testing system. Additional costs will be incurred in the development of a central data collection and analysis point and the development and training of personnel to implement such a system. Some of the infrastructure is already in place for the development of a testing system. Facilities such as toll booths or parking lot booths could be retrofitted to include emission detection and vehicle identification equipment.

1.6.7.2 Private Sector Costs. Development of remote sensor and testing equipment, and in-vehicle analytical and display equipment, would likely be financed privately but could be part of a public-private partnership. Privately-financed development and deployment costs of in-vehicle equipment would likely be included in the cost of the vehicle. Additional costs will be incurred by the public in repairing their vehicles to meet emissions requirements. However, early detection of vehicular air pollution system control failure may lower the cost associated with waiting until the system deteriorates badly over time.

1.6.7.3 Potential Benefits. Benefits associated with this user service include:

- Increased public awareness of air quality problems and the measures being taken to address those problems
- Improved air quality monitoring
- More informed transportation decision-making
- Improved air quality
- Vehicles being operated more efficiently
- Improved health, due to improved air quality
- More attractive, environmentally cleaner cities

1.6.8 Assessment of Roles

1.6.8.1 Public Benefit.

The public would benefit from these applications in the form of improved air quality. This benefit is significant, but general and diffuse. It can be predicted that many individuals, particularly drivers of older cars and trucks, would object to deployment of any IVHS technologies that created, or potentially created, an enforcement mechanism designed to compel them into emissions compliance.

1.6.8.2 Potential for Private Investment in Development.

Only limited private development of these technologies will take place without public sector investment and encouragement. Public entities will be the primary market for these emissions-related products. Assuming that a public sector financial commitment develops for emissions reduction strategies, substantial opportunities for private industry would be created to develop, market, and service these products.

1.6.8.3 Public and Private Sector Roles in Deployment.

Emissions testing and mitigation applications would be of primary interest and value to states and communities concerned about air quality problems, particularly Clean Air Act non-attainment areas. Such areas can be expected to have significant interest in deploying these technologies once their value is demonstrated. States and local jurisdictions will also have to carefully consider any emissions enforcement strategies, in anticipation of public concerns being raised about privacy intrusions, targeting of particular classes, accuracy of readings, etc.

1.6.8.4 U.S. DOT Role in Developing Service.

The U.S. DOT would be expected to have a strong role in stimulating the development of this service. This would include accumulating information about adaptable technologies, participating in operational tests, evaluating results, establishing in-vehicle equipment standards, and disseminating information about the technologies to state and local governments. Deployment support would likely be requested regarding input into standards, comment, or intervention on privacy matters and developing guidelines on the use of highway funds to support such deployments. The Environmental Protection Agency may be expected to take a strong interest in these technologies as well and could be a source for some financial assistance.

1.6.9 Milestones and Activities

Figure 1.6-1 presents a Gantt chart depicting the key activities and milestones associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the chart. An issue is identified as a major potential challenge that has to be met in order to achieve deployability.

1.6.9.1 Issues

1. Issues may be raised regarding the accuracy of test results. Some studies have raised questions as to the reliability of remote sensing data in conducting emissions tests. At least part of this problem appears to be that same-vehicle exhaust emissions vary according to driving conditions; e.g. an accelerating vehicle emits more pollutants than one driven at a constant 25 mph. Thus, care must be taken to properly structure the emissions test, otherwise a vehicle testing positive in one test might test negative in another.

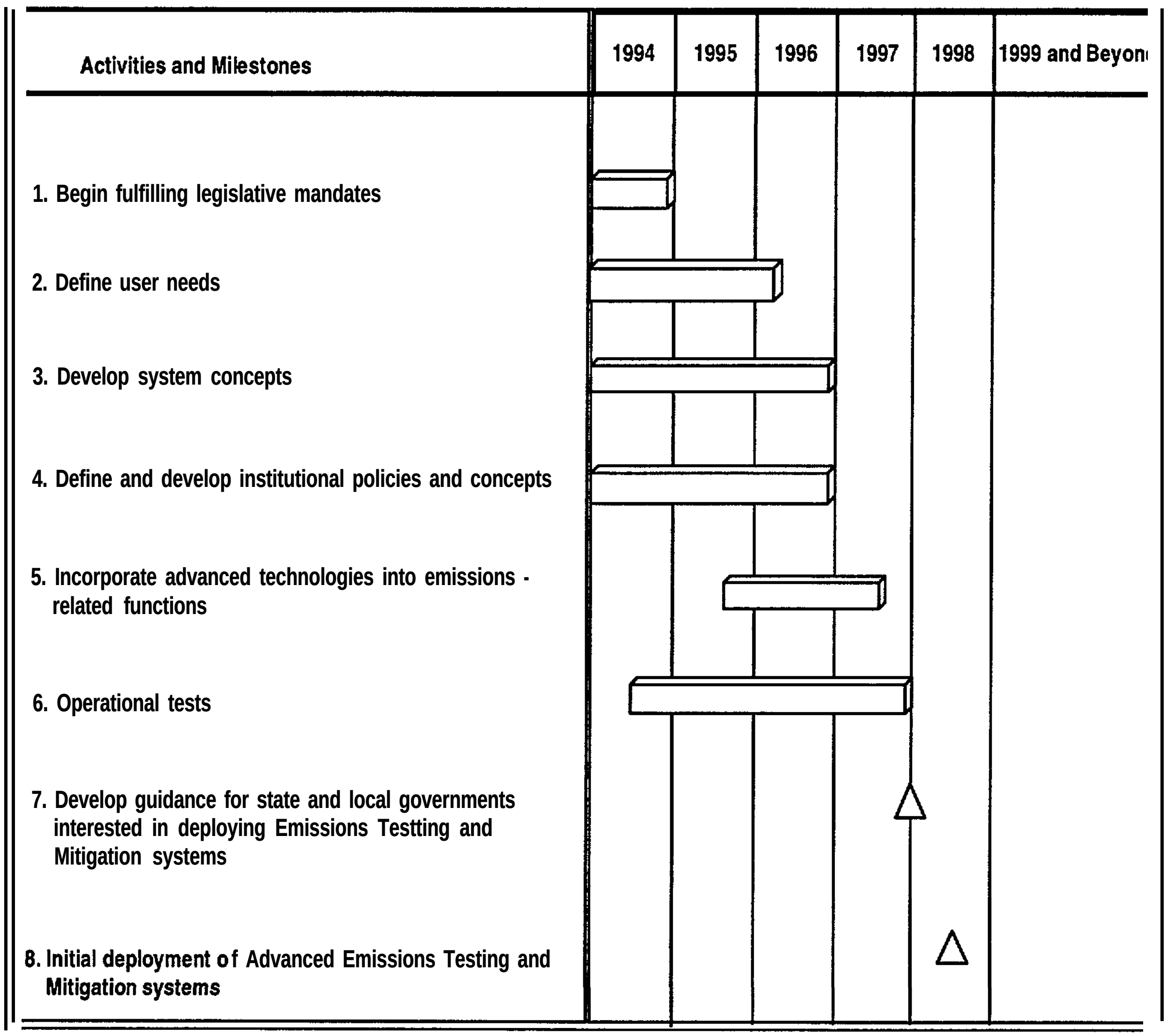

Figure 1.6-1 Emissions Testing and Mitigation

2. There are likely to be concerns expressed about whether, and how, emissions requirements will be enforced against drivers or owners of vehicles that are identified as high emitters. One would not anticipate public opposition to programs that seek to locate emissions problem areas or notify owners discretely that their vehicles may have out-of-range emission readings. Local opposition may develop to the extent that more intrusive enforcement or road pricing activities are initiated based on vehicle emissions levels. These policies are matters of local or state jurisdiction.

3. Personal privacy is likely to be an issue to the extent that individual drivers or owners are identified as emissions violators, with the most extreme example being use of incident photographing and database matching for that purpose.

4. Issues of social equity may be raised. Older, less well-maintained vehicles are more likely to produce high emissions, and these vehicles tend to be owned by less affluent persons and companies. Arguments may be made that testing and enforcement policies unfairly target these individuals and firms. Claims of regional or geographic bias may also be made, if testing stations lie on major access roads to metropolitan areas or testing or enforcement policies otherwise disfavor non-residents.

1.6.9.2 Activities

1. Begin fulfilling legislative mandates.

   The Clean Air Act, as well as ISTEA, have necessitated that serious attention be given to emission problems across the country, especially in non-attainment areas. Strategies directed at reducing pollution levels have been, or are being, implemented in many jurisdictions.

2. Define user needs.

   As noted above, state and local governments are likely to be those most interested in emission testing and mitigation services. Many of these governments have been, and are, in the process of formulating air quality control strategies to meet Clean Air Act requirements and would be expected to find IVHS emissions testing and mitigation services potentially very useful in designing effective programs. However, they are likely to need further data on how the actual air quality improvements that could result from implementation of these services might be quantified, as well as how these services might interrelate with other potential control measures.

3. Develop system concepts.

Many states and localities already have implemented emissions inspection requirements, often on an annual basis. Such programs customarily require all vehicles to be brought into an emissions testing station, where an analysis is performed using computer-based external probes. These programs, while effective, suffer from a number of drawbacks: they require driving to a fixed site, waiting, and taking time for the test. These drawbacks create inconveniences for drivers; they do not cover vehicles registered in non-test jurisdictions, and they take only a temporal "snap-shot," such that vehicles found in compliance one day may be out of compliance a short time thereafter, thus permitting high-emitting vehicles to travel on the roadways for much of the period before or between inspections.

Applications that will accurately test vehicles in motion, with little or no inconvenience to drivers, may be very effective by comparison. Much research has been undertaken in this area, most of it recently, and remote sensing has been used to test over 1 million vehicles worldwide. Refinement of these technologies, and linkage to vehicle identification and notification applications, is now under development.

Another promising technology in this area is the laser-based LIDAR system which has its origins in defense-related systems. More adaptable to localized or area-wide applications, such systems can serve as the basis for air quality initiatives that do not rely on individual vehicle detection and enforcement programs. Systems development in this field is also underway.

4. Define and develop institutional policies and concepts.

As noted above, some of the significant restraints to deployment of these technologies are institutional in nature. Interjurisdictional problems can be confronted as some communities move to test vehicles originating elsewhere. Conflicts may arise between state and local planners in assessing air quality improvement strategies. Privacy, law enforcement, and social equity issues may pose political problems. New U.S. DOT and EPA regulations regarding planning procedures and air quality will need to be implemented. Choices will need to be made among various mitigation strategies, including HOV and transit incentives, subsidized vehicle tune-ups, emission-based vehicle fees, purchasing of non-compliant vehicles, etc.

Several of these issues are specifically discussed Chapter VII, Deployment Considerations, which relates issues and questions that need to be addressed before deployment commitments can be made. Privacy and environmental considerations are also addressed in detail in U.S. DOT's report to Congress on Non-Technical Constraints. Finally, it is expected that additional useful information in these areas will be generated as a result of operational tests.

5. Incorporate advanced technologies into emissions-related functions.

As existing technologies are further studied and refined, new adaptations may develop, or other competing technologies may emerge. This task will involve the incorporation of these modifications or competing technologies into the emissions testing and minimization function. Also, models relating traffic flow, vehicle emissions, and overall air quality must be enhanced and used as the basis for analyzing alternative emission reduction strategies.

6. Operational Tests.

In Fiscal Year 1994, the U.S. DOT invited proposals for operational tests on emissions detection and mitigation systems, and 13 proposals were received. In April, 1994, the following proposals were selected:

- "Travel Demand Management Emissions Detection," proposed by the Idaho Transportation Department, Ada County Air Quality Board, and Ada Planning Association. The objective of this test is to evaluate the feasibility of using active infrared remote sensing technology to monitor vehicular emissions. Owners of vehicles that are identified as emitting excessive amounts of carbon monoxide will be notified by mail.

- "IVHS for Voluntary Emissions Reduction," proposed by the Colorado Department of Transportation, University of Denver, Remote Sensing Technologies, Inc., Conoco, Inc. and Skyline Products, Inc. An active infrared roadside emissions sensor and a variable message sign will give real-time emissions readings to passing motorists. This test will evaluate the usefulness and public acceptance of providing drivers with that information and education material about the fuel savings and air quality benefits of well-tuned vehicles.

- "Evaluating Environmental Impacts of IVHS using LIDAR," proposed by the Minnesota Department of Transportation, Santa Fe Technologies, IBM Federal Systems Company, and the University of Minnesota. This test will combine LIDAR technology for area-wide emissions detection and active infrared technology for roadside detection to evaluate any improvements in air quality attained through different traffic control strategies for events at a sports complex. Objectives include assessment of the overall effectiveness of LIDAR as an evaluation tool.

7. Develop guidance for state and local governments interested in deploying emissions testing and mitigation systems.

   This effort would synthesize the information gathered and lessons learned through the tasks described above, particularly the operational tests.

8. Initial deployment of advanced emissions testing and mitigation systems.

   After successful operational tests have been conducted, needed guidelines developed, and institutional issues addressed, field deployment of advanced emissions testing and mitigation can begin.

CHAPTER 2.0 - TRAVEL DEMAND MANAGEMENT

2.0 INTRODUCTION

The goals of travel demand management (TDM) are to reduce vehicle demands on the roadway by developing and encouraging modes other than the single occupancy vehicle (SOV), to decrease congestion by altering the timing and/or location of a trip, or to eliminate a trip altogether. Because of the growing problem of congestion and air pollution, many areas in the U.S. have already implemented TDM programs or will need to do so under the 1990 Clean Air Act. Besides addressing environmental goals, TDM programs allow employers to better accommodate the needs and lifestyles of employees, improving their productivity and mobility choices.

2.0.1 User Services

The goals of TDM can be achieved through the three TDM user services contained in the bundle grouping. There are two basic components to the bundle. The first component provides the alternatives, arrangements, and incentives that create the choices and opportunities for people to avoid driving alone. The second component of the TDM user services conveys the information on the choices and opportunities in a convenient and timely fashion in order to help affect a change in travel behavior. The two components can work separately, however, they can have significantly more impact on achieving the goals of TDM when they are integrated to work together.

This document describes the TDM bundle of ITS user services, however, effective deployment of any TDM strategy must be closely linked with non-ITS actions such as the development of land use, zoning and other transportation policies. The three TDM user services are listed in the table below, and, for the purposes of the NPP, have been numbered within the bundle as shown.

These services are described briefly below:

- **The Demand Management and Operations** service uses advanced technologies to support policies and regulations designed to mitigate the environmental and social impacts of traffic congestion. This service generates and communicates management and control strategies that support the implementation of programs to reduce the number of individuals who choose to drive alone; increase the use of high occupancy vehicles and transit; and provide a variety of mobility options for those who wish to travel in a more efficient manner, for example in non-peak periods. The service also allows employers to better accommodate the needs and lifestyles of employees by encouraging alternative work arrangements such as variable work hours, compressed work weeks, and telecommuting. The Pre-Trip Travel and Ride Matching/Reservation user services support this service.

Table 2.0-l Travel Demand Management User Services

Bundle	User Services
2. Travel Demand Management	1. Demand Management and Operations • HOV Facility Operation and Control • Congestion/Roadway Pricing • Parking Management and Control • Mode Change Support • Telecommuting 2. Pre-Trip Travel Information 3. Ride Matching and Reservation

- The **Pre-Trip Travel Information** service allows travelers to access a complete range of real-time intermodal transportation information at home, work, and other major sites where trips originate. Information on **TDM** operations and ride matching and reservations are conveyed through these systems to provide travelers with the latest conditions and opportunities in order to plan their travel. Based on this information, the traveler can select the best departure time, route and modes of travel, or perhaps decide not to make the trip at all.

- The **Ride Matching and Reservation** service provides real-time ride matching information and reservations to travelers in their homes, offices or other locations, and assists transportation providers with vehicle assignments and scheduling. The user service provides one of the basic tools for altering the travel behavior of individuals who drive alone during congested periods. This service will expand the market for ridesharing as an alternative to single occupant automobile travel, and will provide for enhanced alternatives for special population groups, such as the elderly or the handicapped.

2.0.2 Bundling the Travel Demand Management User Services

The Travel Demand Management bundle attempts to package the conditions and opportunities for changing travel behavior with the information services that are to necessary if changes are to be realized. The Demand Management and Operations service contains six subservices that support local policies to help effect these changes. The Pre-Trip Travel Information user service provides the user linkage for the conditions and opportunities presented by the Demand Management and Operations and the Ridematching and Reservations user services.

2.0.3 Relationship to ITS Goals

- **Reducing Energy and Environmental Impacts.** These services have a direct impact on achieving energy, environmental, and Clean Air Act goals by providing information and alternatives that encourage travelers to select a more energy efficient alternative to the single occupant vehicle. Travel Demand Management services also facilitates non-travel alternatives, such as telecommuting. These services allow travelers to select travel times and routes that enable them to avoid congested areas, thus reducing unnecessary fuel consumption and emissions. Reducing vehicle demand will also reduce the need for new infrastructure construction and the potentially negative environmental impacts and community disruption such construction might cause.

- **Improving Safety.** Travel Demand Management services allow travelers to make their trips with better information about routes, modes, intermodal connections, traffic conditions, and travel alternatives. This increases traveler security, and helps travelers to avoid hazardous situations and make increased use of the relatively safer rail, transit, or paratransit modes of travel.

- **Increasing Efficiency.** All of the user services in the Travel Demand Management bundle have a direct or indirect impact on improving transportation efficiency and alleviating congestion-related problems. These services provide information that enables travelers to adjust their departure time, mode and/or routes to avoid congested areas, or to determine that making the trip at all is unnecessary. These services also facilitate and encourage the choice of transportation alternatives to SOV travel, and reduces the time lost in intermodal connections. These services will reduce vehicle miles traveled by increasing vehicle occupancy and encouraging travel alternatives, such as telecommuting. This, in turn, will lead to reduced congestion as more vehicles are removed from the traffic stream.

- **Enhancing Productivity.** Traffic Demand Management strategies such as telecommuting, variable work hours, and compressed work weeks, can increase individual productivity by better accommodating employees' needs and lifestyles. In addition, reducing travel demand will reduce congestion, thus increasing the efficiency and productivity of personal, business and commercial travel.

- **Enhancing Mobility.** Better pre-trip travel information, as well as ride matching and reservation services and other demand management strategies, will help to provide cost effective alternatives to SOV travel for the physically challenged, economically disadvantaged, or those in living lower density areas, improving their mobility and access to the surface transportation system.

2.0.4 Cross-Cutting Issues

TDM programs are designed to respond to congestion, environmental, and mobility issues. To be effective, TDM actions require partnerships between the public and private sectors. This is especially true for vehicle trip reduction programs that are implemented at employment sites. Management support is another factor in the success of TDM programs. Research has shown that significant changes in travel behavior are possible when the upper management at an employment site supports the TDM actions.

Other factors in the successful implementation of TDM programs are the reliability, affordability, and availability of the supportive carpool, Vanpool, transit, and telecommuting programs. These operational programs must be designed to support the changes influenced through the user services. In addition, as with other user services, legal, institutional, privacy, and financial issues affect the application of TDM.

2.0.5 Technology Development Timeline Charts

The functional commonalities of the Travel Demand Management user services provide the basis for the technology development timeline chart shown in Figure 2.0-2. The top of the chart shows an estimate of when basic technical capabilities will be available for each function required by the services within the bundle. Using the traffic surveillance function as an example, in-pavement and video surveillance technologies are available now. It is estimated that aerial surveillance will be available by the end of 1995, and machine vision surveillance techniques will be available by the end of 1996. Further, it is estimated that enough properly equipped vehicles will be in the traffic stream by the year 1999 to use these vehicles as probes for traffic surveillance.

The bottom half of the chart shows a high level view of the major research and development (R&D), operational testing, and non-technical activities needed to reach deployment of the Travel Demand Management bundle of user services. The services have been numbered within the bundle, and the number(s) following the activities refer to the corresponding user service(s). The timeframes provide an estimate of when R&D, operational testing, or non-technical activities will be completed, and the user services will be ready for initial deployment.

Using Pre-Trip Travel Information (User Service No. 2.1) as an example, initial R&D has been, or will be completed in the “now” timeframe. Operational tests of first generation systems that have limited intermodal and real-time capabilities will be completed in 1995, and initial deployment can begin. As shown in the chart, it is estimated that metropolitan areawide Pre-Trip Travel Information services, which require advances in traffic surveillance, individual traveler interfaces, and other functions, will be ready for initial deployment in late 1996. Similarly, second generation systems, which generate multimodal travel itineraries based on real-time information and traveler preferences, will be ready for initial deployment in 1999. In the non-technical area, Pre-Trip Travel Information standards, including map database standards, will be completed in 1995.

The User Service Development Plans that follow describe the Travel Demand Management services in greater detail, and discuss the R&D, testing, and non-technical activities required to reach deployment for each of the user services in this bundle. Detailed descriptions of the activities are contained in the supporting material following the Gantt charts in the User Service Development Plans.

Functions — Now, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010

Traffic Surveillance
- Video • Aerial • Cellular Triangulation
- In-Pavement • Machine Vision • Vehicle Probe • Region-Wide

1-Way Mobile Communications
- Voice • Digital
- Analog • STIC • High-speed Digital Subcarrier

2-Way Mobile Communications
- Cellular
- Radio • Digital Cellular • High Capacity Comm

Stationary Communications
- Landline
- Radio • Fiber • Shared Networks

Individual Traveler Interface
- Audio • PCDs • Kiosks • HUD
- PC • In-Vehicle Displays • Voice Activation

Variable Message Displays
- Monochrome Displays • Color Capable

Navigation
- GPS • Map Matching • Real Time Navigation
- Dead Reckoning • Autonomous Navigation

Database Processing
- General Purpose DB S/W • Inter-Agency Sharing • On-line Agency Database
- Standard Map DB • Data Fusion • Integrated Multimodal DBs

Inter-Agency Coordination
- Phone • Agency Coordinated DBs

Traffic Prediction Data Processing
- Historical DBs • Real-time Data Fusion • Long Term Traffic Prediction
- Short Term Traffic Prediction

Routing Data Processing
- Shortest Distance Algorithms • Static • Dynamic • Multimodal

Vehicle Surveillance
- Vehicle Location • Weigh In-Motion
- Vehicle Identification

R&D

(1) Demand Management & Operations
(2) Pre-Trip Travel Information
(3) Ride Matching & Reservation

- Pre-Trip Information (2)
- Evaluate surveillance & communications technologies (1)
- Ride Matching Database Integration (3)
- Multimodal Strategies (1-3)

Test

(1) Demand Management & Operations
(2) Pre-Trip Travel Information
(3) Ride Matching & Reservation

- 1st Generation Op Test (2)
- 2nd Generation Op Test (2)
- Metro Area Op Test (2)
- Telecommuting Op Test(1)
- HOV Enforcement Op Test (1)
- Congestion Pricing Op Test (1)
- Ride Matching Op Test (3)
- Integrated TDM Op Test (1-3)

Non-Technical

(1) Demand Management & Operations
(2) Pre-Trip Travel Information
(3) Ride Matching & Reservation

- Standards Development (2)
- Map & Database Standards (1, 2)
- Human Factors Guidelines (2)
- Policy Guidance (1)
- Decision-Making Methods (1)
- Interagency/Interjurisdictional Issues (1)
- Ride Matching Guidelines & Standards (3)

Figure 2.0-2 Travel Demand Management Technology Development Timeline

2.1 DEMAND MANAGEMENT AND OPERATIONS

2.1.1 Introduction

The Demand Management and Operations user service generates and communicates operational, management, and control strategies that will support and facilitate the implementation of programs, policies, and regulations designed to do the following: (1) reduce the number of individuals who choose to drive alone, especially to work; (2) affect and increase a mode change from SOVs to high occupancy vehicles (HOV) for certain user group markets; and (3) provide a wide variety of mobility options for those who wish to travel either in a more efficient manner, at a different time, or to a different location.

Often Travel Demand Management (TDM) programs are implemented in response to a public or private sector policies or regulations designed to reduce traffic congestion, air pollution, parking space needs, and/or increase the number of persons using HOVs. The implementation and enforcement of Federal, state, and local policies that are intended to reduce, control, and/or manage vehicle usage are enhanced through the Demand Management and Operations user service. In order to insure that the goals and objectives of TDM policies or regulations are being met, monitoring and enforcement may also be a support element of TDM program development.

The Demand Management and Operations user service supports policies designed to promote operational, environmental, and social efficiencies in the transportation system. This can occur in the following ways:

- Facilitating convenient and accessible alternatives to driving alone so as to foster a change of modes for certain trip types, e.g. the work trip.;

- Managing and controlling the availability, location, and price of roadway and parking facilities in order to provide greater space utilization, traffic operations, and auto occupancies; and

- Managing and controlling the pricing of the roadways and related services so as to improve traffic operations, transit operations, and auto occupancies.

In addition to the services in the TDM bundle, many other ITS user services support the effective application of the Demand Management and Operations user service. Examples of user services that can be used to enhance existing TDM policies, programs, and regulations include En-Route Driver Information (User Service No. 1.1), En-Route Transit Information

2.1.2 Needs

Population growth, coupled with an increase in vehicles miles traveled, has contributed to traffic congestion and air pollution problems that constitute a significant threat to the quality of life and productivity in the United States. Furthermore, there are more vehicles on the road because of the lifestyle, land use, and demographic changes that are taking place. The average trip length has increased because of suburbanization. Consequently, roadway demand often exceeds capacity. Many urban highways are already at capacity, and building additional highways to accommodate growth would not, in many cases, be effective or feasible.

In order to address significant traffic congestion and air pollution concerns raised by current conditions, many state and local jurisdictions are developing and implementing policies and regulations that will encourage and/or require the application of strategies to manage and control the growth in the number of persons driving alone; increase the use of carpools, vanpools, and public transport; and mitigate the impacts of high polluting vehicles. These strategies, known as TDM programs, will be required, especially at major employment sites, activity centers, and congested corridors. In addition to state and local policies and regulations, many urban areas will be required to institute employer trip reduction programs that have been mandated under the 1990 Clean Air Act Amendments. The law requires employers with 100 or more employees located in areas with severe or extreme ozone pollution to implement strategies that reduce the impact of high polluting vehicles through a TDM program.

Given this background, there is a significant need for ITS technologies to facilitate the implementation, operation, and enforcement of these management and control strategies.

2.1.3 Service Description

Demand Management and Operations can be broken into three categories:

- Improved Alternatives -- includes transit service and HOV facility improvements, carp001 and vanpool programs, and site improvements.

- Incentives and Disincentives -- includes parking management (including pricing), congestion pricing, transit and ridesharing pricing, and other employer support measures.

- Alternative Work Arrangement -- includes variable work hours, compressed work weeks, and telecommuting.

ITS technologies used by governments and private industry for facilitating TDM will support and encourage strategies to increase HOV use as well as reduce and/or control single occupant vehicles trips at employment sites, activity centers, or along congested corridors. For example, to promote mode changes, ITS technologies can be applied to HOV lane enforcement and to parking control. ITS technologies are also important for achieving public awareness of alternative modes for work/non-work trips and for emission reduction and environmental policy goals. The deployment of ITS technologies, such as those associated with electronic payment systems, will provide the first practical opportunity for road pricing on non-limited access highways. Should jurisdictions so choose, they could adopt road pricing/congestion pricing schemes for the purpose of managing vehicle travel.

The Demand Management and Operations user service functions through interactive computer operations and communications centers that implement the TDM management and control strategies, by the following process:

- Receive information and data from transportation operators (i.e. state and local highway agencies, transit operators, parking operators, and ridesharing agencies) and/or users, on the current status, need, and level of activity and

- Send or disseminate operational information and commands to operators and/or users on how to control or manage activity so as to conform and comply with a TDM program, policy, or regulation.

Operational, management, and control strategies can be generated, implemented, monitored, and revised through this process in order to effectively meet the goals of TDM programs, policies, and regulations.

2.1.4 Operational Concepts

Once a program, policy, or regulation is established, then specific strategies are needed to implement it. Specific TDM strategies are discussed in the following paragraphs. Information on TDM strategies would be disseminated through other user services, especially Pre-Trip Travel Information, to enable travelers to make informed decisions on mode choice and departure time.

HOV facility (lane. ramp. or parking area) management and control: HOV lanes will be operated and enforced to respond to current conditions and situations. Occupancy requirements could be adjusted by the time of day or to reflect current demand and congestion levels, incidents, and enforcement criteria. For example, these requirements could be increased in response to pollution alerts or could be reduced in response to an incident on a parallel roadway. Another example of this operational concept is for traffic management centers to give priority to the movement of carpools, vanpools, and buses at ramp-meters and signalized intersections. The resulting reduction in travel time will make ridesharing and public transit more attractive to current SOV drivers.

Congestion/Roadway Pricing: Financial incentives and services for toll booths, parking areas, and HOV modes (i.e. transit, carpools, and vanpools) could be used to encourage mode changes and reduce vehicle demand. Tolls could also be increased during pollution alerts, while transit fares are lowered to meet the increased number of users changing modes from driving alone. Congestion pricing could be used during peak times in urban areas as well as at tourist attractions or recreational areas.

Parking management and control: The allocation, price, and availability of parking spaces can be managed and controlled to effect a mode change to HOVs. Working from a central point (such as a traffic control center), fee collection equipment, variable message signs, and detection equipment could be used to respond to events by implementing TDM strategies by time of day or in a dynamic manner. For example, the control center could interact with parking facilities to implement TDM strategies that help optimize and enforce parking space use in order to encourage HOV use or off-peak travel. During peak periods or when there is an air pollution alert, a TDM strategy could impose a higher charge for single occupant parking spaces, while discounting the charge for carpools and Vanpools. Implementing this type of strategy makes parking lots more efficient and decreases the need for new parking spaces. Variable parking fees could also be paid electronically, enabling a greater response to trip reduction policies and requirements. Electronic payment technologies could also be used under this strategy to enable a single payment for bus, rail and parking charges, as well as other, non-travel related transactions. This would increases the convenience and equity of the transportation system for the user.

Mode change support: This strategy is supports the Ride Matching and Reservation user service and will provide the public with greater flexibility when cat-pooling or using public transportation. For example, a traveler could ask to be included in a Carpool at a specific time going to a specific place, and the Traffic Management Center (TMC) would find a carp001 willing to carry an additional rider. The TMC could credit the carp001 driver's account and debit the carpooler's account, which would encourage the carpooler to give someone else a ride at a later date to receive credit.

A traveler could also call a TMC and present a travel itinerary and special conditions. The traveler would then receive travel options available for that date and time, so that he/she has flexibility in choosing his or her mode.

A TMC can provide instant service to a large number of employers, allowing convenient and inexpensive guaranteed ride home programs. A TMC can also keep track of increasing alternate mode users and adjust available transit service accordingly.

Telecommuting and Alternative Work Schedules: Advances in telecommunication technologies are making telecommuting and alternative work schedules, such as compressed work weeks, a viable and economically advantageous alternative to driving to work during peak periods. Telecommuting can increase employee morale and productivity, while reducing the cost of parking, office space, and equipment for the employer. An important element of this strategy is to educate both employees and employers on the benefits of telecommuting, job sharing, and other alternative work schedules, perhaps providing incentives to employers who participate.

Public awareness: Educating the public and increasing their awareness and appreciation of the benefits of TDM will be important to its success. This will include public relations, education and outreach activities to build public and political support for TDM, leading to user acceptance of TDM strategies and support for legislative mandates for TDM programs.

2.1.5 Technologies

ITS technologies that facilitate TDM include, but are not limited to, the following:

- **Surveillance** - Automatic vehicle identification and classification can allow prioritization of HOVs (e.g. bus priority at signals, preferential parking), and HOV enforcement and regulation (e.g. HOV lane use, parking charge).

- **Traveler interface** - Information systems to provide the public with travel and environmental information while they are still at home or work, allowing the user to make a decision on mode choice based on the information obtained.

- **Multi-use electronic card or tag** - Enables the use of a one-time payment for bus, train, vanpool, and parking, thus facilitating the application and support of TDM measures. Also allows variable rates to be charged based on time of day or other conditions.

- **Vehicle and air quality monitoring systems** - Aids TDM by collecting and distributing data on roadway conditions, number of travelers, operations (for the vehicle and the roadway), and emission/air pollution levels.

- **Highway Advisory Radio** (HAR) - Provides travel information along a specific stretch of roadway which allows drivers to take an alternate route.

- **Communications** - The TDM user service depends on the establishment of communication links to transmit the strategy from a control or operations center to the location of action (e.g., a parking facility, an HOV lane, a transit center, an employment site, or a toll facility), where physical systems and hardware (e.g., cameras and monitoring equipment, variable/changeable message signs, video/audio transmission equipment, toll and fare collection equipment, surveillance and control devises, and detection and enforcement equipment) will be operated. Communication links enable the strategies developed through the TDM user service to be continuously revised in order to respond to changing environments, conditions, and policy needs.

2.1.6 Potential Costs and Benefits

2.1.6.1 Public Sector Costs

The major cost for the public sector TDM user service is the development of systems to identify, inform, and enforce TDM policies and regulations. In addition, it will be the public sectors' responsibility to participate and help support their share of any public-private arrangements to implement, operate, and enforce TDM. Some of the needed infrastructure is already in place, such as TMCs and toll booths, until automated toll collection is available. Thus the cost of providing the basic services needed to upgrade the systems to facilitate TDM will be comparatively minimal. If the necessary infrastructure is not in place, the costs might be shared through private sector partnerships.

Another major public cost is that assumed by the regulating agency. As the 1990 Clean Air Act requires non-attainment areas to implement TDM programs that will reduce single occupant vehicle trips. Public agencies are to oversee that reduction. In order to determine if companies are actually reducing their trips, public agencies must use technology that will enable enforcement of the regulations. The public sector must also commit to finding a system to identify and enforce air pollution/emission policies and regulations.

2.1.6.2 Private Sector Costs

Costs to an employer in implementing TDM strategies will vary depending on the strategy chosen. Employer costs in operating a commuter alternative can be considerably less than providing on-site parking. For example, the major cost typically born by an employer to support a single employee's travel comes from the provision or subsidization of parking, at an average cost of $73.50 per employee per month. The alternative of operating a vanpool for 12 to 15 people could reduce the employer's cost to $12.35 per employee per month.

The private sector will also share in the cost of the public-private partnerships that are needed for TDM, because, although many of these strategies are required by law, employers will benefit in the long run.

2.1.6.3 Potential Benefits

Travel demand management has high potential benefits. These benefits include the following: (Ref. "Evaluation of Travel Demand Management Measures to Relieve Congestion," prepared by Comsis Corporation, February, 1990).

- **Reduced trips** - a reduction in the range of 20 to 40 percent at employment locations.

- **Reduced congestion** - a reduction in trips in the range of 5 to 10 percent along congested corridors.

- **Reduced peak period vehicle use** - a reduction of approximately 5 percent on an area-wide basis, can be achieved through an aggressive TDM program that is supported by ITS.

- **Reduced need for additional parking** - fewer vehicles need fewer parking spaces thus reducing the need to build additional parking facilities.

- **Improved public transportation** - better public transit attracts more riders, thereby increasing people volume while decreasing the number of automobiles on the roadway.

- **Improved working conditions** - alternative work arrangements and employer support for improved mobility choices can lead to increased employee morale and productivity.

2.1.7 Assessment of Roles

Responsibility for development of ITS services generally resides with the private sector, however, there are situations when the U.S. DOT involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and evaluation of systems with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in the development of the Incident Management user service.

2.1.7.1 Public Benefits

Travel demand management has a high potential benefit to the public. Benefits from the use of TDM strategies and ITS services will include reduced congestion, reduced air pollution, and improved public transportation options.

2.1.7.2 Potential For Private Investment

Travel demand management will, for the most part, remain the responsibility of the public sector, with possible contracting with the private sector for operations and maintenance of system components. HOV lane enforcement, air pollution/emissions information, and mode change information will be developed and marketed primarily by the responsible public agencies. However, there are areas where the private sector may develop their own TDM products and services. One such area is traveler information, where products and services are already being developed that can be used for travel demand management. Other areas are parking management and trip reduction, where employers or private contractors are developing TDM programs for use in private parking facilities. Also, some employers in both the public and private sectors already own and operate vanpool fleets.

2.1.7.3 Public and Private Sector Roles in Deployment

The public sector will have the major responsibility for implementing and operating the components of this ITS service as they are used to administer an areawide travel demand management program. Additionally, private companies will own and operate systems that help them to comply with air quality and trip reduction mandates. Public sector agencies must work closely with one another and with the private sector in order to provide a comprehensive TDM user service.

2.1.7.4 U.S. DOT Role In Developing Service

The travel demand management user service will have a high public benefit but a low private market potential. While the public sector will be the primary provider of TDM services, the private sector will provide some traveler information, trip reduction, and parking management services. As a result, the U.S. DOT will have a strong role in developing, testing, and supporting the deployment of TDM programs.

2.1.7.4.1 ***Research and Development:*** The U.S. DOT role in research and development activities for this service is high, including addressing technical issues involved in developing and implementing TDM strategies.

2.1.7.4.2 ***Operational Tests:*** The U.S. DOT role in operational tests of TDM strategies is high. The U.S. DOT will be responsible for ensuring adequate evaluations of new TDM technologies and strategies, and encouraging the incorporation of TDM strategies as part of operational testing activities.

2.1.7.4.3 ***Institutional and Legal:*** The U.S. DOT role will include appropriate input to standards, developing guidelines for the use of Federal-aid funds, facilitating public/private ventures, and helping to address the various institutional and legal barriers to providing this service. These include the privacy issue surrounding the use of automatic vehicle identification, potential barriers to the use of congestion pricing schemes, and zoning and land use issues brought about by trip generation/reduction guidelines.

2.1.7.4.4 ***Deployment:*** The U.S. DOT role in deployment of this service is high, including providing training, technology transfer, and outreach activities to assist public agencies, employers, and others in developing and deploying advanced Travel Demand Management services.

2.1.8 Milestones and Activities

Figure 2.1-1 presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

2.1.8.1 Issues

1. Institutional acceptance of TDM as a tool
2. Social equity
3. Possible impact on regional economic development, land use, and zoning policies
4. Enforcement of regulatory requirements
5. Operational issues, including determination of pricing policies
6. Means of raising revenues
7. Public/private partnerships

2.1.8.2 Activities

1. Begin fulfilling legislative mandates.

   The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Energy Act of 1992, and the Clean Air Act Amendments of 1990 placed into law the need for TDM programs. Many areas in the U.S. have already implemented TDM programs or enacted local legislation necessitating TDM programs.

   - Hacienda Business Park Owners Association: Hacienda Business Park is located in Pleasanton, CA. The developers of the park, Callahan-Pentz properties and Prudential Insurance Companies of America, were required to implement a TDM program for land owners and lessees as part of the Planned Unit Development requirements. Subsequent development will be required to meet the established TDM goals within a four year timeframe. This requirement was later applied to all Pleasanton employers and building owners (of a certain size) via a city-wide ordinance.

   - Bellevue. Washington - US West Regional Headquarters: This major communications firm consolidated its regional operations into one location. US West faced restrictions on parking, by city regulation, and a requirement to implement a TDM program. The program consisted of: limited on-site parking (408 spaces for 1150 employees), parking charge of $60 per month for driving alone, $45 per month for 2-person carpools, and no charge for carpools of 3 or more, reserved parking for HOVs, flexible work hours, and an on-site transportation coordinator. As a result, only 26% of US West's employees drive alone and the company generates 47% fewer trips than other downtown Bellevue employers.

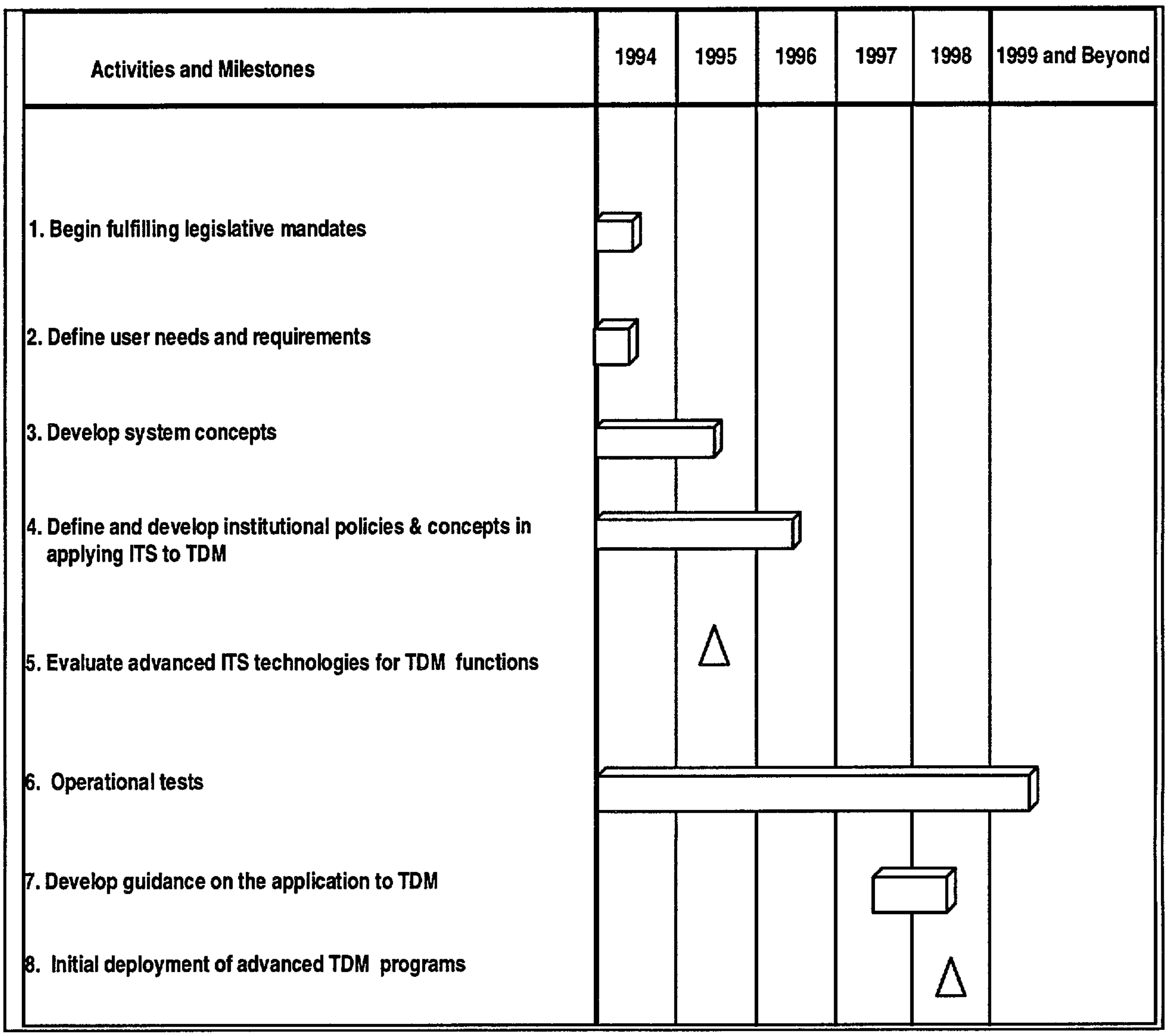

Figure 2.1-1 Demand Management and Operations Activities

2. Define user needs and requirements.

Identify characteristics of TDM programs that are essential for achieving a successful program. These characteristics will vary by location and will change to encompass new technologies.

- Transportation Research Board - National Conference on TDM Research and Innovation. (Fall 1993)

- Distribution of FHWA/FTA technical assistance and guidance materials to develop, implement, and operate effective TDM programs.

3. Develop system concepts.

Based on the needs defined above, this activity will research and develop operational concepts, identify public and private partnerships, and describe the over-all TDM management and control strategies that can be facilitated with ITS technologies.

The following are a few examples of TDM projects funded through a joint partnership between FHWA and FTA:

- NY Metropolitan Transportation Commission - Telecommuting: Established a telecommuting satellite center at Mineola, New York (on Long Island), the first such center in New York Region.

- Texas DOT (Dallas) - HOV Enforcement: Provides innovative enforcement of an HOV lane in Dallas, using advanced imaging and identification systems.

- Central Contra Costa Counts Transit Authority - Guaranteed Ride Home with inter-jurisdictional payment strategy: Provides Guaranteed Ride Home van service with integrated fare collection at Central Contra Costa County BART Station. The system links the fare payment system of BART to after-hours demand-responsive van service.

- Long Island. NY - TRANSCOM's Traveler Information System: This proposed project would expand the already existing INFORM system into southern Long Island. The project would deliver traveler information, especially to employer locations, by computer; local cable television; and traffic reporting services.

4. Define and develop institutional policies and concepts in applying ITS to TDM.

In order to effectively apply TDM, innovative institutional arrangements are needed to implement, operate, and enforce policies and regulations. These institutional arrangements will involve the partnership of the private sector (i.e., employers and developers) and the public sector. Such institutional arrangements and partnerships will place a great deal of emphasis on measures to attract and retain HOV users as well as to monitor and enforce other TDM measures. In addition, institutional arrangements for TDM will also need to address non-technical issues such as legality, equity, privacy, and multi-jurisdictional settings.

State, regional, and local jurisdictions must work together in order to achieve the full benefits of TDM. Non-technical concerns confronting ITS/TDM and inter-jurisdictional cooperation will be studied prior to full-scale TDM deployment. Administrative, policy, and legislative actions that have strong probability of expediting full-scale deployment of a national program will be recommended and implemented.

- ITS AMERICA's TDM Task Force: This task force is charged with coordinating the identification of travel demand and telecommuting technologies and programs within all committees of ITS AMERICA, including on-going programs sponsored by FHWA and FTA

5. Evaluate advanced ITS technologies for TDM functions.

This activity will study and evaluate advanced ITS technologies which hold promise for satisfying TDM program requirements. Key strategies of interest include congestion/parking pricing, HOV enforcement, and parking management.

6. Operational Tests.

This activity is for operational testing of Travel Demand Management strategies. Present efforts fall under three areas: application of traveler information systems, HOV enforcement systems, and congestion pricing through automatic vehicle identification technology. Travel Demand Management will be incorporated into other operational tests as well, even if TDM is not the primary user service being tested.

- Houston Smart Corridor: This project seeks to develop and evaluate a real-time traffic and transit information system. It will address modal change; evaluate the most feasible, cost-effective, and available technologies; and examine the roles and costs involved with getting the information to the public (1992 - 1995).

- Rogue Valley Mobility Manager: This project will demonstrate the Mobility Manager concept to integrate transportation users, providers, and funding sources. Electronic payment services ("smart cards") will be used to record financial transactions. The initial phase will focus on providing transportation services to the elderly and disabled who are unable to use fixed route transit. Using existing hardware and readily-developed software, the second phase will demonstrate the Mobility Manager concept for frequent transit riders in urban and rural environments. The third phase will involve participation of the general public (Late 1991 - Mid 1993).

- Congestion Pricing: Project applications are being studied in a number of cities in response to the congestion pricing demonstration program in ISTEA (1993 - 1999). Using an FHWA grant, the California Department of Transportation, the San Francisco Bay Area's Metropolitan Transportation Commission, and the Bay Area Congestion Pricing Task Force will examine a system of variable tolls for drivers crossing the San Francisco-Oakland Bay Bridge. In addition, a House of Representatives Report 103-190 (July 27, 1993) recommends inclusion of "a specific allocation of $950,000 to address the institutional and political barriers to congestion pricing to be conducted by the University of Minnesota's Humphrey Institute."

7. Develop guidance on the application of ITS to TDM.

   This effort will develop guidance for the application of TDM management and control strategies, incorporating the lessons learned in the previous six activities.

8. Initial deployment of advanced TDM programs.

   After successful operational tests have been conducted, needed guidelines developed, and institutional issues addressed, field deployment of advanced TDM programs can begin.

2.2. PRE-TRIP TRAVEL INFORMATION

2.2.1 Introduction

The Pre-Trip Travel Information user service provides travelers with information prior to their departure and before a mode choice decision is made. Information provided to a traveler before a trip begins can encourage alternatives to SOV travel, including the decision not to make the trip at all. Information about TDM pricing strategies, implemented through the Electronic Payment Services (User Service 4.1), would also be available and could affect a traveler's departure time or mode choice.

Pre-trip travel information is the means by which many TDM strategies can be presented to the public. The service integrates information from various transportation modes and presents it to the user through electronic communications or public information centers. Users of the service include all travelers, including commercial vehicle operators, as well as providers who will develop and market pre-trip information services.

Although related, information provided to travelers once a trip is underway is covered under En-Route Driver Information (User Service No. 1.1) and En-Route Transit Information (User Service No. 3.2). Also related, Traveler Services Information (User Service No. 1.3) provides for a more effective selection of destination, for example the closest location of a product or service.

2.2.2 Needs

The IVHS program is a response to the increasing social and monetary costs of traffic congestion and poor mobility. As compliance with the Clean Air Act compels consideration of various TDM strategies to reduce single-occupant vehicle travel, pre-trip travel information will assist by providing a TDM information source for both employers and employees. Additionally, pre-trip travel information systems can function as an integral part of TDM measures, and interested parties will be able to expand and tailor the information systems to accommodate TDM programs.

Before a trip begins is the time when accurate information can be used to influence the traveler's choice of travel mode, travel schedule, or routing. Pre-trip travel information, if it is timely, accurate, and reliable, can assist travelers in choosing intermodal alternatives to single occupant automobiles, in deciding when, or even if, to begin a trip, and in selecting a route to desired destinations.

Before starting a trip, a traveler must select the time of departure and the mode or modes of travel. Based on pre-trip information, a person may decide to delay the trip, or not take the trip at all. One reason that mode choice often results in driving a car may be that information about other available modes is difficult to get, inaccurate, or not timely. The intent of this user service is to ensure that people making mode and trip decisions have access to real-time information for the full range of existing travel options.

2.2.3 Service Description

Pre-Trip Travel Information systems allow travelers to access a complete range of multimodal transportation information at home, work, and other major sites where trips originate. These systems provide timely information on transit routes, schedules, transfers, and fares; intermodal connections to rail or other transportation systems; and access to ridematching services. Also included are updates of traffic and highway conditions; 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. When fully integrated with Electronic Payment Services (User Service 4.1), the traveler could also make reservations and pay applicable fees when planning a trip.

2.2.4 Operational Concepts

Through Pre-Trip Travel Information, the traveler, including a commercial vehicle operator, gets a quick picture of travel conditions, options, and services for a particular time, along a chosen travel path. In its more advanced forms, Pre-Trip Travel Information performs a practical service, calculating routes and itineraries, and providing mode choices for the traveler based on real-time travel conditions and parameter variables provided by the traveler. Time of departure, time of arrival, total travel time, maximum number of mode transfers, preferred routes and modes, intermediate stops, weather conditions, and other such information could be included. Using these “parameter variables,” the system considers current and predicted travel conditions, and presents one or more alternate itineraries.

To provide travelers with a common information medium for all transportation modes, integration of intermodal information must occur. Traffic control systems generating data about highway conditions must be integrated with public transportation systems providing transit location and route information. Paratransit services and access to ridematching systems must also be included. Integration of this service with electronic payment systems will allow travelers to pay transportation-related fees as part of the trip-planning process, and will also provide transportation pricing information that could affect mode choice and departure time decisions.

Pre-Trip Travel Information systems will likely become a part of wider information services that appeal to a range of consumer needs in addition to transportation. As interactive television and other advances by the telecommunications industry emerge, including the National Information Infrastructure, Pre-Trip Travel Information systems will complement other home information networks such as home shopping, banking or educational services, perhaps even using the same electronic payment system used for personal transactions.

2.2.5 Technologies

Pre-trip Travel Information technologies focus on four main areas:

- Data collection
- Data communications
- Data processing
- Presentation to the user

Data collection refers to the hardware and software necessary to gather information. Data collection methods and technologies vary with the transportation mode, as described in the following paragraphs.

Cellular telephone triangulation may become an important source of vehicle location information. Real-time public transportation data includes information gathered by automated vehicle location (AVL) systems. Vehicle positions are determined using signposts, Global Positioning System (GPS), Land-based Radio Navigation System (LORAN), and others. Required technologies to support AVL systems include GPS receivers, differential transmitters, and radio voice and data communication. Technologies that expand the capacity of existing radio channels will be necessary. Route and schedule data will come from transit operators' planning offices.

Highway condition information is collected through the Traffic Control and Incident Management services (User Services Nos. 1.4 and 1 .5). Technologies include inductive loops, closed-circuit television, microwave and infrared sensors, and image processing, among others. Additional highway condition information is available through Electronic Toll and Traffic Management (ETTM) systems, and equipped vehicles acting as traffic probes.

Data communications occurs between the data collection systems and the data processing systems, and between the data processing systems and the user. Technologies include telephones, cellular telephones, modems, pagers, and radio frequency, including spread spectrum.

Data processing refers to the integration of data from various modes and the transforming or converting the data to an easily understood user interface. It also includes algorithm and software development required to support interactive systems and systems that calculate travel itineraries. Data processing also involves geocoding, or finding a location on a map from an address or other description, so that the traveler knows the location of his destination prior to making pre-trip decisions. Systems involving maps will require the fusion of map data with other data for convenient communication to the user. The technology involved includes personal computers, workstations, and mainframe computers. Systems will need to integrate data from different sources and be able to calculate and compare characteristics, such as distance or travel time, of potential route and mode alternatives.

In simple systems, information can be presented as a voice on a standard or cellular telephone, which asks the listener to push the number corresponding to the desired service, and then provides continually updated information (audiotext). Options and the degree of interactivity can vary. Automated telephone, audiotext, or videotext systems could provide transportation and other information through a single number.

Pre-Trip Travel Information, as part of a wider information network, can also be presented through personal computers with modems. Similarly, cable television or videotext can be provided with videotext terminals connected to telephone lines. Personal Communications Devices (PCDs) that combine many of these technologies into a small palmtop computer or other communications device are also being tested for Pre-Trip Travel Information applications. Some systems may provide only real-time data without any appreciable processing. Again, options and the degree of interactivity can vary.

More complex video systems may include elaborate interactive map presentations requiring larger amounts of computer memory and will probably be provided at public locations or kiosks. Complex systems may support algorithms where the traveler queries the system by indicating the origin and destination of a trip and then provides input for parameters such as travel time, departure or arrival time, and intermediate stops. The system would then calculate and describe various mode options and provide information about how to access each mode, together with graphic displays of regional congestion, link times and travel speeds to assist the traveler in making pre-trip decisions.

2.2.6 Potential Costs and Benefits

2.2.6.1 Potential Costs

Costs of Pre-Trip Travel Information include capital costs for the procurement of equipment and systems integration and operating and maintenance costs. Costs will vary with the sophistication and capacity of the systems. For each added function or capability of the system there are costs associated with data-collection, communications, data processing, and program management. In addition, as a system's capabilities expand, the cost of devices to access those added capabilities will also increase. For example, a relatively simple audio information system could be accessed by telephone, but if the system expanded to include map displays of real-time bus locations, more expensive video displays would be required. However, highly integrated systems with extensive capabilities may have their higher costs offset by gains in efficiency, system flexibility, and public popularity. In addition, Pre-trip information delivery will most likely follow other consumer services resulting from advances by the telecommunications industry which significantly reduces consumer costs and increases availability.

2.2.6.2 Potential Benefits

Potential benefits of Pre-trip Travel Information have not been quantified. However, it is anticipated that pre-trip travel information services will result in more efficient use of congested corridors by encouraging mode changes and changes in departure times and routes. Pre-Trip Travel Information will be closely linked to the Travel Demand Management service, thus increasing the benefits obtained from reducing SOV travel. Pre-trip information will also enhance the efficiency and safety of recreational travelers.

2.2.7 Assessment of Roles

The responsibility for development of IVHS services generally resides with the private sector, however, situations exist where the U.S. DOT involvement is appropriate. The development of systems with high public benefit but low commercial potential is an example, or where government, rather than the private sector, is the primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT encourages joint public/private development efforts. This approach, which underlies the U.S. DOT's strategy for investment in ITS, is used below to assess the U.S. DOT's role in Pre-trip Travel Information.

2.2.7.1 Public Benefit

Many public benefits will be created: increased transit ridership, reduced congestion on roads, reduced travel times, increased traveler safety, reduced emissions, facilitation of real-time ridematching and travel demand management strategies, and increased traveler convenience.

2.2.7.2 Potential for Private Investment in Development

Potential for private investment exists in the development and sale of information systems and user interface terminals. Information systems that provide consumer services outside of transportation may prove popular enough that transportation information systems ride the "coat-tails" of more popular, privately-provided, information services.

2.2.7.3 Public and Private Sector Roles in Deployment

The deployment of Pre-trip Travel Information will be a public and private partnership. While the information infrastructure that carries transportation information will likely be privately developed, the public sector will probably have a role in ensuring that mode choice and other information to encourage ride sharing and public transportation is included. The public's willingness to pay for highway condition information may ensure that this capability is provided by the private sector. The public sector will play a role in defining the requirements for public system use and in helping to establish open standards and architecture. Public sector involvement in the development of this service is important to assure that the functional and interoperability potentials of the systems are fully developed.

2.2.7.4 U.S. DOT Role in Developing Service

The U.S. DOT will have both a direct and supporting role in the development of Pre-trip Travel Information. In all activities supporting this service, the U.S. DOT should actively support timely establishment of standards.

2.2.7.4.1 ***Research and Development:*** The U.S. DOT role in research and development is high for both public transportation and highway applications. However, the public sector is largely reliant upon the creative ability of the private sector to develop prototype products for operational testing.

2.2.7.4.2 ***Operational Tests:*** The U.S. DOT role in operational testing is high. U.S. DOT involvement in the operational testing of integrated systems is critical to the proper development of the service. Careful evaluations are a critical element of this effort. Sites should be chosen to provide sufficient operational testing to accommodate a variety of final deployments.

2.2.7.4.3 ***Institutional and Legal:*** The U.S. DOT role in evaluating whether institutional or legal issues present barriers to deployment is medium. It is expected that many of the perceived problems will be resolved through the initiative of the private sector.

2.2.7.4.4 ***Deployment:*** The U.S. DOT role in deployment is high. U.S. DOT must work to ensure that transit operators have the resources to develop and/or participate in information systems. The U.S. DOT must also work to ensure pre-trip information systems are compatible and consistent with each other. The U.S. DOT will also foster and encourage the inclusion of pre-trip information as part of privately-provided information systems.

2.2.8 Milestones and Activities

Figure 2.2-l presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

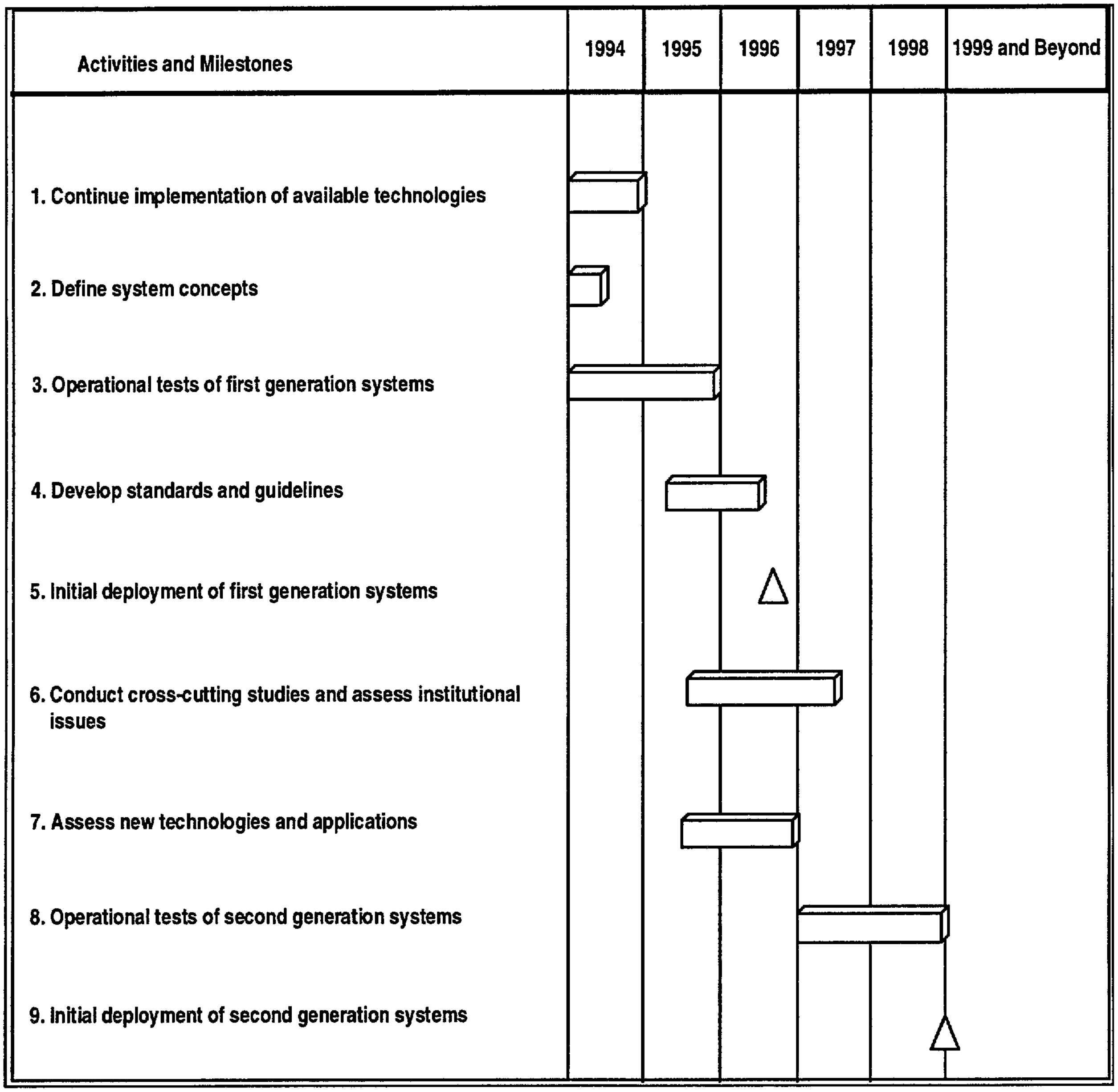

Figure 2.2-1 Pre-Trip Travel Information Activities

2.2.8.1 Issues

The key technical issues are data-oriented and include the following:

- how to obtain and integrate dynamic information from multiple sources;
- maintaining the resulting databases so they contain only current, accurate, and reliable information;
- selecting and transmitting desired portions of the information to output devices;
- presenting the information to travelers to support trip planning and decision-making.

