Michigan Department of Transportation
Regional ITS Architectures and Deployment Plans

Grand Region

Final
Regional ITS Deployment Plan

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LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AMBER	America's Missing: Broadcast Emergency Response
ANSI	American National Standards Institute
ATMS	Advanced Traffic Management System
AVL	Automated Vehicle Location
AWOS	Automated Weather Observing System
CCTV	Closed Circuit Television
CJIC	Criminal Justice Information Center
CRC	County Road Commission
CVB	Convention and Visitors Bureau
DCM	Data Collection and Monitoring
DEM	Department of Emergency Management
DMS	Dynamic Message Sign
DNR	Department of Natural Resources
DPW	Department of Public Works
DSRC	Dedicated Short Range Communication
EOC	Emergency Operations Center
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HRI	Highway Rail Intersection
IDAS	ITS Deployment Analysis Software
IEEE	Institute of Electrical and Electronics Engineers
IMMS	Incident Management Message Sets
ISO	International Standards Organization
ISP	Information Service Provider
ITS	Intelligent Transportation System
MAC	Medium Access Control
MDT	Mobile Data Terminal

LIST OF ACRONYMS

MITSC	Michigan Intelligent Transportation Systems Center
MOU	Memorandum of Understanding
MSP	Michigan State Police
NEMA	National Emergency Management Association
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communications for ITS Protocol
NWS	National Weather Service
RWIS	Roadway Weather Information System
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible and Efficient Transportation Equity Act – A Legacy for Users
SDO	Standards Development Organization
STMF	Simple Transportation Management Framework
TCP/IP	Transmission Control Protocol/Internet Protocol
TEA-21	Transportation Equity Act for the 21st Century
TIP	Transportation Improvement Program
TMC	Transportation Management Center
TOC	Traffic Operations Center
TSC	Transportation Service Centers
UDP/IP	User Datagram Protocol/Internet Protocol
USDOT	United States Department of Transportation
VIVDS	Vehicle Imaging Video Detection Systems
XML	Extensible Mark-up Language

1. INTRODUCTION

1.1 Project Overview

The Michigan Department of Transportation (MDOT) Grand Region Intelligent Transportation Systems (ITS) Deployment Plan is part of an overall effort to develop a statewide ITS architecture along with a deployment plan for each of MDOT's seven regions. To date, ITS deployments have been concentrated almost exclusively in the two largest metropolitan areas, Detroit and Grand Rapids. Both systems include a Transportation Management Center (TMC) that utilizes closed circuit television (CCTV) cameras, detection equipment and dynamic message signs (DMS) to manage traffic on regional freeways. Both systems focus on incident management activities and traveler information with the goal of improving the safety and mobility of the traveling public.

While the smaller urban centers and rural areas of Michigan do not experience the levels of recurrent and non-recurrent congestion (incidents) found in the larger cities, there are unmet needs related to traveler safety and mobility that provide opportunities for the strategic application of ITS technologies and concepts. Given the large number of roadway miles in these areas and the very limited capital budget available for improvements, ITS technologies may provide cost-effective ways of meeting these needs. A number of ITS applications are being proposed in these areas to improve service to the traveling public and to improve the overall efficiency of MDOT's system operations.

While recognizing the potential of ITS applications, MDOT also recognized that implementing ITS technologies in an ad-hoc manner across the State would not provide the system wide integration required; not achieve statewide performance requirements; and would, in the end, not be cost-effective. Coordination of services and communication between regions on program and project investments is a critical requirement for long-term success. Operations, maintenance, and ultimately replacement costs would be increased without this integrated approach. MDOT expects to identify ITS deployment projects in each region that address two major elements:

- **Development of an ITS architecture in regions where none existed and the updating of the architecture in areas where it existed but was out of date.** The program will establish regional architectures for the Superior, Bay, Grand, Southwest, and University Regions and update the existing architectures for the Detroit, Flint and Lansing metropolitan areas. The Federal Transportation Reauthorization bill of 1998 (TEA-21) greatly expanded the eligibility of ITS projects for Federal funding, but also included Section 940, which required that ITS projects eligible for Federal funding be compatible with the National ITS Architecture. The Federal Rule defines the national architecture as "a common framework for ITS interoperability. The National ITS Architecture comprises the logical architecture and physical architecture which satisfy a defined set of user services." The development of a consistent architecture across the State has several benefits. In addition to making ITS type investments eligible for Federal funding, it assures a consistent approach to technology applications across the State. The process also brings a variety of stakeholders together to open a dialogue that discusses issues of common concern and finds common ground on potential strategies to fund and implement the technologies.
- **Development of Regional Deployment Plans where they do not currently exist.** The architecture itself provides a structure that identifies packages of user services and also defines the connections between them. The Deployment Plan is needed to define the geographic location of the projects, the technologies that will be deployed, and the

timing of the deployments. Projects are defined in a manner consistent with the planning, programming, design, and implementation processes of MDOT. The Deployment Plan accounts for financial constraints and provides benefit/cost analysis of various deployment combinations. Combining the Regional Architecture and Deployment Plans within the same project allows consistency between the two. Consistency in the process across regions facilitates the development of multi-regional projects where appropriate. The product of the Deployment Plan is a set of defined projects with estimated costs and benefits. These projects will then be considered for funding through MDOT's statewide planning process in rural regions or through the MPO process in the urbanized areas. These regional deployment plans will reflect an understanding of their impact in advancing statewide policies and objectives and agreed to integrated system performance measures and, as such, will support cross regional applications investment programs.

Both of these focused efforts are impacted by a separate project, the development of statewide software specifications for Advanced Traffic Management Systems (ATMS). The software utilized in the Michigan Intelligent Transportation System Center (MITSC) in Detroit dates back to the mid-1990's and has been in need of replacement for some time. MDOT is making temporary improvements while developing a specification for new software. The West Michigan TMC is currently operating in the Grand Region and additional future TMCs have been identified as part of the ATMS Specifications. These TMCs have been identified in the Regional Architectures and will also be a part of the Statewide Architecture and Deployment Plan. The ATMS project will provide a common platform for all ITS deployments across the state. This will enhance coordination between regions and enable centers to back each other up during off-hours or times of emergency. To this end, a series of stakeholder meetings were held across the state to identify user needs and obtain feedback on how the ATMS software can enhance operational and maintenance activities.

Deployment Plans are based on stakeholder feedback, the recently completed MDOT state long range plan, urban area long range plans, review of data on transportation needs and the technical feasibility of various technologies. The Regional Architectures and the ATMS Software Specification help to define the development and analysis of ITS investment alternatives.

1.2 Grand Region Background

MDOT's Grand Region includes eight western Michigan counties that surround Grand Rapids, which is the State's second largest city and second largest metropolitan area. The region has a prosperous economy with components of services, education, manufacturing, agriculture and tourism. In addition to Grand Rapids and its suburbs, the region has several population centers along Lake Michigan, including Holland, Zeeland, and Muskegon. Major trunklines in the region include I-96, I-196, US-31. I-96 and I-196 are designated Corridors of Highest Significance in the MDOT Statewide Long Range Plan. All of these roads serve high volumes of commuter and commercial traffic, in addition to recreational traffic during peak weekends. US-31, US-131 and I-196 all serve significant volumes of recreational traffic. There are a number of other state trunkline roads serving regional traffic and commercial activity. **Figure 1** shows the Grand Region and the major roadways.

Figure 1 - Grand Region Study Area

The largest county in the region, Kent County, includes Grand Rapids and has a population of approximately 600,000. The Metropolitan Planning Organization's (MPO) regional boundaries include Kent County and eastern areas of Ottawa County. The Grand Valley Metropolitan Council (GVMC), the region's MPO, recently conducted an ITS Architecture Project and Deployment Plan for the area. As a result, this project includes only the portions of the Grand Region not included in the GVMC study. There are two other MPO's in the Grand Region. The Macatawa Area Coordinating Council includes Holland and Zeeland and overlaps into MDOT's Southwest Region. The Muskegon metropolitan area is also an MPO. **Table 1** shows the population and employment figures for the study area. All of Ottawa County is included even though a portion of the County was included in the previous study. The population of the 7 counties in the study area was estimated in 2006 at 617,600, a 5% increase from 2000. Combined with Kent County's increase of 25,000, MDOT's Grand Region has seen a total increase of 57,000, which makes it one of the faster growing areas of the State. The ratio of employees to population in the seven counties is under 0.4, a relatively low ratio reflecting the fact that many residents of these counties work in Grand Rapids and outlying areas of Kent County.

Table 1 - Grand Region Study Area Demographic Data

County	Population 2000	Population 2006	Population Change	Employment 2006
Ionia	61,518	64,821	3,303	15,122
Mecosta	40,553	42,252	1,699	11,265
Montcalm	61,266	63,977	2,711	16,316
Muskegon	170,200	175,231	5,031	65,993
Newaygo	47,874	49,840	1,966	11,690
Oceana	26,873	28,639	1,766	8,407
Ottawa	238,314	257,671	19,357	112,784
TOTAL	**585,080**	**617,610**	**32,530**	**226,455**

The heaviest volumes on the region's roadways are found on the Interstate and major trunkline roads. Average annual daily traffic (AADT) on US-131 through the center of Grand Rapids exceeds 100,000 and a number of roads in Grand Rapids exceed 60,000 AADT. Outside of Grand Rapids, the largest volumes are found on I-96, I-196, US-31 and US-131. US-31 has the largest number of high volume locations and experiences heavy recreational traffic as well. Volumes generally run between 25,000 and 50,000 AADT on these highways with lower volumes found in the northern portions of the region and higher volumes found in spots near the urbanized areas. Volumes exceed 40,000 AADT at the Ionia-Kent County line on I-96 and on the Ottawa-Kent County line on I-196. Some additional high volume locations in the region (outside of Kent County) are listed in **Table 2**.

Table 2 - Routes with AADT Greater than 40,000

City	Route	AADT
Muskegon	US-31 north of I-96	63,900
Grand Haven	US 31 at Grand Haven Bridge	63,200
Holland	US 31 South of BR-31	50,300
Ionia/Kent County Line	I-96	45,200
Grand Haven	US 31 North of Grand Haven Bridge	44,600
Grand Haven	US 31 South of Grand Haven Bridge	43,900
Kent/Ottawa County Line	I-196 West of M-6	41,600
Holland	US 31 North of BR-196	40,900

A Grand Region map indicating AADT volumes is shown in **Figure 2**. Local maps of the Muskegon, Grand Haven, and Holland/Zeeland areas are also shown in **Figure 3, Figure 4**, and **Figure 5**.

