

Operations Plan
for the
Metropolitan Detroit
Advanced Traffic Management/
Advanced Traveler Information
System

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1.0 Background

The Michigan Department of Transportation (MDOT) is currently planning for the expansion of their current Advanced Traffic Management and Advanced Traveler Information Systems (ATMS and ATIS, respectively). Current ATMS and ATIS coverage include 32.5 freeway miles surrounding Metropolitan Detroit and an additional 212 freeway miles of coverage is in the planning stages.

In order to aid MDOT in assessing deployment strategies for the expansion of freeway coverage, MDOT contracted Rockwell International to conduct a 9 month engineering study and to provide guidance in the Early Deployment of ATMS/ATIS Technologies within Metropolitan Detroit. Studies have been conducted by Rockwell International to assess appropriate technologies, architectures, and deployment strategies for the expanded area of coverage.

Established and promising new technologies were assessed in order to maximize system efficiency and minimize costs (installation, operating, and maintenance). System components such as controllers, sensors, communications, and information dissemination systems were evaluated to determine compatibility with the overall system architecture. The system architecture, which was developed and finalized during this project, follows an open architecture model that provides MDOT the capability to use standard commercial-off-the-shelf (COTS) system components.

In addition to technology assessments, the Early Deployment project analyzed area traffic congestion to determine corridor priorities. This assessment was used to aid in the development of implementation plans and to identify which freeway corridors or segments warrant immediate ATMS/ATIS deployment to reduce congestion and improve traveler safety.

1.1 Introduction

Technology, architecture, contracting, and deployment recommendations resulting from the study enable MDOT to begin system design and construction. However, in order to demonstrate the implementation methods of new ATMS/ATIS components and system architecture quickly, an initial deployment phase has been initiated. The initial deployment activity uses an architecture that is a subset of the overall and final system architecture. Components that satisfy system functional requirements are recommended and deployed in a manner which will demonstrate capabilities and functionality of the new system architecture.

The goal of the initial deployment activity is to provide MDOT with an interim system in an area which needs immediate assistance in reducing congestion, increasing traveler safety, and enhancing incident management activities. Additionally, specific emphasis was placed in deploying IVHS technologies where particular user services are mostly needed in metropolitan Detroit. Existing infrastructure and components are used to reduce initial costs and minimize system deployment time. A unique deployment

strategy is recommended to allow the initial deployment solution to be incrementally integrated into the final architectural solution. Although the initial deployment solution may not be physically equivalent to the final solution, the functionality of the system will be retained due to the modular and open architecture techniques used. The distributed processing architecture also allows deployment in a non-linear manner. Linear implementation, usually attributed to laying conduit and cable, cannot provide the mixed deployment functionality required by the initial deployment physical architecture.

In this report, the ultimate system architecture covering over 240 miles of freeway and trunkline is provided. Additionally, the application of existing and newly promising technology is assessed.

This document provides specific engineering analysis details and is segmented into the following sections:

- Section 1 - Background
- Section 2 - Technological Analysis
- Section 3 - Priority Corridor Analysis
- Section 4 - System Description
- Section 5 - Engineering Design for Deployment

2.0 Technological Analysis

Technology assessments are conducted for major Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) components. These assessments evaluate key functional and non-functional (i.e. installation cost, aesthetics, operating and maintenance cost) characteristics which effect deployment strategies. Weight factors are applied to each key requirement and the components are analyzed based on their capability to satisfy the requirements. System components evaluated are:

- Traffic sensors
- Environmental sensors
- Video surveillance
- Control and data processors
- Traveler information dissemination
- Communication systems

Each assessment steps through an evaluation process that identifies alternate technologies, identifies trade matrix/selection criteria, performs analyses, and derives results/recommendations.

2.1 Traffic Sensors

One of the key characteristics of any ATMS is its capability to sense and monitor traffic conditions accurately. Various traffic sensing techniques have been developed in recent years and other innovative techniques are in development.

Traffic sensors are used to determine specific measures of effectiveness (MOEs). These parameters are communicated back to the traffic operations center (TOC) to aid in determining traffic conditions relating to the various sensing locations. Measures of effectiveness parameters that are widely used are:

- vehicle velocity
- lane flow rate
- lane occupancy
- vehicle classification
- vehicle counts
- travel time
- roadway density
- traffic headway

All of the MOEs listed above depend on the precision and accuracy of vehicle presence detection. These MOEs can be directly measured by traffic sensors or can be derived from basic presence and non-presence signals.

In the following sections, various vehicle sensing technologies are evaluated to determine the most viable and cost effective technology to be implemented during the anticipated deployment time frame. The sensor technology assessment is segregated into three categories; active and passive sensor technology and probes. Active sensors require a source signal to be emitted onto the roadway and a receiver circuit measures the change in the source signal reflection as vehicles pass over or through the sensing area. Passive

sensors on the other hand, do not require an emitter signal. These sensors monitor the natural environment and detect vehicles by slight changes in the surrounding environment. Probes use actual vehicle positioning to determine traffic conditions. Such use of vehicles as probes in the near term is not foreseeable because the deployment of such in-vehicle positioning systems in the quantities required for probe use are not expected to happen immediately. However, as automobile manufacturers and private enterprises develop low cost vehicle positioning devices, the use of probes for calculating traffic congestion can be implemented. The system architecture provides the means to accept additional inputs to enhance system accuracy and performance.

2.1.1 Identification of Alternate Vehicle Detection Technologies

Active Sensors

Inductive Loops

The predominant sensor technology currently used is the inductive loop detector. A loop of wire is buried under the roadway nominally four inches below the surface. The wire is excited with a 10 KHz to 200 KHz signal generating an inductive field which is altered by the passage of a metallic object such as a vehicle. As a vehicle stops or passes over the inductive loop, the inductance is decreased. This change in inductance is detected by the associated driver/monitor electronics as a detection. This on/off (presence/non-presence) indication is normally processed by a separate processor to provide measurements of effectiveness parameters.

Inductive loops can be installed in two configurations, a single loop and by pairs. In a single loop configuration, presence and non-presence of vehicles can be detected. Lane occupancy, lane flow rate, and any other MOE which does not require vehicle velocity can be calculated accurately from a single loop configuration. Single loop velocity calculations can be accomplished in two separate ways. First, a statistical average vehicle length can be used to calculate velocity. However, the variance in actual vehicle lengths can contribute to over + 10% velocity errors just in the pure calculation (ignoring any detection fluctuations due to analog rise time variations). Second, an advanced detector amplifier circuit is being developed which measures the rate of change in inductance. This rate can be used to calculate vehicle velocities. Velocity values vary depending upon vehicle height and structure of the vehicle undercarriage.

The two loop configuration provides a more precise means of calculating velocities. The two loops are used as “speed traps” (also known as timing gates) to measure the time a vehicle takes to travel the distance between two loops. This time measurement, in addition to the fixed distance between the two detectors, can be used to determine vehicle velocities. The two detector configuration can also provide vehicle acceleration and deceleration information by comparing the two loop’s presence pulse widths.

A concern with inductive loops is that failures are typically attributed to how well the loops are initially installed. Additionally, the associated maintenance effort and disruption of traffic flow during repairs require careful scheduling of these efforts. Other

failures and reliability concerns can be attributed to poor loop detector design, poor implementation of maintenance practices, or some combination. Newer installation techniques that use better sealants and loop wire in PVC or polyethylene conduits have greatly improved loop reliability.

Inductive loop detector technology has been proven to operate very well for the past few years. Installation and maintenance problems are primary causes for failures and are not an inherent deficiency of the technology itself.

Microwave

Microwave detectors operate in a similar manner to radar detectors. Microwaves are transmitted toward an area of detection from an overhead mount. These microwaves are pulsed toward the roadway at a sampling rate of approximately four times a second. The reflected pulse to the roadway surface is measured as a function of time and as a vehicle passes through the detection zone, this interval is reduced due to the profile of the vehicle. Lane specific volume and occupancy data can be calculated if two detection zones are configured to measure vehicle speed. With slow sampling rates, these detectors do not provide accurate presence data at freeway speeds.

Newer microwave detectors operate at a sampling rate of up to one hundred times a second and are capable of providing multiple lane detection or presence data. However, data from the New Jersey Turnpike RTMS show significant variances in volume, occupancy and speed data as compared to inductive loop detectors. These variances can be attributed to improper or difficult setup procedures. Since microwaves are not visible to the human eye, exact detection zone setup information cannot be verified.

Corresponding setup information can be misaligned with actual locations of detection zones which provides misregistered timing traps to the system software. This misalignment results in variances in calculated speed, occupancy, and vehicle classifications. Additionally, the system software must be able to accommodate different sized detection zones in order to assure accurate presence and timing registration.

Microwave detectors can be mounted in two fashions, 1) Side-fire or 2) Forward-looking. Sidefire mounting can be configured to provide lane specific volume and occupancy data. Vehicle speed and lane occupancy can be provided if two sensors are mounted adjacent to each other emulating a loop speed trap configuration. The side fire mounting technique (see Figure 2-1) allows maintenance activities to occur without lane closures and is virtually unaffected by construction activities. However, side-fire mounting techniques induce occlusion problems where high profile vehicles in the lanes nearest to the sensor block the microwave paths to other lanes. For example, if a smaller vehicle is traveling next to a tractor trailer truck, the sensor cannot detect the smaller vehicle. The truck height profile will most likely trigger the detector providing a false reading. This false reading can be negated by the processing controller by bounding reflected signal intervals to be limited to the lane width under surveillance. This phenomenon can be avoided by placing the microwave detector at a higher position, However, this mounting adjustment may be limited. Moreover, errors tend to increase as detection distances and traffic flow increases.

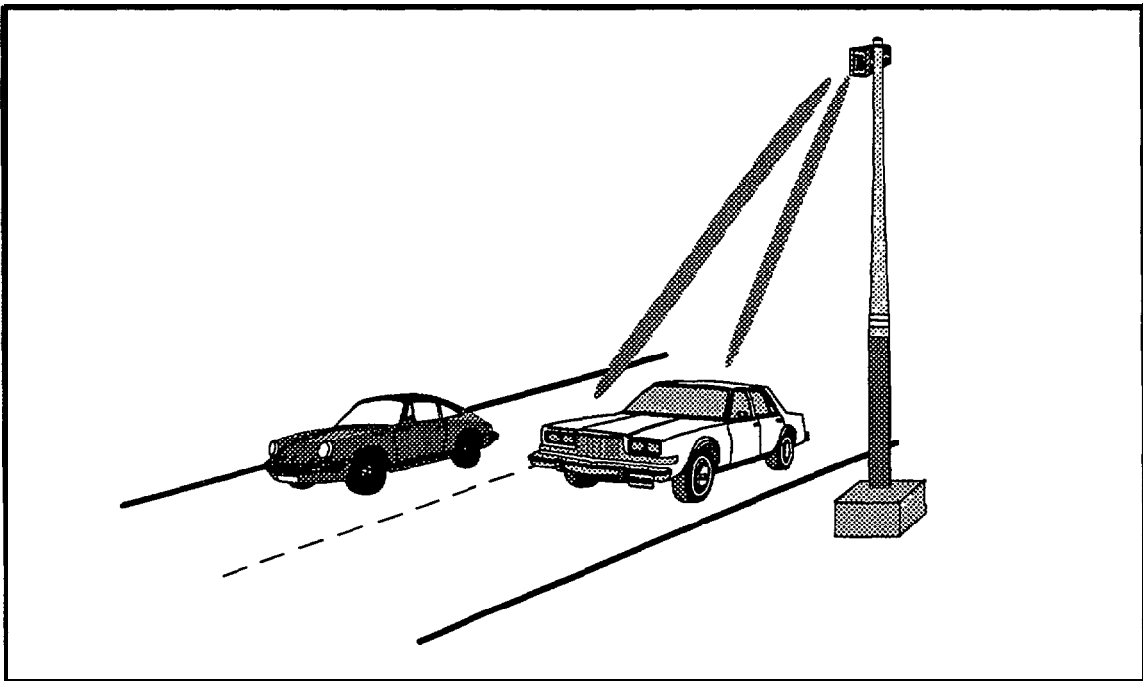


Figure 2-1. Side Fire Sensor Mounting Configuration

Occlusion or similar type of interference from large vehicles can be virtually eliminated by mounting detector units in an overhead fashion (see Figure 2-2) facing on-coming traffic. Two detection zones can be configured in the newer type microwave sensors to measure velocity, occupancy, volume and vehicle classification. To obtain lane-specific information, a detector unit must be placed directly over each monitored lane which in turn increases initial capital costs.

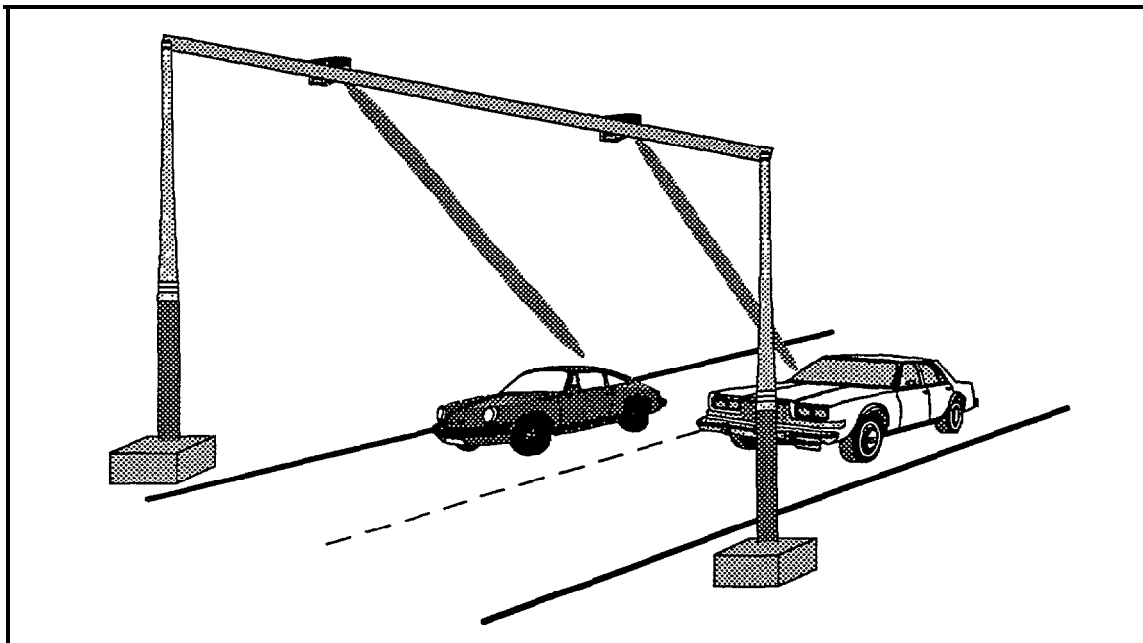


Figure 2-2. Overhead Sensor Mounting Configuration

As with radar detectors, the perceived health effects with microwave based detection units may cause the deployment of this technology to be limited.