2.2.8.2 Non-technical issues

- the reliability of the information;
- interjurisdictional cooperation as well as public/private cooperation needed to collect and disseminate reliable and accurate real-time information;
- willingness of private sector transportation providers to share information, especially negative information such as delays, with other public and private sector entities;
- costs, user-acceptance and willingness to pay for the service.

2.2.8.3 Activities:

1. Continue implementation of available technologies. Some examples of activities underway include:

   - The private sector is marketing systems with varying levels of sophistication (e.g., some use static information only.) For the most part, these systems are focused on driver information only (i.e., single travel mode.)

   - Maryland, California, New York, and Minnesota have implemented traffic information systems using cable TV.

   - Traffic information is broadcast over commercial radio and television in many jurisdictions.

   - In Southern California, transit itineraries of the Metropolitan Transportation Authority are provided by an audiotext system, and the California Highway Information Network (CHIN) provides information on freeway conditions.

   - Extensive deployment of AVL systems throughout transit fleets in preparation for information dissemination.

- Extensive deployment of traffic surveillance equipment so that accurate real-time information will be available for travel planning.

- The Visual Traffic Information Project (VTIP) provides pre-trip travel information on a color-coded map showing incidents and other traffic information along the Long Island Expressway and the Northern State Parkway in New York. Among other locations, displays are located in a major department store and at a rental car office at LaGuardia Airport.

2. Define system concepts.

    - Asses user needs and determine user perceptions of the value of systems and their willingness to pay for the service.

    - Identify the impacts of pre-trip travel information on travel behavior, and define guidelines for pre-trip information to increase the benefits of the service.

    - Explore opportunities to “piggyback” pre-trip travel information onto other information systems.

3. Operational tests of first generation systems. Some examples of operational tests currently planned or underway include:

    - Bellevue, Washington, Smart Traveler Project will test an interactive commuter information center in a downtown office building.

    - Boston SmarTraveler Project is testing a telephone-based audiotext traffic information service.

    - California Smart Traveler Project will test an audiotext/videotext traveler information system for residential and office use.

    - Houston Smart Commuter Project is developing a real-time transit and traffic information system designed to promote mode choice alternatives.

    - Minnesota GuideStar “Genesis” project will test a portable digital Personal Communications Device (PCD) designed to receive traffic and transit information.

    - Minnesota GuideStar “Travlink” project will test real-time transit information provided in the home and workplace using several different output technologies.

- The Transit Network Route Decision Aid project is developing specifications for designing, implementing, and evaluating a computerized information system that aids a telephone operator in rapidly identifying useful itineraries for passengers in a mass transit system.

- The San Francisco Bay Area TravInfo project is developing a multi-modal information system with well-defined interfaces for vendors to access.

- The Colorado Bus Transit Travel Time Information System is evaluating the impact of real-time travel information on traveler's mode choice.

- The TransCal project in California is evaluating the benefits of providing inter-regional traveler information to fixed and en-route travelers using various devices including personal digital assistants and kiosks.

- Project Northstar in New York is evaluating the use of cellular telephone, a portable digital assistant, and speech synthesis for personalized pre-trip and en-route travel information and advisories.

4. Develop standards and guidelines.

- Based on the results of operational tests, FTA and FHWA will develop guidelines for pre-trip travel information.

- The Society of Automotive Engineers (SAE) International Travelers Information Interchange Standards (ITIIS) Working Group is developing information interchange standards. These will be generic, non-proprietary protocols for multi-modal real-time and static traveller information dissemination and exchange.

- The SAE Navigation Working Group is developing standards for the interface between a navigation computer and other subsystems, such as communications devices, positioning devices and the driver interface subsystem.

- The SAE Map Database Committee, or other standards-setting group, will need to develop standards that facilitate consistent map referencing.

5. Initial deployment of first generation systems.

- First generation systems will have limited intermodal and real-time capabilities.

- The TravInfo project in California will evolve into an operational phase, with private vendors accessing the database and selling information to users.

2.3 RIDE MATCHING AND RESERVATION

2.3.1 Introduction

The Ride Matching and Reservation user service is a key TDM strategy for reducing roadway vehicle demand by developing and encouraging ridesharing as an alternative form of travel. The service expands the market for cat-pools and vanpools by providing real-time ridematching information along with reservations and vehicle assignments.

This user service will enable shared-ride vehicles to operate more efficiently through integration with other ITS services, and provide users of shared ride vehicles with improved access to needed transportation services.

2.3.2 Needs

Congestion has been increasing dramatically in urban areas and, as a result, has severely affecting our economy, lifestyle, environment, and quality of living. Increased congestion is a result of a large increase in the number of automobiles and in the number of vehicle miles traveled, without a corresponding increase in road mileage. From 1970 to 1985, the number of vehicles increased 63%, while construction of road mileage increased by only 5%. Vehicle miles traveled reached over two trillion in 1988 (or almost 11,000 miles per vehicle). In 1987, there were an estimated 2 billion hours of delay on urban freeways, representing an economic loss of about $42 billion in the most populous 25 U.S. cities alone.

Until recently, congestion was mitigated by building new roads and expanding facilities. This option has become more difficult to achieve. Aside from the economic infeasibility of building "enough" roads, there is a continued environmental sentiment against building new highways, as evidenced by public opinion and the Clean Air Act Amendments which mandate vehicle trip reductions in urban areas. Construction of additional highway lanes, except for high occupancy vehicle (HOV) lanes, is prohibited in areas that do not attain Clean Air Act standards.

The National Transportation Policy report, ***Moving America,*** is further evidence of the sentiment against building new highways. The first policy direction, "Maintain and Expand the Nation's Transportation System," states that, rather than expanding construction of new roads, ".... we must improve management of existing facilities." Another policy direction, "Protect the Environment and the Quality of Life," emphasizes support of the Clean Air Act Amendments and other environmental considerations.

It is important to note that there is currently sufficient passenger capacity in observed automobile usage to reduce congestion. This capacity is significantly underutilized due to the large number of SOVs. The high density of single-occupant vehicles is a principal contributor to congestion. Ridesharing, such as car-pooling and vanpooling, represents an existing strategy for mitigating traffic congestion and improving management of existing facilities. Indeed, initial development of ridesharing can be seen as far back as the 1940's with the promotion of carpooling to save gasoline and rubber during World War II. Although ridesharing increased immediately after the war, recent statistics show a decline, and this transportation alternative is now vastly underutilized in most urban areas. There is an urgent need to take steps to encourage the public to make greater use of this option. The application of proven advanced technologies to make ridesharing more user-friendly and accessible can help reverse the declining trend in use of public transportation. There is a tremendous need for this user service.

2.3.3 Service Description

The Ride Matching and Reservation user service is a mechanism for expanding the market for shared-ride transportation by quickly matching the preferences and demands of users with providers and providing a clearinghouse for financial transactions. This will expand the market for ridesharing as an alternative to single occupant automobile travel and will provide for enhanced alternatives for special population groups.

An individual desiring to travel would make a single call to a metropolitan number. The traveler would provide a travel itinerary including date, time, origin, and destination. The information would also include any specific restrictions or preferences such as wheelchair requirements or mode of travel. The traveler would then receive ridesharing options for that date, time, and mode with consideration for the restrictions and preferences given.

A database of transportation providers would also be established. The various providers would have billing arranged through this central clearinghouse. Electronic safeguards would protect against fraud and abuse, and the system would automatically generate needed reports and financial documentation.

Instant carpooling has already been established, without direct government involvement, in two notable locations: the Shirley Highway corridor in Washington, D.C. and the Bay Bridge in Oakland. While these operations involve daily commuters, full implementation of this service would provide options for occasional travelers or visitors to the area who are not familiar with local travel options.

2.3.4 Operational Concepts

This user service accomplishes its goal by linking together all travel modes including bus, rail, Vanpools, carpools, express bus, and specialized services. Although this user service is primarily aimed at private vehicle owners/operators, it could also include the occasional commercial operator (i.e. vanpool operator, taxi operator) where or when private passenger vehicles are not available. The communication link is electronic with each transportation service provider retaining their individual identities, policies, and subsidy mechanism. The user service would not establish fare, subsidy, or eligibility policy. It would act as a coordinator, operating and administering a clearinghouse network governed by the rules or programs established by others and providing documentation which verifies that transactions have been conducted in accordance with prevailing guidelines and regulations. Integration of this service with Electronic Payment Services (User Service No. 4.1) would allow users and providers to quickly and conveniently process financial transactions.

This user service assumes that adequate transportation resources exist in the selected community for ridesharing. These resources would provide the informational infrastructure and market mechanisms needed to connect consumers (individuals or organizations) with suitable providers and manage the financial transactions. The system would offer users information on local transportation options through a single point of contact. This service is closely related to other informational user services, most notably Pre-Trip Travel Information (User Service No. 2.1), which could help to provide some of the supporting infrastructure required by Ride Matching and Reservation.

There may be a possibility of this user service being operated privately with funds from transaction fees paid by providers or sources of subsidy such as employers or human service agencies. Transportation service providers would benefit from additional business. Market information could be provided to assist in planning service improvements and maintenance operations.

2.3.5 Technologies

Technologies now being developed and ready for use in ridesharing include low cost, high performance computer hardware, generic relational database systems with dynamic multimodal information, moderately priced scheduling and dispatching software, mobile computers, smart cards and inexpensive card readers, off-the-shelf automatic vehicle location technology, and electronic mapping software. Technologies that will enable users to interact with rideshare systems include touch-tone and cellular telephones, voice synthesis, interactive video displays, personal communication systems, and roadside or transit center monitors. Developing rideshare matching software, interfacing rideshare and traffic information, establishing links with other transit information, and making provisions for integrated billing (see Electronic Payment Services, User Service No. 4.1) will also be part of this user service technology. As discussed in Public Travel Security (User Service No. 3.4), technologies will also be available to address the security concerns of those who are uncertain about sharing a ride with a stranger.

2.3.6 Potential Costs and Benefits

Costs for this user service include hardware, software, management of the system, and operations and maintenance costs. Hardware costs include a central computer, hand-held communication devices, variable message signs, and kiosks. Software costs include a link to a telephone system and a ridematching database comprised of numerous ridesharing providers (including the possibility of commercial providers as well as private vehicle operators.) Management costs are also to be considered not only for setting up the system, but also for operating the system after the initial start-up.

Benefits for this user service include a number of factors: (a) increased public access to shared ride modes; (b) deceased congestion; (c) reduced harmful environmental effects; and (d) more flexible, user-friendly ridesharing service, often at less cost to the user than driving alone.

Employer costs of operating a ride-matching and reservation service can be offset by not having to provide as much on-site parking. For example, the major cost typically born by an employer to support a single employee's travel comes from the provision or subsidization of parking, at an average cost of $73.50 per employee per month. The alternative of operating a vanpool for 12 to 15 people could reduce the employer's cost to $12.35 per employee per month.

2.3.7 Assessment of Roles

The responsibility for development of ITS services generally resides with the private sector, however, there are situations when U.S. DOT involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and evaluation of systems with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, the U.S. DOT will encourage a joint public/private development effort. This approach, which underlies the U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for the U.S. DOT in development of the Ride Matching and Reservation service.

2.3.7.1 Public Benefit

This service has high potential for public benefit in two ways: (1) the individual traveler will benefit from being able to better use ridesharing by being provided with the real-time status of ridesharing opportunities, and (2) increased convenience in using the system as a result of having reliable real-time information on ridesharing. Both of these benefits result in an increasing proportion of travelers using this service and a reduction in the energy and environmental impacts of SOV travel. Thus, the public as a whole will benefit from this service.

Human service agencies benefit from this service by having access to broader transportation service options with reduced administrative overhead.

2.3.7.2 Potential For Private Investment in Development

Without U.S. DOT funding stimulus, the private market potential for vendor products that respond to this service appears to be medium to low. To be effective and affordable, the distribution of ridesharing information will need to be in conjunction with the dissemination of other transportation information, such as that provided by the Pre-Trip Travel Information service. Like other user services, this service will probably rely on an information infrastructure developed primarily for non-transportation applications. For example, existing computer network services could be supplemented with transit data, a public service channel on cable TV could possibly arrange its programming to include transit data, or ridesharing information could be included as part of a privately-provided information service.

2.3.7.3 Public and Private Sector Roles In Deployment

Although this service will require both public and private sector involvement, the public sector role will be dominant. Many of the institutions already providing ridesharing service are public organizations.

Public sector involvement in the development and deployment of this user service will occur at all levels of government, including Federal, State, Metropolitan Planning Organizations (MPO), local government, and public transit operators. All levels are important, but the ultimate decision to deploy publicly-funded systems will be made at the local level.

Establishing an information system that is capable of analyzing and fusing the data, coordinating the network for distributing the information, and responding to the heavy peak inquiry demands for the information could be a private sector function.

2.3.7.4 U.S. DOT Role In Developing Service

The U.S. DOT role for the Ride Matching and Reservation user service is to foster development, operational testing, and evaluation of the technologies and systems. This role will include the development of guidelines and standards for ridesharing information. The U.S. DOT will also need to eliminate barriers that may arise as jurisdictions build the partnerships needed to allow the integration and cooperation required at the local level to share information in common formats and to allow services to be paid for in new ways.

2.3.7.4.1 ***Research and Development:*** The U.S. DOT role in research and development is high. The limited research which the private sector and the non-U.S. DOT public sector will perform is expected to be very site or product specific and lacking in a national perspective. Adequate functional specifications need to be promoted by a national body.

2.3.7.4.2 ***Operational Tests:*** The role in operational testing for the U.S. DOT is high. Early operational testing of innovative technology applications in transit will need to be strongly supported by the U.S. DOT. U.S. DOT involvement will ensure a national perspective for the full systems integration of each possible technology for appropriate ridesharing applications. Careful evaluations are a critical element of this effort. Sites should be chosen to provide sufficient operational testing to accommodate a wide variety of final deployment projects.

2.3.7.4.3 ***Institutional and Legal:*** The U.S. DOT role is medium for ensuring that institutional and legal issues are properly addressed. Coordination with national organizations and advisory committees to encourage compatibility will be a role for the U.S. DOT.

2.3.7.4.4 ***Deployment:*** The U.S. DOT role is expected to be high since very little in initial private sector funds appear to be available for the deployment. Information for the Ride Matching and Reservation user service is expected to be gathered initially by the public sector, including local and state transportation agencies.

2.3.8 Milestones and Activities

Figure 2.3-l presents a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

2.2.8.1 Issues

1. Will the service prove useful, reliable, and cost-beneficial in that a sufficient number of riders will be off-loaded from single occupancy vehicles to justify the cost of the service?

2. Institutional issues on how and who pays for the infrastructure needed by the service and how payments are transferred from rider to driver.

3. To what extent will the advantages of this service (e.g., the ability for travelers to use HOV lanes) encourage more people to use ride sharing in lieu of the single occupancy vehicle?

4. What is the matching process/strategy that will attract people to use this service?

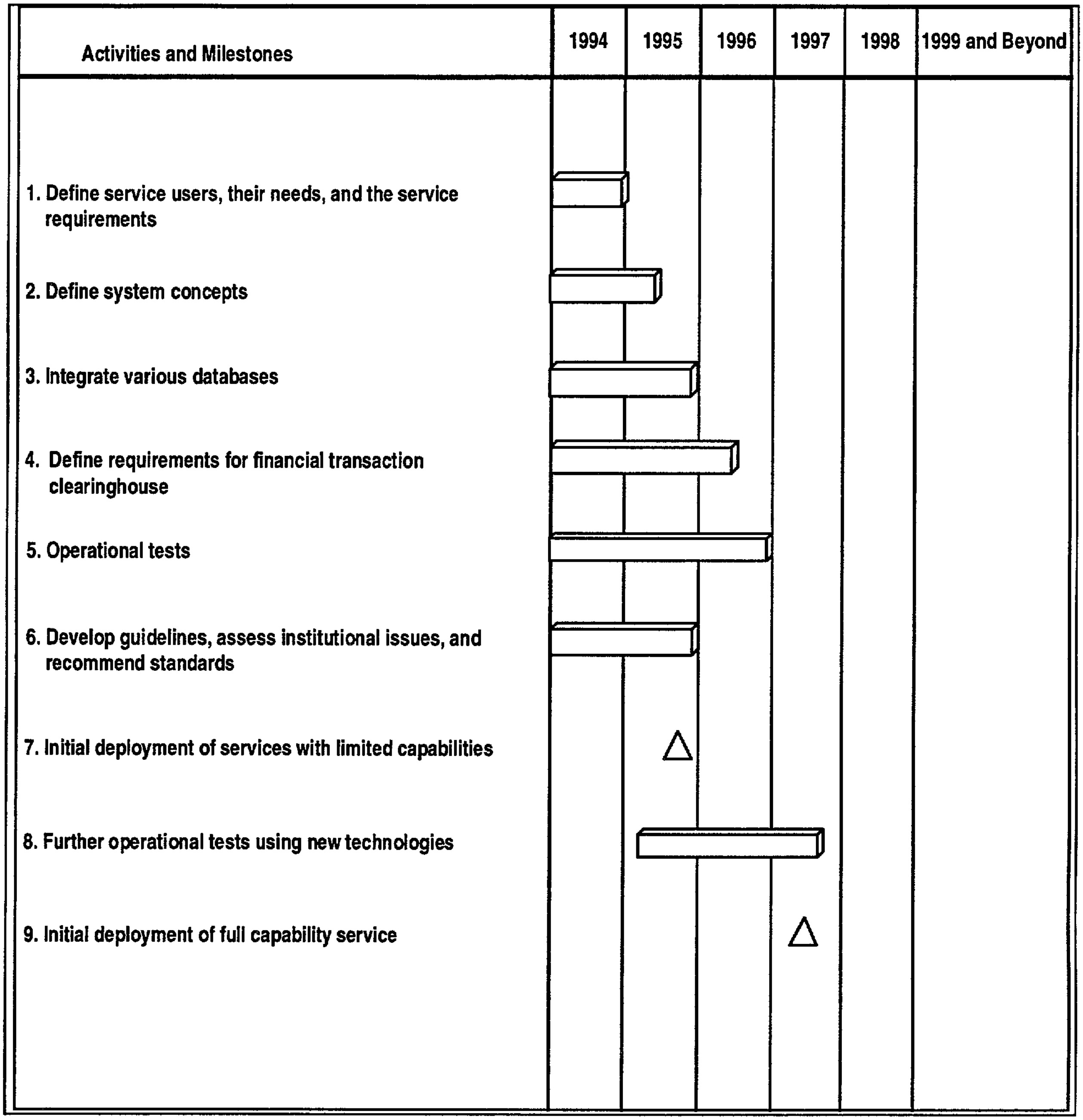

Figure 2.3-1 Ride Matching and Reservation Activities

2.2.8.2 Activities

1. Define service users, their needs, and the service requirements.

   - Initial research will focus on the integration of the various databases along with the supporting software and hardware to provide ride matching information needed for a traveler.

2. Define system concepts.

   - Concepts to be developed will define database contents and the extent of its geographic coverage, how drivers and riders can be attracted to the system, and how drivers and riders are to be added to the database.

3. Integrate various databases.

   - Employer-specific databases must be integrated with regional Council of Government databases.

4. Define requirements for financial transaction clearinghouse.

5. Operational tests.

   - Initial operational tests will feature small urban and medium-sized ridematching services.

   - Potomac Rappahannock Ridesharing System will test single-trip ridesharing with both advance and real-time reservation capabilities.

   - Sacramento, California Real-Time Ride Matching Project will develop functional specifications and evaluate software packages for use in a field operational test of a real-time ride matching system.

   - Bellevue, Washington Smart-Traveler project is evaluting the use of telephone and paging technology to provide real-time traffic information and dynamic ride-matching in order to reduce the number of single occupant vehicles.

   - The TravInfo project in the San Francisco Bay area will provide an integrated database which can be used to support multiple services, including ride sharing.

- Houston Smart Commuter project will provide information on bus, ridesharing, and traffic conditions to encourage transit and ridesharing and reduce single occupant vehicular traffic.

6. Develop guidelines, assess institutional issues, and recommend standards.

7. Initial deployment of service with limited capabilities.

   - Initial deployment will be available for selected technologies only. Capabilities will be limited to advance reservation systems. An initial phase could consist of instant ridematching associated with a single large employer or at a park and ride lot.

8. Further operational tests using new technologies.

   - Additional testing will incorporate multiple providers in medium-sized cities and will incorporate recent developments in Automated Vehicle Location technologies and matching strategies. Operational tests of the Ride Matching and Reservation service will also be incorporated into tests of Travel Demand Management systems.

9. Initial deployment of full capability service.

   - As deployment proceeds, more technologies and capabilities will be provided. For example, ride matching will be possible in real-time instead of being limited to advance reservations.

CHAPTER 3.0 - PUBLIC TRANSPORTATION OPERATIONS

3.0 INTRODUCTION

The four services described in this chapter relate to public transportation, which includes urban, suburban and rural transit in fixed route, route deviation and demand-responsive modes and operated by bus, heavy rail, light rail, commuter rail and van or car-pool or shared ride taxi. In short, all forms of short distance transportation not involving a single occupant automobile will benefit from these services.

The ITS Advanced Public Transportation Systems (APTS) program aims to decrease reliance on the personal auto by enhancing the efficiency, convenience, cost effectiveness, safety and security of public transportation. Particular attention is paid to those aspects of public transportation which have heretofore diminished the popularity of this type of transportation or caused resistance to its use.

3.0.1 User Service Summary

The following paragraphs are short descriptions of each of the user services:

- The **Public Transportation Management** service automates the operations, planning and management functions of public transit systems. It provides real-time computer analysis of vehicles and facilities to improve transit operations and maintenance. The analysis identifies deviations from the schedule and offers potential solutions to dispatchers and drivers. This service will help maintain transportation schedules and assure transfer connections from vehicle to vehicle and between modes and can be coupled with traffic control services to facilitate quick response to service delays. Information regarding passenger loading, vehicle running times, accumulated miles and hours and vehicle maintenance will help improve service and provide managers with a wealth of information on which to base decisions. Service schedulers will have timely data to adjust trips. Personnel management will be enhanced with the automatic recording and verifying of driving and maintenance task performance. Reports, including management, operations, and legally required Section 15 reports, will be prepared with greater efficiency through the application of computers for this function.

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

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

- The **Public Travel Security** service creates a secure environment for public transportation patrons and operators. It provides systems that monitor the environment in transit stations, parking lots, bus stops and on-board transit vehicles and generate alarms, either automatically or manually, when necessary. This improves security, and with it, the perception and acceptance of transit. Transit agencies can integrate this user service with other anti-crime activities.

3.0.2 Relationship to ITS Goals and Objectives

Public transportation modes, by their very nature, further the majority of the goals set for ITS services. Some of the transportation user services contribute more than others. For example, the enhancement of public transit as a mode of choice by deployment of the Transit Security user service would shift more travelers from single occupant vehicle trips, with attendant savings in pollution, traffic congestion and road safety. However, the Personal Public Transit user service would not only foster the same shift, but would, in some instances, replace large transit buses with smaller ones or with vans, both possessing better fuel economy, less pollution (depending on the type of engine and fuel used) and less weight, which has a direct impact on roadway wear and tear.

A discussion of each category of goals follows. Specific goals impacted by each user service are shown in Volume I, Appendix B.

- Energy and Environmental - En-route Transit Information, Personalized Public Transit, Public Travel Security, and Public Transportation Management services are expected to have an indirect impact on meeting those goals.

- Safety and Security - Public Travel Security and En-route Transit Information will have a major impact on meeting this goal, while Public Transportation Management and Personalized Public Transit are expected to have an indirect impact.

- Efficiency and Productivity - En-route Transit Information, Public Transportation Management and Personalized Public Transit will have direct impact in the areas of increasing average vehicle occupancy, reducing time lost in intermodal interchange, reducing travel time and reducing costs to fleet operators and transit-dependent industries.

They will indirectly impact the goals of reducing vehicle miles traveled and time delay associated with congestion. Public Travel Security should have an indirect impact on increasing average vehicle occupancy, but no impact on the other goals in this category.

- Mobility - All four user services will have a positive impact on these goals, particularly in improving the accessibility to transportation, reducing travel stress and improving travel time predictability. Public Travel Security's contribution is expected to be indirect.

- Customer Service - Improved customer service will result from better schedule adherence and passenger information that will accrue from this User Service. The fleet management and control aspects will identify off-schedule buses and will automatically select a schedule recovery strategy and instruct the operator of actions to take to restore schedule adherence. Transportation information, both real-time and static, will be displayed to customers and people planning trips through passenger information kiosks, office and home computers, passenger information displays, etc. The benefits of impacts is expected to be direct.

3.0.3 Integration of Public Transportation Management (PTM) User Services

The heart of each user service is the computer and the communications system, coupled with an AVL system to generate real-time information. Computers will be called upon to receive real time information about transit vehicle locations, operations and passenger boards. They will provide artificial intelligence-like decisions to dispatchers who route vehicles in response to user demand or reroute vehicles around accidents and other obstructions. In addition, computers will perform analyses and facilitate access to a wealth of collected information to allow adjustments in schedules, drivers' and maintenance worker's shifts and changes to preventive maintenance programs.

Sophisticated software systems will be developed or improved. Existing programs which schedule service, track maintenance and drive computer-aided dispatch systems will be integrated. Systems will have the capability of crunching huge amounts of data collected as the result of day to day operations and summarizing it for the benefit of service planners and administrators. The functions and needs of different disciplines within a transit organization will be coordinated to use information in a common information base.

Communications will use a combination of radio, cellular, satellite and conventional telephone technology. There will be an emphasis on digital rather than voice communication to make better use of limited radio channels and to speed up time sensitive chores, such as polling vehicles for location.

3.0.4 PTM Architecture

Although much of the computer software required to operate the various systems in the PTM bundle already exist, a coordinated effort will be required to standardize interfaces and to develop databases which will serve to store information optimally so that frequent, high speed access is enhanced. Some strategic holes exist in the area of transit management information systems software, and this will require a "solution" which fits the majority of transit systems' needs.

A common architecture design for security hardware will need to be developed. Institutional issues will need resolution regarding access to public safety communications and computer systems and, possibly, shared maintenance of certain information, such as GIS map data.

3.0.5 Cross-cutting Issues

There are significant legal issues involved with the deployment of Transit Security services. Issues such as response time by law enforcement agencies, jurisdictional disputes, availability of, or access to, personal computing or communications devices and interagency liability must be resolved.

3.0.6 Activities Chart

Major milestones relating to development, testing and implementation of the Public Transportation Management technology are shown on Figure 3.0- 1.

Functions	Now 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
Traffic Surveillance	• Video • In-Pavement • Aerial • Machine Vision • Vehicle Probe • Region-Wide
1-Way Mobile Communications	• Voice • Analog • Digital • STIC • High-speed Digital Subcarrier
2-Way Mobile Communications	• Cellular • Radio • Digital Cellular • High Capacity Comm.
Stationary Communications	• Landline • Radio • Fiber • Shared Networks
Individual Traveler Interface	• PC • Audio • PCDs • In-Vehicle Displays • Kiosks • Head Up Display • Voice Activation
Variable Message Displays	• Monochrome Displays • Color Capable
Navigation	• GPS • Map Matching • Dead Reckoning • Cellular Triangulation • High Accuracy Navigation • Autonomous Navigation
Database Processing	• General Purpose DB S/W • Inter-Agency Sharing • Standard Map DB • On-line Agency Database • Data Fusion • Integrated Multimodal DBs
Signal Traffic Control	• Timed Ramp Metering • Timed Intersection Control • Dynamic Ramp Metering • Dynamic Intersection Control • Distributed Intersection Control
Traffic Prediction Data Processing	• Historical DBs • Real-Time Data Fusion • Short Term Traffic Prediction • Long Term Traffic Prediction
Routing Data Processing	• Shortest Distance Algorithms • Static • Dynamic • Multimodal
In-Vehicle Sensors/Devices	• Headway/Lateral Sensors • Vehicle Performance Monitoring • Collision Warning Sensors • Vision Enhancement • Driver Performance Monitoring • Collision Avoidance Control
Vehicle Surveillance	• Vehicle Location • Vehicle Identification • Weigh In-Motion
Payment Systems	• Single Purpose Payment Card • Multipurpose Payment Device

R&D

(1) Public Transportation Management
(2) En-route Transit Information
(3) Personalized Public Transit
(4) Public Travel Security

- Bus Service Restoration Strategies (1)
- Dynamic Route Planning and Scheduling (1)
  - Integrated Route Scheduling (1)
- Multiple Access Displays (2)
- Compressed Data Techniques (2)
  - Data Requirements (2)
- Determine Requirements and Technologies (3)
  - Algorithms for Vehicle Assignment (3)
  - Analysis of Efficient Combinations of Fixed/Flexible Routings (3)
  - Intelligent Image Processing (to "detect" crime) (4)
- Low-rate Compressed Video (4)
- Automatically Activated Personal Alarms (4)
- Non-lethal Personal Protective Devices (4)

Test

(1) Public Transportation Management
(2) En-route Transit Information
(3) Personalized Public Transit
(4) Public Travel Security

- Verify R & D Results (1)
- Data Fusion Techniques (2)
- Wireless Information Transfer (2)
- Smart Bus Stops (2)
- Station Car Concept (3)
- Fixed vs Flexible Route Trade-offs (3)
- "Street Test" Mix of Algorithms (3)
- Security Systems Analysis (4)
  - Low Bandwidth Video from Transit Vehicles (4)
  - Combined Alarm Beacon/AVL from Private Vehicles (4)
    - Improved Bus Driver Protection Barriers (4)
      - Smart Sensor Suites/Image Processiing (4)

Non-Technical

(1) Public Transportation Management
(2) En-route Transit Information
(3) Personalized Public Transit
(4) Public Travel Security

- Jurisdictional Control of Databases (1)
- Human Factors and Financing (2)
- Pricing of Services and Public Policy Issues (3)
- Jurisdictional Response and Liability Issues (4)
- Public Perception and Education (4)

Figure 3.0-1 Public Transportation Operations Technology Development Timeline

3.1 PUBLIC TRANSPORTATION MANAGEMENT

3.1.1 Introduction

The Public Transportation Management user service applies advanced vehicle electronic systems to various public transportation modes and uses the data generated by these modes to improve service to the public. Three sub-services are included: Operation of Vehicles and Facilities, Planning and Scheduling, and Personnel Management (as it relates to operations and scheduling). The transportation provider is the user of this service. Some of the generated information can be made available to Pre-Trip Travel Information (User Service No. 2.1), En-Route Transit Information (User Service No. 3.2), Personalized Public Transit (User Service No. 3.3), and Public Travel Security (User Service No. 3.4).

3.1.2 Needs

It **is** imperative to manage the schedule adherence of transit vehicles operating on fixed routes so customers can rely on published schedules. Customer confidence in the system is needed to generate the ridership necessary to justify the fixed cost of providing the transportation service. From the transit agency's perspective, it is important that the fleet be managed in the most effective and efficient manner.

Advances in the fields of communications and information systems can provide innovative methods to make transit and ride-sharing more efficient and more attractive to potential riders, and thus more effective. It has been estimated that the diversion of just one of five solo drivers would save $30 billion per year in congestion costs.

3.1.3 Service Description

Public Transportation Management using ITS technologies applies advanced vehicle electronic systems to various public transportation modes and uses the data generated by these modes to improve service to the public. The Public Transportation Management user service consists of three sub-services: Operation of Vehicles and Facilities, Planning and Scheduling, and Personnel Management as it relates to operations and scheduling. Each of these three sub-services can be performed manually; however, the use of advanced automated systems is more accurate and less costly, and provides better service to the traveler.

3.1.4 Operational Concepts

In the Operations of Vehicles and Facilities sub-service, real-time data from individual vehicles (and facilities) is communicated via a digital data link and is compared with schedule information and other predetermined parameters. A computer identifies deviations, displays them to the dispatcher or controller, and determines the optimum scenario for returning the individual vehicle or fleet to the schedule. Corrective instructions are transmitted to the driver to adjust for the deviation and implement his portion of the service restoration process. If conditions warrant, the dispatcher will assume control. Additionally, integrating this service with Traffic Control (User Service No. 1.4) can help maintain transportation schedules and minimize varied impacts on traffic congestion. Similarly, real-time operation of transportation facilities falls into this user service category.

Another application of this sub-service is connection or transfer protection. Connection protection will ensure that planned vehicle meetings will take place through interaction between computers on the two vehicles. Using the vehicle location sub-system, the computer will calculate the arrival times of two buses approaching a transfer point. The bus that arrives first will be instructed to remain at the transfer point and wait a reasonable, specified amount of time for the second arriving bus. This will permit transferring passengers to wait inside the safety and shelter of the bus instead of outside in the elements.

The Planning and Scheduling sub-service includes off-line storage and analysis of data that has been collected in real-time and stored in the computer for later analysis. These data include information on passenger loading, bus running times, and mileage accumulated by individual buses. These data are stored in a memory storage device and analyzed off-line by the computer so that schedules and plans can be revised using actual data. For example, using such data as route segment running-time and passenger boarding and alighting at each stop, transportation system schedules can be developed much more quickly or adjusted to changes in riding characteristics. The planning efforts required for route and service improvements will also use this data. Maintenance planning and reporting, Section 15, and other reports will be automatically generated by this function.

A principle user of Planning and Scheduling information is the off-line activity of the telephone customer service department. Transit authorities have customer information systems that permit almost instantaneous access to schedule information. Presently, telephone operators answer calls and look up schedule and route information contained in either printed or computerized schedules. Training a new customer service telephone operator on the intricacies of routes, schedules and fare information can take several weeks on large transit systems. Using the automated schedule preparation system, the schedules can be automatically entered into the customer service system as changes are developed. The customer service operator always has the most current information and, when combined with currently available software which automatically looks up route and schedule information based on the customer's origin and desired destination, the training time will be significantly reduced while offering better assurance that-the customer will be given the right information every time. In addition to updating schedule information, new schedules can also be developed for the benefit of the customer as well as the transit provider. The greatest benefit to transit planners, however, would come from the ability of an automated customer information system to document lost business opportunities - cases in which a potential rider's trip requirement could not be met - and help to quantify demand for additional transit services.

The third sub-service involves Personnel Management, as it relates to operations and scheduling. Drivers are assigned to individual daily work assignments (runs) based on seniority, preferences, garage assignment, vehicle qualification, etc. This is done to allow drivers to exercise their seniority in picking their routes and runs while minimizing labor and overtime costs. At most systems this activity is performed manually. Using the off line data and analyzing it in accordance with driver seniority and schedule preferences lists, this "sign up" process can be automated to a greater extent than is possible now even at authorities which have a computerized sign up program.

Similarly, service technicians can be assigned by skill level to work on individual buses. Among the stored data is daily miles traveled by each vehicle. Periodic maintenance schedules can be automatically generated and specific buses assigned into the garage for planned maintenance, thus ensuring that the work is performed and the proper service personnel are available.

Spinoff applications from personnel management systems include automated timekeeping and payroll entry of driver and maintenance employee time, automatic updates to parts and inventory systems and maintenance databases. All information would be available for off-line analysis and later review.

3.1.5 Technologies

Public Transportation Management depends upon the vehicle's communication system. The communication system provides both voice communication and data transfer among the various devices installed on the vehicle, including location equipment and other sensors, and components between the vehicle and a central or regional control facility. Data is collected and temporarily stored in an electronic device on board the vehicle and, when polled or triggered, transmitted to a central repository where it is processed for real-time operations and/or stored for off-line analysis. Successful communication control (e.g., polling schemes) must be developed to control the communication protocols for a large vehicle fleet so incoming messages do not conflict.

On-board sensors automatically monitor such elements as vehicle passenger loading, fare collection, and vehicle operating conditions. These data must be transferred between the vehicle and a central base. To conserve the communication spectrum and minimize data transmission, this could be done only when the vehicle is out of predetermined schedule or route tolerance, depending on the prerogative of the local property. Computational processing relating to a single vehicle can be performed in a distributed fashion (e.g., on-vehicle or at remote locations) to reduce communications system workload.

Another technology area that must be considered is the software required to control operational scenarios. Specific operational scenarios must be developed and then programmed into the computer so the system will select the "proper" scenario when presented with a given set of data. For example, if a bus is off schedule, the system should determine the specific instructions to issue to the driver. Software must also be developed that will properly distribute the data collected. Some data will be presented to the transit dispatcher in real-time or made available for other user services [e.g., En-Route Transit Information (User Service No. 3.2)]; other data will be stored in the computer and analyzed off-line at a later time.

Advanced Passenger Counters must be developed that are reliable and accurate. These are required so the system will be able develop schedules using actual passenger loading, including number of people who board and alight at each bus stop. Using Smart Cards under a distance-based fare scheme, could allow the number of passengers on-board to be calculated, supplanting the need for automatic passenger counters, .

A standardized Vehicle Area Network (VAN) permits inputs from on-board electronic sensors [e.g., Automated Vehicle Location (AVL) system, electronic fareboxes, passenger counters, electronic destination signs, automated bus stop announcement equipment, etc.] through a common cable in the vehicle with a common data format and protocol, thus permitting interchangeability of components and easy equipment upgrades. Society of Automotive Engineers (SAE) Standard J- 1708 has been developed with Federal Transit Administration (FTA) assistance to eventually permit the incorporation of various manufacturer's equipment into systems that were originally installed by a single vendor using proprietary schemes. Use of this standard is considered critical to the success of this user service.

For example, if Company A won the contract to install a communications package, the transit authority was locked-in to this vendor for all subsequent upgrades, changes, replacement equipment, etc., until an entirely new system was procured. This process limited competitive bidding to the initial procurement. Using SAE Standard J-1708, different manufacturers' radio equipment can be plugged into an existing system, thus ensuring follow-on competitive procurement.

3.1.6 Potential Costs and Benefits

3.1.6.1 Potential Costs

The potential costs of these systems is expected to be approximately $10,000 to $15,000 per vehicle, depending on the level of complexity selected by the individual transit authority.

Second generation versions of the systems described herein are being tested in several transit authority operating environments. Additional systems are being planned. High level Research and Development is required to explore the development of technologies to permit faster communications and data processing (so more data can be transmitted and processed within a given time) and more advanced operational command and control scenarios. This research is envisioned as the focus of the FTA. Research and development of individual equipment will be performed by the companies that plan to market individual equipment or entire systems. FTA budget expenditures will be devoted to the high level research and development activities described above and to performing evaluations of systems, once installed.

Individual manufacturers and suppliers will spend an indeterminate amount of funds developing and testing their own equipment; this amount is conservatively estimated to be in the hundreds of million of dollars.

Transit providers generally purchase equipment from private vendors. There are approximately 62,000 public transit buses and vans, 10,000 private (charter) transit buses, and 30,000 par-a-transit vehicles currently operating in the United States. Assuming that 75% of these vehicles will be equipped with smart technologies (e.g. radios, automatic vehicle location, automatic passenger counters, signs, etc.) for the Public Transportation Management user service role at an upper end-of-range cost of $15,000 per vehicle, approximately $1,466 million will be spent on this equipment initially. Equipment service and maintenance activities will offer additional potential for private investment.

The operational tests are being funded through the Intermodal Surface Transportation Efficiency Act of 1991. The costs of these tests is directly related to the proposals received from states and cities planning such tests.

Some of the on-board equipment described previously will need to be purchased in any event to meet the mandates of the Americans With Disabilities Act of 1992 (ADA). These include next stop announcing systems and upgraded destination signage.

3.1.6.2 Potential Benefits

Public Transportation Management assumes both the transportation provider and the passenger to be the user. Benefits accrue to both. The benefits of Public Transportation Management will accrue to the customer in the form of better service through improved service reliability, schedule information accuracy, on-time performance and reduced cost. Greater service reliability is expected to attract more discretionary riders to transit. This user service includes the ability to exert better supervision of vehicles on the street to eliminate bunching and other factors that lead to service deterioration. Also, automatic data collection for management and reporting activities will permit more efficient operations. Riders will also have access to real time “next bus” information at major stops, transfer points and transit centers or rail stations. The non-transit individual can benefit through less congestion on the road as the number of single occupant vehicles decreases.

The transportation operator will benefit from better operational control over his vehicles and through lower costs derived from better utilization of and greater productivity from employees. Many of the labor intensive repetitive tasks now manually performed can be automated. The employee will be greatly assisted with these technologies reducing stress and increasing job satisfaction.

3.1.7 Assessment of Roles

The responsibility for developing ITS equipment and services generally resides with the private sector. The U.S. Department of Transportation (U.S. DOT) involvement is limited to selected situations, including the facilitation of standard setting for common system architecture and in areas where private industry might not pursue development on its own (e.g., initial development of systems with high public benefit but limited commercial potential or where the government is a primary user of the service). If both the expected public benefit and the commercial potential are high, U.S. DOT will encourage joint public/private development efforts. This approach underlies U.S. DOT's ITS technology strategy which is used to assess the Department's role in Public Transportation Management.

3.1.7.1 Public Benefit

The Public Transportation Management user service has high potential public benefit, primarily because much of the passenger transportation vehicle fleet is publicly owned. Since transit fleets are generally large (ranging in size from 100 to 3,800), the ITS benefits will accrue over a large base. Private and nonprofit vehicle fleets provide public transportation service in the case of taxi and para-transit operations, and some charter services. In each case, improved fleet operations, lower costs, and better service to the public can be expected through the Public Transportation Management user service and FTA's Smart Vehicle technology application program.

3.1.7.2 Potential for Private Investment

The private market potential is defined to be the total value of equipment and system sales to public transportation providers. The market potential for Smart Vehicle products within this user service without U.S. DOT stimulus is moderate, as U.S. DOT provides the showcase of these technologies so individual transit agencies can assess their applicability in a local application. Additionally, the FTA provides transit authorities 80% of the funding to purchase capital equipment.

Transit authorities have the option of either purchasing or leasing their Smart Vehicle equipment. Purchasing requires up-front money while leasing offers the technical advantages without the up-front financial burden. Additionally, the authority can readily upgrade the system at the end of the lease by entering a new lease.

3.1.7.3 Public and Private Sector Roles in Deployment

The public sector role for this user service is characterized as high because most equipment purchases will be made by public transit operators who will be most concerned with standards setting for the equipment being developed. Private operators will acquire equipment in many cases through sponsoring public agencies with whom they contract. The gathering of transit information will also be a public role. Private roles may involve establishing an information system that is capable of analyzing the data, coordinating distribution of the information, and responding to the peak inquiry demands for the information.

3.1.7.4 U.S. DOT Role in Developing Service

Public sector involvement in the development and deployment of APTS user services includes all levels of government (Federal, State, Metropolitan Planning Organization, and local) and public transit operators.

The U.S. DOT role for this user service is to foster operational testing and evaluation of the technologies and systems. This includes the development of guidelines and standards for information and the integration of systems between the municipal/state transit and the traffic organizations. U.S. DOT also needs to facilitate public/private ventures, help remove institutional barriers between jurisdictions, foster data exchange in common formats, and encourage the development of new services.

The U.S. DOT role is high in conducting research and development on the innovative application of new defense and commercial technologies to public transit systems.

U.S. DOT intends to coordinate operational testing and evaluation with transit agencies. U.S. DOT will perform a summary evaluation of the tests to assist the transit industry in identifying appropriate system integration opportunities for ITS technologies. To this end, FTA has developed Evaluation Guidelines that will be used in all transit related ITS operational tests so the results from various tests can be compared.

The U.S. DOT role in institutional and legal issues is medium. U.S. DOT will assist in identifying institutional and legal issues concerning the development of ITS technologies in public transportation vehicles.

The direct U.S. DOT role will be low to medium in deployment. Transit agencies and other local transportation providers will purchase their own equipment with Federal financial assistance through Federal discretionary and formula funds.

3.1.7.5 Institutional Issues

Among the principal institutional issues that must be addressed is that of data sharing between separate municipal transit agencies and others wishing to use the data generated by the system. In most transit agency operating areas, the entire area is served by a single authority. In other metropolitan areas (such as the Washington-Baltimore Metropolitan Area) in which there is large intracity commuter and other movement, the situation is more complex. In the Washington-Baltimore case, separate transit authorities operate transit bus and heavy urban rail lines; two separate, independent organizations operate commuter rail lines; and, other transit services are also provided. There must be agreement between these independent agencies to operate their systems cooperatively and to freely share data that will be useful across the various services.

Other institutional issues concern driver training, procurement and maintenance costs of the systems, and union jurisdictional issues. The procurement costs are noteworthy in that local agencies are presently burdened by a shortage of funds to purchase new buses and the required equipment for compliance with ADA. The U.S. DOT must encourage transit agencies to upgrade their transportation management, and identify adequate funding sources to avoid fare increases which would offset increases in ridership.

3.1.8 Milestones and Activities

Figure 3.0-l in the introduction to this chapter identifies selected major milestones associated with developing this user service to a state of deployability.

This section elaborates on these milestones by identifying issues and providing a listing of more detailed, supporting activities. An issue is defined as a major potential challenge that has to be met to achieve deployability.

3.1.8.1 Issues

1. Selecting appropriate technology for the local applications.

2. Modifications of worker tasks and organizational structure to adapt the selected technologies towards improving public transportation management effectiveness and efficiency.

3. Radio spectrum availability for the user service.

4. Cost-benefit of providing this service.

3.1.8.2 Activities

1. Identify transit operator requirements, applicable subsystems, and technologies.

   During this task, and throughout the development of the service, commercial technology will be assessed for its applicability to Public Transportation Management. These technologies include communications, AVL, passenger counters, computers, and software. Advanced technology application of APTS already implemented by the transit industry will be evaluated by FTA and the information gathered will be shared throughout the industry.

   - FTA is sponsoring human factors, system architecture, and user requirements research through Volpe National Transportation Systems Center (VNTSC).

   - Frequency spectrum use analysis studies by VNTSC and the ITS AMERICA APTS Committee

2. Conduct operational tests of subsystems and technologies

   Operational tests will be conducted in selected urban environments through the ITS Program. In these tests, selected technologies identified to address specific user service requirements, will be installed to assess their effect on the user service requirement. All operational tests with Federal ITS funding will design and implement a rigorous evaluation plan to ascertain the results. Evaluations will be cooperative efforts. VNTSC will be responsible for developing and conducting site-specific evaluation plans under the overall guidance of FTA's Office of Technical Assistance and Safety. Evaluations will encompass operational tests as well as a limited number of other systems or services which could provide valuable information to the APTS Program. Much of the data needed for evaluating projects will be provided by the implementing agency. Evaluation reports, including cost-benefits assessment, will be disseminated to the transportation community.

   - Operational tests are under development in several cities, including Baltimore, Chicago, Dallas, Denver, Milwaukee, and New York

3. Conduct cross-cutting studies of operational test results

   - FTA will sponsor cross-cutting studies, including cost-benefits assessment, through VNTSC

4. Develop industry accepted standards and deployment guidelines

   Standards for reliability, performance, and system compatibility are needed.

A workable method of standards development has been devised. Under this method two separate technical working groups would be formed under the ITS AMERICA APTS Committee. Working on two separate tracks, the user group would focus on their requirements, and the manufacturers group would focus on specifications which satisfy the user requirements. The method is an iterative process involving these two groups. The manufacturers know the current state and future of the technology, and the users understand the needs of their system and have the clearest picture of what the public wants. This method generally calls for the groups to meet separately to avoid hesitation on the part of either group brought on by the presence of the other and to foster greater sharing of experiences among the members of each group.

One or more professional societies, such as, the Institute of Electrical and Electronics Engineers, or the Society of Automotive Engineers, will fulfill the role of liaison between the two groups and support development of the equipment standards. Operational tests and evaluations will be held to further evaluate the technologies, to support development of standards for interchangeability, and to support refinement of performance specifications for the equipment.

- The Map and Spatial Database Task Force of ITS AMERICA is developing standards and protocols for map and spatial database applications that will be used by transit operators, among others.

5. Define integrated systems

   Multiple databases have been developed over the years by transit operators. These databases, along with En-Route traveler information, must be integrated with subsystems for vehicle location, communications, and data processing. The integrated systems will be used to feed information to dispatchers in a user-friendly manner and will be used to support off-line scheduling and personnel management functions.

6. Conduct operational tests of integrated systems

7. Define policy and institutional aspects and issues for more advanced deployment.

8. Determine initial availability of more advanced deployment capabilities

3.2 EN-ROUTE TRANSIT INFORMATION

3.2.1 Introduction

The En-Route Transit Information user service provides information to transit riders after their trips have begun. The service will provide real-time, accurate, transit and high-occupancy vehicle information so that travelers can select the most convenient and time effective choice of mass transit in order to reach their destinations.

En-Route Transit Information is distinguished from Pre-Trip Travel Information (User Service No. 2.1) in that the Pre-Trip concentrates on travel and transit information prior to making a trip or mode choice. Once a trip is initiated, travel information still needs to be provided to the traveler. En-Route Transit Information discusses the service provided during the transit commute.

En-Route Driver Information (User Service No. 1 .1) discusses the service provided to the driver during the commute, including information provided to transit vehicle operators (e.g., bus drivers). En-Route Driver Information also provides drivers with information on transit schedules, parking availability, etc. to support mode change decisions mid-trip based on current traffic conditions. Electronic Payment Services (User Service No. 4.1) will allow transit users to pay for services quickly and conveniently, eliminating the need for exact change or awkward collection systems.

3.2.2 Needs

Encouragement to use mass transit as a means of commuting will help alleviate traffic congestion while providing for better management of existing facilities. This transportation mode is under-utilized in most urban and suburban areas. In fact, the 1990 census data indicates that use of transit throughout the country has been continually declining. Like any other good idea, transit will not help solve the traffic congestion problem unless it is put into greater use. To increase ridership and attract riders from other modes of transportation, public transit must provide good service and deliver its product on-time.

It has been found that the perceived wait time for transit passengers is considerably longer than the actual wait time. This is particularly problematic in low density suburban areas, where service is generally infrequent. More widespread use of mass transit, and thus more effective and efficient transit operations, can be achieved through en-route transit information systems that provide better information to travelers and better integration of transit with other modes of transportation.

Transit status information provided at the appropriate time and place will assist the traveler in completing the trip with minimal disruption and with considerably less uncertainty. Thus, there is an urgent need to take steps to provide travel information while En-Route to encourage the public to make greater use of this travel option. Capabilities exist today to provide the information in a number of languages in addition to English. Also, there are many transit users with visual and hearing impairments that need special audio and visual assistance to receive information. The application of proven advanced technologies to enhance information on public transportation can help reverse the declining trend in the use of transit as a travel mode.

Recent advancements in the fields of navigation, communications and information systems provide supporting technology using innovative methods to make transit more efficient and more attractive to potential riders, and thus more effective. It has been estimated that the diversion of just one of five solo drivers nationwide would save $30 billion per year in congestion costs.

3.2.3 Service Description

The En-Route Transit Information user service provides travelers with real-time, accurate transit network information during their travel. This information assists travelers in making effective transfer decisions and modifications as needed to a trip underway. Information also provides traveler “comfort,” reduced anxiety, and convenience. The information provided is inclusive of all transit services and modes in a given area, including car and van pools and shared ride taxis and would, eventually, be available from a single source. The data would be collected from transit systems, traffic management systems, and rideshare programs; and integrated, stored, and maintained on-line for interactive access from a wide variety of locations.

3.2.4 Operational Concepts

A traveler, having already made his mode choice and initiated a travel plan, will be provided with information along the route. Interactive service would be provided through kiosks at travel information centers and other transfer points. Interactive displays on board the bus would allow queries to be made concerning various options while En-Route to a destination. Similar interactive displays would also be available at a wayside stop or transfer point. Available options for completing the trip would be given **to** the traveler based upon real-time information. At bus stops, a visual display would give estimated arrival times of buses based on their actual location and an audio message would announce the arriving bus and route number. The traveler would board the bus and begin the trip. While on board, the traveler would determine if a transfer could be made at a rail station En-Route. If the on board display advises that the rail service is running late, the traveler could arrange to stay on the bus for the completion of the trip. When transferring to another bus is necessary, information about connections would be available on board the first bus.

These dissemination processes could be extended to include the integration and coordination with regional paratransi t services. Public and private providers would be included in the information given throughout the jurisdiction of the service area. Each of the transit systems within the service jurisdiction would continually provide the integrated information service bureau with scheduled and actual service being provided. The information would include the next available vehicle based upon actual operating conditions. Information would be integrated with actual road and traffic data, resulting in on-the-fly route detours, where possible without missing riders.

During peak hours, there may be large crowds of people in several different queues at terminals or major stops where the same bay or stop is shared with more than one route. In these situations, the order of bus arrivals may be more important to the customer on the platform than the actual arrival time.

Since interactive displays at kiosks require on-line, interactive service similar to that offered by automatic teller machines (ATM's), arrangements can be made with the local ATM networks to tie into their communications networks to provide an integrated financial-transportation service. For example, tickets and farecards could be obtained as well as cash withdrawals in future applications of this user service.

3.2.5 Technologies

Multiple technologies can be employed for presenting the information to the traveler. Output devices include:

- Low-powered radio, which would be directed to a small geographic area and picked up by a receiver on the vehicle for transmission to the traveler. This concept is similar to that currently used for Highway Advisory Radio communication.

- Variable message signs, already used on highway systems, would provide travel information to the traveler en-route and at bus stops, and monitors would allow display to several travelers at once.

- Portable Personal Communications Devices (PCDs) would be carried by the traveler. Transportation information is but one of many applications that are anticipated for these devices.

- Interactive video displays in the form of smart kiosks at roadside or in transit centers. These would provide an on-line, interactive service.

- Audiotex over touch-tone phones.

- Videotex over television.

- Cable TV would provide information concerning the status of transit operations and would eventually do this as soon as the status changes.

- Voice Stop Annunciators announce bus stops and the bus' ultimate destination as well as preplanned reroute announcements, as required by the Americans With Disabilities Act (ADA). These are especially important to the sight impaired.

- Automatic Visual Information Signage, which is activated by annunciators, permits deployment of next-stop information for the hearing impaired. The potential for displaying advertisements in a different color can also be supported. To function without driver intervention, both the visual and voice annunciators must make use of automatic vehicle location technology.

An infrastructure must be developed to supply the information to the output devices. Technologies within the En-Route Transit Information infrastructure include computers, telecommunication equipment, digital maps, voice synthesis, transponder-based vehicle - roadside systems, tag-based automated stop identification systems, and dynamic multimodal database applications. Furthermore, on-board access to information regarding the location of a bus would be possible if a vehicle tracking system were being used locally.

Several technologies will need to be integrated to achieve the complete user service anticipated. For example, telecommunication equipment, touch-tone telephones, voice synthesis would be expected to be integrated to provide the needed user service information for smart kiosks.

3.2.6 Potential Costs and Benefits

[NOTE: Financial cost and benefit data are requested for this section of the En-Route Transit Advisory Program Plan. Targeted costs for individual equipment or systemwide cost could be used for this discussion. Distribution of costs between the public and the private sectors and the consumer could also be included.] Cost sharing is expected by non-direct users or service providers, since shifting travelers to public transit actually impacts all travelers positively in the transportation network.

3.2.7 Assessment of Roles

3.2.7.1 Public Benefit

This service has high potential for public benefit in three ways: (1) the individual traveler will benefit from being able to better use transit through the provision of real-time status information on transit-use opportunities and schedules, (2) readily available and accurate information will have the effect of "demystifying" a potentially complex experience for first time and infrequent transit users and, (3) increased convenience in using the system as a result of having reliable real-time information on vehicle location and coordinated timed transfers. Both of these benefits are expected to result in increased market share for transit. The public as a whole will benefit from the greater use of transit that would result from this service.

3.2.7.2 Potential For Private Investment

Without U.S. Department of Transportation (U.S. DOT) funding stimulus, the private market potential for vendor products that respond to this service appears to be medium. The U.S. DOT may, for example, help to support the private sector in the development and testing of low cost products such as personal portable traveler information systems for transit applications. To be affordable, transit information may need to be distributed in conjunction with other information. For example, existing computer network services could be provided with transit data that could be communicated to the public directly, or a public service channel on cable TV could possibly arrange its programming to include transit data.

3.2.7.3 Public and Private Sector Roles In Deployment

Although this service will require both public and private sector involvement, the public sector role will be dominant. Most transit providers are public organizations. Gathering of traffic and transit information will be a public role. Establishing an information system that is capable of analyzing and assimilating the data, coordinating the network for distribution of the information, and responding to the heavy peak inquiry demands for the information could be private. It is possible that media traffic reporting companies in major metropolitan areas would desire to be a part of this effort as a logical extension of their business.

Public sector involvement in the development and deployment of this user service will occur at all levels of government, including Federal, State, Metropolitan Planning Organizations, local government, and the public transit operator. All levels are important, but the ultimate decision to deploy publicly funded systems will be made at the local level.

3.2.7.4 U.S. DOT Role In Developing Service

The U.S. DOT role for the En-Route Transit Advisory user service is to foster development, operational testing, and evaluation of technologies and systems for both transit operators and users. This role will include assistance given for the development of guidelines and standards. The U.S. DOT will also need to eliminate institutional barriers that may arise. This is especially pertinent where jurisdictions build the partnerships needed to allow the integration and cooperation required at the local level. The information will need to be shared using common formats and will allow services to be funded in new innovative ways.

3.2.7.4.1 Research and Development: The U.S. DOT role in research and development is moderate. The limited research which the private sector and the non-DOT public sector will perform is expected to be very site or product specific and lacking in a national perspective. Adequate functional specifications need to be promoted by a national body.

3.2.7.4.2 Operational Tests: The role in operational testing for the U.S. DOT is high. Early operational testing of innovative technology applications in transit will need to be strongly supported by the U.S. DOT. There are many new technologies available from research in the defense industry with potential for commercial development in the transit industry. U.S. DOT involvement will ensure a national perspective for the full systems integration of each possible technology for appropriate transit applications. Careful evaluations are a critical element of this effort. Sites should be chosen to provide sufficient operational testing to accommodate a wide variety of final deployment projects.

3.2.7.4.3 Institutional and Legal: The U.S. DOT role is medium for ensuring institutional and legal issues are properly addressed. Coordination with national organizations and advisory committees to encourage compatibility will be a role for the U.S. DOT.

3.2.7.4.4 Deployment: The U.S. DOT role in deployment is high since the Department funds 80% of transit agencies' purchase costs of equipment. Information for the En-Route Transit Advisory will be gathered by the public sector, including local and state transportation agencies.

3.2.8 Milestones and Activities

Figure 3.0-l in the introduction to this chapter identifies selected major milestones associated with developing this user service to a state of deployability.

This section elaborates on these milestones by identifying issues and providing a listing of more detailed, supporting activities. An issue is defined as a major potential challenge that has to be met to achieve deployability.