Figure 2 - AADT Grand Region

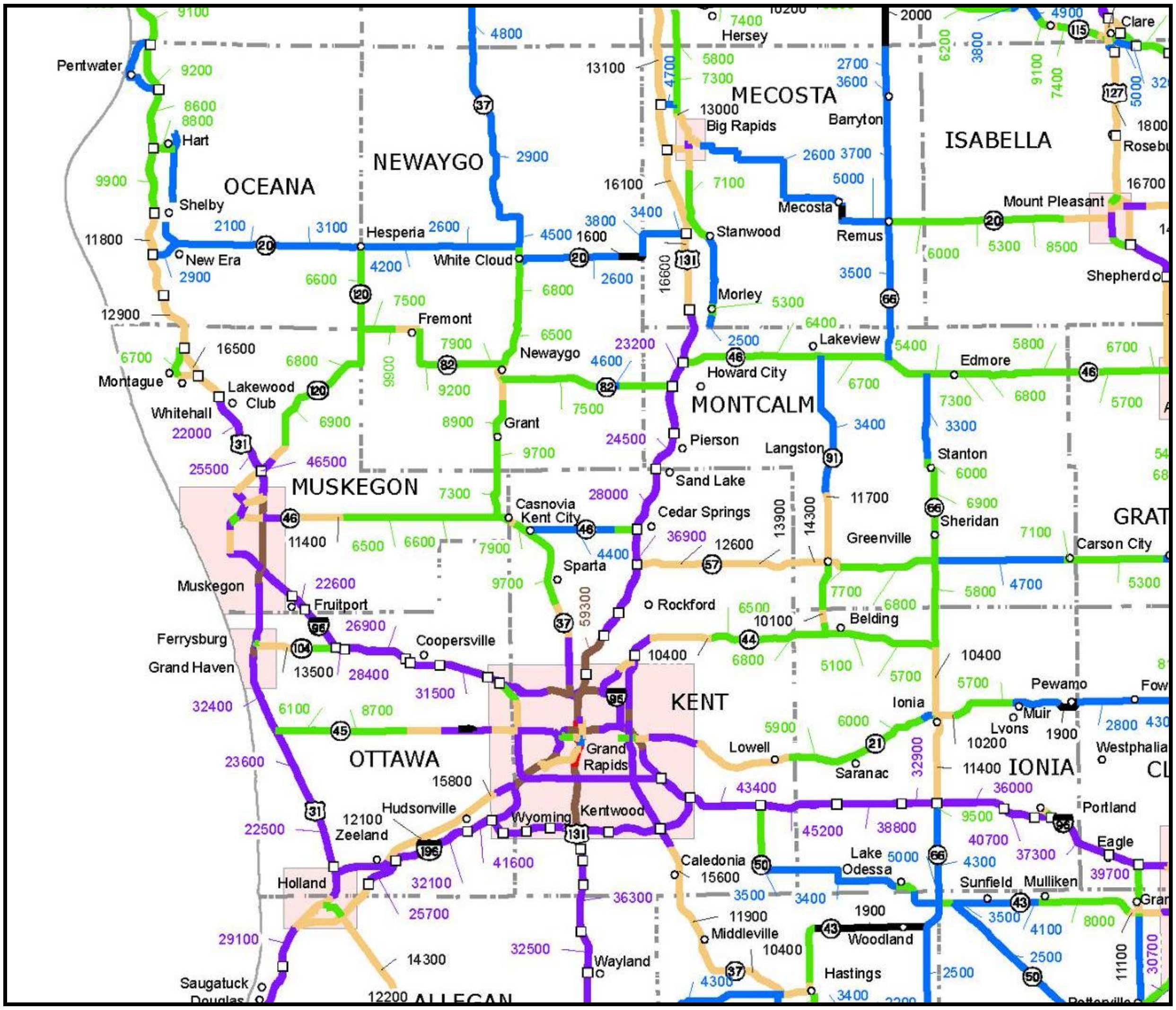


Figure 3 - AADT Muskegon Area

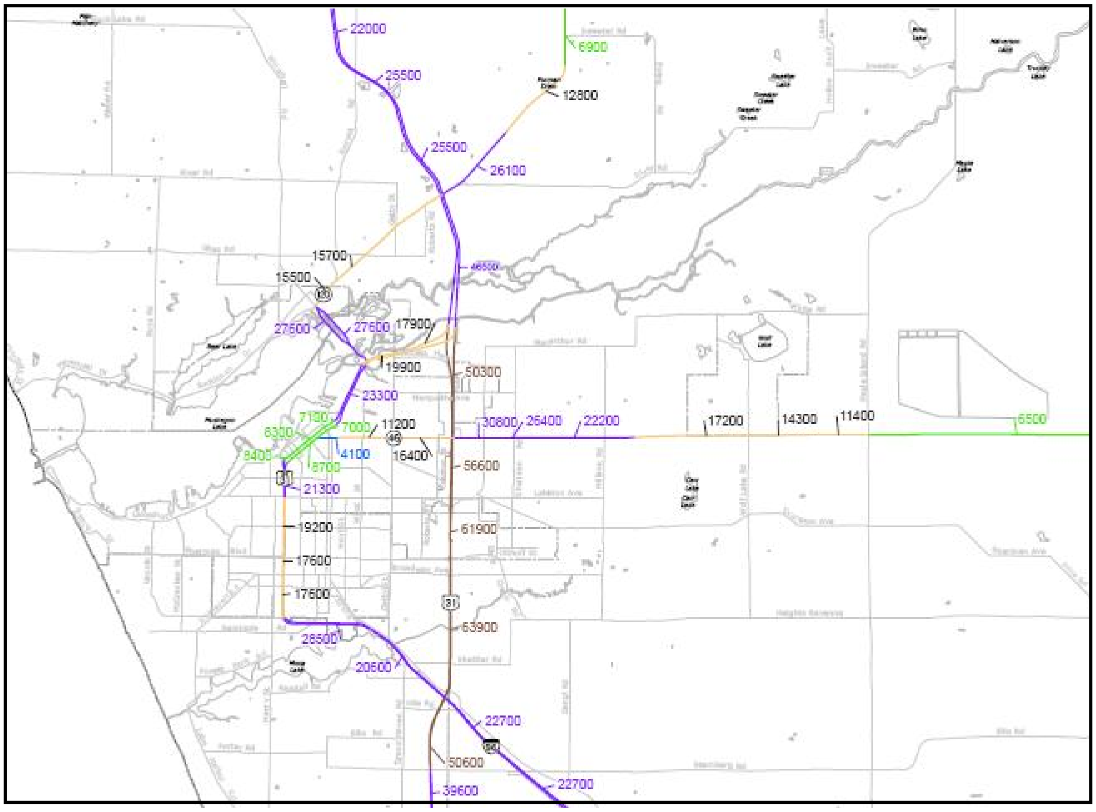


Figure 4 - AADT Grand Haven Area

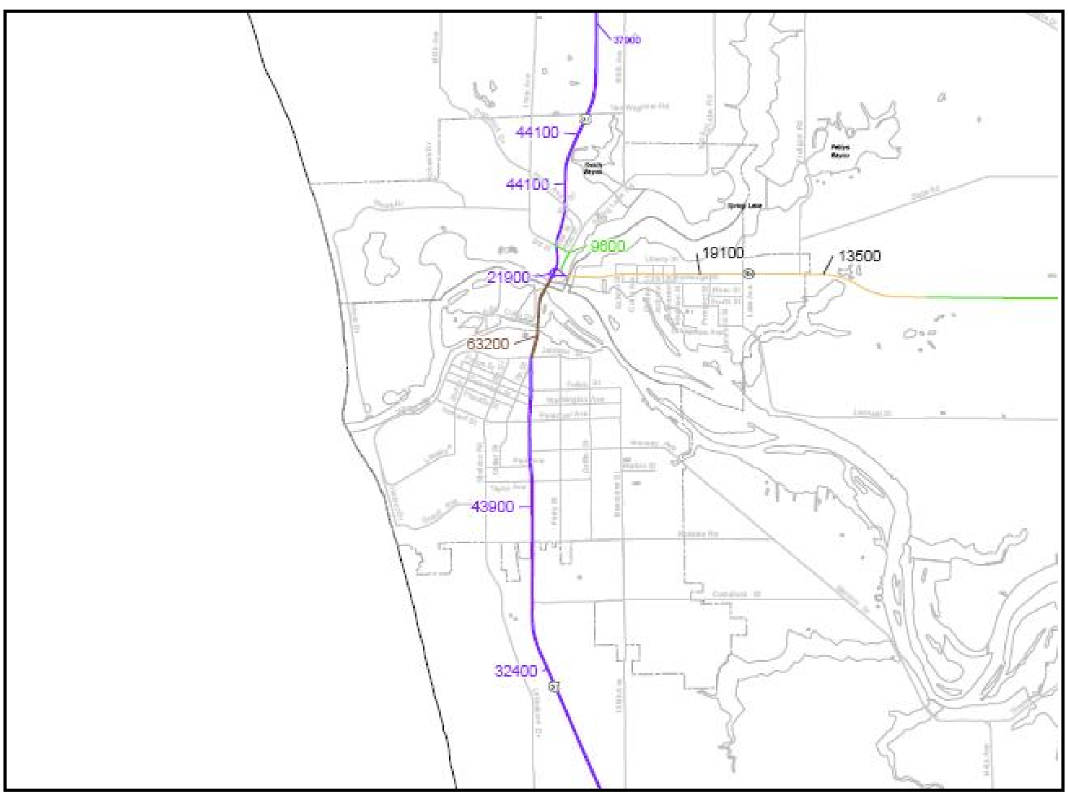
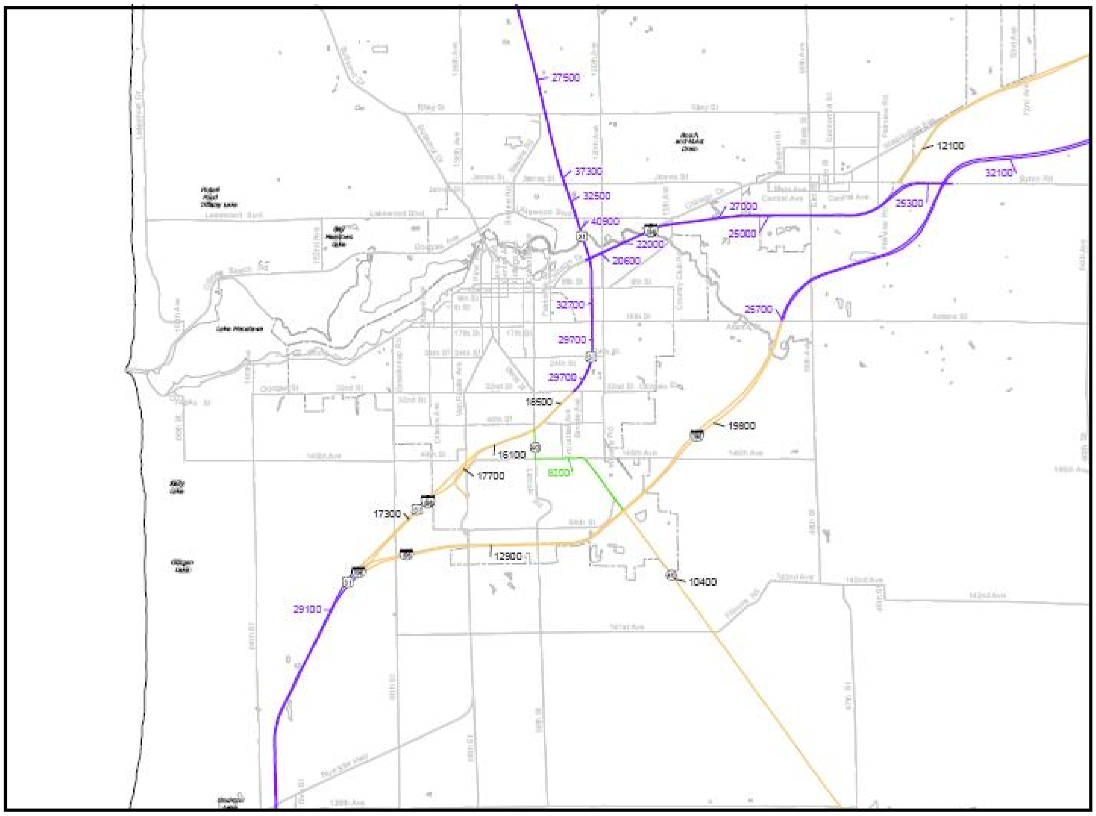


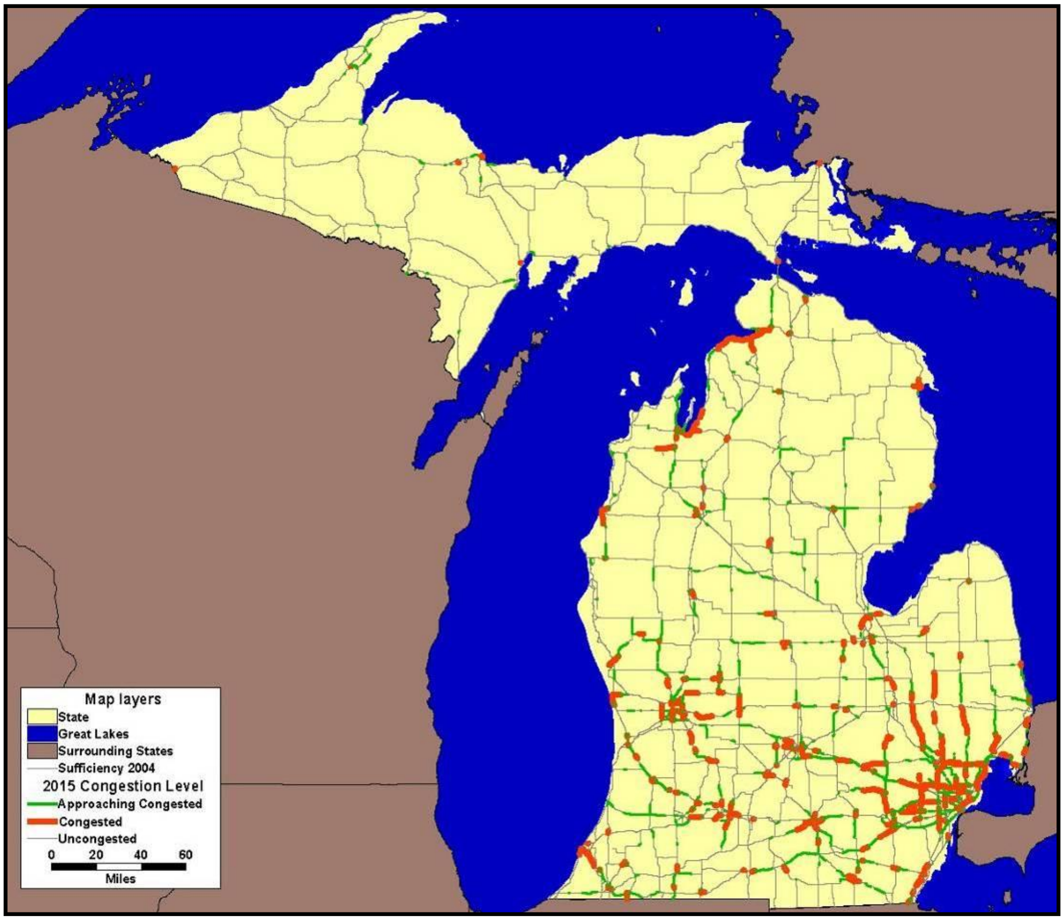
Figure 5 - AADT Holland/Zeeland Area



MDOT prepared a series of congestion maps for the recently released 2030 State Long Range Transportation Plan. Due to continuing changes in technology, ITS projects are generally planned over a short period. Even though an agency's operational approach may not change, the technology options and the communications approach can vary and thereby greatly affect the designs of an ITS deployment. **Figure 6** shows projections of congested locations and locations approaching congested conditions for 2015. Outside of the immediate Grand Rapids area it appears that the region's freeways will be able to handle projected traffic volumes. Many of the congested areas projected are arterial routes including US-31 and M-104 in the Grand Haven area, M-120 in the Muskegon area, M-21 in Ionia County, M-66 in Ionia and Montcalm Counties, M-57 and M-91 in Montcalm County, and around the towns of Big Rapids in Mecosta County and Newaygo and Fremont in Newaygo County. As growth continues in the outlying areas of the Grand Region it appears that many of the commercial areas and two-lane trunkline roads will experience increased delays. Increased bottlenecks along these roads will make it more difficult to use them as relief routes when major incidents occur on area freeways.

In addition to increases in traffic volumes, which are driven by population and employment growth, recreational traffic continues to increase in the region. I-196, US-31 and US-131 are major routes from Indiana and the greater Chicago area to the resort areas of northern Michigan.

Figure 6 - 2015 Congested Levels



1.2.1 Safety

Safety is another key issue in the region. Lake effect storms are common in the region during winter, creating blizzard conditions. These can be especially hazardous on US-31 which runs along the Lake Michigan shoreline. Like other areas where suburban growth is spreading into rural areas, lack of roadway lighting, animal hits and higher volumes at rural and suburban at-grade intersections are major safety problems.

According to Michigan's most recent Highway Safety Report, produced by the Governor's Highway Safety Office, fatalities in the Grand Region increased from 87 in 2004 to 94 in 2005 and then dropped back to 82 in 2006. In all three years, Muskegon and Ottawa Counties accounted for the majority of fatalities. Ottawa had 22, 30, and 28 fatalities over the three years while Muskegon County had 18, 16, and 22. Alcohol-related crashes are also a concern for the region. The State Highway Plan showed that the four northern counties in the region, Oceana, Newaygo, Mecosta and Montcalm, had HBD (Had Been Drinking) rates for fatal crashes that were higher than the statewide average.

1.2.2 Public Transportation

Public transportation is an important component of providing transportation service options in the Grand Region. As shown in **Table 3,** there are 8 transit agencies in the Grand Region, including both regional and County-based systems. The Grand Rapids system is clearly dominant in the region, carrying 85% of the 7.6 million annual transit riders in the region and accounting for 75% of the region's $32.7M annual transit budget. After Grand Rapids, the largest systems are located along the Lake Michigan shore. The Macatawa Express system in Holland (which also serves part of the Southwest Region) carries over 200,000 annual riders on 43 buses. The Muskegon Transit Authority carries nearly 500,000 riders on 40 buses and the Grand Haven system carries 165,000 annual passengers on 22 buses. The combined annual budget of the three agencies was about $6.7 million in 2005. The other agencies in the region are smaller and provide primarily dial-a-ride service. Cost per passenger varies from $3.75 in Grand Rapids to $13.38 for the Macatawa system. The average cost per passenger for the authorities outside Grand Rapids is $7.42.

Two options discussed for improving transit service in the region include installation of CCTV on buses for security and the implementation of Automated Vehicle Location (AVL) technology. The latter would be beneficial as a joint effort of the three Lake Michigan shore transit authorities which could coordinate implementation and thus reduce cost.

Table 3 - Characteristics of Grand Region Transit Authorities – 2005

Agency	Vehicles	Pop	Employees	Veh Miles	Veh Hours	Passengers	Budget	Cost per Pass
Big Rapids Dial-A-Ride (Mecosta Co)	7	10,849	10	93,431	7,873	56,576	$359,468	$6.35
Grand Haven	15	18,407	22	373,497	24,644	165,225	$1,460,429	$8.84
Grand Rapids	174	483,740	269	3,878,787	291,695	6,440,697	$24,151,108	$3.75
Greenville Transit (Montcalm Co)	9	8,108	9	137,050	10,418	99,035	$427,913	$4.32
Holland (Macatawa Area Express)	27	77,377	43	774,966	57,358	212,167	$2,838,164	$13.38
Ionia(City of) Dial-A-Ride	12	15,549	18	144,639	10,946	73,018	$499,986	$6.85
Mecosta Osceola Transit Auth	11	63,758	8	249,467	9,661	51,007	$518,046	$10.16
Muskegon	21	106,252	40	567,018	43,257	493,631	$2,437,958	$4.94
Total	**276**	**784,040**	**419**	**6,218,855**	**455,852**	**7,591,356**	**$32,693,072**	**$4.31**
Outside of Grand Rapids	*102*	*300,300*	*150*	*2,340,068*	*164,157*	*1,150,659*	*$8,541,964*	*$7.42*

Source: MDOT Transit Management System, 2007

1.3 Report Summary

MDOT, like many other transportation agencies, is looking for ways to gain greater capacity out of existing facilities and to better "manage and operate" the system. As more ITS systems are deployed, more information becomes available about the costs, benefits, and performance characteristics of these systems. This document focuses on the benefits and costs of various ITS deployments as they relate to overall system performance. This enables MDOT to make the most cost-effective use of limited available funds, coordinate ITS investment with normal road and bridge project decisions, and to evaluate ITS on the same footing as other transportation improvements. The tools being applied to this study will permit ITS to be "mainstreamed" into the day-to-day business of MDOT and other transportation agencies. This report presents the general process designed by the MDOT and the Study Team to develop an ITS Deployment Plan for the Grand Region.

The remainder of the report includes the following information:

- A description of the study process including:
  - Overview of Study Process
  - Needs assessment methodology
  - Inventory
  - Stakeholder feedback
  - Definition of alternatives
  - Evaluation of alternatives– criteria and process
  - Grand Region projects for analysis
- Findings
  - Benefit/cost analysis methodology
  - IDAS model documentation
  - IDAS results
  - Description of benefit/cost analysis

2. Regional ITS Architecture Development Process

2.1 Overview of Study Process

The purpose of the Grand Region ITS Deployment Plan is to identify feasible ITS projects that can meet the needs of the region's stakeholders and develop a realistic plan to implement them. A key outcome of this process will allow the "mainstreaming" of ITS technologies, concepts and projects into the planning process and the project development process of MDOT and other key planning and transportation agencies in the region. In order to accomplish this objective, the process used to evaluate ITS projects must be compatible with that used to evaluate more traditional transportation projects. For example, ITS projects have been considered as alternatives to major roadway capital investment, or at least as a way to provide temporary relief until major capital investments can go through what is often a lengthy funding and approval process. In order to help make investment decisions, planners and engineers must have the tools and procedures to compare the benefits and costs of ITS investments and their impact on meeting agreed-to system performance goals with those of other projects. This process facilitates activities that will allow MDOT to better manage and indeed operate its transportation system assets and get the most from its transportation investment decisions. The process developed for this project was designed to address this objective.

Figure 7 provides a high-level overview of the process used to accomplish the study objectives. The primary feature of this approach is that it follows the process used to plan other types of transportation improvements. Steps included:

- Review previous studies and documents including documentation of any existing ITS system and corridor studies which address ITS as a potential solution to transportation problems.
- Define the transportation facilities and services to be included in the study.
- Collect and review planning level data to identify specific system problems. Sources primarily included statewide and urban area transportation plans, traffic volumes, accident data and travel demand forecasts.
- Develop and implement a stakeholder process to help identify transportation system needs and problems, and potential ITS solutions. Extensive meetings were held with a wide range of regional stakeholders.
- Define and document transportation system problems and needs based on the information obtained from the above sources.
- Develop a process for defining ITS alternatives and a set of alternatives.
- Conduct a benefit/cost analysis of the proposed alternatives, using the statewide travel demand model as a basis. The ITS Deployment Analysis System (IDAS), a sketch-planning tool used to estimate the impact of ITS deployments, was used for this purpose.
- Develop an implementation plan with funding options as a guide to help decision-makers prioritize ITS deployments.