Laser/Infrared

Laser detector systems require a laser emitter and receiver pair. These sensors generally use a diode laser operating in the 1.5 - 1.9 micrometer wavelength. The sensor is mounted directly over the lane and emits a laser beam onto the roadway surface. The detection system uses pulsed time-of-flight, laser range finding techniques to measure vehicle presence. As passing vehicles pass through the detection zone, the change in the laser reflection is detected by the receiver. On-board processing allows the system to detect vehicles with 10 inches of separation at 25 miles per hour when the laser beam is pointed vertically downward. The output of the laser sensor system is similar to inductive loop detectors. However, the detection signal represents the physical length of the vehicle rather than the structure of the vehicle undercarriage.

Two laser emitter and receiver pairs are necessary to acquire sufficient presence data to calculate the MOEs listed above. The beam spacing and receiver sensitivity must be aligned accurately to avoid reflection interference from each of the two laser beams. Two different wavelengths are utilized in conjunction with appropriate receiver filters to discriminate between the two detection zones. At times, different modulation frequencies are used for each laser beam, thus providing the means to discriminate between detection zones. Laser sensors can be mounted either over the lane or sidefire.

The laser system typically has a range of over 150 feet, however the potential and perceived health hazard realized from this technology makes this sensor system somewhat unattractive. Also, laser systems are currently in the experimental phase and are not likely to become a deployable product in the early deployment time frame.

Sonic

There are two dominant active sonic sensor operating schemes. The sonic emitter generates source waves at frequencies between 20 KHz and 70 KHz in a pulsed or continuous manner. The pulsed system emits bursts of energy at rates of 50 to 100 times per second. Measurements are taken to determine the time it takes to receive the reflected sonic wave. As a vehicle passes through the detection zone, the difference in the reflected signal time measurements determine the presence of a vehicle. Reflected sonic waves from overhead mounted sensors are used to determine the height and profile of the passing vehicle, thus providing classification data in addition to volume and occupancy. Since sound waves are carried through the air, this scheme of sonic detectors is susceptible to air turbulence and acoustic interference.

Continuous wave sonic method is based on the Doppler shift principle and is accurate for vehicle speeds from 5 to 80 miles per hour. The Doppler shift technique, however, is not able of detecting motionless vehicles. Therefore, occupancy and queue lengths cannot be provided. The sensor can be mounted either directly over the lane or sidefire.

Radar

Radar technology-based sensors operate on a Doppler effect principle. Low power microwaves operating in the range of 10 GHz are directed toward the area of the roadway from units which are usually pole mounted. As vehicles pass through the beam, the energy is reflected back to the sensing element at a different frequency. The receiver senses the change in frequency and denotes it as a passage of a vehicle.

Radar detectors are available in two configurations, 1) wide beam and 2) narrow beam. Wide beam units are installed either above the roadway or to the side. These units are used only to gather general freeway flow and speed information. Whenever a vehicle enters the detection zone, its velocity is measured using the Doppler principle. If multiple vehicles enter the zone simultaneously, usually the largest vehicle's speed is recorded.

Narrow beam units are used whenever lane-specific speeds and volumes are required. One detector is required for each lane in this configuration. The sensor can be mounted either over the lane or sidefire.

The majority of the radar based sensors use the Doppler effect principle to record vehicle speed and flow rate. However, with this technology, slow moving or stopped vehicles cannot be detected. Thus, these sensors are not able to provide occupancy and queue information. Additionally, a Federal Communications Commission (FCC) license is required to operate such detectors.

Radar detectors are currently being installed and field tested in Connecticut, Missouri, New Jersey, Texas, California, Florida and Toronto, Canada. Operational field test results from these deployments are not yet available.

Passive Sensors

Sonic

Passive sonic detectors use sonic technology derived from previous U.S. Navy projects. An array of microphones gathers acoustic data and by using digital signal processing techniques, determine vehicle presence. The microphone array can be mounted directly overhead or on existing roadside structures and various detection zones can be configured and used to calculate velocity, occupancy, and flow rate. The microphones monitor a wide range of frequencies providing capability to detect slow and fast moving vehicles. However, the system cannot detect stalled vehicles, thus making incident detection slightly difficult.

Operational characteristics and accuracy of data from passive sonic detectors are currently not available due to the lack of system deployment. The use and recommendation of this technology for vehicle detection will not be able to be determined until actual field data is collected and results published.

Infrared

Passive infrared detection technology has been deployed in several military applications. Thermal signatures of objects are used to detect presence and motion. Traditional far infrared detectors which discriminate objects from thermal signatures require that the detector array be cooled to 77 degrees Kelvin (-196 degrees Celsius). This is accomplished by using dewars filled with liquid nitrogen or by thermal electric coolers. Objects can be detected through fog, rain, haze, snow, etc. The image acquired by the infrared focal plane array is further processed by an on-board processor. Image processing techniques are then applied to determine object presence. Additional processing is then performed to determine object position and motion characteristics. Accuracy of the processed data depends upon the robustness of the image recognition algorithm and image scan rates. Accuracies of up to " 0.5% can be realistically achieved.

Currently, there are no known operating area passive infrared traffic detection systems. However, with activities associated with "defense conversion" projects, it is inevitable that passive infrared traffic detectors will emerge. It is anticipated that detectors which use this technology will be mounted directly above traffic lanes or on road side structures. Data should be able to be obtained for each lane and provide lane specific MOEs. Recurring activities associated with maintaining liquid nitrogen dewars increase operation and maintenance costs significantly.

Recently, passive lane infrared detectors which do not require cooling have been developed. This particular application of infrared technology uses a near infrared point detector and can provide presence, count, speed, occupancy and queue length data. However, this technology is typically used where background infrared signatures remain constant. Varying thermal signatures which occur during the day and changes in the seasons could result in erroneous vehicle detection. Additionally, the thermal resolution of the sensor may not provide reliable detection. Further field testing of such devices needs to be performed in order to determine applicability of this particular infrared technology.

Magnetic

Magnetic detectors (magnetometers) were one of the earliest forms of vehicle detection systems. Magnetometers operate by sensing changes of the vertical component of the earth's magnetic field. Magnetometer probes, which are typically cylindrical (2 inches in diameter, 4 to 5 inches in length) are buried approximately 12 inches below the road surface and provide a point detection zone. Sensor probes are connected to an electronic circuit board which converts the analog signal into a discrete digital pulse. A series of probes must be buried to provide area coverage. Accuracy of data is similar to inductive loop detectors.

As metallic objects travel over the magnetometer, the earth's magnetic field changes depending upon the metallic content of the object. Resulting magnetic field signatures are generally unique to the type of vehicle. With sufficient digital signal processing,

vehicles can be characterized by make and model. By tracing the movement of the magnetic field signature, velocities, vehicle counts, and flow rates can be obtained. Installation of these types of sensors requires road closures and generally does not provide any more information than inductive loop detectors. However, in applications where drilling or cutting of the road surface is prohibited (bridges, overpasses, etc.), magnetometers can be mounted underneath such structures to provide traffic characteristics.

Machine Vision

Machine vision is one of the latest technologies to be applied to traffic detection. Images are typically acquired through the use of closed-circuit television (CCTV) cameras and processed via image processing circuit boards. CCTV cameras are mounted either overhead or on road side structures. The cameras are connected to a processor unit (which is located at ground level) for image processing. Vehicle presence, speed, lane occupancy, lane flow rate, and classification information can be extracted. Discrete outputs similar to inductive loops are typically provided to enable the system to be integrated with existing traffic controllers.

Multiple detection zones can be defined within the field of view of the CCTV camera, thus providing multiple lane coverage. Multiple cameras can be connected to one processor unit providing wide area coverage.

Accuracies of machine vision detector systems heavily depend upon system setup and camera mounting location. The optimum camera position is typically located as high as possible and centered over the roadway with the viewing angle as perpendicular to the road surface as possible. If these camera mounting criteria are not available, the cameras must be mounted from road side structures. In such cases, as with any line-of-sight sensors, visual occlusion reduces calculated MOE accuracies.

Additionally, in low-light or night conditions, headlights are generally used to detect vehicles. In such cases, the rear end of vehicles cannot be distinctively detected, thus effecting the accuracy of vehicle lengths and classifications. Low light CCTV cameras can somewhat alleviate this problem if ambient light conditions provide sufficient illumination of the detection zones.

Machine vision sensors are currently operating in Oakland County, Michigan, Minnesota, Fontana, California, and Long Beach, California. Initial results from the implementation of machine vision sensors are favorable. With additional software algorithms, incident detection may be accommodated. Although current systems require heavy up front investments, lower cost machine vision systems are emerging and may be more cost effective within the next few years.

Probes

The use of vehicles as probes in determining traffic conditions have been studied in recent years. Vehicles transmit their current positional data acquired from in-vehicle

navigation systems. Such navigation technologies include Global Positioning System (GPS), differential GPS, dead reckoning, and systems which rely upon established navigation supporting infrastructure such as beacons.

Vehicle probes provide an accurate depiction of travel and delay times on particular corridor segments. As vehicles travel on a certain corridor segment, positional data which are time-stamped are stored. Incremental changes in position and time are used to calculate actual travel times and thus delay times are derived.

Additional information can also be acquired with the use of vehicle probes. In times of recurring and non-recurring congestion, probes can be polled for their current position to identify traveled alternate routes. The collection of this type of information can be used in enhancing incident management plans and identifying alternate route patterns selected by traveling motorists.

Vehicle probe information can only be beneficial when a sufficient sample of the traveling motorist can be taken. Some commercial trucking and package delivery firms have started outfitting their vehicles with automatic vehicle location (AVL) systems. Most of these systems are used to enhance dispatching and delivery functions. However, due to the low number of such systems within the metropolitan Detroit area, positional sample data collected from such instrumented vehicles do not accurately reflect traffic patterns of the traveling majority. Until a higher sampling of the traveling vehicles can be acquired, the use of vehicle probes for traffic monitoring should not be relied upon. Therefore, vehicle probes will not be considered as a sole supplier of traffic data. The use of probe data from experimental or existing probes is recommended to supplement the recommended traffic sensor system.

Traffic Sensor Technology Summary

Table 2-1 summarize the characteristics of the discussed sensor technologies. System capabilities are listed in addition to generalized advantages and disadvantages. A representative freeway installation scenario was used to determine initial installation costs and to estimate operational and maintenance (O&M) costs for 20 years. O&M includes costs associated with operation, maintenance, and more importantly, preventative maintenance. A four lane freeway section with an adjacent two lane on-ramp configuration was used as shown in Figure 2-3. Each lane is also configured to collect speed, occupancy, presence, count, and queue length data. Figure 2-4 shows estimated life cycle costs (LCC) over 20 years. Subsurface sensors show higher annual O&M costs due to failures contributed by mechanical stress induced by thermal expansion and road surface deflections. Above ground sensors require less maintenance and require substantially less labor for annual maintenance and repair.

Figure 2-3 depicts an inductive loop detector configuration. However, configurations for the cost summary vary depending upon the sensor type and its lane coverage capability.

Table 2-1. Traffic Sensor Technology Characteristics

Technology	Measuring Capabilities	Advantages	Disadvantages	System Cost (Install +20 yrs O&M)
Inductive Loop	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Proven technology • All weather, day/night operation • Size & shape of detection zone shaped by loop geometry • Capable of measuring all traffic parameters 	<ul style="list-style-type: none"> • Lane closure required for installation and maintenance • Susceptible to damage due to thermal coefficient of expansion (TCE) mismatch • Cutting of pavement reduces life span of road 	\$194,856
Microwave	Count Speed	<ul style="list-style-type: none"> • Above ground mounting • Only a single head needed to measure velocity 	<ul style="list-style-type: none"> • Unable to detect motionless vehicles • Precision setup required • Potential health hazard • Deployment numbers limited 	\$110,928
Laser/ Infrared (Active)	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Accurate vehicle length measurement 	<ul style="list-style-type: none"> • Susceptible to spectral interference • Potential health hazard • Not proven technology in traffic applications 	\$148,740
Pulsed Sonic (Active)	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Can be used at locations with irregular surfaces • Can provide height profile 	<ul style="list-style-type: none"> • Non-directional • Conical beam pattern provides inaccurate measurements • Accuracies degrade under congested traffic 	\$108,240
Continuous Sonic (Active)	Count Speed	<ul style="list-style-type: none"> • Above ground mounting • Can be used at locations with irregular surfaces • Slightly improved speed measurements than pulsed sonic 	<ul style="list-style-type: none"> • Sensitive to environmental conditions • Cannot detect motionless vehicles 	\$132,432
Radar	Count Speed	<ul style="list-style-type: none"> • Above ground mounting • Not effected by electromagnetic interference 	<ul style="list-style-type: none"> • Requires FCC license to operate • Does not measure presence/occupancy • Precision setup required • Potential health hazard • Currently in field test 	\$116,304
Passive Sonic	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Potentially accurate vehicle classification 	<ul style="list-style-type: none"> • Cannot detect stalled vehicles • Not a proven technology • Susceptible to environmental interference 	\$105,552
Passive Infrared Lane Coverage	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Operates in snow, rain, fog • Can provide all traffic parameters 	<ul style="list-style-type: none"> • Currently under test • Potential high O&M cost • Detailed setup required 	\$135,300
Passive Infrared Area Coverage	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Operates in snow, rain, fog • Can provide all traffic parameters 	<ul style="list-style-type: none"> • No current traffic applications • Potential high O&M cost • Detailed setup required 	\$143,940
Magnetic	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Proven technology • Not effected by noise from direct current power lines • Can be mounted under bridges without cutting pavement 	<ul style="list-style-type: none"> • Requires lane closure during installation and maintenance • Multiple units needed to measure velocity • Potential multiple triggers on single vehicle due to magnetic material distribution 	\$209,760
Machine Vision	Presence Count Speed Occupancy Queue Length	<ul style="list-style-type: none"> • Above ground mounting • Proven technology • Does not depend upon pavement condition 	<ul style="list-style-type: none"> • Detailed setup required • Units currently being field tested • Long term operation unknown 	\$177,393