3.2.8.1 Issues

The key issues are data oriented. Up to the minute, real-time transit information (on vehicle locations, etc.) must be obtained. This will require major hardware and software systems to be in place, such as Automatic Vehicle Location (AVL) and computerized scheduling. Accurate databases must be maintained and kept current, incorporating schedule changes and congestion data, for example. Technologies are needed for transmitting the data to appropriate user devices, and effective means of outputting the data are needed. Improvements in radio or cellular system capacity will be needed to handle a quantum increase in communications. Finally, software must be developed for such functions as predicting travel times, recommending alternate transit routes, and determining transfer points and times.

Security of display devices at unsecured places, such as bus stops, must be addressed.

The overall benefit of the service is also an issue--to what extent will provision of this service encourage more people to use mass transit in lieu of the automobile?

3.2.8.2 Activities

1. Define En-Route Transit Information system concepts

   - The Federal Transit Administration (FTA) will be responsible for defining the system concepts, including those involving fixed location devices (e.g., kiosks) at traffic information centers and those involving portable devices on people or in vehicles. The appropriate technologies for making the data available will be considered. Candidates include kiosks, audiotex and videotex, and PCDs.

2. Sponsor En-Route Transit Information R&D

   FTA will sponsor the following R&D projects:

   - Research on the impact that traveler information has on mode choice
   - Research on the technological support needed for traveler information centers
   - Research on information display types
   - Research on formats to be used in displaying En-Route transit information
   - Initial studies will be single modal (e.g, "next bus" information). Later studies will focus on integrating multimodal information (e.g., bus/rail transfer information).

3. Conduct operational tests

   - Travel Information Centers. Kiosks and other fixed location devices will be tested using traveler information centers and home and office information using audiotex and videotex. Initial tests will focus on single modal travel (e.g., buses only). Tests will be cooperative partnerships between FTA and local transit agencies. Examples follow.

     - A Denver Smart Vehicle project will evaluate an automated, fully integrated, mass transit communications system using GPS and automatic vehicle location technologies for travelers. Major boarding and transfer points will be equipped with passenger displays.

     - The Minnesota GuideStar "Genesis" project will test a portable digital PCD that is designed to receive traffic and transit information to allow a traveler to make appropriate mode and transfer choices during the travel.

- The Minnesota "Travlink" project will evaluate real-time transit schedule and traffic information provided through a combination of kiosks and audiotex at various locations, including transit stations.

- The San Francisco Bay Area "TravInfo" project is testing a regionwide, multi-modal traveler information system to encourage the use of public transportation and ridesharing.

- A New York City operational test will evaluate the effectiveness of various methods of providing comprehensive transit information at bus stops and on-board buses.

- A Los Angeles Smart Traveler project will provide public transportation users with appropriate and timely data to improve their travel decision making. Kiosks and other fixed location devices will be tested.

- Other Traveler Information Sources. The following are included in the 1994 ITS Operational Tests chosen by U.S. DOT.

  - TransCal (California, Nevada) will test a comprehensive inter-regional Traveler Information System integrating transit, road, traffic, weather, and value-added services information sources from along the I-8OAJS 50 corridor between San Francisco and the Lake Tahoe-Reno metropolitan areas.

  - Seattle Wide Area Communication System--Bellevue Smart Traveler (Washington) will test three types of traveler information delivery devices: the Seiko Receptor Message Watch, an in-vehicle FM subcarrier radio to be developed by Delco Electronics, and a palm top computer provided by IBM. Each device will also support personal information and messaging services. The project will maximize the use of existing information systems, including Seattle METRO's vehicle location and scheduling systems. The Smart Traveler portion of the plan expands the 1993 FTA operational test, which supplies transit and real-time traffic information.

  - Project Northstar (New York State). Traveler Assurance Services (TAS), an existing privately-developed traveler information service, will offer additional services over an FM subcarrier combined with cellular telephone and a portable digital assistant speech synthesis for personalized en-route traveler advisories and information. Included is an element of transit information, transit incident alerts and the use of a personal security device, which could be adapted for use by public transportation passengers. The emergency notification and personal security system includes a response to customer initiated panic alerts.

- Advanced Rural Transportation Information and Coordination (ARTIC) (Minnesota) will coordinate the communications systems of several public agencies (transit, highway, and state patrol) by establishing a centralized communication site. Trilogy will provide traveler information through the Radio Broadcast Data System--Traffic Message Channel, an FM subcarrier, and 220 MHz system. Selected transit, volunteer and emergency response vehicles will be AVL equipped using portable mobile data terminals. The operational test also has a demand response element.

- Atlanta Driver Advisory System (Atlanta, Georgia) tests a traveler information system that uses an FM subcarrier for metro-wide travel advisory. Vehicles will be outfitted with in-vehicle data processing, displays and storage, and a Mayday system. Information will include traffic condition and public transit information/options (routes and schedules).

4. Develop standards and guidelines for travel information centers

- FTA will support the development of kiosk performance standards

- Society of Automotive Engineers (SAE) will develop Information Interchange Standards for PCDs.

5. Initial deployment of travel information centers

- Deployment will be the responsibility of local transit agencies.

6. Conduct operational tests with portable Personal Communications Devices (PCDs)

- Additional tests will refine testing previously conducted and will focus on traveler information using portable devices

- The full operational concept will be explored in FTA-sponsored operational tests. These tests will incorporate the use of AVL system technologies and will include multi-modal information (e.g., bus/rail transfers).

7. Initial deployment with PCDs

- Transit agencies will be responsible for collecting and disseminating the information. To be eligible for Federal grants, agencies will be required to adhere to standards and guidelines that have been developed

- This service will develop as consumers decide to purchase PCDs. Individual riders will be responsible for purchasing their own PCDs.

8. Initial deployment of Automatic Voice Stop Annunciators and Automatic Visual Information signage systems, which are compliant with ADA requirements.

- FTA has funded a demonstration project to test available automated technology in Houston, Texas, where buses serving a concentration of visually impaired riders will be equipped with devices which feature both audio and visual display of next stop and destination information on the interior and voice annunciation of destination sign information on the exterior when bus doors open at stops. Demonstration projects in over 10 other cities are scheduled to get underway during 1994.

- Several transit systems have or are in the process of procuring voice annunciation hardware which is triggered manually by the bus driver. These include Santa Clara County, California with 300 units, Stockton, California, Honolulu, Hawaii and Oklahoma City, Oklahoma.

- New Jersey Transit is procuring an on-board passenger information system for its buses and trains which will give announcements of service changes and carry advertising. The system will ultimately be expanded into a full digital and voice annunciator system.

3.3 PERSONALIZED PUBLIC TRANSIT

3.3.1 Introduction

Personalized Public Transit (PPT) involves the use of flexibly routed transit vehicles offering more convenient service to customers. These transit vehicles include small buses, taxicabs, other shared ride vehicles, or fixed-route transit buses that are detoured from their pre-established route to pickup/discharge passengers. They are able to provide essentially door-to-door service, thus expanding a route's service coverage area in lesser populated localities and neighborhoods. This type of service can offer shared ride transportation at lower cost, increased revenue and with greater convenience than can conventional fixed route transit.

3.3.2 Needs

Fixed route transportation service involves the operation of high occupancy vehicles over predetermined, fixed routes according to a published schedule. These services are most applicable to corridors with a relatively dense population to generate the ridership necessary to justify the cost of providing the service. In low density areas, conventional fixed route transit is prohibitively expensive and cost inefficient. The transit agency's desire to provide service is balanced by the need to manage the fleet in the most effective and efficient manner. In these lower density areas, flexibly routed transit offers a more cost effective transportation alternative to the single occupant automobile.

3.3.3 Service Description

The PPT user service involves flexibly routed transit operations that are tailored to specific applications and scenarios. These include random-route (Dial-A-fide) transit, fixed-route transit capable of deviating on call and resuming the fixed route, and specialized transportation for the transit dependent. The principal characteristic of these services is that they involve shared ride services (i.e., multiple passengers sharing the vehicle). Small publicly or privately operated vehicles operate on demand assignments to pick up passengers who have requested service and deliver them to their destinations.

The key to PPT is flexibility. This flexibility translates into lower operational costs and gives each vehicle a larger service area. Assume that a passenger is willing to walk 4 blocks from his/her home to a bus stop (this may be less in bad weather); the service corridor for this route would then be 8 blocks wide. In low density areas, route deviation on request can broaden the service corridor and encourage additional people to use transit. Increased ridership lessens people's dependence on the single occupant automobile, increases transit revenues, and lessens the need for additional downtown parking facilities. The transit system in Hamilton, Ohio converted to a route deviation system in 1992 and has reported dramatic increases in productivity and passenger acceptance. The small operation in Merrill, Wisconsin has operated a demand-responsive system since the early seventies.

Potential users of this service include several categories of people. One category includes the transit dependent (including the economically disadvantaged, the elderly, and the physically impaired). A second category of user consists of people living in low density areas in which fixed route service with large buses is impractical. These two categories of riders will benefit jointly by rapid service which permits spontaneous trip planning. A third user category includes travelers in low-demand time periods (e.g., night time and weekends). Children old enough to travel alone, but not old enough to drive, are potential users. The transit operator also represents a user because cost savings from operating this service with small fuel-efficient vehicles can result in lower operating costs.

3.3.4 Operational Concepts

There are two types of operations in PPT: flexibly routed operations and random route operations. For flexibly routed operations, fixed-route buses are detoured off the main route to pick-up and discharge passengers, thus expanding the vehicle's service area. For random route operations, the vehicles operate in completely random fashion, being assigned trip origin and destinations that fall within similar, general travel patterns. Vehicles are assigned on a reservation basis for random route operations. Most current reservation systems require passengers to place their request for service 24 hours (or longer) in advance of the need. This allows the system to plan routes and optimize the vehicle schedule. Tentative driver and vehicle assignments can be developed with consideration to cost effectiveness. "Instantaneous" requests for both flexibly routed and random routed operations will be honored only if there is enough slack in the system to allow an additional passenger pickup and delivery.

This service could also be operated with a base of subscriber passengers, who would get a fare discount for subscribing on a regular basis. These passengers would be supplemented by on-route or near-on-route dispatch pickups, who would pay the normal fare. Ultimately fares could also be paid electronically with a "smart" card (see User Service 4.1).

A goal of the PPT user service is to allow reservations, vehicle assignments, and scheduling assignments to be developed in real-time. Riders wishing to use PPT notify the dispatch center of the origin and destination of their trip. The computer then assigns the closest vehicle to service the request by matching the passenger's needs, for example, provision of a wheelchair lift, if required. Once the vehicle is assigned, the computer automatically informs the driver of the passenger's destination and directs the vehicle to the passenger's trip origin. The passenger is then notified that the trip is assigned and when to expect the vehicle's arrival. Passenger notification is important to relieve passenger uncertainty. Also it tells the passenger when to be at the curb to minimize vehicle waiting time and trip delays.

One key element of PPT is the requirement of keeping close track of the vehicles, the passengers, and the amount of time each passenger must ride in order to minimize passenger ride time and inconvenience. If the system attempts to pick-up too many passengers and expand its service area too much, excessive passenger ride times will result. This will decrease passenger satisfaction, and may result in lower ridership.

Although vehicle assignments can be made manually by a dispatcher who keeps track of the assignments using a simple cardex file or scheduling board, the complexity of the job generally limits the number of vehicles and trips-in-progress that can be tracked. Computers with advanced software algorithms have proven they can provide a significant increase in the number and complexity of the trips-in-progress. Also, the use of a computer can reduce the number of mistakes and customer inconvenience experiences. Elderly/disabled systems in larger areas increasingly have the need to improve productivity by using the software to group two or more passengers traveling in a similar direction on one trip.

3.3.5 Technologies

Communications is the common element linking all PPT services into a single entity. Data must be transferred between geographically dispersed points (both vehicles and locations where riders are situated) and a central base. Computational processing can be performed either centrally or in a distributed fashion (e.g., on-vehicle). As on-board sensors automatically monitor such elements as vehicle location, passenger loading and fare collection; their data can be processed on the vehicle to reduce the amount of data that is transmitted to the central headquarters or dispatch station where additional computational actions are performed in a central computer. The central computer then determines vehicle assignments and routing. The data can also be stored and maintained for off-line analysis and planning purposes. In those cases in which fares are paid by social service agencies or others, an off-line billing service can be provided.

PPT relies heavily on the application of advanced electronic systems and components. The technologies employed include advanced communications, automatic vehicle location, computer hardware and software systems, passenger and driver information (voice and visual), smart card readers, and automated demand-responsive dispatching systems.

Another major technology requirement is automatic data processing capability. In simple systems with few vehicles and minimal pick-up points, manual vehicle/passenger match-up is possible and has been successfully used for a number of years. With more complex systems involving larger areas, more passengers and more vehicles, a computer with appropriate and efficient software is definitely preferred. Continuing development of improved routing, scheduling and control software is extremely desirable so data processing activities are fast and accurate.

For the system to estimate when a vehicle will arrive at its pick-up or drop-off locations, it is necessary for the system to know each vehicle's location with respect to the existing road network. A vehicle location system must be installed in each vehicle and be connected to the computer through the communications system. A Geographical Information (Database) System must also be installed in the computer so the location data can be matched to addresses and streets. There are a number of candidate location systems that can be employed; for example, the Global Positioning System or dead-reckoning with map matching offer accurate location information. Presently the cost of these technologies is high; with advances in technology and economies of scale from larger production, it is expected that these costs will decrease.

Fare payment systems present another technology area that must be developed. Transit operators desire to move from a cash-based system to an electronic system. The necessity of transporting, handling and accounting for cash is expensive and a security concern. It also delays transit service as people and drivers search for cash and verify the proper payment. One example of an electronic fare collection technology that has direct application to transit operations is Smart Cards. In cases where the passenger pays the fare, Smart Cards permit direct electronic payment. In those cases in which the fare is paid by another party, e.g., an employer or social service agency, the fare can be directly billed to the service with no cash changing hands.

A large challenge for integrated service payment appears to be institutional barriers from financial institutions that have invested heavily in magnetic strip cards. Another significant stumbling block is that the balance should be printed on the card so the card holder knows his balance at any time, thus minimizing uncertainty. A viable alternative was tested during a card feasibility demonstration at the Washington (DC) Area Metropolitan Transit Authority, where the balance was visible at the card reader during use and at the add-fare machines whenever the card was inserted.

3.3.6 Potential Costs and Benefits

3.3.6.1 Potential Costs

The costs of Personalized Transportation Systems include the procurement, installation, test, and operations of advanced communication systems, automatic vehicle location, data bases, advanced software and the costs of operating the dispatch center.

The current approximate costs of these systems follow:

- Computer hardware systems cost about $20,000-$50,000 per system

- The necessary software packages for management information, computer aided scheduling, computer-aided or automatic dispatching, automated billing and brokering, etc. cost about $30,000-$70,000 per system.

- The cost of the communications system is about $15,000 $30,000 per system and $5,000-$6,000 per vehicle

- AVL costs about $1,000-$5,000 per vehicle

- Smart Card systems cost about $2,000 per vehicle

Costs for these systems will go down as the technologies mature. Also, the cost of communications and AVL systems may be dramatically reduced by a personal communication system infrastructure, (e.g. automatic determination of location via cellular triangulation). Such a system is currently being tested by Houston (Texas) METRO, whose elderly/disabled service, METROLift, has a one year contract with PacTel systems to provide vehicle location on a demand basis.

3.3.6.2 Potential Benefits

The potential benefit to the users, operator, and the community of these systems include the following:

- From the users' perspective, time savings when making trip requests, reduced waiting time for the bus to arrive, and increased confidence that the requested service will be delivered. The availability of this service in suburban areas might also allow a family to have only one car, a significant economic benefit.

- From the transportation operator perspective, better vehicle utilization, increased ridership and revenues, increased system capacity with no additional vehicles, increased average vehicle occupancy, increased average speed due to reduced dwell times, and increased productivity of employees

- From the community perspective, there may benefits from fewer adverse environmental impacts.

3.3.7 Assessment of Roles

The responsibility for developing PPT equipment and services generally resides with the private sector. U.S. Department of Transportation (U.S. DOT) involvement is limited to selected situations, including facilitating the standard setting for a common system architecture and in areas where private industry might not pursue development on its own (e.g., initial development of systems with high public benefit but long-term commercial potential or where the government is a primary user of the service). If both the expected public benefit and the commercial potential are high, U.S. DOT will encourage joint public/private development efforts. This approach underlies U.S. DOT's Intelligent Transportation Systems (ITS) technology investment strategy which is used to assess U.S. DOT's role in PPT user service development.

3.3.7.1 Public Benefit

The PPT user service has high potential public benefit, primarily because most of shared-ride passenger transportation in urban areas is presently publicly provided. In specific cases, private and nonprofit vehicle fleets provide public transportation service, e.g., taxi and para-transit operations. In each case, improved fleet operations, lower costs, and better service to the using public can be expected through PPT technology application.

3.3.7.2 Potential for Private Investment

Transit providers purchase equipment from private vendors. The private market potential is defined to be the total value of equipment and system sales to public transportation providers. The market potential for PPT products without U.S. DOT stimulus is moderate. As the U.S. DOT provides funding to install these systems in local areas, equipment service and maintenance activities will offer additional potential for private investment.

3.3.7.3 Public and Private Roles in Deployment

The public sector role for this user service is characterized as high, particularly in the area of standards setting for equipment being developed, thus ensuring compatibility of equipment. The collection of information on transit performance will also be a public role. Fare payment and system specifications, fare collection and analysis of passenger data will be performed by the transit operator. Private roles may involve establishing information systems capable of analyzing the data, coordinating distribution of the information, and responding to the peak inquiry demands for the information. Developing and coordinating a regional fare payment system will require significant public involvement; however, a public and private partnership will be needed for its success.

3.3.7.4 U.S. DOT Role in Developing Service

Public sector involvement in the development and deployment of Advanced Public Transit Systems (APTS) user services will occur at all levels of government, including Federal, State, Metropolitan Planning Organization (MPO), local, and public transit operator.

The U.S. DOT role for this user service is to foster operational testing and evaluation of the technologies and systems. Operational tests will also evaluate actual costs and benefits PPT systems, and help to determine the potential for private sector investment. The U.S. DOT will also develop guidelines and standards for information and the integration of systems between the transit and the traffic organizations. The U.S. DOT will also need to facilitate public/private ventures, and help remove institutional barriers between jurisdictions, foster data exchange in common formats, and encourage the development of new services.

U.S. DOT role is high in conducting research and development on the innovative transit application of new technologies developed for defense and commercial applications. The U.S. DOT will coordinate with transit agencies the operational testing and evaluation efforts. U.S. DOT will perform a summary evaluation of the tests to assist the transit industry identify appropriate system integration opportunities for ITS technologies. Once these systems are proven, the Federal Transit Administration’s (FTA's) capital grant program will help transit agencies procure them.

The U.S. DOT role in institutional and legal issues is medium. U.S. DOT will assist in identifying institutional and legal issues concerning the development of ITS technologies in public transportation vehicles.

The U.S. DOT role will be medium to high in deployment. Transit agencies and other local transportation providers will purchase their own equipment (with Federal financial assistance through Federal discretionary and formula funds). It is conceivable that the Department may eventually mandate certain ITS standards or systems to facilitate national compatibility.

3.3.8 Milestones and Activities

Figure 3.0-l in the introduction to this chapter identifies selected major milestones associated with developing this user service to a state of deployability.

This section elaborates on these milestones by identifying issues and providing a listing of more detailed, supporting activities. An issue is defined as a major potential challenge that has to be met to achieve deployability.

3.3.8.1 Issues

1. Increasing the efficiency of the service and thereby increasing productivity.

2. Providing more real-time capabilities and higher customer satisfaction.

3. Effective response to Americans with Disabilities Act requirements.

3.3.8.2 Activities

1. Identify customer base, service suppliers, and system issues

   There are many applicable technologies presently being used and many others available or under development. An important aspect of the PPT user service is the identification of these technologies and the determination of their capabilities. To increase the knowledge base, the assessment of technologies will include a literature search and interviews with researchers, practitioners, and manufacturers. A list of technologies to investigate will be established. Such investigation will involve in-depth research and may include laboratory and operational testing to determine their full capabilities. These assessments will help determine the utility of specific technologies and identify those needing additional testing to ascertain appropriate applications and actual costs and benefits.

2. Operational tests to validate concepts

   A key characteristic of the operational tests is that they will represent a partnership among the principal stakeholders: the state and local governments, FTA, and, when appropriate, the private sector. FTA assumes the responsibility for working with transit operations and technology providers to define and implement appropriate operational tests supporting the user service.

   Operational tests will be conducted using those technologies appearing to offer promise and represent useful applications. It is expected that the tests will typically take one to two years to develop implementation plans, another year to implement, and then two more years to operate and to fully evaluate market impacts and equipment performance. The information gathered during operational tests will be shared throughout the industry. Evaluations will be cooperative efforts. The Volpe National Transportation Systems Center will be responsible for developing and conducting site-specific evaluation plans under the overall guidance of FTA's Office of Technical Assistance and Safety.

   - The Rogue Valley Mobility Manager project in Oregon will use advanced electronics technology to record financial transactions in a non-urban setting. The initial phase will focus on providing transportation services to the elderly and disabled.

   - The Winston-Salem Mobility Management project will test a mobility management system for a fixed-route transportation system in a medium-sized city. A central phone number will provide access to integrated transit information, including personalized public transit. Software will be developed for the following: scheduling, reservation, dispatching, smart card interface, communications to the vehicle and dispatcher, mobile digital data display terminals, billing, record keeping, and administration.

- The Potomac-Rappahannock project in Virginia will test single-trip ridesharing with both advance and real-time reservation capabilities.

- The Advanced Rural Transportation Information and Coordination (ARTIC) project in Minnesota will coordinate the communications systems of several public agencies (transit, highway, and state patrol) by establishing a centralized communication site. Selected transit, volunteer and emergency response vehicles will be AVL-equipped using portable mobile data terminals. In addition, current dial-a-ride services in two suburban cities will be augmented with a computer-assisted scheduling system for centralized reservation-dispatch-recording services.

- Ideally, a major urban transit operator who is also responsible for suburban service in an area where density is low and service is largely underproductive, will fully test the concepts of route deviation and demand responsive service as an alternative to an entirely fixed route network. Before and after comparisons would then be carefully monitored and results widely publicized.

  In this regard, Dallas (Texas) Area Rapid Transit (DART) has experimented with some of these service concepts in the suburban areas west and north of Dallas with significant savings in operating costs. They are beginning an ITS operational test which will use existing AVL and GIS-based software to allow fixed-route buses to deviate within certain time and mileage limits to pick up passengers based on real-time phone requests. The route deviation scheme will serve to expand the route's service corridor area.

3. Develop guidelines for initial deployment

4. Conduct cross-cutting studies of operational test results

5. Determine initial availability of personalized public transit

   Some cities have already implemented aspects of personalized public transit in conformity with the Americans With Disabilities Act of 1992. Initial systems will lack some of the sophisticated features of later systems. For example, initial systems rely on manual operations, require advanced reservations, and are not integrated with vehicle location subsystems.

6. Define more sophisticated system concepts

   Later systems will provide more sophisticated capabilities than those in the systems that are first available. More automation and real-time capabilities will be provided. These include real-time vehicle rerouting in response to real-time reservations. Such systems must be integrated with vehicle location subsystems.

7. Conduct operational tests of more sophisticated systems

8. Develop industry accepted standards and deployment guidelines

   A workable method of standards development has been devised. Under this method two separate technical working groups would be formed under the ITS America APTS Committee. Working on two separate tracks, the user group would focus on their requirements, and the manufacturers group would focus on specifications which satisfy the user requirements. The method is an iterative process involving these two groups. The manufacturers know the current state and future of the technology, and the users understand the needs of their system and have the clearest picture of what the public wants. This method generally calls for the groups to meet separately to avoid hesitation on the part of either group brought on by the presence of the other and to foster greater sharing of experiences among the members of each group.

   One or more professional societies, such as, the Institute of Electrical and Electronics Engineers, or the Society of Automotive Engineers, will fulfill the role of liaison between the two groups and support development of the equipment standards. Operational tests and evaluations will be held to further evaluate the technologies, to support development of standards for interchangeability, and to support refinement of performance specifications for the equipment.

9. Define policy and institutional aspects for full-scale deployment

10. Determine initial availability of more sophisticated systems

    More sophisticated capabilities will evolve over time and be introduced into the field as they become available.

3.4 PUBLIC TRAVEL SECURITY

3.4.1 Introduction

The Public Travel Security (PTS) user service supports innovative applications of technology to improve the security of public transportation. The detection, identification, and notification of security incidents are within the scope of this service; responses taken (by police, for example) fall outside the scope of this service.

Security concerns include protecting transit patrons and employees from street crime, maintaining an environment of actual and perceived security, reducing the vulnerability of public transportation to terrorist incidents, and developing innovative technical measures to respond to such incidents.

Users of the service include transit customers and employees, transit operators, law enforcement agencies, and the general public. Portions of this user service concerned with personal computing devices and personal alarms are also applicable to personal security of patrons of Ride Matching and Reservation as described in User Service 2.2.

3.4.2 Needs

The Department of Transportation's (U.S. DOT) Intelligent Transportation Systems (ITS) program is a response to the increasing social and monetary costs of traffic congestion and poor mobility. By using ITS to improve public transportation, significant gains in solving these problems can be made.

Fear of street and on-vehicle crime has been cited as a significant detraction to public transportation use. Whereas the automobile separates its passengers from the surrounding environment and allows a sense of security and personal control, transit customers rely on the transit operator and local police for security. If customers do not perceive an atmosphere of control and security, ridership falls. Serious crime on public transportation is often highly publicized, increasing its negative effect. ITS offers potential solutions to security problems to enhance customer safety and the appeal of public transportation.

In addition to random street crime, organized terrorist activity may also threaten public transportation systems. Large numbers of people and easy public access can make public transportation systems vulnerable targets. ITS offers potential solutions to reduce the risk of terrorism on public transportation and enhance the response of transportation agencies to terrorist incidents.

3.4.3 Service Description

PTS services will help create a secure environment in public transportation where patrons will be more comfortable and fear of crime will not detract from transit ridership. This includes walking to bus stops or rail stations and park-and-ride activity, as well as riding on transit vehicles.

3.4.4 Operational Concepts

In transit stations, parking lots and at bus stops, advanced sensor technologies could monitor the surroundings and generate alarms. Alarms could also be generated manually. For example, push button alarm systems installed at these remote sites could be activated when an individual perceived a threatening situation. However generated, alarm signals would be monitored by central dispatch or the local police.

On vehicles, employees and patrons will be assisted by on-board silent alarms and connected microphones that allow central dispatch to monitor the vehicle when requested by the driver. Such systems are in use today in a number of locations . In real-time ridematching systems, participants may be identified through computerized identification cards, assuring mutual safety and an atmosphere of control and security.

The same monitoring systems used in detecting street crime can also be used to prevent and assist in responding to terrorist incidents. Monitoring systems capabilities can be incorporated into transportation agencies' plans for addressing terrorism.

3.4.5 Technologies

Numerous technologies are involved in PTS. These include closed circuit television, image processing, microphones, smart cards, personal communication devices, radio communications, satellite communications, cellular telephone, and public transportation fleet management systems.

Push button alarms can be operated from remote sites, including vehicles, bus stops, and parking lots. The alarms could be in the form of vandal-proof fixtures or hand-held devices. Hand-held personal alarms could automatically give the identification of the owner and location of the device. Alarm signals would be monitored by central dispatch or the local police. Communication of the alarm signal would be by radio, telephone lines, or cellular telephone technology.

Personal Communication Devices (PCDs) may play a major role in security. PCDs are palm-top computers with cellular telephone communications, potentially connected to a variety of information networks. PCD users could set up their devices to send out emergency signals if the operator felt endangered. The devices could also be programmed to send out signals if a prearranged travel itinerary were not followed or completed. False alarms would be checked by automating an identification signal of the PCD. PCDs tied with an appropriately configured PCS infrastructure would also report their current location as determined by cellular triangulation.

A simpler form of the PCD is the Personal Alarm Communicator (PAC) that could be used strictly as an alarm communicator. It could be sold to public transportation users or provided on a rental or loan basis.

Closed circuit television (CCTV) systems could use telephone or other communications lines to link networks of cameras. The cameras could be programmed to turn on only in the presence of potentially threatening motions, assuming the appropriate processing intelligence can be developed. Techniques to compress the images digitally, reduce the frame rate, or reduce the resolution transmitted will reduce the high CCTV bandwidth requirements.

Smart cards are further described in the Electronic Payment Services user service, and PCDs are further described in the Pre-Trip Travel Information, En-Route Driver Information, and En-Route Transit Information user services. Technologies involved in automatic vehicle location and real-time fleet management are covered under the Public Transportation Management user service.

Some of the services and functions described in Paragraph 3.4.3, Service Description, cannot be provided in a practical implementation today. These functions will be the subject of future R&D efforts by government and industry. A few of these functions are described below.

- *Advanced pattern recognition:* The need exists for both video and audio pattern recognition systems that can provide alarms in emergency situations. Because the difference between an argument and an assault may be subtle, this is a very difficult challenge. The need is for electronics to reduce the load on drivers, personnel monitoring CCTV, and others charged with remotely detecting emergency situations.

- *Driver barriers:* This need is more for development than research. Bus drivers should be accessible to the public, yet protected from assault. They should be free to respond to crimes on their bus without concern for their personal safety. They also should be protected from the cold or hot air blasts associated with cycling of the doors at stops.

- *Safety/security trade-offs of bus doors:* This also is a development need. Safety requirements dictate that passengers be able to freely exit a bus without driver intervention in case of an emergency. Yet security concerns in certain situations may require the driver be able to securely lock up the vehicle to prevent escape of a criminal. Doors should be designed to accommodate both functions.

3.4.6 Potential Costs and Benefits

Quantifying the costs and benefits of PTS is a potentially controversial matter. In private automobiles, drivers have a sense of being in control of their own security, and some of the costs of security are left to the individual driver. But public transportation is different. By quantifying the costs and benefits of security, transit operators may subject themselves to public criticism that they are placing dollar values on human life. A more upbeat scenario -- that of business opportunity currently lost due to perceived security shortfalls -- may provide another avenue by which the cost of these systems may be justified.

Ultimately, when the perceived cost (financial and political) of operating without certain security systems exceeds their capital and operating costs, the systems will be developed and installed. Accordingly, all transit operators have taken security measures commensurate with their perception of the risk and cost of crime and terrorism.

3.4.6.1 Potential Costs

The financial cost of developing and installing PTS systems varies with technology and capability. Systems that use remote sensors and cameras may incur relatively large capital and operating costs. Liability may be an issue in determining cost. Use of PCDs may cost both the transit operator, who ties into the system, and the owner of the PCD who has to buy the device. The current cost of PCDs may be beyond the capability of many transit customers, especially in portions of major urban areas where a large share of riders are economically disadvantaged.

3.4.6.2 Potential Benefits

Providing an increased amount of security will keep more people from being hurt by crime and may well save lives; such benefits cannot be quantified.

3.4.7 Assessment of Roles

3.4.7.1 Public Benefit

Where lack of security affects transit ridership, the potential benefits will be increased transit ridership and reduced traffic congestion. In transit systems where lack of security is not perceived as a problem, benefits of ITS security technologies will be as a deterrent to terrorist incidents and a facilitator of coordinated response.

3.4.7.2 Potential for Private Investment in Development

The potential for private investment is high, but is dependent upon transit operators' perception of a problem where they have a responsibility. Unless transit operators or public concern creates the market, it will not fully develop.

3.4.7.3 Public and Private Roles in Deployment

The deployment of PTS will be a public and private partnership. Private sector expertise will help keep the public sector's aspirations within existing technical capabilities. Communications between public and private sectors is necessary to ensure that projects undertaken with public funds are technically sensible and not just politically popular. The public's willingness to pay for security will certainly be important. The public sector will play a role in defining the requirements for systems, and in helping to establish standards and an open architecture. Public sector involvement in the development of this service is important to assure that the functional and interoperability potential of the systems is fully realized.

3.4.7.4 U.S. DOT Role in Developing Service

The U.S. Department of Transportation (U.S. DOT) will have both a direct and supporting role in the development of PTS.

- Research and Development: The U.S. DOT role in research and development is high. However, the public sector is largely relying upon the creative ability of the private sector to develop prototype products for operational testing.

- Operational Tests: The U.S. DOT role in operational testing is high. U.S. DOT has a direct concern about passenger safety on the nation's public transportation systems in regard to terrorist incidents. Careful evaluations are a critical element of this effort.

- Institutional and Legal: The U.S. DOT role is low to medium for evaluating institutional and legal barriers to implementation of these systems. Issues of liability and privacy may be important.

- Deployment: The U.S. DOT role in deployment is high. U.S. DOT must work to ensure that transit operators have the capability to develop appropriate security systems. U.S. DOT must also work to ensure that systems are compatible and consistent with each other.

3.4.8 Milestones and Activities

Figure 3.0-l in the introduction to this chapter identifies selected major milestones associated with developing this user service to a state of deployability.

This section elaborates on these milestones by identifying issues and providing a listing of more detailed, supporting activities. An issue is defined as a major potential challenge that has to be met **to** achieve deployability.

3.4.8.1 Issues

1. The scope of this user service and its cost are the key issues. It will be necessary to find the optimal level of complexity and cost-effectiveness. There are potentially high capital and operating costs.

2. Close coordination with appropriate law enforcement agencies is necessary to:

   - Assess their ability to respond, given the increasing demands on city and transit police departments

   - Gauge effectiveness of particular hardware and response approaches detailed in Paragraphs 3.4.4

   - Assess potential legal issues that may arise from the use of certain types of technology, such as the use of video tape for prosecution

3. Coordination with social agencies, who may get involved with subsidizing

3.4.8.2 Activities

1. Identify user needs and define scope of concept

   - The scope of this user service must be defined. Decisions are needed as **to** whether, for example, transit garages, major transfer points, and/or individual bus stops are included in the concept.

2. Define system concepts and determine R&D needs

3. Conduct operational tests

- Atlanta Driver Advisory System (Georgia) tests a traveler information system that uses an FM subcarrier for metro-wide travel advisory. Vehicles will be outfitted with in-vehicle data processing, displays and storage, and a Mayday system.

- Project Northstar (New York State) includes transit incident alerts and the use of a personal security device, which could be adapted for use by public transportation passengers. It also features an emergency notification and personal security system which includes a response to customer initiated panic alerts.

4. Conduct cross-cutting studies, develop guidelines, and assess institutional issues

5. Conduct further operational tests

6. Initial deployment

CHAPTER 4.0 - ELECTRONIC PAYMENT

4.0 INTRODUCTION

Electronic Payment consists of one user service, Electronic Payment Services. This user service provides travelers with a common electronic payment medium for all transportation modes and services. It may, as envisioned, also serve broad non-transportation functions and may be integrated with credit and debit cards in banking and other financial transactions.

The users and operators of all modes of transportation will benefit from the high level of convenience this service introduces. Parking lot operators will benefit from electronic capture of fees, reduced cash handling and increased security. Electronic toll collection is already speeding up traffic and reducing backups at toll facilities. Public transportation systems should benefit from the increased user friendliness of the fare collection process, easing passenger transfers among bus, metro, and commuter rail systems. Electronic payment can also facilitate congestion pricing to help reduce traffic loads during the peak hours. Travelers benefit from the added convenience and security of electronic payment methods.

4.0.1 Relationship to ITS Goals and Objectives

The use of electronic payments services is expected to ease transfers among modes and to contribute to reductions in single occupant auto trips in favor of the various forms of public transit. Use of integrated circuit (IC) Cards, commonly referred to as “smart cards,” for public transit fare payment will increase mobility for those who shun transit because of uncertainty and confusion over fares, zone payments, transfer charges, the need to carry enough change for the exact amount of fare(s) and the universal feeling of looking foolish and uninformed in front of the often overburdened bus driver and other passengers. Studies have shown that if the fears of being a first time or infrequent rider are overcome, travelers are more likely to use public transportation when other factors of time and convenience are similar.

Decreasing the use of single occupant vehicles (SVOs) and increasing the modal share of transit will help to alleviate congestion and improve safety by reducing the number of vehicles on the region’s roads. To the, extent that this modal shift occurs, there will also be a positive effect on the environment, including positive effects on wetlands, water quality and air quality through reduction in emissions. Improving the flow of traffic and greater use rail, transit, paratransit, carpools, and vanpools will have a positive impact on safety through a net decrease in the number of vehicles on the region’s roads.

Studies have already shown that the adoption of non-stop electronic toll payment alone can reduce emissions and fuel consumption, and can increase throughput at toll plazas without adding more roadway and infrastructure. The convenience that a single payment medium offers for parking and toll collection may also stimulate additional car pooling and ride sharing, however, these effects are more difficult to predict. It is also possible that increased convenience may also attract additional single occupancy vehicles to parking, which will have the reverse effect on meeting the goals detailed here.

Consumer acceptance of a universal electronic payment device may spawn new applications for non-transportation related and financial services for travelers.

4.0.2 Integration of Electronic Payment User Services

The concept of the use of a “smart card” for ITS electronic payment user services is that of one device to handle multiple applications, such as for the payment of tools, parking fees, and transit fares. The purpose of the transaction; for example, “vehicle-based” transactions (i.e. toll collection, parking fees) or “person-based”transactions (e.g., rail transit, bus fare, taxi), will determine the requirements for such a device. Electronic payment could be accomplished with a card that is physically waved in front of or comes in contact with a stationary “reader,” or it could be accomplished with the use of an in-vehicle radio frequency transponder that remotely communicates transaction data between the vehicle and roadside transceivers. A combination of both characteristics, i.e., a transponder with smart card interface, could readily accommodate all types of both person-based and vehicle-based transactions. Such a transponder device could also support credit and debit type systems, or even personnel identification badges or passes used by a number of business for security, access, and monitoring purposes.

4.0.3 Electronic Payment Architecture

Architecture for this service makes use of electronic technologies in three main areas; Automatic Vehicle Identification (AVI), “Smart Card” systems and Electronic Funds Management systems. At the center of each of these are computer systems interlinked by worldwide communications networks which will link “point of sale” transportation devices (such as toll tag readers) with financial service clearing houses.

4.0.4 Cross-cutting Issues

A number of issues must be resolved before integrated payment systems can be fully deployed. Legal and privacy issues involve the protection of individual users’ financial transactions information and the resolution of billing errors. The prevention of theft and fraud are also issues of concern in any monetary application.

While technically feasible, the concept of road pricing faces tough political and institutional challenges. However, this comes at a time when the issue is receiving attention and study worldwide.

Architecture issues involve the development of a standard for both the smart cards and the card reader/writers that would work within the operational settings of each of the transportation modes. As with other user services, the goal is for a seamless system that offers the traveler financial access equally to all the choices available.

4.0.5 Activities Chart

The broad milestones leading to deployment are shown on Figure 4.0-l.

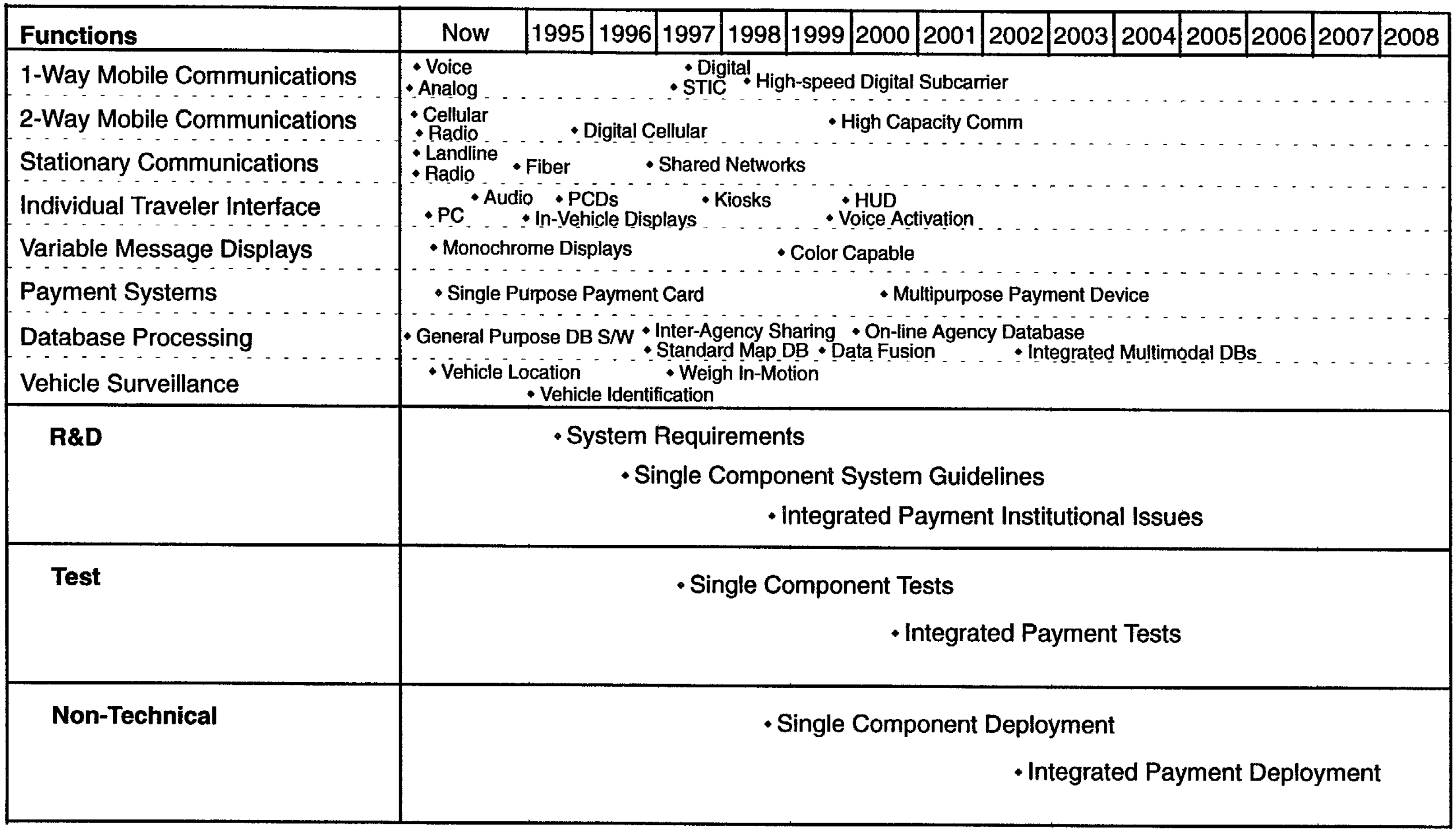

Figure 4.0-1 Electronic Payment Technology Development Timeline

4.1 ELECTRONIC PAYMENT SERVICES

4.1.1 Introduction

Electronic Payment Services will allow travelers to pay for transportation services with electronic cards or tags. The goal is to provide travelers with a common electronic payment medium for all transportation modes and functions, including tolls, transit fares, and parking. Electronic Payment Services directly support integrating payment systems of transportation modes to create an intermodal user service. The service is also directed at improving the payment systems of separate transportation modes, because modal transportation payment systems will have to be further developed and perfected independently before they reach a state where integration is feasible. The goal of eventual integration should be recognized as payment systems are developed within each mode. A further goal of integration among systems in different states is a priority, particularly to facilitate toll payment. Users of the service include the traveling public as well as transportation agencies that will implement or support implementation of any aspects of the Intelligent Transportation Systems (ITS) program.

4.1.2 Needs

One area where significant gains in transportation efficiency can be made through ITS is in payment for transportation services. Delays at roadway payment barriers result in economic and environmental costs and potential safety hazards. Public transportation is seen as inconvenient because fare payment systems are awkward and inflexible, and transportation authorities shy away from estimating cash losses from fraud. New applications of technology provide potential solutions to these and other payment related problems.

In applying advanced technologies to transportation, however, it is desirable to develop systems that cross transit and transportation modes. Applying technology independently to the various modes provides gains in productivity for those modes. However, integrating payment services across a number of modes should further increase convenience for private and commercial travelers and improved productivity for operators. Electronic Payment Services provides a plan for addressing the previously mentioned problems while ensuring a systemic approach through an intermodal plan for service development.

4.1.3 Service Description

Electronic Payment Services will allow travelers to pay for transportation services with a common electronic payment medium for all transportation modes and functions. Electronic toll collection, transit fare payment, and parking payment would be linked through an intermodal multi-use electronic system. A common transportation service fee payment structure could be used with all modes, possibly tying into roadway pricing options.

Coordinated pricing strategies, including incentives for high occupancy vehicles, ride-sharing, congestion pricing, and transit are covered under Demand Management and Operations (User Service No. 2.3).
Electronic Payment Services has the following components:

- Electronic Toll Collection
- Electronic Fare Collection
- Electronic Parking Payment
- Integrated Electronic Payment Services

Electronic Payment Services also offers the possibility of facilitating the implementation of Travel Demand Management strategies as described in the user service of that name.

4.1.4 Operational Concepts

4.1.4.1 Electronic Toll Collection

Electronic Toll Collection (ETC) allows drivers to pay tolls without stopping or slowing from cruising speed, thus decreasing delays and improving system productivity. ETC systems are installed in various configurations, including at mainline barrier plazas, open highway collection systems at main line speeds and closed systems where tolls are based on entry and exit points and collected at the exit point.

ETC systems automatically determine tolls for classes of vehicles, such as passenger cars, small trucks, transit buses, and semi-trailer trucks. To assure customers that correct transactions have occurred, confirmation of toll charges are provided through roadside message signs or in-vehicle devices. Various methods could be used to provide receipts for transactions if required. Automated enforcement of violations is also part of the ETC system. Video cameras in the toll lanes take a photograph or video image of the vehicle and/or license plate whenever the system detects a violation.

Commercial vehicles may have their financial transactions handled under a commercial account, whereby the carrier makes a monthly pre-payment based on its historical usage of the toll road. Such a system is in place at the Oklahoma Turnpike Authority, which had over 50,000 commercial vehicles registered in its ETC system as of 1993. Commercial carriers receive a statement of its monthly charges, and prepayment adjustments are made periodically based on increased or decreased usage.

Multiple toll authorities could join together to offer unified services such as toll tag distribution, billing, and customer service. For cross-country commercial carriers, a standard Automated Vehicle Identification (AVI) tag could be used for all toll transactions and combined with other commercial vehicle operations (CVO)-related services such as transparent borders for permits, weighing, and safety inspections. Such a system is in operation in New Mexico where over 8,000 commercial vehicles using an AVI tag, which meets the American Trucking Association's Automatic Equipment Identification (AEI) standard, are registered in a port of entry program. Motor carriers with the proper identification tags may completely eliminate stops at border truck weigh stations.

ETC systems already in use have shown they reduce the costs of collecting tolls as well as reducing the costs of cash handling, improving security and minimizing opportunities for fraud.

4.1.4.2 Electronic Fare Collection

Electronic fare collection eliminates the need for transit customers to provide exact change and facilitates the creation of a single fare medium for all public transportation services. Fare systems of multiple transportation providers are integrated from the point of view of the traveling public, while individual operators maintain the integrity of their fare systems. Distance-based or other fare structures are easier to implement for all public transportation modes. For example, transferring between modes or lines might not require additional fare, because the fare card would "remember" earlier trips. The service includes both debit and credit capability, and immediately identifies voided cards. Electronic card systems facilitate the participation of employers in transit benefit programs where employers pay for their employees transit accounts which are debited only for work trips.

Paratransit operators will electronically verify rider eligibility upon boarding, and ride tracking capabilities will improve the efficiency of third party billing processes. Payment systems might also tie into private operations such as taxis and airport limousines.

Electronic fare collection serves all transit operators by reducing cash handling and losses from fraud. Substantial increases in prepaid fares are likely from the system, providing operators with additional revenue. Significant growth in ridership may also occur as card systems develop beyond transportation services and into retail, telephone and other areas.

Electronic fare systems also help transit operators in areas of operations and service and route planning. Operators will be able to collect accurate and precise data about passenger boardings on specific routes and trips at all times of the day. Bus trips can also be made in less time since there is a significant reduction in boarding times with the use of electronic passes.

4.1.4.3 Electronic Parking: Pavment

Electronic parking payment enables the automobile driver to pay for parking without cash. Upon entry or exit from a parking lot a driver would have the parking charge billed or debited by the use of an electronic card or tag system. In the optimally integrated Electronic Payment Service, the level of integration achieved with the other components may depend on the ownership of parking facilities involved. Transit operators providing park-and-ride lots will be able to easily integrate parking payment systems into their overall fare structure. Also, discounts may be provided to high occupancy vehicles.

4.1.4.4 Integrated Electronic Payment Services

Ultimately, Electronic Payment Services may be fully integrated across transportation modes, enabling one payment medium to be accepted for transportation services across a given region. For example, a traveler driving on a tollway to a park-and-ride lot to use commuter rail would be able to pay for all three transactions -- toll, parking, and fare -- with the same device.

In addition, the fare structures of public transportation agencies would be integrated with toll collection agencies. This would allow regional governments and transportation agencies to develop coordinated pricing strategies that could favor certain modes or routes. Such strategies could help reduce congestion and increase transit ridership.

4.1.4.5 Implementation of Travel Demand Management Strategies

The flexibility offered by Electronic Payment Services technologies, principally automated vehicle identification and electronic financial transactions, offers the possibility of facilitating the implementation of Travel Demand Management (User Service No. 1.8) strategies. In particular, they will enable relatively easy implementation of road pricing policies. Discounts for high occupancy vehicles and congestion pricing are two such strategies. When coordinated with other transportation modes within an overall transportation fee structure, roadway pricing could significantly influence mode choice decisions.

4.1.5 Technologies

The technologies involved in Electronic Payment Services focus on three main areas: AVI technology for electronic toll collection, parking payment and road/congestion pricing strategies; Smart Card systems for transit fare collection, electronic toll collection, and parking payment; and electronic funds management systems that will be used to support the entire service.

4.1.5.1 Automated Vehicle Identification

AVI is a key component of electronic payment services such as toll collection and parking fees, where remote sensing of a specific vehicle for billing purposes is needed. AVI typically involves radio frequency interrogation of an electronic memory located within a “tag” placed on or within the vehicle. Such AVI technology is also referred to as Radio Frequency Identification (RFID). The adoption of a national standard for AVI and RFID systems would benefit toll facility operators and patrons, commercial vehicle operators, and other ITS services that use vehicle-roadside communications (VRC) provided by AVI.

National compatibility would allow a customer's AVI tag to be used in many applications and many geographical areas. An example of existing compatibility is the J.B. Hunt Motor Carrier, which has over 6,000 trucks equipped with AVI tags with the Oklahoma Turnpike Authority for electronic toll collection. These tagged trucks may also be registered with the two Harris County (Houston), Texas toll roads and at two ports-of-entry operated by New Mexico for by-pass identification.

4.1.5.2 Smart Card Systems

A variety of "smart card" technologies and systems exist for electronic payment services applications in ITS. These include magnetic-stripe cards, proximity cards, and integrated circuit chip cards, but may also refer to RF transponders that function as "smart tags" or interface to "smart cards." Generally, a smart card or tag refers to a device with an imbedded integrated circuit (IC) chip containing memory and a microprocessor. The key differentiating function of a "smart" card or tag versus other payment devices is its capacity for multi-purpose use and an interface to an electronic funds management system.

Smart cards are well suited for "person-based" transportation, i.e., whenever cards must be carried on the person, such as for rail transit, bus and taxi fares, since the size of these cards makes them convenient to store and handle. Both Smart cards and tags are suitable for "vehicle-based" travel, such as for the payment of tolls and parking fees. An in-vehicle transponder would be required for the use of a smart card in non-stop application such as toll collection where data exchange at speed and distance is required.

Smart cards can be divided into Contact, Contactless, and Proximity cards. An International Standards Organization (ISO) standard exists for contact cards, which use metal-to-metal contact with the card reader. Contact-less cards typically use magnetic induction to interface with the card reader. Both contact and contactless cards can be inserted into transponders for use in electronic toll collection (ETC). Contactless cards are typically employed in proprietary systems not adhering to IS0 card standards.

Proximity cards interface with the reader at a distance usually greater than two centimeters using radio-frequency (RF) technology. Proximity cards, typically waved over a reader or carried through a portal, function similarly to an ETC transponder, but with reduced range. They have strong potential for public transportation, making boarding faster and simpler, and enabling distance-based fare structures. Proximity cards vary in thickness, as they often have an internal battery. Some are too thick to be conveniently carried in a wallet or purse.

The range of capability and extent of integration of various transportation modes will determine what type of electronic payment system is best suited.

4.1.5.3 Electronic Funds Management Systems

Electronic funds management forms the backbone of the user service. It is only through the coordination of electronic financial systems of participating agencies that an integrated payment medium can be developed. The technology involved is well developed and is unlikely to present any technical problems; however, coordinated electronic funds management systems for ITS applications are slow to take hold. This is chiefly because of a lack of widespread penetration, multi-use, and compatibility. Standards, multi-use capability and widespread adoption would make the handling and clearing of these transactions highly desirable business for financial institutions and networks. The anticipated development of the National Information Infrastructure (NII) will further facilitate the development of electronic funds management systems.

4.1.6 Potential Costs and Benefits

4.1.6.1 Potential Costs

Costs of electronic payment services include capital costs for the procurement of equipment and systems integration, and operating costs. While capital costs for most electronic payment services will be higher than traditional systems, decreased operating costs and increased revenue will result in less expensive systems overall. Costs will vary with the sophistication and capacity of the systems. Highly integrated systems will likely have higher development costs which will be recovered through gains in efficiency and system flexibility. Installation costs for Electronic Toll Collection at all current toll facilities is estimated at about $720 million.

4.1.6.2 Potential Benefits

Electronic Payment Services have many potential benefits: increased transit ridership; reduced congestion on toll roads; reduced cash handling by transportation agencies (with associated labor savings); reduced fraud; facilitation of real-time ride-matching and Mobility Manager operations; efficient CVO operations; traveler convenience; reduced administrative costs for paratransit operations; and facilitation of the adoption of road pricing.

4.1.7 Assessment of Roles

4.1.7.1 Public Benefit

Through an integrated transportation fee system, Electronic Payment Services will provide local and state governments and toll facilities with the ability to develop transportation fee policies and structures. Public agencies will be able to formulate policies to determine the balance of transportation services provided, and to assess the true cost of those services.

Electronic Payment Systems help reduce traffic delays, congestion and air pollution. They also improve safety, based on the experiences of toll facilities presently using such services. AVI tags are being used as traffic flow detectors to increase areawide traffic control surveillance capabilities and roadway-vehicle AVI communications may be used for other short-range information transfer purposes. In Houston Texas, information derived from such a system is used to provide information to commuters on incident management, potential alternate route selection and other traffic management applications. The construction and operation of toll facilities will require fewer resources, such as rights-of-way and labor costs.

Public Transportation will be made more user-friendly, and an increase in ridership may occur. The inconvenience of “exact change” and delays in boarding will be minimized. Fare payment will be simpler also for the transportation disabled, allowing them increased mobility. Information developed through the system will improve transit planning and operations management.

The extent of all of these potential benefits has not been estimated nationwide.

4.1.7.2 Potential for Private Investment in Development

The potential for private investment in the development and implementation of electronic payment products and services is high. Independent private investment is already occurring in the development of AVI and “smart card’ systems. AVI/RFID tags and toll collection systems are in place and operational at numerous toll facilities in the U.S. Multi-use smart card systems are still mainly experimental world wide.

4.1.7.3 Public and Private Sector Roles in Deployment

The deployment of Electronic Payment Services will be a joint public and private activity. The public sector role will be largely in defining the requirements for public systems use, and in helping to establish open standards and architecture. Public sector involvement in the adoption of standards for this technology service is important to assure that systems are compatible to the fullest extent possible.

Public toll authorities are already deploying electronic systems because of the potential economic benefits. Many new toll facilities are committed to electronic toll systems or already have them in operation. The public sector does have a strong interest in assuring interoperability of hardware systems, especially regarding the use of one vehicle tag among many installations, which is especially important for CVO-related services such as safety and credentials verification, and in areas with multiple toll facilities.

The market potential for vending of ETC systems breaks down into two distinct areas: (1) supplying the infrastructure-based tag readers, communications, enforcement, account servicing, and data processing systems, and (2) providing large numbers of the actual "toll tags" which identify a specific vehicle or account. As most toll authorities are considered public sector entities, the infrastructure-based elements have a limited private market potential. However, the marketing of tags to private individuals and commercial carriers is a potentially large market opportunity, especially if "value-added" services providing for multiple uses of the tags are offered.

4.1.7.4 U.S. DOT Role in Developing Service

The U.S. DOT will have both a direct and supporting role in the development of Electronic Payment Services. Developments such as read-write capability, on-tag data storage, and RF smart cards present many opportunities. Maximizing such goals as commercial productivity and interoperability of vehicle tags and fare cards among toll and fare systems is considered a public sector objective. To the extent that U.S. DOT can encourage transportation agencies to develop compatible purchase specifications, this goal can be achieved. With the goal of creating a national compatible VRC specification, the U.S. DOT intends to undertake a comprehensive review of available technologies and needs within the ITS program. When a proposed specification is ready, U.S. DOT will follow normal rulemaking procedures in promulgating a national compatible VRC specification.

- Research and Development: The U.S. DOT role in research and development is medium for public transportation applications, and low in other applications. The public sector is largely relying upon the creative ability of the private sector to develop prototype products for operational testing.

- Operational Tests: The U.S. DOT role in operational testing is high. Operational testing of integrated systems is critical to the proper development of the service, and U.S. DOT is a principal advocate of an integrated, compatible approach to system development . Careful evaluations are a critical element of this effort. Sites should be chosen to accommodate a variety of operational and institutional conditions.

- Institutional and Legal: The U.S. DOT role is medium for ensuring that institutional and legal issues are properly addressed. Potential problems may emerge in areas of privacy and personal information. Legal issues will arise in the area of banking regulations as financial clearinghouses are created to accommodate multi-use payment devices.

- Deployment: The U.S. DOT role in deployment is high. Systems will be purchased by public transportation agencies, State DOT's, and toll road authorities, most of whom receive Federal assistance. U.S. DOT must work to ensure that deployed systems are compatible and consistent with each other. Since modes will initially deploy systems independently, U.S. DOT has a role to closely follow deployment and continually reassess the requirements of systems with higher levels of integration.

4.1.8 Milestones and Activities

Figure 4.0-l in the introduction to this chapter identifies selected major milestones associated with developing this user service to a state of deployability.

This section elaborates on these milestones by identifying issues and providing a listing of more detailed, supporting activities. An issue is defined as a major potential challenge that has to be met to achieve deployability.

4.1 .8.1 Issues

1. Problems in the integration of the components of this service may occur with banking regulations or individual transportation agency policies. Administrative and policy difficulties may occur when transportation fee financial systems become shared between agencies or across political boundaries. Local will to resolve such conflicts may determine the level of integration possible. Similar problems may arise between private parking operators and public transportation agencies.

2. Achieving consensus over multiple competing approaches for implementing the service: How can different systems be integrated or uniform standards applied? If standards are developed, how do they apply to previously installed systems?

3. Maintaining absolute privacy of use while replacing cash transactions with electronic payment services using cards or tags.

4. Detecting and correcting incidence of billing error or fraud. Users should expect the same level of protection and customer service as they enjoy with their present bank cards. Sponsoring agencies should be able to establish procedures for correcting billing errors and detecting fraud at reasonable cost.

5. The use of "wide area" versus "lane based" electronic toll systems presents the technical issue of proper and reliable identification of authorized vehicles as they pass through a multi-lane electronic toll collection zone.

4.1.8.2 Activities

Currently, electronic payment services for components such as ETC, Transit Fare Collection, and parking are being separately implemented today. Over time, it is expected that new and proven applications will be developed to provide more integrated service across all modes of transportation.

1. Identify Users, User Needs, and System Requirements

   Users, needs, and requirements have, to a great extent already been identified for Electronic Toll Collection and Electronic Fare Collection. The following U.S. DOT ITS projects are underway to further refine this area:

   - Project MA-06-0209, Advanced Fare Media Assessment
   - Project TCRP A-l, Fare Policies, Structures and Technologies

2. Operational tests on single component systems

   This task supports the first generation of operational tests of smart card systems. Most are mode-specific, with a limited amount of integration. None involve fully integrated transportation payment systems.