Figure 7 - Deployment Study Process Chart

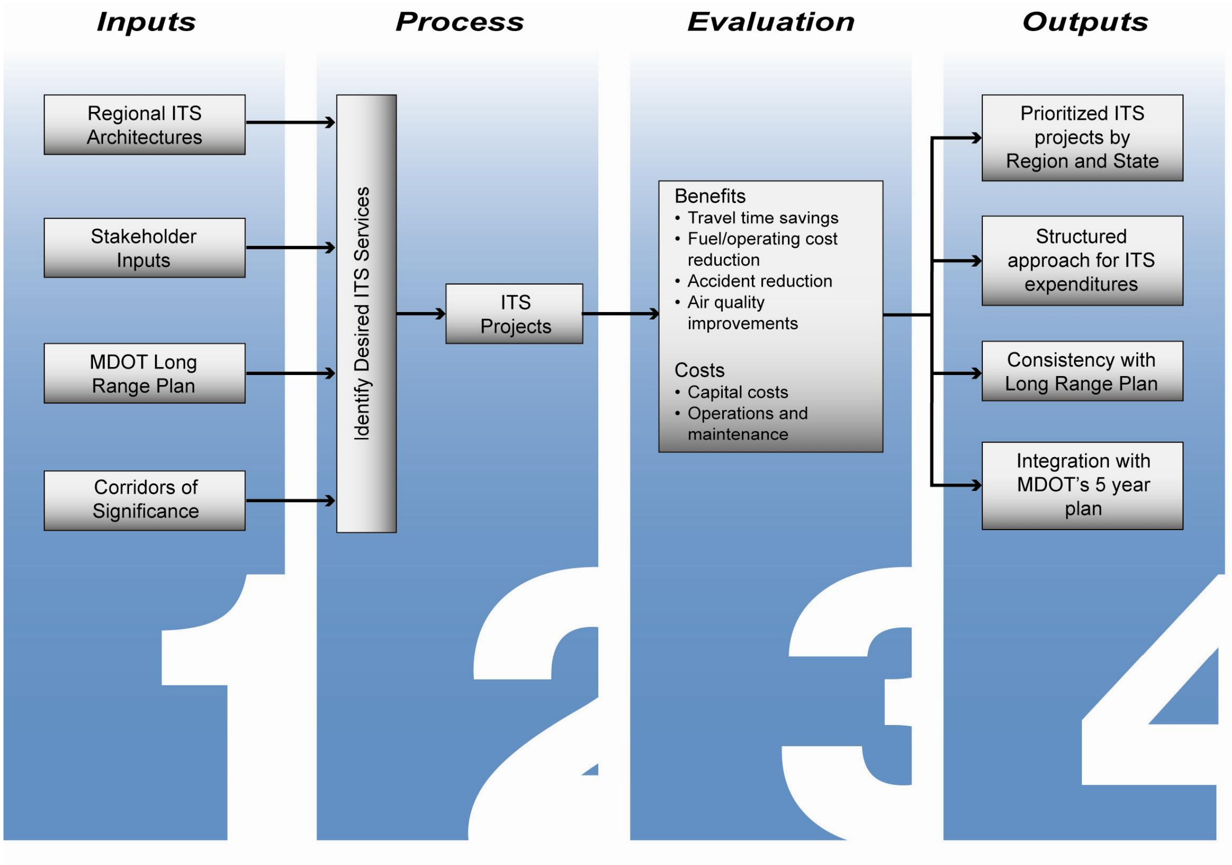
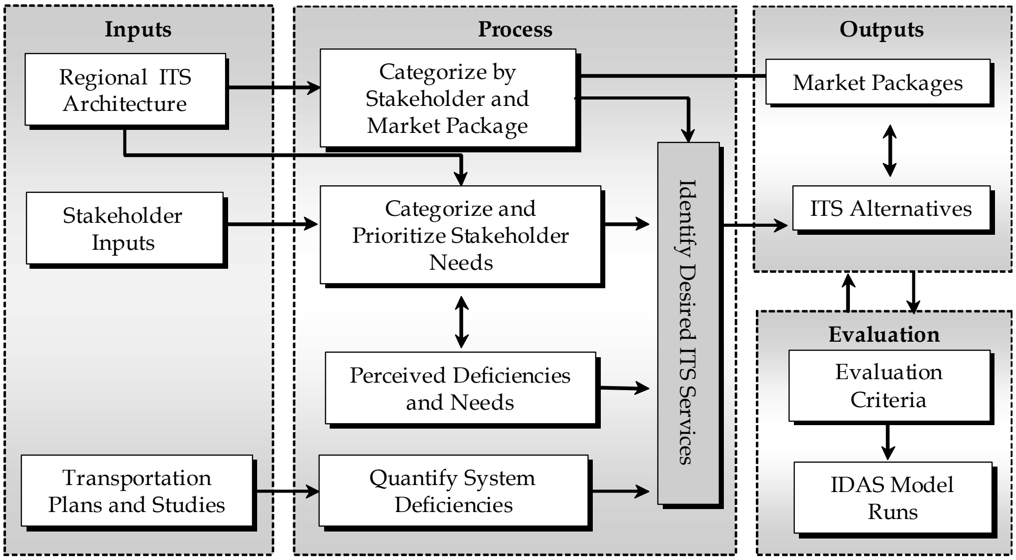


Figure 8 provides a more detailed view of the process used to develop and evaluate ITS alternatives. Inputs used to develop the alternatives are shown in more detail and include:

- Output of the regional ITS architecture process;
- Stakeholder input; and
- Review of transportation plans and studies for the study area.

Regional needs were identified using these inputs. Subsequently, the needs served as the base for the development of alternatives.

Figure 8 - Process to Develop and Evaluate ITS Alternatives



The process shown graphically in the middle box includes four steps.

1. Categorize the output of the Grand Region's architecture projects by stakeholder and market package. This information is used to help identify ITS-related projects of interest to various stakeholders, and to assure that the ITS plan is compatible with the regional architecture.
2. Categorize and prioritize needs that were identified by stakeholders through meetings, reports and interviews. This information is used to help identify system problems and deficiencies, attitudes toward existing ITS services, and potential applications of ITS.
3. Identify perceived needs and deficiencies in terms of congestion, safety and other criteria.
4. Quantify system deficiencies and problems to the extent possible using the data described above and other data such as traffic volumes, existing and projected volume/capacity ratios and accident data.

The output of this process is used to identify ITS alternatives that address the needs identified. The process of defining and developing ITS alternatives is described in Sections 2.2 and 2.3. The ITS alternatives are then evaluated using the IDAS model. The model provides cost estimates in addition to benefit calculations related to travel time/mobility; accident reduction; fuel and operating cost savings; and air quality.

2.2 Needs Assessment

This section includes a summary of the needs assessment conducted for the Grand Region Deployment Plan. While the data presented in Section 1 provided a good foundation for analysis, the discussions at the stakeholder meetings provided the critical information focus required to develop alternatives for analysis. The Study Team worked with MDOT to identify a list of key stakeholders, who would provide input to both the architecture and the deployment plan. During the meetings stakeholders were asked to focus on:

- Identification and assessment of existing ITS systems;
- Perceptions of current transportation system, including system performance and effectiveness;
- Existing transportation needs that could be addressed by ITS;
- Future needs that could be addressed by ITS;
- Problems and opportunities in ITS deployments;
- Impact of technology on future ITS deployments; and
- Priorities for future ITS deployments.

2.2.1 Inventory

The first step in the needs assessment process was to develop an inventory of existing ITS and ITS-related services in the Grand Region. The needs assessment process was also used to identify agencies that may benefit from ITS solutions. There have been significant recent deployments in the Grand Region, primarily in Kent County, that can serve as a basis for expansion to the rest of the region. In addition, there are a number of systems in place elsewhere in the region. This section lists existing systems in the Grand Region and their intended purpose. The inventory created from the needs assessment will aid the stakeholders in learning about the operations and available information that is currently used throughout the Grand Region.

Advanced Traffic Management Systems (ATMS) in the Grand Region include:

- The West Michigan TMC is the largest ITS system in the region and is the only major Freeway Management System (FMS). At the current time the system only serves Kent County, but may be expanded outward in the future. It is likely that ATMS alternatives will be proposed for the outlying counties of the Grand Region, as well as those proposed for the Southwest Region, will be operated out of the West Michigan TMC in Grand Rapids.
- There are several advanced signal systems in the region. In Big Rapids, MDOT upgraded a signal corridor with wireless interconnects. This system is running in semi-actuated mode on the same clock and there are coordination plans programmed into the controllers. There is a similar system in Grand Haven that can be monitored from Lansing, but it can only be controlled locally. Both corridors are subject to heavy tourist volumes and it would be beneficial to modify timing during periods of heavy usage. There is a closed loop system from Holland northward from US 31 to M 45. It has fiber-optic interconnect and can also be accessed thru phone lines.

- MDOT maintains a construction website and information on construction activity is fed to media outlets directly from Lansing. Management of tourist traffic is a major issue in the region. Construction schedules are important for keeping traffic flowing with an initiative to "get barrels out of the way". It is a constant effort to try to balance construction needs with travel needs.
- Portable DMS are heavily used in the region. They are controlled remotely and MDOT is using standardized messages. The majority of the DMS are utilized as part of construction contracts, but the Grand Region owns four (4) that can be deployed anywhere, but it can be a logistical challenge to get signs to the right location. To date, MDOT has not found a place where a permanent DMS is warranted outside of the existing Grand Rapids FMS. MDOT is focused on construction applications so portable signs are a higher priority.
- There are permanent count stations that provide real-time data outside of the Grand Rapids area.
- Flashing school zone signs are considered an ITS technology. These signs are generally controlled by school officials and not transportation agencies. Manual switches are used in many areas so the signs do not stay on when school is not open.
- Four-way stop signs or flashing beacons are generally used in rural intersection applications. In Kent County, a rural surveillance study is being conducted by the University of Minnesota. The study is evaluating the use of signals versus other ITS technologies for dangerous stretches of rural roadway or intersections. MDOT funds a program to improve safety at rural intersections with high crash rates. While ITS technologies have not been used to date, there may be potential applications in the future.
- The S-Curve in Grand Rapids is the only actuated warning sensor in the region.
- Dynamic merging in work zones has been previously used in Grand Region. It was used once in the Muskegon area as well but there have not been any projects lately where the use has been justified. Feasibility of the application is largely dependent on the roadway geometry.

Improving the efficiency and safety of snowplowing and other maintenance activities is a major concern to stakeholders in the region. The activities underway in this area include:

- MDOT's Motor Carrier Division has portable Weigh In Motion (WIM) devices. These devices can be easily set-up in rest areas along roadway segments where overweight trucks are perceived to be a problem. Some locations are set-up seasonally to coincide with the agricultural harvest. Traffic volume data are used to determine the best times to enforce weight limits. The data from some of the permanent counters need to be manually downloaded, but certain counters have the capability to send back data automatically. Historical traffic count data available on the archive system are also used. MDOT has a crash data system that is helpful, but it is not easy to get data from that system. There are new stations on M-6 that are very accurate. They use a 6" bending plate with wireless hookup. There is a permanent WIM on I-196 near 44th Street. Police indicated there are locations outside of Kent County that could benefit from WIM sites, but the cost may be prohibitive.

- Seasonal weight restrictions are utilized on some roads. Monitoring is done manually with frost tube installations at key locations. There is an interest in technologies that would make monitoring of the frost heaves easier and cheaper for the maintenance personnel.
- In many areas, all maintenance services are contracted, primarily to the County Road Commissions and a few smaller municipalities. In the Grand Region, MDOT does not own any snowplows so all of the plowing is contracted with these agencies. MDOT is leading a coordination effort on the I-96 corridor from Ionia County to Lake Michigan to standardize and better coordinate plowing activity. An operational plan is being developed. Muskegon City has a GPS system and Muskegon County and some smaller municipalities are considering it the use of GPS technology.
- There are NWS and ASOS/AWOS weather stations in the region. Most agencies use the internet and weather channel to track current conditions and forecasts.

Incident Management initiatives in the Grand Region include:

- Grand Haven, Ottawa, and Muskegon Counties have central emergency dispatch. Osceola and Mecosta Counties share a dispatch center. Most systems are county-based, but it is not clear how much coordination exists between counties, which can lead to confusion about responsibilities. Based on successful relationships, there are opportunities for improving coordination in the Muskegon area and along major corridors.

Advanced Public Transportation System (APTS) initiatives in the Grand Region include:

- In Muskegon, which has the region's largest regional transit system outside Grand Rapids, there is limited ITS technology on the fixed route system. There are plans for the new buses to have CCTV cameras and GPS-triggered voice annunciation, but they will not have the ability to track vehicle location. Video surveillance is internally contained and used primarily for security and liability. Muskegon operates ten (10) routes on weekdays and does not border any other transit system. The demand response system has had Computer-Aided scheduling for five years. They do not have mobile display terminals and still transmit by radio. They have a self-contained video surveillance at their downtown terminal. They have recently implemented a new website, but it does not provide any real time interaction. The County Road Commission has worked with the State to develop a GPS station. Surveyors can access it and it can be helpful to transit systems and other agencies.
- Ionia has two transit systems and is pursuing Federal funds to expand or integrate these systems. Ionia has AVL on demand responsive vehicles. Big Rapids has demand responsive radio contact only.

In addition to the West Michigan TMC in Grand Rapids, the Grand region has a number of ITS elements and planned system improvements that will provide the basis for a more coordinated system on a regional and statewide level. MDOT and public safety agencies in the region make use of radios and other means of communication to exchange important information across this large region. ITS technologies have the potential to improve these operations, but should build upon the existing systems and the well-supported partnerships between MDOT, public safety agencies, and the local transportation authorities. These partnerships will aid the region to effectively implement programs and technologies that can manage incidents; coordinate incident-related traffic; and improve the coordination of winter maintenance activities.

2.2.2 Stakeholder Feedback

Stakeholder feedback was the major input in identifying transportation needs of the Grand Region. Three different workshops provided contributions to this process. While the first two were specifically geared toward architecture development, they provided an opportunity for stakeholders to identify specific ideas and projects. Stakeholders were asked to identify other interested parties and to respond to ideas developed by the consultant team. The three meetings included:

- December 5, 2006 – Architecture Kick-Off Meeting – Stanwood, Michigan
- January 17, 2007 – Architecture Development Workshop – Fremont, Michigan
- August 2, 2007 – Deployment Plan Workshop – Grand Haven, Michigan
- December 4, 2007 – Comment Resolution Workshop – Grand Rapids, Michigan

Needs identified in the workshops are summarized below:

Traffic/Incident Management

- There are major issues with seasonal traffic. Congestion is greater in the summer, but incident management is a bigger issue than tourism itself. There is recurring congestion in Grand Rapids, but it also exists in other spots in the region such as Grand Haven.
- There are a few severe crashes at rural intersections. A surveillance system from for Public Safety would be helpful and there is a need to get better information to the first responders. Integrating the TMC with the EMS CAD systems would improve coordination. This integration has been talked about in Kent County, but it could expand to other portions of region and with other districts. This integration could include the Michigan State Police in Grand Rapids and some of the counties to the north in MSP Region 6.
- There are several special events in the region that require traffic management. The Coast Guard Festival in Grand Haven is a major event that draws over 100,000 people during a two-week period in late July and early August. Some smaller towns have festivals and could benefit from solutions for handling the traffic during these events. Enforcement works with local officials for signing. As part of the coordination effort, it is important to note that the home rule is a big issue and can impact who gets contacted and how information is shared.
- Surges of traffic may be 50-100% higher during peaks and it would be helpful to have remote access for controlling arterial signals during these periods. Within MDOT, signal system technology planning is more centrally managed and there is a need to bring signals and ITS closer together. Some Ottawa County municipalities near Muskegon (Grand Haven, Ferrysburg, and Spring Lake) have recently been integrated into the MPO. This integration should help to overcome an historic separation and improve coordination between these agencies.
- There is a need for CCTV surveillance in specific locations. One is the Bascule Bridge in the Grand Haven area. CCTV camera surveillance would also be useful along the Holland-Grand Haven corridor (US 31) which experiences lots of crashes, aggressive driving and frequent red light running. This type of driver behavior is prominent because the drivers are transitioning from freeway conditions to signalized corridor. CCTV cameras and DMS would be good for

incident management and an initial deployment for a regional system. Improved coordination of signals and the implementation of detour routes could be integrated as part of the regional traffic management system. MDOT is currently developing incident detour routes in the Muskegon area and DMS installations could provide an opportunity to mitigate the need for a greater number of fixed-route detour signs.

- As part of the incident management initiative in the Grand Region, annual incident management meetings with key agencies are held to review the response to major incidents. Informal incident management plans have been in place in the Ottawa/Grand Haven area and there is a move to formalize these plans. The Michigan State Police would like to be able to access and manipulate CCTV cameras, primarily during incidents. MSP would like to transition detour and emergency plans to be a more dynamic and electronic approach instead of the use of thick manuals that are difficult to reference in emergency situations. There has been some discussion of the possibility of using DHS funds for implementation of some solutions.
- Countywide Wi-Fi has the potential to enhance communications and it is being developed in certain places already. Grand Haven has implemented Wi-Fi and other municipalities are investigating the opportunities. Wireless communication is used by Grand Haven for a CCTV camera that was installed at the city Pier due to multiple drownings.
- Help is needed in working through communications issues between agencies.

Maintenance Activities

- Commercial Vehicle Operations (CVO) needs include improved access to remote WIM sites. Remote access is currently available and provides quality data, but the interface is not user friendly. Of interest are MDOT counts (volume), weight, and speed data. MSP monitors the data that is collected for quality control.
- The deployment of RWIS has been documented as a need for Western Michigan.
- A need was identified for automated anti-icing systems on key structures. Specific locations would have to be identified.

Traveler Information

- The West Michigan TMC currently provides traffic information and CCTV camera feeds to the local media. Outside the area covered by the TMC, a major issue is the coordination with local media when an incident occurs. It can be difficult to get the information to the correct agencies and users. The public has an interest in knowing how the traffic is flowing and, if there is a delay, what is the cause and what is an alternate route.

Public Transportation

- Transit systems could see great benefits from additional traveler information, but these agencies need staff to manage and interpret the data. Public transportation agencies like the idea of utilizing technology, but often find it difficult to implement operations that can manage the information collected due to limited staffing and resources.

2.2.3 Demand Model Projections

MDOT's statewide travel demand model was used as the basis for the analysis of benefits and costs for the different ITS alternatives. The model uses average annual daily traffic (AADT). A short time frame, 2010, was selected for the analysis. The model was also used, along with data from the Statewide Long Range Transportation Plan, to identify congested areas.

2.3 Definition of Alternatives

2.3.1 Alternatives Definition Overview

One of the major challenges in the evaluation of ITS alternatives is the definition of those alternatives. Unlike roadway and public transportation improvements, ITS can include a wide range of technologies, packaged and implemented in different ways. One of the early efforts in this study was the development of a framework for evaluation of ITS alternatives. Several characteristics of ITS alternatives were established early in the process, including:

- **Timing/Phasing** – Like other transportation improvements, ITS options need to be evaluated for a specific point in time, but the deployment can be phased in over a period of years with the most appropriate portion of the recommended solutions implemented to address the most pressing problems, and at the same time setting the technology framework for longer term investments. With limited funding available, projects need to be prioritized for implementation. While 2010 is used for the analysis, the presentation of specific alternatives in this report does not tie them to a specific year. This approach provides flexibility to implement portions of these plans and assess their effectiveness.
- **Geographic Coverage** – Depending on the technology used, ITS alternatives can cover a specific facility, a corridor, or a region. Surveillance and management elements are tied to a specific corridor, while traveler information may be provided over a wide area. It is important that the geographic component of the ITS alternative be clearly defined. Some of the larger projects may be broken into segments and implemented in phases. Clear geographic limits also provide the opportunity to incorporate ITS projects into larger bridge or roadway reconstruction projects. It is also critical that statewide or inter-regional impacts or alternative deployments be considered.
- **Technology Component** – ITS consists of a series of technology deployments that work together to meet safety and congestion-related objectives. It is this component that makes ITS more complex and therefore more difficult to define than physical improvements or additions to roadways or public transportation systems. Also, the level of ITS deployment can vary in intensity. On heavily congested urban freeways, for example, full coverage with cameras and detectors may be desirable. In less congested areas, coverage may be needed only at major interchanges and/or high accident locations. The following section addresses the methodology used to develop conceptual alternatives, and specifically appropriate levels of deployment. This serves not only as documentation for the study, but also as a template for future use by MDOT.