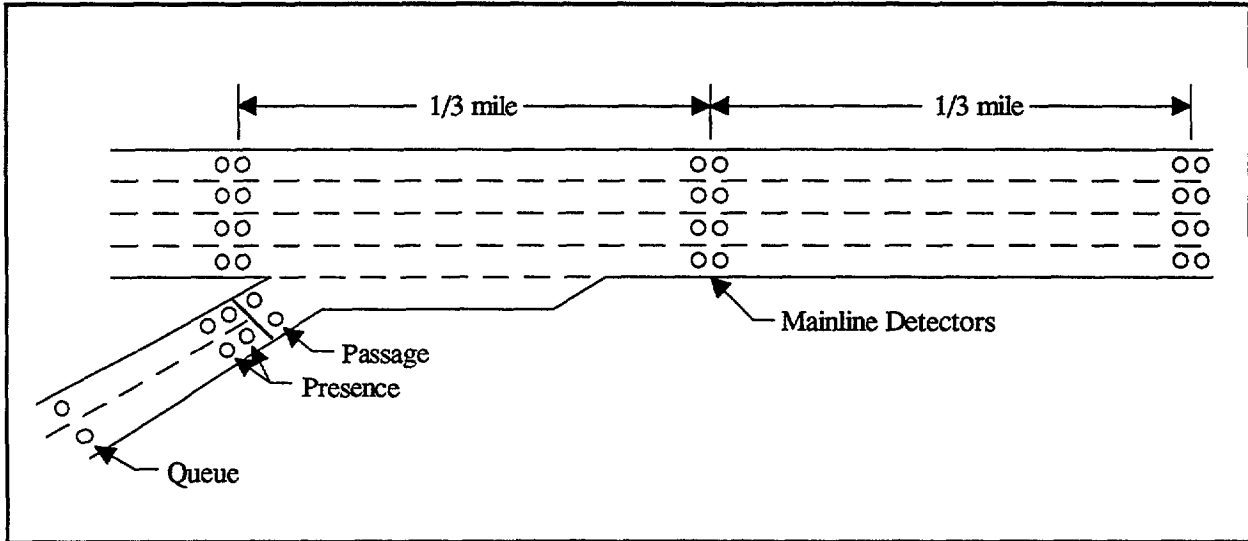


Figure 2-3. Representative Freeway Sensor Layout

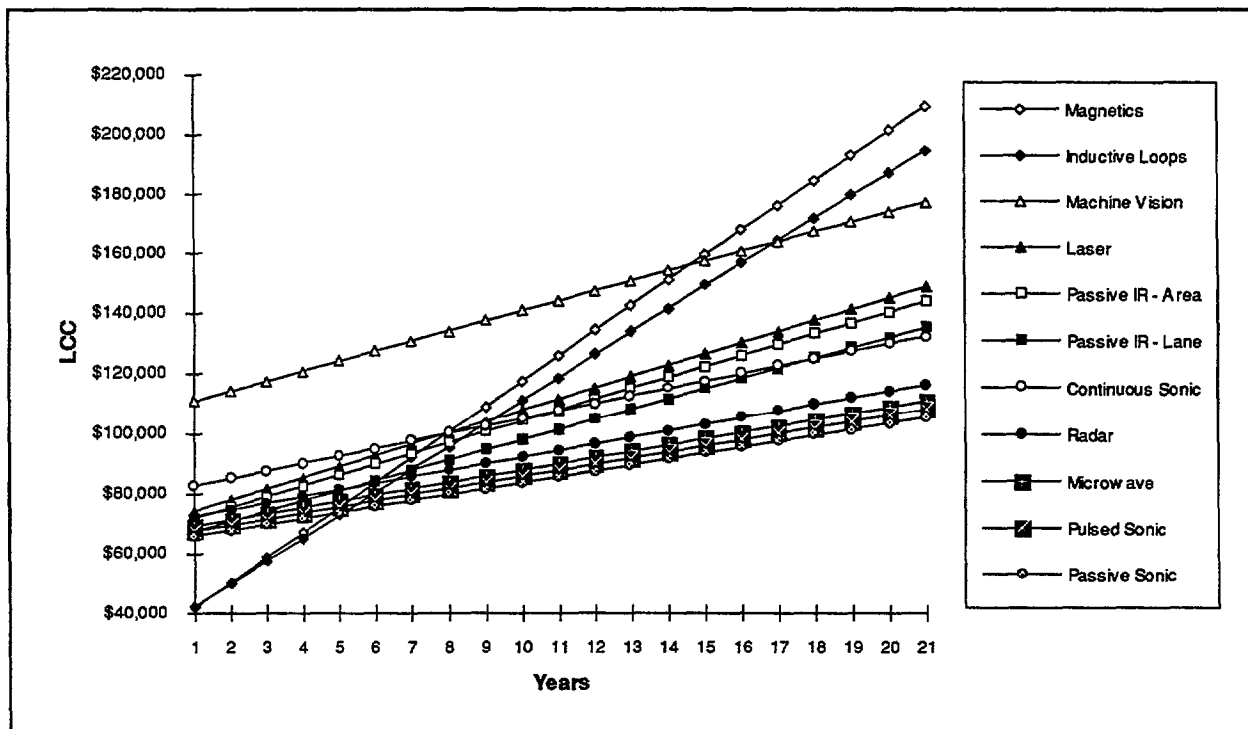


Figure 2-4. Traffic Sensor Technology Life Cycle Cost Comparison

2.1.2 Trade Matrix and Selection Criteria

The criteria used for this evaluation consist of the parameters listed in Table 2-2 and their relative importance to the implementation of the specific detector technology. The list represents criteria categories to achieve desired goals. These criteria are used to evaluate technologies applied in various vehicle detection technologies.

Table 2-2. Traffic Sensor Evaluation Criteria and Weight Factors

Evaluation Criteria	Weight Value	Comments
Feasibility/Ease of Implementation	10	Assessment of technical risk.
Implementation and O&M Cost	10	Assessment of required budgetary Funds.
Upgradeable	8	Assessment of openness options.
Environmental Durability	8	Assessment of tolerance to the surrounding environment.
Satisfaction of Required MOEs	7	Assessment of traffic monitoring.
Accuracy	6	Assessment of sensing repeatability and precision.
Proven Technology	6	Assessment of technology field readiness.

Each sensor technology is evaluated based upon the satisfaction of evaluation criteria. Raw scores are tabulated and an overall ranking is established using weight factors and assessment guidelines in Table 2-2 and 2-3.

Table 2-3. Traffic Sensor Evaluation Assessment Guidelines

Level of Compliance	Score
Exceeds Compliance	10
Fully Compliant	9
Good Compliance	8
Above Average Compliance	7
Average Compliance	6
Minimum Compliance	5
Marginal Compliance	4
Partial Compliance	3
Poor Compliance	2
Does Not Comply	1

2.1.3 Analysis

Raw scores presented in Table 2-4 are translated into composite scores (see Table 2-5) using the evaluation criteria weighting factors. Relative ranking of each technology was then determined, with results provided in Table 2-5.

Table 2-4. Traffic Sensor Technology Comparison Raw Scores

Technology	Ease of Implement	Implement./ O&M Cost	Upgradeable	Durability	Satisfaction	MOE Accuracy	Proven Technology
Inductive Loop	10	6	5	5	6	8	10
Microwave	8	10	6	6	6	5	4
Laser/Infrared (Active)	8	8	6	5	6	7	4
Pulsed Sonic	6	10	5	5	6	5	4
Continuous Sonic	6	9	5	5	5	5	4
Radar	7	10	6	6	5	5	4
Passive Sonic	6	10	7	5	7	5	4
Passive IR – Lane	8	8	6	6	10	6	4
Passive IR – Area	7	8	7	7	10	6	3
Magnetic	8	6	4	5	5	7	10
Machine Vision	8	8	8	7	10	7	7

Table 2-5. Traffic Sensor Technology Composite Scores And Ranking

Technology	Composite Score	Relative Ranking
Inductive Loop	390	2
Microwave	372	5
Laser/Infrared (Active)	356	7
Pulsed Sonic	336	10
Continuous Sonic	319	11
Radar	355	8
Passive Sonic	359	6
Passive IR - Lane	386	4
Passive IR - Area	386	3
Magnetic	349	9
Machine Vision	434	1

2.1.4 Traffic Sensor Technology Results and Recommendation

The resulting technology trade analysis identifies machine vision sensors to be favored over other sensor technologies. The margins between composite scores of various technologies are not wide spread. This indicates that there is no one technology which is far superior than others. However, the machine vision technology shows high potential in

future expansion and enhancements to current capabilities without changing the basic sensor implementation.

The technology uses “image processing” techniques to determine the measures of effectiveness locally to the sensor unit, thus, distributing data processing and reducing communications requirements. Additionally, the technology provides an attractive life cycle cost figure and tends to require less operational maintenance due to above ground mounting methods. Machine vision application in traffic management will increase in the next several years. It is inevitable that hardware costs will significantly decrease as the technology matures. The use of machine vision technologies has been prevalent in manufacturing applications for several years and is migrating into traffic applications. Software algorithms used in such detection technologies are inherently upgradeable as detection techniques mature (i.e. fuzzy logic, neural networks, artificial intelligence, etc.). Additionally, lower cost machine vision sensors are appearing in the transportation market and it is foreseeable that the initial hardware and installation cost will dramatically be reduced in the near future.

However, the inductive loop technology has been a proven technology in traffic detection. Loop detector electronics are very inexpensive and widely available. The technology cannot cost effectively be improved upon. This technology has matured to the point that costs associated with deployment and O&M costs will not decrease. Changing pavement conditions reduce the reliability of loops and tend to have a high life cycle cost. If properly installed and preventative measures are taken to maintain the road surface, inductive loops have the potential to be cost effective. Extreme adverse weather conditions in Michigan, however, reduce the reliability.

It is recommended that machine vision sensors be used to maximize the benefits from long term life cycle costs. Inductive loop detectors should remain as an option for areas where machine vision technologies cannot be deployed due to visual obstruction, height restrictions or cost effectiveness (i.e. ramp metering or off ramps). Furthermore, areas which previously could not be instrumented (i.e. bridges) can now be monitored with machine vision sensors.

2.2 Environmental Sensors

Environmental sensors provide MDOT with the capability to monitor road and driving conditions. Various sensors can be used to monitor road surface temperature, humidity, wind speed, etc. Correlating various inputs from these sensors will allow MDOT to close a freeway segment if unsafe conditions arise.

It is anticipated that the excess computing capacity at remote controllers will be used to process raw inputs from environmental sensor systems which do not have an on-board processor. Since these types of sensors do not require fast conversion times (time to convert analog data into a digital format), the processing burden on remote controllers is almost negligible.

Two different configurations of environmental sensor systems were investigated. The two configurations are 1) separate environmental sensors controlled by the field controllers; 2) a self contained integrated environmental sensor system.

Separate Environmental Sensor Components

In this configuration, individual sensors which can monitor temperature, humidity, wind speed, and road surface temperature can be individually attached to a field controller to collect environmental data. This configuration requires a separate controller interface for each sensor component. Software to acquire and convert raw analog or discrete data from individual sensors must be written unless supplied by individual sensor vendors. Environmental sensor parameters must then be stored in the field controller's memory to be further placed into the data stream which is to be transmitted back to the operations center. Integration of environmental sensor components requires relatively moderate efforts to deploy and overall costs can add up to over \$400.

Self Contained And Integrated Environmental Sensor

The advancement in micro-electronics production enables various environmental sensors to be integrated into a self contained electronics package. These sensor systems have their own on-board processors which provide raw data conversion internally. The output from these systems typically uses the industry standard EIA-232 serial interface. Further processing in field controllers is only limited to receiving the processed information and placing the data into its appropriate position in the controller data stream. Software development and hardware integration require relatively low efforts to deploy and the associated cost for such sensors is around \$200 - \$300.

Environmental Sensor Components

The number of environmental sensor components (temperature, humidity, etc.) depend widely upon options provided by vendors. Area temperature and humidity are two environmental parameters which can be mostly used in the metropolitan Detroit freeway traffic management system. The ability to sense potential hazardous road conditions allow MDOT to take preventative measures.

There are two predominant temperature sensor types which are available today. The first is the contact type sensor which depends upon direct contact with surfaces. These sensors typically use either resistive temperature devices (RTD) or thermal couple technologies. These sensor technologies provide the advantage of acquiring direct road surface temperatures. However, these sensors must be in contact with the road surface in order to measure the temperature.

The second method uses infrared technology to measure the road surface temperature. Typical infrared measuring devices can only measure surfaces which are a maximum of 10-15 feet away. There are some devices which can measure surface temperatures at larger distances, however, the cost of such devices is extremely high. This method significantly limits available mounting positions.

Low cost passive element humidity sensors which can be electronically monitored by computer processors are widely available. Wind speed measuring devices are available, however, placement of sensors are critical in providing accurate wind speed measurements. Sensors which are typically used at airports can also provide visibility measurements. Table 2-6 show a compilation of environmental sensor techniques and methodologies.

Table 2-6. Environmental Sensor Components

Sensor Type	Technology	Ease of Deployment	Cost of Deployment	Accuracy	Comments
Ambient Temperature	RTD Thermal couple Diode	Low	Low	+2 Degrees F	<ul style="list-style-type: none"> • Can be used in combination with humidity sensor to predict icing • Surface temp. can be projected
Surface Temperature	RTD Thermal couple Diode Infrared	Moderate	Moderate	+1 Degrees F	<ul style="list-style-type: none"> • Must be mounted in close proximity of road surface
Humidity	Passive element	Low	Low	+2%	<ul style="list-style-type: none"> • Must be used to predict icing
Wind Speed	Mechanical Pilot Tube	Moderate	Moderate	+3 mph	<ul style="list-style-type: none"> • Susceptible to damage
Visibility	Optical Reflective IR	Moderate	High	+50 feet	<ul style="list-style-type: none"> • Low benefits

Environmental sensors provide additional information to aid in regional traffic management. Basic temperature and humidity sensors can provide sufficient information in determining hazardous conditions, especially during the winter seasons. Areas within Michigan, specifically the greater Detroit area, encounters such harsh conditions as snow and ice. The ability to predict these hazardous conditions will enable MDOT to take preventative measures to ensure driver safety.

It is recommended that the use of an integrated environmental sensor system be deployed at predefined intervals. A one mile increment is recommended since sufficient data can be collected to model representative road conditions. This type of sensor system requires only a small amount of software development and very low integration efforts.

Ambient temperature sensors are recommended for temperature measurements due to the lower deployment cost and lower susceptibility to damage. Humidity sensors should be used in conjunction with the temperature sensor since the combination of the two sensors can provide sufficient information to predict icing conditions. Other environmental

sensors such as wind speed and visibility sensors should only be deployed in areas where recurring wind and visibility problems arise.

2.3 Video Surveillance

Video surveillance provides the MTC with a visual means to determine the nature of traffic congestion. Images provided by the video technology are transmitted to the MTC for viewing and incident assessment. Resolution of the image must have the granularity whereby the MTC Detroit Freeway Operations Unit (DFOU) operator can determine the nature of the incident or other roadway impairment. Surveillance coverage locations will be strategically selected through an analytical analysis of metropolitan Detroit incident data obtained from the Michigan State Police (MSP) and the Michigan Emergency Patrol (MEP). This data will be normalized to identify incident problem areas.

The video surveillance technology must be versatile to provide video images in bright light (day), flat light (overcast/low contrast), adverse weather (rain, snow), and low light (night) conditions. Color images tend to provide maximum resolution for daylight conditions, while black and white images provide the best contrast for low light conditions.

In general, the camera, mounting, and communications interface equipment/enclosures must be designed to function year-round (i.e., rain, ice, snow, etc.) in the local metropolitan Detroit urban environment. These equipment/enclosures include integrated environmental conditioning features (i.e., defogger, cooling, etc.), be modular in design, and promote ease of maintenance.

The following paragraphs list video surveillance requirements of which the early deployment video surveillance technology shall satisfy.