   Project PA-06-0006, Develop and operationally test Smart Card System for paratransit ridetracking and third party billing (1993)
   Project MI-26-0003, Develop and operationally test Smart Card System for bus service and parking payment (1993)
   Proposed: Operationally Test Smart Card System for bus service and employer transit benefit program in Delaware (1993)
   Proposed: Operationally test public transportation Smart Card System for multiple operators (1993)

3. Develop guidelines for single component systems

   - Potential Project; Guidelines for Electronic Toll Collection Systems Procurement

4. Initial deployment of single component systems

- Toll systems are in operation in Oklahoma, Texas, California, Louisiana and Georgia. Some authorities provide regional multi-agency compatibility, allowing the same tags to be used across systems. For example, the Harris County Toll Road Authority in Houston, Texas accepts tags issued by the Oklahoma Turnpike Authority; and tags issued by the Crescent City Connection and Lake Pontchartrain Causeway in New Orleans may be used at either facility.

- Electronic toll systems using AVI technology are already in operation in various states, including California, Colorado, Florida, Georgia, Illinois, Louisiana, New York, Oklahoma and Texas

- Numerous airports have implemented AVI for a form of congestion/road pricing to charge airport access fees and increased fees based on "dwell time" or the number of "loops" made on the airport roadways.

5. Define concepts for integration of electronic payment service components.

- Proposed Project, Development of Compatible Toll Collection and Truck Network Systems

- VNTSC OMNI Task IA, Multi-use Stored Data Cards for Toll and Fare Payment

- Potential Project; Potential for integration of Electronic Toll Collection and Electronic Fare Collection Systems

6. Further operational tests using new techniques and greater modal integration

- Fare collection and toll systems will be integrated. Opportunities for integration with parking systems will be taken advantage of as they arise.

7. Assess institutional issues associated with integrated payment services

8. Develop guidelines for integrated payment services

9. Initial deployment of integrated payment services

10. Operational tests on variable roadway pricing

CHAPTER 5.0 - COMMERCIAL VEHICLE OPERATIONS

5.0 INTRODUCTION

Commercial Vehicle Operations (CVO) encompasses a broad range of diverse operators and operating environments. The interstate motor carrier industry, which includes approximately 275,000 businesses operating trucks, 4,000 for-hire passenger carriers, and 6.6 million commercial drivers, is a complex mix of businesses that transport goods and passengers for profit or as part of another business function. A similar number of intrastate carriers may also benefit from ITS/CVO technologies.

The User Services presented in this bundle are concerned primarily with freight movement and focus in two specific areas; those which improve private-sector fleet management and freight mobility, and those which streamline government/regulatory functions. While not directly addressed in the CVO user services, for-hire passenger carriers and buses may benefit from aspects these and other user services, including those described in the Public Transportation Management user services bundle. CVO operators and customers can gain direct benefits from a number of other user services presented in the plan. For example, the Advanced Vehicle Control and Safety Systems user services include collision avoidance technologies which have direct application to heavy vehicle operations and safety; and those services intended to reduce congestion and delay will enhance the productivity of motor carriers operating in urban areas. .

The Federal Highway Administration ITS/CVO program is a voluntary effort consisting of public and private organizations working together with the goal of improving highway safety and motor carrier productivity through the application of advanced technology. The primary "users" of the developed technology applications are the motor carrier industry and state highway and motor carrier regulatory authorities. The vision statement for the ITS/CVO program is:

- **Assisted by advanced technology, trucks and buses will move safely and freely throughout North America.**

This vision can be achieved by using cost-effective methods and technology to streamline current State regulatory and enforcement activities and motor carrier practices, while increasing levels of safety and productivity for both States and carriers.

5.0.1 CVO User Services

The technology applications for CVO have been categorized into six user services, which are briefly described below:

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

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

- The **Automated Roadside Safety Inspection** service will use safety data provided by the Electronic Clearance service combined with state-of-the-art technology to allow for more selective and rapid inspections. Through the use of sensors and diagnostics, inspectors will eventually be able to check vehicle systems and driver requirements and ultimately driver alertness and fitness for duty.

- The **On-board Safety Monitoring** service will non-intrusively monitor the driver, vehicle, and cargo and notify the driver, carrier, and, possibly, enforcement personnel if an unsafe situation arises during operation of the vehicle. Such an unsafe situation might involve the status of driver fatigue, vehicle systems, or cargo shift. This service will tie into the later stages of the Automated Roadside Safety Inspection and Electronic Clearance services.

- The **Commercial Vehicle Administrative Processes** service will allow carriers to purchase credentials and to collect and report fuel and mileage tax information electronically. Through automation, this service should provide to carriers and States a significant reduction in the paperwork burden and has the potential for simplifying compliance operations.

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

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

These six user services do not necessarily represent the final or complete set of new services that ITS will offer CVO. The Commercial Vehicle Information Systems Network effort, undertaken by the ITS America CVO Subcommittee with support from Johns Hopkins

University Applied Physical Laboratory, along with market assessment studies will identify other services and concepts that may extend these core services and support the ITS Program goals in other ways. Contact ITS America to obtain a draft of the CVO principles, concepts and architecture.

5.0.2 Integration of CVO User Services

Information systems for the foundation for all of the CVO user services. Each service will require some data on the motor carrier, the vehicle, the driver and, in some cases, the cargo. Consequently, an interoperable information network providing data access is fundamental to the CVO user services and program. This network will provide the link between existing and future databases and systems which hold the necessary information. States and motor carriers will have access to this network nationwide, with eventual access available throughout North America.

The CVO user services are interrelated in terms of the specific types and uses of data required. Commercial Vehicle Electronic Clearance will require information on safety (e.g., carrier safety fitness rating, vehicle out-of-service, driver license record), credentials (e.g., vehicle registration, fuel-use tax, operating authority, oversize/overweight permits), and size & weight (e.g. legal size and weight limits). The safety information used in Electronic Clearance would be updated from the roadside by the Automated Roadside Safety Inspection and On-board Safety Monitoring services through SAFETYNET (SAFETYNET is an information system used by the FHWA and States to store and access inspection records). Similarly, a subset of the motor carrier credentials information that is collected, stored, and updated in the Commercial Vehicle Administrative Processes service will be used in the credential component of Electronic Clearance.

The Hazardous Materials Incident Response user service would require a much smaller set of safety data related to hazardous materials carriers. This service may not be viable by itself, but as a safety component add-on to a basic information system, supporting Electronic Clearance or a carrier's existing freight mobility system, benefits could be achieved at minimal costs. Carriers that use technology for freight mobility will be able to tie their existing systems into the CVO information network when it becomes available.

5.0.3 Safety in the CVO user services

Improving safety is a high priority goal of the CVO program. Four of the CVO user services focus on safety improvements: Electronic Clearance, Automated Roadside Safety Inspection, On-board Safety Monitoring, and Hazardous Materials Incident Response.

In the Electronic Clearance user service, enforcement officials will initially be provided with historical safety data on the carrier and the current safety inspection status of the vehicle and driver to assist in their decision to bypass or stop a particular vehicle and driver for an inspection. Once the decision to inspect a vehicle has been made, the safety technologies under the Automated Roadside Safety Inspection would be applied with the intent of reducing the total inspection time. These technologies would support automated methods for quickly checking brakes, lights, and other systems that do not require an inspector to go under or into the vehicle. As these roadside-based advanced safety checking technologies continue to develop, technologies for the On-board Safety Monitoring service that are vehicle-based or involve on-board systems diagnostics (e.g., oil pressure levels, driver alertness) will mature. Eventual integration of on-board safety diagnostic systems into the Electronic Clearance and Automated Roadside Safety Inspection user services is a long-term goal. Hazardous Materials Incident Response, as stated earlier, would be a cost-effective add-on to a basic information system, Electronic Clearance or a carrier's existing freight mobility system, for interested HM motor carriers.

5.0.4 CVO System Design

Given the number of CVO services which have national implications and are functionally interrelated, there is the need to establish an overall system design for the development and deployment of the CVO User Services. This design effort in the near-term is part of the overall ITS architecture effort, but is on a faster track because of the unique position in the CVO area to offer early successes and meet: 1) a Congressional deadline of equipping 100 roadside safety inspection sites with technology to allow access to carrier safety data and driver license status nationwide by 1996 and 2) a U.S. DOT deadline of designing and implementing an information infrastructure for nationwide Electronic Clearance by 1997.

This near-term CVO system design effort is working in concert with the larger overall ITS architecture effort, which anticipates preliminary designs by 1996, to minimize any duplication of effort and ensure CVO compatibility throughout ITS.

The FHWA, States, motor carriers, national laboratories, and private industries are in the process of determining the functional requirements of the CVO services, developing and assessing alternate designs, and recommending the appropriate design framework for the CVO services. At the same time, a system design for the Safety and Fitness Electronic Record System (SAFER) is being developed. This system is intended to provide historical safety information about carriers to enforcement officials at weigh stations and other enforcement facilities and will be the foundation for the carrier safety component of the Electronic Clearance service.

A related effort, the Commercial Vehicle Information System (CVIS) will test the feasibility of checking a carrier's safety fitness rating at the time of vehicle registration. If results of the study are positive, the CVIS would then be integrated with other current and planned CVO safety activities.

The SAFER and CVIS will be designed in concert with the overall CVO system design. A national prototype will then be designed, with the input from the CVO stakeholders--the States, the motor carrier industry, the FHWA, the major CVO projects/initiatives, the CVO consortia, and other relevant organizations, for the Electronic Clearance service based on the selected design. This prototype will become the basis of an operational test.

States, carriers, and others interested in deployment of various services will be identified and recruited to participate in the system design of Electronic Clearance and other services, in preparation for deployment and operational testing of prototype systems.

5.0.5 Goals and **Objectives of CVO User Services**

The six CVO user services address a number of ITS goals and objectives. Some of these services have narrow focus; others potentially have wide implications. These User Services are expected to change and evolve to reflect increased input from stakeholders in the COV community, and to keep pace with the dynamic CVO community.

- Improved Highway Safety - Four of the CVO user services will impact the goal of improving safety. Commercial Vehicle Electronic Clearance, Automated Roadside Safety Inspection, and On-Board Safety Monitoring reduce the frequency of accidents. Hazardous Materials Incident Response will reduce the severity of accidents.

- Improve Service Level - Three of the CVO user services will impact the goal of improving service level. Commercial Vehicle Electronic Clearance will increase the vehicle capacity of highways. Hazardous Materials Incident Response will reduce congestion due to incidents. Freight Mobility will increase capacity of the transportation system, reduce congestion due to accidents, and improve transportation customer service.

- Reduced Energy and Environmental Impact -Four of the CVO user services will impact the goals of reduced energy and environmental impacts. Commercial Vehicle Electronic Clearance and Freight Mobility will reduce harmful emissions per unit of travel, reduce energy consumption per unit of travel and reduce new right-of-way requirements. Automated Roadside Safety Inspections will also reduce harmful emissions per unit of travel.

- Enhance Productivity - Five of the CVO user services will impact the goal of Enhanced Productivity. Automated Roadside Safety Inspections, Commercial Vehicle Electronic Clearance, and Freight Mobility will reduce costs incurred to fleet managers, operating agencies, and others in regulating vehicles, as well as reduce travel times. Commercial Vehicle Electronic Clearance will reduce cost of regulation, reduce travel times, and improve transportation system management and planning. Commercial Vehicle Administrative Processes will reduce costs incurred to fleet managers.

- Improve Mobility - Only two CVO user services will impact the goal of Improved Mobility. Both Commercial Vehicle Electronic Clearance and Freight Mobility will reduce travel stress.

5.0.6 Cross-cutting Issues

Before the CVO services can be fully deployed, technical, legal, and institutional issues need to be resolved. The CVO system design effort will provide a broad set of user requirements and systems development for the CVO user services. However, in the implementation of the CVO user services, specific operational issues will need to be further refined and resolved by all participants. These issues, which apply to each of the CVO services, include: standards, privacy and security issues, potential cost and benefits, institutional issues, operations and maintenance responsibilities, education and training programs, and intermodal applications in ITS/CVO

5.0.6.1 Standards

The ITS America CVO Architecture & Standards Subcommittee was formed to address the area of standards. This group is made up of CVO stakeholders who are committed to identifying standards which will allow a bus or truck to travel throughout the U.S., Mexico and Canada with full interoperatbility. The subcommittee is also addressing the intermodal aspects of these standards as well as electronic payment compatibility. The FHWA fully recognizes the importance of having national and international standards for hardware, communications, and procedures established in the ITS/CVO program and is diligently working in concert with ITS America in this area. The standards being developed will be driven by the requirements of the users (States, carriers, others) and should follow an open-architecture approach. However, the key to a national system is, and must always be, interoperability. Future infrastructures should complement existing infrastructure and on-board systems to the full extent possible.

5.0.6.2 Privacy and Security Issues

The security and privacy of data is a major concern to the States and the motor carrier industry. The removal of institutional barriers without compromising the privacy and security of the driver, carrier, or State is imperative to the successful deployment of the CVO user services. Participation in the CVO program is voluntary and the goals of these user services are to increase highway safety and State and motor carrier productivity. Therefore, the FHWA, State agencies, carriers, and other relevant parties will need to work together to reach agreement on these issues.

5.0.6.3 Potential Costs and Benefits

Exact costs and benefits of these user services have been only broadly quantified in the past. Assumptions about benefits at reasonable costs can be made for activities that streamline State and industry practices through the application of advanced computer and communication technologies. Costs and benefits listed in the user service descriptions are estimates of the actual costs and benefits that will accrue as the services are implemented. These estimates will become more defined with the completion of more operational tests, pilot projects, and deployment.

5.0.6.4 Institutional Issues

Institutional issues are non-technical barriers to CVO productivity that exist between internal and external State agencies, between States, between public and private sector agencies in deployment partnerships, and between States and carriers in terms of regulatory requirements (registration, fuel use tax reporting, operating authority, etc.). Since the ITS/CVO program is a voluntary program based on public/private partnerships, it is imperative that the participants -- States, carriers, and service providers -- work together and reach agreement on a set of specific uniform policies and procedures associated with deploying and maintaining cost-effective CVO services. Uniformity among the stakeholders will lay the foundation on which advanced technologies can be applied. The first steps were taken in this area in September of 1991. The FHWA offered States up to $50,000 each to establish a multi-agency working groups to identify and study the institutional impediments to deploying CVO systems within their borders. Forty-nine States either individually or jointly responded to this offer. These studies brought together, in a unique forum, all parties involved in the regulation, taxation or enforcement of motor carriers. The discussions among the States, motor carriers, and other relevant organizations were very successful in identifying a number of CVO-related activities that will improve both State and carrier operations.

Due to the successful results achieved in this first round, the FHWA has sponsored a second round of State-led institutional issue studies that are focussed on the deployment of CVO technologies. This effort, beginning in late 1994, will further define performance and technical requirements for regional electronic data sharing among internal and external state agencies and the motor carrier industry. Projects include the development and support for regional automated truck weigh station clearance systems and remote electronic transaction systems for purchasing carrier credentials and reporting mileage data for tax purposes.

Cooperation between state and industry partners present in the consortia is the foundation on which ITS/CVO technology deployments can be applied. One of the initial studies concluded, “Technology will fail without sufficient parallel investment in institutional arrangements.”

5.0.6.5 Funding; for Operation and Maintenance

Funding for operation and maintenance of deployed ITS/CVO systems is a major issue facing States in the ITS/CVO program. To date, ITS/CVO funds, authorized by the Intermodal Surface Transportation Efficiency Act of 1991, have been used only for research, institutional issues, pre-deployment, and testing of emerging technologies. The use of Federal-aid funds and the development of public/private partnerships for operations and maintenance of ITS/CVO systems are two avenues of funding which need to be explored. The key to this issue is, however, to eventually establish self-sustaining ongoing operations of the ITS/CVO program.

5.0.6.6 Outreach

The education and training of State and industry users of CVO technologies is critical to successful long-term deployments. The ITS America CVO Outreach Subcommittee will act as an outreach mechanism to address the informational and educational needs of the trucking and bus communities, the governmental/regulatory communities as well as the general public. The FHWA, while working closely with the CVO Outreach Subcommittee, is also committeed to the important areas of education and training. The FHWA ITS/CVO team, working closely with ITS/America, has developed an outreach strategic plan that includes training courses, speaker bureaus, and outreach materials for State regulatory officials and carrier representatives. Education and training will be a continual process throughout the life of the ITS/CVO program.

5.0.6.7 Intermodalism

Intermodal issues are another area of opportunity in the area of Commercial Vehicle Operations. The development of a national ITS architecture will ensure that systems for identifying cargo in commercial motor vehicle, air, rail, and marine transportation are compatible. The Freight Mobility service will provide communication links among operators of motor vehicle, rail, air, and marine. The goals of these efforts in the CVO area are to achieve a seamless system for the transportation of cargo between various modes of transportation and to support just-in-time operations.

5.0.6.8 Reevaluation and Assessment of Current Operations

The aim of the systems described in the CVO user services is to use available technology in the short-term (5-7 years) to streamline current state and motor carrier operations for safer and more productive highways. They automate time-consuming procedures and requirements, which have been out paced by growth and changes of the motor carrier industry as well as increasing demands on public agencies' budgets. In some cases, the user services call for a new way of doing business.

As the development of the CVO user services proceeds, the CVO stakeholders (states, carriers, project consortia, and other relevant organizations) will look to focus technology toward the goal of developing a current procedure, rather than merely automating existing procedures. As an example, future weight compliance strategies could still have some fixed facilities, but a greater focus might be given to mobile weight enforcement activities and even on-board weighing systems checked at highway speeds. The Commercial Vehicle Information Systems Network (CVISN) is an ongoing effort to develop a long-term vision for commercial vehicle information systems, which will lead to the development of a CVISN architeture.

5.0.7 Milestones and Activities

The research and testing activities leading to deployment of the CVO user services are broadly described and graphically depicted in the Gantt charts in Figures 5.0-l and the technology development timeline chart in Figure 5.0-2.

Definition of CVO terms:

AP	Administrative Processes
ARSI	Automated Roadside Safety Inspection
CDLIS	Commercial Driver License Information System
SAFER	Safety and Fitness Electronic Records System
EC	Electronic Clearance
FM	Freight Mobility
HMIR	Hazardous Materials Incident Response
MCSAP	Motor Carrier Safety Assistance Program
OBSM	On-board Safety Monitoring
CVIS	Commercial Vehicle Information System
DVIS	Driver Vehicle Information System

5.0.7.1 Activities

1. **CVO System Design, Development of Scenarios, Cost/Benefit Analysis (current - 3/95)** This activity includes examining the institutional and technical needs of each of the CVO user services, determining possible solutions for electronic data interchange, and examining the cost-effectiveness of possible scenarios.

2. **SAFER: System Design (current -** 10/95) The Safety and Fitness Electronic Records System (SAFER) will provide the roadside inspectors access to historical carrier safety data and create an algorithm by which carriers can be selected for inspection. This activity is being conducted in cooperation with the CVO system design and scenario development effort.

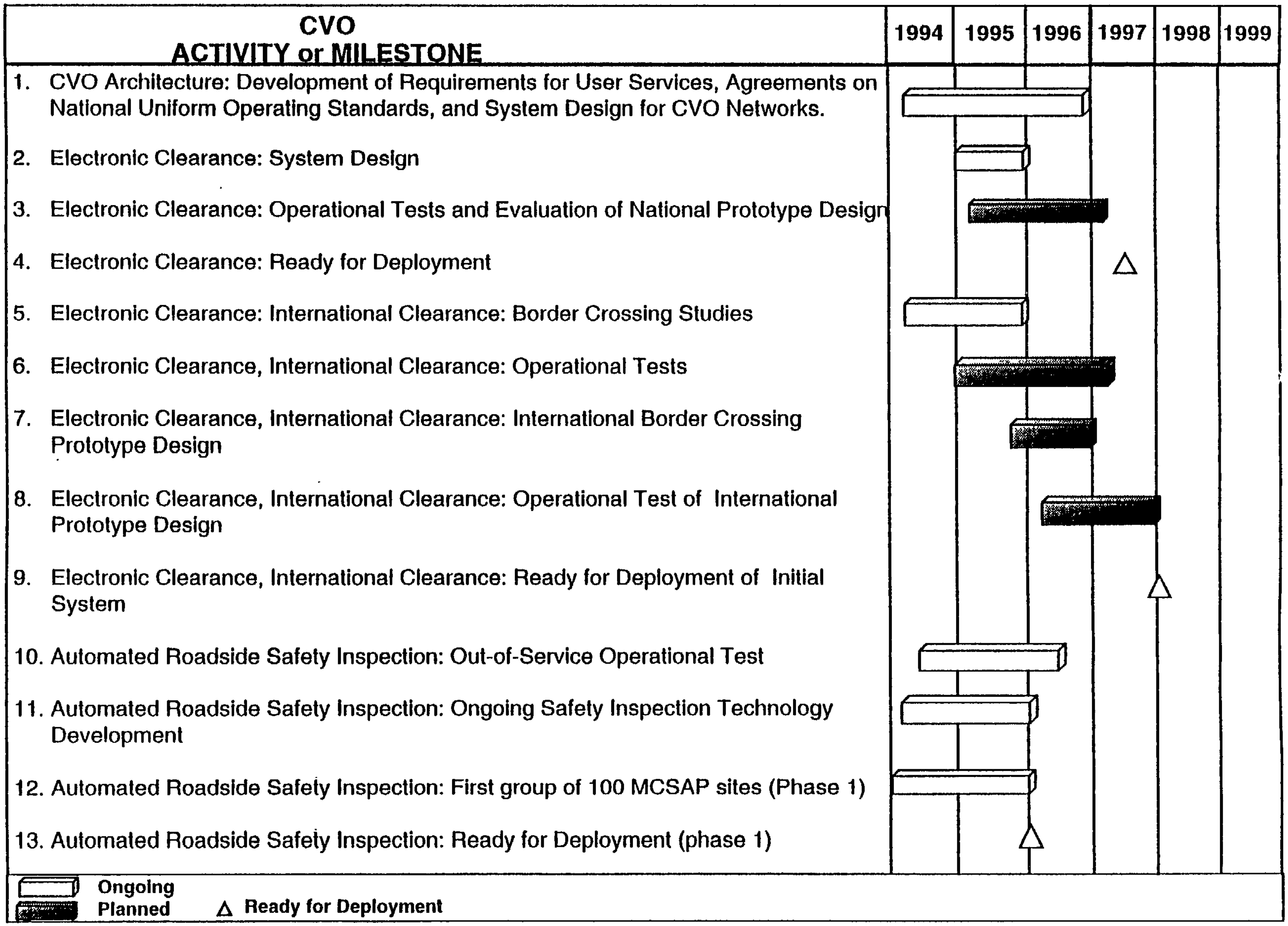

Figure 5.0-1 CVO Activities

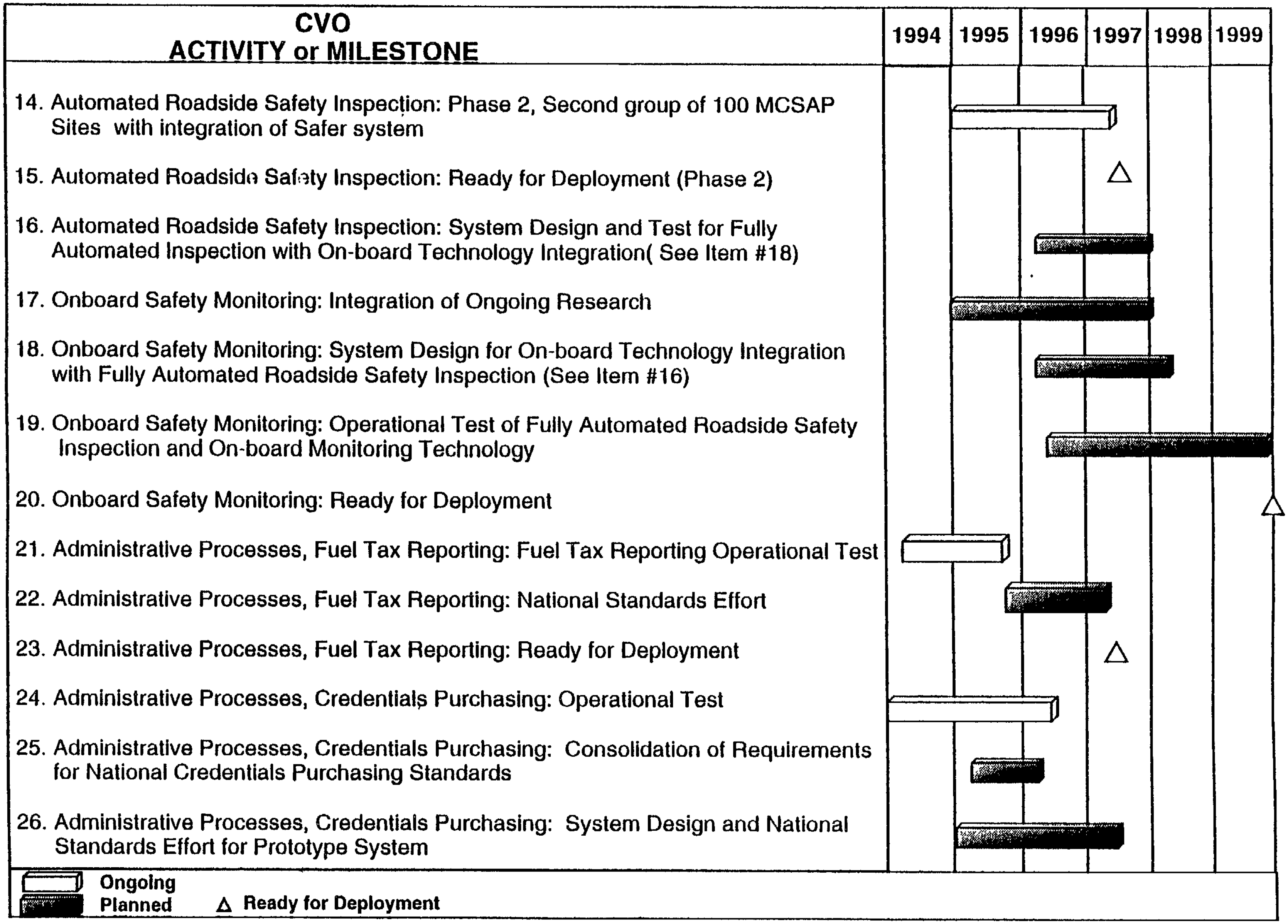

Figure 5.0-1CVO Activities (continued)

CVO ACTIVITY or MILESTONE	1994	1995	1996	1997	1998	1999
27. Administrative Processes, Credentials Purchasing: Ready for Deployment				△		
28. Administrative Processes, Compliance Review: Automated Compliance Review Feasibility Study	Ongoing	Ongoing				
29. Administrative Processes, Automated Compliance Review: Design and Test the ACRP Prototype			Planned			
30. Administrative Processes, Automated Compliance Review: Ready for Deployment				△		
31. Hazardous Materials Incident Response: Research Activities	Ongoing					
32. Hazardous Materials Incident Response: Operational Test of System Prototype		Planned	Planned			
33. Hazardous Materials Incident Response: Ready for Deployment				△		
34. Freight Mobility: Federal Role Study	Ongoing	Ongoing				
35. Freight Mobility: System Design with Integration of Intermodal Issues		Planned	Planned			
36. Freight Mobility: Operational Test			Planned	Planned		
37. Freight Mobility: National Standards Effort including Uniform Manifest		Planned	Planned	Planned		
38. Freight Mobility: Standards Effort Ready for Deployment				△		

Ongoing
Planned
△ Ready for Deployment

Figure 5.0-1CVO Activities (continued)

3. **100 MCSAP Sites: Operational Test Integrating SAFER and CDLIS (3/95 - 3/97)** A group of States will pilot test and evaluate accessing carrier data from the SAFER system and the Commercial Driver License Information System (CDLIS) at 100 MCSAP sites. (The Motor Carrier Safety Assistance Program (MCSAP) is a Federal grant program that provides over $65 million annually to States to monitor vehicle and driver safety programs and review of safety activities at carrier offices.)

4. **EC: System Design (l/95 - l/96)** This activity is being conducted in conjunction with the CVO system design and scenario development. Current regional and local clearance systems will be examined and a detailed design for a national prototype of the electronic clearance system will be produced.

5. **EC: Operational Test of Initial System (3/96** - 3/97) A partnership of States and interested parties will test and evaluate an initial national prototype for electronic clearance. It is possible that groups such as HELP, Inc., ADVANTAGE I-75, PASS, regional multi-State consortia, and others will conduct this test.

6. **EC: Initial System Ready for Deployment (12/97)** An initial national prototype for electronic clearance will be ready for wide scale deployment after this date.

7. **EC, International Clearance: Border Crossing Studies (cm-rent - 12/95)** Several studies are being conducted to determine the applicability of ITS technologies to enhance international border crossing by commercial and private vehicles.

8. **EC, International Clearance: Operational Tests (l/95 - l/97)** A partnership of United States, Canadian, and Mexican border States or Provinces, carriers, Customs and Immigration agencies, and other interested parties will conduct this activity to test and evaluate technology applications recommended by the studies conducted in Activity 7.

9. **EC, International Clearance: International Electmnic Clearance Prototype Design (l/96 - l/97)** Following the operational tests in Activity 8, a prototype for an international clearance system will be developed.

10. **EC, International Clearance: Operational Test of International Electronic Clearance Prototype (12/97 -** 12/98) The prototype system design created in Activity 9 will be tested by a partnership of United States, Canadian, and Mexican border States or Provinces, carriers, and Customs agencies.

11. **EC, International Clearance: Ready for Deployment (12/98)** The prototype system tested in Activity 10 will be ready for wide scale deployment after this date.

12. **ARSI: Out-of-Service (OOs) Verification Operational Test (6/94 -** 6/96) This activity will test and evaluate a wide variety of technologies that will be used for OOs verification, including analyses of RF "tags" and automated license plate readers called "visual imaging."

13. **ARSI: Ongoing Safety Inspection Technology Development (current -** l/96) This activity is currently being conducted by States and other groups. This activity includes brake inspection technologies such as accelerometers, dynamometers, infra-red, torque, and other technologies that are currently being tested.

14. **ARSI: Selection and Integration of Advanced Inspection Technologies (l/96 - 7/96)** The inspection technologies being developed and tested in Activity 13 will be examined in this activity. Technologies will then be selected and combined to design a state-of-the-art inspection facility.

15. **ARSI: Operational Test of Integrated Inspection System (7/96 -** 7/98) The state-of-the-art inspection facility design created in Activity 14 will be tested in this activity by a partnership of States and interested parties.

16. **ARSI: System Design for Fully Automated Inspection with On-board Technology Integration (3/96 -** 3/98) This activity will consist of long range research in order to create a conceptual design for a fully automated roadside inspection facility which will include the integration of off-the-shelf on-board safety monitoring technologies. This activity will be coordinated directly with Activity 18.

17. **OBSM: Integration of Ongoing Research (l/95 -** l/97) This activity will integrate ongoing research in the area of human factors, driver fatigue, and fitness-for-duty.

18. **OBSM: System Design for On-board Technology Integration with Fully Automated Roadside** Safety **Inspection (3/96 -** 3/98) This activity will create a design for on-board safety diagnostics, using the results of Activity 17 and including the integration of a fully automated roadside inspection facility. This activity will be conducted in conjunction with Activity 16.

19. **OBSM: Operational Test of Fully Automated Roadside Safety Inspection and On-board Monitoring Technology (6/96 -** 3/00 A prototype operational test will be performed by pilot States and other relevant groups. The test will cover the integrated system designs created in Activity 16 and Activity 18.

20. **AP, Fuel Tax Reporting: Fuel Tax Reporting Operational Test (3/94 -** 9/95) This test will examine current methods of mileage data collection for the purposes of fuel tax reporting and auditing. This test will also examine the feasibility of an automated fuel

tax reporting system.

21. **AP, Fuel Tax Reporting: National Standards Effort (9/95 -** 3/97) Assuming positive cost/benefit results from the completion of the automated fuel tax reporting test, the next logical step would be for State members of the International Fuel Tax Agreement (IFTA) and the International Registration Plan (IRP), with the guidance of the FHWA, the motor carrier industry, service providers, and any other affected parties, to establish national standards, in terms of equipment, procedures, and personnel training, for mileage data collection and fuel tax reporting.

22. **AP, Credentials Purchasing: Operational Test for Electronic Purchase (6/94 - 6/96)** Operational tests for electronic credentials purchasing will be conducted by regional multi-State consortia.

23. **AP, Credentials Purchasing: Consolidation of Requirements for National Credentials Purchasing Standards (3/95 -** 3/96) This activity will examine the operational tests in Activity 22 and the results of other studies conducted to identify and classify motor carrier regulatory requirements. Using these results and recommendations, the next logical step would be for the State members of IFTA and IRP, with the guidance of the FHWA, the motor carrier industry, service providers, and any other affected parties, to consolidate the requirements for a national electronic credentials purchasing standard.

24. **AP, Credentials Purchasing: Development of Prototype System (l/95 -** l/96) Using the requirements determined in Activity 23, the FHWA, with the input of States and industry, will develop a system design for a national electronic credentials purchasing prototype.

25. **AP, Credentials Purchasing: Operational Test of Prototype System (3/96 - 3/98)** An operational test for the prototype system for electronic purchase of credentials designed in Activity 24 will be performed by pilot States and participating motor carriers.

26. **AP, Credentials Purchasing: National Standards Effort (9/96 - 6/98)** The FHWA, with the input of States and industry (motor carriers, vendors, compliance service providers), will establish national standards for the electronic purchasing of credentials.

27. **HMIR: Operational Test (l/95 -** l/97) This activity will use the recommendations of previous studies and the Transportation Research Board Special Report 239 as a baseline in its research. Following the identification and evaluation of the cost-effectiveness of alternative designs, a prototype system for Hazardous Materials Incident Response will be developed. This system will be tested and evaluated by a group of pilot States and other interested parties.

28. **FM: Federal Role Study (current -** 6/95) This study is being conducted to determine the

Federal role, if any, in the area of freight mobility, which includes the examination of intermodal applications in ITS. The completion of the following activities will be determined by the result of this study.

29. **FM: System Design (6/95 -** 6/96) A system design for freight mobility ITS applications in which there is a Federal role will be developed, integrating capabilities of the Route Guidance user service and others in the area of Travel and Traffic Management as needed. This activity is dependent on the results of Activity 28, the identification of a Federal role in freight mobility in ITS.

30. **FM: Operational Test (6/96 -** 12/97) This activity will test the system developed in Activity 29. This activity is dependent on the results of Activity 28, the identification of a Federal role in freight mobility in ITS.

31. **FM: National Standards Effort (6/95 -** 6/97) The FHWA, with the input of states and the motor carrier industry, will establish national standards in the area of freight mobility. This activity is dependent on the results of Activity 28, the identification of a Federal role in freight mobility in ITS.

5.1 COMMERCIAL VEHICLE ELECTRONIC CLEARANCE

5.1.1 Introduction

The Commercial Vehicle Electronic Clearance User Service consists of two parts:

- Domestic Electronic Clearance
- International Electronic Clearance

Today, commercial trucks and buses are required to stop at check points where they undergo routine weight, credential, and safety checks. For lengthy trips, the vehicles may be required to stop and undergo similar checks a number of times. Domestic Electronic Clearance will allow commercial vehicles, whether operating under interstate or intrastate registration, to continue past the check points at mainline speeds without stopping. International Electronic Clearance will allow vehicles to pass international border checkpoints without stopping, or at least with expedited checks. Both parts will operate using Vehicle to Roadside Communication (VRC). As a vehicle approaches a domestic or international checkpoint, communications take place that identify the vehicle and make available to authorities the necessary data about credentials, vehicle weight, safety status, and cargo. Enforcement personnel can then select potentially unsafe vehicles for inspection and allow safe and legal vehicles to bypass the checkpoint.

The top priority of the Commercial Vehicle Operations (CVO) user services of the Intelligent Transportation Systems (ITS) program is for commercial vehicles, much like automobile traffic, to travel over the Nation's highways without having to stop in each State for weight, credential, or safety inspections. The challenge that faces CVO is to enhance the information available to officials at check points so they may clear vehicles or have them stop so specific items can be checked. The information used for clearance may be on the vehicle itself and/or in centralized or distributed databases. Regardless, this information exchange would be transparent to the users through advanced information systems and ITS technologies. The information used for electronic clearance will probably include the following:

- High-speed weigh-in-motion (HSWIM) system data to screen vehicle weight compliance;

- Motor Carriers' safety fitness ratings, including "Premier Carrier" status (the Premier Carrier Program is an ongoing effort of the Federal Highway Administration (FHWA) which is investigating the concept of allowing carriers with excellent safety records to bypass inspection stations. This would not preempt random checks of a participating driver, vehicle, or carrier);

- Vehicle/driver inspection and maintenance data, including date of last inspection and out-of-service verification;

- Credentials information, including annual registration, fuel use tax, operating authority, insurance, oversize/overweight permits; and
- Driver information, such as citation records.

As the capabilities of the Automated Roadside Safety Inspection and On-board Monitoring user services develop, the vehicle diagnostics, sensors, and real-time information will be integrated to supplement the historic information listed above. These sensor capabilities will become more and more sophisticated, from conducting advanced mechanical checks of the vehicle to assessing fitness of the operator by, for example, sensing driver alertness.

The International Electronic Clearance component will extend the Electronic Clearance concept to the Mexican and Canadian borders and support the North American Free Trade Agreement (NAFTA) by facilitating the traffic flow of safe and legal carriers across international borders. The service will also have to address specialized enforcement and cargo issues associated with crossing national borders.

5.1.2 Needs

The Domestic Electronic Clearance component is needed primarily by States and carriers. Manually inspecting commercial vehicles to collect information on the driver and vehicle regarding weight, credentials, and safety status is labor intensive, but necessary to ensure safe, legal, and equitable transportation services, and to collect the revenue necessary to build and maintain highways. Through the electronic screening of commercial vehicles prior to reaching a weigh station or inspection facility, States' resources would be used more effectively by selecting only those vehicles that warrant safety and compliance checking. Thus, electronic clearance will allow recently checked safe, legal vehicles to bypass these facilities. Motor carriers that are safe and legal will have reductions in operational costs from this component by avoiding the time delays of manual compliance and safety checks. The States and carriers will also benefit from reducing the paperwork burden through automation.

Commercial truck and passenger transportation represents a vital link in the Nation's commerce. Currently, there are significant delays for auto and truck drivers crossing between the U.S. and both Canada and Mexico. While this poses an inconvenience for the occasional crossing, it creates a significant economic hardship for commercial carriers and drivers that regularly traverse these boundaries. With the passage of the NAFTA, the U.S. DOT recognizes that this problem is likely to be worsened because it is expected to increase the flow of commercial vehicles across both borders. The U.S. DOT is committed to provide a more efficient traffic flow, meeting the needs of the users associated with the NAFTA through ITS/CVO technology. The International Electronic Clearance component will help provide relief to these problems by enabling border crossing officials to target their enforcement resources more effectively and allowing carriers to increase their productivity.

5.1.3 Service Description

The vehicles in the Electronic Clearance service will be equipped with a transponder that will carry their unique identification code (and possibly some information about the carrier, vehicle, and/or driver) and be able to receive and send information to and from the roadside readers. Participation in the Electronic Clearance service will be voluntary for both carriers and States. Motor carriers that choose to participate in the Electronic Clearance service, and that are willing to go through an application process to certify that they have met both safety and legal requirements will be able to take advantage of significant savings by passing checkpoints, ports-of-entry, weigh stations, etc., at mainline speeds, thereby reducing regulatory impediments for safe, legal trucking operations. The system should accommodate both interstate and intrastate carriers. Less information may be required for intrastate carriers than interstate carriers, but they will still need to prove that their vehicles, drivers, and operations are safe and legal. The States will get maximum benefits from the system if the proper controls, procedures, and technologies are in place to facilitate the electronic exchange of information that is currently exchanged in paper form today.

The International Electronic Clearance component is specifically aimed at facilitating cross-border commercial vehicle traffic. Its purpose is to extend the service and technologies for Domestic Electronic Clearance at State borders to North American border crossings. This component, as envisioned, would allow automated clearance of cargo from frequent and known cross-border shippers through customs and automated immigration clearance of the driver. This would likely involve the development of electronic credentials and records that could be used to automatically verify the identity of the driver, the shipper, and the nature of the cargo, check carrier safety and credential records, etc.

The development and deployment of this service, while based on advanced technologies, will be dependent on a number of legal, technical, and institutional issues. These issues can be resolved through cooperation among U.S. DOT, States, carriers, shippers, and other relevant parties. Market analysis and outreach programs will be implemented to determine the institutional barriers and possible solutions. Continuing participation in these multi-agency efforts by representatives from U.S. DOT, States, carriers, shippers, and private investment firms will be necessary to reach resolution. Automating the international border crossing process will require the involvement and cooperation of the immigration and customs organizations of all three countries as well as shippers, carriers, local officials from the border States and provinces, and other relevant parties. While the general framework for this concept might be the same at either border, specific system designs will have to be developed and tested to accommodate the variations in border crossings, laws, and language.

5.1.4 Operational Concepts

When a participating carrier with a transponder-equipped vehicle approaches a mobile or fixed checkpoint site, it will cross a reader and HSWIM sensors upstream of the facility. The vehicle will be identified, classified and weighed. This information will be sent, via communication link, to the checkpoint.

The system will then check the weight, credential, and safety information by reading the information from a transponder on the vehicle or by using the vehicle's unique identification code to access the information. Examples of such information may include: weight information (thresholds for gross vehicle weight, axle weight, and actual weight versus registered weight), credentials information (registration to operate in the State, fuel tax payment, delinquent payment flags, etc.), and safety information (fitness rating, date of last check, and out-of-service violations). If any of the information warrants being checked, the vehicle will be signaled to pull into the checkpoint. The system will then alert the official as to the reason the vehicle was pulled in so that the vehicle check can be focused on the specific problem area.

If the information indicates safety and regulatory compliance, but the vehicle is selected for a random check, the vehicle will be signaled to pull into the checkpoint and the official will be notified. If the facility is closed or at capacity, the system will be overridden and the vehicle will continue uninterrupted. If the vehicle is stopped and checked, the information will be updated as to the last inspection date, any out-of-service violation, etc.

5.1.5 Technologies

The implementation of Commercial Vehicle Electronic Clearance requires the use of several technologies that support the electronic exchange of safety, credentials, and weight information.

Identification of the vehicle as it passes a checkpoint at mainline speed is key to the idea of electronic clearance. This will likely require a transponder on the vehicle with, at minimum, a unique identification code that can be used as a search key in the information system. A reader will be placed upstream of the facility to read the transponder as it passes and send the information to the checkpoint. This will require both hardware (reader and on-site computer) and the associated data interchange protocols for the local information exchange. A standard for vehicle to roadside communication is critical to this service.

The on-site computer may be part of a Local Area Network (LAN) supporting several work stations at the facility. It may also be linked to remote information systems to access the necessary historical information on carriers and vehicles.

National, regional and/or State information systems will provide the necessary safety and credentials information on the participating carriers. Linking these systems with the checkpoints will also require a standard protocol for data linkage and exchange and will likely exploit the latest in open system networking.

To screen vehicles for weight compliance at mainline speed, weigh-in-motion sensors will be installed in the pavement. Also, in order to obtain bridge formula compliance, Automatic Vehicle Classification (AVC) is needed.

5.1.6 Potential Costs and Benefits

Development costs associated with Electronic Clearance include hardware design; software design, development and testing; and institutional expenses for various organizations **to** support the effort. National, regional, and/or State databases may have to be developed and maintained, either publicly or privately, to contain the credentials and safety information associated with participating carriers. Communication links will have to be established between these host databases and all remote users. Requirements for the system have not been drafted and, therefore, the costs are highly speculative.

Current cost per site for full installation of high-speed weigh-in-motion equipment, Automated Vehicle Identification (AVI), AVC, vehicle signaling equipment and pavement rehabilitation/reconstruction, is in the range of $300,000 to $500,000. The majority of this cost is in the reconditioning of the pavement to enhance the accuracy of the Weigh-in-Motion (WIM) system.

The cost of a transponder for the vehicle is less than $50.

Benefits of implementing this technology include increased carrier productivity and greater safety due to targeted checks of higher-risk carriers, vehicles, and drivers. Elimination or reduction in transportation delays boosts efficiency for shippers, enhances just-in-time inventory systems for manufacturing, and also reduces costs of delivery, which may reduce costs to consumers in a competitive environment. The public, States, and carriers may benefit from better roads and ride quality because of better weight enforcement and 24-hour mainline monitoring. Another benefit is the automation of tasks currently performed manually, allowing enforcement personnel to concentrate on other important tasks.

Electronic clearance, providing mainline bypass of weigh stations, will reduce safety hazards caused by commercial vehicles exiting and reentering the main flow of traffic because of static weight checks. Other important benefits include decreased fuel consumption and emissions from vehicles in queues.

An electronic system also provides better highway traffic data collection than manual systems. It gives an accurate reflection of the traffic stream, including weight, volume, and time of day data. This data, collected around the clock, is not limited to fixed positions and lends itself easily to creating custom reports.

Implementation of this technology also enhances enforcement by automating clearance for participating carriers and reducing the number of trucks that must be manually cleared, assuming substantial market penetration, A smaller population leads to a greater percentage of vehicles that can be checked with existing resources, generating improved compliance levels. Improved compliance helps to level the playing field by assuring that all carriers have proper credentials, maintain their vehicles properly, pay the proper amount of fuel tax, etc. Improved safety compliance will also contribute to lowering the number of accidents and breakdowns in which commercial vehicles are involved.

No cost estimates have been made for the International Electronic Clearance component. It is presumed that the potential cost per vehicle would likely range from several hundred to a few thousand dollars, depending on requirements and needs. Also, significant costs are likely to be associated with the establishment and deployment of the Customs and Immigration information systems for carriers, vehicles, drivers, and cargo and the real-time communication networks necessary to allow automated border clearance and possibly high-speed weigh-in-motion.

Significant benefits from the International Electronic Clearance component should be realized by regular international shippers and carriers through reduced down-time at border crossings. Enforcement officials would also realize benefits from reduced manpower costs and more selective (and therefore more effective) enforcement.

5.1.7 Assessment of Roles

5.1.7.1 Potential for Private Investment

The potential for profitable investment in products to support this service appears to be significant for electronic, computer, and services firms, although the market itself may be relatively small and slow to develop. The credentials component of electronic clearance program may require the development of a shared data center/clearinghouse for electronically verifying the credential and safety status of vehicles. This data center/clearinghouse could possibly be developed and managed by private companies. Potential markets also include the development and deployment of products for on-board monitoring and for roadside detection. The demand for HSWIM equipment, transponders, and beacons is expected to be met by existing private suppliers.

5.1.7.2 Public and Private Roles in Deployment

Development of the Electronic Clearance service and associated procedures will be a partnership between the Federal Highway Administration (FHWA), States, industry and others (academia, etc.). The FHWA will work with State DOTS and other agencies, especially State enforcement agencies, in testing and evaluating the use of HSWIM, AVC, AVI and communications in the Electronic Clearance service. The results will be used to develop recommendations and training for the use and maintenance of such systems. It is anticipated that all equipment involved in an installation will be provided by private suppliers through contract processes with States.

Although maintenance and operation of Federal-aid projects historically have been a State activity, there may be segments of these activities that may be more amenable to contract operation by a private firm. Deployment opportunities may exist for private firms (or a consortium) to operate the communications/data system that would link national, regional, State, and local systems. Standards, criteria, and thresholds for this communications/data system would be established by the State and Federal telecommunications and motor carrier safety enforcement communities.

5.1.7.3 U.S. DOT Role in Developing Service

The U.S. DOT will support current and future research, development and testing of electronic clearance programs. It must provide support, oversight, and direction during the testing and evaluation phases of the Electronic Clearance service. The U.S. DOT will play a significant role with other stakeholders in the development of minimal requirements and desirable elements. Technical support will include data processing representatives as well as developers. The FHWA will support testing and integration of promising technologies, such as portable HSWIM weighing systems and on-board diagnostics and sensors. From these activities, a national Electronic Clearance prototype that includes defined minimal requirements and desirable elements can be developed, tested, and evaluated to serve as a guideline to future deployment.

The U.S. DOT also must work with States and industry to refine how the electronic clearance concept will be phased in. This includes issues such as: interstate versus intrastate carrier needs; which credentials need to be checked for electronic clearance of both types of carriers; how and when temporary permits can be phased into the system; and if and when on-board sensor equipment can be phased into the system.

The U.S. DOT will play a major role with other stakeholders in addressing institutional and legal issues that include questions about the security of carriers' proprietary information, driver privacy issues, accuracy of the data, and access rights/tracking. The U.S. DOT will also work with State enforcement agencies to resolve technical and institutional issues related to establishing HSWIM thresholds and other aspects of safety enforcement, especially if a weight tolerance is involved to allow for nationwide, uniform application. The FHWA will work with the American Trucking Associations (ATA), National Private Truck Council (NPTC), and owner-operator organizations to facilitate the acceptance of ITS/CVO technologies by drivers and motor carriers.

The U.S. DOT has a crucial role to play in establishing guidelines for the development of compatible VRC standards and protocols. The functional user requirements developed will need to be facilitated by the proposed architectural design. Human factors issues relating to VRC standards and protocols will also need to be addressed. Ongoing human factors studies fall under the On-board Safety Monitoring User Service and are also discussed in the introduction to the CVO user services.

The U.S. DOT will facilitate deployment with guidelines for mainline HSWIM systems, training information for HSWIM maintenance, and instrumented weigh station design. Likewise, the U.S. DOT will continue to support credential repositories, simplification and uniformity of credentials, and the training and marketing of credential services for States and carriers to expedite deployment. Also, the U.S. DOT, with the help of enforcement associations such as the Commercial Vehicle Safety Alliance (CVSA), will develop outreach materials and activities targeted at all levels of the motor carrier enforcement community.

A period of transition between the current manual system and the new automated system will occur as this user service is implemented. The U.S. DOT will work to keep the redundancy of duplicate systems for checking vehicles at the roadside to a minimum. The U.S. DOT will review funding alternatives and investigate the use of incentives to expedite participation by both States and carriers.

In the case of the International Electronic Clearance component, U.S. DOT will work with Customs, Immigration, and State agencies and industry to apply technologies developed for other ITS applications to streamline the cross-border process and integrate these systems into the overall ITS system design. The U.S. DOT will also support research to achieve compatibility in North American automatic vehicle identification, communications, safety, and credentials.

5.2 AUTOMATED ROADSIDE SAFETY INSPECTION

5.2.1 Introduction

Safety is a special emphasis of CVO program. The Automated Roadside Safety Inspection service is specifically aimed at significantly enhancing the safety of commercial trucking and passenger transportation. Commercial vehicle operations and safety are paramount issues today. Vehicles have gotten larger and more complex, making the inspection task more important and more difficult. Advanced technology offers the potential for providing assistance to the inspector, improving the overall safety and operation of trucks and buses, and making the inspection process more efficient.

The Automated Roadside Safety Inspection service will provide automated inspection capabilities that check safety requirements more quickly and accurately during a safety inspection that is performed when a vehicle has been pulled off the highway at a fixed or mobile inspection site. These capabilities will include the more rapid and accurate inspection of vehicle systems such as brake performance. This service will also include a communications link for updated inspection data, such as out-of-service information, to complement the nationwide availability of CVO information discussed in the Electronic Clearance user service. These new capabilities will enable safety inspectors to check more vehicles that are likely to have safety violations and, thus, increase safety compliance and reduce the number of serious accidents caused by poor commercial vehicle safety.

Several States are beginning projects to test and evaluate innovative devices for vehicle safety performance testing under the Motor Carrier Safety Assistance Program (MCSAP). The Motor Carrier Safety Assistance Program is a Federal grant program that provides over $65 million to States to monitor vehicle and driver safety programs and reviews of safety activities at carrier offices. The technologies being tested include flat plate devices and rolling dynamometers that measure brake performance, some of which also include ways to check steering and vehicle suspension systems performance without having to manually inspect the vehicle. Prototype infrared brake inspection devices are also being tested. In addition, the Sandia National Laboratory is identifying other advanced technologies that can be used to enhance roadside inspections. These devices measure system performance rather than relying on manual measurements of individual components such as push rod travel in brakes. Future generations of these devices might be mounted onboard the vehicle or in the roadway to measure performance at mainline speeds.

The driver’s condition and performance are the most critical elements in the safe operation of any vehicle. It is especially important to CVO given the potential injury and damage resulting from unsafe operation and/or accidents of large commercial vehicles. Driver issues are also the most difficult and complex to address. In addition to the ability to review an operator’s driving history and violations, technologies will emerge to assess the driver’s current performance and alertness. Both on-board sensing devices and driver fatigue issues are discussed further in the On-board Safety Monitoring user service.

5.2.2 Needs

Even though the rate of fatal accidents involving medium to heavy vehicles has fallen from 4.1 per 100 million miles in 1982 to 2.5 in 1992, this rate is still significantly higher than for all vehicles (1.6 per 100 million miles). In terms of losses, it is estimated that these accidents cost carriers, drivers, and the general public billions of dollars annually.

In an effort to reduce commercial vehicle accidents States receive over $65 million a year in Federal MCSAP grants to help support safety inspection activities. The States also spend many times this amount on their own local enforcement activities. Under MCSAP, over 1.6 million State-conducted roadside safety inspections of commercial motor vehicles occur per year. These inspections, however, account for only a small percentage of the vehicles that pass inspection sites yearly. The limited resources of time and space available to State enforcement personnel for inspecting commercial vehicles prevents the inspection of a large percentage of the population of commercial vehicles.

With the implementation of the Automated Roadside Safety Inspection service State enforcement personnel will be able to inspect more vehicles with their resources. Safety information provided by the Electronic Clearance service will enable inspectors to target problem areas during inspections. Advanced inspection technologies will reduce the length of time required to perform an inspection, which will enable enforcement personnel to check a larger percentage of vehicles yearly. These two major benefits will allow State inspection personnel to increase their productivity, which will potentially reduce commercial vehicle accidents.

It is envisioned that the Automated Roadside Safety Inspection technologies will be integrated with On-board Safety Monitoring technologies. On-board technologies may be able to provide real-time safety data presenting a more accurate picture of the safety status of the vehicle and driver and could potentially further increase State inspectors' ability to rapidly and accurately inspect vehicles.

5.2.3 Service Description

The Automated Roadside Safety Inspection service is specifically aimed at significantly enhancing the safety of commercial motor vehicle operations through the development and integration of inspection technologies. These technologies include the inspection of vehicle systems (such as brakes), driver requirements, and ultimately driver alertness and fitness for duty through the use of sensors and diagnostics.

The service expects a phased approach for the development and implementation of these technologies. The first phase of this service will include the use of new brake inspection technologies and the aid of pen-based computers. A later phase of implementation will include integration with the Electronic Clearance and On-board Safety Monitoring user services.

5.2.4 Operational Concepts

After a vehicle has been selected for inspection and signaled to pull into the fixed or mobile inspection site, the inspector will use automated inspection technologies to more accurately and efficiently inspect the vehicle. The use of these technologies will reduce the amount of time spent per inspection and result in a more accurate picture of the safety status of the vehicle.

The automated inspection process will, initially, supplement the visual or manual procedures. It may include advanced flat plates and/or dynamometers to measure brake performance. Ultimately, this service might result in an automated “inspection pit” at the inspection station where all critical vehicle and driver components could be inspected rapidly with hand-held diagnostic devices. This inspection would not only provide pass/fail data but actual condition or expected life projections as well. Many of these technologies and approaches could also be used by carriers in their preventive maintenance operations.

The most effective safety assurance will occur as the Automated Roadside Safety Inspection, Electronic Clearance, and On-board Safety Monitoring user services are integrated. Since the three user services are only partially dependent on each other, a phased integration over an extended period of time is expected to occur. The overall CVO system design address the issues involved in a phased integration of these user services. Also, a strategy needs to be developed for carriers that already have on-board processing capability so that added processing for this service can be integrated with existing capabilities.

5.2.5 Technologies

Alternative approaches exist for providing real-time safety information about carriers, drivers, and vehicles. Although the technology exists to create any of the alternative scenarios, deciding which information and system design will be deployed will be difficult. This decision will have to consider the institutional aspects of operating and maintaining each system as well as the funding sources.

There are several technologies currently available to the States that show promise of addressing the need for fast and accurate brake inspections. The FHWA is currently working with the National Highway Traffic Safety Administration (NHTSA) and several States to evaluate and test devices that show substantial promise of increasing the efficiency of roadside inspections. Devices under consideration include the Vehicle Inspection Trailer (VIT), a portable roller dynamometer, a combination flat-plate brake testing and vehicle weighing device, an infra-red brake testing device, and a torque brake testing device. The FHWA believes that the use of innovative brake testing technologies such as these and others could reduce the time of inspection by as much as two-thirds.

On-board systems that monitor driver and vehicle condition will require examination. The roadside detection of an abnormal safety status indicator on a vehicle traveling at mainline speeds could be accomplished by several different approaches. These approaches will need to be investigated under the ongoing VRC research and development in the Electronic Clearance and On-board Safety Monitoring user services.

5.2.6 Potential Costs And Benefits

5.2.6.1 Potential Costs

The costs for developing a safety database for interstate carriers (only) accessible in real-time is estimated at about $3 million. To add intrastate carrier information will require modifications to SAFETYNET and many State systems and is not included in this $3 million figure. The ongoing cost of operating and maintaining this system will likely exceed $1 million per year.

The cost of roadside access to information varies depending on the implementation approach; one approach would be to assume workstations or processors at a State inspection station share a leased line to a central national facility. The hardware, software, and communication are expected to cost about $5,000 per site initially and $1,000 annually thereafter. The cost of mobile remote access will drive up the communication cost for those installations using this capability.

5.2.6.2 Potential Benefits

The Automated Roadside Safety Inspection user service will potentially reduce commercial vehicle crashes, which could result in millions of dollars in savings to the nation’s carriers and drivers, as well as the general public. Additionally, the per-inspection time saving from this service in individual State inspections will lead to an increase motor carrier productivity and a potential increase in the total number of safety inspections performed by States.

5.2.7 Assessment of Roles

The responsibility for development of ITS services generally resides with the States and private sector. However, the U.S. Department of Transportation (U.S. DOT) will play a significant role along with other stakeholders, e.g., the States, industry, and associations in the development of safety CVO services. This approach, which underlies U.S. DOT's strategy for investment in ITS technologies and systems, is detailed below to assess the appropriate role for U.S. DOT in the Automated Roadside Safety Inspection user service development.

5.2.7.1 Public Benefit

The amount of time a driver would normally spend waiting for a roadside safety inspection will be reduced with the implementation of the Automated Roadside Safety Inspection service. Also, States will be able to check more vehicles, which will result in increased safety compliance and, possibly, fewer accidents. Motor carriers and drivers will be able to increase productivity and possibly reduce losses due to accidents. Safer motor carrier operations will greatly benefit the general public. The annual cost of highway incidents to the general public could possibly be reduced by lowering the number of crashes and breakdowns involving commercial vehicles.

5.2.7.2 Potential for Private Investment in Development

Demand for products responding to this service appears to be significant. The development and operation of roadside inspection equipment could potentially develop into a large market.

5.2.7.3 Public and Private Sector Roles in Deplovment

States, with input from motor carriers, the FHWA, technology suppliers, and others, will have to play a large role in developing and deploying this service. Infrastructure, such as the roadside components, will probably be the responsibility of the States. The public sector will have to establish standards and guidelines to ensure that components can be integrated effectively and that public funds are invested wisely.

5.2.7.4 U.S. DOT Role in Developing Service

U.S. DOT's role in the Automated Roadside Safety Inspection user service will be to build consensus among the various State agencies, industry, and others; to foster the development and testing of promising technologies; and to support deployment of those technologies with a high benefit-cost ratio. The public portion of the service includes the development and testing of the roadside inspection equipment. U.S. DOT will foster the development of guidelines or standards, as appropriate, for interactions among service components and for Federally-funded portions of this service. U.S. DOT will facilitate public/private ventures working toward establishing specifications and standards, including those for universally readable electronic tags or decals. Furthermore, U.S. DOT will work toward removing the institutional barriers to implementing this service.

5.3 ON-BOARD SAFETY MONITORING

5.3.1 Introduction

On-board Safety Monitoring will provide for the ability to sense the safety status of a vehicle, cargo, and the driver at mainline speeds. Driving time and driver alertness are the conditions sensed for the driver. Warnings or indications of the safety status are provided to the driver. This capability may be used for pre- or post-trip inspections by the driver, as well for warnings and indications while underway. Sensing the safety status of the vehicle, cargo, and driver on the vehicle and making provisions for reporting this status to the driver and to sources external to the vehicle will be provided by this service. The capability to read out this safety status at mainline speeds will be provided as part of the Commercial Vehicle Electronic Clearance service. The capability for an enforcement official to read out this safety status at the roadside will be provided as part of the Automated Roadside Safety Inspection service.