2.3.2 Alternatives Technology Definition

Some of the key concepts in defining ITS alternatives are:

Coverage of ITS Deployment is a collective term that represents the extent of ITS deployment in a region. It accounts for:

- Number and length of routes covered;
- Number of infrastructure facilities covered (for example, number of traffic signals in an arterial traffic management system);
- The area covered, in the case of systems that have a network-wide impact (i.e. transit CAD and AVL);
- Equipment; and
- Overall geographical expanse of the ITS deployment including availability of traffic information.

ITS Deployment Intensity indicates the intensity of ITS deployment within the area of coverage which is a function of the quantity and quality of the ITS user services provided. There is no all-inclusive list of parameters that influence the deployment intensity, but typical examples of parameters that represent deployment intensity are:

- Spacing of ITS equipment such as CCTV cameras, detectors, DMS;
- Number of buses in an APTS that are equipped with CAD/AVL;
- The hours of operation of a TMC or ATMS center; and
- The hours of operation of an FSP.

Deployment intensity is different from coverage of deployment as it represents the degree of the ITS functionality of a deployment within the coverage area. Therefore, two similar ITS deployments can have the same coverage but differ in their deployment intensities. A typical example would be the case where there are two FSPs that cover the same roadway mileage, but one of them operates only during the peak hours and the other operates from sunrise to sunset. In this case, the deployment intensity of the latter FSP is higher, thereby resulting in a higher functionality than the other FSP.

Conventional ITS Applications collectively include ITS applications and services that have been deployed extensively in different metropolitan and rural areas in the United States, and have been in operation for a significant period of time. ITS applications, technologies and services that are still under development or testing, or those that are yet to achieve widespread market penetration, do not fall under this category. A majority of conventional ITS applications and services are public infrastructure oriented rather than private infrastructure or vehicle oriented. Examples include electronic DMS and surveillance cameras. The capital, deployment, and operating costs of conventional ITS applications and services have mostly been paid for by public agencies, although there are exceptions.

Emerging ITS Applications collectively include ITS applications, technologies, and services that are either in the process of development or testing, and have not achieved significant market penetration or have not been widely deployed in the United States as of date. A majority of emerging ITS applications and services are private infrastructure and vehicle oriented rather than public infrastructure oriented, with the Vehicle Infrastructure Integration

(VII) project as a primary example. Private companies are paying many of the capital, deployment and operating costs of emerging ITS applications and services. These technologies will not only result in a shift of some services to the private sector, but will change the way that the transportation and public safety agencies in the public sector do their work. Once an ITS application achieves widespread usage and market penetration, it may be considered as conventional at that point in time.

2.3.3 Deployment Philosophy

One of the major objectives of the project is identifying the optimal level of investment in ITS. The results of the needs analysis indicated that the level and nature of ITS investment in the study area should be varied based on several variables. These included traffic volumes, projected congestion, safety and proximity to the existing ITS system.

The concept of *deployment intensity* is the method used to address these needs. Low-intensity deployments can be viewed as both a way to provide ITS coverage in areas of lesser need where only limited investment is justified, and as a first step toward higher intensity deployment. In this section, major ITS deployments are defined in terms of high and low density. These are flexible definitions and deployments are tailored to the specific system performance expectations of the region. For purposes of display, individual technologies are sorted into several categories. In the architecture section of the report, these broad categories are tied to specific architecture packages.

- Freeway Traffic Management;
- Arterial Traffic Management;
- Portable Traffic Management;
- Advanced Traveler Information Systems;
- Incident Management Systems;
- Advanced Infrastructure Based Warning Systems;
- Advanced Public Transportation Systems;
- Emergency Vehicle Dynamic Routing Systems;
- Parking Management Systems;
- Road Weather Information Systems; and
- Advanced Vehicle Technology.

2.3.4 Deployment Packages

Core deployments represent the basic ITS services that are likely to be monitored or managed by MDOT. These generally include proven technologies that have been in operation for some time. The amount of deployment, level of monitoring, and the specific services provided on a given portion of the transportation system, depend on whether it is slated for high-intensity or low-intensity deployment.

Freeway Traffic Management

The core grouping of freeway traffic management provides the basic monitoring, traveler assistance, and information feedback mechanisms for highway infrastructure. Together with arterial traffic management, freeway management functions provide the information skeleton on which additional services depend and build.

Table 4 - Freeway Management Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Detection	***100% roadway coverage*** (Loop Detector, Microwave, Radar or Imaging technology) ▪ At least one detector on each segment and ramp, plus additional detectors for long segments	***Majority coverage*** (Loop Detector, Microwave, Radar or Imaging Technology) ▪ Detector on each segment
Surveillance/ Verification	***100% roadway coverage*** (Streaming CCTV camera images able to view entire mileage) ▪ Fixed cameras at priority locations; pan/tilt/zoom cameras at non-priority locations ▪ Pan/tilt/zoom camera coverage of all interchanges	***Priority coverage*** ▪ Major interchanges and other priority locations have pan/tilt/zoom camera coverage
Freeway Service Patrol	Dedicated service to specific routes during peak periods	Deployed only during busiest travel days; applies primarily to recreational routes.
Highway Advisory Radio (HAR)	***100% reception coverage*** No need for HAR in high-intensity deployment, due to frequent DMS units	▪ Announcement signs upon entering or leaving low-intensity coverage area ▪ Will include roadway weather information where available
Dynamic Message Signs (DMS)	▪ Approaching every interchange, at critical decision-making locations ▪ On both surface road approaches to interchange (allowing sufficient time to change route)	▪ At major regional decision points ▪ For specific safety warnings.
Cell phone probes for reporting travel times	▪ Reporting of travel times using cell phone probes on all roads where service is available and traffic volumes provide an adequate sample	▪ Reporting of travel time using cell phone probes on major trunkline routes

Arterial Traffic Management

Arterial traffic management caters to the unique needs of high-volume surface streets. Deployments must address additional delay and safety concerns, resulting from the presence of signalized intersections and railroad grade crossings. Implementation of formalized incident management strategies require that excess traffic resulting from freeway incidents or construction information be accommodated. Information must be provided to both agency personnel and the public on arterial conditions, and where possible, signal timing be adaptable to major change in traffic flow. Both high and low-intensity deployments have been identified for the Grand region.

Table 5 - Arterial Management Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Traffic Signal Coordination	Full signal coordination on all corridors identified as high-intensity, with "the bells and whistles" that go with it (actuation, coordination, control, traffic signal TOC, adaptation)	Traffic actuated signals isolated on an as needed basis; may be connected to TOC if needed for status determination purposes
Surveillance/ Verification	CCTV cameras deployed on an as needed basis at major locations, including: ▪ High accident, delay, or strategically important intersections, segments, or railroad grade crossings ▪ Key decision point for freeway/arterial incident management strategies ▪ Can be pan/tilt/zoom or slow-scan fixed cameras ▪ Can be combined with detection (in case of camera detection)	▪ No CCTV cameras deployed except when needed to monitor isolated high accident/traffic locations ▪ Tie existing detection data to TOC at specific locations
Signal Preemption for Emergency Vehicles	Deployed on an as needed basis, mainly in and around intersections/corridors such as: ▪ Intersections with high emergency vehicle traffic (around hospitals, fire and police stations) ▪ Densely developed areas (like central business districts) ▪ Low capacity/long signal phasing/high accident intersections (typically single-lane approaches)	Generally, no signal preemption. However, individual intersections or corridors may be equipped on an as needed basis, using the high-intensity criteria
Rail Road Crossings	All railroad grade crossings on major arterials have advanced deployments, consisting of: ▪ Cross-bucks and flashing lights ▪ Quad-gates and incursion detection systems ▪ Railroad signal preemption At locations where major backups occur regularly and alternate routes are available: ▪ DMS, advanced warning/real-time rerouting, and at-location status updates ▪ Speed-based gate timing	All rail grade crossings have standard deployments consisting of: ▪ Cross-bucks and flashing lights Advanced deployments (listed under high-intensity) should be considered on an as needed basis for high rail traffic, accident, or delay locations.

Portable Traffic Management

Elements of a portable traffic management system work in tandem with both the freeway and arterial traffic management functions to cover activities likely to cause non-recurring congestion, such as roadway construction, major events, or interim traffic management. These functions extend the reach of the basic freeway and arterial management programs by giving the system the potential to temporarily increase the level of coverage and share specific local event and weather information on sections of the roadway network, without investing in permanent ITS infrastructure. Portable traffic management has great potential for the Grand region since there is heavy recreational traffic volumes during the peak construction season and in a number of cases there are alternate routes available.

Table 6 - Portable Traffic Management Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Portable detection	Portable detection and information equipment at construction sites along freeways and major trunklines, including: ▪ Portable DMS ▪ Detection equipment approaching and within the impacted zone	Portable DMS with remote connection to TMC providing advanced warning of activity Depending on length of impacted roadway and duration of activity, portable detectors may be installed to track impact
Portable DMS	Direct wireless communication between field equipment and TMC Wireless communication between detectors and DMS with pre programmed advance information	

Advanced Traveler Information Systems (ATIS)

ATIS can be accomplished through public/private partnerships. Many agencies contract their ATIS function to a private contractor. MDOT, through the MITS Center, has participated in private partnerships. The private sector has, to date, shown interest primarily in major urban areas with high levels of congestion. Decisions regarding high- and low-intensity deployment require assumptions about what services a private provider would be willing to offer, policies that a public agency could use to encourage particular service, and actions that a public agency should take to support full information provision. Some of the in-vehicle technologies being explored may enable traffic information to be obtained and disseminated to a larger number of rural roads. In the Grand region, it is anticipated that ATIS deployments will build upon services currently provided by the West Michigan TMC.

Table 7 - ATIS Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Cellular phones, Pagers, Handheld devices	▪ Complete broadcast coverage ▪ Complete interactive, route-planning capabilities	▪ Partial broadcast coverage ▪ Complete interactive, route-planning capabilities, within coverage ▪ Emphasis on real-time regional route choice information (for long-distance/intercity travelers)
Internet	Network Coverage for all portions of system where information is available ▪ Route-planning services for metropolitan areas focused more on disaggregated/ localized information ▪ Availability of real-time TMC CCTV camera feeds and speed data	Network Coverage concentrated on major routes ▪ Route-planning services for outlying areas focused on regional information
Kiosks ▪ Multimodal and public transportation only ▪ Broadcast (static TV screens and terminals) and interactive	Linked to TMC or other sources of transportation information Deployed at high pedestrian traffic facilities, on an as needed basis including major multi/modal terminals (airports, park-and-ride lots, rail stations, transit transfer points) and major commercial centers (office complexes, shopping centers, universities, public parking garages)	Displays static information on construction activity and/or transit routes. Deployed at similar locations to high intensity, but at fewer locations.
511 travel information service	Complete Coverage	Coverage confined to major, high-intensity routes

Incident Management – Freeway/Arterial Integration

Functions in this grouping are used to implement a defined incident management plan, to respond to major accidents or natural disasters. The functions help the designated relief arterials to accommodate increased traffic that has been rerouted off of impacted freeway segments. In high-intensity applications, active management of both freeway and arterial corridors is provided. In low-intensity applications, information is provided but proactive management of the arterial system is not.

Table 8 - Incident Management Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Incident freeway-arterial signal coordination	For freeway-alternate arterial pairs identified in a regional incident management plan. ▪ Arterial signals along alternate corridor able to adjust for shifting traffic pattern ▪ Can be either manual control between freeway TMC and signal coordination center, or seamless sensor-automated control	For freeway-alternate arterial pairs identified in a regional incident management plan. ▪ Information provided on freeway through DMS ▪ Traffic monitored on parallel arterials but no proactive management
Alternate route guidance (Trailblazer)	"Trailblazer" or similar dynamic route guidance signs deployed at all potential decision points along alternate arterial corridor	"Trailblazer" signs not deployed but portable DMS may be used in certain situations

Advanced Infrastructure-Based Warning and Safety

These include additional deployments that are generally deployed on an as needed basis at or in advance of roadway locations where potential safety hazards exist. They consist of detection, surveillance and/or information display systems that are deployed on the roadway or roadside. Based upon the characteristics of individual vehicles detected (for example, vehicles classification, and vehicle speed), these systems can trigger warning messages about potential safety hazards. These are different from advanced in-vehicle systems, in that, they are deployed on the roadway or roadside, and they are monitored and controlled by public agencies. These systems may be deployed in isolated areas where the core ITS infrastructure deployment is not very intensive, or may be deployed to supplement the core deployments. Since these are limited deployments tied to a single location, there is no explicit difference identified between high-intensity and low-intensity deployments.

Table 9 - Advanced Warning and Safety Deployment Types

Function	Deployment Criteria and Assumptions
Ramp rollover detection and warning systems. These are used to detect the speeds of exiting vehicles on a ramp and, based on the vehicle speed in relation to the geometry of the ramp, display advance warnings to prevent potential rollover. These apply generally to large trucks and trailers.	▪ Deployed at specific ramps which meet the following criteria: – Ramps that have a high rollover accident history. – Ramps with tight geometrics and low exit speeds. – Stakeholder identified safety hazard at that ramp location. ▪ Deployed at all ramp locations identified as "safety hotspots."
Downhill speed detection and warning systems are similar to ramp rollover systems, but they apply to roadway sections where the vertical gradient can prove to be potentially hazardous.	▪ Deployed at specific locations where there is a downhill gradient, and where there are documented or observed safety hazards.
Advanced curve warning systems are again similar to ramp rollover systems, but they are used to warn motorists in advanced of hazardous curves based on real-time detection.	▪ Deployed at specific locations where there is a hazardous curve, and where there are documented or observed safety hazards. ▪ Deployed at all roadway locations identified as "safety hotspots."

Advanced Public Transportation Systems (APTS)

APTS functions take advantage of electronic systems deployed on transit vehicles, at transit stops, or along transit routes. These deployments serve a variety of functions, including enhancing passenger safety; improving information and convenience to transit riders; improving speed and reliability; and reducing cost to the transit operator.

Table 10 - APTS Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Electronic fare payment	Fare card and readers deployed throughout system, can be connected to park-and-ride payment system or used to pay for other goods and services (Smart card)	Fare card and readers deployed throughout system
Automatic Vehicle Location (AVL)	All transit vehicles equipped with AVL. Vehicle locations monitored by central transit monitoring center. Communication links provided so that data can be used for traffic management system.	AVL used only on most heavily traveled routes or in largest divisions. Vehicle locations monitored by central transit monitoring center.
Transit safety systems	All transit vehicles equipped with incident monitors. Incidents detected by central transit monitoring center.	Incident monitors provided on new transit vehicles, or vehicles serving specific routes. Incidents detected by central transit monitoring center.
Advanced routing for demand responsive transit	Para-transit routing controlled in real-time by central AVL enhanced dispatching. Communication links provided so that data can be used for traffic management system	Para-transit routing controlled in real-time by central AVL enhanced dispatching. May be limited to certain routes and services.
Advanced transit vehicle monitoring/ maintenance	All transit vehicles equipped with vehicle status/driver condition monitors. Vehicle status monitored by central transit monitoring center.	Vehicle status/driver condition monitors limited to certain routes and services. Vehicle status monitored by central transit monitoring center.
Enhanced transit information	Real-time vehicle location and time to arrival provided both at stops and in-vehicle	Real-time vehicle location and time to arrival provided at a limited number of high-volume stops

Emergency/Service Vehicle Dynamic Routing

Functions in this grouping take advantage of AVL equipment and the availability of real-time traffic information to improve the dispatching – and hence arrival time, utilization, and level of service – of service and emergency vehicles. Since this technology would be applied to all vehicles in a fleet, or division, there is no distinction made between high-intensity and low-intensity deployment.

Table 11 - Emergency Vehicle Deployment Types

Function	Deployment
Emergency and service vehicle AVL	All emergency and service vehicles equipped with AVL devices.
Computer aided real-time dispatch	Vehicle location and status monitored to provide optimum real-time dispatching

Parking Management Systems

In areas with pronounced peaks in demand for parking such as central business districts, park and ride facilities, universities, major medical centers, and sporting and entertainment venues, ITS technologies can provide information on parking cost and availability.

Functions in this group help reduce congestion and delay associated with finding or paying for a parking space. It is anticipated that these systems will be implemented primarily through local authorities, financial institutions, and the private sector.

Table 12 - Advanced Parking Management Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Parking garage status monitoring	All participating garages equipped with occupancy sensors/vehicle counters to determine number and location of available spaces	Participating garages keep track of parking occupancy through sensors or other means and report to local control center
Regional parking availability information	Real-time information on parking status provided through varying channels: ▪ To dedicated parking management DMS at major local decision points ▪ Over Internet for pre-trip planning purposes ▪ To in-vehicle information systems (if available)	Information provided regarding parking availability is static or based on historic data through means similar to those in high-intensity deployment Information delivery mechanisms similar to those used in high-intensity deployment
Automated payment	All participating garages equipped with electronic payment tag readers. ▪ Optional service for equipped vehicles	Same as high-intensity deployment

Weather and Road Condition Monitoring/Management

Road condition monitoring and management functions help traffic managers detect potential weather-related problems and take appropriate measures to minimize the risks to travelers. One of the major benefits in a region such as Grand is improved efficiency in winter maintenance. This includes both more efficient deployment of resources based on localized weather condition information and tracking and subsequent analysis of materials usage. These functions can be most useful on isolated roadway segments (where weather conditions are not reported as intensively, and response time and cost is greater), or segments with a history of weather-related accidents. Due to the Lake effect weather in the Grand region conditions can vary dramatically within a limited area.