Environmental Conditions

Video surveillance technologies must operate and endure many years in the adverse metropolitan Detroit environment. They must be robust and operate in temperatures ranging from sub-zero with snow and ice, high heat (cabinet) with high humidity, to corrosive elements and electromagnetic interference.

All fielded components shall provide features to protect the components from the local metropolitan Detroit urban environment. In addition to weather effects, consideration must be given for equipment vandalism and theft. Features such as low value materials, camouflage (or neutral colors), or low-profile equipment mounting (or locations) should be considered to aid against damage.

To minimize excessive development costs, field components should capitalize on readily available, commercial-off-the-shelf (COTS) equipment which has been designed for operation in adverse weather.

Table 2-7 summarizes environmental conditions for video surveillance field components.

Table 2-7. Video Surveillance Environmental Conditions

Parameter	Requirement
Temperature	-50 degrees F to +140 degrees F
Humidity	100 percent relative.
Lightning/Electrostatic discharge	All equipment shall incorporate features to prevent damage from transient electrical discharges in the fielded configuration.
Radio Frequency Interference (RFI)/Electromagnetic Interference (EMI)	All CCTV subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MTC office and Metropolitan Detroit urban environments. Correspondingly, all video equipment shall not emanate RFI/EMI which will interfere with other MTC and localized fielded equipment.
Wind/salt/sand/dust/contaminants	Protection from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment.
Other environmental-related effects	Insulation from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, vandalism and theft, etc.

Performance Requirements

Specifications for the video surveillance equipment shall satisfy the requirements listed in Table 2-8.

Table 2-8. Video Surveillance Performance Requirements

Camera Feature	Minimum Requirement
Full color (daylight)/low light black and white (dawn/dusk/night) capability:	Adjustable aperture, 0.1 lux (0.01 FC)
Bright/low light compensation/transition	Automatic/Manual (selectable)
Image resolution (min.):	500 lines horizontal, 400 lines vertical; NTSC compatible
Image zoom/telephoto:	Effective zoom/telephoto of the video image shall be 25-180 mm @ f1.2, with manual focus, remotely controlled.
Frame speed:	Full motion video (real-time).
Display text:	Programmable (operator-entered (i.e., "I-94 Ford Freeway @ I-75 Chrysler Freeway").
Power Compatibility	115 VAC +/- 15% VAC; 60 Hz +/- 5%; min 20A
Power Surge Protection	Circuits shall be protected from current surges and voltage transients up to 1000 Volts.

2.3.1 Identification of Alternate Video Surveillance Technologies

Video camera technologies which have been examined include day light color, low light black/white, machine vision (high and low resolution), visually-enhanced infrared, and low-light intensified systems. A summary of these technologies is listed in Table 2-9.

Table 2-9. Video Surveillance Technology Characteristics

Video Technology	Advantages	Disadvantages
Daylight Color Video	<ul style="list-style-type: none"> • High bright light contrast resolution (colors) • Maximum resolution determination • Good viewing aesthetics • Commercially available • Proven technology 	<ul style="list-style-type: none"> • Degraded low light capability • Low light versions costly • Colors cannot be easily seen in low light conditions
Low light Black/White Video	<ul style="list-style-type: none"> • High low light contrast resolution • Average viewing aesthetics • Commercially available • Proven technology • Lower communications bandwidth requirements than color 	<ul style="list-style-type: none"> • Degraded viewing resolution in bright light
High Resolution Machine Vision	<ul style="list-style-type: none"> • Comparable to NTSC video • Digital format for communications compatibility 	<ul style="list-style-type: none"> • Higher cost than NTSC video • Specialized digital signal processing adaptation (programming required) • Specialized support base
Low Resolution Machine Vision	<ul style="list-style-type: none"> • Low cost • Digital format for communications compatibility 	<ul style="list-style-type: none"> • Impaired visual resolution capability • Specialized digital signal processing adaptation (programming required) • Specialized support base
Video-Enhanced Infrared	<ul style="list-style-type: none"> • Not dependent on optical vision 	<ul style="list-style-type: none"> • Impaired visual resolution capability • Specialized support base • Requires special visual training • Low visual aesthetics
Low Light Intensified	<ul style="list-style-type: none"> • High performance in extreme low light conditions 	<ul style="list-style-type: none"> • Low performance in bright (daylight) environment • Potential to burn out intensifier during daylight hours • High cost

2.3.2 Trade Matrix and Selection Criteria

Criteria used for the evaluation of video surveillance equipment consists of the parameters listed in Table 2-10. The criteria weight values are also listed in the table. The list represents categories to achieve the desired performance goals of video surveillance.

Table 2-11 details the evaluation guidelines used in evaluating each video surveillance technology.

Table 2-10. Video Surveillance Evaluation Criteria and Weight Factors

Evaluation Criteria	Weight Value	Comments
Cost	10	Installation and O&M costs
Color Discrimination	7	Aid in vehicle determination
Low-light Capability	7	Low light & night operation
Image Resolution	7	Provides detail for incident response
Image Zoom/Telephoto	7	Added area coverage
Frame Speed	7	Motion clarity
Text Display	7	Location and positioning information
Durability	7	Operation under harsh environments
Input Power Compatibility	7	Power availability
Power Surge Protection	7	Lightning and power distribution protection

Table 2-11. Video Surveillance Evaluation Assessment Guidelines

Level of Compliance	Score
Exceeds Compliance	10
Fully Compliant	9
Good Compliance	8
Above Average Compliance	7
Average Compliance	6
Minimum Compliance	5
Marginal Compliance	4
Partial Compliance	3
Poor Compliance	2
Does Not Comply	1

2.3.3 Analysis

Raw scores presented in Table 2-12 are translated into composite scores (Table 2-13) using the evaluation criteria weighting factors. Relative ranking of each technology was then determined, with results provided in Table 2-13.

Table 2-12. Video Surveillance Technology Comparison Raw Scores

Technology	Cost	Discern Colors	Low-Light Capability	Image Resolution	Zoom/Tele-photo	Frame Speed	Text Display	Durability	Compatible Input Pwr	Surge Protection
Daylight Color Video	8	10	6	8	9	8	8	9	8	8
Low light Black/White Video	10	1	9	8	9	8	8	9	8	8
High Resolution Machine Vision	6	10	6	8	9	8	8	8	8	8
Low Resolution Machine Vision	4	4	6	2	9	8	8	9	8	8
Video-Enhanced Infrared	3	1	10	8	9	8	8	8	8	8
Intensified Black/White	5	1	10	8	9	8	8	6	8	8

Table 2-13. Video Surveillance Technology Composite Scores And Ranking

Technology	Composite Score	Relative Ranking
Daylight Color Video	598	1
Low light Black/White Video	576	2
High Resolution Machine Vision	571	3
Low Resolution Machine Vision	474	6
Video-Enhanced Infrared	506	5
Intensified Black/White	512	4

2.3.4 Video Surveillance Results and Recommendations

Video surveillance technologies reviewed included traditional video, non-traditional devices and visual image processing. Advanced video technologies were assessed for incident verification and response resolution; however, these technologies tend to fall short of satisfying day and night viewing and visual resolution. The recommended video surveillance technology is a combination of color and black/white video, color for bright light conditions, and black/white for low light/night viewing. This combination is currently deployed for this application and offers the most cost-effective solution for day and night traffic surveillance.

The recommended configuration should also use commercial-off-the-shelf components. Additionally, the dual camera configuration is also compatible with video surveillance equipment currently installed in Oakland County.

2.4 Control and Data Processors

Distributed processing techniques to reduce communications bandwidth require raw data to be processed at remote locations. These processors will not only process traditional traffic MOEs or parameters, but will also be used (depending upon site locations) to process data and control other system components such as:

- Video Surveillance Controls
- Changeable Message Signs (CMSs)
- Highway Advisory Radios (HARs)
- Environmental Sensors

In addition to the processing of raw data, remote controllers must be able to manage the communication protocol. To maximize data through-put and minimize the number of communication channels, a more robust Carrier-Sense-Multiple-Access/Collision Detection (CSMA/CD) communications scheme must be used. CSMA/CD does not operate in a traditional master-slave poll-response method. All node participants have equal access to the communication network and “talk” whenever required provided that the node participant follow the rules of the protocol. Therefore, higher than traditional local communication processing capability is required.

Requirements for the remote controller and data processing component of the ATMS/ATIS are established to describe the requirements which must be satisfied by the “node.” The node supports multiple functions and are:

- Calculate mainline MOEs
- Process ramp data and control ramp meters
- Provide control of CCTV, CMS, HAR (where required)
- Acquire and process environmental data
- Conduct Built-In-Test (BIT) (power up and background)
- Handle communication to and from host system (host-to-peer)
- Handle communication between controllers (peer-to-peer)

It is not a requirement that a single piece of hardware perform all the functions listed above. However, node components, which may contain multiple functions, must be able to process the required data.

Processing Requirements

In order to establish the required processing capacity for remote controller and data processing nodes, the functions listed above are tabulated and estimates of the number of lines of code (LOC) were generated. LOC estimates are based upon standard mathematical equations used to determine MOEs, control algorithms (CCTV, CMS, and HAR), standard BIT processing, and communication protocol processing. Table 2-14 lists the LOC estimates and conversion to processor instruction counts. Eight (8) processor instructions per LOC are used based upon non-optimized, commercially available “C” compilers. Execution optimization may be realized if optimizing compilers are used.

Node processing capacity of 0.33 million instructions per second (MIPS) is required to perform functions which are currently required (based on 10 ms polling resolution), Additional capacity will be required if other IVHS functionality is imposed on the system such as Weigh-In-Motion (WIM), Advanced Vehicle Control System (AVCS), moveable barriers (lane control), automated toll collection, Automated Vehicle Identification (AVI), etc.

Table 2-14. Node Processing Estimates

Function	Lines of Code (LOC)	Total LOCs	Total Instructions
Calculate MOEs - Mainline			
Speed	5		
Vehicle Length	5		
Cum. Speed	2		
Cum. Length	2	25	200
Cum. Presence Time	2		
Increment Count	1		
Time Stamps	3		
Create MOE Message	5		
Ramp Control			
Get Ramp Data	2		
Rate Calculation	10	25	200
Time Stamp	3		
Output Control	5		
Create Status Message	5		
CCTV Control			
PTZ Control	10		
Focus	4	23	184
Iris Control	4		
Create Status Message	5		
CMS Control			
Setup	3		
Message Parsing	3	14	112
Message Transmit	3		
Create Status Message	5		
HAR Control			
Setup	3		
Message Parsing	3	14	112
Message Transmit	3		
Create-Status Message			
Built-In-Test (BIT)			
CPU	50		
Memory	50		
I/O	50	215	1720
Communications	50		
software checksum	10		
Combine Status w/MOE	5		
Communications			
Interrupt Service Routine	7		
Retrieve Message	30	82	656
Validate Message	30		
Post Message	5		
Send Message	10		
Environment Sensing			
Acquire Data	5		
Calculate Results	5	20	160
Compare To Thresholds	5		
Create Message	5		
TOTAL		418	3,344
Worst Case Processing Requirements (If all instructions must be executed at 10 ms intervals)			0.33 MIPS

2.4.1 Identification Of Alternate Node Configurations

Various configurations can be used to support the required functions. It is only required that the collection of hardware within a node support required processing, input/output, and data handling tasks. Various architectures within a node can be used to perform such tasks. Table 2-15 summarizes the various computational and data handling characteristics.

2.4.2 Trade Matrix and Selection Criteria

The criteria used for this evaluation consists of parameters listed in Table 2-16 and their relative importance to the implementation of the specific control and data processing technology. The list represents criteria categories to achieve desired functional and performance goals.

Each control and data processor configuration are evaluated based upon the satisfaction of evaluation criteria. Raw scores are tabulated and an overall ranking is established using weight factors and evaluation guidelines in Tables 2-16 and 2-17.

Table 2-15. Alternate Node Configurations

Configuration	Description	Advantages	Disadvantages
170 Controller	<ul style="list-style-type: none"> • Traditional Traffic Controller • 768 KHz Clock Frequency • Approx. 0.10 MIPS • Integrated I/O • 6800 CPU 	<ul style="list-style-type: none"> • Standard traffic controller 	<ul style="list-style-type: none"> • Limited functionality • Serial port limitation • Cannot support additional IVHS functionality
179 Controller	<ul style="list-style-type: none"> • Traditional Traffic Controller • 1.5 MHz Clock Frequency • Approx. 0.25 MIPS • Integrated I/O • 6809 CPU 	<ul style="list-style-type: none"> • Standard traffic controller 	<ul style="list-style-type: none"> • Limited functionality • Serial port limitation • Cannot support additional IVHS functionality • Limited Availability
NEMA Controller	<ul style="list-style-type: none"> • Traditional Traffic Controller • Integrated I/O • Functionally Defined By NEMA Specs. 	<ul style="list-style-type: none"> • Standard traffic controller 	<ul style="list-style-type: none"> • Limited functionality • Serial port limitation • Cannot support additional IVHS functionality
Integrated Single Board System w/CPU, I/O, Comm, and Standard Backplane	<ul style="list-style-type: none"> • Standard Industrial Computer • Clock Frequencies Up to 50 MHz • 1 to 40 MIPS • Integrated Serial and Discrete I/O • 8, 16, 32 bit CPUs <ul style="list-style-type: none"> - 8086, 8088, 80 x 86 - 68 x X, 680 x 0 - 320 x 0 	<ul style="list-style-type: none"> • Daughter board can be installed <ul style="list-style-type: none"> - RAM (8 MBytes) - ROM - Up 4 serial ports • Many vendors • High level programming language supported <ul style="list-style-type: none"> - Many programming languages - Source level debuggers - Larger software support 	<ul style="list-style-type: none"> • Not a standard traffic controller
Modular System w/Standard Backplane	<ul style="list-style-type: none"> • Standard Industrial Computer • Clock Frequencies Up to 50 MHz • 1 to 40 MIPS • Integrated Serial and Discrete I/O • 8, 16, 32 bit CPUs <ul style="list-style-type: none"> - 8086, 8088, 80 x 86 - 68 x X, 680 x 0 - 320 x 0 	<ul style="list-style-type: none"> • Modular design • Additional components can be added when required <ul style="list-style-type: none"> - RAM (> 256 Mbytes) - ROM - Serial I/O - Discrete I/O - Image processing • Many vendors • High level programming language supported <ul style="list-style-type: none"> - Many programming languages - Source level debuggers - Larger software support 	<ul style="list-style-type: none"> • Not a standard traffic controller
Industrial Programmable Controllers	<ul style="list-style-type: none"> • Standard Process Control Platform • Clock Frequencies Up to 33 MHz • 1 to 10 MIPS 	<ul style="list-style-type: none"> • Potentially lower cost • Expandable I/O 	<ul style="list-style-type: none"> • Not a standard traffic controller • Typically requires ladder logic software

Table 2-16. Control and Data Processor Evaluation Criteria and Weight Factors

Criteria	Weight Value	Comments
Installation / O&M Cost	10	Effects on Cost / Funding Availability
Excess Processing Capacity	8	Support For Full Deployment Applications
I/O Capabilities	8	Support For Future IVHS Applications
Expansion Capabilities	8	Capability of Adding CPUs, Memory, I/O Resources
Software Development Environment	6	Ease of Software Maintenance
Upgradeability	6	Migration Path for Next Generation Applications
Multiple Vendors/Suppliers	6	Component Availability

Table 2-17. Control and Data Processor Evaluation Assessment Guidelines

Level of Compliance	Score
Exceeds Compliance	10
Fully Compliant	9
Good Compliance	8
Above Average Compliance	7
Average Compliance	6
Minimum Compliance	5
Marginal Compliance	4
Partial Compliance	3
Poor Compliance	2
Does Not Comply	1

2.4.3 Analysis

Raw scores presented in Table 2-18 are translated into composite scores (see Table 2-19) using the evaluation criteria weight factors. The relative ranking of each technology is then determined, with results provided in Table 2-19.