A number of potential safety applications of advanced technology have been identified. These include truck and bus specific highway warning systems, vehicle and driver monitoring/inspection systems, and driver sensory enhancements. In order to apply advanced technology practically to the problems of commercial vehicle safety and operation, it is necessary to comprehensively explore various proposed concepts while simultaneously searching out new technology that might be applicable. It will then be possible to determine where cost-effective applications of these technologies can make significant contributions to truck and bus safety and operation.

5.3.2 Needs

On-board safety diagnostic systems for commercial vehicles represent a possible direction for future safety inspection activities. The implementation of these on-board technologies would be market driven and would depend upon the feasibility of such systems. Today, several motor carrier firms use on-board diagnostics that monitor engine and vehicle systems for equipment servicing and maintenance. When on-board sensors detect an irregularity in system functioning, a message is immediately sent from the vehicle to the firm’s headquarters with information about the identity and location of the vehicle as well as the nature of the problem.

The need exists to review the safety inspection process and determine how on-board safety monitoring technologies, if proved practical, can be used in the long term direction of commercial vehicle safety enforcement.

5.3.3 Service Description

The On-board Safety Monitoring service will require (1) Vehicle-to-Roadside Communication (VC) technology as developed in the Commercial Vehicle Electronic Clearance user service, (2) the ability to identify the vehicle and driver and communicate with an on-board computer, and (3) the development and integration of the following safety-oriented functional capabilities:

- Sensing and collecting data on the condition of critical vehicle components such as brakes, tires, and lights and determining thresholds for warning and countermeasures.
- Sensing shifts in cargo as the vehicle is moving and/or other unsafe conditions relating to the cargo.
- Monitoring driving time and time-on-task.
- Monitoring driver alertness level using non-obtrusive technology and developing warning systems for the driver, carrier, and/or enforcement officials.

A warning of unsafe condition would first be provided to the driver. Also, warning information would be accessible by carriers and roadside enforcement officials prior to the vehicle reaching an inspection facility. Roadside safety officials will then have access to both historical data provided by the Safety and Fitness Electronic Records system (SAFER), and real-time safety data to decide if a vehicle, driver, or cargo should be stopped and checked.

5.3.4 Operational Concepts

The operational concepts of On-board Safety Monitoring include:

- Safety warnings to the driver;
- Integrating real-time safety information on the vehicle, driver, and/or cargo with the Electronic Clearance user service; and
- Pre- and post-trip inspections.

Diagnostic and warning systems would alert drivers to pending emergencies, allowing corrective action to be taken. Also, real-time safety data would improve electronic clearance decisions. As a transponder and sensor-equipped vehicle approaches a weigh station or safety inspection station at mainline speeds, roadside sensors would identify the vehicle and driver. The appropriate safety data would be checked as well as transmitted from the on-board system to the roadside for processing automatically by a computer. The computer would recommend to an enforcement official candidate vehicles for inspection. The decision whether to check or allow a vehicle to pass, however, remains with the official.

Current research efforts underway in the FHWA as well as the National Highway Traffic Safety Administration (NHTSA) include studies to investigate commercial vehicle driver fatigue, rest, and recovery. The NHTSA program emphasizes continuous in-vehicle monitoring of driver performance and psychophysiological status to detect driver drowsiness/fatigue. As research is conducted and technology improves, the ability to sense driver and vehicle characteristics will become more accurate and reliable. The ability to accurately detect some unsafe characteristics will develop before the ability to detect others. During this development, security and privacy issues will arise and need to be addressed. As these issues are resolved and reliable methods of detecting different driver and vehicle characteristics are made available, the system architecture should allow for the implementation and integration of On-board Safety Monitoring components.

The technology to provide on-board safety data, as envisioned above, is not yet available. Safety data and advanced roadside inspection technologies as part of Electronic Clearance and Automated Roadside Safety Inspection will be available before on-board systems. The most effective safety assurance will occur if the Automated Roadside Safety Inspections, Commercial Vehicle Electronic Clearance, and On-board Safety Monitoring user services operate interactively and are compatible with current carrier systems. Full implementation of all three services is achievable in the overall system design for these three safety-oriented services with a phased approach. For example, assuming on-board safety data is available, it could be accessed by inspectors after the vehicle is stopped for inspection rather than at mainline speeds in the first phase of this user service. If the records appear to be in order, the inspection could be waived. The next phase of deployment would include access to on-board safety data at mainline speeds. In all cases, the driver would be alerted whenever there is a critical safety problem.

5.3.5 Technologies

Some sensors already exist for monitoring vehicle systems, cargo temperature, and driver alertness. The Sandia National Laboratory is studying the availability of sensors for conducting the current roadside inspection process, driver alertness, and cargo condition/securement. Sensing other vehicle functions, including brake performance or tires, may involve new and complex technologies.

Approaches to on-board driver identification and safety monitoring will need to be established. Devices will monitor steering movements to detect “drift-and-jerk” and other erratic steering wheel movements characteristic of driver fatigue or other impairment. Monitoring of driver/vehicle lateral lane position (lane tracking) is likely to be a key element in driver performance monitoring. Research is underway to develop machine vision and/or optical scanning devices to continuously monitor vehicle lateral lane position in relation to normal lane edge markings and to process this data to detect excessive weaving or other aberrant patterns. These vehicle-based optical lane position monitors may be forward-looking or sideward-looking.

A number of organizations are pursuing the development of low-cost, unobtrusive psychophysiological monitoring devices, including eye activity monitors, electroencephalographs (EEGs), galvanic skin response (GSR) monitors, and gross body activity/rest monitors (actigraphs). Eye activity has been found to be indicative of state of alertness and, moreover, excessive eye closure is an a priori indication of unsafe driving since vision is the principal sensory modality used in driving.

The safety data collected by vehicle, cargo, and driver monitoring sensors will be integrated onboard and warning thresholds, sequences, and displays developed. This information will be compiled and transformed into a comprehensive output. One method of compiling this data could be to use an on-board microprocessor. This output will be communicated to roadside enforcement officers with the VC established in the Commercial Vehicle Electronic Clearance user service.

5.3.6 Potential Costs and Benefits

5.3.6.1 Potential Costs

Onboard Safety Monitoring of vehicle operations will be a significant step forward from the monitoring systems in today's vehicles. Vehicle, driver, and cargo sensors will need to be developed and integrated. Warning thresholds and sequencing will need to be determined.

Lane position monitoring is likely to be the most critical and expensive component of driver performance monitoring. The cost of direct psychophysiological monitoring is difficult to predict since there appears to be a trade-off between cost and degree of obtrusiveness. The least obtrusive systems under development (e.g., video-imaging processing of driver eye activity) appear to be the most expensive. More obtrusive systems (e.g., miniature opto-electronic eye monitors attached to glasses) appear to be less expensive.

The cost of roadside signalling and detection of safety status will vary depending on which approach is selected. At this point, actual cost figures are not known. Research into the cost-effectiveness of these technologies is currently planned.

5.3.6.2 Potential Benefits

The On-board Safety Monitoring user service will potentially reduce commercial vehicle crashes, which could result in millions of dollars in savings to the nation's carriers and drivers, as well as the general public. This service will complement the efforts in the Automated Roadside Safety Inspection service and further increase the time-saving of safety inspections and, possibly, the total number of them annually.

5.3.7 Assessment of Roles

The U.S. Department of Transportation (U.S. DOT) will work with State safety enforcement officials, the Commercial Vehicle Safety Alliance (CVSA), vehicle manufacturers, and technology suppliers to develop functional requirements and system designs for testing and evaluating on-board safety systems.

5.3.7.1 Public Benefit

Safer commercial vehicles greatly benefit the general public by lowering the number of crashes and breakdowns involving commercial vehicles. This service also has the potential for significant benefit to carriers and drivers in saving time, money, and increasing safety.

5.3.7.2 Potential for Private Investment

Demand for this service appears to be low to medium by carriers and States. The development and operation of roadside infrastructure are potential market segments, and the development and deployment of on-board units for carriers and drivers is another. The motor vehicle manufacturers and electronics industry are expected to play a major role in this area.

5.3.7.3 Public and Private Roles in Deployment

Determinations need to be made as to the minimum safety elements to be monitored onboard, the thresholds for warning, and how the system should operate. Both public and private sector involvement is required for the development and deployment of this user service. The in-vehicle components will be commercial products developed by private vendors and sold to carriers. Infrastructure, such as the roadside and communication components, will be the responsibility of the public sector. The public and private sectors, primarily truck manufacturers and electronic suppliers, will have to cooperate to establish standards and guidelines that ensure components operate effectively and that funds, public and private, are invested wisely. Inherent in the development of this user service are assessments of cost-effectiveness by the public and private sectors.

5.3.7.4 U.S. DOT Role in Developing Service

The U.S. DOT's role in the On-board Safety Monitoring user service will be to foster the development and testing of promising technologies, and support the development of functional requirements, research, tests, evaluation, and deployment of technologies with a high benefit-cost ratio. More specifically, the public portion of the service includes the development of vehicle-based devices, development and maintenance of the roadside monitoring equipment and devices which communicate with on-board sensors. U.S. DOT will facilitate public/private ventures working toward establishing specifications and standards, including those for universally readable electronic tags or decals. Furthermore, U.S. DOT will evaluate the need for resolution of any institutional barriers, privacy issues, and liability issues; and will review agreements among State DOTS and enforcement agencies to implement this service. Finally, U.S. DOT will foster the establishment of communications standards for this service in addition to other ITS services.

5.4 COMMERCIAL VEHICLE ADMINISTRATIVE PROCESSES

5.4.1 Introduction

The Commercial Vehicle Administrative Processes User Service consists of two parts:

- Electronic Purchase of Credentials
- Automated Mileage and Fuel Reporting and Auditing

The Intelligent Transportation Systems (ITS) vision for commercial motor vehicles is to create, by the year 2000, an electronic licensing system that would allow interstate and intrastate motor carriers of freight and passengers to electronically purchase and pay for vehicle registration and other motor carrier taxes and licenses. This Electronic Purchase of Credentials component will allow carriers to file applications electronically for credentials such as registration, fuel use taxes, trip permits, oversize/overweight permits, or hazardous materials permits. The credentials will be approved in a much shorter time than with the current paper process, giving carriers greater flexibility in their operations. This component will provide States the opportunity to receive the data electronically and to process it with higher levels of automation, thereby reducing both the amount of manual processing required and the error associated with data entry. This component is also expected to permit carriers to pay for their credentials through some form of electronic funds transfer. Data received by the States from the Electronic Purchase of Credentials is expected to form part of the information system that is searched during the Commercial Vehicle Electronic Clearance user service.

For mileage and fuel reporting and auditing purposes, an interstate carrier is required to collect, report, and maintain accurate mileage and vehicle information for each trip by State. Registration fees and fuel taxes are based on the proportion of miles traveled in each State during the previous year, with the amount of fuel tax paid by a carrier with each fuel purchase in a particular State deducted from the tax due as calculated by mileage. States must process this mileage and fuel purchase information to collect taxes, distribute the appropriate amount to each State, and audit carriers. The Automated Mileage and Fuel Reporting and Auditing component will allow carriers to automatically record the vehicle trip miles and fuel purchased in each State. This data could then be downloaded, compiled, and submitted electronically to the States as the required mileage and fuel tax reports. The necessary capabilities to allow States to audit the automatic recording and reporting will be incorporated into this service.

5.4.2 Needs

Even with greater standardization stemming from the International Registration Plan (IRP) and the International Fuel Tax Agreement (IFTA)--which all States are required to join by 1996--

the administrative burden on carriers to collect and report mileage and fuel information is significant. The States also experience a large administrative burden in processing the information. One estimate is that it costs carriers $1 billion to $2 billion annually.

An electronic purchase of credentials function will improve industry productivity and competitiveness by reducing the time and paperwork required for motor carriers to obtain a variety of annual and temporary credentials. The electronic purchase of credentials function will allow a carrier to receive all credentials within hours, rather than weeks. This service will also benefit States by reducing administrative processing.

Compliance service firms and technology firms currently offer carriers, to some degree, similar electronic purchasing services and automated mileage calculation. Compliance service firms provide an option for motor carriers, which may not have the time or resources to meet their multiple jurisdictional regulatory compliance, by acting as the carrier's agent in acquiring its necessary credentials. The Electronic Purchase of Credentials portion would complement existing compliance service functions and would look to provide opportunities to these firms for expansion of their operations. For mileage calculation, however, private sector automated mileage data collection systems have not been approved by State tax auditors. The compliance service firms, technology firms, the States, and the motor carriers must work together to define the requirements for the Commercial Vehicle Administrative Processes user service so that all can benefit. A step in this direction has already been made with an operational test that will investigate automated mileage collection. Partners in the test include: State administrators and auditors from Iowa, Minnesota, and Wisconsin, State motor carrier associations from these States, the FHWA, Rockwell International, Rand McNally, the Iowa Transportation Center, and the Western Highway Institute.

The Commercial Vehicle Administrative Processes service will provide for the development of current and new technologies in these areas while incorporating the requirements of State authorities, such as controls against fraud.

5.4.3 Service Description

The Electronic Purchase of Credentials component will provide the carrier with an option to electronically select and purchase annual credentials via computer link to its base-State and temporary credentials via computer link to individual States. Payment for the credentials could also be handled through electronic funds transfer. The cost of the credentials could automatically be deducted from the carrier's account with the State.

The Automated Mileage and Fuel Reporting and Auditing component will enable participating carriers to electronically capture mileage, fuel purchase, trip and vehicle data by State. It would also automatically calculate mileage by State and fuel purchased within each State, eliminating the need to manually collect and prepare quarterly reports for fuel taxes and annual reports for registration.

The development and deployment of both of these components will be dependent on a number of legal, technical, and institutional issues. These issues can be resolved through cooperation among U.S. DOT, States, carriers, and private sector firms. Market analysis and outreach programs will be implemented to determine the institutional barriers and possible solutions. Continuing participation in these multi-agency efforts by representatives from States agencies and carriers especially will be necessary to reach resolution. The data for credentials and fuel use tax reporting status collected in this user service will be integrated in some degree with the Commercial Vehicle Electronic Clearance service. A subset of this information, determined by the stakeholders, will make up the credentials component of Electronic Clearance.

5.4.4 Operational Concepts

Given a system for the electronic purchase of credentials, a carrier could apply for and obtain annual credentials, such as registration, fuel tax, trip permits, oversize/overweight permits, and hazardous materials permits, via computer link. Temporary credentials could be purchased under a separate set of options. A carrier could acquire multiple permits in one computer link (there will be multiple transactions) for infrequent trips that go beyond the carrier's normal operating territory. The carrier could also purchase oversize/overweight permits and hazardous material permits through the system in the same, or similar manner.

The State's system would receive the carrier's application(s) and scan the information on the application for completeness and accuracy. If the application is in order, the State's system, would then calculate and collect fees, and enter all of the licensing information into a shared information system. A receipt acknowledging the purchase would be faxed, mailed, or sent electronically to the carrier.

For registration and auditing purposes, a carrier is required to maintain accurate mileage and vehicle information for each trip on an Individual Vehicle Mileage Record (IVMR). Information including location, date, time, and mileage can be collected now by electronic log systems. Fuel purchases could be captured from credit card or smart cards. Alternatives will be tested for electronically documenting the odometer reading, date, time, and vehicle I.D. at State lines. This will be used for calculation and audit purposes. This information could replace the manual trip log and other receipts which are typically prepared by the driver. The mileage information could be stored in an on-board computer or on a land-based system. The date, time and odometer readings could be captured at State borders and provided to State agencies. This data would then provide the means to automatically create and audit tax reports.

5.4.5 Technologies

The Electronic Purchase of Credentials component would require software to be developed, which includes screen formats for each license and permit (vehicle registration, fuel tax, registration of operating authority, etc.) and instructions on how to complete each of the screen formats. Communications software must also be developed to send licensing information from the carrier to the States and information/credentials from the States back to the carrier. If the electronic credentials were to be provided directly to the vehicle there would have to be a read-write transponder, smart card, or some other technology for an authorized source to put the data on the vehicle. Software would also be needed for electronically transferring the funds from the carrier's account to the appropriate base State.

The Automated Mileage and Fuel Reporting and Auditing component would require the development of systems for electronically collecting, calculating, and reporting mileage and fuel data by State. On-board electronic logs and smart card technology could be used for this purpose. Mileage information at State borders could possibly be captured through the use of a global positioning system (GPS) receiver and recorded through an on-board computer or by other means. An alternative technology for capturing mileage data (but not for fuel purchases) is a network of beacon sites located at State border crossings. This approach also requires equipment on the vehicle. A freight mobility software package could calculate tax liabilities and prepare tax reports.

Encryption and/or other forms of security devices and procedures must be built into the technology for the security and privacy of State and carrier credential and mileage data.

5.4.6 Potential Costs and Benefits

Implementation costs for the Electronic Purchase of Credentials component are expected to be medium since it will require the nationwide availability of carrier credential data and the development of application and communications software. Important cost factors include computer hardware and software, communications equipment, integration with current State data processing systems and base State systems like IRP and IFTA, administrative expenses such as staff training, creation of uniform procedures and forms, and consultant support.

The benefits expected from this component include significant savings in time and administrative costs for both States and carriers. This component will benefit carriers by allowing them to get credentials much faster than under the current mail-in or walk-in processes. Processing time will be reduced from weeks to hours. The extent of benefits will depend on the number of States and carriers that implement the necessary systems.
Implementation costs for the Automated Mileage and Fuel Reporting and Auditing component are expected to include: costs associated with meeting the States' requirements for accepting automated mileage recording, fuel tax reporting, and auditing; and costs incurred in

purchasing, implementing, and maintaining and operating the hardware and software. One possible system would require an on-board computer, the use of GPS receivers, and vehicle-to-roadside communications. It would cost approximately $2,000 per power unit, plus the ongoing costs of communications. There is also the cost of automating State processing. The cost of an alternative approach of on-board systems, placing enough beacons to adequately cover a given area or State, is currently not known.

The benefits expected from this component will accrue to both carriers and States. For carriers, benefits appear to be significant because of expected increases in productivity and competitiveness due to the reduction of paperwork. Another significant benefit for carriers would be to level the playing field and help ensure that all motor carriers would be required to have the proper credentials and pay the proper amount of fuel tax. Participating States would benefit from the improved efficiency in processing credentials and auditing information, and possibly from less evasion of taxes.

5.4.7 Assessment of Roles

5.4.7.1 Public Benefit

This service has an indirect public benefit because the time and cost savings gained by carriers using these technologies could possibly result in lower commercial goods prices and lower shipping costs. A reduction in evasion of fuel-use taxes may also result in an increase in revenue for States.

5.4.7.2 Potential for Private Investment

There are business opportunities for companies to sell communications equipment and services, information processing systems, and accounting systems to carriers and States. Vehicle equipment manufacturers should find ready buyers among the carriers for the in-vehicle mileage, location, and fuel recording equipment. There may also be opportunities for compliance service firms to expand their operations by serving a larger number of carriers.

5.4.7.3 Public and Private Sector Roles in Deployment

The States will have responsibility for establishing the systems to receive and store the Electronic Purchase of Credentials and Mileage and Fuel Tax data from the carriers. In fact, a majority of States already operate the systems in-house and others have hired a contractor to carry out this function in a State specific capacity. Both the States and their current service contractors will need to work together in developing the links and procedures that will make this service available nationwide.

5.4.7.4 U.S. DOT Role in Developing Service

The U.S. DOT has a very distinct role in the development and implementation of the Commercial Vehicle Administrative Processes service. The U.S. DOT will focus on working with the States, the industry, and others to define a national model for the Commercial Vehicle Administrative Processes service, including the facilitating the development of administrative and electronic data processing standards and uniform procedures for States to follow in implementing the program for interstate carriers. The States will retain their role in issuing, verifying, enforcing, and auditing credentials. The U.S. DOT will also provide support, oversight, and direction during the testing and evaluation phases of this service.

5.5 HAZARDOUS MATERIALS INCIDENT RESPONSE

5.5.1 Introduction

Hazardous materials shipments cover a range of commodities and activities from paint being transported to the local hardware store, truckloads of gasoline being delivered to local service stations, and nuclear weapons or weapons-grade plutonium being delivered to military installations. These shipments all vary in frequency, travel patterns, and associated risk.

Applying advanced technology to hazardous materials shipments offers opportunities to enhance the safety of emergency response personnel and the general public. Implementing this technology requires a good practical understanding of the safety issues involved, including the performance of the existing hazard communication system, the information needs of emergency responders, and the development of cost-effective system concepts which address real problems. While these functions are all related, a universal, integrated low-cost incident response system that can be used by local responders is needed to reduce the vulnerability of first responders and others at the scene of a Hazardous Materials incident and to reduce the overall costs associated with such incidents. This user service will provide for such a system to convey a description of the hazardous materials carried on a vehicle after an incident has occurred.

5.5.2 Needs

Roughly 10,000 to 20,000 truck transportation incidents occur each year that involve release of a hazardous material or a circumstance that threatens a release to which public-sector emergency responders are dispatched. In some cases emergency responders were unable to obtain information that they sought or experienced significant delay in obtaining it. (Reference: Transportation Research Board [TRB] special report 239, 1993). Highly publicized incidents have heightened the public awareness of the potential dangers in hazardous materials transportation. Quick response is a major concern because of the real and perceived risks hazardous materials can pose to public safety, health, and to the environment.

For those consequential hazardous materials incidents with information problems, the combined costs of property damage, evacuations, traffic delays, productivity losses, and response personnel and equipment could possibly amount to several hundred million dollars. Data is insufficient to estimate the environmental damage and cleanup costs. Improved information could prevent a fraction of the dollar costs of consequential incidents with information problems, for an annual savings in the tens of millions of dollars. Also, improved information probably would lead to more efficient use of emergency response resources in all hazardous materials transportation incidents, for additional savings. (Reference TRB Special Report 239, 1993)

5.5.3 Service Description

The National Academy of Sciences determined that it is not cost-effective to track all hazardous material shipments (Reference TRB Special Report 239, 1993). For certain types and amounts of hazardous materials it may only be important to locate these trucks when they are involved in a serious accident/incident and then provide specific cargo information to the appropriate emergency responders.

This service is aimed at improving hazardous materials incident response by providing law enforcement and HAZMAT response teams with timely, accurate information on cargo contents. The system focuses on being able to identify the materials involved so they can be handled properly.

5.5.4 Operational Concepts

The Hazardous Materials Incident Response system focuses on providing information to emergency responders at the scene of an accident. This information could reside in infrastructure-based systems such as existing carrier databases, State information systems, and other CVO user service systems or in vehicle-based systems such as transponders used for Electronic Clearance. If the pertinent information is stored in an infrastructure-based system, emergency responders will have remote access to pertinent data. If the information is stored in a vehicle-based system, emergency responders will be provided with readers to access the information from the vehicle at the scene of the incident and be able to respond quicker and more efficiently. One example of this concept is "Operation Respond." This program is a joint FRA-rail industry initiative to improve the flow of critical HAZMAT Information to first responders to rail accidents.

5.5.5 Technologies

A variety of communication technologies are possible for manual and/or automated systems to send the cargo information from the vehicle to the response unit. One method of transmitting information could be the use of read only or read/write transponders. In this case, response units would need readers and other equipment necessary for retrieving information from a transponder at the site of an incident.

Key factors in determining the type of technology selected will be costs, crash survivability, and integration with the other CVO user services as an add-on to an existing Electronic Clearance system or other information systems.

5.5.6 Potential Costs and Benefits

5.5.6.1 Benefits

To the consumer, the benefits of this service include improved traffic safety, reduced delays, and decreased risk. The improved information would potentially reduce adverse impacts of incidents such as: injuries, property damage, evacuations, traffic delays, and non-optimal emergency response resources.

5.5.6.2 Costs

Costs for in-vehicle equipment to implement the hazardous materials incident response system will be determined largely by the requirements for crash survivability. Efforts will be made during the development of this service to confine the costs of the in-vehicle equipment to the minimum necessary to provide meaningful reductions in the risk associated with damaging hazardous materials incidents.

To the system provider, the costs of implementing, maintaining and operating these systems could be substantial, if a communications system requires new infrastructure changes and equipment. However, if the hazardous materials incident response system interconnects with existing communications channels, or functions as an add-on to a basic information system supporting Electronic Clearance, costs to the response agencies may be minimal.

5.5.7 Assessment of Roles

5.5.7.1 Public Benefit

Hazardous Materials Incident Response has the potential for significant public benefit with the increase in timely and effective response to hazardous materials incidents. Agencies or response services trained and equipped for dealing with hazardous materials would have access to the type of hazardous materials involved in an incident and then are able to quickly implement the appropriate response. The safety of motorists and people occupying residences and businesses adjacent to the incident site is enhanced through the more efficient response as well as the ability to quickly broadcast precautionary information.

5.5.7.2 Potential for Private Investment in Development

The incentive for some motor carriers and/or shippers of hazardous materials to invest in a cost-effective Hazardous Materials Incident Response service is to reduce potential liability or insurance costs, and to be a good corporate citizen in terms of safety and the environment. The market potential for private investment in this area will largely depend upon the cost-effectiveness of the system and the ability of the system to be integrated with existing ITS/CVO systems.

5.5.7.3 Public and Private Sector Roles in Deplovment

The public role for the Hazardous Materials Incident Response service is significant. While ultimately there will be a market created for the technology needed to provide this service, there is little incentive for the private sector to invest in its initial development or integration. The Federal government will have to establish standards for the communication of hazardous materials information. Local emergency responders will have to obtain devices to access the required information utilizing local, state and federal funding. Carriers may eventually have to purchase equipment to convey cargo information and update the cargo data for each trip.

5.5.7.4 U.S DOT Role in Developing Service

Although U.S. DOT believes considerable benefit can be derived from such an incident response system, there is very little incentive for carriers or shippers to invest in only a Hazardous Materials Incident Response system for these isolated benefits. Hazardous materials safety will be a beneficiary of overall operational improvements from ITS/CVO applications. Therefore, U.S. DOT will have a role in fostering the development and testing of this technology. U.S. DOT will also have a significant role in determining the societal benefit and cost effectiveness of this service and promoting its deployment.

5.6 FREIGHT MOBILITY

5.6.1 Introduction

This service will provide real-time communications for vehicle location, dispatching, and tracking between commercial vehicle drivers, dispatchers, and intermodal transportation providers, thereby reducing delays for drivers and providing commercial drivers and dispatchers with real-time routing information in response to congestion or incidents.

Research, operational tests, and deployment of Intelligent Transportation Systems (ITS) technologies for freight mobility activities have been, historically, a private sector activity with limited, if any, public sector involvement. Currently, advanced freight mobility systems are deployed in limited capacities by a small number of motor carrier companies.

Even though involvement by the public sector is limited, there is research currently underway that will assess the communication needs of dispatchers and fleet managers and other roles, if any, the Federal Government would play in furthering freight mobility and productivity.

5.6.2 Needs

The different segments of the motor carrier industry will use this service to satisfy their varied business needs. The parts of the industry that would benefit the most from freight mobility are ones that are demand responsive. The need for compatible automated vehicle identification is apparent with intermodal operations. Just-in-time delivery as well as just-in-time pickup could be supported by technologies that track the location and movements of intermodal containers (ship, train, truck chassis), many of which are already equipped with transponders.

The availability of real-time traffic information and vehicle location for commercial vehicles would help dispatchers optimize their fleet operations. By adjusting driver assignments to meet real-time conditions, carriers would be able to cut down on dead-head miles. The information would also provide route guidance to avoid congested areas and improve the reliability of pickup-and-delivery operations. Curbside delivery of goods could likewise be improved by the availability of traffic and vehicle location information. In the congested streets of urban areas, parking spaces could be reserved for delivery of goods on a just-in-time basis.

Another need possibly addressed by this service would assure more compatibility between public and carrier information and mobile communication systems to minimize duplication and maximize benefits. For example, both carriers and public agencies would require access to much of the same information, such as safety and mileage data, and mobile communications are needed both for carrier operations and for many of the ITS user services offered through systems operated by the public sector.

5.6.3 Service Description

This service will provide real-time communications between commercial vehicle drivers, dispatchers, and intermodal transportation providers, which will reduce delays for drivers and provide commercial drivers and dispatchers with real-time routing information in response to congestion or incidents. The Federal Highway Administration (FHWA) is investigating whether or not there is a need for public or Federal involvement in the development and deployment of this service to facilitate intermodal transfer and provide real-time traffic information to dispatchers. Depending on their assessment of benefits and needs, individual carriers will implement elements of this service at levels of sophistication ranging from low to high.

5.6.4 Operational Concepts

Motor carrier companies with substantial fleet sizes are investing in computer, communication, and position determination technologies to improve efficiency and effectiveness. The operational concepts for the application of technologies may vary with the number of technologies employed, but they share a common objective of providing freight mobility headquarters or dispatch centers with data on vehicle location, driver hours of service, cargo location, estimated and actual delivery times, fuel consumption and general trip condition information. Integrating these categories of information enables fleet managers to make timely decisions designed to improve customer service, driver effectiveness, and equipment maintenance.

The CVO architecture will accommodate and will be upwardly compatible to current communication systems between commercial vehicle drivers, dispatchers, and intermodal transportation providers.

5.6.5 Technologies

Research and development of new technologies in the freight mobility area will continue on its accelerated path to achieve more efficient fleet operations and lower costs. Current available technologies are as diverse as the segments of the motor carrier industry. Technologies include on-board sensors and computers, land-based systems, satellite positioning systems, two-way digital and voice communication systems, and route guidance.

5.6.6 Potential Costs and Benefits

The costs for development and deployment of this service will be borne by the commercial fleet industry. Federal costs will be restricted to funding research projects to determine the role, if any, the Federal Government should play.

The benefits from this service appear to be substantial for those intermodal and time-sensitive fleets who can use the technologies to make their operations more efficient and services reliable.

5.6.7 Assessment of Roles

5.6.7.1 Public Benefit

This service has an indirect public benefit because the time and cost savings gained by carriers using these technologies may result in lower commercial goods prices and shipping costs.

5.6.7.2 Potential for Private Investment

The market potential for this service is substantial for larger truckload carriers and local pickup-and-delivery operations, since they can benefit by providing their dispatchers with advanced routing, congestion, and freight tracking information on a national level. Some fleets have already implemented similar systems and are showing a reduction in operating costs and an increase in reliability.

5.6.7.3 Public and Private Roles in Deployment

Freight mobility, including real-time communications, is currently operational for over 300 carriers. The majority of carriers do not have or sense a need for real-time traffic information, beyond radio broadcasting, nor a need for technology to facilitate intermodalism. The public sector’s role in deployment is to ensure that any future ITS system design is modular in form to accommodate future freight mobility needs and intermodal applications and to build on current technologies used by fleets in the development of other CVO services.

5.6.7.4 U.S. DOT Role in Developing Service

The U.S. DOT role is to facilitate the integration of CVO technologies into freight mobility and intermodal activities by carriers. Based on the results of a current research project and other potential freight mobility research activities, the U.S. DOT hopes to identify any barriers or gaps in the area that could be changed through appropriate Federal Government support to improve productivity and safety.

CHAPTER 6.0 - EMERGENCY MANAGEMENT

6.0 Introduction

The Emergency Management User Service Bundle contains user services that relate directly to the detection, notification and response to emergency and non-emergency incidents which take place on or adjacent to the roadway. The focus of this bundle is the improvement of the ability of police, fire and rescue operations to provide an appropriate response to such situations, thereby saving lives and reducing property damage, as well as the ability of roadside service providers to expedite responses to emergencies.

6.0.1 Emergency Management User Services

The Emergency Management User Service Bundle is made up of two individual user services, which are briefly described below:

- The **Emergency Notification and Personal Security** user service focuses on reducing the time from occurrence of an emergency or non-emergency incident until the notification of the appropriate response personnel and on providing an accurate estimate of the location of the vehicle in need of assistance. This user service is divided into two subservices; Driver and Personal Security and Automated Collision Notification.

  - The <u>Driver and Personal Security</u> subservice will provide the ability to manually initiate the 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.

  - The <u>Automated Collision Notification</u> subservice will provide automatic notification of automobile crashes. This subservice has the goal of reducing the response time for medical assistance in incidents where serious injury has occurred to the vehicle occupants rendering them unable to initiate manual incident notification.

- The **Emergency Vehicle Management** user service is oriented towards reducing the time from receipt of notification of an incident by a Public Safety Answering Point operator to arrival of the emergency vehicles on the scene. This user service is divided into three subservices: Emergency Vehicle Fleet Management, Route Guidance, and Signal Priority.

  - The <u>Emergency Vehicle Fleet Management</u> subservice will provide improved display of emergency vehicle location and automation support to dispatchers to help them dispatch the vehicle that can most quickly reach the incident site. It includes improving communications between response vehicles and the dispatch center.

- The Route Guidance subservice will assist the dispatcher and emergency vehicle driver in determining the minimum time route to reach the incident scene, and, if required, from the incident scene to a suitable hospital. It will also provide in-vehicle route guidance for directing the emergency vehicle driver to the destination. This subservice will provide capabilities needed by emergency response vehicles that are not provided by systems developed for private or commercial vehicles under the Route Guidance user service.

- The Signal Priority subservice will provide the capability to preempt traffic signals on an emergency vehicle's route so that the emergency vehicle is nearly always presented with a green signal. It includes the capability to warn drivers of affected vehicles that an emergency vehicle is approaching.

Both the Emergency Notification and Personal Security and the Emergency Vehicle Management user services address the need for timely, appropriate responses to emergency and non-emergency situations. The primary "users" of the Emergency Notification and Personal Security user service are the vehicle drivers and passengers who may benefit from more timely responses in the event of an incident. The "users" of the Emergency Vehicle Management user service are service providers including law enforcement agencies, emergency medical services (EMS), and fire services. Additional users of the Emergency Vehicle Management user service would include rescue services, extrication services, hazardous materials clean up services, and other such secondary responders, as the nature of the incident demands.

6.0.2 Relationship to ITS Goals and Objectives

The Emergency Notification and Personal Security and the Emergency Vehicle Management user services will directly address the ITS goal of improving safety on the roadways. The Emergency Notification and Personal Security user service will reduce the time elapsed between the occurrence of an incident and notification of an emergency response center, while the Emergency Vehicle Management user service will reduce the time between notification of the emergency response center and the arrival of the appropriate services at the site. The Emergency Vehicle Management user service, through the Route Guidance and Signal Priority subservices, may also reduce travel time from the incident site to an appropriate treatment facility. The underlying concept of both user services is that savings in time of intervention translate directly into health benefits for the victim. Timely response to medical emergencies significantly improves the victims chances of survival, and reduces the severity of injuries. These individual health benefits compound into societal benefits through the reduction of insurance costs and public service costs.

Both user services should also contribute to a reduction in the number of secondary accidents. The Signal Priority subservice of the Emergency Vehicle Management user service should reduce the number of crashes that occur involving emergency vehicles by providing the emergency vehicles the right-of-way as they pass through intersections.. To a lesser extent, by decreasing the response time to emergency and non-emergency incidents, both user services should speed the clearing of the vehicles involved in emergency and non-emergency incidents from the roadway, which in turn should reduce the incidence of secondary crashes.

6.0.3 Interaction With Other User Services

The Emergency Management user services share enabling technologies and ties with a number of other user services. For example, the communications, navigation (or automated vehicle location) and in-vehicle data processing technologies that are key **to** both the Emergency Notification and Personal Security and the Emergency Vehicle Management user services are common to many other user services. Also, the vehicle and traffic surveillance technologies important to the Emergency Vehicle Management user service are shared by the Travel and Traffic Management, Advanced Vehicle Safety Systems, and the Public Transportation Management user services.

6.0.4 Activities and Chart

The research and testing activities leading to deployment of the Emergency Management User Services are broadly described and graphically depicted in Figure 6.0-l.

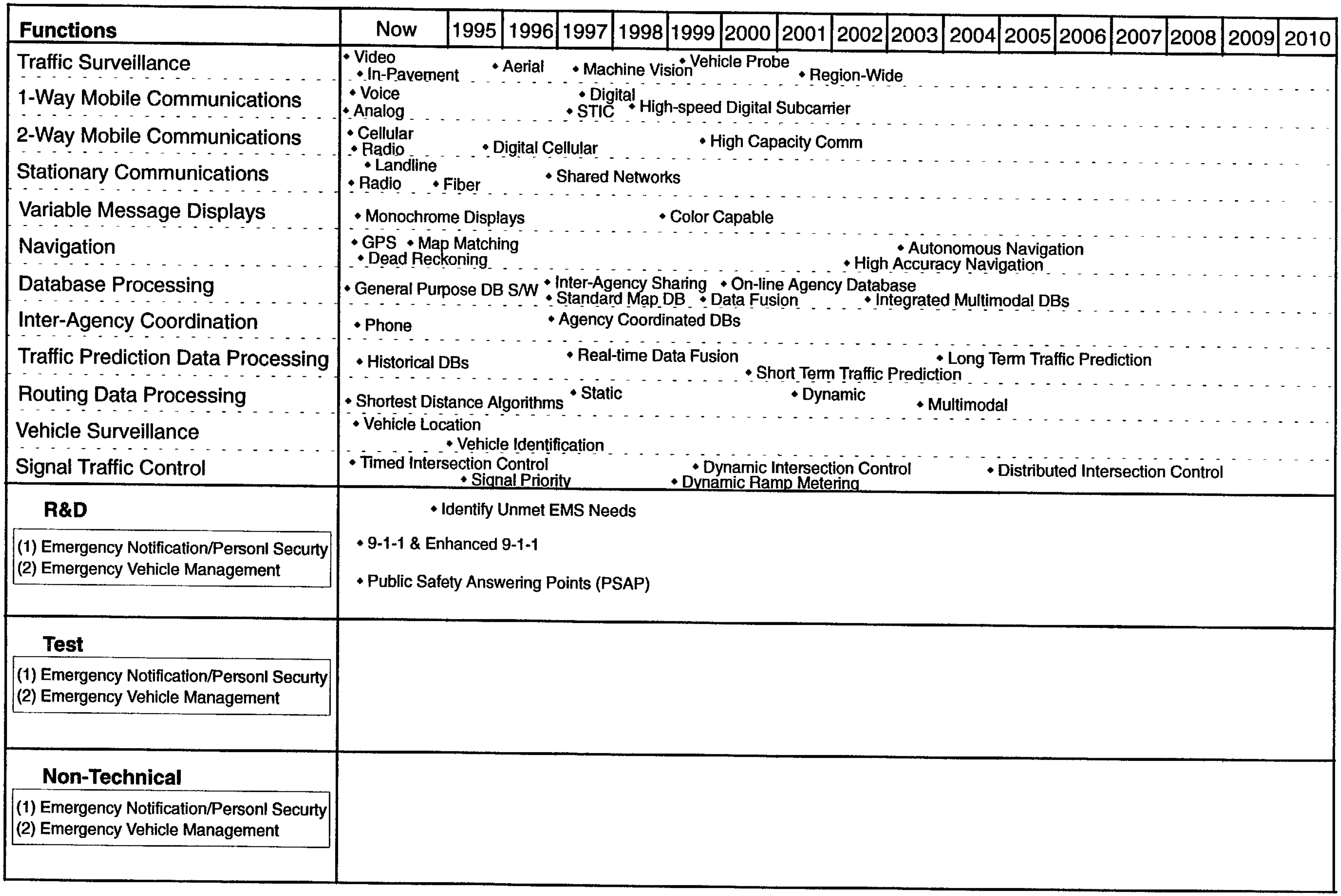

Figure 6.0-1 Emergency Management Technology Development Timeline

6.1 EMERGENCY NOTIFICATION AND PERSONAL SECURITY

6.1.1 Introduction

The Emergency Notification and Personal Security User Service includes two capabilities: the Driver and Personal Security subservice, and the Automated Collision Notification subservice. The Driver and Personal Security subservice provides the capability for the user to manually initiate a distress signal for incidents like mechanical breakdown or non-injury accidents. The Automated Collision Notification subservice helps ameloriate the consequences of a serious collision by automatically sending information regarding the location, nature, and severity of the crash to an emergency medical services (EMS) dispatcher.

The users of this service are vehicle drivers and passengers, who will benefit from more timely responses in emergency situations. Primary service providers include telecommunications carriers (such as telephone companies and cellular radio companies), emergency response centers, police departments, highway patrols, fire and rescue units, emergency medical service providers, as well as those providing towing and other motorist assistance services.

This service directly addresses the ITS goal of improving safety by improving EMS and roadway services responses, reducing the number of fatalities and the severity of injuries resulting from a collision, and reducing the number of pedestrian and vehicle collisions secondary to an incident. Driving stress is reduced by providing a means of summoning assistance in the event of an emergency.

6.1.2 Needs

Thousands of roadway incidents occur every day on our nation's highways. Most highway incidents, such as disabled or abandoned vehicles and minor crashes, are not serious in and of themselves; however, delay in providing notification of the location and nature of an incident often exacerbates the safety, mobility and environmental consequences of the incident. These incidents not only cause capacity reductions on freeways that result in congestion and delay, they can be dangerous for motorists, police officers, and other response personnel who are out of their vehicles as a result of an incident. Studies have shown that 20 to 30 percent of freeway pedestrian fatalities are associated with disabled vehicles. The motorist may also be personally at risk, particularly late at night or in isolated areas, due to criminal acts or exposure to a harsh environment.

The Driver and Personal Security subservice will directly reduce the personal risk to motorists, police officers and other response personnel, as well as other motorists. This will be achieved by reducing the time necessary to notify response personnel that an incident has occurred, and thus will reduce the time a disabled vehicle is in the roadway.

The ability to respond quickly to serious injury crashes is directly limited by the ability to notify EMS personnel that the crash has occurred and to identify precisely where the crash took place. Studies have shown that the likelihood of fatality and long-term health consequences of injuries increase as the response time of medical service personnel increases. This can be particularly important in rural areas. Data from the Fatal Accident Reporting System (FARS) show that, in 1991, the average elapsed time between a fatal crash and notification of the dispatcher is about 5 minutes in urban areas and about 10 minutes in rural areas. This increase in response time is attributed to the lack of traffic providing the opportunity for someone to see and report the crash, travel distance to a telephone to report the crash, or difficulties in locating crash sites. Data also exists that indicate that once notified, the response time of EMS personnel is significantly greater in rural areas compared to urban areas. This can be attributed to the longer distances that may have to be travelled by the EMS personnel to arrive at the scene of the crash, and the inability of witnesses to accurately identify the location of the crash.

The Automatic Collision Notification subservice will directly address the issues associated with providing fast, appropriate response to serious automobile crashes, by providing the capability to automatically sense that a serious crash has occurred, and to immediately relay critical information on the severity of the crash and the crash location to an EMS dispatcher.

6.1.3 Service Description

The Emergency Notification and Personal Security user service is divided into two subservices; Driver and Personal Security and Automated Collision Notification.

6.1.3.1 Driver and Personal Security

The Driver and Personal Security subservice will provide the ability to manually initiate notification of emergency and non-emergency incidents such as mechanical breakdowns, medical emergencies, fire, non-injury accidents, or injury accidents where a person on the scene is able to manually initiate the notification. Requests for assistance can be directed to emergency or non-emergency response personnel including emergency medical, fire, law enforcement, as well as towing or repair assistance to deal with a disabled vehicle. The systems providing this capability will include the ability to automatically determine the vehicle's location and will transmit the location as part of the notification message. Initially this service will provide for manually initiated notifications, however, future enhancements may combine both subservices to allow automatically initiated messages. Primary service providers include telecommunications carriers (such as telephone companies and cellular radio companies), providers of real time location services (such as the Global Position System, or the LORAN-C System), emergency response centers, law enforcement, fire and rescue units, emergency medical service providers, as well as those providing towing and other motorist assistance services.

ITS Auto Theft Recovery and Prevention systems may incorporate driver-specific recognition systems already being provided for motorist-security or convenience. For example, personalized door-locking/unlocking or vehicle-interior adjustments might be embellished to link driver identification codes (e.g. voice, smart card/key) with ignition locks and other electronic controls. Alarm signals of unauthorized starts might be automatically transmitted to police receivers, or vehicle owners who discover a theft could trigger unannounced locator transmittals from the stolen vehicle (similar to the system marketed by LO JACK). New cellular systems technology will allow vehicles to be located even if the phone is off. With owner approval, police departments might have electronics and the staff to track stolen vehicle movements. On board transmitters and wide spread standardized passive detectors could also hasten vehicle interception. Interception and remote control would lessen the risks of thieves, hazardous driving, and vehicle dismantling by professional “chop shops”..

6.1.3.2 Automated Collision Notification

The Automated Collision Notification subservice will provide automatic notification of EMS personnel of serious automobile crashes. The systems providing this capability will have the ability to automatically detect that a serious crash has occurred, and will automatically relay a notification message to an EMS dispatcher that includes the location of the crash and an indication of the severity of the crash. Additional information that may be transmitted as part of the notification message might include vehicle identification information and data on the vehicle condition, e.g., indication of roll over or fire, final vehicle orientation, and indication of the number of occupants of the vehicle. Primary service providers include telecommunications carriers (such as telephone companies and cellular radio companies), providers of real time location services (such as the Global Position System, or the LORAN-C System), emergency response centers, police departments, highway patrols, fire and rescue units, emergency medical service providers, and towing services.

6.1.4 Operational Concepts

The operational functions of the Driver and Personal Security subservice and the Automated Collision Notification subservice of the Emergency Management and Personal Security user service are described below.

6.1.4.1 Driver and Personal Security

The Driver and Personal Security subservice has two basic operational functions: a communications link and a navigation or vehicle location capability. When a vehicle driver experiences a mechanical breakdown, or other situation that requires assistance, he would manually initiate a call for help. The communications link may be two-way voice communications, some kind of electronic messaging, or even something as simple as pushing a button In any case, the notification message would include some indication as to the nature of the incident and the type of assistance required, such as: minor property damage crashes; break downs due to mechanical failure, flat tire, overheating, or running out of gas; medical emergencies; or police emergencies. The ability to manually send a cancellation message in the event the system is improperly activated is required.

The second major operational function is some means of identifying the location of the vehicle. The Driver and Personal Security subservice will include a navigation or vehicle location capability. Location information will be automatically obtained by the in-vehicle system and will be included as part of the notification message. It may also be desirable to include an estimate of the accuracy of the location estimate, if such is available.

One possible approach is to have the in-vehicle system automatically route the incident notification message directly to the appropriate response personnel (i.e., mechanical breakdown to a repair or towing service, a medical emergency to EMS dispatcher, or a police emergency to the police department). Another approach is to utilize a centralized dispatch facility that would decide on the appropriate response and route the message accordingly.

Aspects of this service can tie into the existing infrastructure of Public Safety Answering Points (PSAP). PSAP or Public Safety Answering Point, is a communications center operated as an agency of a government entities responsible for answering 9-l-l calls. The PSAP either dispatches a response from Emergency Response Agency (ERAs, e.g. police, fire, or emergency medical services) under its direction or it transfers the call to that ERA or another PSAP for dispatch. Basic 9-l-l services direct phone calls to the appropriate PSAP or, if no PSAP exists, to the designated agency responsible for answering emergency calls. Enhanced 9-l-l services incoprorate additional features such as AN1 (Automatic Number Identification) and AL1 (Automatic Location Identification). With Enhanced 9-1-1, the ALI is a computer display that shows the caller’s phone number and adddress, and identifes which agency would respond for law enforcement, fire, and EMS. The addition of AL1 and AVI technology to cellular phones will allow PSAP personnel to locate the vehicle from which an emergency call was placed.

6.1.4.2 Automated Collision Notification

The Automated Collision Notification subservice is made up of three basic operational functions; incident detection, vehicle location, and communications.

The first operational function, incident detection, allows the system to sense that a serious crash has occurred. It would be desirable for the system to also provide some indication of the severity of the crash and to provide supplemental information on the condition of the vehicle (e.g., has the car rolled over, is the car on fire, how many occupants were in the car when it crashed). It is not necessary for the crash detection portion of the Automated

Collision Notification system to survive the crash, it only has to sense that a crash has occurred and relay that information to the communications component before it fails.

The second operational function of an Automated Collision Notification system is the ability to identify the location of the vehicle. The system must include a navigation or vehicle location capability. Location information will be automatically obtained by the in-vehicle system and will be included as part of the notification message. It may also be desirable to include an estimate of the accuracy of the location estimate, if such is available. As with the crash sensing portion of the system, the navigation portion of the system may not be required to survive the crash if accurate location information can be obtained and forwarded to the communications component before it fails. However, as the vehicle may travel a significant distance after the initial impact has occurred, it would be desirable for the navigation component to survive the crash.

The communications component is the third operational function of an Automated Collision Notification system. This component will automatically initiate a one-way communications link with an EMS dispatch facility and pass a notification message containing the vehicle location, an indication of the crash severity, and possibly additional supplemental information. Obviously, it is critical that the communications capability must survive the crash. The ability to manually send a cancellation message in the event the system inadvertently sends an inappropriate notification message may also be needed.

6.1.4.3 Key Onerational Features

Both subservices of the Emergency Management and Personal Security user service share several key operational characteristics:

- Information sent by the vehicle must reach an appropriate response facility or dispatcher in a timely and efficient manner.

- It is a goal of the system to have full coverage, i.e., drivers should be able to contact at least one response facility or dispatcher from any given location in the United States. This full coverage capability may be phased in to the system over some period of time.

- A driver should be able to travel region to region without adjustments to in-vehicle equipment or changes in procedures.

- Incident notification communications systems should take advantage of the various existing networks (e.g., 9-l-l services for emergency situation notification) to the extent possible.

- The communication system may support one-way or two-way transmission to notify the appropriate response facility or dispatcher of an incident, and it may use voice or data or a combination of the two.

6.1.5 Technologies

The Driver and Personal Security and the Automated Collision Notification subservices of the Emergency Notification and Personal Security user service share requirements for several in-vehicle technologies. Specifically, navigation and communications technologies are required for both subservices. The Automated Collision Notification subservice also has the requirement for crash sensing technologies.

6.1.5.1 Navigation

A number of navigation technologies exist that may be appropriate for providing an automated vehicle location capability for both the Driver and Personal Security and the Automated Collision Notification subservices. The navigation technologies fall into three basic categories: satellite, terrestrial, and dead reckoning. Satellite options include the Global Positioning System (GPS) and satellite communications systems that provide geolocation services. Terrestrial systems include marine navigation systems such as Loran-C. Dead-reckoning systems employing gyros, compasses and differential odometers are also available.

The three most important features that will determine which navigation technologies are most appropriate for the Emergency Notification and Personal Security user service are accuracy, availability, and cost. For example, while GPS satellite navigation systems appear to offer a highly accurate vehicle location capability for a reasonably low cost, studies have shown that in an obstructed environment (such as under a stand of trees off the side of a road, or when the view of the sky is blocked by a rock outcropping) GPS accuracy can be significantly reduced, even to the point that the system is unable to obtain a position fix. A combination of technologies, such as GPS combined with a dead-reckoning capability, may be required, particularly for an Automated Collision Notification system.

6.1.5.2 Communications

A number of potential communications technologies exist that could support the requirements for the Emergency Notification and Personal Security user service. These include voice or data linked through geosynchronous (GEO) orbit and low earth orbit (LEO) satellites, terrestrial (mobile and fixed) voice and data systems in the 220-, 450-, 800-, and 900~MHz band, and citizens band (CB) radio.

The factors that will drive the communications technology for this user service will be coverage (or availability) and cost. For the Automated Collision Notification subservice, crash survivability is also an issue for the communications portion of the system. For example, it is expected that systems requiring multiple components dispersed about the vehicle, or with large or complex (e.g., tracking) antennas will be less survivable than single unit communications terminals with small antennas. Therefore, LEO satellite terminals are not expected to survive crashes as well as, say, a cellular telephone. However, LEO satellite systems can provide global coverage and have good foliage penetration capability due to the low operating frequency, while cellular telephone coverage is limited by the number of cell sites constructed. It is expected that geographic coverage provided by cellular telephone service will level off at 65% of the Continental U.S. (CONUS).

Both the Driver and Personal Security and the Automated Collision Notification subservices will require the ability for the communications capability to interface with an appropriate incident response or EMS dispatch facility. Clearly, an Automated Collision Notification system should take advantage, as much as is possible, of the established emergency reporting systems, such as the 9-l-l capability. This may require additional equipment or technology at the Public Safety Answering Point (PSAP) facilities.

6.1.5.3 Crash Sensing

The Automated Collision Notification subservice has a unique requirement to detect that a serious collision has occurred. Devices that are considered appropriate for crash sensing include inertial switches and accelerometers to sense deceleration forces. Cost, reliability, accuracy, and the ability to provide supplemental information on the condition of the vehicle (such as an indication of roll over and the orientation of the vehicle) are some of the factors that will determine which technologies are most appropriate of the crash sensing component of an Automated Collision Notification system.

6.1.6 Potential Costs and Benefits

6.1.6.1 Benefits

The Driver and Personal Security subservice will provide benefits both to individual drivers and to the driving public. The benefits to the individual driver include improved personal security and safety, bestowed by providing the ability to immediately summon help for emergency and non-emergency incidents. Benefits to the general public include improved traffic safety, reduced delays, and a reduction in pedestrian fatalities, achieved by enhancing the ability of the appropriate service provider to respond to an incident and remove it from the roadway.

The Automated Collision Notification subservice will benefit individual drivers, emergency medical services providers, and also the driving public. Benefits to the individual drivers are an increased chance of surviving an automobile crash and a reduction in the long-term consequences of injuries sustained in a crash, achieved by reducing the time required to notify an EMS dispatcher. Emergency medical services providers will benefit from the improved ability to respond quickly and efficiently to an automobile crash, which will be achieved by providing immediate notification of the crash and the crash location. Additional benefits may be derived in EMS response management by providing the EMS dispatcher with supplemental information indicating the severity of the crash, number of occupants, etc. The general public should also benefit from the Automated Collision Notification subservice by the system's contributions to a reduction in insurance costs due to the reduction in the consequences of injuries sustained in automobile crashes, and by a reduction in the tax costs of providing emergency medical response services due to improved management of emergency responses.

6.1.6.2 Costs

While difficult to assess at this time, the costs associated with both a Driver and Personal Security and an Automated Collision Notification system do not appear to be prohibitive. Navigation and communications technologies that could at least partially support the requirements for both systems currently exist. The cost of cellular telephone service could be quite reasonable, especially considering the proliferation of car phones, which would preclude additional costs to a great degree. GPS and Loran-C navigation systems are currently available for on the order of $200-400. Furthermore, the use of these systems to support other ITS services will increase the likelihood that they may already be available. Reliable solid state crash sensors have been developed to support air-bag technology and are available for very low cost (<$100). It is anticipated that these component prices will come down further as the market for them grows. For example, some manufactures are predicting that certain types of accelerometers, which may be appropriate for crash sensing, may soon be available for as little as $5.00.

More difficult to estimate are the costs that will be associated with the development of the infrastructure to allow the communications component of the Driver and Personal Security and Automated Collision Notification systems to interface with the existing service providers. For the Automated Collision Notification system, this interface may be as simple as a computer processor and a modem located at the PSAP facility. For the Driver and Personal Security system, a network of non-emergency service dispatching facilities may be required. The costs associated with the development of such a network could potentially be borne to a large degree by the service providers, or the motorists themselves. For example, motorists now willing to pay for 24 hour roadside service may also be willing to invest in a low-cost system that allows them to directly notify traveler assistance centers of the need for assistance.

6.1.7 Assessment of Roles

6.1.7.1 Public Benefit

The Emergency Notification and Personal Security user service will have a direct and significant public benefit by increasing the chance of surviving an automobile crash and reducing the consequences of injuries sustained in a crash, and by increasing the personal security and safety of automobile drivers and passengers. Secondary benefits to the driving public include improved traffic safety and reduced traffic delays.

6.1.7.2 Potential for Private Investment in Development

As previously discussed, the technologies for the in-vehicle components required for both the Driver and Personal Security and the Automated Collision Notification subservices are currently commercially available. Increased demand for the components and technological advances are expected to continue to reduce the cost of these components to the point where the car buying public may be willing to pay the cost for the in-vehicle components as a safety related option for a new car, or as an aftermarket addition to an existing vehicle. In addition, it may be possible to use system elements from other user services to provide a communications and a vehicle navigation capabilities for these subservices. If this happens, the synergistic effect of providing more than one service with a single in-vehicle system may increase the likelihood of private sector investment in component integration and interface.

The potential for profitable private investment in the development of the infrastructure for the Driver and Personal Security subservice is medium to high, based on the value placed by the driving public in obtaining fast and reliable assistance. Motorists who are now willing to pay for 24 hour roadside service may also be willing to invest in a low-cost system that allows them to directly notify traveler assistance centers of the need for assistance. This could allow the private sector to recoup the costs associated with the development of a network of traveler assistance centers.

An Automated Collision Notification system could build on the technological components of the Driver and Personal Security subservice, or other user services that employ communications or navigation technologies. However, as the public sector is the primary service provider for this subservice (i.e., emergency medical services), public investment in the development of the necessary infrastructure to support the capability will likely be required. The costs associated with the infrastructure development and maintenance are not expected to be large.

6.1.7.3 Public and Private Sector Roles in Deployment

The Driver and Personal Security subservice will require involvement from both the public and private sectors. A "courtesy" service which provides assistance for common mechanical breakdowns or other non-emergency incidents could be privately operated and coordinated with other relevant sectors, public or private. The expected public sector involvement is low if the response facilities are privately operated. The extent of public involvement in this case would be **to** restore the roadway capacity to its pre-incident condition. However, this response service may also be provided by the public sector and blend in well with an existing state or local incident management program.

For the Automated Collision Notification subservice, the vehicle and equipment manufacturers will need to develop the in-vehicle systems. These can be made available to consumers as either original equipment in new vehicles or as after-market equipment for installation in existing vehicles. The public sector role will be high since the service is dependent on the emergency service dispatchers in communities across the nation being prepared to receive the crash notification messages and respond to them. This means that a communication interface for entry into the emergency dispatch systems will be needed, and it may be necessary to have national standardization of the types of communication links and message formats for this service. The possibility exists that a private sector clearinghouse may be used as an intermediate step between the vehicle involved in the crash and the medical services dispatcher, which would increase the likelihood of private sector involvement in the deployment of an Automated Collision Notification system.

6.1.7.4 U.S DOT Role in Developing Service

The Driver and Personal Security subservice has an expected medium to high public benefit, a medium public sector involvement, and a high private market potential. Therefore, the U.S. Department of Transportation (U.S. DOT) role would be to encourage private industry to develop the necessary technology and equipment to be compatible with the functional specifications of the system.

For the Automated Collision Notification subservice, the U.S. DOT level of involvement will be high because of the high public benefits and the low likelihood of private investment without U.S. DOT involvement. The U.S. DOT involvement will be in two areas. First will be to support the development of performance specifications for in-vehicle systems and the demonstration of proof-of-concept; the second area will be to support standardization of communications links, message content and formats, and the procedures associated with an Automated Collision Notification capability in cooperation with private industry partners.