Table 13 - Roadway Weather Information Deployment Types

Function	High-Intensity Deployment	Low-Intensity Deployment
Roadway condition monitoring	Selected segments to be equipped with weather monitoring/forecasting deployments ▪ Regular spacing in isolated areas ▪ Targeted monitors for segments with a history of weather-related accidents	Selected segments to be equipped with weather monitoring/forecasting deployments ▪ Targeted monitors only for locations with a history of weather-related accidents
Motorist warning systems	Selected facilities/segments equipped with DMS and/or Variable Speed Limit Signs to warn motorists of dangerous pavement conditions	Static warning signs or portable DMS used to warn motorists
Centrally controlled road closure gates and alternate route guidance	Remotely controlled barriers can close major ramps on selected isolated roadway segments. Accompanying DMS provide alternate route instructions.	Public safety officials notified through TMC when closure is warranted

Advanced In-Vehicle Technology

The advanced in-vehicle technology grouping takes advantage of assumed private-sector improvements in the passenger vehicle fleet over the project-planning horizon. While many technologies that enhance vehicle safety and functionality already exist in prototype form, modeling the impact of these technologies requires assumptions about the degree of market penetration into the overall passenger fleet. The deployment and market penetration of these advanced in-vehicle technologies is beyond the control of MDOT and other public agencies. However, they can incorporate provisions in their long-term plan to advocate implementation of suitable systems, particularly those related to public safety.

Table 14 - Advanced In-vehicle Deployment Types

<table>
<tr><th>Function</th><th>Deployment</th></tr>
<tr><td>In-vehicle traveler information devices. (In the long term in-vehicles information may begin to phase-out traditional roadside information systems such as DMS or road signs.)</td><td rowspan="6">▪ Information collected by the public sector for traffic management can help support in-vehicle travel information services provided by private firms
▪ Mayday system connected to public safety and transportation agencies can help to expedite response</td></tr>
<tr><td>In-vehicle safety warnings to detect hazardous roadway/pavement conditions</td></tr>
<tr><td>Enhanced driver vision to enhance the driver’s view of the roadway, or potential obstacles</td></tr>
<tr><td>Driver condition monitoring to detect the driver’s ability to operate the vehicle safely</td></tr>
<tr><td>Collision avoidance systems to prevent longitudinal, lateral, and roadway departure collisions</td></tr>
<tr><td>In-vehicle mayday systems that either deploy automatically in case of an accident, or can be used to automatically notify public safety or emergency response agencies at the push of a button</td></tr>
</table>

2.4 Evaluation of Alternatives

2.4.1 Evaluation Criteria

Evaluation of the alternatives is based on several criteria, including:

Local Stakeholder Input

An understanding of local requirements and performance expectations is critical to the evaluation of alternatives. As documented earlier in this section, an extensive stakeholder process was used to help identify needs, define projects, and determine priorities. The process in the Grand Region was effective in bringing in a wide range of stakeholders, although participation from some sectors, such as public transportation, was limited. Through a series of meetings, stakeholders provided a clear set of priorities for the Grand Region.

- Traffic and Road Condition Information – This is a critical need for the region as growth moves outward from Grand Rapids increasing commuter traffic on trunkline roads. The US-31 corridor is also experiencing heavy growth in addition to high volumes of recreational traffic. Services that help clear incidents and provide information on traffic conditions and alternative routes, particularly during peak recreational season, is considered a high priority need. A variety of informational services have been identified to let the public know of dangerous road conditions and unexpected delays. Many of these options build upon existing services. Better information on construction activity and resulting traffic backups is also noted as a major need.
- Safety – Winter weather in the region is severe and can vary dramatically within a relatively small area. Improved weather information is considered essential to provide faster clearance of snow and ice, and to provide motorists with more detailed information on roadway weather conditions. A need for anti-icing systems and possibly hazard warnings has been noted for some locations.
- Winter maintenance – The majority of MDOT's regional maintenance budget is spent during the winter. Most MDOT roads are cleared by County Road Commissions and there is a need for better real-time coordination between MDOT and County maintenance crews. Improved information on pavement conditions is also considered a high priority.

Compatibility with MDOT Programs and Projects

One of MDOT's objectives in developing ITS Regional Architectures and Deployment Plans was to provide a common framework across the State. In addition, projects will need to be compatible with the statewide ATMS software that is being developed under a separate contract and will be installed in the West Michigan TMC. MDOT wants to assure that systems developed at the regional level are compatible with statewide requirements. There is also a need to coordinate projects between regions. Seasonal congestion on US-31 and US-131 can impact both the Grand and the North Regions. Technologies and deployment intensity across the corridor should be similar in all regions.

With a limited budget available, projects that can be implemented as part of the overall capital program may receive a higher priority for implementation. These projects can be implemented more cost-effectively and possibly take advantage of other funding sources.

The budget of the ITS statewide program will have a major impact on project implementation. With a current budget of $12 million per year, initial capital costs as well as long term operation and maintenance requirements will have a major impact on feasibility. Larger projects will need to be phased in over a period of time, meaning that interim deployments should be able to show some benefit on their own.

Benefit/Cost Analysis

Using the IDAS model benefits and costs for various ITS deployments, "packages" have been developed. Detailed evaluation criteria include:

- Benefits, including:
  - Impacts on recurring and non-recurring congestion (mobility savings and travel time reliability savings);
  - Safety (accident reduction);
  - Operating costs (fuel and operating savings); and
  - Emissions reductions.
- Life-cycle costs, including capital and operating and maintenance (O&M) costs for both public and private sectors.

2.4.2 Technical Evaluation Process

This section describes the methodology used to conduct this technical evaluation which included several objectives:

- To quantitatively assess the benefits and costs of each alternative;
- To refine alternatives based on benefit-cost analysis;
- To develop viable projects for implementation; and
- To provide guidance on deployment decisions.

The tools used also provide information that can be used to:

- Estimate implementation timeframe and resource requirements; and
- Documentation for transition into design and implementation.

2.4.2.1. IDAS Description

The most important quantitative tool used in the evaluation was the ITS Deployment Analysis System (IDAS). This software package was used to conduct the benefit-cost analysis of identified ITS improvements. IDAS is a sketch-planning software and analysis methodology developed by Cambridge Systematics for the Federal Highway Administration (FHWA).

IDAS was developed to assist state, regional, and local agencies in integrating ITS into the transportation planning process. Planners and others can use IDAS to calculate relative costs and benefits of ITS investments. IDAS currently predicts costs, benefits, and impacts for more than 60 types of ITS investments that are shown in **Table 15**. These ITS components can be deployed in combination or isolation.

In order to be consistent with current transportation planning processes, IDAS operates as a post-processor to travel demand models used by Metropolitan Planning Organizations (MPO) and by state DOTs. IDAS, although a sketch-planning tool, can implement the modal split and/or traffic assignment steps associated with a traditional planning model. These are key steps in estimating the changes in modal, route, and temporal decisions of travelers resulting from ITS technologies.

The bold items shown on **Table 15** are those for which IDAS was applied during the project. Other projects, such as Advanced Vehicle Control and Safety Systems, are being developed at the statewide level as part of the VII program, but could not be analyzed with IDAS at the regional level. The 2010 MDOT Statewide Travel Demand model served as the basis for this analysis.

The set of impacts evaluated by IDAS included changes in user mobility, travel time/speed, travel time reliability, fuel costs, operating costs, accident costs, emissions, and noise. The performance of selected ITS options can be viewed by market sector, facility type, and district. The district function was used in this project to produce data for the study area sectors. Given the diverse types of performance measures that may be impacted by ITS and the desirability of providing a comprehensive analysis tool, IDAS is comprised of five different analysis modules as shown in **Figure 9**.

Table 15 - ITS Components Assessed in IDAS

1. **Arterial Traffic Management Systems**
   - ☑ **Isolated Traffic Actuated Signals**
   - ☑ **Preset Corridor Signal Coordination**
   - ☑ **Actuated Corridor Signal Coordination**
   - ☑ **Central Control Signal Coordination**
   - ☐ Emergency Vehicle Signal Priority
   - ☑ Transit Vehicle Signal Priority

2. **Freeway Management Systems**
   - ☑ Preset Ramp Metering
   - ☑ Traffic Actuated Ramp Metering
   - ☑ Centrally Controlled Ramp Metering

3. **Advanced Public Transit Systems**
   - ☑ Fixed Route Transit – Automated Scheduling System
   - ☑ **Fixed Route Transit – Automated Vehicle Location**
   - ☑ Fixed Route Transit – Combination of Automated Scheduling System and Automated Vehicle Location
   - ☑ Fixed Route Transit – Security Systems
   - ☑ Paratransit – Automated Scheduling System
   - ☑ **Paratransit – Automated Vehicle Location**
   - ☑ Paratransit – Combination of Automated Scheduling System and Automated Vehicle Location

4. **Incident Management Systems**
   - ☑ **Incident Detection/Verification**
   - ☑ **Incident Response/Management**
   - ☑ **Combination of Incident Detection/Verification/Response/Management**

5. **Electronic Payment Collection Systems**
   - ☐ Electronic Transit Fare Payment
   - ☐ Basic Electronic Toll Collection

6. **Railroad Grade Crossing Monitors**
   - ☑ Railroad Grade Crossing Monitors

7. **Emergency Management Services**
   - ☐ Emergency Vehicle Control Service
   - ☐ Emergency Vehicle Automated Vehicle Location
   - ☐ In-Vehicle Mayday System

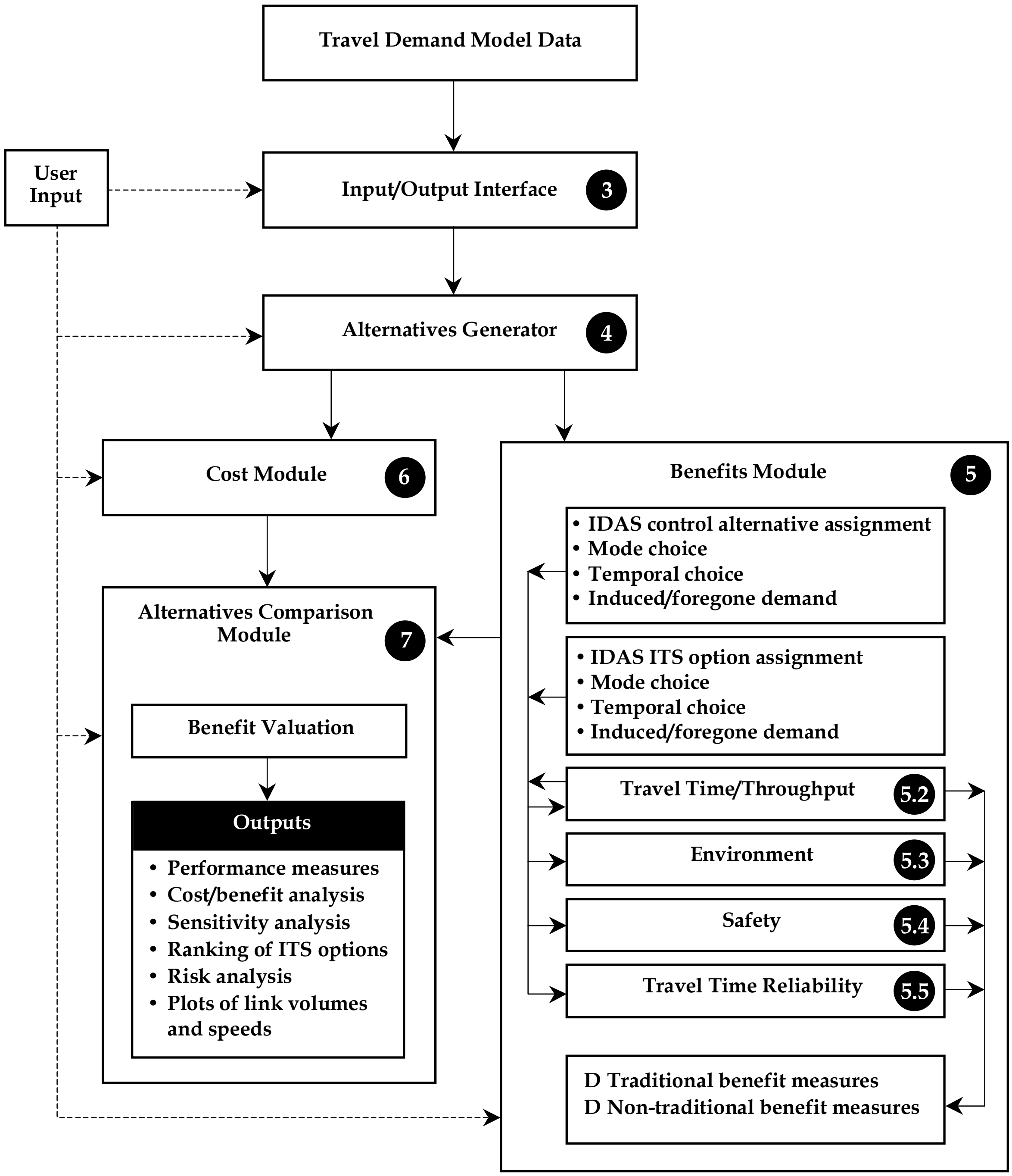
8. **Regional Multimodal Traveler Information Systems**
   - ☑ **Highway Advisory Radio**
   - ☑ **Freeway Dynamic Message Sign**
   - ☑ Transit Dynamic Message Sign
   - ☑ **Telephone-Based Multimodal Traveler Information System**
   - ☑ **Web/Internet-Based Multimodal Traveler Information System**
   - ☑ Kiosk with Multimodal Traveler Information
   - ☑ Kiosk with Transit-Only Traveler Information
   - ☑ Handheld Personal Device – Traveler Information Only
   - ☑ Handheld Personal Device – Traveler Information with Centralized Route Guidance
   - ☑ In-Vehicle – Traveler Information Only
   - ☑ In-Vehicle – Traveler Information with Centralized Route Guidance

9. **Commercial Vehicle Operations**
   - ☐ Electronic Screening
   - ☐ Weigh-in-Motion
   - ☐ Electronic Clearance – Credentials
   - ☐ Electronic Clearance – Safety Inspection
   - ☐ Combination Electronic Screening and Clearance
   - ☐ Safety Information Exchange
   - ☐ On-Board Safety Monitoring
   - ☐ Electronic Roadside Safety Inspection
   - ☐ Hazardous Materials Incident Response

10. **Advanced Vehicle Control and Safety Systems**
    - ☐ Motorist Warning – Ramp Rollover
    - ☐ Motorist Warning – Downhill Speed
    - ☐ Longitudinal Collision Avoidance
    - ☐ Lateral Collision Avoidance
    - ☐ Intersection Collision Avoidance
    - ☐ Vision Enhancement for Crashes
    - ☐ Safety Readiness

11. **Supporting Deployments**
    - ☐ **Traffic Management Center**
    - ☐ Transit Management Center
    - ☐ Emergency Management Center
    - ☐ **Traffic Surveillance – CCTV**
    - ☑ **Traffic Surveillance – Loop Detector System**
    - ☐ **Traffic Surveillance – Probe System**
    - ☐ Basic Vehicle Communication
    - ☐ **Roadway Loop Detector**
    - ☐ **Roadway Weather Information System**
    - ☐ **Drawbridge Management System**
    - ☐ **Parking Management System**

Figure 9 - IDAS Model Structure



2.4.2.2. IDAS Inputs and Default Values

For this evaluation, data outputs were obtained from the statewide travel demand model to use as inputs into the IDAS model. The model data included both network files and travel demand files (trip tables) representing daily volumes for 2010. Only highway facilities, including automobile and truck trips, were evaluated using the models.

Other parameters, such as baseline travel time skims (zone to zone), turn prohibitors, volume-delay curves, in- and out-of-vehicle travel times, and vehicle occupancies from the model were incorporated into IDAS.

IDAS estimates the impacts of the various ITS deployments by drawing on a database of default impacts for each separate ITS component. These defaults were developed by assembling and analyzing observed impacts and evaluation results for similar deployments across the United States.

The default impacts form the basis for the estimation of impacts on traffic, such as travel time and speed, in the IDAS software. The project team used a combination of default values and values developed for the Southeast Michigan ITS Deployment Study conducted from 2000 to 2002. That study included a commuter survey of both the Detroit and Lansing regions that helped to refine the national parameters. In general, a conservative approach to estimation of benefits was taken. In some cases, the national default values were used for this analysis, while in others, default values produced very high impact estimates. Modifications were made based on Michigan specific data. **Table 16** presents the adjusted impact values used for the MDOT system benefits evaluation as compared to the IDAS national default values.