Table 2-18. Control and Data Processor Comparison Raw Scores

Method	Install. / O&M Costs	Proc. Capacity	I/O Capacity	Expansion Capability	S/W Dev. Environ.	Ability to Upgrade	Multiple Sources
170 Controller	10	3	3	3	3	4	4
179 Controller	9	3	3	3	3	4	3
NEMA Controller	7	3	3	3	3	4	4
Modular System	8	10	10	9	10	10	7
Integrated CPU, I/O, Comm.	6	10	7	7	10	7	7
Industrial Programmable Controller	9	7	8	7	6	8	5

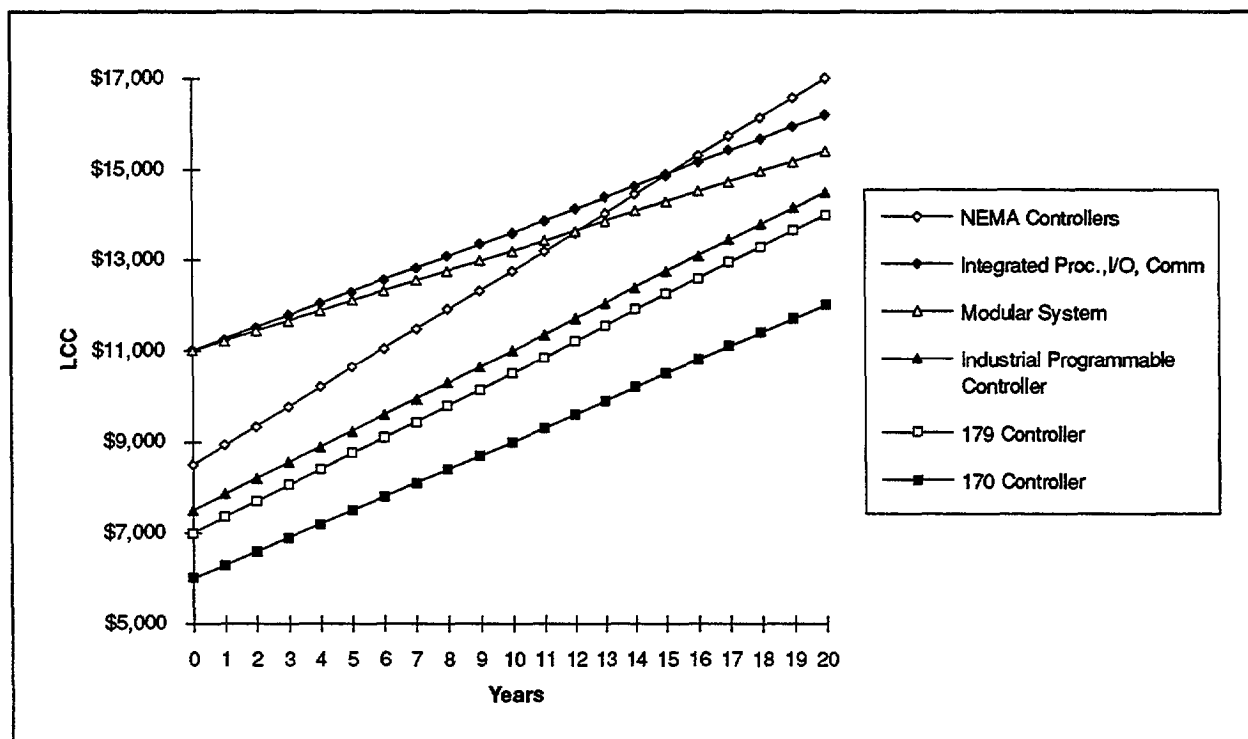


Figure 2-5. Control and Data Processor Life Cycle Cost Comparison

Life cycle cost analysis was performed for each control and data processor configuration. A single node configuration was used as a model in determining installation, operational and maintenance costs. The following lists the minimum configuration requirements used for the analysis:

- Minimum 3 MIPS processing capability
- 4 Mbytes of RAM
- 4 serial I/O ports
- 16 discrete parallel lines

Modular node configurations show higher initial costs as compared to traditional traffic controllers. However, further investigation identified deficiencies in traditional traffic controllers which do not satisfy expansion capabilities, CPU capacity, I/O and availability requirements.

**Table 2-19. Control and Data Processing
Composite Scores and Relative Ranking**

Processor Configuration	Composite Score	Relative Ranking
170 Controller	238	4
179 Controller	222	5
NEMA Controller	208	6
Modular System	474	1
Integrated CPU, I/O, Comm.	396	2
Industrial Programmable Controller	380	3

2.4.4 Control and Data Processor Recommendation

The use of modular components is recommended for early deployment implementations. The modular aspect enables controllers to be configured in a manner that will support incremental upgrades as the early deployment migrates into other configurations supporting additional IVHS functionality. With this particular control and data processor configuration, memory and computational capacities can be sized to accommodate the early deployment requirements and be upgraded by means of memory and I/O expansion as required. Additionally, with the modular architecture, the communication interface can be easily exchanged as the communications media is upgraded (i.e. wireless to fiber optic).

Several communications plug-in boards have resident processors and handle all necessary communications protocol processing. This feature reduces the processing requirements for the master processor. A standard backplane or bus structure is recommended (i.e. VME) in order to accept multi-vendor board products. The industry is leaning toward the VME bus configuration. The new 2070 controller specification, which is currently being developed by Caltrans, uses a 3U VME configuration. Since the specification is not complete, it is recommended that industry standard VME components be used. The 2070

architectural functionality will be maintained and can be demonstrated before the release of the 2070 specification.. The following modular configuration is recommended:

- 80x86 or 680x0 CPU board with general purpose serial and parallel I/O
- Serial I/O (38.4 Kbps x 2)
- Communications specific interface module (fiber optics, coax, radio modem, etc. if required)

It is also recommended that the CPU module be programmable in a higher level language such as FORTRAN or 'C'. Various software development environments and compilers are available for various CPU types. The use of higher level programming languages also makes the software easier to maintain and upgrade.

Node processors shall also have the capacity to accept a minimum of 2 additional multifunction boards to support future IVHS applications. This expansion capability will allow other features to be added without replacing the backplane.

2.5 Traveler Information Dissemination

Advanced Traveler Information Subsystems (ATIS), in conjunction with Advanced Traffic Management Subsystems (ATMS), will provide a variety of information services to assist travelers in arriving at their destinations whether the mode is via private vehicles, law enforcement, commercial dispatchers, public transportation, and intermodal travel systems.

Disseminated information includes congested and incident locations, alternate routing, roadway/freeway network status, weather and road conditions, roadway limitations and closures, and speed recommendations. Dissemination of traffic information will evolve over several phases, beginning with currently available communications media (i.e., AM/FM radio, variable message signing, printed material, etc.), then to more specialized telecommunications devices (i.e., personal communication devices, intelligent terminals and kiosks, roadway infrastructure devices, full featured call-up services, and other interactive information services), and finally to autonomous, in-vehicle navigation systems, pre-trip planning services from homes, offices, and roadside kiosks, and portable personal data assistants which interact with the infrastructure for real-time traffic and traveler information.

This evaluation examines the performance required to manage and disseminate traveler and traffic information from within the ATIS. Performance for information delivery to users will vary depending upon the telecommunications device and the service used, and is considered beyond the scope of this evaluation.

The scope of this evaluation encompasses traffic and roadway information management and transport between the system and the driver/traveler or third-party user. This function is anticipated to be performed by integrated subsystems which form an ATMS/ATIS.

Traffic and roadway information have the potential to be collected from a variety of sources. These include the ATMS, MDOT highway maintenance/construction crews, weather service bureaus, other TMCs, local and state government agencies (i.e., MSP, Detroit Police, Sheriff departments), courtesy patrols, public volunteer services, and local businesses. The following list represents a candidate list of the sources and users that may provide or receive traffic, weather, and roadway status information.

- Traffic surveillance and control subsystems
- Michigan Emergency Patrol
- Michigan Department of Transportation (MDOT) divisions / districts
- Michigan State Police (MSP)
- Metropolitan Detroit cities and counties public works (i.e., city/county road departments, Edison electric, Ameritech/Michigan Bell, water departments, etc.)
- Local weather bureaus/reports
- Roadway commuters and travelers (i.e., cellular call-ins)
- Commercial traffic reporting agencies

2.5.1 Technique/Technology Identification

Traffic and road condition information/status management and delivery methods and techniques are evaluated according to the stated evaluation criteria. The methods and techniques identified for this evaluation were selected from information systems architectures and dissemination methods currently used today, but not necessarily used for traffic reports. Technologies anticipated to be used in this capacity are available or currently under operational test, and are being specifically developed from new technologies which have shown promise for ATIS applications.

2.5.1.1 MTC Information Management.

Before any information can be effectively disseminated, it has to be collected, validated, and organized into a form that can be identified, processed (if necessary), and logged. Management of this information needs to occur in an efficient manner in order for effective operations and to provide timely, valid traffic information and status to outside users. In addition, the operators must be able to easily manage the information and system functions from an integrated work station which minimizes excessive operator actions. This information subsystem interfaces with the various subsystems (i.e., traffic surveillance and control subsystem [ATMS], Changeable Message Sign System (CMSS), etc.). Figure 2-6 illustrates a candidate information systems architecture which manages traffic information flow into and from the system.

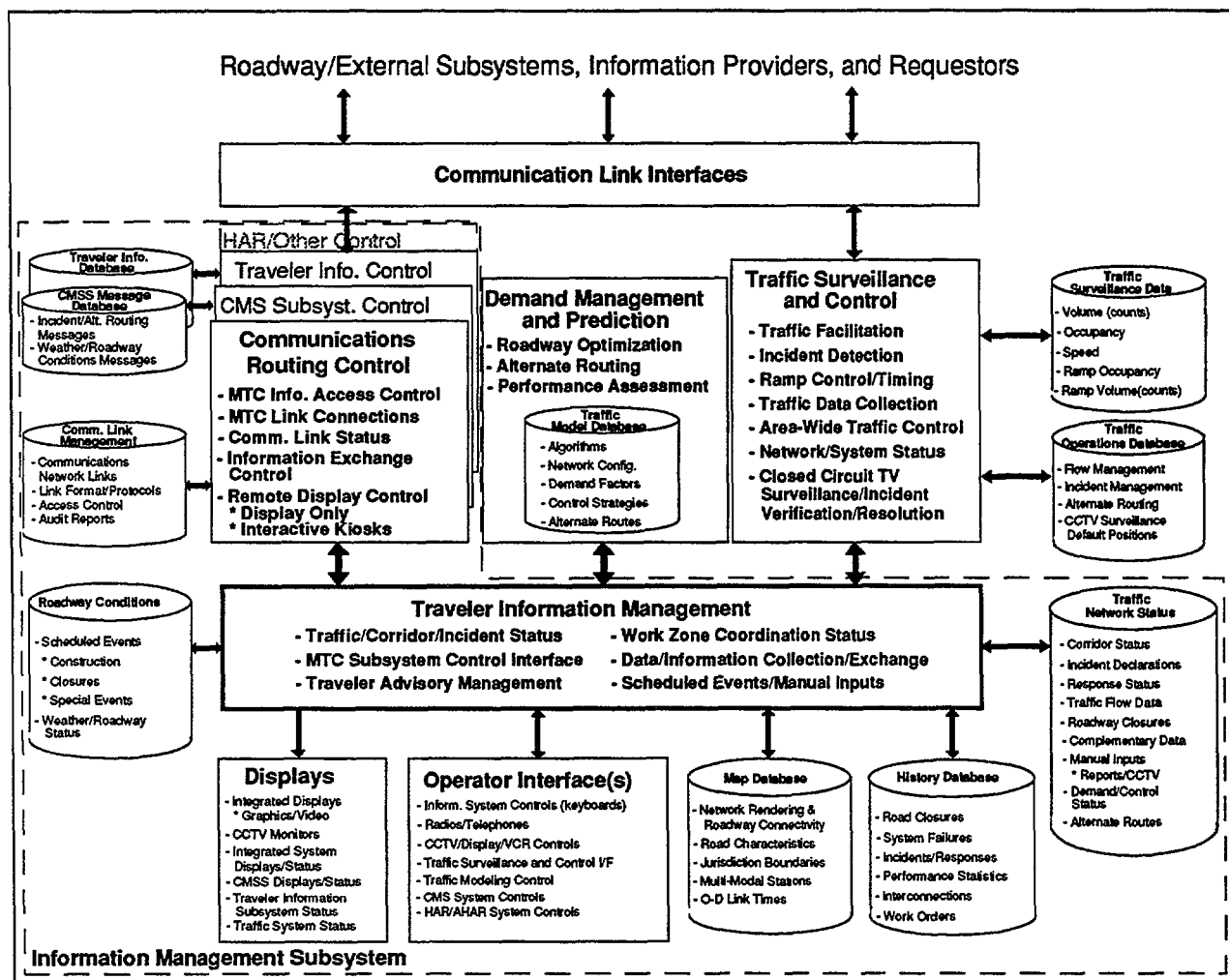


Figure 2-6. Candidate ATMS/ATIS Information Management Architecture

2.5.1.1.1 Information Subsystem Inputs

The traffic and roadway information collected by the system comes from many sources. The ATMS will provide traffic flow statistics, potential incident displays/alarms, system status (i.e., Failure Status, Controller Status, Traffic Page, and Incident Page), and CCTV video signals. The Detroit Freeway Operations Center (DFOC) operators monitor the ATMS displays/status, MSP dispatcher radio frequencies, Michigan Emergency Patrol (MEP) printouts, DFOU field unit radio calls, weather reports, and perform other DFOC duties (i.e., secretarial) to input and log incidents, system failures, repair work orders, weather and road conditions, and daily summaries. Local and state government agencies, public services, sporting and special event organizers, and businesses may provide schedules for events which could impact traffic flow. Information regarding these pre-planned events may be input (by DFOC operators) into the information management subsystem to provide traffic advisories through advanced equipment (i.e., CMS displays, HAR/AHAR announcements, etc.) and to further assist in implementing traffic control strategies (i.e., ramp control timing). Table 2-20 provides a summary of the inputs into the Information Management Subsystem.