6.1.8 Milestones and Activities

Figure 6.1-1 is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing the Emergency Notification and Personal Security user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

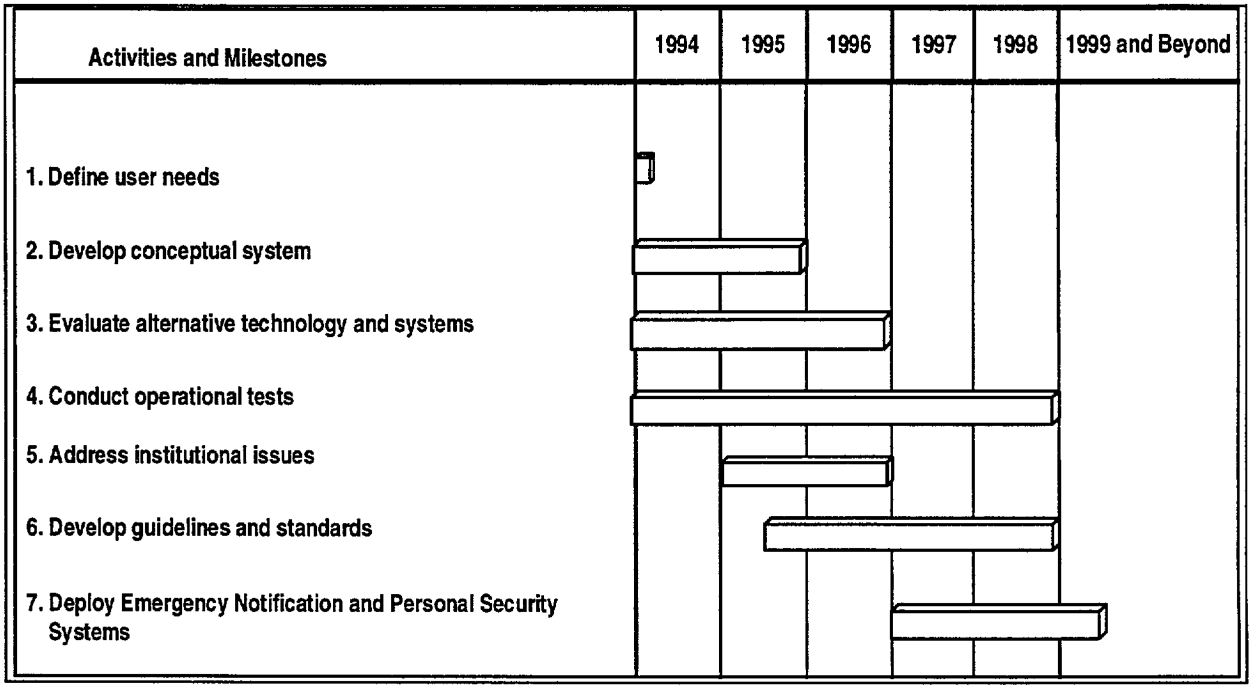

Figure 6.1-1 Emergency Notification and Personal Security

6.1.8.1 Issues

Issues associated with the Driver and Personal Security subservice include:

- Balance betwen benefits and costs for both user and providers.
- Form of the driver interface
- Standardization of driver interface
- Types of notification messages to be provided (e.g., medical emergency, police emergency, fire emergency, traffic incident, mechanical assistance, etc.)
- Acceptance by emergency service providers of one-way digital notifications
- Management of and ability to reduce the number of inadvertent emergency notifications
- Routing of notification messages to emergency or non-emergency responders
- Use of multiple communications media
- Area of coverage

Issues associated with the Automated Collision Notification subservice include:

- Balance betwen benefits and costs for both user and providers.
- Management of and ability to reduce the number of inadvertent notifications
- Standardization of message content and format
- Use of multiple communications media
- Area of coverage
- Interface with EMS facilities

6.1.8.2 Activities

Activities required for development and implementation of the Emergency Notification an Personal Security user service include:

1. Identify the needs of the system user/providers and assess the feasibility of various technical approaches that could be applied in system development. It may be found that certain components of the system, e.g., manual system for vehicle breakdowns, automated system for crashes, will meet these needs in a cost-effective manner. Conduct further evaluations and testing to assess the costs and benefits of implementing an incident notification capability for each subservice.

2. Assess the need for both subservices of the Emergency Notification and Personal Security user service versus the benefits to the motoring public. This task will quantify, if possible, the anticipated improvement in public health directly attributable to these capabilities. Recommendations for additional data and methods to collect it will also be identified.

3. Develop system concepts and determine functional requirements for meeting the needs of both subservices of the Emergency Notification and Personal Security user service identified in Activity 1. In this activity, USDOT should clearly address the operating environment, maintenance, communications and other factors that will affect the development of systems to implement these subservices. This activity will be carried out through the following existing or proposed projects:

   - "Rural Applications of Advanced Traveler Information Systems (ATIS)," (1992- 1994). This study involves developing conceptual system designs based on the need for rural ATIS, including traveler assistance and emergency notification.

   - "Automated Mayday Systems," (1993). This project examined in-vehicle sensors, in-vehicle navigation systems, and vehicle-to-EMS center communication systems. This was preliminary conceptual work done by The Johns Hopkins University Applied Physics Laboratory (JHU/APL) leading to a more comprehensive understanding of potential technologies for an Automated Collision Notification system.

- "Advance Traveler Information Systems (ATIS) Communications Alternatives Test and Evaluation," (1993 - 1996). This study will identify and analyze ITS communication requirements. Preferred communications alternatives will be recommended for specific ITS functions.

4. Evaluate available technologies and system designs for implementing the Emergency Notification and Personal Security user service concepts, and select the most promising approaches. Consideration of the costs and the benefits of the alternatives will be part of the evaluation. Support research of alternative technologies and configurations necessary to provide this user service. This work will include a comprehensive examination of sensors, and will investigate data fusion techniques to provide information about an automobile crash and to reduce probability of false alarms. Efforts will be made to identify and employ communications media that will support the service in remote rural areas as well as densely populated urban areas. This activity will build on the preceding activities and will be carried out through the following projects:

   - "Development of a Knowledge Base for Collision Notification," (1993-1994). This project focused on studying in-vehicle technologies for crash sensing, navigation and communications. The study looked at alternative communication concepts, the ability to capture sensor and vehicle location data during a crash. Laboratory experiments with sensors and data fusion techniques quantified crash sensor systems performance and established trigger thresholds. Investigation of navigation technology' identified promising candidates, and characterized availability and accuracy issues associated with the Global Positioning System. Research in communications technologies identified limitations and design considerations for employing cellular telephone as the communications component of an Automated Collision Notification system.

   - "Development of System Design for Driver and Personal Security, and Automated Collision Notification Subservices," (Proposed). FHWA proposes to fund a contractor to develop a system design for these subservices. FHWA will establish a steering committee made up of representatives from FHWA the emergency and non-emergency incident responders, equipment and vehicle manufacturers, communications service providers, and various segments of the driving public, to advise the contractor during the system design. The system design will include recommended resolutions to the issues identified above. This project will maintain active two-way coordination with the ITS architecture effort.

5. Conduct prototype and operational tests to evaluate how well newly developed technologies and systems work under real world operating conditions, and to assess the benefits and public support for the products or systems. USDOT will solicit partners to

conduct operational tests focused on evaluating various system approaches the Driver and Personal Security and Automated Collision Notification subservices described.

The following operational tests are underway and will provide information on certain aspects of the Emergency Notification and Personal Security user service:

- DIRECT (1991-1995) (communications)
- *ADVANCE* (1991-1996) (AVL)
- FAST-TRAC (1992-1994) (AVL)
- Travel-Aid (1992-1996) (communications, human factors)
- Puget Sound Help Me (PuSHME) Mayday System (1995-)
- Colorado Mayday System (1995 -)

The following are proposed prototype tests and evaluations:

- Rural Applications of Advanced Traveler Information Systems (ATIS) (1992-1994). This project includes developing a plan to test and evaluate prototyping system(s), possibly including traveler assistance and emergency notification.

- Development of a Knowledge Base for Collision Notification (1994-). A second phase of this project will develop an evaluation plan for an operational test of an Automated Collision Notification system. Requirements for data collection equipment will also be identified.

- Advanced Traveler Information Systems (ATIS) Communications Alternatives Test and Evaluation (1993-1996). This project includes developing test and evaluation plans, and conducting prototype tests.

The following are proposed operational tests:

- Driver and Personal Security Operational Tests (1994-). This test will evaluate the benefits of systems that allow travelers to notify traveler assistance centers of the need for assistance. The tests will focus on low-cost systems that automatically convey location of the vehicle.

- Automated Collision Notification (1995-). The systems tested will have the capability to automatically sense that a crash has occurred, identify the vehicle's location, and initiate a request for emergency assistance.

6. Develop the procedures and infrastructure to support the implementation of the Emergency Notification and Personal Security user service. This activity will assess the many institutional issues involving State, Local and Federal agencies regarding implementation

of this user service. Assess the risks associated with implementation of these capabilities and the potential benefits of the services relative to the costs, in order to avoid undue burden on the industry and local responders. Foster and promote cooperation and coordination within and between communities and states and assist in overcoming product liability constraints.

7. Develop the minimum operational performance specifications, standards and guidelines for deploying proven technology. While the emergency response portion of this service will be implemented by many local jurisdictions, the service must be implemented in such a way that the communications protocols, procedures, and driver interface on the vehicle remain the same for all areas of the country. USDOT will take an active role to ensure that appropriate organizations are chartered in 1995 - 1996 to create standards for communications equipment performance, communications protocols, information exchange standards and message content. USDOT will also charter an appropriate working group to develop and publish guidelines that will help local jurisdictions implement a uniform incident response capability and uniform procedures across the country. USDOT will also work with the automobile industry to establish standards for in-vehicle crash sensors.

6.2 EMERGENCY VEHICLE MANAGEMENT

6.2.1 Introduction

The Emergency Vehicle Management User Service is oriented toward reducing the time from the receipt of notification of an incident by a Public Safety Answering Point operator to arrival of the emergency vehicles on the scene. It consists of three subservices:

- Emergency Vehicle Fleet Management
- Route Guidance
- Signal Priority

Emergency Vehicle Management (also called Public Safety Services or PSS) will respond to the full range of needs that may arise in IVHS operations including intervention by police, emergency medical services, fire services, and allied public safety services. The same PSS that serves the mobile needs of IVHS users will also serve to reduce deaths, injuries, and property damage arising from natural, or manmade mishaps at fixed locations accessible to PSS vehicles. A common need of these services for IVHS response purposes therefore, is the ability to access, process, and exchange real-time information on the location and nature, of mishaps on roadways, both those included and those not included in the IVHS infrastructure, so as to enable appropriate PSS responses to be promptly programmed and implemented at all potential response sites within the designated area of coverage of PSS.

This service has three primary users: law enforcement services, emergency medical services (EMS), and fire services. These primary users may have need for assistance by rescue services, extrication services, hazardous materials clean up services, and other such secondary responders, as the nature of the incident demands.

6.2.2 Needs

Data from the U.S. Department of Transportation and the National Safety Council document situations where injury has, or may, occur and where timely attention will reduce the severity of consequences to the victims. Thus, there is a need for timely intervention to improve the likelihood of recovery for those cases where injury or illness have already occurred and the likelihood of preventing injury in those hazardous situations where injury has not already occurred.

6.2.3 Service Description

The Emergency Vehicle Fleet Management subservice will have at least three components: fire, EMS, and police.

- **Emergency Vehicle Fleet Management** subservice provides improved display of emergency vehicle location, and automation support to dispatchers to help them dispatch the vehicle that can most quickly reach the incident site. It includes improving communications between the response vehicles and the dispatch center.

- **Route Guidance** subservice assists the dispatcher and vehicle driver determine the minimum time route to reach the incident scene, or a suitable hospital. It also provides in-vehicle route guidance for directing the driver to the destination. This subservice provides capabilities needed by emergency response vehicles that are not provided by systems developed for private or commercial vehicles under the Route Guidance service.

- **Signal Priority** subservice provides for pre-emption of traffic signals on an emergency vehicle's route so that the emergency vehicle is nearly always presented with a green signal. It includes the capability to warn drivers of affected vehicles that an emergency vehicle is approaching. For the purposes of this user service, two terms, Emergency Vehicle Management and Public Safety Services (PSS), will be used interchangeably. All references to PSS should be interpreted as being equivalent to Emergency Vehicle Management.

IVHS technologies can enable Public Safety Answering Point (PSAP) operators receiving first notification of response requirements, to immediately identify the appropriate, closest, available PSS responder or mix of responders, and to transfer complete, accurate information regarding the nature and location of the response need, resulting in more effective, safer, and less costly operations. A working model for this TVHS function already exists in the Enhanced E-9-l-l (E-9-l-l) function known as selective routing. Selective routing automatically routes a 9-l-l call to the PSAP responsible for public safety in the region where the call originated.

PSS is the primary or core IVHS user system whose operations are directed to responding to, and preventing or reducing the consequences of mishaps requiring emergency services. The PSS System uses a broad range of IVHS capabilities that can provide the dispatchers with accurate information on the location of the appropriate, available vehicle closest to the scene, so shorter response times can be achieved. For example, an ambulance may be considered to be out-of-service while it returns to its station at the completion of an emergency dispatch. Until it arrives back at its station, it is generally not dispatched again. With vehicle location technology, the dispatcher can identify and dynamically dispatch the vehicle nearest to the scene of an emergency. This can reduce response times and improve public service.

The underlying concept of this service is that savings in time of intervention translate directly into health benefits for the victim. These individual health benefits compound into societal benefits through reduction in insurance costs and public service costs. The systems which provide this service are designed to minimize the time between notifying a dispatcher of the need and the availability of appropriate intervention to the victim(s). Thus, the primary measure of effectiveness of a concept or system is the reduction in time between notification and availability of intervention.

6.2.4 Operational Concepts

The systems that implement the Route Guidance subservice provide the emergency vehicle driver with guidance on how to achieve "minimum-time" response to the scene of the emergency and other locations, such as hospitals. One key component of these systems not found in the requirements for "routine" route guidance for private citizens is the monitoring of other emergency vehicles responding to the same location. The systems should be integrated with an external automated crash detection location and reporting system.

The systems that will provide the Signal Priority subservice are a part of the traffic management infrastructure. Many of the system concepts for this subservice will include direct communication between IVHS/PSS dispatcher and the traffic signal; direct communication between the emergency vehicle and someone or something else; such as, the private automobiles within a certain radius so that the drivers are aware that an emergency vehicle is approaching, or an emergency vehicle communicates directly with traffic signal controls to provide right-of-way for the vehicle.

PSS vehicles (police, EMS, and fire)operate as authorized by State or local governments, to respond to reported emergent needs of citizens for police, emergency medical, fire, and similar interventions. PSS vehicles may be owned by governmental or private sector organizations, and may be operated by government employed responders, such as sworn police officers, by private sector employees such as hospital employed Emergency Medical Technicians (EMTs) who are certified by State Emergency Medical Services authorities, or by a mix of volunteer, government employed and private sector employed personnel such as in paid, volunteer and privatized fire services.

PSS deliver direct aid to individuals (or groups) in situations requiring intervention by police, emergency medical technicians, or fire fighters . Present control of PSS vehicles is often based on assumed location information and decisions are made on these assumptions. IVHS technologies can enable PSAP operators receiving first notification of response requirements, to immediately identify the appropriate, closest, available PSS responder or mix of responders, and to transfer complete accurate information regarding the nature and location of the response need, resulting in more effective, safer, and less costly operations.

In the case of fire trucks and ambulances, the dispatcher generally assumes that the vehicle is located at a known facility (e.g. fire station or hospital). For police patrol cars, the dispatcher assumes that the car is located somewhere within its assigned patrol area. In each case, there may be another vehicle closer to the scene of the distress.

6.2.5 Technologies

Several technologies will need to be integrated to allow the visions of the public safety service system management user service to be fully achieved. Real-time reliable transportation information is essential to police responding to traffic incidents. They require use of current traffic information, location of the incident and navigational alternatives to arrive at their destination.

Determination of IVHS communications spectrum requirements (See Transportation Research Board [TRB] Report Jan 1992 for activities, and schedule) is needed. The IVHS PSS System will make use of the variety of telecommunications developed for other IVHS Services. It is noted that there is a separate development plan, developed by the TRB Communications Committee for IVHS Communications. The milestones and schedule for some communications requirements for IVHS PSS will be dictated by the IVHS Communications plan.

With changes in assignments of frequency spectrum and the development of digital voice and new modulation schemes, there is envisioned a need to develop a new PSS communications infrastructure as an integral part of IVHS requirements

6.2.6 Potential Costs and Benefits

6.2.6.1 Potential Costs

Direct costs to motorists for these services are minimal. The costs of these systems fall upon service providers. Fleet management and route guidance systems are already on the market for specialized EMS applications. As these systems become further developed and are more widespread in the market, EMS service providers should be able to benefit from reduced costs and increased power. Development of signal priority systems will require cooperation between EMS providers and traffic authorities. The costs for simple systems should be moderate.

6.2.6.2 Potential Benefits

The consumer will benefit from improved emergency response times. Research has demonstrated that prompt, appropriate medical care is an important factor in reducing the severity of injuries received in a crash.

Emergency vehicle fleet management will assist service providers in managing their fleets and assigning appropriate vehicles to emergency calls. Route guidance systems, already in use by some EMS providers, assist response teams in locating crash sites, and transporting victims to a medical facility. EMS providers will also be able to take advantage of improvements in route guidance as described in that user service. Signal Priority at intersections for EMS vehicles would provide additional protection for EMS vehicles crossing intersections by providing more warning to drivers on opposing routes.

6.2.7 Assessment of Roles

The responsibility for development of IVHS services generally resides with the private sector; however, there are situations when the U.S. Department of Transportation (U.S. DOT) involvement is appropriate. In the case of the Emergency Vehicle Management user service, U.S. DOT/National Highway Traffic Safety Admimistration (NHTSA) has statutory authorization to support Public Safety Services responsive to the needs of highway safety. These responsibilities are described in Highway Safety Guidelines promulgated by the Secretary of Transportation pursuant to the Highway Safety Act of 1966. Specifically Highway Safety Guide Number 11 on Emergency Medical Services and Highway Safety Guide number 15 on Police Traffic Services (PTS) are envisioned as being applicable to IVHS.

Under the Highway Safety Act of 1966 (as currently amended) the Governors of the States are responsible for implementing the highway safety guidelines promulgated by the Secretary of Transportation. The Act provides that the Governors will implement the guidelines through local governmental authorities. To enable the States to implement the Highway Safety Guidelines, States are provided with Section 402 funds which are provided annually through the Federal budget process. Section 403 funds are provided also to NHTSA for related research, development, demonstrations and seed funding of programs to be implemented by the States.

NHTSA envisions that the Federal role for PSS for IVHS will be implemented through its current statutory role for PSS for highway safety.

For this purpose, NHTSA will continue to work with State and local law enforcement and emergency medical authorities to apply evolving IVHS technology to its current EMS and PTS programs. Thus the existing NHTSA sponsored EMS and PTS programs can serve to facilitate demonstration of the applicability of IVHS concepts and developments for highway safety.

An example of this is the recently completed Section 402 funded demonstration in Murfreesboro, Tennessee of the use of traffic signal preemption by public safety vehicles to improve public safety service response times.

In New Jersey, Congressionally earmarked Section 403 funding is being used to demonstrate the benefits of consolidated county-wide state-of-the-art PSAPs to improve response to highway public safety response needs in connection with New Jersey implementation of a New Jersey statute mandating statewide Enhanced 9-l-l services.

6.2.7.1 Public Benefit

This service has high potential for public benefit in that the public has accepted that responding to situations by police, emergency medical technicians, and fire services is a public responsibility. The public benefit in this case is not limited solely to the traveler.

6.2.7.2 Potential for Private Investment in Development

The private sector market potential for products that respond to the public safety service system management service appears to be medium to high.

6.2.7.3 Public and Private Sector Roles in Deployment

The public sector role for this service is characterized as high although this service will require both public and private sector involvement. There is public involvement since the operations of the public safety service system are normally conducted by a public agency. There is private involvement due to the support equipment coming from private vendors. The gathering of traffic information which will be supplied to the public safety services will be a public role. Establishing an information system that is capable of analyzing and fusing the data, coordinating the network for distribution of the information to traffic, transit, and the public safety services could be a private role.

The public sector would be involved in public safety services as a result of U.S. DOT's involvement in research, development, operational testing, and deployment. This involvement would be for the primary purpose of demonstrating the enhancement of PSS using IVHS concepts and technology. Information from such demonstrations would be provided for the benefit of transit and traffic organizations as well as for the general motoring public and commercial vehicle operations.

6.2.8 Milestones and Activities

Figure 6.2-l is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

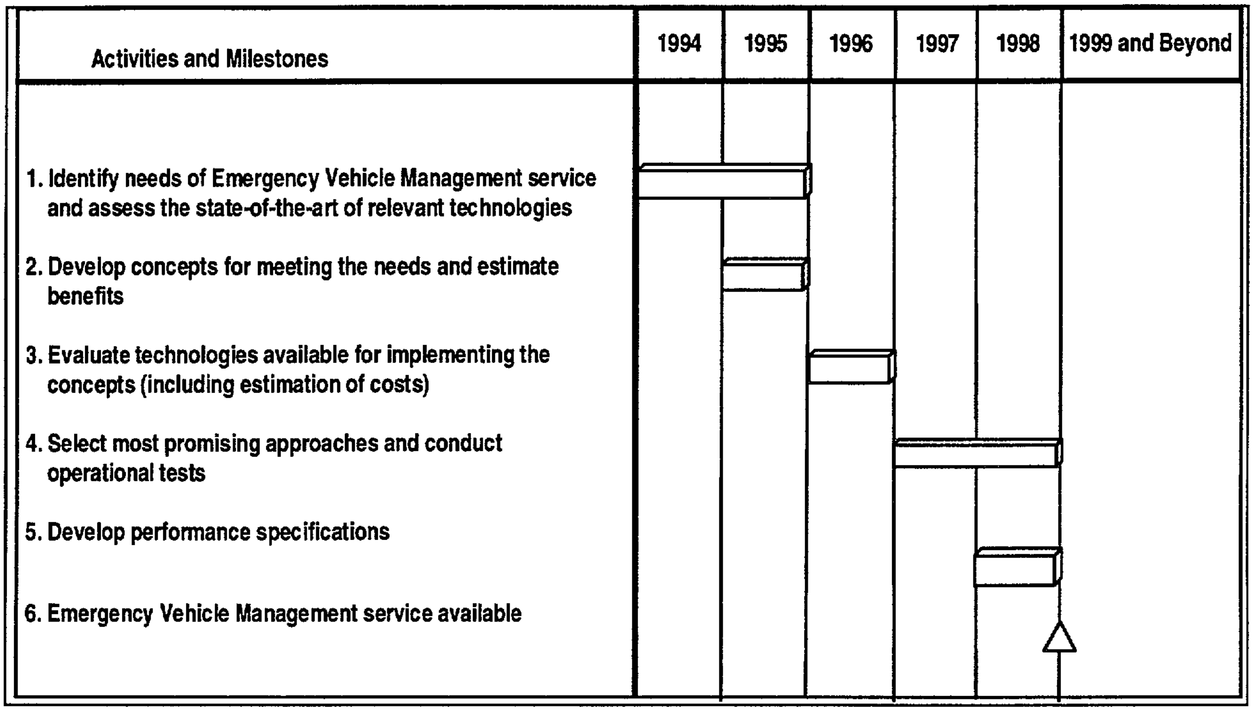

Figure 6.2-1 Emergency Vehicle Management Activities

6.2.8.1 Issues

1. Most areas have existing emergency vehicle communications infrastructure. How can a transition to advanced capabilities be managed in a cost-effective way?

2. Is there sufficient benefit and can operationally suitable and cost-effective concepts be developed to warrant implementing each of the advanced concepts within Emergency Vehicle Management?

6.2.8.2 Activities

1. NHTSA proposes an R&D project to carry out this task. The task will identify the unmet needs of today's emergency vehicle management systems, and will identify the opportunities for improving response times through application of current or emerging IVHS technologies. The task will consider the needs of both urban response centers and

rural response centers. The task will monitor the developments and operational tests currently underway under the En-route Driver Information, Route Guidance, and Commercial Fleet Management services to determine the extent to which the capabilities being developed for private or commercial vehicles are not adequate for emergency vehicles.

2. NHTSA would support an R&D project to carry out this task. This activity would respond in part to both issues above. This activity would consider and estimate the benefits for the following capabilities:

   - next generation voice and data communications capabilities for communications between emergency dispatch centers and emergency vehicles
   - automatic frequent position reporting capability, based on Global Positioning System (GPS) or other Automated Vehicle Location (AVL) capability from emergency vehicles to the dispatch center
   - route selection and in-vehicle route guidance capability
   - the capability to provide a warning, and possibly instructions, to drivers of affected private vehicles that an emergency vehicle is approaching
   - the capability to control traffic signals to ensure that emergency vehicles have green signals
   - the capability to control multiple emergency vehicles responding to the same incident
   - various levels of automation support for dispatchers to assist them in selecting the minimum response time vehicle, and in selecting a route for that vehicle.

3. NHTSA would support an R&D project to carry out this task. This activity will estimate the costs of both the vehicle and dispatch center equipment to implement the concepts. It will also estimate the costs of deploying any communications infrastructure unique to this service.

4. NHTSA would solicit offers of participation and, with selected partners, would carry out operational tests of promising concepts. These operational tests would be carried out in conjunction with operational tests of other user services such as Route Guidance, Incident Management, and Traffic Control.

5. Based on the results of the operational tests, NHTSA would develop performance specifications and standards for the appropriate Emergency Vehicle Management capabilities

6. Enhanced Emergency Vehicle Management services as provided through IVHS capabilities will be available as of this date.

CHAPTER 7.0 - ADVANCED VEHICLE CONTROL AND SAFETY SYSTEMS

7.0 Introduction

Driver error has been determined to be a contributory or causal factor in over 90% of the approximately 6 million reported motor vehicle crashes that occur in the United States each year. There are a number of ways in which driver error can be manifested as a crash factor. These include, for example: inattention, distraction, misjudgement or decision error, intoxication or fatigue, and reckless behavior.

Until recently, the existing level of technology did not offer the promise of enhancing the crash avoidance capabilities of motor vehicles. However, the past several years have seen advances in electronics, communications and processor and control systems that make such improvements more feasible than was previously thought possible. A wide variety of innovations can be implemented both inside and outside the motor vehicle to supplement the driver's ability to maintain vigilance and effective vehicular control. These innovations would monitor the driver's own physiological condition, enhance perceptions of the driving environment, provide additional information about potential safety hazards, warn of impending collisions, assist in making appropriate vehicle maneuvers, and, eventually, even intervene with automatic controls to help avoid such incidents.

This Advanced Vehicle Control and Safety Systems, or AVCSS, bundle contains seven user services. All of these user services relate primarily to the safety goals of ITS by having a direct impact on diminishing both the number and severity of crashes, thereby reducing injuries, fatalities, and societal costs. Services in this bundle can be provided by systems that are part of the vehicle. The seven user services included in this bundle are:

- Longitudinal Collision Avoidance,
- Lateral Collision Avoidance,
- Intersection Collision Avoidance,
- Vision Enhancement for Collision Avoidance,
- Safety Readiness Systems,
- Pre-Collision Restraint Deployment, and
- Automated Highway System (AHS).

Most of these user services will also have an indirect impact on reducing costs to fleet operators and transportation dependent industries. This is accomplished by reducing the losses in productivity and other direct and indirect costs of crashes.

The Automated Highway System user service not only addresses the safety related goals and objectives, but also has direct impacts on the capacity of existing facilities, and on reducing travel time and the time delays associated with congestion. Indirectly, the AHS user service can reduce new right-of-way requirements by making better utilization of existing facilities and improving travel time predictability.

7.0.1 Needs

More than 40,000 persons are killed and over three million injured in the United States each year as a result of traffic accidents. It has been estimated that these fatalities and injuries, along with the consequent property damage, costs the nation's economy about $140 billion annually. And even though the fatality rate has been declining in recent years, this level of deaths, injuries and damage is still unacceptably high. It is essential that efforts be made to reduce both the number and severity of these incidents.

In 1993, for example, it **is** estimated that there were about 6,093,000 motor vehicle crashes reported to state and local law enforcement authorities resulting in 35,747 involved fatalities. An additional and unknown number of collisions occur which, for various reasons, went unreported. Some estimates have put these numbers as roughly equal to the total of police-reported crashes; however, the level of damage or personal injury that results from these unreported crashes is generally assumed to be significantly less than for reported crashes.

These 9,093,000 reported crashes in 1993 can be categorized into six major and mutually exclusive types, as shown in Table 7.0-2.

Table 7.0-2 Police-Reported Motor Vehicle Accidents in the U.S., 1993

Accident Type	Incidents	% of Total
Rear-End	1537,000	25.2
Single Vehicle Roadway Departure (SVRD)	1,241,000	20.4
Intersection/Crossing Path	1,805,000	29.6
Lane Change	237,000	3.9
Head-On	169,000	2.8
Backing	177,000	2.9
Other	927,000	15.2
Total	6,093,000	100.0

Among the 'other' types of crash are collisions with pedestrians or cyclists, on-road rollovers, non-lane change sideswipes, and other intersection crash types. Approximately 43 percent --- or about 2,600,000 -- of these crashes occurred in non-daylight (darkness, dawn or dusk) or during inclement weather conditions (rain, sleet, snow, fog or smog) that normally impair visibility.

Detailed studies have recently been concluded or are currently underway to determine the major causal factors for each of these crash categories, including reduced visibility situations, as well as a range of potentially effective evasive actions that could be taken to avoid such incidents. The results of these investigations will be of great value to the design and development of effective countermeasures, including those ITS systems described in this document.

7.0.2 Service Description

This bundle contains seven user services that are focused on increasing the safety and efficiency of vehicle operations.

- Longitudinal Collision Avoidance systems address one or two vehicle crashes in which vehicles are moving in essentially parallel paths prior to the collision, or one in which the struck vehicle is stationary. The subservices included are:

  - Rear-End Crash Warning and Control,
  - Adaptive Cruise Control (ACC),
  - Head-On Crash Warning and Control, and
  - Backing Crash Warning and Control.

- Lateral Collision Avoidance systems augment the driver's ability to avoid collisions that arise when a vehicle leaves its own lane of travel while moving in a forward direction, including both single-vehicle and two-vehicle collisions. Two types of subservices are associated with providing this user service:

  - Merge/Lane Change/Blind Spot Situation Displays, Crash Warning and Control, and
  - Lane/Road Departure Crash Warning and Control.

- Intersection Collision Avoidance systems address situations that arise when vehicles improperly violate the right-of-way of another vehicle, or when the right-of-way at an intersection is not clear. The service will provide warnings of imminent collisions with crossing traffic, as well as warnings of control devices -- either a stop sign or a traffic signal -- in the intersection ahead.

- Vision Enhancement for Collision Avoidance user service will reduce the number and severity of collisions in which impaired or reduced visibility is a causal factor. Systems that provide this service will augment visually-acquired information in situations where driving visibility is low, such as nighttime or foggy conditions. (This service does not deal with overcoming obstructions to visibility or blind spots caused by the vehicle's body, and it does not deal with conspicuity enhancement of roadways or objects.)

- Safety Readiness user service focuses on reducing the number and severity of collisions caused by inattentive, drowsy or impaired drivers; degraded or failed vehicle components; or degraded infrastructure conditions. This user service consists of three subservices:

  - Driver Condition Warning and Control Override,
  - Vehicle Condition Warning, and
  - In-Vehicle Infrastructure Condition Warning.

Warnings derived from sensors or manual inputs from outside the vehicle are covered in the In-Vehicle Signing subservice of the En-Route Driver Information user service.

- Pre-Collision Restraint Deployment user service provides a means to anticipate an imminent collision and to arm or activate passenger safety systems (for example, side-impact airbags) prior to actual impact. The equipment implementing this service is contained entirely in the protected vehicle.

- Automated Highway System (AHS) user service focuses on improving the safety, efficiency of operation, and comfort of roadway systems. AHS systems will provide fully automated control (i.e., "hands-off" and "feet-off" operation) of suitably equipped instrumented vehicles traveling on instrumented highways, as well as partial vehicle control systems that are extensions of collision avoidance systems where only limited control of the vehicle is automatic. AHS systems will likely be based on systems developed for the Longitudinal Collision Avoidance, Lateral Collision Avoidance, Intersection Collision Avoidance, and Safety Readiness user services.

These services are applicable in urban, suburban and rural settings. However, in order to be able to operate effectively in these varying environments -- with significantly different levels of traffic, speed and distance -- the operational characteristics of these services and their applications will need to be flexible. For example, longitudinal collision avoidance systems such as Adaptive Cruise Control will need to respond to both the shorter headways common on urban freeways, as well as the longer headways more typical of rural interstates.

7.0.3 Operational Concepts

There are many diverse causal factors involved in crashes, depending on the specific situation and crash type. These factors can in turn be grouped into categories, such as: driver recognition or decision error (inattention, failure to look, excessive speed or reckless driving); driver impairment (intoxication or fatigue); vehicle defects (brake or steering system failure); and environmental conditions (slippery roads, reduced visibility). Given this situation, no single countermeasure concept can cover this range of potential causal factors. Rather, countermeasure concepts are likely to be developed from a number of services and subservices.

It can also be expected that individual countermeasure concepts will be targeted at one (or possibly more) of these causal categories. For example, one concept for a countermeasure system may be directed at assessing the driver's ability to operate the vehicle safely. Another concept may attempt to identify and respond to a sudden and potentially dangerous change in the vehicle's momentum or direction.

One of the most important aspects of crash analysis is the time-intensity of the event. This can be graphically represented as the amount of time between the appearance of the initial crash threat and the actual collision impact. During this period, the intensity of action needed to avoid the crash increases at an accelerating rate through four typical phases, as shown in Figure 7.0-1, “Time-Intensity Graph of Pre-Crash Avoidance Requirements”.

Collision avoidance services may incorporate various levels of warning or control, which are closely related to these pre-impact time phases. At the first “normal driving” phase, the driver would be assisted by a *presence* indicator. This is a system that would scan some or all of the area immediately adjacent to the vehicle for the presence of other vehicles or objects that may present a collision hazard. In most cases, information would be displayed to the driver only when such a potential hazard existed, or when the driver made directional changes that created the collision hazard. An example of this type of driver assistance system is one which provides information about the presence of vehicles in the driver’s blindspots.

At the second phase, a collision is imminent yet sufficient time remains for the driver to recognize the potential hazard and take appropriate actions. At this point, a driver-warning system would be activated to focus the driver’s attention on the situation, so that appropriate actions could be immediately taken. An example would be a system which advises the driver of the need to apply the brakes immediately because a stationary vehicle has been detected ahead and the driver has not taken timely action.

In the third phase, with the collision imminent, a control-intervention system could be activated as a means of avoiding the collision. For example, the braking, steering and/or throttle systems may provide variable feedback to the driver, or even make certain behavior (such as steering in the direction of the collision hazard) more difficult.

At the final “fully-automatic control” phase, insufficient time remains for a successful, voluntary driver reaction. The system would then assume automatic, temporary control of the vehicle in an attempt to avoid the crash. A system which automatically applies the brakes in a way that matches the deceleration of a vehicle which suddenly stops in front of another vehicle is an example of this type of system.

Development of these systems must include careful consideration of false alarms, and incorporate a method for distinguishing true pre-collision incidents from non-collision deviations from the driving norm. Detailed assessments of the behavioral and human factors characteristics of the driver-vehicle interface is also essential. Finally, in systems where partial or full automatic action is taken by a controller, it is particularly important to ensure that these actions are compatible with vehicle and driver capabilities and limitations.

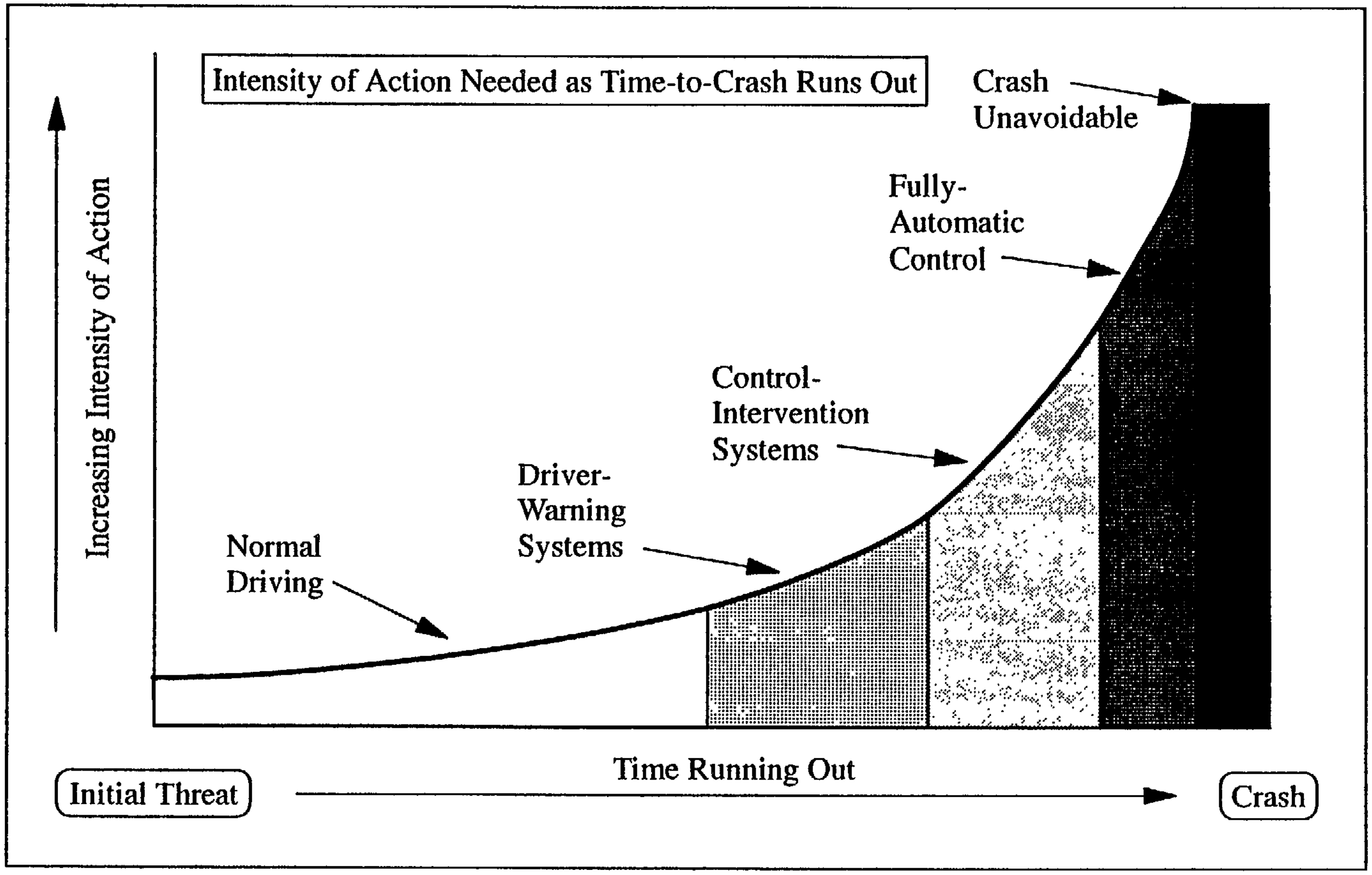

Figure 7.0-1 Time-Intensity Graph of Pre-Crash Avoidance Requirements

7.0.4 Technologies

Figure 7.0-2, "Advanced Vehicle Safety Systems Technology Development Timeline", depicts the various major technological components needed to bring these user services to a state where they are available for large-scale deployment. Each user service plan in the AVCSS category contains information on the technologies and specific components needed for the related systems. Volume I demonstrates how knowledge of the necessary components may be used to help determine how to integrate various user services for more effective eventual deployment.

To some extent, many of the subservices in this AVCSS bundle incorporate the functions sometimes described as the "three Ps" -- *perceive, process and present.* These systems must: *perceive* or sense critical information about an impending collision, *process* the information into a form which is useable by the driver or an automatic control system, and *present* this information to the driver (or directly to the vehicle) in a manner which elicits appropriate collision avoidance action.

7.0.4.1 Sensors

The highly variable characteristics of the different hazard situations that may confront a driver means, in turn, that the specific sensing requirements of the various types of collision avoidance systems differ substantially. This suggests that different technologies may often be appropriate for different situations. This is particularly true in the longitudinal, lateral and intersection collision avoidance user services. For example, rear-end collision avoidance systems need to detect changes in relative speed between two vehicles traveling in the same direction, while head-on systems deal with two vehicles approaching each other at very high speeds. Lateral and intersection collision situations would require different sensing capabilities focussing on the sides of the vehicle, rather than the front or back. In contrast, there is another grouping of systems which are more concerned with the condition and capabilities of the driver, vehicle and roadway, than with detecting potential collision objects and changes in vehicle momentum. These will be more prevalent in the vision enhancement for crash avoidance and safety readiness user services.

The sensing capabilities needed for many of these systems could be cooperative or autonomous. Cooperative systems would communicate with other vehicles or the infrastructure, while sensors for autonomous systems are wholly contained within the vehicle and would require neither passive nor active input from the infrastructure or another vehicle. This sensing will be to the front, sides and/or rear of the vehicle, and will gather information regarding the distance to and relative velocity of adjacent vehicles or other potential collision hazards such as objects, pedestrians or animals.

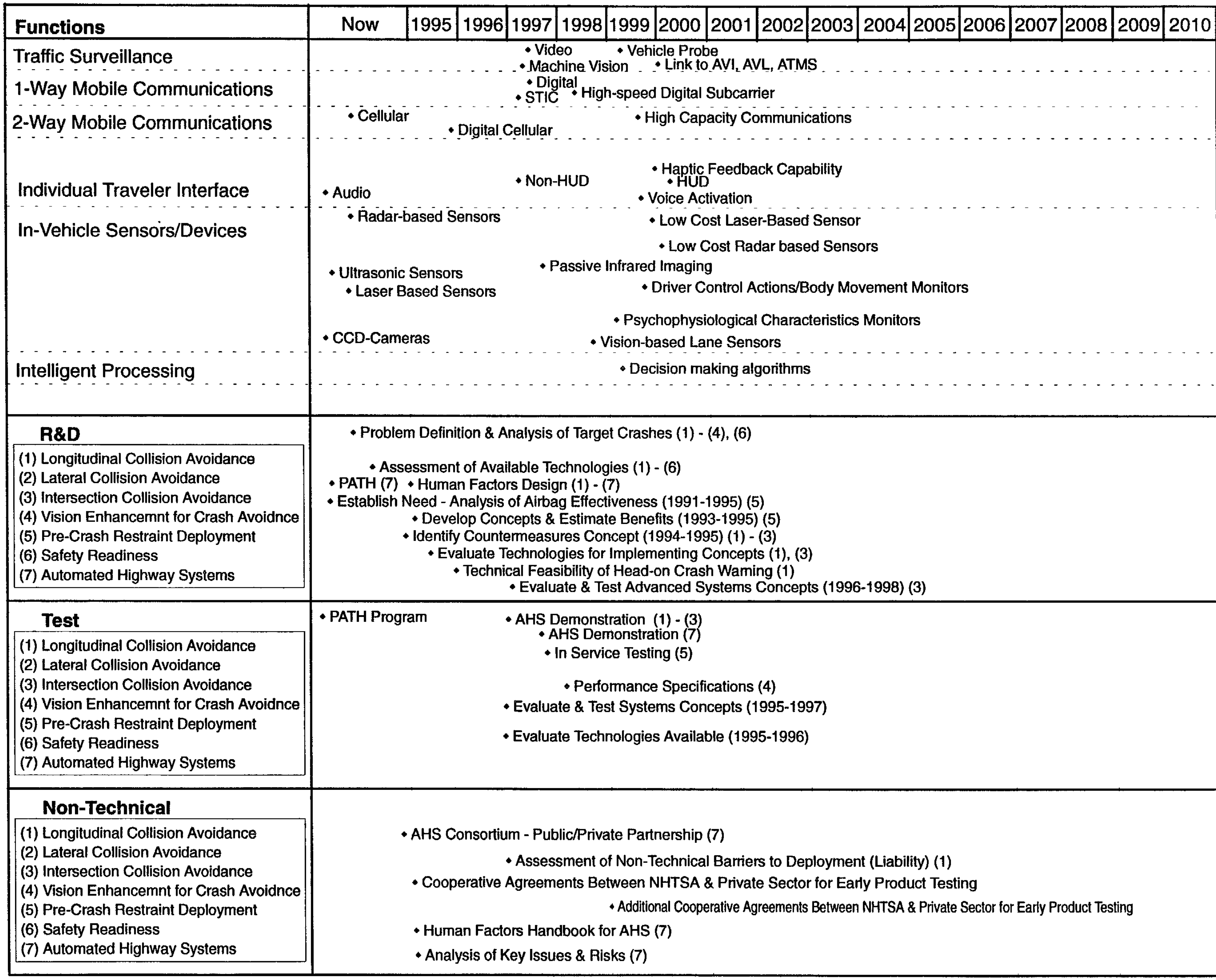

Figure 7.0-2 Advanced Vehicle Control and Safety Systems Technology Development Timeline

Candidate sensor technologies for use in these collision avoidance systems include: Global Positioning System (GPS) satellite location; microwave (below 30 GHz) and millimeter-wave (30 - 300 GHz) radar; laser radar (also known as lidar or light detection and ranging); ultrasound; video image processing; infrared imaging; and infrared or ultraviolet illumination. Radar systems would probably utilize pulse, pulse doppler, frequency-modulated continuous-wave (FM/CW), binary phase modulation, or pulsed frequency modulation transmission modes. Each of these technologies has its own unique combination of strengths and weaknesses in different applications, which provides the researcher with a rich field of technological candidates for the various systems concepts in this user service bundle.

7.0.4.2 Processors

The processing subsystem implements the control logic of the system. Some possible approaches to control include a continuous presentation to the driver of the “threat content” of the surrounding driver environment, advice that an unspecified collision avoidance action is necessary, advice on the specific collision avoidance action to take, and partial or full vehicle control. The “threat content” consists of information regarding the presence and location of vehicles in the same lane, or of objects in the vehicle’s path.

Additional research will be needed to determine the kinds of algorithms required to differentiate and interpret the sensor data correctly. For example, a common sensor system possibly could be used for multiple purposes, with interpretive algorithms differentiating one condition from another.

For systems which advise of needed collision avoidance actions or which take control of the vehicle, careful consideration of false/nuisance alarms (including both deploying safety systems when not needed, as well as not deploying systems when needed) must be included in the processing algorithms. This is necessary in order to enhance both safety and service reliability. The system must be able to distinguish non-threatening situations from potentially dangerous ones. The system should also be able to distinguish between hazardous objects, such as another vehicle, and non-hazardous objects, such as a blowing piece of newspaper or a sudden, heavy downpour of rain. It is important that the system be self-diagnosing, and that it give the driver appropriate warning of when it is not operational. Finally, advanced processing technologies may need to be integrated into the final service to enable its full potential to be achieved. For example, neural networks (or their equivalent) could be used to interpret sensor data to differentiate one potential longitudinal collision condition from another.

7.0.4.3 Driver/Vehicle Interfaces (or Controllers)

As noted above, there are three basic implementations of collision avoidance systems: those that provide collision threat information to the driver (‘presence indicator’), those that provide a warning or instructions on collision avoidance action (‘driver-warning’), and those that take partial or complete control of the vehicle’s driving functions (‘control-intervention’). For those systems that provide information or warning, the driver interface can be visual, audible, tactile or a combination of these methods. The interface can also be either continuous, or only activated when a driver action is needed. Systems that take temporary and partial automatic control of the vehicle could simply back off the throttle, downshift the transmission, or activate various levels of vehicle braking, depending on the particular situation. Finally, full control of the vehicle's longitudinal movement -- including braking, throttle and steering -- could be imposed to avoid a collision. This step would likely involve integrating longitudinal and lateral control functions.

The specific characteristics of the driver interface will depend on the technologies used in the system. Potential technologies include: cathode ray tube, liquid crystal, dot matrix, "head-up" (HUD) and light-emitting diode (LED) displays; computer generated voice messages; and proprioceptive feedback through the steering wheel and/or accelerator and brake pedals. Control systems technologies will include the traditional technologies of feedback control system and servo-mechanism design, as well as adaptive control using fuzzy logic and neural networks. Whichever design is chosen for a given system, it should not perform in a manner that confuses or distracts the driver, or the result may be a less safe driving experience.

7.0.5 The NHTSA ITS Program

The National Highway Traffic Safety Administration, or NHTSA, has been facilitating the development, evaluation and deployment of those IVHS technologies and systems which have a potential to contribute to attaining its agency mission, which is to reduce traffic accidents and the resulting injuries and deaths. As part of its ITS effort, NHTSA is pursuing a multi-faceted research and development program. This program includes five major thrusts:

- *Build research tools and compile knowledge base.* This effort will expand and improve the collection of systems and data bases available to researchers. This includes the National Advanced Driving Simulator (NADS) and portable data acquisition systems that can be installed in vehicles, as well as human factors and driver workload assessment studies.

- *Identify promising crash avoidance opportunities.* Various crash categories (head-on, rear end, lane change/merge, backing, roadway departure, etc.) will be studied in detail. The emphasis here is on identifying potentially promising countermeasures for further research.

- *Demonstrate proof of concepts for crash avoidance.* Performance specifications will be developed for the various crash categories. These specifications can then be used to design and evaluate actual crash avoidance systems.

- *Facilitate the commercial development* ***of*** *promising crash avoidance products.* NHTSA will work cooperatively with private industry in this effort. One major technique will be to enter into cooperative, cost-sharing research efforts with non-governmental organizations such as major automobile manufactures and component suppliers and university research institutions.

- *Access the safety of other ITS concepts.* This process will assure that ITS systems developed for purposes other than enhanced safety will, in turn, not degrade the safety of the driving experience when they are deployed.

7.0.6 Potential Costs and Benefits

Throughout the development and deployment of any AVCSS system or service, the potential benefits attributed to the product will need to be carefully judged against their costs. This is a normal business function that is applied to any major automotive system, and one with which the private sector has extensive familiarity. The final test will come with the marketplace, when individual vehicle drivers and owners decide whether or not to pay the additional costs for installing these systems. It can also usually be assumed that the process of developing and refining a product that achieves market success, especially those with the potential for mass deployment, will lead to a decrease in unit costs.

7.0.6.1 Potential Costs

In 1990, there were nearly 193 million registered motor vehicles in the United States, of which 143 million were automobiles. Approximately 10 million new passenger vehicles are sold in the U.S. each year. If all, or a substantial proportion, of these vehicles included these advanced vehicle safety systems, the total monetary costs could be substantial. The actual cost of these systems have not yet been determined, due to the relatively limited capabilities and the small number of systems currently available. Some commercially-available systems of this nature currently range in cost between about $100 to $2,500 per unit. As a measure of the potential market for these products, however, it is worth noting that adding a $500 system to every registered vehicle would require a total initial investment of nearly $100 billion.

7.0.6.2 Potential Benefits

As was mentioned earlier, motor vehicle accidents are a major cause of deaths, injuries, property damage and related losses to the nation and its economy. Any contributions that ITS technologies can make to a less dangerous driving experience, and a safer and more efficient national transportation system, would bring concomitant benefits to the nation.

7.0.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant potential opportunities for achieving improvements in highway safety and reductions in vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of IVHS's potential benefits to the public means that U.S. DOT has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the ITS program. This includes encouraging and coordinating the development of key technologies and the supporting knowledge base, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In the case of improved highway safety, U.S. DOT needs first to facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT needs to ensure that no loss of safety occurs from the deployment of any IVHS services not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications for crash avoidance technologies need to be developed for different crash categories. This will enable the identification of the specific causal factors and potential countermeasures for each category. These performance specifications can then be used by product developers as design targets for the services they are developing. U.S. DOT will also use these same safety concepts in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the service has the requisite performance reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort. For ITS systems with perceived safety benefits, however, the Department will be explicitly involved in developing performance specifications and evaluating safety performance.

This approach is the basis for the Department’s strategy for investing in ITS technologies and systems, and is used to assess the appropriate role for U.S. DOT in the development of the various user services.

7.1 LONGITUDINAL COLLISION AVOIDANCE

7.1.1 Introduction

A longitudinal collision is a two-vehicle collision in which vehicles are moving in essentially parallel paths prior to the collision, or one in which the struck vehicle is stationary. This category includes rear-end, backing and head-on crash-types. In addition, this category could include collisions where objects, pedestrians or animals are struck on the roadway.

Systems providing this service augment the driver's ability to avoid or decrease the severity of longitudinal collisions. The following four types of systems are associated with providing the Longitudinal Collision Avoidance user service:

- Rear-End Crash Warning and Control,
- Adaptive Cruise Control (ACC),
- Head-On Crash Warning and Control, and
- Backing Crash Warning and Control.

The USER for this service, which may be applied in both urban and rural environments, is the vehicle driver. This user service relates directly to the goal of improving safety and the objectives of reducing the number and severity of collisions and the level of resulting fatalities, injuries and societal costs. Longitudinal Collision Avoidance also relates indirectly to goals of enhancing productivity by reducing congestion delays due to crashes of this type, which in turn reduces costs incurred by fleet operators and transportation dependent industries.

7.1.2 Needs

According to data from the GES (General Estimates System) and FARS (Fatal Accident Reporting System) databases, rear-end collisions are the second largest single category of collisions. They represent almost 23% -- or about 1.4 million -- of all collisions in 1991. Although the number is high, crashes of this type accounted for less than five percent of all fatal collisions in that year. Backing collisions account for a much smaller number of such incidents -- only 1.2% of the total and just 0.3% of all fatal collisions. Trucks, especially combination-unit trucks, are from five to more than ten times more likely to be involved in backing collisions than are automobiles. (There is evidence, however, that the number of backing collisions not reported to the police is high, so the actual number of such incidents may be somewhat higher than the databases portray.)

The number of collisions represented by these categories is high, even though the likelihood of such an event being fatal is lower than with other collision categories. Approximately 70% of all rear-end collisions occur when the moving vehicle strikes a decelerating or stationary vehicle in front of it, while in the remaining cases the front vehicle is also moving. In over 90% of these events, either driver inattention and/or following too closely were identified as contributing factors. More than three-quarters of these incidents occur on straight, as opposed to curved, roadways. This situation is dramatically reversed, however, in the case of head-on collisions. These accounted for only 2.5% all collisions, but more than 15% of all fatal crashes, in 1991.

7.1.3 Service Description

The longitudinal collision avoidance service is specifically aimed at providing vehicle operators with assistance in avoiding longitudinal collisions to the front and/or rear of the vehicle. The four types of longitudinal collision avoidance systems will assist the driver by: (1) sensing potential and/or impending collisions or dangers to the front or rear of the vehicle; (2) eliciting proper collision avoidance actions from the driver; and/or (3) providing temporary automatic control of the vehicle to assist the driver in avoiding the potential collision situation.

- Rear-end collision warning: and control would, through driver notification and (possibly) partial vehicle control, help avoid collisions with the rear end of either a stationary or a moving vehicle or object.

- Adaptive Cruise Control (ACC) would allow the driver to select a cruise control feature that tracks the vehicle in front of it and automatically maintains a ‘desired’ spacing between that vehicle and the one traveling in front of it. In more sophisticated systems, leading vehicles would include rearward-looking transponders or other means of transmitting information on vehicle dynamics to a following vehicle. This subservice would allow two or more vehicles to travel in a cooperative platoon on the highway.

- Head-On Collision Warning and Control would detect an impending collision with a vehicle moving in the opposite direction but in the same lane.

- Backing collision warning would detect slow moving or stationary objects, vehicles, livestock, and pedestrians in the path of a vehicle when it is backing.

7.1.4 Operational Concepts

There are many diverse causal factors involved in longitudinal collisions. These include, for example: driver inattention, following too closely, loss of vehicle control, and evasive maneuvers to avoid a sudden collision threat. Given this situation, no single countermeasure concept can cover this multiplicity of potential causal factors. Collision avoidance systems such as those in this user service category include the “three Ps” subsystems of “perceive, process and present”.

7.1.4.1 Rear-End Collision Warning and Control

Rear-end collisions are often associated with maintaining an insufficient distance from the vehicle in front, or failure of the striking vehicle driver to perceive a slowing or stopped vehicle in the roadway ahead. These systems may simply warn drivers, or may incorporate some level of vehicle control. When the system senses a dangerous condition, such as a stationary vehicle on the roadway ahead, the driver is warned. If the driver does nothing, or. is unable to react in sufficient time, automatic vehicle control actions might be initiated to avoid the danger.

Rear-end collision warning systems might be deployable as purely autonomous systems (wholly contained within the vehicle). Advanced systems, however, may require communication between vehicles and perhaps assistance from roadway instrumentation to eliminate path-of-travel ambiguities.

7.1.4.2 Adaptive Cruise Control (ACC)

ACC systems incorporate a cruise control feature that tracks the vehicle in front of it and automatically maintains desired minimum distance from that vehicle. When the minimum distance is maintained, the vehicles travels at the set speed. However, if the distance between the controlled vehicle and the one in front of it falls below the minimum, the system may warn the driver (who must then take action). The system may also initiate control actions (such as throttle closure, downshifting or braking) to slow the vehicle and reestablish the minimum spacing.

Leading vehicles could also include a means of transmitting information on vehicle dynamics to a following vehicle. Two or more vehicles with this capability could travel in a cooperative “platoon” on the highway using basic ACC sensing plus inter-vehicle communications and on-board computer processing. These concepts may also include receiving information from the infrastructure about roadway speed limits, in order to maintain a lawful vehicle speed.

7.1.4.3 Head-On Collision Warning and Control

These systems detect impending collisions with a vehicle moving in the opposite direction that is in the same lane as the vehicle equipped with this system. Head-on collision control must have a complete and accurate picture of the road configuration, adjacent vehicles, roadside hazards, and path alternatives if it is to assume control of the vehicle. Because of the distances at which these systems must operate, they are likely to require vehicle-to-vehicle communications.

7.1.4.4 Backing; Collision Warning and Control

These systems would detect slow moving or stationary objects, animals and pedestrians in the path of a vehicle when it is backing. Because of the generally lower speeds involved in backing movements and the kinds of objects that could be in the backwards path (dogs, children, bicycles), the required range of sensors will be relatively short. For crashes where the backing vehicle strikes or is struck by a vehicle traveling in a perpendicular direction, sensors with longer range will be needed.

7.1.5 Technologies

Given the primary causal factors in head-on, rear-end and backing collisions, there are several promising ITS technologies that could address these situations. An effective collision avoidance system would need to monitor the separation distance and closing rate between vehicles travelling in the same lane, either in the same or opposite direction. The system would then provide the driver with information on potential unsafe conditions and, in case of an immediate danger, would advise the driver of the need for immediate action to avoid an impending crash. Beyond this warning capability, it is also possible that variations of cruise control features which automatically exert partial or full control over the vehicle -- such as throttle closure, transmission downshifting or automatic braking -- may contribute to reducing the number and severity of these collisions.

The specific sensing requirements of the various types of longitudinal warning systems differ substantially, suggesting that different technologies may often be appropriate for different situations. For example, rear-end systems detect changes in relative speed between two vehicles traveling in the same direction, while head-on systems deal with two vehicles approaching each other at very high speeds. In contrast, except for “crossing-path” collisions, backing systems are concerned with detecting immobile or slowly moving objects in the vehicle’s path at a close proximity when the vehicle is traveling backwards at a very slow rate of speed.

Candidate sensor technologies include microwave and millimeter-wave radar, laser radar, and video image processing. Ultrasonic sensors could also be appropriate for some applications. Combining these sensors -- such as radar plus image processing -- into a single system has also been suggested. The sensing capabilities needed for these systems could be cooperative or autonomous, depending on the threat situation and the technologies chosen. Systems which address situations where one vehicle has moved into the lane of an on-coming vehicle (for example, head-on collisions), or the detection of parked vehicles, may need the ability to determine with considerable accuracy the lane position of vehicles within range.

There are a few commercial radar-based headway detection systems currently on the market for rear-end collision avoidance, and several systems based on image processing. Tests have been conducted on cooperative systems using passive transponders on the rear of vehicles. Research is also underway to improve the performance and reduce the cost of all of these sensor types. For example, one problem with some of the early prototype systems was a high false alarm rate, due to signal returns from objects adjacent to the lane of travel (parked cars, guard rails, lamp posts) which pose no collision threat.

7.1.6 Potential Costs and Benefits

7.1.6.1 Potential Costs

The actual cost of these longitudinal collision avoidance systems have not yet been determined, due to the relatively limited capabilities and the small number of systems currently available. However, some commercially-available systems currently cost about $2,500 per unit.

7.1.6.2 Potential Benefits

Recent NHTSA analysis of accident data bases concludes that rear-end collisions are the most common type of accident for automobiles and the second ‘most common type for combination-unit trucks. In fact, about 20 percent of all passenger vehicles and almost one-half of all combination-unit trucks will experience a police-reported crash of this nature at least once during the vehicle’s life, either as the striking or struck vehicle. In addition, nearly 10% of all combination-unit trucks will be in a backing collision during their life. Thus, the potential benefits of enhanced warning and control systems for these types of collision could be significant, particularly for combination-unit trucks. Given the likelihood of such an occurrence, it is fortunate that this collision category has a relatively low fatality rate, compared to other categories.

For head-on collisions, however, the potential benefits could be substantially higher. Even though head-on collisions occur only one-tenth as often as rear-end or backing collisions, the likelihood of a head-on collision leading to a fatality are much higher. In fact, head-on collisions are about thirty times more likely **to** lead to a fatality than are rear-end or backing collisions. Thus, any system that can decrease the number and/or severity of head-on collisions is a prime candidate for further development.