Table 16 - Comparison of Impact Values Used for IDAS Analysis

Deployment	Benefit	Parameter
Freeway Service Patrols	Reduction in incident duration	20%
	Reduction in fuel consumption	1%
	Reduction in fatality rate	1%
Traffic Signal Progression	Capacity improvement on impacted links	11%
Roadway Weather Information Systems	Applied to only days with more than 1" of snow	27
	Reduction in travel time	3%
	Reduction in crashes	10%
	Reduction in winter maintenance costs	7% without AVL 10% with AVL
Smart Work Zones	Amount of time useful information is displayed	10%
	Percent of travelers responding to information	28%
	Time saved per traveler	11 minutes
	Additional travel time impacts from rerouting of traffic due to work zone capacity reductions	Impacts dependent on specific roadway volumes and alternative routes
Drawbridge Management System	Benefits only during boating season May through September	150 days
	Amount of time useful information is displayed	1% (Long openings and malfunctions in open position)
	Percent of travelers responding to information	75%
	Time saved per traveler	5 minutes
Traverse City Regional Parking System	Benefits only during peak recreational seasons	120 days
	Amount of time useful information is displayed	10%
	Percent of travelers responding to information	28%
	Time saved per traveler	3 minutes
APTS CAD and AVL	Operating Cost Savings	5%
Automated Weigh-in-Motion Stations	Crash reduction	-0.5% in all categories
	Travel time savings	2 minutes for commercial vehicles

Table 17 includes the monetized values of the benefit parameters used in this analysis. The parameters were developed by FHWA in 1995 and have been inflated to 2010 using a 3% annual inflation rate. The one exception was the price

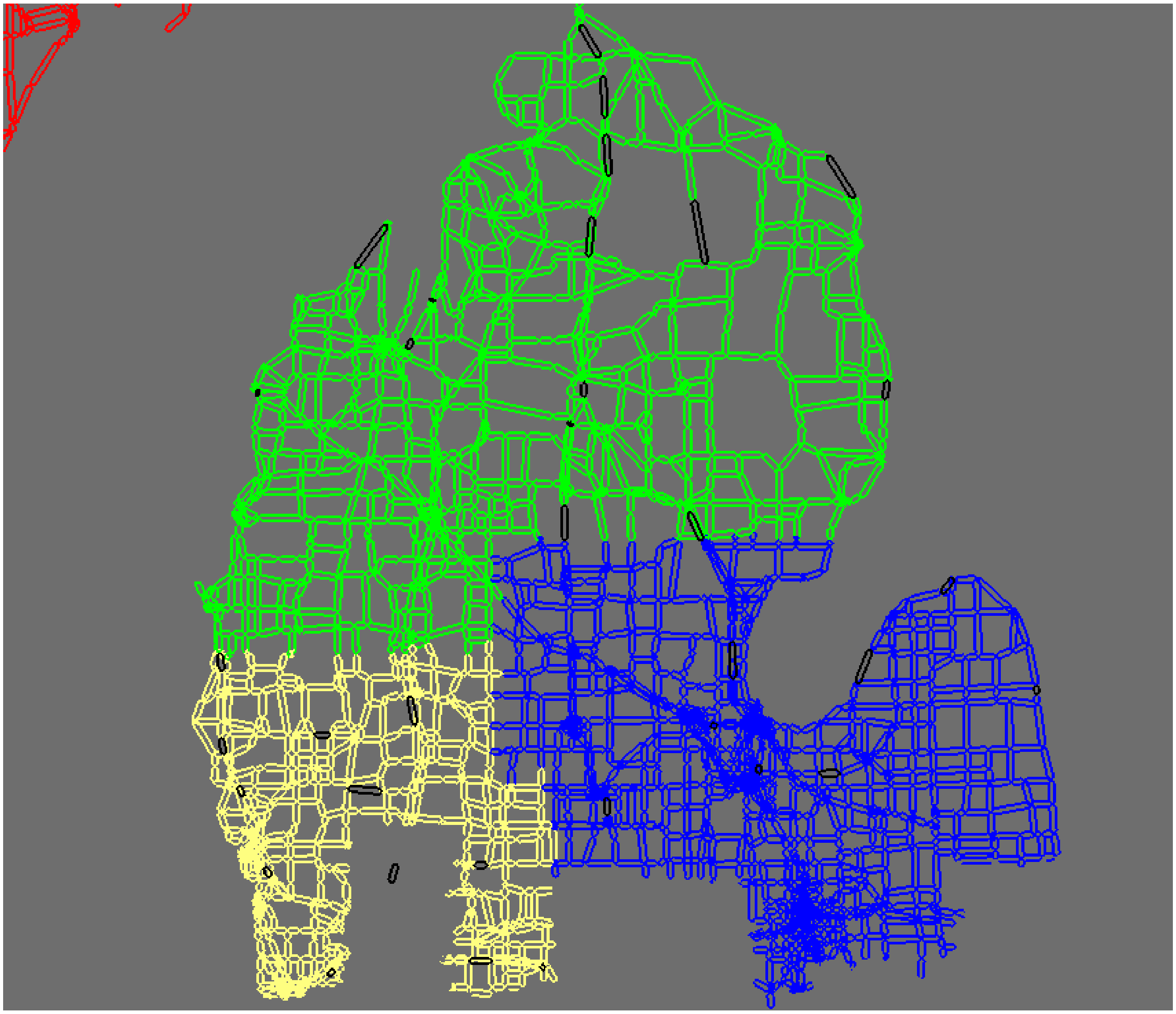
of fuel, which significantly exceeded the 3% inflation rate. This cost was raised to $3/gallon.

Table 17 - Monetary Values of IDAS Default Parameters

Benefit Parameters		Parameter Values
	Number of travel days in a year	247
	Year of $ values	2010
	Inflation Rate	3%
	Value of In-vehicle time	$15.00
	Value of In-vehicle time (commercial)	$26.42
	Value of Out-of-vehicle time (commercial)	$26.49
	Value of time multiplier for Emergency Vehicle	30.0
	Value of Out-of-vehicle time	$26.49
	Value of reduced delay time	$45.03
	Fuel Costs (gallon)	$3.00
Emissions Costs ($/ton)		
	HC/ROG	$2,763.83
	NOX	$5,812.78
	CO	$6,058.94
	PM10	$17,240.47
	CO2	$5.55
	SO2	$5.55
	GW	$0.00
Accident Costs	***Internal***	
	Fatality	$3,610,430.58
	Injury	$79,082.43
	Property damage	$4,399.70
	External	
	Fatality	$637,133.89
	Injury	$13,956.27
	Property damage	$775.87
	Non-Fuel operating costs ($/mile)	$0.10
	Noise Damage Costs ($/mile)	$0.0011
	Other mileage based ($/mile)	$0.00
	Other non-mileage based ($/mile)	$0.00
	Cost of winter Maintenance ($/mile)	$2,000.00

Figure 10 shows how individual elements of the ITS systems are deployed on links of the network in IDAS. In this case, proposed RWIS stations for the Lower Peninsula are shown. It should be noted that these are conceptual only since planning studies to select locations have not yet been initiated. Other ITS deployments are added to the transportation network in this fashion in order to create an alternative that can be modeled in IDAS.

Figure 10 - IDAS Representation of RWIS Deployment in the Lower Peninsula



Once an alternative is defined, the analysis procedures are initiated to estimate the incremental costs and benefits of ITS improvements. These benefit-cost results can then be compared with other alternatives defined and analyzed in the IDAS software. Summaries of project benefits and costs for each deployment package are shown in Section 4. In order to simplify the results, impacts were collapsed into four categories for purposes of presentation. These are shown below in **Table 18.**

Table 18 - Summary Categories for IDAS Benefits

Summary Category	IDAS Subcategories Included
Travel Time Savings	Change in User Mobility Change in User Travel Time ▪ In-vehicle travel time ▪ Out-of-vehicle travel time ▪ Travel time reliability
Fuel/Operating Cost Savings	Change in Costs Paid by Users ▪ Fuel Costs ▪ Non-fuel operating costs
Accident Reduction	Change in Costs Paid by Users ▪ Accident Costs (Internal Only) Change in External Costs ▪ Accident Costs (External Only)
Air Quality/Environmental	Change in External Costs ▪ Emissions – HC/ROG – NOx – CO – PM10 – CO_2 – Global Warming ▪ Noise ▪ Other Mileage-based External Costs ▪ Other Trip-Based External Costs

2.4.2.3. Estimation of ITS Alternative Costs

Development of cost estimates for the various ITS alternatives required full consideration of the unique characteristics and requirements of ITS strategies that impact the costs, funding, and implementation of improvements. Planning of ITS improvements requires an increased effort on operational planning that is not generally considered in planning for traditional transportation infrastructure projects. ITS strategies typically require that a greater proportion of resources be expended for ongoing O&M activities than do traditional improvements. A "rule of thumb" based on general experience is that annual operations and maintenance expenditures are about 15-20 percent of the original capital cost. However, this figure can vary depending on the size and complexity of the operation. A lower percentage may indicate that there is a lack of investment that will require premature replacement of equipment. The replacement cycles of equipment also must be carefully considered as ITS equipment does not have as long a life cycle as traditional transportation agency assets. Failure to account for these continuing costs and funding responsibilities may result in future shortfalls in funding, personnel, or resources.

IDAS software can generate default values for a wide range of cost elements, in a manner similar to that used to calculate benefits. For this project, however, two separate efforts were undertaken in order to develop costs that better reflect the operating conditions in northern Michigan. Several sources were used to develop costs:

- The Michigan ITS Typical Deployment and Systems Communications reports developed for the Southeast Michigan Deployment Study were reviewed. It includes descriptions, conceptual drawings, and unit cost estimates for typical deployments of ITS components, including freeway management, arterial management and some specialized applications such as railroad grade crossing applications and "smart" park-and-ride lots.
- MDOT cost data for operations and maintenance of the Detroit and Grand Rapids systems were obtained, as well as costs for recent ITS capital purchases. The System Communications report included alternative operating and communications strategies for implementing alternative deployments. While the Michigan ITS Typical Deployment report focused on field deployment, this report focuses primarily on center-to-center requirements.
- An initial set of cost estimates were available from the Southwest Region Deployment Study.

These sources were used to develop data for input into the IDAS cost module. IDAS provides information, such as assumed equipment life, that is used to develop life-cycle costs for the identified projects. Preliminary estimates of life-cycle costs and resource requirements were developed for the initial IDAS runs and then modified based on a review of the results. While preliminary design work is essential to refine cost estimates, the results of this study provide a reasonable initial estimate for up-front capital and ongoing O&M costs required for successful deployment of identified alternatives.

Table 19 shows the unit costs assumed for the deployments analyzed for the Grand Region. These are based primarily on procurements in Michigan but supplemented with information from the IDAS database. This includes both capital items, which were amortized based on the number of years and a 3% interest rate and operations and maintenance costs.

Table 19 - Unit Costs

Units	Years (1)	Description	Unit Price
Ea	10	ITS Cabinet (Ground Mounted)	$15,000.00
Ea	10	Microwave Vehicle Detection System (MVDS)	$25,000.00
Ea	5	Midblock Detector	$15,000.00
Ea	10	CCTV Camera	$45,000.00
Ea	10	CCTV Camera with MVDS	$55,000.00
Ea	20	Dynamic Message Sign (DMS)	$180,000.00
Yr	Annual	Communications for DMS	$500.00
Mi	30	Fiber Optic Backbone	$175,000.00
Ea	30	Wireless Communications Link - Unlicensed (5 miles or less)	$12,000.00
Ea	30	Wireless Communications Link - Licensed Backhaul	$150,000.00
Ea	30	Wireless Communications Tower (200')	$250,000.00
Ea	30	Retrofitted 800MHz Radio Tower	$50,000.00
Ea	20	Highway Advisory Radio Site	$50,000.00
Ea	10	Highway Advisory Sign w/ Flashing Beacon	$14,000.00
LS	10	Highway Advisory System Software	$74,000.00
LS	10	Highway Advisory Radio Central Equipment	$5,000.00
LS	10	Highway Advisory Software Integration	$50,000.00
LS	10	ATMS Software Set-up	$25,000.00
Ea	10	Refurbish Existing Network Surveillance Systems	$150,000.00
Ea	25	Basic Drawbridge Management System	$550,000.00
Ea	25	Advanced Drawbridge Management System	$1,450,000.00
Ea	20	Local Parking Management System	$825,000.00
Ea	Annual	Operation of Parking Management System	$125,000.00
LS	Lump sum	Maintenance of Traffic (less than 7 signals)	$11,000.00
LS	Lump sum	Maintenance of Traffic (7 or more signals)	$16,000.00
Ea	15	Wireless Interconnect for Master Intersection	$11,000.00
Ea	15	Wireless Interconnect for Slave Intersection	$5,000.00
Ea	15	Replacement of Signal Controller	$5,000.00
Ea	Annual	Full Time Freeway Service Patrol Driver	$62,400.00
Ea	Annual	Full Time Freeway Service Patrol Supervisor	$83,200.00
Ea	5	Freeway Service Patrol Vehicle	$62,400.00
Ea	Annual	Weekend Only Freeway Service Patrol Driver	$18,000.00
Ea	Annual	Weekend Only Freeway Service Patrol Supervisor	$24,000.00
Ea	10	RWIS Control System	$25,000.00
Ea	10	ITS Control System	$40,000.00
Ea	15	Reduced Power RWIS ESS	$68,000.00
Ea	15	Basic RWIS ESS	$78,000.00
Ea	15	Enhanced RWIS ESS	$116,500.00
Ea	10	Anti-Icing System	$150,000.00
Ea	Annual	Annual Maintenance and Replacement Costs per RWIS ESS	$8,000.00
Ea	Annual	Annual Training and Operational Costs per RWIS ESS	$700.00
Ea	Annual	Annual Maintenance Costs per Anti-Icing System	$6,500.00
Ea	Annual	Annual Cost of Telephone Connection	$500.00
Ea	Annual	Annual Training and Operational Costs for TMC	$500,000.00
Ea	Annual	Smart Work Zone Mobilization	$100,000.00
Ea	Annual	Monthly rental of equipment	$20,000.00
Ea	1	TMC: Level II New facility	$500,000.00
Ea	1	TMC: 1/2 of Level II New facility	$250,000.00
Ea	5	AVL System for regional transit vehicles	$500
Ea	5	System Interface	$10,000
Ea	10	Computer Hardware	$15,000
Ea	10	System Software	$815,000
Ea	Annual	CCTV maintenance	$2,250
Ea	Annual	DMS maintenance	$4,500

(1) This column shows the assumed annual life of each component.

These components were combined in order to form the deployment packages analyzed for the project. The deployment combinations are shown in **Table 20** with the different cost components. Detailed results of the benefit/cost evaluation are shown in Section 4.

Table 20 - Major Components of ITS Deployment Packages

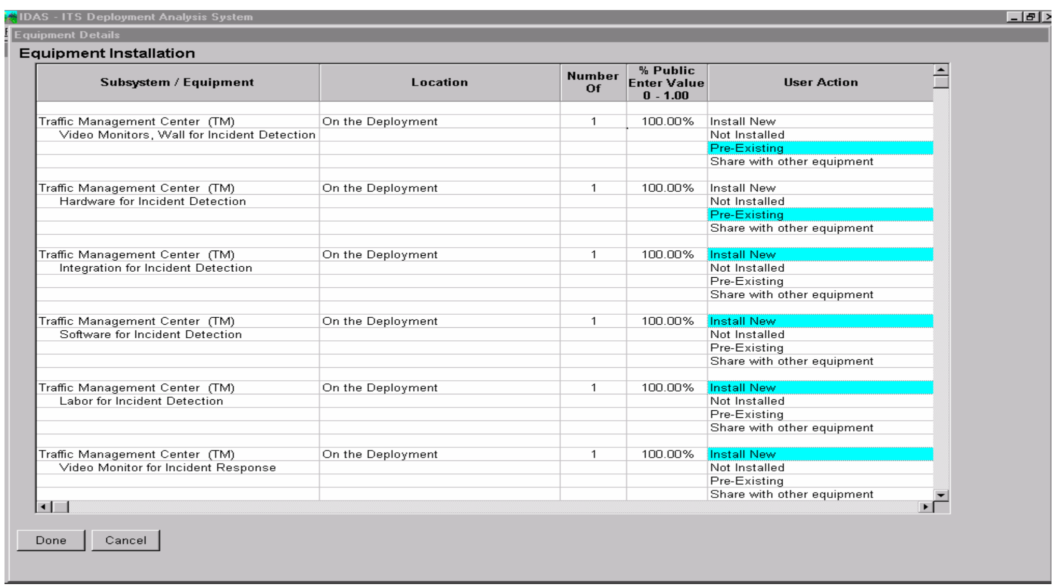
Qty	DEPLOYMENT PACKAGES AND EQUIPMENT
	Freeway/Traffic Management System
10	CCTV Camera with MVDS
Annual	CCTV Camera annual Maintenance Costs
5	Dynamic Message Sign (DMS)
5	Communications for DMS
Annual	DMS annual Maintenance Costs
1	Wireless Communications Link - Licensed Backhaul
4	Wireless Communications Tower (200')
0.25	$125,000 Annual Allocation for Operations in W. Michigan TMC
	Smart Work Zones
5	Smart Work Zone Mobilization
29	Monthly rental of equipment
	Road Weather Information System
1	RWIS Control System
20	Basic RWIS ESS
5	Enhanced RWIS ESS
Annual	Annual Maintenance and Replacement Costs per RWIS ESS
Annual	Annual Training and Operational Costs per RWIS ESS
Annual	Annual Cost of Telephone Connection
35	AVL Units
1	AVL Hardware
1	AVL Software
Annual	Operating cost per unit
13	800 MHz Radios
	Grand Haven Drawbridge Management System
4	CCTV Camera
4	CCTV Camera annual Maintenance Costs
3	Dynamic Message Sign (DMS)
3	Communications for DMS
3	DMS annual Maintenance Costs
1	Advanced Drawbridge Management System
Annual	Operation of Advanced Drawbridge Management System
	Freeway Service Patrols – Peak Recreational Weekends
4.5	Full Time Freeway Service Patrol Driver
1	Full Time Freeway Service Patrol Supervisor
4.5	Freeway Service Patrol Vehicle
	Traffic Signaling – US 31 Corridor
10	ITS Cabinet (Ground Mounted)
1	Maintenance of Traffic (7 or more signals)
1	Wireless Interconnect for Master Intersection
9	Wireless Interconnect for Slave Intersection
Annual	Annual Maintenance per upgraded signal
	Weigh-in-Motion Upgrades (4 locations/1 WIM in each direction)
8	Weigh in Motion Equipment
Annual	Weigh in Motion Equipment O&M Costs
8	Wireline to Weigh-In-Motion Facility
Annual	Wireline to Weigh-In-Motion Facility O&M Costs
8	Weigh in Motion O&M Costs: Wireless Communication, low usage
One time	Freeway Maintenance of Traffic
	Advanced Public Transportation Systems
3	Computer Hardware
1	AVL Software
3	Transit Agency Interface
105	Vehicle AVL units
Annual	Operations and Maintenance

Once alternatives are evaluated in IDAS, the software produces several cost-related outputs that are valuable in refining the alternatives and developing an implementation plan:

- Inventory of ITS equipment needed to deploy the identified alternatives;
- Identification of potential cost-sharing opportunities where ITS equipment may be shared between two different deployments.
- Summary of the capital and ongoing O&M costs of the planned ITS improvements for the public and private sectors;
- Forecast of the life-cycle stream of costs for the improvement on a year-by-year basis; and
- Estimate of the average annual cost for each individual improvement and for all improvements.

The inventory of equipment needed will be produced by the IDAS software for each improvement specified by the model user. **Figure 11** shows a sample inventory of some of the equipment necessary to deploy an incident detection system. This inventory is based on ITS equipment packages required in the ITS National Architecture to deploy the various improvements; use of the same ITS equipment as in the National ITS Architecture guarantees compatibility of the plan with the Architecture. After initial review of the inventory developed by IDAS and the costs incurred in the development of the existing ITS system, packages and deployments were modified.