Table 2-20. Information Management Subsystem Inputs

Input Information	Source	Input Method	Destination/Database
Traffic Conditions Traffic Flow Data Corridor Status - Demand/Control Status - TOC Data Exchanges	- Traffic surveillance subsystems (ATMS) - Michigan State Police (MSP) - Operator - Roadway commuters and travelers (i.e., cellular call-ins)	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions Database
Incident Declarations - CMS messages - Advisories - Alternate Routing	- Operator - MSP - MEP	- Manual	- Traffic Network Database - History Database
Incident Response Status	- Operator - MSP - MEP - Removal Service	- Manual	- Traffic Network Database - History Database
Maintenance Work Orders	- Operator	- Manual	- Traffic Network Database - History Database
Scheduled Events - Sports - Conventions - Public Works	- Operator - Data Exchange Link - Metropolitan Detroit cities and counties public works (i.e., city/county highway departments, Edison electric, Ameritech/Michigan Bell, water departments, etc.)	- Manual - Electronic	- Traffic Network Database - History Database - Roadway Conditions - Traffic Modeling Database - Traffic Operations Database
Weather Reports	- Operator - Local weather bureaus/ reports	- Manual	- Traffic Network Database - History Database - Roadway Conditions - Traffic Operations Database - CMSS Message Database - Traveler Info. Subsystem
Roadway Closures - Construction	- Operator - Data Exchange Link	- Manual - Electronic	- Traffic Network Database - History Database - Roadway Conditions - CMSS Message Database - Traveler Info. Subsystem
System Status - Performance Statistics - System Failures - Work Orders	- Operator - ATMS - MTC Subsystems	- Manual - Electronic	- History Database - Roadway Conditions
System Configuration - Comm. Network Links - Access Control	- Operator	- Manual	Comm. Link Management
Operator Control Commands - ATMS - Traffic Modeling - CMSS - Communications - Traveler Information - Information System Administration	- Operator	- Manual	- Traffic Operations Database - Traffic Modeling Database - CMSS Message Database - Comm. Link Management - Traveler Info. Subsystem - System Database

2.5.1.1.2 Management Processing

The Information Management Subsystem (IMS) will provide the “virtual” database for management of all system and subsystem data. The IMS will fuse data received from multiple sources, both internal and external to the system. Operator commands and controls will be routed through the IMS to electronically interface to other subsystems.

2.5.1.1.3 Operator Interfaces

The information management subsystem must provide timely information upon operator request. System responses and requested information should be provided to the operator without disrupting the continuity of the task (e.g., respond within 10 seconds of the request). The DFOC operator interface must provide an integrated station where all freeway operations can be managed. Traffic information management and control displays will be integrated to handle [1] overall system status, [2] freeway network surveillance and control, [3] subsystem displays and controls, [4] administrative management (i.e., operator inputs, incident reports, system status reports, work orders, communications link access control. etc.), and [5] software and system updates.

2.5.1.1.4 Information Outputs and Routing

The IMS will provide DFOC personnel with an integrated station from which to monitor and control all subsystems (i.e., ATMS and ATIS). Outputs from the IMS consist of electronic data and information exchanges with subsystems, and also administrative reports for the purpose of record keeping, traffic studies, data reduction, and maintenance work orders. Table 2-21 identifies information and corresponding output methods used for dissemination to freeway network users.

Table 2-21. Information Management Subsystem Outputs

Output Information	Output Method	Destination
Traffic Conditions - Traffic Flow Data - Corridor Status - Incidents/Response Status	ATIS - CMSS - HAR/AHAR syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Roadway Conditions - Weather - Closures	ATIS - CMSS - HAR/AHAR syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Traffic Modeling and Prediction	ATMS - Electronic - Printouts	- Traffic Operations Database - History Database
Work Orders	- Hard copy Printouts - Electronic Storage	- DFOC Personnel - History Database
System Reports - Traffic Data - Weather Reports - System Performance Reports - Incident/Response Reports	- Hard copy Printouts - Electronic Storage	- DFOC Personnel - System Archives
Operator Control Commands - ATMS - Traffic Modeling - CMSS - HAR/AHAR Subsystem - Communications - Traveler Information - System Administration	- Electronic Storage	- Traffic Operations Database - Traffic Modeling Database - CMSS - HAR/AHAR Subsystem - Communications Routing - Traveler Information Subsystem - Information Management Subsystems

2.5.2 Trade Matrix and Evaluation Criteria

The criteria used for this evaluation consists of the parameters listed in Table 2-22 and their relative importance to providing benefits to the driver/traveler or third-party user. This list represents both mandatory and optional criteria categories to achieve the desired goals defined by MDOT. These criteria will be used to evaluate technologies applied in different information delivery techniques. Table 2-23 show guidelines used in the assessment.

Table 2-22. Traveler Information Dissemination Evaluation Criteria

Evaluation Criteria	Weight Value	Need Category	Comments
Feasibility/Ease of Implementation	10	mandatory	Assessment of technical risk.
Implementation Cost	10	mandatory	Assessment of required budgetary funds.
Operations/Maintenance Cost	10	mandatory	Assessment of recurring costs.
Dissemination Effectivity	8	mandatory	Assessment of delivery effectiveness.
Expandability/Flexibility/Growth	8	mandatory	Assessment of openness options.
Environmental Durability	8	mandatory	Assessment of tolerance to the surrounding environment.
Ease of Use	7	optional	Assessment of practical use/application.
Potential Market Support/Cost Recovery	5	optional	Assessment of service viability to develop a market base.
Distribution of Benefits/Costs	5	optional	Assessment of fair distribution of benefits and costs of service

Table 2-23. Traveler Information Dissemination Evaluation Assessment Guidelines

Level of Compliance	Score
Exceeds Compliance	10
Fully Compliant	9
Good Compliance	8
Above Average Compliance	7
Average Compliance	6
Minimum Compliance	5
Marginal Compliance	4
Partial Compliance	3
Poor Compliance	2
Does Not Comply	1

2.5.3 Analysis

Evaluation of candidate methods and associated technologies was conducted through assessments using the evaluation criteria listed in Table 2-22. The assumption is made that a traffic information management system provides the platform to control the collection, management, and dissemination to the subsystem technologies. Dissemination methods were identified (see Table 2-24) based upon general traffic information type, candidate technologies, and associated advantages and disadvantages as related to generally-accepted information distribution techniques available today and in the near future (see Table 2-25) .A trade study of technologies, associated with each dissemination method and candidate technology, was conducted to evaluate the level to which each supported the criteria areas within the context of information delivered to the motorists or roadway users. The results of this evaluation are tabulated in Table 2-26.

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Table 2-24. Traveler Information Dissemination Methods

Dissemination Method	Information Type/Use	Candidate Technology	Advantages	Disadvantages
Radio Frequency Broadcast	<ul style="list-style-type: none"> • Traveler Advisories • Routing Information • Roadway Network Status 	<ul style="list-style-type: none"> • Highway Advisory Radio (HAR)/Automatic HAR • Public Radio (AM/FM) • FM Subcarrier Broadcast • CB Radio • Amateur Radio 	<ul style="list-style-type: none"> • Wide area dissemination • Relative low implementation cost • Little or no traveler costs • Available to all travelers 	<ul style="list-style-type: none"> • One way communications • Special access information (tuning) • No interaction/requests capability • Reliant on broadcaster
Roadway Signing	<ul style="list-style-type: none"> • Traveler Advisories • Diversion Advise 	<ul style="list-style-type: none"> • Changeable Message Signs • Fixed Signs • Portable Signs 	<ul style="list-style-type: none"> • Location specific • Effective diversion capability • No user costs • Available to all travelers 	<ul style="list-style-type: none"> • Limited information • Reliant on broadcaster
Passive Visual Aides	<ul style="list-style-type: none"> • Roadway Network Status • Education 	<ul style="list-style-type: none"> • Printed Service Ads • Public TV Broadcast • CATV 	<ul style="list-style-type: none"> • Comprehensive information • Graphics capable • Wide area dissemination • Little or no traveler cost • Available to ail travelers 	<ul style="list-style-type: none"> • Not timely • Questionable effectiveness • Reliant on broadcaster
Passive Information Services	<ul style="list-style-type: none"> • Traveler Advisories • Routing Information • Roadway Network Status 	<ul style="list-style-type: none"> • Kiosks • Public TV Broadcast • Remote Traffic Status Displays • Public Radio (AM/FM) • Pagers • Dial-up telephone • CATV 	<ul style="list-style-type: none"> • Wide area dissemination • Relative low implementation cost • Graphics capable • Little or no traveler cost • Available to all travelers 	<ul style="list-style-type: none"> • Reliant on broadcaster • No interaction/request capability
Interactive Information Services	<ul style="list-style-type: none"> • Traveler Advisories • Routing Information • Roadway Network Status 	<ul style="list-style-type: none"> • Call-in Traffic Message Service (Cellular/Wireline) • Personal Communications Devices/System (PCS) • Public/Office e Kiosks • In-Vehicle Guidance • Computer Bulletin Board Service • CB Radio • Digital Data Link to MTC • Mobile Data Terminal • Amateur Radio 	<ul style="list-style-type: none"> • In-vehicle capabilities • On-request/interactive • Specific Information • Convenient • Real-time information capable 	<ul style="list-style-type: none"> • User equipment costs required • Infrastructure m system required • Not affordable to all users
Electronic Links	<ul style="list-style-type: none"> • Traveler Advisories • Routing Information • Roadway Network Status 	<ul style="list-style-type: none"> • Digital Data Link to MTC • Fax 	<ul style="list-style-type: none"> • On-request/interactive • Specific Information • Convenient • Real-time information capable • Large public support base 	<ul style="list-style-type: none"> • User equipment costs required • Limited service request.

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Table 2-25. Traveler Information Dissemination Candidate Technology Descriptions

Index	Candidate Technology	Information Type/Use	Dissemination Link Type	Technology/ Equipment Required	Implementation Cost
A	Highway Advisory Radio (HAR)/Automatic HAR	Local advisories Diversion advise	RF	Special vehicle AHAR equipment Special RF transmitters	Infra – Moderate User – Low
B	Changeable Message Signs	Local advisories Diversion advise	Electronic RF or wireline	Specialize sign equipment Control Terminal	Infra – Moderate User – None
C	Public Radio (AM/FM) Broadcast	Local/wide area advisories Diversion advise	RF	AM/FM radio Radio Transmitter	Infra – Low User – Low
D	Public TV Broadcast	Local/wide area advisories Diversion advise Graphical displays	RF	NTSC TV TV transmitter	Infra – Low User – Low
E	Personal Communications Devices/System (PCS)	Local/wide area advisories Interactive data	RF	Personal Communications Unit Infrastructure transmitter	Infra – High User – Moderate
F	Call-in Traffic Message Service (Cellular/Wireline)	Local/wide area advisories Interactive data	Telephone	Cellular telephone Wireline telephone	Infra – Moderate User – Moderate
G	Public/Office Kiosks Local/area wide advisories	Interactive data Graphics capable	Wireline/ wireless	Display terminal Control terminal	Infra – Moderate User – None
H	In-Vehicle Guidance	Local/area wide advisories Interactive data Graphics capable	Wireless	In-vehicle computer and display unit Control terminal	Infra – High User – High
I	Remote Traffic Status Displays	Local/area wide advisories Interactive data Graphics capable	Wireline/wireless	Display terminal Control terminal	Infra – Low User – Low
J	Printed Service Ads	Local/area wide advisories Interactive data Graphics capable	Manual/mailings	Printed matter	Infra - Moderate User - None

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Table 2-25. Traveler Information Dissemination Candidate Technology Descriptions (continued)

Index	Candidate Technology	Information Type/Use	Dissemination Link Type	Technology/ Equipment Required	Implementation Cost
K	Computer Bulletin Board Service	Local/area wide advisories Interactive data Graphics capable	Wireline	PC	Infra - Low User - Low
L	CB Radio	Local/area wide advisories Interactive data Graphics capable	RF	CB radio unit	Infra - None User - Low
M	Digital Data Link to MTC	Local/area wide advisories Interactive data Graphics capable	Wireline/wireless	Interfacing computer system	Infra - Low User - Low
N	Mobile Data Terminal	Local/area wide advisories Interactive data Graphics capable	RF	Mobile Data Terminal Dispatcher station	Infra - Moderate User - Moderate
O	Display Only System (DOS)	Local/area wide advisories Interactive data Graphics capable	Wireline	NET DOS	Infra - Low User - Moderate
P	Pagers	Local/area wide advisories Interactive data Graphics capable	RF - satellite	Pager units Transmission station	Infra - High User - Low
Q	FM Subcarrier Broadcast/RDBS	Local/area wide advisories Interactive data Graphics capable	RF	Special radio unit	Infra - High User - Low
R	Fax service	Point-to-point information service Graphics capable Still-frame data	Telephone	Fax equipment	Infra - Low User - Low

Table 2-26. Traveler Information Dissemination Technology Assessment Raw Scores

Evaluation/Criteria	SCORES																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Feasibility/Ease of Implementation	8	9	8	7	6	7	8	6	8	9	8	9	7	8	9	7	7	9
Implementation Cost	8	8	9	9	5	8	7	4	7	8	8	8	8	6	8	7	7	9
Operations/Maintenance Cost	9	9	9	9	8	9	8	1	8	1	7	7	7	6	7	8	8	9
Dissemination Effectivity	8	8	9	6	9	5	8	9	8	6	5	5	8	7	9	6	8	7
Expandability/Flexibility/Growth	8	8	6	6	8	6	8	9	8	6	8	5	9	8	8	6	7	7
Environmental Durability	7	8	7	7	7	7	8	8	8	5	7	7	7	7	7	8	8	8
Ease of Use	8	8	8	8	8	8	8	8	8	9	8	8	8	7	8	8	8	6
Potential Market Support/Cost Recovery	7	7	6	6	4	4	7	4	6	6	6	6	6	5	8	5	5	5
Distribution of Benefits/Costs	8	9	8	7	7	6	8	8	8	6	7	7	8	6	8	6	7	8
Total Scores	565	588	557	523	493	490	553	494	548	499	531	517	558	500	588	491	520	559

2.5.4 Information Dissemination Recommendations

Recommendations for implementing dissemination technologies (and supporting systems) are consistent with criteria defined through discussions with MDOT. The premise that an information management system supports the dissemination technologies is assumed. This recommendation is divided into two steps: [1] initial deployment; and [2] follow-on strategies to expand the information dissemination capabilities of the system.

Due to the nature of coordination with other government agencies and effective public participation, traffic information dissemination to travelers and other users for initial deployment is recommended to be accomplished with CMS messages displayed on the roadway, data availability and electronic exchanges accomplished with the RCOC TOC, and composite traffic data (i.e., graphic traffic status, video, and fax information) provided to MSP, MEP, Metro Traffic Control, and other TOCs via direct data/electronic links. These data consist of CCTV images and passive graphical displays.