7.1.7 Assessment of Roles

As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS’s potential benefits to the public means that the U.S Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and supporting knowledge bases, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In all cases where highway safety can be improved, U.S. DOT will facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT will ensure that no loss of safety occurs from the deployment of ITS services including those that are not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications for crash avoidance technologies need to be developed for various crash categories. This development will include the identification of the specific causal factors and potential countermeasures for each category. These performance specifications can then be used by product developers as design targets for the systems they are developing. U.S. DOT will also use these same safety concepts in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the systems have the requisite performance, reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort. This approach, which is the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the longitudinal collision avoidance service.

7.1.7.1 Public Benefit

The rear-end collision warning/control system would reduce the number of collisions, injuries and societal costs resulting from one of the most common types of accidents. Thus, the public benefit for these systems is rated HIGH.

The ACC systems are primarily customer convenience features which will also provide some marginal measure of added safety for highway travelers. For this reason, the public benefit is rated MEDIUM.

The head-on collision warning and control system could help reduce the number of fatalities and serious injuries that result from this category of collision. Thus, the public benefit is judged to be HIGH. The number of collisions prevented by backing collision warning and control systems will probably be relatively small. However, many of these collisions will probably involve small children and other pedestrians. Thus, the public benefit of these systems is judged to be MEDIUM.

7.1.7.2 Potential for Private Investment in Development

The market potential for ACC and rear-end collision warning and control systems should be HIGH. Their safety and convenience characteristics should make them attractive to the public. In addition, the fact that they are essentially autonomous from the infrastructure means that they can function on all roadways without additional investments, and drivers can receive benefits even if they are the only vehicles equipped with such systems.

The market potential for the head-on collision warning and control system is somewhat smaller. It would be most useful on rural non-divided roadways. Unless it is a mandated safety feature, these systems may not receive high priority for development. Thus, the potential for private investment is judged to be LOW. Backing collision warning features would be useful for commercial and recreational vehicles, and to a lesser extent for private automobiles. Therefore, the potential for private sector investment in these systems is rated MEDIUM.

7.1.7.3 Non-Federal Public Role in Deployment

Rear-end collision, backing and ACC systems will probably be vehicle-based and function autonomously from the infrastructure. Thus, public sector investment or involvement in deployment will probably be LOW. As long as passive or active infrastructure sensing is not required, these same factors would apply to head-on systems. If such infrastructure sensors are required, then the public role will be MEDIUM.

7.1.7.4 U. S DOT Role in Developing Service

Since these longitudinal collision avoidance systems are safety-related, U.S. DOT involvement is judged to be HIGH. The one exception to this is the Head-On Collision Warning and Control System. Due to the small number of fatal accidents in which two vehicles were involved in a head-on collision -- only 5,215 in 199 1 -- U.S. DOT involvement in this system is judged to be LOW.

In addition, several systems have medium or high public benefit and may have some unique sensor requirements. The Department should sponsor appropriate research and development to develop safety performance specifications, operational tests and evaluation criteria.

A summary of the assessment of roles for these systems is given in Table 7.1-1.

Table 7.1-1 Assessment of Roles for Longitudinal Collision Avoidance Systems

	Public Benefit	Private Investment	Non-Federal Public Role	U.S. DOT Involvement
1. Rear-End Collision Warning and Control	High	High	Low	High
2. Adaptive Cruise Control (ACC)	Medium	High	Low	High
4. Head-On Collision Warning and Control	High	Low	Low/Medium	Low
6. Backing Collision Warning and Control	Medium	Medium	Low	High

7.1.8 Milestones and Activities

Figure 7.1-2 is a Gantt chart depicting the key tasks, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt charts. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

User Service 7.1 -- Longitudinal Collision Avoidance

7.1.8.1 Issues

1. From industry perspective, can marketable products be developed that have a reasonable prospect for commercial success?

2. From Government perspective, can effective products be developed that provide societal benefits at affordable cost?

3. From both perspectives, in what time frame can a technically feasible solution be produced?

4. To what extent will implementation impact highway capacity?

5. Is product liability a possible barrier to private sector investment? How might it be overcome?

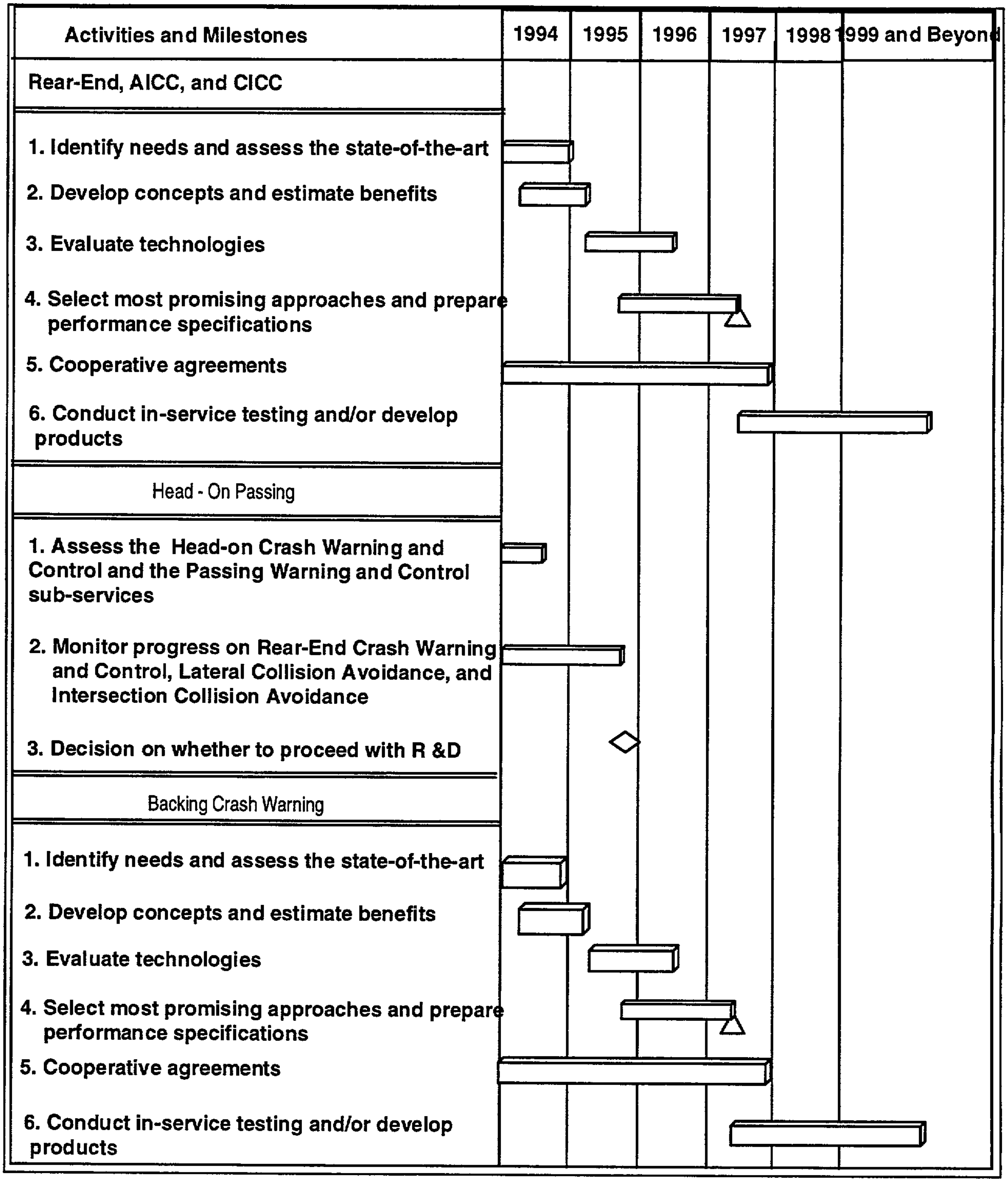

Figure 7.1-2 Gantt Chart

7.1.8.2 Activities

Rear-End Crash Warning and Control. AICC. and CICC

1. Identify needs and assess the state-of-the-art

   - NHTSA is conducting an accident analysis through Volpe National Transportation Systems Center (VNTSC) project "Problem Definition and Analysis of Target Crashes and ITS/Countermeasure Action." (1991 - 1994)

   - NHTSA is funding a contract with Frontier Engineering which includes a task to assess available systems. (1993 - 1994)

2. Develop concepts and estimate benefits

   - NHTSA is funding a contract with Frontier Engineering which includes a task to identify countermeasure concepts. This task includes modeling, human factors, simulations, and simulator use. (1994 - 1995)

3. Evaluate technologies

   - NHTSA is funding a contract with Frontier Engineering which includes a task to evaluate technologies that are available for implementing the concepts. This task will include estimation of costs. (1995)

4. Select most promising approaches and prepare performance specifications

   - NHTSA is funding a contract with Frontier Engineering which includes a task to test and evaluate advanced system concepts. Three levels of driver interaction (i.e., situation displays, crash warnings, and control) will be considered in the advanced concepts. This task concludes with recommendations on which concepts are most feasible to be pursued. Performance specifications will be prepared for the recommended concepts. (1995 - 1997)

   - The milestone concluding this task is the availability of performance specifications for the recommended concepts.

5. Cooperative agreements

   - Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing.

6. Conduct in-service testing and/or develop products

- Per the recommendations made in task 4, in-service testing and/or other product development will be pursued.

Backing Crash Warning

1. Identify needs and assess the state-of-the-art

- NHTSA is conducting an accident analysis through VNTSC project "Problem Definition and Analysis of Target Crashes and ITS/Countermeasure Action." (199 1 - 1994)

- NHTSA is funding a contract with TRW which includes a task to assess available systems. (1993 - 1994)

2. Develop concepts and estimate benefits

- NHTSA is funding a contract with TRW which includes a task to identify countermeasure concepts. This task includes modeling, human factors, simulations, and simulator use. (1994 - 1995)

3. Evaluate technologies

- NHTSA is funding a contract with TRW which includes a task to evaluate technologies that are available for implementing the concepts. This task will include estimation of costs. (1995)

4. Select most promising approaches and prepare performance specifications

- NHTSA is funding a contract with TRW which includes a task to test and evaluate advanced system concepts. Three levels of driver interaction (i.e., situation displays, crash warnings, and control) will be considered in the advanced concepts. This task concludes with recommendations on which concepts are most feasible to be pursued. Performance specifications will be prepared for the recommended concepts. (1996 - 1997)

- The milestone concluding this task is the availability of performance specifications for the recommended concepts.

5. Cooperative agreements

   - Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing.

6. Conduct in-service testing and/or develop products

   - Per the recommendations made in task 4, in-service testing and/or other product development will be pursued.

<u>Head-On Crash Warning: and Control and Passing: Warning and Control</u>

1. Identify needs and assess the state-of-the-art

   - NHTSA is conducting an accident analysis through VNTSC project "Problem Definition and Analysis of Target Crashes and ITS/Countermeasure Action." (1991 - 1994)

2. Monitor progress on Rear-End Crash Warning and Control, Lateral Collision Avoidance, and Intersection Crash Warning and Control

   - NHTSA will assess the dimensions of Head-On Crash Warning and Control and of Passing Warning and Control. NHTSA will monitor the progress on Rear-End Crash Warning and Control and on user services 22 and 23.

3. Decision on whether to proceed with R&D

   - If the decision is made to proceed, NHTSA will establish an R&D activity to assess the technical and economic feasibility of the Head-On Crash Warning and Control and the Passing Warning and Control sub-services, beginning in late 1995.

7.2 LATERAL COLLISION AVOIDANCE

7.2.1 Introduction

The Lateral Collision Avoidance (LCA) systems augment the driver's ability to avoid collisions that arise when a vehicle leaves its own lane of travel while moving in a forward direction. Such collisions can involve one or by providing warnings and/or assuming temporary control of the vehicle if a crash situation is imminent.

Two types of subservices are associated with providing the LCA user service:

- Lane Change/Blind Spot Situation Display, Collision Warning, and Control
- Lane/Road Departure Warning and Control.

The USER for this service, which may be applied in both urban and rural environments, is the vehicle driver. The LCA service relates directly to the goal of improving safety and the objectives of reducing the number and severity of accidents, as well as the number of fatalities and injuries. This service also relates indirectly to goals of enhancing productivity by reducing costs incurred by fleet operators and reducing costs to transportation dependent industries.

7.2.2 Needs

Lateral collisions are those resulting from a vehicle leaving, or attempting to leave, its own lane of travel while moving in a forward direction. Examples include single vehicle roadway departures (SVRD) and lane change/merge (LCM) collisions. Together, these represent a significant highway safety problem. Preliminary estimates based on 1991 data from the GES (General Estimates System) and FARS (Fatal Accident Reporting System) databases suggest that this category of collisions represents about 32% -- or almost 2 million -- of all vehicle collisions and more than 40% -- or 16,000 -- of all motor vehicle fatalities in that year.

Most SVRD collisions occur in non-urban areas, on straight and level roadways, and during normal weather conditions; 45% of all single-vehicle hit-fixed object fatalities occur on curves. Approximately one-half of these events occur during non-daylight hours. Recent studies suggest that in at least 75% of LCM collisions, the driver of the merging vehicle did not see the other vehicle until a collision with it was unavoidable. Ninety-five percent of LCM collisions are angle or sideswipe collisions, with the remainder being rear-end collisions. It is believed that a large portion of both SVRD and LCM incidents are amenable to reduction or even elimination by the application of ITS technologies.

7.2.3 Service Description

The Lateral Collision Avoidance service is specifically aimed at augmenting the vehicle operator's ability to avoid collisions by first providing information, and second, if a crash situation is imminent, providing warnings and/or assuming temporary control of the vehicle. The service will produce a reduction in the number and severity of lateral collisions that occur.

- Lane Change/Blind Spot Situation Display Collision Warning and Control would provide information about the presence of vehicles in the driver's blind spots, actively warn of potential collisions due to lane change or merging activities, and ultimately, assume temporary control of vehicle steering, braking and/or throttle actions to avoid collisions.

- Lane/Road Departure Warning and Control would assist in maintaining the vehicle in its proper lane of travel through driver warnings, advice on necessary actions, and eventually, assuming temporary control of vehicle steering and throttle to avoid a lane/road departure incident.

7.2.4 Operational Concepts

There are numerous and diverse causal factors involved in lateral collisions, depending on the specific situation and collision type. These factors include: driver intoxication, inattention or fatigue; slippery roads; excessive speed or reckless driving; blind spots in the driver's field of vision; evasive maneuvers to avoid another collision threat; and vehicle component failure. Given this situation, no single countermeasure concept can cover this multiplicity of potential causal factors.

Collision avoidance systems such as those in this user service category include the "three Ps" subsystems of "perceive, process and present".

7.2.4.1 Lane Change/Blind Snot Situation Display Collision Warning: and Control

The systems that provide this subservice incorporate three implementations or stages. At the first stage, drivers are continuously provided information about the presence of vehicles in the driver's blind spots (to the right-rear and left-rear sides of the vehicle). At the second stage, the driver is actively warned of potential collisions due to lane change or merging activities initiated by the vehicle upon which the sensor is mounted. This would be activated, for example, by the driver showing an intended lane change by using the turn signal. At the final stage, the system implements automatic control of vehicle systems such as acceleration, braking and steering.

One example of this type of system consists of a red light mounted inside the vehicle on the line of sight to the side view mirror. The light illuminates when another vehicle is in the driver's blind spot. Sensors will be primarily vehicle-autonomous, but may include exceptions such as transmitters on all vehicles that indicate when a lane change is being initiated or when a collision is imminent. Advanced versions of this system may include vehciel-to-vehicle communications, such as a vehicle about to change lanes issuing an electronic notification of that intent to adjacent vehicles.

7.2.4.2 Lane/Road Departure Warning and Control

Driver warning systems may indicate an impending road departure, based on road/lane edge detection capabilities. They may also provide advice on necessary actions. In addition, systems that provide partial control for lane keeping could include automatic control of the vehicle's steering, with manual override. In advanced versions of this capability, fully automatic lateral control of the vehicle's steering and throttle may be exerted to disallow dangerous movements from being made or to take evasive action to avoid making a dangerous maneuver. This capability would be a necessary component of any Automated Highway System (AHS).

7.2.5 Technologies

There are a number of technological concepts within the national IVHS program which could make a positive contribution to enhanced lateral collision avoidance. Among the concepts that may prove most useful are: road/lane edge, longitudinal, blind-spot and near-proximity detection systems; drowsy driver and other driver status warning systems; road speed and condition warning systems; and vehicle status monitors.

In the case of the Lane Change/Blind Spot Situation Display, Collision Warning and Control system, also known as "lateral encroachment", sensors are necessary **to** detect vehicles which are either in, or rapidly approaching, the two zones along and behind either side of the vehicle, corresponding to the driver's blind spots. Ultrasonic, radar and video technologies have been used for commercially-available Proximity Detection Systems (PDSs) which could cover these blind spots, and a number of companies are currently marketing such systems. Most of the available ultrasound detectors operate **in** the 40 to 50 KHz frequency range, while the radar systems are microwave (less than 30 GHz).

Ultrasonic systems, when compared to radar, have the advantages of lower cost. However, ultrasonic detectors are more vulnerable to environmental conditions -- such as wind noise, temperature and precipitation -- than is radar. NHTSA has recently assessed the performance and human factors characteristics of a number of these commercial systems for use in heavy trucks.

For the Lane/Road Departure Warning and Control systems, road/lane edge detecting can be accomplished by either vehicle-based or cooperative vehicle-infrastructure technologies. Vehicle-based components could utilize video image processing, optical scanning or infrared laser scanning techniques. These sensors might be enhanced by "passive" infrastructure features such as painted lines along the road/lane boundaries.

Vehicle-infrastructure concepts could also be more complex, such as vehicle-based radar units and reflectors mounted along the road/lane edge, or coded magnetic array systems utilizing magnets or induction loops embedded in the road lane. The California PATH system, for example, utilizes magnetic nails in the center of the road lane which are read by sensors in the vehicle bumpers. Active lane boundary indicators or markers of certain road features are another possible method of sensor enhancement. For example, a roadside beacon may transmit information about the geometry and speed limit of an upcoming curve to passing vehicles. In all of these situations, care should be taken to assure that adverse weather conditions, such as ice or snow buildup, would not adversely affect these systems.

Regardless of the technological approach chosen, lateral systems should include a method for detecting true pre-collision incidents, as opposed to normal lane deviations. One approach to making this type of determination is to combine information about the state of the vehicle (speed, suspension and tire characteristics); the state of the driver (drowsy, inattentive, intoxicated); the state of the roadway (traction coefficient, radius of curvature); potential threats from surrounding vehicles; and driver responses to all of these conditions. Roadway information may be supplied by such devices as an on-vehicle sensor of traction coefficient, a digitized map of the road which contains details such as radius of curvature, or a video image processing system with a forward-looking capability.

7.2.6 Potential Costs and Benefits

7.2.6.1 Potential Costs

The actual cost of these LCA systems have not yet been determined, due to the relatively limited capabilities and the small number of systems currently available. Some of the commercially-available proximity detection systems, currently range in price from about $400 to $2,000 per unit, depending on the technology used.

7.2.6.2 Potential Benefits

Recent NHTSA analysis of accident data bases suggests that single vehicle roadway departures, the most prevalent form of lateral collisions, are one of the most common forms of accident. In fact, about 10% of all passenger vehicles and over one-fourth of all combination-unit trucks will experience an SVRD accident at least once during the vehicle's life. This is, in fact, the single most common type of accident for combination-unit trucks, and the second most common type for passenger vehicles. In addition, over fifteen percent of all trucks can expect to have an LCM collision during their life span, compared to about two percent of automobiles. Thus, the potential benefits of enhanced warning and control systems for this type of collision could be significant, particularly for combination-unit trucks.

7.2.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant potential opportunities for achieving improvements in highway safety and reductions in collision-caused congestion and vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS's potential benefits to the public means that the U.S. Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and supporting knowledge bases, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In all cases where highway safety can be improved, U.S. DOT will facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT will ensure that no loss of safety occurs from the deployment of ITS services, including those that are not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications need to be developed for countermeasure systems for various crash categories. This development will include the identification of the specific causal factors and potential countermeasures for each category. These performance specifications can then be used by product developers as design targets for the systems they are developing. U.S. DOT will also use these same safety concepts in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the systems have the requisite performance, reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort.

This approach, which is the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the Lateral Collision Avoidance service.

7.2.7.1 Public Benefit

The road departure systems address a very injurious type of collision -- SVRD -- which accounts for over 40% of all motor vehicle fatalities, and offers the potential for substantial reductions in the number of injuries and fatalities. The lane change/blind spot systems deal with a type of collision with a lower fatality rate, but which has significant potential to cause traffic backups and congestion when it does occur. The public benefit of both services is therefore rated as HIGH.

7.2.7.2 Potential for Private Investment in Development

Manufacturers see both potential benefits and potential marketability in these systems, as evidenced by the number which are already available. One recent study identified at least thirteen ultrasound, microwave or video proximity detector systems and proximity sensors now commercially available from as many different vendors. Therefore, the potential for private sector investment is rated as HIGH.

7.2.7.3 Non-Federal Public Role in Deployment

Unless infrastructure changes are involved, the public role in deployment of this service is judged to be LOW.

7.2.7.4 U.S. DOT Role in Developing Service

The lateral collision avoidance service is a representative example of a service with a high public benefit in the area of safety. Thus, U.S. DOT should sponsor appropriate research and development to develop safety performance specifications, operational test and evaluation criteria, and deployment guidelines for such systems. U.S. DOT involvement in this service is judged to be HIGH.

A summary of the assessment of roles for these systems is given in Table 7.2-l.

Table 7.2-l -- Assessment of Roles for Lateral Collision Avoidance Systems

	Public Benefit	Private Investment	Non-Federal Public Role	U.S. DOT Involvement
1. Lane Change/Blind Spot Situation Display, Collision Warning and Control	High	High	Low	High
2. Road Departure Warning and Control	High	High	Low	High

7.2.8 Milestones and Activities

Figure 7.2-2 is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

7.2.8.1 Issues:

1. From industry perspective, can marketable products be developed that have a reasonable prospect for commercial success?

2. From Government perspective, can effective products be developed that provide societal benefits at affordable cost?

3. From both perspectives, in what time frame can a technically feasible solution be produced?

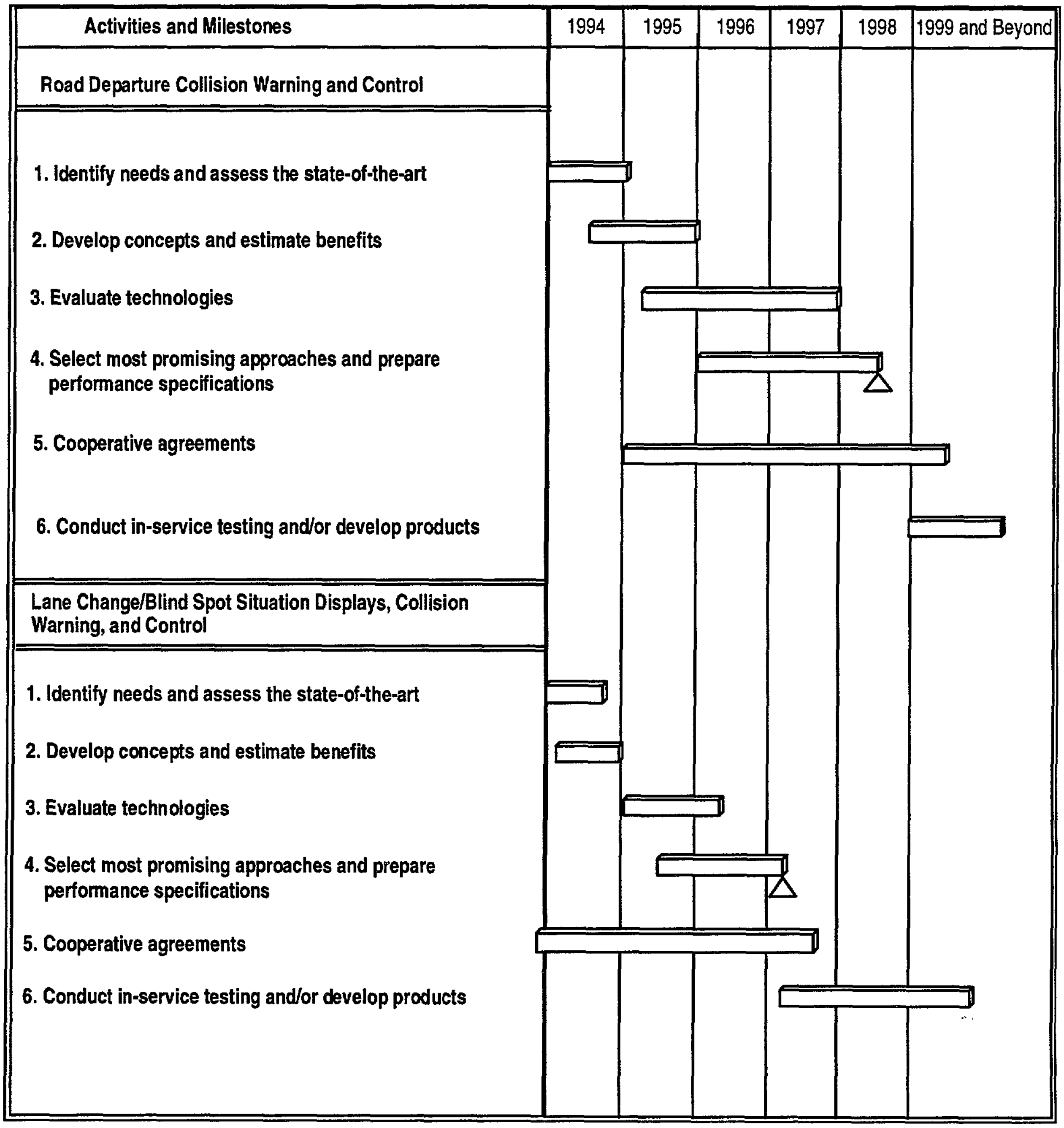

Figure 7.2-2 Gantt Chart
User Service 7.2 -- Lateral Collision Avoidance

7.2.8.2 Activities

Lane Change/Blind Snot Situation Displays. Collision Warning. and Control

1. Identify needs and assess the state-of-the-art

   - NHTSA is conducting an accident analysis through VNTSC project "Problem Definition and Analysis of Target Crashes and IVHS/Counermeasure Action." (1991 - 1994)

   - NHTSA is funding a contract with TRW which includes a task to assess available systems. (1993 - 1994)

2. Develop concepts and estimate benefits

   - NHTSA is funding a contract with TRW which includes a task to identify countermeasure concepts. This task includes modeling, human factors, simulations, and simulator use. (1994 - 1995)

3. Evaluate technologies

   - NHTSA **is** funding a contract with TRW which includes a task to evaluate technologies that are available for implementing the concepts. This task will include estimation of costs. (1995- 1996)

4. Select most promising approaches and prepare performance specifications

   - NHTSA is funding a contract with TRW which includes a task to test and evaluate advanced system concepts. Three levels of driver interaction (i.e., situation displays, crash warnings, and control) will be considered in the advanced concepts. This task concludes with recommendations on which concepts are most feasible to be pursued. Performance specifications will be prepared for the recommended concepts. (1995 - 1997)

   - The milestone concluding this task is the availability of performance specifications for the recommended concepts.

5. Cooperative agreements

   - Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing.

6. Conduct in-service testing and/or develop products

   - Per the recommendations made in task 4, in-service testing and/or other product development will be pursued.

Road Departure Warning. and Control

1. Identify needs and assess the state-of-the-art

   - NHTSA is conducting an accident analysis through VNTSC project "Problem Definition and Analysis of Target Crashes and IVHS/Countermeasure Action." (1991 - 1994)

   - NHTSA has a contract with Carnegie Mellon University that includes a task to assess available systems. (1993 - 1994)

2. Develop concepts and estimate benefits

   - NHTSA has a contract with Carnegie Mellon University that includes a task to identify countermeasure concepts. This task will include modeling, human factors, simulations, and simulator use. (1994 - 1995)

3. Evaluate technologies

   - NHTSA has a contract with Carnegie Mellon University that includes a task to evaluate technologies that are available for implementing the concepts. This task will include estimation of costs. (1995 - 1997)

4. Select most promising approaches and prepare performance specifications

   - NHTSA has a contract with Carnegie Mellon University that includes a task to test and evaluate advanced system concepts. Three levels of driver interaction (i.e., situation displays, crash warnings, and control) will be considered in the advanced concepts. This task concludes with recommendations on which concepts are most feasible to be pursued. Performance specifications will be prepared for the recommended concepts. (1996 - 1998)

   - The milestone concluding this task is the availability of performance specifications for the recommended concepts.

5. Cooperative agreements

- Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing.

6. Conduct in-service testing and/or develop products

. Per the recommendations made in task 4, in-service testing and/or other product development will be pursued.

7.3 INTERSECTION COLLISION AVOIDANCE

7.3.1 Introduction

The Intersection Collision Avoidance (ICA) User Service systems will augment driver capabilities to avoid or decrease the severity of collisions that occur at intersections.

The USER for this service, which may be applied in both urban and rural environments, is the vehicle driver. The ICA service relates directly to the goal of improving safety and the objectives of reducing the number and severity of accidents, as well as the number of fatalities and injuries. This service also relates indirectly to goals of enhancing productivity by reducing costs incurred by fleet operators and reducing costs to transportation dependent industries.

7.3.2 Needs

The high number of both total and fatal incidents represented by intersection collisions make this category a prime candidate for amelioration through the application of ITS technologies. According to data from the GES (General Estimates System) and FARS (Fatal Accident Reporting System) databases, intersection collisions are the third largest single category of collisions, representing almost 22% -- or over 1.3 million -- of all such events in 1991. (Single vehicle roadway departures and rear-end collisions are the first and second most common crash categories). Intersection collisions also accounted for almost 24% -- or nearly 9,000 -- of all fatal collisions in that year. More than one-third of these fatal incidents occurred at intersections with no traffic control device, such as a stop sign or signal light. Crossing path collisions at intersections account for about one-eighth of all fatalities and represent 29.5 percent of all crashes. Thus, this is the largest crash problem in terms of number of police-reported crashes.

Two of the most common types of intersection collisions are straight crossing path (SCP) and crossing left turn (CLT). SCP collisions occur when two vehicles are both attempting simultaneously to pass straight through an intersection at right angles. In CLT incidents, one vehicle is attempting to turn left across the path of the second vehicle. The ICA service provides countermeasures to reduce both of these collision types.

7.3.3 Service Description

The intersection collision warning and control service is specifically aimed at providing vehicle operators with assistance in avoiding collisions at intersections. The situations addressed include those that arise when vehicles improperly violate the right-of-way of another vehicle, or when the right-of-way is not clear. The service will provide warnings of imminent collisions with crossing traffic, as well as warnings of stop control -- either a stop sign or a traffic signal -- in the intersection ahead.

There are many diverse causal factors involved in intersection collisions. Among the most common of these are driver inattention, failure to obey traffic control devices (red signal indications and stop signs), attempting to beat the yellow phase of traffic signals, proceeding against cross traffic due to faulty perception and obstructed view, and driver intoxication. A variety of countermeasures may be devised depending on both crash type (SCP, CLT or other) and intersection traffic control type (signalized, stop signs, and uncontrolled).

7.3.4 Operational Concepts

The function of this service is to track the position and state of vehicles within a defined area surrounding an intersection. The systems may involve infrastructure-to-vehicle and/or vehicle-to-vehicle communications. For example, if a vehicle is waiting to cross a high-speed roadway, the driver of the crossing vehicle could be alerted when there is high speed traffic approaching. In turn, once a vehicle begins crossing the intersection, the other vehicles could be warned and/or controlled to avoid a possible collision.
One important operational approach is the Cooperative Intersection Collision Avoidance System, or CICAS. This system would include both vehicle-to-vehicle and vehicle-to-infrastructure links, incorporating both one-way and two-way communications. These communications technologies would provide various coverage zones and ranges. Several media can be used for this purpose, including spread spectrum, microwave, millimeter wave, and infrared.

A type of vehicle-based countermeasure for SCP collisions could utilize video and digital image processing to recognize traffic signs and signals and advise or warn the driver to stop the vehicle before it encroaches into the intersection in an unsafe manner. This concept could be integrated with the In-Vehicle Signing subservice, which is part of the En Route Driver Information user service (see User Service Plan 1.2). In addition, several systems developed primarily for other collision categories, such as headway detection systems, **may** also be useful in intersection collision situations. For additional information on HDS, please refer to Longitudinal Collision Avoidance (see User Service Plan 7.1).

7.3.5 Technologies

The specific requirements of the various types of systems differ substantially, suggesting that different technologies may be appropriate for different situations. Several technologies may need to be integrated to allow the potential of this service to be fully achieved. Decision-making algorithms which rely on both knowledge-based information and sensor signal processing are needed. Artificial intelligence technologies, such as adaptive neural networks or fuzzy logic, may be employed. In addition, the system logic needs to be able to determine whether, for example, a driver is slowing down appropriately to a safe stop, or whether the driver is initiating a potentially dangerous left turn against fast-approaching traffic.

Global Positioning Satellite (GPS) navigation systems may be used on-board a vehicle to determine its position relative to the intersection zone and other similarly-equipped vehicles. Given the existing accuracy of GPS signals, however (plus or minus 10 feet) the resolution and accuracy needed for collision avoidance capabilities is lacking in GPS alone. There may be cheaper and more accurate concepts for determining vehicle location, such as roadway and in-vehicle sensors, to detect possible impending problems.

In one of the less sophisticated ICAS concepts, roadside transmitters/beacons at the entrance to intersection zones will transmit (one-way) information on the traffic signal status at the intersection to approaching vehicles. In a related and more elaborate concept, two-way communications is established between vehicles entering an intersection zone and that zone's local area network. A roadside processor will manage communications, control the data processing, and track all vehicles in the network. Ultimately, this system could inform left-turning drivers of any other vehicles that might cross the turning vehicle's path. Regardless of the level of technology, deployed ICMS must be prompt in delivering information, highly reliable, and able to adapt to varying conditions.

There are two potentially different types of sensors which could be used for the intersection services. The first of these would be autonomous to the vehicle, and would conceivably involve direct vehicle-to-vehicle sensing. The second incorporates interaction with the infrastructure. One class of this vehicle-to-infrastructure sensing could rely primarily upon vehicle-to-vehicle sensing using intersection or other third point location relays or communication links, while a second class could involve the vehicle motions and position activation of intersection controls similar to sensing-type traffic lights. Any autonomous system would probably resemble sensors described in other sections of this report. In particular, please refer to Longitudinal Collision Avoidance (see User Service Plan 7.1) and Lateral Collision Avoidance (see User Service Plan 7.2).

Candidate sensor technologies include Global Positioning System (GPS) satellite location sensing, microwave and millimeter-wave radar, laser radar, and video image processing. Another alternative is to provide a vehicle with information about its distance from an intersection at a specified distance from that intersection. This information can be transmitted to the vehicle via radio waves or embedded magnets in the roadway. The vehicle odometer can then be used to determine continually the distance between the vehicle and the intersection. Research is underway to improve all of these technology areas. Combinations of these technologies -- such as radar plus image processing -- into a single system have also been suggested.

Several processing technologies will need to be integrated into the final service to enable its full potential to be achieved. For example, neural networks (or their equivalent) could be used to interpret sensor data to differentiate one potential intersection collision condition from another. One vehicle approaching the intersection too fast is a different collision condition, and would probably require a different response, than would the situation of two vehicles heading toward the intersection at reasonable speeds. A device currently under development to characterize the vehicle motion environment is also a candidate for this application.

7.3.6 Potential Costs and Benefits

7.3.6.1 Potential Costs

In 1990, there were nearly 193 million registered motor vehicles in the United States, of which 143 million were automobiles. Approximately 10 million new passenger vehicles are sold in the U.S. each year. If all, or a substantial proportion, of these vehicles included Intersection Collision Avoidance systems, the total monetary costs could be substantial. The actual cost of these systems, however, has not yet been determined.

7.3.6.2 Potential Benefits

Recent NHTSA analysis of accident data bases suggests that intersection collisions are among the most common forms of accident. In fact, nearly one-quarter of all collisions, including those resulting in fatalities, occur at intersections. Since the potential benefits of enhanced warning and control systems for these types of collision could be significant, any Intersection Collision Avoidance system that can decrease the number and/or severity of these collisions is a prime candidate for further development. An additional benefit that can be derived from deploying such a system is a reduction in traffic delay and congestion.

7.3.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant potential opportunities for achieving improvements in highway safety and reductions in collision-caused congestion and vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS's potential benefits to the public means that the U.S. Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its **own** mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and supporting knowledge bases, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds may be available to state and local governments to help pay for the deployment of ITS services.

In all cases where highway safety can be improved, U.S. DOT will facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT will ensure that no loss of safety occurs from the deployment of ITS services, including those that are not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications for crash avoidance systems and technologies need to be developed for various crash categories. This development will enable the identification of the specific causal factors and potential countermeasures for each category. These performance specifications can then be used by product developers as design targets for the systems they are developing. U.S. DOT will also use these same safety concepts in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the systems have the requisite performance, reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort.

This approach, which is the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the Intersection Collision Avoidance service.

7.3.7.1 Public Benefit

This user service addresses one of the most common and deadliest categories of accidents, those that occur at intersections. Thus, the public benefit for this service is rated HIGH.

7.3.7.2 Potential for Private Investment in Development

This service may require significant infrastructure investment, particularly if roadside beacons, transmitters, sensors and/or processors are involved. Additionally, the service may need to be designed as a capability that is integrated with other vehicle-warning devices and perhaps other IVHS services as well. The market for the infrastructure equipment will be state and local governments responsible for traffic management, while private individuals and fleet owners will purchase vehicles with IVHS systems and equipment. Thus, the likelihood of near-term private investment in the development of these systems is projected to be LOW due to the complexity and need for parallel development of both in-vehicle and infrastructure support capabilities.

7.3.7.3 Non-Federal Public Role in Deployment

As described above, the public role in deploying the infrastructure segments of this service is vital to the success of the vehicle-infrastructure systems. Thus, the non-federal public role in these systems is rated HIGH. For in-vehicle systems, the non-federal public role would be LOW.

7.3.7.4 U.S. DOT Role in Developing Service

Due to the significant number of fatal crashes in this collision category, the Intersection Collision Avoidance service has a very high safety impact. At the same time, however, the anticipated level of private investment is low, while the need for non-federal public involvement could be quite high. Thus, U.S. DOT involvement in the development and deployment of this service is judged to be HIGH. The Department could both encourage and/or conduct research into promising concepts which lack private backing, and could assist state and local governments in the infrastructure-based segments of this service. Given the high safety impact of this service, the Department should also sponsor appropriate research and development to develop safety performance specifications, operational test and evaluation criteria, and deployment guidelines.

A summary of the assessment of roles for these systems is given in Table 7.3-l.

Table 7.3-l Assessment of Roles for Intersection Collision Avoidance Systems

	Public Benefit	Private Investment	Non-Federal Public Role	U.S. DOT Involvement
1. Vehicle-Infrastructure Systems	High	Low	High	High
2. In-Vehicle Systems	High	Low	Low	High

7.3.8 Milestones and Activities

Figure 7.3-2 is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

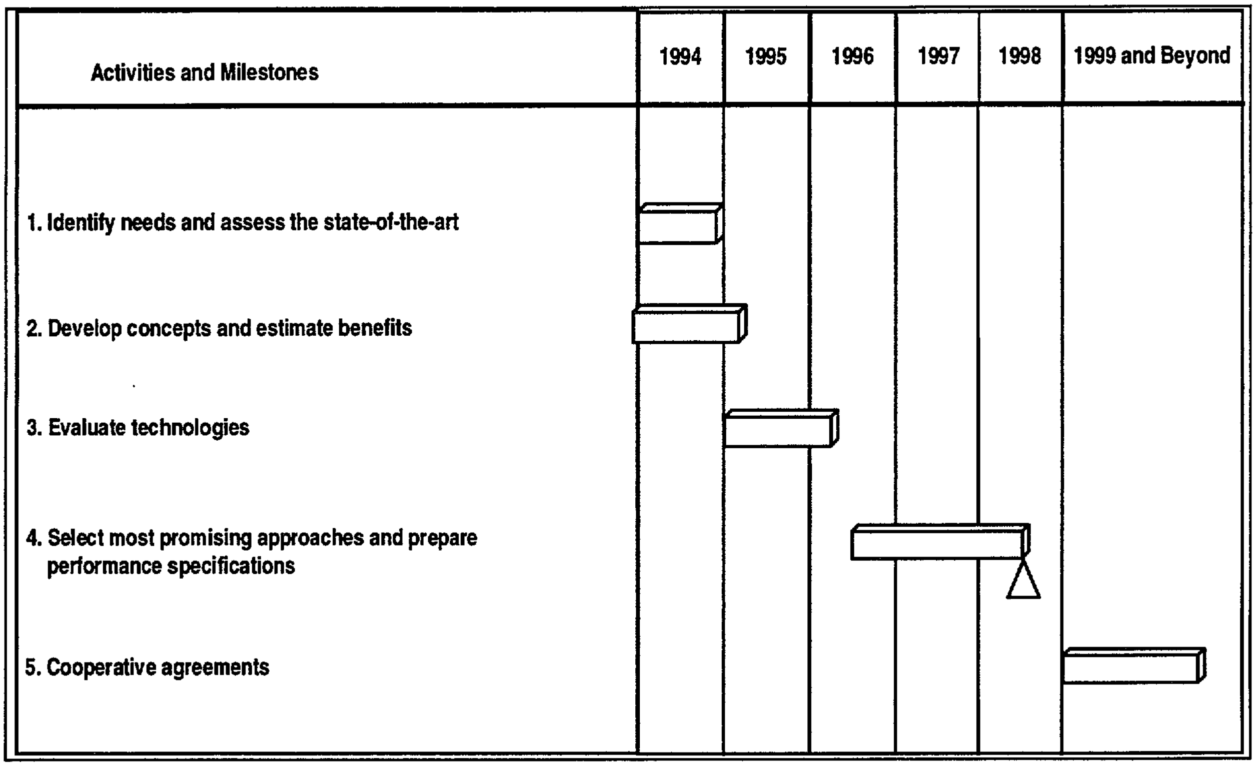

Figure 7.3-2 Gantt Chart

7.3.8.1 Issues:

1. From industry perspective, can marketable products be developed that have a reasonable prospect for commercial success?

2. From Government perspective, can effective products be developed that provide societal benefits at affordable cost?

3. From both perspectives, in what time frame can a technically feasible solution be produced?

7.3.8.2 Activities:

1. Identify needs and assess the state-of-the-art

   - NHTSA is conducting an accident analysis through VNTSC project "Problem Definition and Analysis of Target Crashes and IVHS/Countermeasure Action." (1991 - 1994)

   - NHTSA is funding a cooperative agreement with the University of Michigan Transportation Research Institute and the Environmental Research Institute of Michigan to develop a data gathering device that can help characterize the vehicle motion environment (VME). This equipment can be useful in assessing positions, velocities, and yaw angles of vehicles in the vicinity of intersections (1993-1994)

   - NHTSA is funding a contract to the CALSPAN Corporation which includes a task to provide additional problem definition (1993-1994)

2. Develop concepts and estimate benefits

   - NHTSA is funding the above contract which includes a task to identify countermeasure concepts. (1993 - 1995)

3. Evaluate technologies

   - NHTSA is funding the above contract which includes a task to evaluate technologies that are available for implementing the concepts. This task will include estimation of costs. (19951996)

4. Select most promising approaches and prepare performance specifications

   - NHTSA is funding the above contract which includes a task to test and evaluate advanced system concepts. Three levels of driver interaction (i.e., situation displays, crash warnings, and control) will be considered in the advanced concepts. This task concludes with recommendations on which concepts are most feasible to be pursued. Performance specifications will be prepared for the recommended concepts. (1996 - 1998)

   - The milestone concluding this task is the availability of performance specifications for the recommended concepts.

5. Cooperative agreements

- Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing. Specific agreements have not yet been identified (1999 -)

7.4 VISION ENHANCEMENT FOR CRASH AVOIDANCE

7.4.1 Introduction

The Vision Enhancement for Collision Avoidance user service will reduce the number and severity of collisions in which impaired or reduced visibility is a causal factor. Systems that provide this service will augment visually-acquired information in situations where driving visibility is low (such as night or foggy conditions). This service does not deal with overcoming obstructions to visibility or blind spots caused by the vehicle's body, and it does not deal with conspicuity enhancement of roadways or objects. The Longitudinal, Lateral and Intersection Collision Avoidance user services address other approaches to collision avoidance (see User Service Plans 7-1, 7-2 and 7-3).

The USER for this service, which may be applied in both urban and rural environments, is the vehicle driver. This user service relates directly to the goal of improving safety and the objectives of reducing the number and severity of accidents, as well as the number of fatalities and injuries. This service also relates indirectly to goals of enhancing productivity by reducing costs incurred by fleet operators and reducing costs to transportation dependent industries.

7.4.2 Needs

According to preliminary estimates based on 1991 data from the Fatal Accident Reporting System (FARS) and General Estimates System (GES) databases, approximately 772,000 collisions, or 12.6% of all collisions in that year, occurred during foggy or dark (unlighted) conditions. However, a much higher proportion of fatal collisions -- 12,452 out of 36,895, or 33.7% -- occurred in these conditions. Nearly one-half of all pedestrian fatalities -- 2,599 out of 5,797 in 1991 -- occurred between the hours of 6 pm and 12 midnight. The high level of fatalities associated with this category of collisions represents a significant highway safety problem.

7.4.3 Service Description

The Vision Enhancement for Collision Avoidance user service can reduce the number of vehicle crashes that occur during periods of poor visibility. The focus of this effort is on systems that can improve the ability of the driver to perceive the roadway itself and objects on and along the roadway. This improved visibility would allow the driver to avoid potential collisions with other vehicles, fences and railings, pedestrians, wildlife and livestock, or obstacles in the line of travel; and would assist the driver in complying with traffic signals and signs.

7.4.4 Operational Concepts

This service would be implemented through in-vehicle sensors capable of imaging the outside scene and producing a graphical display of the image, perhaps through a Head-Up Display that overlays the image on the out-the-windshield view. Both active and passive technologies may be applied to improve the driver's perceptual abilities during inclement weather or unlit conditions by transforming detected energies into a visual display that the driver can observe. Passive systems detect energy radiated by all objects without any system-generated illumination. For instance, passive far infrared (FIR) systems form images of the environment based on identifying differences in thermal energy intensity emanating from different objects. Passive millimeter-wave systems construct images based on an object's natural emissions at millimeter-wave frequencies, independent of light conditions.

Active detection systems, on the other hand, need to illuminate the environment in order to obtain images of obstacles based on their reflection of the emitted energy. For example, active radar and laser radar (also known as lidar or light detection and ranging) can be used to form images by scanning the environment in both the azimuth and elevation directions. In addition, regular charge-coupled device (CCD) cameras may be employed for visual enhancement when an external light source is used to extend their visibility band.

7.4.5 Technologies

The most promising current technological application that could improve the driver's perceptual abilities is Infrared Imagers, also known as IRIs or thermal imagers. These systems detect the infrared energy radiated by all warm objects, and transform that energy into a visual display which the driver can then observe. One of the most striking advantages of IRIs is that no light source is needed. Thus, the driver can obtain an infrared image of the line of travel ahead without the need for headlights or street illumination. However, it should be remembered that infrared systems are based on identifying differences in infrared energy intensity (as opposed to visible light) emanating from different objects. Thus, they should be used as a supplement to visual perception, and not as a total replacement for it.

Most infrared imagers use detectors to gather information about the infrared energy levels and then process this information into a form that can be visually displayed. The earliest IR systems included an electro-optical multiplexer, or E-O MUX, which used light-emitting diodes (LEDs) to reformat (i.e., process) the data and transmit it via a TV camera to a monitor, which displayed the data to the viewer. More recent systems have replaced the E-O MUX with solid state components.

The more complex and sensitive IR systems, such as forward-looking infrared (FLIRs) for the military, require that the detector arrays be cooled to extremely low temperatures. However, an uncooled FLIR system for motor vehicles has been built and demonstrated. This system provides drivers with nighttime visibility of objects and lane markings in the line of travel at a range up to three times greater than that available from headlights alone.

The high demand for IR capabilities, for both military and civilian applications, is driving considerable development activity in this field. Further advances in IRI performance, reliability and affordability -- such as two-dimensional, high-density, uncooled detector arrays -- are anticipated.

In addition to IRI devices, passive sensors that are sensitive to microwave energy could provide improvements in some aspects of the low-visibility problem. However, their development for application to civilian vehicle is not as far advanced as that of IR sensors. Passive millimeter-wave imaging sensors use a focal plane array to produce radiometric images even in dense fog and most inclement weather. Current systems operating at 94 GHz are installed on aircraft to allow pilots to land safety under all weather conditions. A distinct disadvantage of such systems, however, is that a large aperture is required to obtain a good cross-range resolution.

Other technologies being explored by the European PROMETHEUS program for driver visual enhancement include ultra-violet and infrared illumination in conjunction with CCD cameras.

7.4.6 Potential Costs and Benefits

7.4.6.1 Potential Costs

In 1990, there were nearly 193 million registered motor vehicles in the United States, of which 143 million were automobiles. Approximately 10 million new passenger vehicles are sold in the U.S. each year. If all, or a substantial proportion, of these vehicles were to become equipped with IR systems, the total monetary costs could be substantial. The actual cost of these systems have not yet been determined.

7.4.6.2 Potential Benefits

The potential benefit of the Vision Enhancement for Collision Avoidance user service is that some fraction of the accidents and fatalities caused each year by poor visibility could be prevented. The fraction that actually would be prevented would depend on the effectiveness of the equipment, the driver's ability to use the equipment, and the number of vehicles that become equipped with the capability, which in turn would depend on the cost of the equipment.

7.4.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant potential opportunities for achieving improvements in highway safety and reductions in collision-caused congestion and vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS's potential benefits to the public means that the U.S. Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and supporting knowledge bases, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In all cases where highway safety can be improved, U.S. DOT will facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT will ensure that no loss of safety occurs from the deployment of any ITS services, including those that are not primarily designed to enhance safety. In order to accomplish this important role, performance specifications for collision avoidance systems need to be developed for various categories of crashes. These performance specifications can then be used by product developers as design targets for the systems they are developing. U.S. DOT will also use these same performance specifications in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the equipment has the requisite performance reliability, safety, maintainability, and cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department **may** encourage a joint public/private development effort.

This approach, which **is** the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the Vision Enhancement for Crash Avoidance user service.

7.4.7.1 Public Benefit

This service addresses a collision category with a particularly high fatality rate -- more than on-third of all fatal accidents occur in conditions of impaired visibility. It is believed that the service, if widely deployed, could prevent a significant number of these fatalities. Given this potential, the public benefit of this service is rated as HIGH.

7.4.7.2 Potential for Private Investment in Development

There is some potential marketability for IR systems; in fact, they may be available as an option on some more expensive automobile models within the next few years. Unless the price can be kept to a reasonable level, however, the demand may not be high. In addition to the cost considerations, an issue that needs to be resolved is the way in which this information will be presented to the driver safely and effectively. Given these constraints, the potential for private sector investment is rated as LOW.

7.4.7.3 Non-Federal Public Role in Deployment

Unless infrastructure changes are involved, such as changing the paint used on lane markers and traffic signs for enhanced IR visibility, the public role in deployment of this service will be LOW.

7.4.7.4 U.S. DOT Role in Developing Service

The Vision Enhancement for Collision Avoidance user service is an example of a service with a high public benefit in the area of safety. Thus, U.S. DOT should sponsor appropriate research and development to develop safety performance specifications, operational test and evaluation criteria, and deployment guidelines for such systems. The bulk of the actual development effort, however, will probably occur within the private sector. U.S. DOT involvement in this service is judged to be MODERATE.

7.4.8 Milestones and Activities

Figure 7.4-l is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

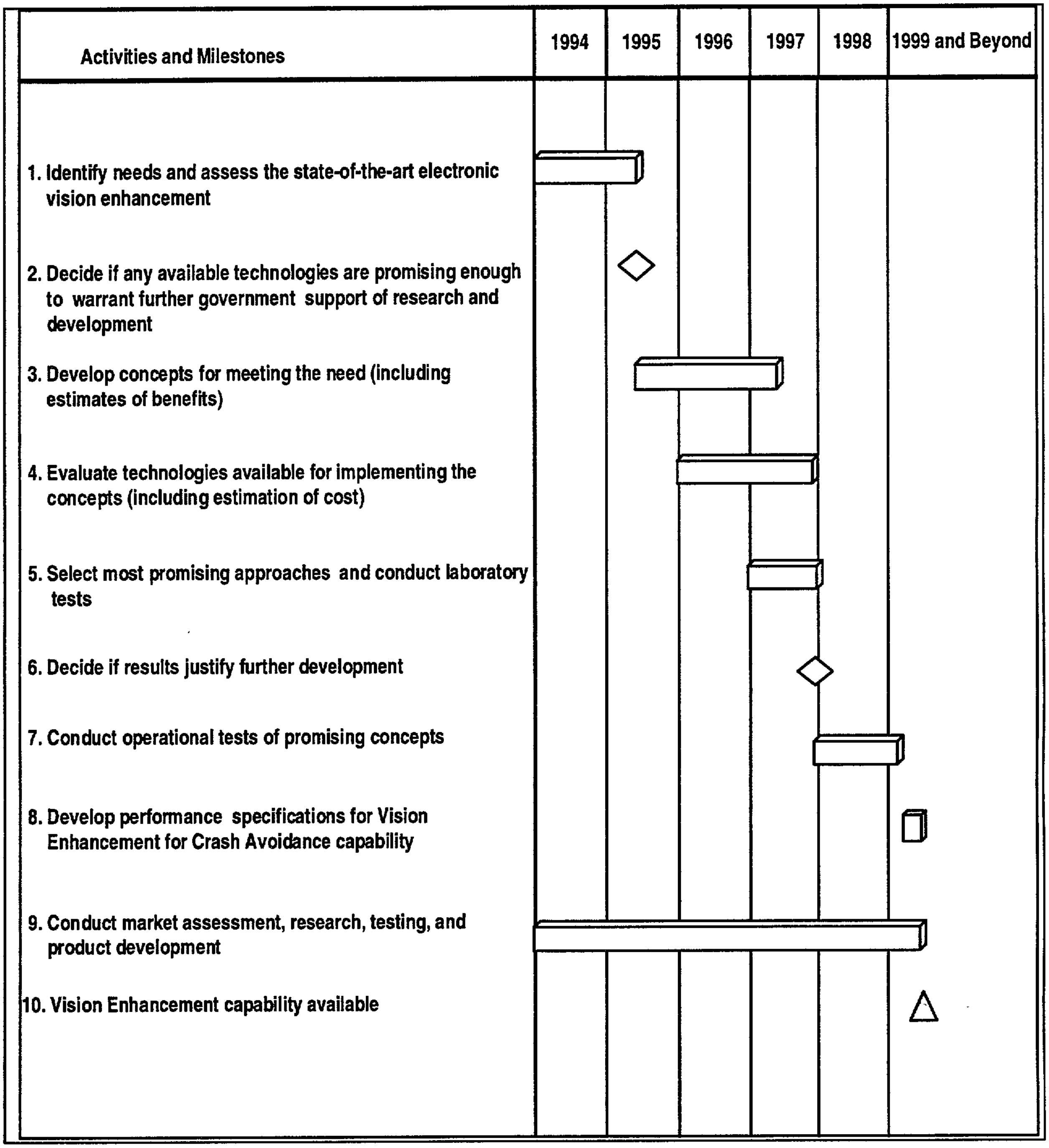

Figure 7.4-1 Gantt Chart

7.4.8.1 Issues

1. Can Vision Enhancement sensors and displays be developed or adapted from military equipment to be viable in motor vehicles?

2. Can such equipment, as installed in motor vehicles at an affordable cost, provide adequate performance to prevent a significant number of low-visibility highway accidents?

3. From industry's perspective, can marketable products be developed that have reasonable prospects for commercial success?

4. Can the human factors of the equipment be developed such that it can be comfortably and effectively used by a normal driver for extended periods?

7.4.8.2 Activities

1. The National Highway Traffic Safety Administration (NHTSA) is considering an R&D project entitled "Performance Specifications: Vision Enhancement Systems for Nighttime and Inclement Weather" that deals with this service. The project would investigate the feasibility of equipping motor vehicles with Vision Enhancement systems to assist driver visibility during nighttime and inclement weather, thus preventing low-visibility crashes. It would consider the effectiveness, reliability, costs, practicability, and potential hazards introduced by such systems. Task 1 of this project would evaluate the state-of-the-art of several different technologies for sensors and for the driver interface. This activity would address, in part, Issues 1 and 2 above.

2. NHTSA would make this determination, based on the results of Activity 1.

3. This activity would employ modeling, simulations, and simulators. It would estimate the benefits of the service and would consider human factors, data processing, sensor, and display aspects of the problem. This activity would address in part Issues 2, and 4 above.

4. This activity would evaluate the technologies available and estimate the cost of equipment suitable for installation in motor vehicles. It would address in part Issue 2 above.

5. This activity would test promising equipment in the laboratory. Such tests would be designed to show that the equipment does, in fact, enhance driver vision in low-visibility conditions. The equipment to be tested would be selected based on cost/benefit comparisons using the results of Activities 3 and 4.

6. NHTSA would make the decision to support further development of the service, if the results of the preceding activities show a significant societal benefit.

7. NHTSA would solicit offers of participation and, with selected partners, would carry out operational tests of promising concepts. A number of vehicles would be outfitted with the equipment and would be driven in normal operation. This activity would address Issues 2, 3, and 4 above.

8. Based on the results of the operational tests, NHTSA would develop performance specifications for the Vision Enhancement for Crash Avoidance capability. Such specifications would be developed in performance terms without constraining the systems to particular devices or technologies.

9. Individual industry companies would carry out these activities on their own initiative, based on their assessment of the market potential for equipment that implements the Vision Enhancement for Crash Avoidance service.

10. The Vision Enhancement for Crash Avoidance capability would be available. Owners would voluntarily equip their vehicles, most likely by choosing to have the equipment installed as an original purchase option.

7.5 SAFETY READINESS

7.5.1 Introduction

The Safety Readiness user service will reduce the number and severity of collisions caused by impaired drivers, vehicle component failures, or degraded infrastructure conditions. Systems that provide this service warn about driver, vehicle or infrastructure conditions based on monitoring by in-vehicle equipment. This user service consists of three subservices:

- Impaired Driver Warning and Control Override,
- Vehicle Condition Warning, and
- In-Vehicle Infrastructure Condition Warning.

Warnings about infrastructure conditions derived from sensors or manual inputs from outside the vehicle are provided by the In-Vehicle Signing subservice of the En-Route Driver Information user service.

The USER of this service, which is applicable in both urban and rural areas, is the vehicle driver. The Safety Readiness user service directly addresses the goals and objectives of improved safety by reducing injuries and fatalities, reducing the number of impaired drivers, and reducing the number and severity of accidents.

7.5.2 Needs

According to preliminary estimates based on 1991 data from the General Estimates System (GES) and Fatal Accident Reporting System (FARS) databases, approximately 553,000 collisions, or more than 9% of all incidents in that year, involved alcohol use and/or driver blackout or drowsiness. However, a much higher proportion of motor vehicle fatalities -- 38.5%, or almost 16,000 -- involved a driver or other party (i.e., a struck pedestrian) with a blood alcohol level of more than 0.10 grams per deciliter (g/dl), which is considered the legal level of intoxication in most states. More than 36% -- or nearly 9,000 -- of all driver fatalities, and one half of those between the ages of 21 and 34, had this or a higher blood alcohol level. Thus, it is obvious that impaired drivers -- particularly those under the influence of alcohol -- represent a significant highway safety threat. These accidents tend to occur at night, in non-urban areas with high (55 to 65 MPH) speed limits. The majority of these collisions are single vehicle roadway departures.

Failure of vehicle components is also a contributing factor to collisions. The GES and FARS databases for 1989, for example, reveal that about 2.7% (or 182,000) of all collisions and 4.1% (or 1,860) of all fatalities in that year were associated with such component failures. The two most common component failures were brakes (31.2%) and tires (19.6%).