Figure 11 - IDAS – ITS Deployment Equipment Details



IDAS - ITS Deployment Analysis System

Equipment Details

Equipment Installation

Subsystem / Equipment	Location	Number Of	% Public Enter Value 0 - 1.00	User Action
Traffic Management Center (TM) Video Monitors, Wall for Incident Detection	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment
Traffic Management Center (TM) Hardware for Incident Detection	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment
Traffic Management Center (TM) Integration for Incident Detection	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment
Traffic Management Center (TM) Software for Incident Detection	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment
Traffic Management Center (TM) Labor for Incident Detection	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment
Traffic Management Center (TM) Video Monitor for Incident Response	On the Deployment	1	100.00%	Install New Not Installed Pre-Existing Share with other equipment

Done Cancel

Based on the agreed-upon list of ITS equipment for the preferred alternative(s), a detailed breakout of the life-cycle costs was estimated using IDAS and presented in the IDAS reports as year-by-year breakouts of anticipated costs. This stream of costs includes the up-front capital costs necessary for deployment, the equipment replacement costs necessary to replace obsolete equipment in later years, and the continuing O&M costs necessary to operate the improvements.

The stream of life-cycle costs for the various improvements is used as the basis of the average annual cost figure in IDAS. This average annual cost figure was used for comparison with the average annual benefits figure calculated by the model to provide a benefit-cost ratio for the alternative.

3. Deployment Plan

3.1 Deployment Plan Projects

Developing the initial list of projects to study within the Deployment Plan began, as noted earlier, with the Architecture itself. Based on the input from the Grand Region and its stakeholders, a number of ITS services and associated Market Packages were identified. Translating those services and Market Packages into projects is the first step of the Deployment Plan. This translation was done initially at a functional level by the Study Team and that initial list is presented in **Table 21**. This table contains the following elements:

- The Architecture category the project falls under;
- A brief project description;
- A relative cost estimate for that type of project;
- Some of the benefits of that project;
- Relevant Market Package from the Architecture; and
- The Market Package's regional priority.

This initial list however, is only the first step in developing projects to study in the Deployment Plan. The next step involved a screening process which would eliminate projects that were not appropriate for the scope of the Deployment Plan. The screening process would also, through stakeholder input, develop detailed projects which could then be analyzed and ranked against each other.

Table 21 - Initial List of Deployment Plan Projects

Market Package Regional Priority	Category	Project	Cost	Benefit Parameters	Relevant Market Package
HIGH	Maintenance and Construction Management	RWIS System	$$	– Weather-related crashes – Winter maintenance costs – Some linked to DMS for spot problems – Cameras assumed at all locations	MC03 – Road Weather Data Collection MC04 – Weather Information Processing and Distribution
HIGH	ATMS	Network Surveillance	$$	– Reduced incident response time – Reduced incident-related delays – Reduced secondary crashes	ATMS01 – Network Surveillance
MEDIUM	ATMS	Drawbridge Management System	$$ Per	– Reduced delays – Improved travel time reliability	ATMS20 – Drawbridge Management
MEDIUM	ATMS	Real-Time Speed Detection and Monitoring	$	– Reduced crashes from more effective speed reduction – Reduced operating costs for data collection	ATMS19 – Speed Monitoring
LOW	Emergency Management	Roadway Service Patrols on Major Corridors	$$	– Faster incident response times – Reduced secondary crashes – Reduced fatalities due to faster response – Reduced delays	EM04 – Roadway Service Patrols
MEDIUM	Maintenance and Construction Management	Anti-Icing Installations Connected to RWIS	$$	– Reduced crash rate – Reduced incident-related delays – Reduced operating cost	MC05 – Roadway Automated Treatment
MEDIUM	Traveler Information	Web Site Information	$$$	– Reduced delays – Improved travel time reliability	ATIS2 – Interactive Traveler Information
MEDIUM	Traveler Information	511	$$$	– Reduced delays – Improved travel time reliability	ATIS2 – Interactive Traveler Information

Table 21 - Initial List of Deployment Plan Projects

Market Package Regional Priority	Category	Project	Cost	Benefit Parameters	Relevant Market Package
N/A	ATMS and Construction and Maintenance	Roadway Closure Management System and	$	– Reduced frequency of roadway closures – Reduced accidents related to closures – Reduced delay related to closures	ATIS1 – Broadcast Traveler Information
HIGH	Maintenance and Construction Management	Smart Work Zone and Work Zone Management Systems	$$	– Work zone location and duration – Reduced work zone related delays – Reduced work zone-related crashes	MC09 – Work Zone Safety Monitoring
HIGH	Construction and Maintenance	Maintenance Tracking using GPS for Maintenance Vehicles and Snowplows	$$$	– Reduced response time for maintenance crews – Reduced winter maintenance costs – Reduced Weather-related crashes	MC01 – Maintenance and Construction Vehicle and Equipment Tracking
HIGH	Emergency Management	Emergency Signal Preemption	$ per	– Number of locations – Approximate traffic volumes	EM02 – Emergency Routing
HIGH	Advanced Transit Management System	AVL systems	$$$	– Increased ridership – Reduced schedule delays – Reduction in operating cost per hour/unanticipated overtime costs	APTS – Transit Vehicle Tracking
LOW	ATMS	Signal Coordination at RR Crossings	$$	- Reduced travel time - Improved travel time reliability	ATMS13 – Standard Railroad Grade Crossing
HIGH	Commercial Vehicle Operations (non-MDOT)	Weigh-in-Motion Stations	$ per	– Reduced enforcement cost	CVO06 – Weigh-in-Motion
HIGH	Emergency Management	Vehicle Tracking for MSP, Local Public Safety, and Maintenance Vehicles	$$$	– Reduced incident response times – Reduced operating costs	EM02 – Emergency Routing

Table 21 - Initial List of Deployment Plan Projects

Market Package Regional Priority	Category	Project	Cost	Benefit Parameters	Relevant Market Package
HIGH	Emergency Management	Common Radios	$$$	- Reduced incident response times - Reduced incident related traffic delays - Reduced operating cost (from more efficient deployment of resources)	EM01 – Emergency Call-Taking and Dispatch
HIGH	ATMS	Sharing of CCTV Video Feeds	$$$	– Reduced incident response times – Reduced incident related traffic delays – Reduced operating cost (from more efficient deployment of resources)	ATMS06 – Traffic Information Dissemination
HIGH	Advanced Transit Management System	CCTV and Panic Buttons for Security	$$	– Possible ridership increase	APTS5 – Transit Security
MEDIUM	Advanced Transit Management System	Electronic Fare Payment	$$$	– Reduced fare collection costs – Possible operating cost reductions due to more efficient operation (faster boarding times)	APTS4 – Transit Passenger and Fare Management
N/A	N/A	Frost Tube Monitoring System	$	– Improved safety – Reduced maintenance burden	N/A
N/A	Advanced Transit Management System	DMS with Real-Time Buss Schedule Information	$$	– Improve ridership experience	APTS8 – Transit Traveler Information
LOW	N/A	Kiosks with Fare and Traveler Information	$$	– Improve ridership experience	ATIS1 – Traveler Information
Low	ATMS	Local Parking System Management	$$	– Increased parking revenue and operating costs – Reduction in excess VMT due to circulating traffic	ATMS16 – Parking Facility Management
LOW	ATMS	Regional Parking System Management for Commercial Vehicles (Interstate)	$$	– Reduced travel time by guiding CV's to closest open spot – Reduced crashes resulting from illegal/unsafe parking	ATMS17 – Regional Parking Management

$ denotes lowest cost; $$ denotes medium cost; $$$ denotes highest cost

3.2 Screening Process

The projects that were initially derived from the Regional Architecture and presented in **Table 21** represent all of the potential projects that are discussed in the Architecture. Some of these projects are not appropriate for the scope of the Deployment Plan, so a screening process was developed to narrow the focus of the types of projects as well as develop regionally specific projects. This screening process is the subject of this section.

Thirty-four projects were initially derived from the Architecture. Of these projects, five were eliminated from consideration from this plan for either lacking viable benefits data, being redundant, or overlapping other project functions. The projects eliminated were:

- Tracking CV Contents,
- CV Central Permitting Systems,
- Roadside Equipment for Automated Highway System,
- Intersection Collision Avoidance Systems, and
- Data Archive for Traffic, Incident, and Weather Data.

In order to develop regionally specific projects with project limits and specific deployments, the 25 remaining projects were then grouped into eleven project packets. These project packets were based on real-world deployment functionality and designed to illustrate how these individual projects would be deployed together in order to achieve the desired benefits. For example, DMS signs would typically not be deployed to provide traveler information without detection or CCTV cameras, which would ensure the traveler information is accurate and timely. The final list of these project packets is presented in **Table 22**.

The initial list of 25 projects as well as the eleven project packets were presented to the Grand Region stakeholders in a Deployment Plan Workshop held on August 2, 2007. At this meeting, the stakeholders were asked for their input in ranking the project packets. A pair-wise comparison exercise was utilized to solicit their opinions and the results are presented in **Table 22** in order of their priority.

The stakeholders were also broken out into three break-out groups around three key functional areas:

- Weather and Maintenance
- Commercial Vehicle Operations and Transit
- Traffic Incident Management and Freeway Management

During these break-out sessions, stakeholders worked with the Study Team and developed regionally specific projects; including project limits as well as locations of key field devices. This effort resulted in the final list of projects which would be used in the Deployment Plan analysis outlined above. These projects are presented in Section 3.3.

Table 22 - Deployment Plan Project Packets

Project Packet	Project
Traffic Management Packet	Network Surveillance Bridge Surveillance Real-Time Speed Detection and Monitoring Roadway Service Patrols on Major Corridors Common Radios Sharing of CCTV Video Feeds Roadway Closure Management System
RWIS Packet	RWIS Surveillance (CCTV) Frost Tubes Anti-Icing Installations Connected to RWIS*
Work Zone/Construction Packet	Roadway Closure Management System Smart Work Zone and Work Zone Management Systems
Winter Maintenance Vehicles Packet	Maintenance Tracking using GPS for Maintenance Vehicles and Snowplows Anti-Icing Installations Connected to RWIS Common Radios Vehicle Tracking for MSP, Local Public Safety, and Maintenance Vehicles
Bridge Packet	Drawbridge Management System
Arterial Packet	Emergency Signal Preemption Signal Coordination at RR Crossings
Traveler Information Packet	511 Web Site Information
Transit Packet	AVL CCTV and Panic Buttons for Security Electronic Fare Payment Kiosks with Fare and Traveler Information DMS with Real-Time Bus Schedule
Maintenance Vehicles Packet	Vehicle Tracking for MSP, Local Public Safety, and Maintenance Vehicles Common Radios
WIM Packet	Weigh-in-Motion Stations
Parking	Regional Parking Management Systems Local Parking System Management

3.3 Final List of Projects for Analysis

The final list of projects presented in **Table 23** was developed by the stakeholders during the Deployment Plan Workshop. These are the projects which will be analyzed with the IDAS model for the Grand Region Deployment Plan and ultimately combined into a statewide ITS Investment Plan. **Table 23** provides short descriptions of each project; denotes each project with a unique project identifier so it can be easily referenced; and identifies whether the project occurs on a Corridor of Significance or has any anticipated economic development impact.

Table 23 - Final List of Grand Region Deployment Plan Projects

Project #	Name	Description	Corridor of Significance (y/n)	Economic Development Impact (y/n)
GRITS – 001	Drawbridge system at Grand Haven	(4) CCTV and (3) DMS	●	●
GRITS – 002	DMS project	(2) NB and SB US 31 at M 20.	●	●
GRITS – 003	Flood warning system	M – 20 at Shrader Creek	●	●
GRITS – 004	Common radio project	Assume MDOT purchases one radio per county	○	○
GRITS – 005	Common radio II	Assume MDOT equips 5 vehicles per county with AVL	○	○
GRITS – 006	RWIS	(25) RWIS deployments	●	○
GRITS – 007	AVL	Ottawa and Muskegon Counties and Grand Haven Transit – equip all transit vehicles with AVL.	○	○
GRITS – 008	Transit Security CCTV	CCTV systems on Grand Haven, Muskegon and Holland Transit	○	○
GRITS – 009	Traffic Signal Systems	Signal corridor enhancements in Muskegon, Grand Haven, and Holland	●	●

4. Analysis of Grand Region ITS Alternatives

4.1 Project Categorization

A total of twelve ITS deployments were identified for further analysis in **Table 23**. For purposes of evaluating benefits and costs, these projects must be combined into implementation packages that form a logical system. CCTV cameras, for example, are considered part of a Traffic Management System but do not inherently provide benefits. There must be staff in place to watch them, interpret what they see and disseminate information to those who can make use of it. Users may include incident responders, transportation agency personnel or the general public. Accurate representation of benefits and costs requires that various elements be modeled together as a system. The deletion of one key element may reduce or eliminate the benefits, but that element in and of itself, may not produce benefits.

There are also a number of deployments that support multiple functions and projects. In the Grand Region, for example, the West Michigan TMC could take over dispatching duties for a number of functions outside its current core area. A proposed drawbridge management system proposed in Grand Haven, for example, would logically be operated from the TMC. The operation of the IDAS model was documented in Section 2, along with the benefit parameters and cost assumptions. The benefit summaries below have been developed for the Grand Region and modeled by category. It is important to note that the study area for the Grand Region does not include Kent County. For some projects that are regional in nature, however, it is not logical to exclude Kent County. Examples of such projects are the Weigh-in-Motion system upgrades and the RWIS system.

It should also be noted that in the initial runs, entire systems were combined across the region. Based on review of the plan by stakeholders, these runs may be modified to test the addition or removal of specific deployments. **Table 24** shows the how the deployments have been grouped for IDAS analysis.

Table 24 - Grouping of Projects for IDAS Modeling

Project #	Name	Description	Comments
Drawbridge Management System			
GRITS – 001	Drawbridge system at Grand Haven	(4) CCTV and (3) DMS (see map).(need to flesh out remainder of Draw bridge deployment (detection, signal retiming, etc.)(from IDAS standpoint, treat as incident detection, incident management, and en-route traveler information)	
Traffic and Freeway Management Systems			
GRITS – 002	DMS project	(2) NB and SB US 31 at M 20.	To be operated from West Michigan TMC.
Freeway Service Patrols			
GRITS – 010*	Freeway Service Patrols	Peak season weekends and holidays along major freeways and US-31	To be operated from West Michigan TMC.
Road Weather Information Systems and Related Improvements			
GRITS – 006*	RWIS	(25) ESS locations for RWIS deployment as outlined in MDOT plan	Exact locations will be determined in upcoming planning study. Approximate locations used for this project.
GRITS – 003	Flood warning system	M 20	
GRITS – 004*	Common Radio Project I	Common radios (assume MDOT purchases one radio per county)	Primarily for winter maintenance coordination but can be used for other purposes as well
GRITS – 005*	Common Radio Project II	(assume MDOT equips 5 vehicles per county with AVL)	
GRITS – 008*	AVL	Ottawa and Muskegon Counties and Grand Haven Transit – equip all county vehicles with AVL.	
Advanced Public Transportation Systems			
GRITS – 008*	AVL	Ottawa and Muskegon Counties and Grand Haven Transit – equip all county vehicles with AVL.	
GRITS – 009*	Transit Security CCTV	CCTV systems on Grand Haven, Muskegon and Holland Transit	
Smart Work Zones			
GRITS – 011	Smart Work Zone Deployment	Deploy smart work zones on trunklines with lane or shoulder closures due to construction. Deployment should be required as part of construction contracts.	2007 construction season activities used to estimate benefits
Traffic Signal Improvements			
GRITS – 012	Traffic Signal System Improvements	Traffic signal upgrades along the US-31 corridor in the Grand Haven area	
GRITS – 014	Traffic Signal System Improvements	Traffic signal upgrades along the US-31 business in Muskegon	
GRITS – 015	Traffic Signal System Improvements	Enhanced signal system on US-231 around Grand Haven	
GRITS – 016	Traffic Signal System Improvements	Traffic signal upgrades in Holland	
Automated Weigh in Motion Stations			
GRITS – 013	Upgraded Weigh in Motion Stations	Upgraded WIM stations with communications at 4 locations	

**Denotes projects that are not shown on the Grand Region Deployment Plan Maps.*

Figure 12 shows the location of the projects that have a defined geographic component. Projects shown in **Table 23** with an "*" are not included on **Figure 12** because they are either region wide projects or do not have a specific location determined at this time.

Figure 12 - ITS Deployment Plan Projects: Grand Region

Figure 13 - ITS Deployment Plan Projects: Grand Haven

Figure 14 - ITS Deployment Plan Projects: Muskegon

Figure 15 - ITS Deployment Plan Projects: Holland

4.2 Results of Benefit/Cost Analysis

Four packages of ITS deployments were evaluated using the IDAS model while one, APTS, was evaluated using a spreadsheet methodology. A spreadsheet methodology based on the IDAS parameters more easily accommodates the relatively small passenger volumes found in rural transit systems.

Results are shown below by package, with benefits combined into four categories:

- Travel time savings
- Crash reduction benefits
- Operating Costs, including both fuel savings and agency cost savings
- Environmental benefits, primarily air quality improvements

Annualized costs are a combination of amortized capital costs and annual operations and maintenance costs. IDAS uses a life cycle costing methodology that assigns a life to each capital component. A 3% interest rate was used to annualize this cost.

4.2.1 Drawbridge Management System – Grand Haven Bridge

The Grand Haven Bascule Drawbridge on US-31 is one of the busiest locations in the Grand Region, serving over 60,000 AADT. Traffic volumes increase during peak tourist season. There is recreational activity in the Grand Haven area itself, as well as a large volume of through traffic going to destinations further north. When there are backups due to bridge openings or the occasional malfunction, the traffic consequences can be severe. The next crossing of the Grand River is about 20 miles to the east near the town of Eastmanville, thus requiring a 40-mile detour. While this detour would only be implemented on rare occasions, monitoring and informing motorists of traffic conditions on US-31 would have several benefits. When long backups occur, those making discretionary trips could stop and eat or participate in other activities. For some traffic coming from the east, alternative routes could be taken. Even those who must sit in traffic will at least be informed of conditions and their likely crossing times. The project would consist of CCTV cameras at the bridge approaches that could be used for both security and traffic monitoring. Three DMS would be placed at strategic locations to inform motorists of conditions. **Figure 16** shows the physical architecture of a basic Drawbridge Management System.