A printed material educational campaign via auto clubs or DMV should also be directed by MDOT to educate the general public about the new services being offered. To support commercial businesses, the current plans to provide UPS, Greyhound Bus, Smart Bus, Detroit Department of Transportation, and Commuter Transportation Service with NET-developed Display-Only Site (DOS) terminals should be carried out.

For future deployments, it is recommended to launch a marketing campaign to attract other potential users for the DOS terminal or similar method of dissemination. Because of the versatility of the DOS platform (PC-based), future ATIS applications could potentially use the same platform through software upgrades. Considerations for a DOS in the State Plaza Building, as a simple kiosk, should also be investigated. Information dissemination through the DIRECT program for the implementation of HAR/AHAR transmitters should be carried out; however, smooth integration of the AHAR operation into the DFOC should be studied. In addition, a marketing campaign should be launched to attract motorists to purchase HAR/AHAR vehicle radio units.

2.6 Communications

A major cost driver in implementing an advanced traffic control and traveler information system can be attributed to the communications infrastructure. Specific installation and O&M costs must be analyzed along with technology bandwidth and expansion capabilities.

Bandwidth capacities directly effect the supportability of data types. Use of distributed processing techniques reduce data rate requirements considerably. However, video distribution at operational resolutions and frame rates still require equivalent bandwidths of 6-9 MHz for each video distribution channel.

The following analyses evaluate potential use of various communications technologies for digital and video data. Characteristics for evaluated technologies are compiled and then separate analyses were conducted for digital and video data types.

2.6.1 Identification of Alternate Technologies

Various established communications technologies are evaluated to determine the most cost effective and expandable system. Alternative communications analyses are conducted for the following technologies:

- Voice Grade Channel
- Twisted Pair Wire
- Coaxial Cable
- Fiber Optics
- Power Line Carrier
- Packet Radio
- Trunked Radio
- Microwave
- High speed digital line
- Spread spectrum radio

Voice Grade Channel

Voice grade channels are currently being used at several traffic operations centers (TOC) including Oakland County's FAST-TRAC TOC to communicate between remote and central computers. At each end of the communications link reside a data modem. Modems are used to provide audio communications between two devices. The modem can generate either of two separate audible carrier tones. One end of the link is designated as the host (i.e. central computer when connected to remotes) and transmits one of the carrier tones and the other unit transmits on the other carrier tone. In this configuration, data can be transmitted simultaneously from both sides (full duplex). Usable bandwidth of a typical voice grade line is approximately 2700 Hz and data rates of 9600 bps and above can be achieved using various data compression and modulation techniques.

A separate connection is required for each point-to-point link. Typically, a voice grade line is connected from remote computers to the host after being routed through a regional telephone company (telco) facility. If numerous connections are returned to the host system, a line multiplexer can be used at the telco facility to reduce the number of input/output ports required at the host and to reduce operating costs. The data is multiplexed together and transmitted to the host input/output port sequentially. This approach requires special multiplexers and demultiplexers at both the telco and host facilities.

Twisted Pair Wire

Twisted pair wires can be used to provide serial connectivity in point-to-point or point-to-multipoint communications topologies. The pair of wires typically operate in a "balanced" mode such as RS-422 or RS-485. Both types of circuits provide digital communications with the pair of wires operating in opposing polarities. In other words, digital data is sensed by monitoring the voltage difference between the pair of wires. This method is highly immune to noise since the induced noise signal is seen on both wires simultaneously, however, the voltage difference between the two wires remains the same.

Differential twisted pair wires can operate at data rates up to 10 megabits per second, depending on the quality of the cable and cable length. As the length of cable increases, additional line capacitance somewhat degrades the signal properties such as rise and fall times. The maximum recommended distance between two points is 4000 feet at 19,200 bps without intermediate amplifiers or signal conditioners.

System operation using RS-422 drivers limits the communications architecture to point-to-point applications. Multiple devices cannot be connected onto one link unless special circuit isolators are used for each device. However, RS-485 drivers are tri-state (on, off, and high impedance) devices which allow multiple devices to share a single communications line. In this manner, each device is polled and the device with the matching unit address can respond. By using a round robin master-slave polling scheme, data from all of the devices on the communications line can be received. Multiplexing schemes similar to the one described in voice grade channels can also be used to reduce the number of wires returning to the host system.

Coaxial Cable

Coaxial cable systems, commonly known as “coax”, operate with a carrier frequency of 5-350 MHz. Data signals, either analog or digital, are modulated and transmitted along the length of the cable. Various carrier frequencies can be applied to one coax cable providing multiple channels on a single line. Typical channel bandwidths are 6 MHz and may be further subdivided for digital data transmission. Data rates of up to 7.5 MHz can be achieved based on channel subdivision. Frequency Division Multiplexing (FDM) techniques are used for channels and Time Division Multiplexing (TDM) is used for data on a channel. Various types of data can be accommodated by coax systems including digital data, voice, analog data, full motion video, and compressed video.

Several Community Access Television Channel (CATV) systems use coax as a video transmission and distribution medium. In some cases, excess CATV system capacity is available for lease from the CATV providers. The use of the excess bandwidth is beneficial since the communications infrastructure already exists; however, existing coax cable may not be easily accessible from each of the widely distributed remote computer/controller locations.

If CATV cable access is not available, the coax infrastructure can be installed by the user; however, costs of approximately \$26 per foot for trenching, conduit, and installation will be incurred, excluding the cost of the cable itself.

Fiber Optics

Fiber optics communications systems use a beam of light, which is generated by a laser diode or gas laser, transmitted through a glass fiber in a serial manner. The pulses of light with wave lengths between 850 and 1550 nanometers turn on or off depending upon the logic state of the transmitted data bits. Fiber optic cables are typically bundled with multiple fibers, providing several data channels. Data rates of up to 2.4 giga bits (2.4

billion bits) per second can be accommodated by using time division multiplexing. Multiple channels of digital data can be transmitted at high speeds providing extraordinary through-put capabilities. Data can be transmitted over several miles (25 to 30 miles) and the transmission range is rarely a limitation provided communications hubs or fiber optic repeaters are installed.

Optical fibers are immune to electrical disturbances and noise. Since this technology uses no metallic conductors or shields, noise and other electrical disturbances such as magnetic fields cannot be coupled onto the optical fiber. Additionally, optical fibers with diameters as small as human hair can be used providing a small cable bundle with the capability to handle hundreds of data channels.

Many CATV subscription providers and telecommunications companies are currently installing several miles of fiber optic backbone. Spare fibers are typically available for other uses under a leasing agreement; however, not all locations surrounding metropolitan Detroit currently have fiber optic capabilities. A dual ring communications topology usually provides redundancy and a backup data path.

Power Line Carrier

Power line carrier communications use existing AC or DC power cables as the communications medium. Advanced power line carrier equipment uses spread spectrum techniques to couple data onto power lines. The low signal levels do not effect the purity of the power line and can be operated at data rates up to 5 Mbps. Data can be transmitted at distances of up to 4000 feet provided that the entire transmission path is on the same side of a power transformer. Many metropolitan areas use multiple power transformers to reduce line losses throughout the area of coverage. Therefore, long distance communications between devices cannot be accommodated.

Packet Radio (Area Wide Radio)

Packet radio data transmission has been used over the past several years to transmit data from one point to another over a wireless medium. Various radio bands such as HF, VHF, UHF, and microwave have been used to transmit messages. Data bytes are packetized into a serial stream and transmitted using modulation techniques such as Frequency Shift Keying (FSK). Data error checking is accommodated by either firmware or by software. Data can be transmitted at rates of up to 256,000 bits per second depending on the operating frequency band and can accommodate voice, digital data, and compressed video. However, state and local government frequency bands for VHF and UHF limit the data rate to 9600 bps.

Packet transmissions may use a request-response protocol, or they may be initiated by a remote unit when there is new data to send which has exceeded a pre-defined block size. Each packet sent is acknowledged by the receiving node. Individual remote units are uniquely addressed, and can be configured to respond only when requested to do so from the master. This polled mode does induce extra link turn-around times since there are actually 4 transmissions required -- one request, an acknowledge of the request packet,

one response, and an acknowledge of the response. The radio transmitters also have a minimum key-up time (similar to push to talk--PTT on voice radios) of approximately 20 milliseconds before data can be sent. This reduces packet turn-around time by a small amount at 300 baud, but much larger amounts at higher data rates (a 128 byte packet with overhead takes about 3.5 seconds to send at 300 bps but only 0.46 seconds at 2400 baud). UHF frequencies can generally be obtained for use by local governments with a range of 20 to 30 miles using low power (less than 2.5 watts) units and simple antennas with a central antenna placed about 100 feet above average terrain and direct line-of-sight access.

Trunked Radio

Trunked radio service (also known as Special Mobile Radio (SMR)) operates similar to packet radio in transmitting data. However, the turn around time is significantly longer due to the method of operation of trunked radio services. Trunked radio systems multiplex 5 to 20 frequencies in a round robin fashion. One channel is allocated as a control channel and as a unit is keyed up, the control channel digitally synchronizes group identifications, and selects an available frequency for the group to use. This method allows multiple users to be assigned to an identical frequency group without disturbing operations of other users. However, the channel select sequence can take up to 0.75 seconds to synchronize.

Microwave

Microwave communications systems operate at high frequencies (928 MHz to 40 GHz) and are normally used for high speed and live video applications. Multiple channels can be supported at a microwave site of which each channel is operating at data rates of up to 7.5 Mbps depending on channel allocation. Typical uses for a microwave system include multiplexing analog voice circuits and live video. Data transmission range varies and day extend to over 30 miles depending on the frequency and environmental variables.

Microwave systems are typically used in long haul video surveillance and data transmission. The cost of one point-to-point link can be as much as \$75,000. Due to the high cost of a single link, the use of microwave communication for remote-central applications is not recommended unless some method of regional multiplexing is provided to reduce the number of dedicated links back to the central facility. However, if video surveillance is required at strategic locations, the excess bandwidth of a channel can be used to transmit data from regional to central facilities.

High Speed Digital Line

High speed digital communications lines are available from most local communications providers and are available at various data rates. Data is transmitted over these dedicated lines using Pulse Code Modulation (PCM) techniques. There are many advantages to using PCM systems.

- a. Signals may be regularly reshaped or regenerated during transmission since information is no longer carried by continuously varying pulse amplitudes but by discrete symbols.

- b. All-digital circuitry may be used throughout the system.
- c. Signals may be digitally processed as desired.
- d. Noise and interference may be minimized by appropriate coding of the signals.

High speed digital lines can be used to accommodate multiplexed streams of serial data. Several 64 Kbps lines can be multiplexed at a central location to allow one high speed digital link between two locations. Up to twenty-four 64 Kbps lines can be time division multiplexed, sampled, and coded onto one 1.544 Mbps (also known as T1) PCM for carrier transmission, or for further multiplexing for longer distance communications. Multiplexing schemes used to support high speed communications can accommodate input lines of varying bit rates. 64 Kbps lines can be multiplexed to one 1.544 Mbps line, and then four 1.544 Mbps lines can be multiplexed to one 6.312 Mbps (T2) line. The multiplexing of these signals allows a given transmission channel to be shared by a number of users, thus reducing costs.

By using multiplexing techniques, the number of communications lines back to each central computer can be reduced. The reduction in the number of lines can provide significant cost savings to system operations. In order to gain maximum benefit of this technique, other IVHS components should share the communications link whenever possible.

Spread Spectrum Radio

Available spread spectrum radios which operate in the 902 MHz and 2.4 GHz range in an FCC unlicensed mode contain the logic needed to handle network protocol including relay among nodes (where required). These units are designed to work in “cells” where there is a “headend” radio connected to the central facility, one for each cell. Adjacent cells use different frequency channels and each remote controller requires a radio.

Frames are used for transmit / receive / network join functions, with a typical frame time of 1 second. During the top of frame time, the central site sends all polls, etc. to its headend radio for all controllers in the cell. The headend then initiates outbound transmission of all bundled traffic in a single packet. Each radio receives the transmission and removes the message for its controller (passing it to the controller over an RS-422 or RS-232 serial link of selected data rate). If the radio is also providing relay service for other nodes (who cannot receive the headend directly), it builds a new packet containing the messages for its “customers” and sends it. This process repeats until all radios have received outbound messages. When a response comes from a local controller, it is placed into a new packet by the radio and combined with responses from other “customers” of the radio before being sent in a burst back to the headend. The process repeats until the headend has collected all inbound messages, which are then forwarded to the central facility.

This system is similar in concept to packet radio. No additional infrastructure is required (beyond supplying power for the units). Approximately 30 nodes could be accommodated

on a single frequency. Disadvantages include the cost of the units and the uncertainty of future use of the 902 MHz band (which could interfere with radio operation).

Cellular Telephone

Cellular telephones have been widely used for personal and business communications. Use of communicating digital information over the cellular infrastructure have increased significantly over the past two years. Cellular telephone communications is accomplished using techniques similar to trunked radio service. Several channels are available for use in the 850 MHz frequency range and are allocated to a user in a round robin fashion. However, connections using cellular telephone systems can only be accomplished by dial-up techniques. Each time a connection between two devices is required, the requesting system must dial-up the remote units assigned telephone number. This interaction can take up to 15 seconds. Additionally, modems must be used in establishing a digital communication link and takes an additional 7-10 seconds.

Digital information can reliably be exchanged at rates of 9600 bits per second, and some special modems can provide 14,400 bits per second transfer rates using data compression. Charges for cellular phone use range from a standard rate of approximately 20 cents a minute (minimum of one minute). The use of cellular telephones to exchange mainline detector data is not cost effective. However, cellular telephones can be used effectively for highway advisory radio message generation and changeable message sign control.

Communications Technology Summary

Table 2-27 summarize characteristics and system capabilities of the discussed communication technologies.

Table 2-27. Summary of Communications Characteristics

Technology	Expansion Capability	Max. Data Rate per Channel	Information Types Supported	Transmission Range	Comments
Voice Grade Channel	Additional channels can be easily added	9600 bps	Data, voice, Slow, Scan TV (SSTV)	Several miles (10-100 miles)	High recurring lease costs
Twisted Pair Wire	Additional construction required	9600 bps	Data, voice, SSTV	9-15 miles w/repeaters	Construction is key cost driver
Coaxial Cable	Bandwidth available, Additional construction required	7.5 Mbps	Data, voice, live video	Several miles (10-12 miles)	Construction is key cost driver
Fiber Optics	Bandwidth available, Additional construction required	2.4 Gbps	Data, voice, live video	Rarely a limitation with repeaters (20-30 miles without repeaters)	Construction is key cost driver
Power Line Carrier	Expansion limited to single side of power transformer	100 Kbps	Data, voice, SSTV, compressed video	4,000 feet	Limited to single side of power transformer or 4000 ft w/bridge
Packet Radio	H/W expansion easily accommodated frequencies can be added for data volume	9600 bps	Data, SSTV, voice	Several miles with repeaters (30 miles without repeaters)	FCC license required for each channel used
Trunked Radio	H/W expansion easily accommodated frequencies can be added for data volume	9600 bps	Data, SSTV, voice	Several miles (25-50 miles)	Protocol used does not lend to fast response
Microwave	Extensive construction needed for additional sites	7.5 Mbps	Data, voice, live video	Several miles, range varies (up to 30 miles)	Line of sight availability, weather, multipath sensitivity
High Speed Digital	Additional channels can be easily added	DSO 64 Kbps	Data, voice, compressed video	Several miles (10-50 miles)	High recurring costs
Spread Spectrum Radio	H/W expansion easily accommodated	256+ Kbps	Data, voice, SSTV, compressed video, live video	Several miles (up to 50 miles)	No FCC license costs
Cellular Phone	Infrastructure exists for expansion	9600 bps	Data, voice	Several miles Point-to-point	No FCC license required High recurring costs

2.6.2 Trade Matrix and Selection Criteria

The criteria used for this evaluation consists of the parameters listed in Table 2-28 and their relative importance to the implementation of the specific communication method. The list represents criteria categories necessary to support the required digital and video

data types. Each communication method is evaluated based upon the satisfaction of the evaluation criteria. Raw scores are tabulated and an overall ranking is established using weight factors and evaluation guidelines in Table 2-28 and 2-29.