A high proportion of collisions occur on wet, icy or snowy road surfaces. More than 27% of all collisions in 1991 (or about 1,665,000), and 23% of all collisions with severe or fatal injuries (or about 79,000), occurred in such conditions.

7.5.3 Service Description

The systems which implement this service provide drivers with warnings regarding their own driving performance, the condition of the vehicle, and the condition of the roadway as sensed from the vehicle. At the more complex level, Safety Readiness systems will also include the ability to assume temporary, partial control of the vehicle in situations deemed to be highly hazardous.

- Impaired Driver Warning and Control Override systems monitor driver performance features and either warn of impaired driver condition or take temporary control of the vehicle to prevent or discourage continued driving under such circumstances.

- Vehicle Condition Warning systems monitor the performance of components, such as tires and brakes, whose degradation could have a significant impact on the safe operation of the vehicle, and warn of their imminent failure.

- In-Vehicle Infrastructure Condition Warning systems detect and warn the driver of unsafe conditions on the roadway or bridge infrastructure, such as the presence of ice or water.

7.5.4 Operational Concepts

Each of the systems that will provide the Safety Readiness service typically include three functions, sometimes described as the “three Ps” -- perceiving, processing, and presentation. These functions are for sensing critical information about the performance of the driver or vehicle or the condition of the infrastructure; processing that information into a form which is useable by the driver or an automatic controller; and presenting this information to the driver (or directly to the vehicle) in a manner which elicits appropriate action. In systems where partial automatic action is taken by a controller, it will be necessary to ensure that these actions are compatible with vehicle and driver capabilities and limitations. It is also important that the system be self-diagnosing, in order to limit the negative impact of system failures. Some in-vehicle infrastructure condition warning systems concepts also incorporate either one-way or two-way communications capabilities from the vehicle to the infrastructure an/or another vehicle.

7.5.4.1 Impaired Driver Warning and Control Override

These systems would monitor various driver performance features for indications that the driver may not be in a condition to continue operating the vehicle safely. If such a situation were detected, the driver could be warned of his/her impaired condition, or temporary control over the vehicle could be exercised to prevent or discourage continued driving. One possible method would be to utilize various 'shut-down' features that would render the vehicle temporarily inoperable until the operator is able to resume driving safely.

Recent research suggests that there are certain driver performance and psychophysiological characteristics that indicate the possibility of imminent unsafe driving behavior due to drowsiness or impairment. In most cases, drowsy drivers exhibit symptoms of that condition for periods of time before their driving abilities are noticeably impaired.

Significant research is currently underway to identify and understand these symptoms. Among the performance features being studied are: abrupt and unnecessary lateral vehicle lane changes, changes to the use of accelerator and brake pedals, and erratic driver seat shifting and steering movements, often called "drift-and-jerk" steering. Psychophysiological features being researched include: heart and respiratory rates, electrodermal activity, eye closure (blink rate), and head nodding. An Impaired Driver Warning and Control Override system that could monitor driver behavior and detect preliminary symptoms such as these, and then either warn the driver or render the vehicle inoperable until the symptoms dissipated, would offer obvious and substantial safety benefits.

7.5.4.2 Vehicle Condition Warning

Most modern motor vehicles already have a significant number of component and systems monitoring features -- oil pressure and level, engine temperature, brake pad thickness, alternator level, and so on. Vehicle Condition Warning systems would extend this internal monitoring capability to additional components with a specific safety aspect, such as tire pressure or brake temperature. This capability could also be expanded to alerting other nearby vehicles of a breakdown on the roadway through an extension of the Emergency Notification and Personal Security service (see User Service Plan 6-1), in which the disabled vehicle transmits a message to nearby emergency services centers. Conceivably, this same information could also be broadcast locally by the affected vehicle for reception by other vehicles in the immediate vicinity, so that collisions with the disabled vehicle could be avoided.

7.5.4.3 In-Vehicle Infrastructure Condition Warning

There are a number of potentially unsafe infrastructure conditions that could contribute to an accident. Among the most dangerous of these conditions is the loss of tire traction due to water or ice on pavement or bridges. These In-Vehicle Infrastructure Condition Warning systems would monitor the roadway from the moving vehicle and provide warnings to the driver of the presence of such unsafe conditions. The capability for equipment on the vehicle to receive warnings from infrastructure-based components -- as opposed to vehicle-mounted systems -- that monitor roadway conditions is provided by the En-Route Driver Information service.

An approach to implementing one aspect of this subservice is to exploit the existing traction control systems (TCSs) that are often integrated into anti-lock braking systems (ABS). The purpose of TCS, which is also known as an antiwheel spin regulation (ASR) system, is to deter the loss of vehicle traction due to excessive wheel spin which can occur when the vehicle is traveling on a slippery roadway. Wet or slick roadway surfaces, when combined with extreme roadway geometry such as sharp or inadequately banked curves, can be very hazardous. Using these systems to recommend a lower speed at a sufficient distance in advance of these conditions may prevent many of these crashes.

7.5.5 Technologies

The three systems described above have been identified as technological concepts within the national ITS program which could make a positive contribution to reducing the number and severity of accidents attributable to driver impairment, vehicle component failure, and roadway conditions. These systems contain, to a greater or lesser extent, the “three Ps” of sensors, processors, and driver/vehicle interfaces (or controllers). In addition, some In-Vehicle Infrastructure Condition Warning system concepts include one-way or two-way communications capabilities.

Depending on the specific driver performance and/or psychophysiological characteristics that are being monitored, an Impaired Driver Warning and Control Override system could incorporate a variety of sensor concepts. For example, measuring driver control actions (steering, braking, accelerating) and body movements (seat movements) can be readily accomplished with current technologies. However, measuring such psychophysiological characteristics as heart rate and eyelid activity in a way that does not impair the driver’s ability to continue performing the driving task poses a real challenge. One of the issues that would need to be resolved for these system processors is the incidence of false alarms. Current algorithms enable the detection of drowsiness in drivers to be 75% accurate, with a false alarm rate of about 3%. If it is assumed that 1% of all drivers are drowsy at any one time, then the false alarms would outnumber true alarms by a factor of 4 to 1. This-rate increases if the proportion of drowsy drivers decreases.

This fals alarm rate is obviously too high to be the basis for a deployed safety system. One means of significantly reducing this rate is to combine two or more different simultaneous measures of impairment symptoms status into the system, such as, for example, erratic steering and slow eye closure. The first of these is a performance symptom, and the second is a psychophysiological symptom. In such a “dual mode” system, indications of both performance and psychophysiological decrement would generally be required before a warning signal is activated. There would likely be some circumstances, however, where an extreme reading in only one of the measures would be sufficient to activate the system.

In this context, individual variations in performance must be accounted for. For example, 'baseline' heart and respiratory rates and change patterns may differ significantly from one person to another. Thus, a system programmed to issue a warning with a given heart rate change may issue a 'true' alarm for one driver but a 'false' alarm for a second driver, even though they both had the same heart rate changes. One possible means accomplishing this would be to develop systems with the capability to adapt to data inputs on each driver's 'baseline' of performance.

One new capability, the tire monitor system (TMS) has reached a certain level of maturity. The TMS continuously reports the status of tire pressure to the driver. The sensor portion of this system is relatively simple. A pressure transducer and support electronics is integrated into the tire valve stem. When tire air pressure falls below a threshold level, the message is sent by a either a microchip radio wave transmitter or a transformer-type configuration. The system can be powered by either a watch-type battery or the vehicle power source.

Current traction control system sensors detect variations in the rotational speed of the vehicle's wheels. When these variations exceed a threshold, the system is activated to take control of the accelerator and brake pedals from the driver and limit the amount of excessive engine torque applied to the wheels. Thus, this system senses slippery road conditions only when the vehicle itself is already traveling on the slippery surface; it cannot "anticipate" when such surfaces will be encountered. However, some suggested In-Vehicle Infrastructure Condition Warning system concepts include the use of forward-looking laser radar sensors to determine pavement conditions ahead of the moving vehicle.

7.5.6 Potential Costs and Benefits

7.5.6.1 Potential Costs

The actual cost of these systems have not yet been determined, due to the relatively limited capabilities and the small number of systems currently available. The one exception is the tire monitor system, which currently retails for about $180.

7.5.6.2 Potential Benefits

Recent NHTSA analysis of accident data bases suggests that collisions involving impaired drivers, particularly those under the influence of alcohol, are one of the major causes of highway fatalities in the country today. As was mentioned previously, nearly 40% of all drivers killed in vehicle accidents were legally intoxicated at the time of death. In addition, nearly one-fourth of all accidents with severe or fatal injuries occur on wet, icy or snowy road surfaces. It therefore follows that any advances in systems that can warn of impaired driver behavior or unsafe vehicle or infrastructure conditions, and even disable the vehicle until driving conditions are again safe, could bring major safety-related benefits.

7.5.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant opportunities for achieving improvements in highway safety and reductions in vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS's potential benefits to the public means that the U.S. Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and the supporting knowledge base, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In the case of improved highway safety, U.S. DOT needs first to facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT needs to ensure that no loss of safety occurs from the deployment of any ITS services, including those that are not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications need to be developed for the capabilities that protect against different categories of crashes. These performance specifications can then be used by product developers as design targets for the services they are developing. U.S. DOT will also use these same performance specifications in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the service has the requisite performance reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort. For ITS systems with perceived safety benefits, however, the Department will be explicitly involved in developing performance specifications and evaluating safety performance.

This approach, which is the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the Safety Readiness service.

7.5.7.1 Public Benefit

Drowsiness, fatigue and other forms of driver impairment are a major contributor to motor vehicle accidents, particularly those resulting in severe injuries or fatalities. As a consequence, the public benefit for Impaired Driver Warning and Control Override systems is judged to be HIGH. Vehicle Condition Warning systems, on the other hand, do not provide the same level of benefit as impaired driver detection, because vehicle failures cause a much smaller number of collisions. Thus, the public benefit for this system is judged to be LOW. Finally, given the large proportion of collisions that occur on wet or icy pavement and the expected effectiveness of In-Vehicle Infrastructure Condition Warning systems in preventing such collisions, the public benefit of this system is rated MODERATE.

7.5.7.2 Potential for Private Investment in Development

An Impaired Driver Warning and Control Override system could be an optional ‘add-on’ to a vehicle, in which case the actual demand for it would be apparent from the market for the product. The potential safety benefits deriving from such a system, particularly given the high level of fatalities due to driver impairment, would likely be an attractive features for many buyers. Depending on its price and attributes, however, the demand for such a system may not be high unless it were mandated for safety reasons. The potential for private investment in Impaired Driver Warning systems is thus judged to be MODERATE.

Vehicle Condition Warning systems are autonomous to the individual vehicle. Further, in many cases they could simply be extensions of current sensing systems with which the driving public is becoming increasingly familiar. The popularity of individual systems, however, will probably depend in their final cost. The potential for private investment in these services is therefore rated as MODERATE.

Finally, In-Vehicle Infrastructure Condition Warning systems may be very attractive to many drivers as a means of extending their perceptions of the overall driving environment and improving travel safety. Depending on the individual system, however, it may require a parallel public investment in the infrastructure (sensors, communications, etc.) to be effective. Thus, the potential for private investment is judged to be HIGH (if vehicle-autonomous) or MODERATE (if public infrastructure investment is also required).

7.5.7.3 Non-Federal Public Role in Deployment

Autonomous monitoring of the status of the driver and/or vehicle would require little if any modification to the infrastructure, so public involvement in deployment is rated as LOW for both systems. However, certain In-Vehicle Infrastructure Condition Warning concepts would require public investment in infrastructure support items such as sensors, communications systems, and so on. Thus, the public role is judged to be LOW (if no infrastructure investment is needed) or HIGH (if such an investment is needed).

7.5.7.4 U.S. DOT Role in Developing Service

Because of their potential safety benefits, DOT is currently conducting research on driver condition detection concepts. If these concepts appear promising, then operational test and evaluations of their capabilities will also be conducted. The Department will then be involved in the development of safety performance specifications and deployment guidelines for those concepts that appear feasible. DOT involvement in Impaired Driver Warning systems is thus judged to be HIGH.

In the case of vehicle and roadway condition monitoring, systems are already being developed within the private sector. In these cases, the DOT role is judged to be LOW. It consists primarily of evaluating systems, cooperating in operational tests, and perhaps providing Federal-aid funding for deployment of the infrastructure-based aspects of these services.

A summary of the assessment of roles for these systems is given in Table 7.5-l.

Table 7.5-l Assessment of Roles for Safety Readiness System

	Public Benefit	Private Investment	Non-Federal Public Role	U.S. DOT Involvement
1. Impaired Driver Warning and Control Override	High	Moderate	Low	High
2. Vehicle Condition Warning	Low	Moderate	Low	Low
3a. In-Vehicle Infra-structure Condition Warning (autonomous)	Moderate	High	Low	Low
3b. In-Vehicle Infra-structure Condition Warning (non-autonomous)	Moderate	Moderate	High	Low

7.5.8 Milestones and Activities

Figure 7.5-l is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

7.5.8.1 Issues

1. Can the Impaired Driver Warning and Control Override system gather and process data with sufficient discrimination to distinguish between functional and impaired drivers?

2. Can concepts that are operationally acceptable be developed for warning the driver and controlling the vehicle?

3. To reduce false alerts is it necessary to integrate the Safety Readiness systems with the systems from the Collision Avoidance services so that Safety Readiness warnings are only issued in situations where a collision is imminent? If so, can such integration be successfully accomplished?

4. From industry perspective, can marketable products be developed for each of the subservices of this service that have reasonable prospects for commercial success?

5. From Government perspective, can effective products be developed that provide societal benefits at affordable costs?

7.5.8.2 Activities

1. Activity 1 is being addressed through the following projects:

   - “Problem Definition and Analysis of Target Crashes and IVHS/Countermeasure Action”. (1991 - 1994) This project is being carried out under Interagency Agreement between NHTSA and the Volpe National Transportation Systems Center. The findings of this project will help NHTSA prioritized and guide research and development on these countermeasures.

   - “Drowsy Driver Monitor”. (1991 - 1994) This project is being carried out under cooperative agreement between NHTSA and Virginia Polytechnic Institute. The current program will develop vehicle-based algorithms for detecting reduced driver performance (e.g., symptomatic of drowsiness/fatigue). This project addresses Issue 1 above.

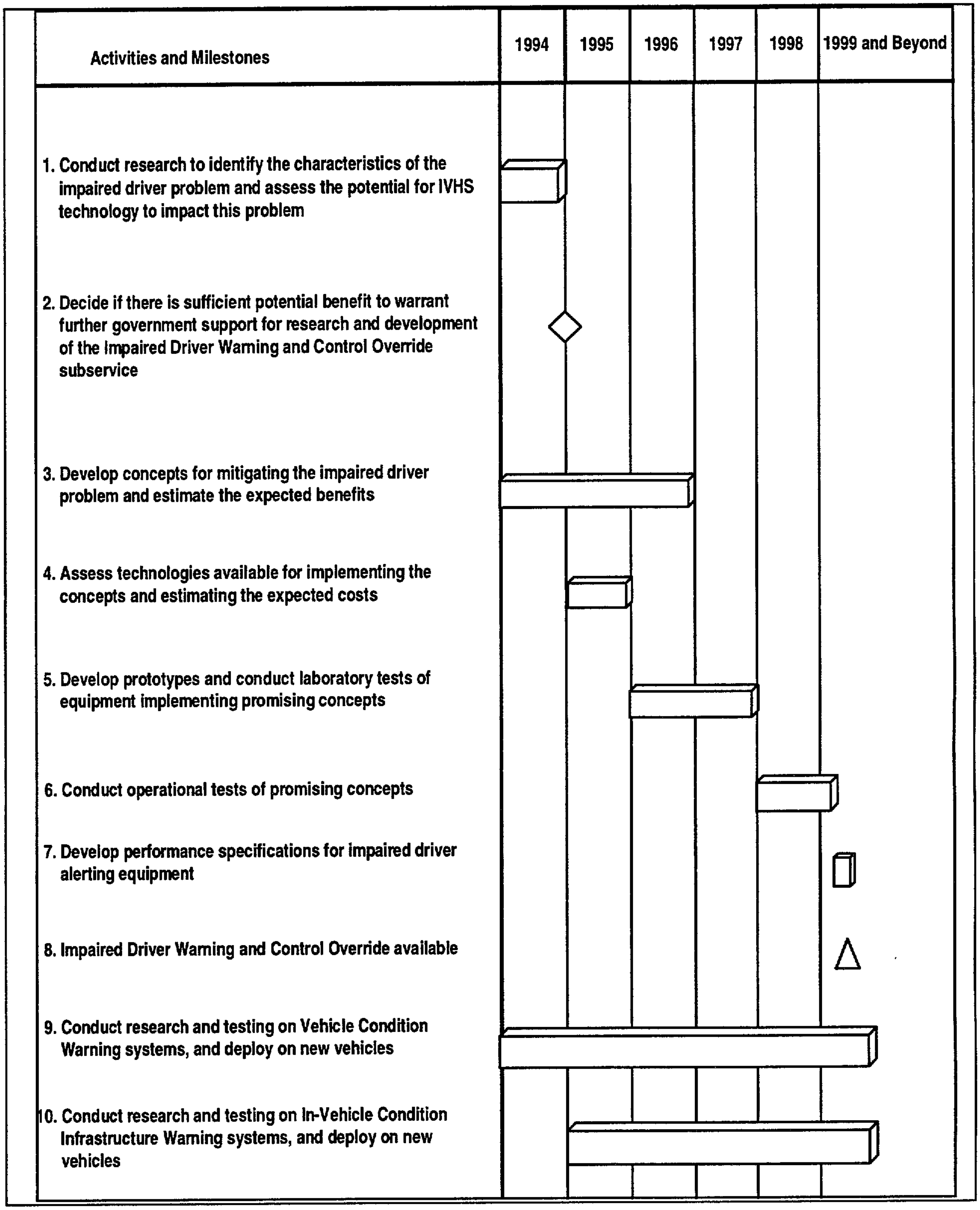

Figure 7.5-1 Gantt Chart

2. NHTSA would make this determination, based on the results of Activity 1.

3. If a positive decision is reached in Milestone 2, a proposed project to be funded through NHTSA and to be carried out in 1995 and 1996 would carry out this activity. The project would capitalize on the results of the studies in Activity 1, and would develop and assess concepts for presenting warnings to the driver and for taking partial or total control of the vehicle. It would employ modeling and simulation, and would consider human factors, data processing and sensor factors. This study would address Issues 1, 2, and 3 above.

4. NHTSA would fund a project to carry out this activity. The assessment of technologies would include estimating the cost of in-vehicle equipment for providing this service. This activity would address Issues 4 and 5 above.

5. NHTSA would work with manufacturers to develop and test prototype equipment in controlled laboratory tests. This activity would address Issues 1, 2, and 3 above.

6. NHTSA would solicit offers of participation and, with selected partners, carry out operational tests of promising concepts. These tests would be focused to determine if Issues 2, 3, 4, and 5 have been adequately addressed.

7. Based on the results of the operational tests, NHTSA would develop performance specifications for Impaired Driver Warning and Control Override systems.

8. The Impaired Driver Warning and Control Override capability would be available. Purchase of the system would be voluntary on the part of the vehicle owner, Should the operational tests show that this equipment can be effective in reducing accidents caused by impaired drivers, insurance companies may offer incentive premium reductions for vehicles that have this equipment installed.

9. The private sector will carry out this activity and offer advanced Vehicle Condition Warning as standard or optional equipment on new vehicles as the technology matures and market demand builds.

10. The private sector will carry out this activity and offer In-vehicle Infrastructure Condition Warning as standard or optional equipment on new vehicles as the technology matures and market demand builds.

7.6 PRE-CRASH RESTRAINT DEPLOYMENT

7.6.1 Introduction

The Pre-Collision Restraint Deployment user service provides a means to anticipate an imminent collision and to activate passenger safety systems prior to actual impact, or earlier after crash onset than is currently feasible. The equipment implementing this user service is contained entirely within the protected vehicle.

The USER for this service is the vehicle driver and passenger. This user service relates directly to the goals of improving safety by reducing injuries and fatalities resulting from vehicle accidents.

7.6.2 Needs

Today's vehicle restraint and passenger safety systems -- including seat belts, air bags and rollover bars -- undoubtedly protect thousands of vehicle occupants each year from death or serious injury during a collision. However, these systems are not perfect. For example air bags are occasionally deployed in relatively minor crashes in which lap-shoulder belt restraints alone would provide sufficient protection. The air bag deployment process itself is quite aggressive, involving the controlled explosion of a pyrotechnical device, the rapid splitting and pushing aside of the cover, and the inflation of the air bag itself directly at the vehicle occupant. Injuries have in fact occurred as a consequence of this process, especially when the occupant is closer than normal to the air bag at the time of deployment. This can happen, for example, when the occupant is sitting or leaning closer to the dashboard, or is shorter than average in height.

In addition to the potential for injury during deployment, current air bag systems are designed to be responsive primarily to longitudinal frontal collisions. They are not as effective in protecting occupants during side-impact, rear-end or rollover crashes. The 1991 reports on the GES (General Estimates System) and FARS (Fatal Accident Reporting System) databases reveal that 35% of all collisions (1.728.000) and 34% of all collisions resulting in severe or fatal injuries (86,000) were side impact collisions. Ideally, any passenger safety system protecting against either longitudinal or side impacts should be able to anticipate or sense an imminent collision, determine whether the collision will be of a sufficient force to require deployment of a safety system, and begin the process of deploying the appropriate safety system prior to actual impact, or at least earlier in the crash event than is currently technologically feasible.

7.6.3 Service Description

The Pre-Collision Restraint Deployment service will reduce the number and severity of injuries caused by vehicle collisions. This is accomplished by developing means both to anticipate an imminent collision and to activate passenger safety systems prior to the actual impact, or earlier after crash onset than is currently feasible. These safety systems would be more effective if their deployment were based on information such as details of an imminent collision situation (velocity, mass and direction of the vehicle being hit and the vehicle or object it is hitting); and the number, location and major physical characteristics of the vehicle occupants.

7.6.4 Operational Concepts

Current passenger safety systems are designed to assess the severity of an impact after the onset of the crash, and determine whether a deployment of the safety feature (air bag inflation, belt tightening or rollbar deployment) is warranted. However, the most potentially injurious rate of vehicle crush is experienced during this initial stage of impact. If the occupant could be restrained to the passenger compartment structure before this early crush occurred, the crush loading on the occupant would in turn be significantly reduced.

Pre-Collision Restraint Deployment systems would use sensors capable of detecting the rapid closing of distance between the vehicle itself and other vehicles or objects presenting a collision threat before an actual impact occurs. This information would allow the appropriate safety system deployment to be initiated earlier in the period of fastest vehicle crush.

Early deployment is particularly important for side impact collisions, since most passenger vehicles lack sufficient structural strength or buffer space on the sides to absorb or dissipate the initial force of the impact. In the case of air bags, adequate pre-impact sensing could also enable the system to select the optimum gas pressure to use during deployment. Accurate information about the physical characteristics of vehicle occupants (seat location, weight, height and age) would also assist in selecting the appropriate safety system response.
Most Pre-Collision Restraint Deployment systems will include two phases. The first, or sensing, phase will gather appropriate information concerning the imminence of collision or rollover events from the driving environment. The second, or processing, phase will process this information and initiate the appropriate passenger safety system response when warranted. Responses could include tightening of lap-shoulder belts, arming and/or deployment of air bags, or deployment of rollbars.

7.6.5 Technologies

Significant research into pre-collision, or anticipatory, sensing for the deployment of passenger safety systems was undertaken in the 1960s and 1970s. At that time, however, no feasible pre-collision concept which could be deployed into the mass market was identified. Among the sensor technologies explored during that period were infrared, mechanical, radar and sonar. Each of these has its own capabilities and limitations in such areas as sensor range, vulnerability to weather or other environmental changes, and total system cost.
Current passenger safety systems are activated by on-board electromechanical or totally electronic crash sensors. These sensors detect and respond to the sudden deceleration resulting from an impact to ascertain that the crash-induced velocity change of the car exceeds the threshold above which additional occupant protection is required. Therefore, the activation signal from these sensors is delayed from the onset of the crash until a critical

velocity change is exceeded. This results in a significant delay before enhanced occupant protection can be provided.

In the case of current air bags, the time consumed before full deployment ranges from forty to over one hundred milliseconds (.040 - .100 seconds) as a function of frontal crash severity, while the entire crash event is normally completed in ninety to two hundred milliseconds. Thus, by the time the systems have deployed, the collision is already well underway or almost completed and the occupant has slid close to the air bag. However, if a potential collision can be anticipated, the safety system can begin to deploy upon initiation of the crash or even before actual impact. This will reduce the probability of injury from the collision.

At the present time, there is no commercially-available Pre-Collision Restraint Deployment system that can anticipate a vehicle collision. There have been, however, several concepts suggested for such a system. One approach is based on a C-Band frequency modulation continuous wave (FM-CW) radar sensor built into a single integrated circuit chip. The system would consist of an array of such sensors connected to a signal processor, which would in turn trigger the safety feature to deploy. An effective range of only 3 meters could provide an additional one-tenth second (.100 second) of warning at 65 miles per hour. This system could be used either as a primary sensor to trigger the restraint system, or as an auxiliary sensor in conjunction with current on-board crash sensors. If radar is used as an auxiliary to the on-board crash sensors, it would be possible to confirm the need for deployment earlier in the crash event than is now feasible.

Optimum pre-crash restraint deployment decisions require knowledge of both the closing speed and the mass of the ‘crash partner’. However, range and proximity sensing systems now existing or under development for automotive applications cannot identify the mass of target objects. Technology in military systems may allow target recognition, but their sophistication, size, and costs make them impractical for automotive application. Attachment of passive electronic tags to all vehicles and roadside objects which might be crash partners (trees, posts, signs, etc.) could provide the target mass information required to allow reliable pre-collision restraint deployment decisions.

As can be seen, earlier applications of closing speed information even without identification of target mass will allow more timely deployment of restraint systems after crash onset than is now possible. This will add significantly to the protection of crash victims. When sufficient affordable technology is applied to identify both closing speed and mass, pre-collision restraint deployment actions will dramatically reduce occupant injuries and fatalities.

In addition to these technologies, there are others that could contribute to the development of Pre-Collision Restraint Deployment systems. These include, for example, headway detection systems (HDSs) and proximity detection systems (PDSs). Side-looking radar concepts may also prove useful in detecting imminent side impact collisions and triggering passenger safety systems. For additional information on these systems, please refer to Longitudinal Collision Avoidance (for HDS, see User Service Plan 7.1), and Lateral Collision Avoidance (for PDS, see User Service Plan 7.2).

7.6.6 Potential Costs and Benefits

7.6.6.1 Potential Costs

In 1990, there were nearly 193 million registered motor vehicles in the United States, of which 143 million were automobiles. Approximately 10 million new passenger vehicles are sold in the U.S. each year. If all, or a substantial proportion, of these vehicles included Pre-Crash Restraint Deployment systems, the total monetary costs could be substantial. The actual cost of these systems have not yet been determined, due to the relatively limited capabilities and the small number of systems currently available. It can be assumed, however, that the process of developing and refining these systems will lead to a decrease in unit costs, especially for those with the potential for mass deployment.

Throughout their development and deployment, the benefits attributed to these systems will need to be carefully judged against their costs. This is a normal business function that is applied to any major automotive system, and one with which the private sector has extensive familiarity. The final test will come with the marketplace, when individual vehicle drivers and owners decide whether or not to pay the additional costs for these systems.

7.6.6.2 Potential Benefits

If successful, the potential benefits of Pre-Collision Restraint Deployment systems could be significant. Increasing numbers of vehicles have air bags, and driver and front passenger air bags will be a Federal requirement starting in 1998. Advances in this area could also lead to successful deployments of additional side impact safety features, such as side-mounted air bags. This would enhance occupant safety in the one-third of all collisions involving side impact.

7.6.7 Assessment of Roles

ITS collision avoidance countermeasures provide significant potential opportunities for achieving improvements in highway safety and reductions in vehicle delay. As with other products with a commercial potential in the U.S. economy, responsibility for developing ITS services generally resides with the private sector. However, the importance of ITS's potential benefits to the public means that the U.S. Department of Transportation (U.S. DOT) has particular roles to play in the national ITS program, consistent with its own mission and objectives.

In general terms, U.S. DOT will provide a national framework of support for the evolution of the national ITS program. This includes encouraging and coordinating the development of key technologies and the supporting knowledge base, commissioning research, funding specific projects, and ensuring the nationwide compatibility of ITS services and products. In addition, Federal-aid funds will be available to state and local governments to help pay for the deployment of ITS services.

In the case of improved highway safety, U.S. DOT needs first to facilitate the development and deployment of ITS services that provide a safer driving environment. Second, and of equal importance, U.S. DOT needs to ensure that no loss of safety occurs from the deployment of any ITS services, including those that are not primarily designed to enhance safety. In order to accomplish this important safety role, performance specifications need to be developed for different crash categories. This will enable the identification of the specific causal factors and potential countermeasures for each category. These performance specifications can then be used by product developers as design targets for the services they are developing. U.S. DOT will also use these same safety concepts in evaluating the impact on safety of operational testing and in-service projects. This will ensure that the service has the requisite performance reliability, safety, maintainability, cost and driver acceptability characteristics to be a viable and deployable ITS product.

There are additional situations where U.S. DOT involvement is appropriate. For example, there may be cases where private industry might not pursue a service on its own which nevertheless has a high public benefit. In such a situation, the Department may encourage a joint public/private development effort. For ITS systems with perceived safety benefits, however, the Department will be explicitly involved in developing performance specifications and evaluating safety performance.

This approach, which is the basis for the Department's strategy for investing in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the development of the Pre-Crash Restraint Deployment service.

7.6.7.1 Public Benefit

Developing and deploying a system that could initiate passenger safety features prior to an actual collision impact could further reduce the severity of injuries and the number of highway deaths, particularly from frontal and side impact collisions. Since nearly all vehicles now include systems that could benefit from this service, the public benefit is rated as HIGH.

7.6.7.2 Potential for Private Investment in Development

These systems could require sophisticated and potentially expensive in-vehicle sensor and processors. There may also be institutional or legal issues regarding the determination of increments of passenger restraint deployment based on the output from these systems. For example, responsibility would have to be assigned for deciding how much of a response from the safety system to set, depending on different impact forces. On the other hand, the public benefit is both reasonably significant and apparent. Thus, the likelihood for private investment is judged to be MODERATE.

7.6.7.3 Non-Federal Public Role in Deployment

Most current Pre-Collision Restraint Deployment concepts are in-vehicle systems. There are some concepts, however, which involve labeling vehicles and potentially hazardous roadside objects, such as light and telephone poles, with tags which would respond to active infrared, radar or sonar queries from in-vehicle systems. Such systems, however, are at an early stage of development. Unless other infrastructure changes are involved, the public role in deployment of **this** service is judged to be LOW.

7.6.7.4 U.S. DOT Role in Developing Service

The Pre-Collision Restraint Deployment service is a representative example of a service with a high public benefit in the area of safety. Thus, U.S. DOT should sponsor appropriate research and development to develop safety performance specifications, operational test and evaluation criteria, and deployment guidelines for such systems. U.S. DOT involvement in this service is judged to be HIGH.

7.6.8 Milestones and Activities

Figure 7.6-l is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

7.6.8.1 Issues

1. From industry perspective, can marketable products be developed that have reasonable prospects for commercial success?

2. From Government perspective, can effective products be developed that provide societal benefits at affordable cost?

3. From both perspectives, in what time frame can a technically feasible solution be produced?

7.6.8.2 Activities

1. Identify needs and assess state-of-the-art.

- The National Highway Traffic Safety Administration (NHTSA) is conducting an accident analysis evaluating current air bag effectiveness in providing occupant protection in real world car crashes. (1991 - 1995)

- NHTSA is funding cooperative agreements (Romeo Engineering International and Hittite Microwave Corporation) which include tasks to assess available systems.

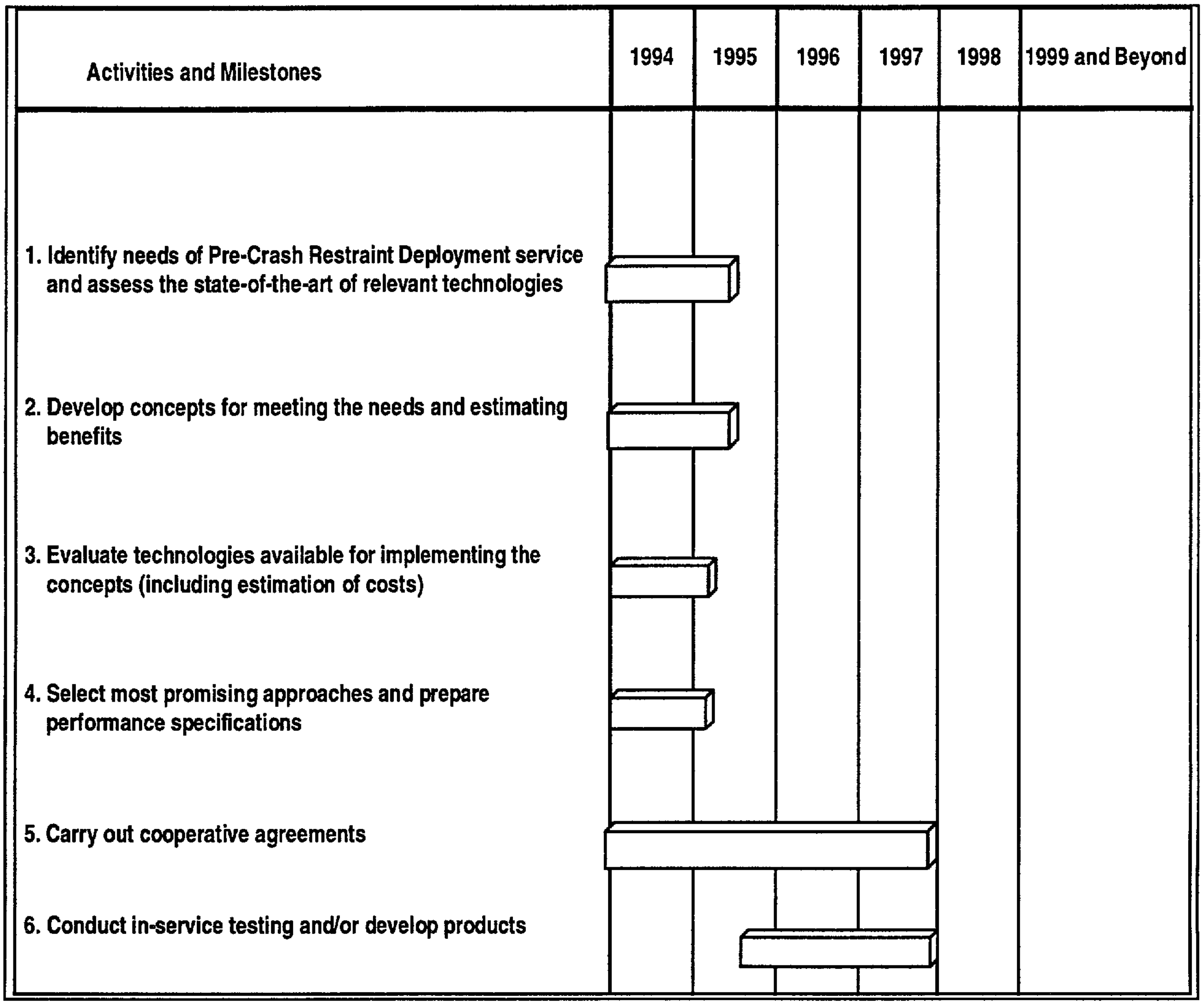

Figure 7.6-1 Gantt Chart

2. Develop concepts and estimate benefits.

. Details to be developed. (1993 - 1995)

3. Evaluate technologies.

. Details to be developed. (1993 - 1995)

4. Select most promising approaches and prepare performance specifications.

. Details to be developed. (1993 - 1995)

5. Carry out cooperative agreements.

. Cooperative agreements between NHTSA and private industry will encourage the development of early products and testing. (1993 - 1997)

6. Conduct in-service testing and/or develop products.

. Details to be developed. (1995 -)

7.7 AUTOMATED HIGHWAY SYSTEM

7.7.1 Introduction

The Automated Highway System user service is a vehicle-roadway system that will substantially improve the safety and efficiency of highway travel, greatly enhance driver comfort, and help reduce air pollution. This will be achieved by moving suitably equipped vehicles under fully automated control (i.e., hands-off and feet-off operation) along dedicated highway lanes. The AHS interacts with a number of other user services including Longitudinal Collision Avoidance, Lateral Collision Avoidance, and Safety-Readiness.

The AHS is a powerful transportation alternative that will integrate with, and enhance the state and regional transportation plans to ensure full compliance with ISTEA, the Clean Air Act, and the Americans with Disabilities Act. AHS have a direct impact on several ITS goals and objectives including increased safety and efficiency.

7.7.2 Needs

Automated vehicle-highway systems offer the potential for a major breakthrough in the performance and safety of the nation's highways. Research has shown conceptually that an automated system has the potential to provide safe, dependable, highly efficient movement of vehicles on our nation's roadways. Specific examples of potential societal benefits that could be derived include the following:

- Reduce the number and severity of crashes Highway accidents cost this nation $137 Billion in 1991. Over 90 percent of all crashes are either directly caused, or contributed to, by human error. the AHS will **be** accident free in the absence of malfunctions because human errors will be eliminated; when AHS malfunctions do occur, crashes will be avoided and/or their severity will be minimized.

- Decrease congestion By the year 2000, over 80 percent of urban Interstate rush hour traffic will be in congestion. Today this congestion costs the U.S. over $100 billion in lost productivity per year. AHS can significantly reduce congestion by moving vehicles more efficiently over the same highway right-of-way. Researchers estimate that AHS can increase vehicle-per-hour lane capacity by 200 to 300 percent, and provide more predictable travel times to commercial and private users.

- Reduce vehicle emissions and fossil fuel consumption The AHS can reduce both by moving vehicles more efficiently (i.e., less accelerating and decelerating) and by reducing idling in traffic jams.

- Enhance operation of multiple occupant vehicles The AHS can substantially enhance the operation of non-rural transit operations, including buses, urban rapid transit systems, and multiple passenger private vehicles. AHS will improve service by providing (1) safety and efficiency of travel; (2) more predicable travel times; (3) enhancement of dedicated lane operation; and (4) support of congestion pricing of single occupancy vehicles.

7.7.3 Service Description

The long range goal is to develop a practical, affordable, user-friendly, fully automated vehicle-highway system in which instrumented vehicles operate on instrumented roadways without operator intervention. This section describes the service and how the nation's highway and vehicle industry may evolve to it.

7.7.3.1 Target Service

The target system for providing this service is a fully automated highway system (AHS). Drivers will enter an AHS lane through a check-in area where the AHS will 1) check the worthiness of the vehicle and driver, 2) accept or reject vehicles for operation in the AHS lanes, and 3) divert disapproved vehicles back to the non-AHS lanes or assume control of approved vehicles. The AHS assumes control of an approved vehicle and **moves** it onto an AHS lane, merging it with the other AHS traffic, Vehicles are moved as part of the traffic flow; and when the destination exit is reached, the system moves the vehicle to an off-ramp where control is returned to the driver after the driver's ability **to** resume control has been demonstrated. Existing vehicles may be retro-fitted with AHS instrumentation.

The AHS target performance specifications in key areas include the following:

- Safety - Improve safety through collision free operation in the absence of malfunctions, and a malfunction management capability that minimizes the number and severity of collisions that occur as a result of AHS malfunctions

- Efficiency - Decrease congestion in a traffic corridor by significantly increasing the efficiency with which today's highway right-of-ways are used by (1) increasing traffic density and speed of AHS lanes because of faster system reaction times, (2) eliminating traffic flow variances caused by humans such as uneven performance, weaving and distractions; (3) managing entries and exits so that AHS lanes maintain optimum speed and spacing in heavy demand traffic; and (4) increasing the number of traffic lanes possible on the highway right-of-way.

- All-weather operation - The operational capability of the AHS must meet or exceed that of an un-instrumented vehicle and driver on the roadways for complete range of weather conditions that are typical in the continental U.S.

- Level of Service - provide a full range of dependable service to passenger vehicles, heavy commercial vehicles, and transit vehicles (not necessarily intermixed) in both urban and rural environments as an integrated part of a community's transportation system.

- More user comfort - reduce the strain on drivers, more trust in the system

- Fossil fuel consumption and emissions - reduce fuel consumption and emissions per vehicle mile traveled by reducing delay.

7.7.4 Operational Concepts

The AHS assumes fully automated control of vehicles as they travel on instrumented and/or specially designated highways. The AHS target system characteristics and assumptions include the following:

- The AHS must be practical, affordable and/or cost-effective, desirable and user-friendly

- AHS lanes will have freeway-type design characteristics. AHS operation must be consistent with the continued efficient operation of near-by non-AHS traffic.

- Vehicles will contain instrumentation that will allow their fully automated operation on instrumented segments of roadway

- Vehicles will be 'dual mode";

  - Instrumented vehicles will be able to operate on regular (non-AHS) roadways and use the AHS instrumentation for collision avoidance and/or lane-keeping
  - Only instrumented vehicles will be allowed to operate on AHS lanes.
  - Future vehicles may be instrumented on a retrofit basis

- The AHS may be a cooperative system, incorporating vehicle-infrastructure and vehicle-vehicle communications for a number of functions including vehicle check in, and longitudinal and lateral vehicle control.

- Vehicles will have on-board status systems that will continually sense the condition of components of the vehicle that are critical for AHS operation. Some of this assurance may come from periodic inspections at local service stations, and/or state inspection stations.

There are many different concepts for AHS. Below, one concept is interpreted to give the reader a sense of how the AHS would appear to a driver of a vehicle. It is recognized that there are other concepts of AHS operation; this one was selected for illustrative purposes only.

7.7.4.1 Acquiring a Vehicle

Drivers will choose to purchase one of three AHS classes of new or used vehicles:

- AHS-Certified Vehicles - The vehicle fully meets the AHS specifications
- AHS-Capable Vehicles - The vehicle is capable of being upgraded to fully meet the AHS performance specification
- Non-AHS Vehicles - The basic vehicle is not reasonably capable of being upgraded to meet the AHS specifications.

Drivers that acquire an AHS-certified vehicle may need to have a special electronic drivers permit that (1) shows that the driver has been trained to use AHS, and (2) that he or she meets other requirements, including an adequate safety and licensing record. AHS should be easy and simple to use, however, drivers may need to be aware of safety, emergency or other special procedures. Perhaps the vehicle's AHS capabilities are not enabled unless a qualified AHS electronic license is entered into the on-board system.

7.7.4.2 Using the Svstem

As a driver approaches a freeway that includes one or more AHS designated lanes, he or she may choose to either drive on the non-AHS lanes or on the AHS lanes. If the driver chooses the AHS lanes, the vehicle will give the driver a GO or NO-GO indication that reflects the status of the vehicle's present ability to operate on the AHS. This assumes that the vehicle has an on-board status system that continually senses components of the vehicle that are critical for AHS operation. All of the vehicle's on-board status sensors will need to be positive to get the GO indication.

When the GO indication is given, the driver will enter his desired destination into the system by voice, if driving, or by touch-pad if the vehicle is stopped. For commuters, the destination may be pre-determined and the driver need only confirm it. In doing this, the driver may be told that there is insufficient fuel, and disallow AHS entry. If allowed, the driver will then drive the vehicle into an AHS-only check-in lane where the vehicle's (and perhaps the driver's) AHS worthiness will be verified by the infrastructure through communications between the infrastructure and the vehicle, preferably while the vehicle is moving at normal speed. Some of this assurance may come from periodic inspections at local service stations, and/or state inspections. If the vehicle is not approved, it will be diverted back to the non-AHS lanes. The diversion may be through signing (i.e., arrows and lights) or conceivably through the use of perceived barriers that would discourage a rejected driver from proceeding onto the instrumented lane.

If approved, the AHS assumes control of the vehicle in the check-in lane, moves the vehicle onto one of the AHS lanes, and merges it with the other traffic. Once in the AHS lane, the system will manage the vehicle individually (throttle, brakes, transmission, steering and lights) and as part of the traffic flow. Depending on how the system is designed, it may pass slower moving traffic (e.g., commercial vehicles or buses). When the destination exit is reached, the system will move the vehicle to an off-ramp where the driver's ability to resume control of the vehicle will be tested before control is returned.

While in the AHS, the driver will have a smooth, safe ride. The driver may be able to relax, work, read a book; or may choose to act an a "supervisor". As a supervisor, the driver would receive information on traffic and on the vehicle performance, and would be able to enter data into the system such as spacing from the vehicle in front, preferred lane of travel, change of exit, and "sensed" information such as "engine running rough" or "caution, bad weather approaching." The driver does need to remain alert and be prepared to resume control when exiting the system. In extreme cases of malfunction it is conceivable that the AHS system may bring all vehicles to a stop. In that case, it is possible that the driver may need to resume manual control of the vehicle to exit from the AHS lane under police supervision.

7.7.4.3 Transition

A major concern in transitioning to AHS is that there must be sufficient "market penetration"; that is, a given area must have sufficient vehicles that are instrumented, sufficient highways upon which the instrumented vehicles could operate, and sufficient number of drivers that desire to use the service. Specific transition strategies will need to be developed that address each of these areas as part of the AHS program, particularly the operational test and evaluation phase. Below, each of the three areas is discussed.

- Vehicle Transition - It is envisioned that the full automation of AHS will be achieved progressively; that is, progressively automated collision avoidance and vehicle control services will probably be offered prior to AHS so that when the first dedicated AHS lanes are installed and the first fully automated service is offered, many of the vehicles will have instrumentation that will require little or no enhancement to be AHS-compliant. For example, many vehicles may have instrumentation for services such as Intelligent Cruise Control (ICC), and integrated longitudinal and lateral collision avoidance. These services require sensors, processors, and electronic actuators that should be upward-compatible to AHS. One of the major goals of the AHS program is to define the specifications and standards for these components as early as possible so that they can be, in fact, upward-compatible and be used as integrated components of the AHS. And these services will continue to have value on non-instrumented roadways. For example, as a vehicle leaves an urban AHS system, it could move onto a rural non-instrumented roadway where the AICC services resume control, and vice-versa.

Early use of ITS technologies for transit use seems to offer benefits. In congested urban settings, tight ITS operation tolerances will allow narrow guideways and accurate positioning of terminals for buses. Inside of the city, the buses can operate on dedicated AHS transit lanes, or on non-AHS roadways to service the passengers.

- Highway Transition - The AHS will develop as part of our nation's highway transportation system. It is believed that initial AHS lane deployments are likely to be on heavily traveled urban highway segments where there is a high need; the AHS lanes may be separately accessed as are the High Occupancy Vehicle (HOV) lanes on some of today's highways and, in fact, may be HOV lanes themselves. Special lanes for transit vehicles could be established as an early step in transition. Similarly, separate lanes for heavy commercial vehicles may be possible. Rural AHS may be less complex that urban AHS, but can provide valuable inter-city travel links.

  At some point after the AHS performance specifications are established, the highway community will develop standards in coordination with the U.S. Department of Transportation (U.S. DOT) and other standards bodies for AHS instrumentation of highways. Doing this early could somewhat reduce the transition costs in the future. Additionally, some roadway lanes may have passive or active instrumentation placed on them for lateral collision avoidance and lane keeping purposes. With some preplanning, these enhancements might be easily upgraded for AHS use.

  The AHS is a tool to be used by transportation planners in developing their state transportation plans. AHS has many benefits that will help the planners meet the goals of ISTEA, the Clean Air Act, and the Americans with Disability Act. Thus, the first AHS implementations will be compatible with these acts and will be an integrated part of the states' transportation plans. Phased implementations are likely. For example, it is possible that some highway lanes may be time-shared between normal traffic and AHS traffic; for example, at rush hours, the lanes could be AHS only, while during normal hours all traffic could use the lanes. It is conceivable that AHS lanes could also be reversible.

- User Transition

  User transition concerns are two-fold--user acceptance and economics. By the time AHS becomes operational, many drivers will be accustomed to other AVCSS services. The next step to AHS should not seem so large to those drivers.

The economics of the AHS is of key importance. If users must pay for the service either in purchasing an instrumented vehicle, or in tolls for the special roadway, then they must be convinced that the AHS service is cost-effective, safer and more convenient. Commercial users will quickly switch if there are savings. Transit operators may move to AHS for the improved services. The initial investment in the vehicle instrumentation will need to be reasonable enough that the user can see a rapid return on the investment or feel good about the cost of the extra service. For example, if the AHS is in fact accident-free except when there is a malfunction, then insurance rates for the AHS drivers should be substantially less, and the driver will feel safer and more comfortable in highway travel Initial government incentives may also be considered.

7.7.5 Technologies

The range of technologies is quite broad. These technologies, including sensors, lateral and longitudinal control techniques, and obstacle detection, are being addressed in a series of Precursor Systems Analyses (PSAs) that will be concluded by December, 1994. Further technology investigations will be conducted by the AHS consortium that was selected in the fall of 1994.

7.7.6 Potential Costs and Benefits

7.7.6.1 Potential Costs

The PSA contracts are costing $14.1 million. The estimated cost for the AHS consortium to conduct the program through selection and specification of the AHS concept to be used for operational test and evaluation, is about $200 million; about $50 million of that will be paid with non-Federal funds. Costs for the operational evaluation, which will involve public participation, and eventual deployment will initially be estimated by the AHS consortium by 1995.

7.7.6.2 Potential Benefits

AHS savings to society will increase as the level of implementation increases. Each . implementation will result in saving due to reduced injury and death for the occupants of the vehicles, and reduced personal property losses because of fewer, less severe accidents. Savings in time lost due to congestion, will accrue immediately, but will be hard to measure. Savings for commercial shippers will be immediate in that they will have reliable delivery times as well as safer travel. The AHS consortium will initially estimate saving and benefits based on level of implementation in 1995.

7.7.7 Assessment of Roles

The responsibility for development of ITS services generally resides with the private sector; however, there are situations when U.S. DOT involvement is appropriate. This would include cases where private industry might not pursue development on its own, such as the initial development and operational test and evaluation of systems with high public benefit but low commercial potential. Another example is where the government, rather than the private sector, is a substantial or primary user of the service. If both the expected public benefit and the commercial potential are high, U.S. DOT will encourage a joint public/private development effort. This approach, which underlies U.S. DOT's strategy for investment in ITS technologies and systems, is used below to assess the appropriate role for U.S. DOT in the AHS service development.

7.7.7.1 Public Benefit

The public benefit of AHS is HIGH, as described in section 7.7.6.2, Benefits. However, there are potentially many institutional and societal aspects of the system that must be addressed if AHS is to become a reality. These aspects include legal (tort liability), community land use, environmental concerns, needs for increased mobility, safety and adaptation to existing operating agencies and regulatory structures. For this reason, the AHS program is being conducted as a broad public/private partnership so that both the technical and non-technical aspects of AHS can be voiced and addressed as the program proceeds.

7.7.7.2 Potential for Private Investment in Development

The private market potential for AHS is high in virtually all facets of the service once the service is specified. There will be substantial markets for infrastructure instrumentation to be marketed to state and local governments, and there will be markets for the instrumentation of vehicles, both new and retrofit. Also, some of the AHS technologies will have applicability to "pre-AHS" collision avoidance products. Private investment alone, however, cannot develop and deploy AHS. This must be done in partnership with the Federal, state and local governments because of the investment size and the need for national standards. For this reason, this is rated MEDIUM-HIGH. This is reflected by the fact that so many AHS industry stakeholders are a part of the AHS consortium responsible for the system definition portion of the program.

7.7.7.3 Non-Federal Public Sector Role in Deployment

The public sector role for this service is characterized as HIGH since this service will require Federal investment initially in the research and development of AHS and in definition of the AHS performance specifications and standards. Additionally, the role of state DOTs and MPOs is high. The state DOTS and MPOs will include AHS as part of the State

Transportation Implementation Plans. Also state and local DOTs will be involved in the implementation of the infrastructure, and in setting the AHS vehicle standards.

7.7.7.4 U.S DOT Role in Developing Service

The Federal role in AHS is HIGH. It will (1) act as facilitator in initiating this partnership for conduct of the AHS program, (2) represent the public interest in ensuring that any AHS that is eventually deployed meets the societal interests of our nation; and (3) represent the public interest in the development of the infrastructure elements of the system. Additionally, the U.S. DOT will be responsible for helping to develop performance specifications for the AHS implementation, deployment and maintenance, and for working with the American Association of State Highway and Transportation Officials (AASHTO), Society of Automotive Engineers (SAE), and Institute of Electrical and Electronics Engineers, Inc. (IEEE), and others in setting relevant standards.

7.7.8 Milestones and Activities

Figure 7.7-l is a Gantt chart depicting the key activities, milestones, and, if applicable, decision points associated with developing this user service to a state where it is available for deployment. The accompanying supporting text identifies probable issues and describes the activities, with associated projects, identified on the Gantt chart. An issue is defined as a major potential challenge which has to be met in order to achieve deployability.

7.7.8.1 Issues

The key issue is "Can a technically feasible AHS service be selected that is acceptable to all AHS stakeholder categories?"

7.7.8.2 Activities

1. AHS R&D Projects

- The Partners for Advanced Transit and Highways (PATH) Program was established in 1986 by Caltrans and the Institute of Transportation Studies of the University of California at Berkeley. PATH research is conducted across a large range of subject areas. In AHS, current FHWA-funded PATH activities are focused on the development of technology to support high-speed platooning using electronic sensing and communications. These efforts include characterization of the performance of vehicle-to-vehicle sensors, vehicle-to-vehicle communications systems, and braking actuation systems. Extensive on-road testing is included. (1992 - 1994 for the current phase of research)

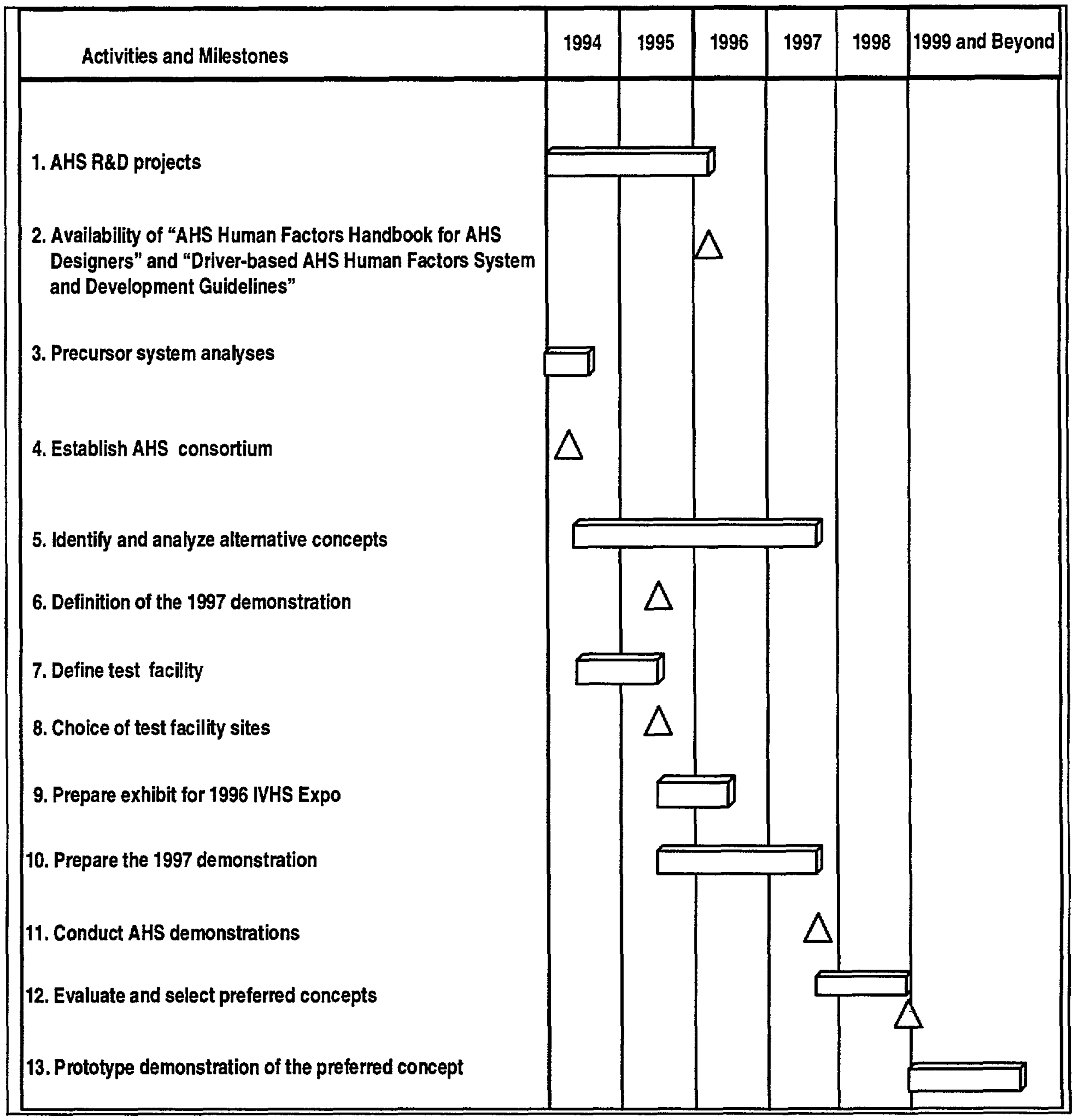

Figure 7.7-1 Gantt Chart

2. Provide a "AHS Human Factors Handbook for AHS Designers" and "Driver-based AHS Human Factors System and Development Guidelines"

- The Federal Highway Administration (FHWA) is funding the "Human Factors Design of Automated Highway Systems" contract with Honeywell. In the early portion of this project, AHS scenarios have been developed iteratively. These scenarios will form the basis for a set of empirical research investigations, addressing more detailed, system-specific AHS Human Factors Issues.

- The Handbook and Guidelines products will be the culmination of the efforts of the Human Factors Design of Automated Highway Systems project.

3. Conduct Precursor System Analyses

- Multiple FHWA-awarded contracts are analyzing key issues and risks of the AHS, including requirements definition, deployment, and operation.

4. Establish AHS Consortium

- A public/private partnership has been established between the U.S. DOT and the AHS consortium. The consortium is composed of AHS stakeholders and other interested parties, and will be responsible for conducting the system definition phase of the AHS program objectively and with full stakeholder participation.

5. Identify and analyze alternative concepts

- The AHS Consortium will:

  Analyze feasible AHS alternatives considering needs, technologies and transitions.
  System elements that be can be demonstrated in 1997 will be identified.
  Additional analyses will proceed in parallel with the preparation of the 1997 demonstration.
  Model and simulate AHS systems concepts.
  Develop of a cost/benefit analysis capability.
  Define requirements
  Conduct risk analyses of the key technology areas
  Evaluate institutional and legal aspects of AHS

6. Define the 1997 proof of technical feasibility demonstration

   - This will demonstrate important portions of a fully automated AHS system and/or subsystems and key AHS technologies. It may also address use of some of these technologies in collision avoidance products. This milestone results from the analyses in task 5.

7. Define test facility

   - The AHS Consortium will identify test facility needs and review eligible sites.

8. Choice of test facility sites

   - This milestone results from the activities in task 7.

9. Prepare exhibit for 1996 AIT/ ITS World Congress

   - An AHS exhibit will be prepared for the 1996 World Congress held in the United States in October, 1996.

10. Prepare the 1997 demonstration

    - The AHS Consortium will prepare test facilities, vehicles, electronics, and test plans for the 1997 demonstration.

11. Conduct a 1997 AHS demonstration

    - AHS feasibility will be assessed in this major milestone, which is a Congressionally-mandated demonstration.

12. Evaluate and select preferred concept

    - The results of the analyses (task 5) and the AHS demonstration (milestone 11) will be used to select a preferred concept to be prototype. This selected concept may include portions of several concepts merged into a single concept.

13. Test a prototype of the preferred concept

    - This test will institute all of the a major system functions. It will ensure that the selected concept operates as projected.

- Testing will also allow AHS performance specifications and standards to be refined.

- Transition to the preferred concept may also be addressed as part of testing.

14. Prepare performance specifications and standards for the preferred concept. Develop plans for an operational test and evaluate with public participation.

15. Prepare for and conduct an AHS operational test and evaluation.

    - This operational test and evaluation will be conducted on an existing highway and will involve the public. It will show operational viability, and public and community acceptance.

    - The test may or may not be conducted by the AHS consortium.