Only travel time benefits were measured for the project and these exceed annual costs with a benefit/cost ratio of about 2.2. Initial capital costs at $2.17 million, however, are relatively high for a deployment that serves a single location. **Table 25** summarizes the overall annual cost savings associated with the Grand Haven Drawbridge Management system.

Figure 16 - Drawbridge Management System Physical Architecture

Table 25 - Grand Haven Drawbridge Management System Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$755,609
Crash Reduction	$0
Operating Costs	$0
Emissions	$0
Total Annual Benefits	$755,609
Annualized Cost	$338,383
Net Benefits	$417,226
Benefit/Cost Ratio	2.23
Capital Cost	$2,170,000
Annual O&M cost	$169,000

4.2.2 Freeway Management Systems

The Freeway Management System (FMS) includes CCTV cameras, detection, DMS, and a TMC. As mentioned before, the West Michigan TMC currently provides surveillance and detection of major freeways in the Grand Rapids area. Stakeholders indicated a need for five additional DMS in the region, beyond those currently proposed for the Grand Haven Drawbridge Management System. Three would be located along the US-31 corridor, one on I-196 and one on I-96. CCTV cameras are provided for support at each location since there is currently no surveillance in the areas where the DMS would be located.

IDAS shows only travel time benefits for the FMS, but these are very substantial in the Grand Region at over $8 million annually and the benefit/cost ratio is very strong as well, at nearly 19. It should be noted that there would probably be some additional benefits in the area of fuel consumption and emissions, occurring primarily when there are incident related delays or hazardous conditions. While the benefit/cost ratio is strong, the initial capital investment is significant at $2.6 million. Operations and maintenance costs are relatively low; since it appears that the West Michigan TMC will be able to manage the system. **Table 26** summarizes the overall annual cost savings associated with FMS.

Table 26 - Freeway Management System Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$8,431,467
Crash Reduction	$0
Operating Costs	$0
Emissions	$0
Total Annual Benefits	$8,431,467
Annualized Cost	$449,207
Net Benefits	$7,982,260
Benefit/Cost Ratio	18.8
Capital Cost	$2,600,000
Annual O&M cost	$172,500

(1) DMS, CCTV, Detection, TMC

4.2.3 Roadway Weather Information Systems (RWIS)

The proposed RWIS would include 25 Environmental Sensor Stations (ESS) to be installed around the region. MDOT will begin developing an RWIS plan for the region later this year so exact locations have not been determined. For purposes of the Deployment Plan, ESS were spread across the region, focusing on major trunkline roads. Initially, benefits were calculated only for the days when snow exceeds one inch. Using an average of NWS data from several cities in the region, this figure is estimated at 25 days per year. An additional 20% was added for days where snow is less than one inch. RWIS will also be helpful during periods of heavy rain and fog, and may have some benefits for summer as well as winter maintenance. RWIS is also an important supporting deployment for the proposed Traffic Management System. Net benefits are approximately $1.95 million while the benefit/cost ratio is just over 5. in general, benefits are equally balanced between crash reduction and travel time with additional savings from reduced winter maintenance cost. **Table 27** summarizes the overall annual cost savings associated with RWIS deployment.

Table 27 - Road Weather Information System (RWIS) Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$1,036,172
Crash Reduction	$1,269,800
Operating Costs	$114,731
Emissions	$0
Total Annual Benefits	$2,420,703
Annualized Cost	$470,746
Net Benefits	$1,949,957
Benefit/Cost Ratio	5.14
Capital Cost	$2,272,500
Annual O&M cost	$233,500

4.2.4 Advanced Public Transportation Systems

Table 28 summarizes the overall annual cost savings associated with APTS. As noted earlier the three transit authorities along the Lake Michigan shore, Macatawa (Holland), Grand Haven and Muskegon carry approximately 900,000 annual passengers with a combined fleet of 105 vehicles and an operating budget of $6.7 million. Due to their close proximity it appears that a cooperative implementation of an Automated Vehicle Location (AVL) system could benefit all three agencies. Real-time tracking of these vehicles could help to improve the efficiency of real-time operation and provide an archive of data that could be used to adjust schedules and routes. A need was also identified for CCTV cameras on certain bus routes to improve security. There is not adequate data to support a benefit/cost analysis for this deployment so only the AVL deployment is analyzed.

The benefit/cost ratio of the proposed AVL deployment is relatively low at just under 2.0, but it is higher than what was found in more rural applications. All benefits are categorized as operating cost savings, although in reality there may be a mix of both operating cost savings and travel time savings.

Table 28 - Advanced Public Transportation Systems Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$0
Crash Reduction	$0
Operating Costs	$337,000
Emissions	$0
Total Annual Benefits	$337,000
Annualized Cost	$171,000
Net Benefits	$166,000
Benefit/Cost Ratio	1.97
Capital Cost	$527,000
Annual O&M cost	$100,000

4.2.5 Smart Work Zones

Smart Work Zones use ITS technology to monitor work zones and approaches. CCTV cameras, detectors, and DMS are part of these systems, which are often offered by vendors as packages. Information from the Smart Work Zone can be sent to TMCs and websites for broader dissemination. Motorists may save time by taking an alternate route to avoid the work zone. They may also change their departure time or make a stop if there is a backup in a work zone. The Freeway Management System will support the Smart Work Zone program by allowing information to be disseminated to a wider audience. While Smart Work Zones are considered part of the regional ITS Plan, they are not proposed to be part of the ITS program itself. Funding should be provided through the relevant construction contracts and the work zone equipment supplied by the construction contractor. Contract requirements should provide for the information to be made available to the TMC on a real-time basis.

Smart work zones were analyzed by modeling all 2007 MDOT Grand Region construction projects that involved either lane or shoulder closures on trunkline routes. These projects are shown in **Figure 17**. Reduced capacities were calculated and run through the IDAS model. Time savings came from two sources, more efficient flow of traffic through the work zone and the use of faster alternative routes to avoid areas where capacity was reduced. The travel time savings were significant, but there were also significant savings in crash reduction and fuel consumption, as well as a smaller environmental benefit. Both net benefits and the benefit/cost ratio are very high. It is important to note these benefits are measured against the delays that would occur with construction activity without smart work zones. They do not entirely offset the impacts of the work zones. For this project, it was assumed that equipment would be rented or leased on an annual basis. Therefore all costs are considered Operations and Maintenance. An alternative scenario is for MDOT to purchase the equipment. **Table 29** summarizes the overall costs savings associated with the Smart Work Zone deployments.

Figure 17 - Scheduled Work Zones: 2008 - 2011

Table 29 - Smart Work Zone Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$4,651,155
Crash Reduction	$1,839,674
Operating Costs	$1,261,301
Emissions/Noise	$260,355
Total Annual Benefits	$8,012,486
Annualized Cost	$1,180,145
Net Benefits	$6,832,340
Benefit/Cost Ratio	6,79
Capital Cost	$0 #
Annual O&M cost	$1,180,340

 # It is assumed that all equipment will be leased

4.2.6 Traffic Signal Improvements

A need for traffic signal upgrades was identified along the US-31 corridor in the Grand Haven area. Stakeholders noted that traffic flow problems occur particularly where the highway transitions from limited access to non-limited access. Approximately 10 intersections were identified for improvement. The project provides some travel time savings but minimal impacts in the other benefit categories. Overall the net benefits and the benefit/cost ratio are low. **Table 30** summarizes the overall costs savings associated with the Traffic Signal Improvements.

Table 30 - Traffic Signal Improvement Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$69,797
Crash Reduction	-$3,970
Operating Costs	$7,186
Emissions/Noise	$11,542
Total Annual Benefits	$84,735
Annualized Cost	$52,478
Net Benefits	$32,256
Benefit/Cost Ratio	1.61
Capital Cost	$222,000
Annual O&M cost	$22,000

4.2.7 Automated Weigh in Motion Stations

A need for upgraded WIM stations in the region was identified by stakeholders. Automated WIM stations result in time savings for commercial vehicle traffic and also result in decreased crash rates for the entire vehicle stream. The safety benefits can be significant at locations where commercial vehicles may queue back to the main highway.

Four locations were identified in the Grand Region, including two on US 31 and one on US-131 and I-96. Even at 0.5%, the overall crash reduction yields a very high level of benefit for a relatively low cost. Due to the high value of commercial vehicle travel time, the value of time savings in this area is significant as well. **Table 31** summarizes the overall costs savings associated with the Automated WIM Improvements.

Table 31 - Automated WIM Improvement Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$838,850
Crash Reduction	$1,258,329
Operating Costs	$0
Emissions/Noise	$0
Total Annual Benefits	$2,097,179
Annualized Cost	$151,676
Net Benefits	$1,945,503
Benefit/Cost Ratio	13.83
Capital Cost	$346,000
Annual O&M cost	$30,000

4.2.8 Freeway Service Patrols

Freeway Service Patrols (FSP) were identified as an alternative to help clear incidents during peak periods. FSP's were proposed on major recreational routes through the region including US-31, I-196, I-96 and US-131. FSP's would only be in place during peak weekends in the summer, fall and possibly winter. Forty-two days of operation were assumed. The FSP's have a positive, but relatively low benefit/cost ratio, with benefits consisting of a mix of improved travel time reliability, fuel cost savings and crash reductions. It was noted during the stakeholder process that the Michigan State Police increase the frequency of their patrols on these roads during peak recreational periods. This analysis does not account for the fact that the FSP's may be redundant to that service, and therefore have a negative benefit/cost ratio. Capital costs are low but the FSP would take advantage of the large investment in CCTV cameras and detection equipment shown under the Freeway Management System. **Table 32** summarizes the overall costs savings associated with the Freeway Service Patrols.

Table 32 - Freeway Service Patrol Cost Savings

Benefits and Costs	Monetary Values
Travel Time Savings	$156,479
Crash Reduction	$100,055
Operating Costs	$278,791
Emissions/Noise	$0
Total Annual Benefits	$535,324
Annualized Cost	$464,752
Net Benefits	$70,572
Benefit/Cost Ratio	1.15
Capital Cost	$280,000
Annual O&M cost	$364,000

4.3 Summary of Results

Table 33 through **Table 38** show the comparison of benefits and costs between different ITS packages. It is important to note that these results represent only one portion of the criteria that will be used by MDOT to select projects for implementation. Other considerations include eligibility of various funding sources; compatibility with the priorities of MDOT's ITS program as well the agency's overall program priorities; ability to incorporate in major construction projects; and compatibility with other regions' investment strategies. The benefit and cost data, however, provide useful guidance into which investments provide the best return.

Table 33 - Deployment Packages – Total Benefits

Deployment Package	Total Benefits
Freeway/Traffic Management Systems	$8,430,000
Smart Work Zones*	$8,010,000
Road Weather Information Systems	$2,420,700
Automated WIM Improvements	$2,100,000
Drawbridge Management Systems	$756,000
Freeway Service Patrols	$535,000
Advanced Public Transportation Systems	$337,000
Traffic Signal Improvements	$84,700
TOTAL	**$22,673,400**

**Costs should be captured by overall construction project costs.*

Table 34 - Deployment Packages – Net Benefits

Deployment Package	Net Benefits
Freeway/Traffic Management Systems	$7,980,000
Smart Work Zones	$6,830,000
Road Weather Information Systems	$1,950,000
Automated WIM Improvements	$1,945,000
Drawbridge Management Systems	$417,000
Advanced Public Transportation Systems	$166,000
Freeway Service Patrols	$70,500
Traffic Signal Improvements	$32,000
TOTAL	**$19,390,500**

Table 35 - Annualized Cost

Deployment Package	Annualized Cost
Smart Work Zones	$1,180,100
Road Weather Information Systems	$471,000
Freeway Service Patrols	$465,000
Freeway/Traffic Management Systems	$449,000
Drawbridge Management Systems	$338,000
Advanced Public Transportation Systems	$171,000
Automated WIM Improvements	$151,600
Traffic Signal Improvements	$52,500
TOTAL	**$3,278,200**

Table 36 - Benefit/Cost Ratios

Deployment Package	Benefit/Cost Ratios
Freeway/Traffic Management Systems	18.80
Automated WIM Improvements	13.83
Smart Work Zones	6.79
Road Weather Information Systems	5.14
Drawbridge Management Systems	2.23
Advanced Public Transportation Systems	1.97
Traffic Signal Improvements	1.61
Freeway Service Patrols	1.15

Table 37 - Total Capital Costs

Deployment Package	Capital Costs
Freeway/Traffic Management Systems	$2,600,000
Road Weather Information Systems	$2,270,000
Drawbridge Management Systems	$2,170,000
Advanced Public Transportation Systems	$527,000
Automated WIM Improvements	$346,000
Freeway Service Patrols	$280,000
Traffic Signal Improvements	$222,000
Smart Work Zones *	$0
TOTAL	**$8,415,000**

** All costs classified as O&M*

Table 38 - Annual Operations and Maintenance Costs

Deployment Package	O&M Costs
Smart Work Zones *	$1,180,000
Freeway Service Patrols	$364,000
Road Weather Information Systems	$233,500
Freeway/Traffic Management Systems	$172,500
Drawbridge Management Systems	$169,000
Advanced Public Transportation Systems	$100,000
Automated WIM Improvements	$30,000
Traffic Signal Improvements	$22,000
TOTAL	$2,271,000

** All costs classified as O&M*

There are several major components to the Grand Region ITS Deployment Plan. The Freeway Management System and Smart Work Zone projects have the highest level of benefits, while RWIS and WIM benefits are significant as well. These projects account for most of the costs, as well as the benefits and all of them have very positive benefit/cost ratios as well. It is assumed that the existing West Michigan TMC would house the management and control of these systems. Although there would be some additional costs associated with this responsibility, it does provide substantial savings. Most of the other projects, including FSP, transit system AVL, and traffic signal systems show limited benefits and low benefit/cost ratios. It should be noted that traffic signals may be in need of upgrade due to age, and that if such upgrades are necessary, some travel time benefits will result.

4.4 Project Timeframes

Project priorities will be set by MDOT based on a number of factors, of which benefit/cost analysis is only one. Other criteria include availability of funding, funding eligibility of proposed projects, geographic scope of project benefits and the feasibility of phasing projects into place over time. While benefits may be similar between different projects, some projects may offer more immediate relief to a problem. An assessment of emerging technologies is another key consideration. Certain deployments may show high benefits, but at a substantial capital cost. MDOT, through its work on the VII program and other technology initiatives, is a national leader in looking ahead to emerging technologies. If there is likelihood that a specific technology can be replaced by something more cost-effective during its life cycle, agencies may prefer to forego large investment and instead use a temporary solution that will not preclude the emerging technology.

Based on the analysis conducted for this report and the input from the stakeholders, the following project implementation plan is identified for near-term, medium term, and long term deployments. For the purposes of this assessment, short-term deployments are anticipated to be implemented within 0-3 years; medium term in 4 to 8 years; and long-term deployments are expected to occur in more than 8 years.

Table 39 - Grand Region Short-Term (0 – 3 Years) ITS Deployment Plan Projects

Short-Term Deployments	Components	Comments
Traffic Management System	Deployment of additional CCTV cameras and DMS, primarily focused on US-31 corridor.	These deployments can be operated by West Michigan TMC.
Smart Work Zones	Adequate capacity to cover all trunkline construction with lane and shoulder closings within 3 years. Initial focus on summer construction on recreational routes.	Project shows very high positive impact in terms of both net benefits and benefit/cost ratio. Benefits are realized quickly after implementation
Road Weather Information Systems	- First phase deployment with roughly 50% of proposed 25 ESS - Distribution of common radios - Initial phase of AVL deployment on winter maintenance vehicles, probably in larger contract counties.	-MDOT will initiate study later this year to develop RWIS Concept of Operations and locate ESS. A two-phase implementation is assumed here although this will depend on the outcome of the study. - Expanding the 800MHz radio system to winter maintenance vehicles was a priority for stakeholders. - M20 flood warning system should be part of first phase.
Automated Weigh-in-Motion System Upgrade	This is relatively inexpensive option with a high level of benefits.	

Table 40 - Grand Region Medium-Term (4 – 8 Years) ITS Deployment Plan Projects

Medium Term Deployments	Components	Comments
Drawbridge Management System	Implementation of Traffic Management System at Grand Haven Bridge	- Planning for system should begin during short-term phase with implementation in 4 to 8 year time frame. - Concept of operations is needed to finalize system requirements and understand how system should tie in with regional traffic management systems
Road Weather Information System	Second (final) phase implementation of RWIS.	- Timing and specific sites to be determined based on RWIS Concept of Operations and plan to be developed in 2007-08. - Reassessment of second phase will occur following 1st phase deployment
Traffic Signal Systems	Projects to be determined by need for equipment replacement	Since travel time benefits of proposed traffic signal systems are small, deployment should be based on age and condition of assets.
Advanced Public Transportation System	Evaluate feasibility of implementation in Muskegon, Holland and Grand Haven. Initiate implementation where benefit appears greatest.	Technology advances may improve cost-effectiveness.

Table 41 - Grand Region Long-Term (Over 8 Years) ITS Deployment Plan Projects

Long- Term Deployments	Components	Comments
Traffic Signal Systems	Projects to be determined by need for equipment replacement	Since travel time benefits of proposed traffic signal systems are small, deployment should be based on age and condition of assets.
Advanced Public Transportation System	Implementation decision to be based on assessment conducted in medium term as well as any implementation occurring during that time.	Technology advances may improve cost-effectiveness.
Freeway Service Patrols	Consider for implementation depending on traffic conditions	The benefit/cost analysis does not indicate that FSP's are economically viable at this point. It has also been noted that the MSP patrols major highways extensively during peak periods so this service may be redundant. The issue should be revisited to see whether the need has increased.