Table 2-28. Communications Evaluation Criteria and Weight Factors

Evaluation Criteria	Weight Value	Comments
Implementation and O&M Cost	10	Assessment of Installation and operating costs
System Expandability	7	Infrastructure Capability for System Growth
Maximum Data Rate	7	Capability to Accommodate Required Data
Effective Range	7	Assessment of Area Coverage

Table 2-29. Communications Evaluation Assessment Guidelines

Level of Compliance	Score
Exceeds Compliance	10
Fully Compliant	9
Good Compliance	8
Above Average Compliance	7
Average Compliance	6
Minimum Compliance	5
Marginal Compliance	4
Partial Compliance	3
Poor Compliance	2
Does Not Comply	1

2.6.3 Analysis

Separate analyses were conducted for each ATMS/ATIS system component in order to identify minimum acceptable communications techniques and to provide acceptable performance in a cost effective manner. Additionally, analyses were based upon the capability to implement the specific communications technology in a timely manner to support the initial deployment implementation phase. Table 2-30, 2-31 and Figure 2-7 reflect analyses of digital data. Table 2-32, 2-33 and Figure 2-8 reflect analyses of video data. The life cycle cost analyses were based upon a 6.5 mile freeway segment with communications nodes to highway advisory radio, changeable message signs, detector stations, and ramp controllers.

Table 2-30. Digital Communications Technology Comparison Raw Scores

Technology	Impl./O&M Cost	Expandability	Data Rate	Range
Voice Grade Channel	4	9	6	9
Twisted Pair	3	4	8	6
Coaxial Cable	3	4	10	9
Fiber Optics	3	10	10	9
Packet Radio (Area Wide)	10	9	6	9
Trunked SMR	8	8	6	8
Microwave	4	4	10	9
HS Digital DS0	4	10	8	9
Spread Spectrum Radio	8	9	9	8
Cellular Phone	0	10	6	10

Table 2-31. Digital Communications Technology Composite Scores and Relative Ranking

Technology	Composite Score	Relative Ranking
Voice Grade Channel	208	6
Twisted Pair	156	10
Coaxial Cable	191	8
Fiber Optics	233	4
Packet Radio (Area Wide)	268	1
Trunked SMR	234	3
Microwave	201	7
HS Digital DSO	229	5
Spread Spectrum Radio	262	2
Cellular Phone	182	9

Table 2-32. Video Communications Technology Comparison Raw Scores

Technology	Impl./O&M Cost	Expandability	Data Rate	Range
Coaxial Cable	3	4	10	9
Fiber Optics	3	10	10	9
Microwave Only	4	5	10	9
HS Digital DS1 - Codec	0	7	6	9
Wideband wireless/ Microwave link	10	5	10	9

Table 2-33. Video Communications Technology Composite Scores and Relative Ranking

Technology	Composite Score	Relative Ranking
Coaxial Cable	191	4
Fiber Optics	233	2
Microwave Only	208	3
HS Digital DS1 – Codec	154	5
Wideband wireless/ Microwave link	268	1

MDOT Early Deployment of ATMS/ATIS

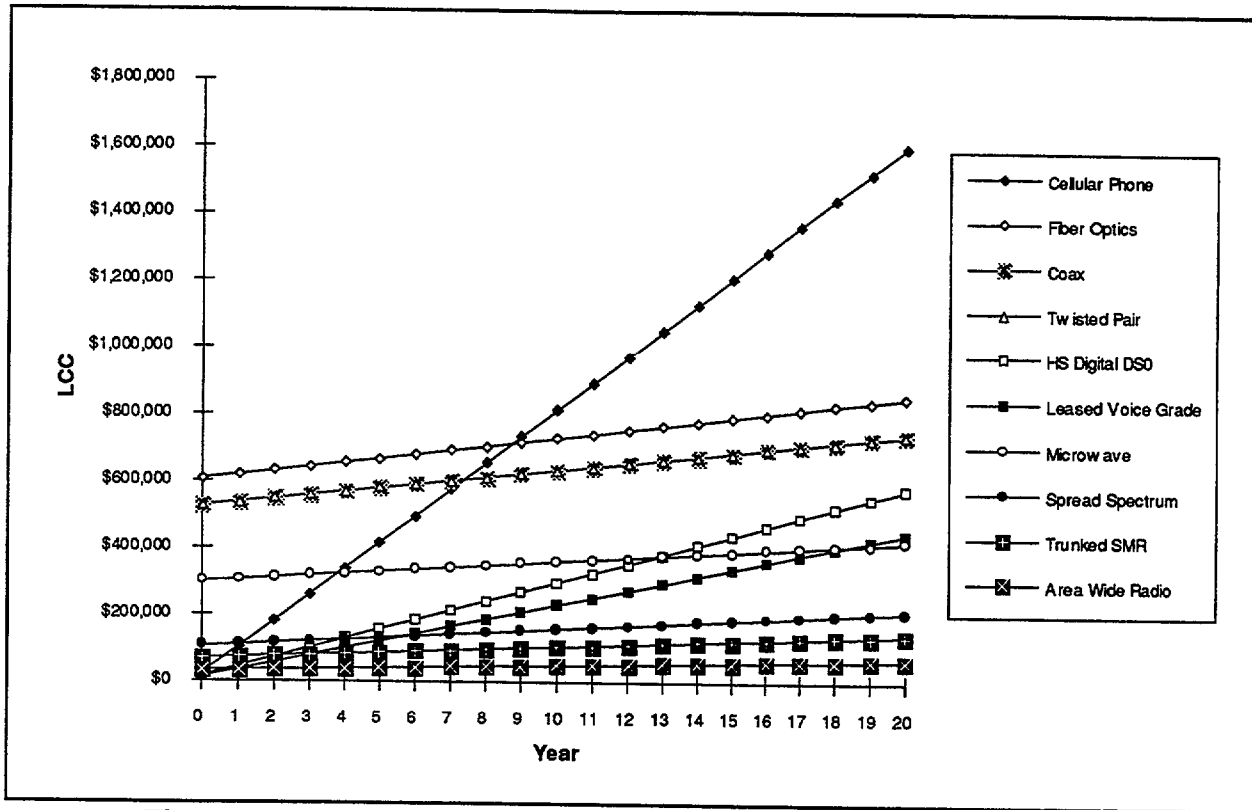


Figure 2-7. Digital Data Communications Life Cycle Cost Comparison

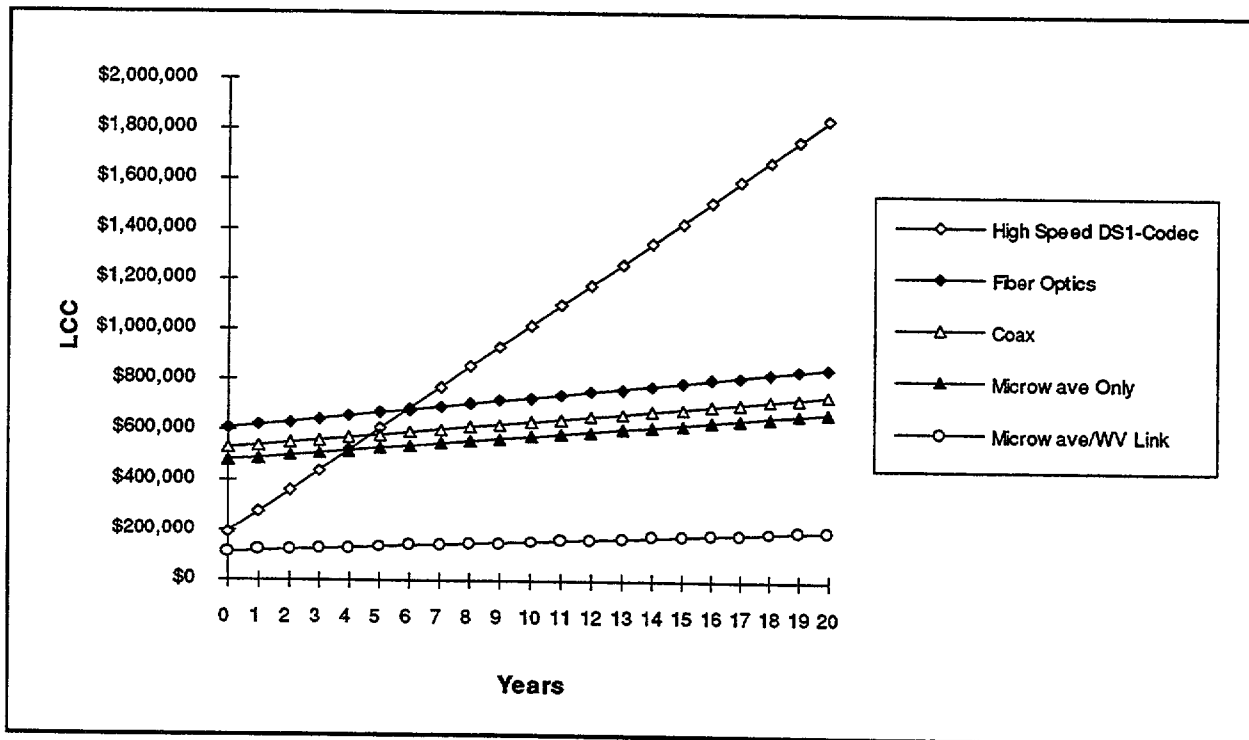


Figure 2-8. Video Communications Life Cycle Cost Comparison

2.6.4 Results and Recommendations

Results from a similar communication study performed for the Road Commission for Oakland County (RCOC) indicate that owned cable (twisted pair, fiber or coax) was not a cost effective near term solution even though the media support required bandwidths for all system components, including live video for fiber and coax. However, fiber optic communications has been identified as the ultimate solution which has enormous expansion and bandwidth capacities. The recommendations provide a migration path to other communications means as the system expands and other IVHS functions are applied. With the modular and open architecture defined, each system component is not dependent upon a single communication solution. The following recommendations are based upon the immediate need to implement the early deployment system.

Power line carrier communications is not recommended due to its range limitations and the uncertainty of power distribution topologies in various areas. Leased media do have attractive characteristics. However, to support live video transmission, high leasing costs will be incurred.

Detector Stations /Ramp Controllers

It is recommended that communications to and from detector station / ramp controllers be accomplished by packet radio. The required bandwidth in communicating the digital data does not warrant higher capacity mediums. However, if an existing backbone (i.e. fiber optic or coax) is available for use, it is recommended that communications be done over the backbone. The cost of installing a backbone for the initial deployment prohibits its use in the near term. Currently, several community access TV (CATV) suppliers are identifying the need to install a backbone in metropolitan Detroit. Freeway right of ways are the most appropriate for their application. It is possible that MDOT could grant right of way access to CATV or fiber providers in exchange for communications bandwidth use. The timeliness of implementing such an agreement will dictate the final initial deployment solution. If the agreement cannot be achieved during the initial deployment phase, packet radios should be used on an interim basis. As the backbone is installed in the corridor, communications for the detector stations / ramp controllers can be converted over to the new medium. The packet radio equipment then can be used for the next corridor on a “leap frog” basis until total coverage is achieved by the backbone.

When a backbone type communication system is implemented, across-the-roadway communications can still be accommodated by wireless packet radio. This implementation method eliminates the need to trench under the freeway (jacking) or to route conduit on an overpass.

CMS/HAR

The current architecture, as described in Section 4 of this document, supports multiple means of controlling CMSs and HARs. If detector / ramp control nodes are used to control CMSs and HARs, the main communication medium will be the one identified for the detector / ramp control nodes. Communications between these controllers and the

CMS can be accomplished by wireless modems or dedicated cables depending upon the distance between the devices.

If the placement of the CMS or HAR device is not near a controller, it is recommended that the communications link be accomplished the same way as the detector/ramp control node (packet radio or backbone). Since the architecture identifies CMS/HAR nodes as independent functions with identical interfaces, the communications and control methods are the same for all system components. However, if CMS/HAR devices are remotely located, away from any infrastructure components (such as Detroit Metro Airport or Pontiac Silverdome) cellular phone modems could be used since CMSs and HARs do not require continuous communications to the traffic operations center.

Video

Similar to the other nodes, it is recommended that a wireless approach be used for video control and video return. Since the required bandwidth for the video returns far exceeds packet radio, other means of wireless communications are required. New techniques with wide band communications allow short distance live video transmission. Several live video channels (3 to 5) can be concentrated to one central point and then relayed back to the control center on a single microwave link or leased digital line.

As a more permanent and cost effective communications medium becomes available (i.e. CATV fiber optics access), the control and video return transmission can be migrated onto the new system. The existing RF equipment is then salvaged and used to expand the system further.

3.0 Priority Corridor Analysis

The identification of priority corridors aids in determining which freeway segment in metropolitan Detroit require initial deployment of advanced traffic control components. The analysis evaluated various demand and capacity characteristics for each corridor segment and relative deployment rankings were developed.

The highest priority corridor can also be used to acquire measurable effects of traffic conditions once the advanced system is deployed. Although not a primary requirement, segments adjacent to existing monitored freeway segments were considered to allow a “before and after” analysis to be performed. The results from this analysis will provide the means to measure the effectiveness of the advanced traffic control and information dissemination system. The results can be used to enhance control schemes in order to acquire maximum benefits for the remaining freeway segments.

3.1 Corridor Identification

Corridors which were listed in various strategic planning and MDOT documents were initially used in identifying corridor segments. Results from initial analysis indicated that there was a potential that the original thirteen (13) segments did not provide complete coverage of the entire 250-mile freeway system in metropolitan Detroit. Also, the corridor along I-75 from I-94 to Pontiac was too long in relation to other corridors being evaluated.

As a result from the initial assessment, the analysis was expanded to include nineteen (19) corridor segments from the initial quantity of thirteen. The I-75 corridor was split in two at 9 Mile Road (due to average daily traffic (ADT) densities) and five additional corridor segments were added to the evaluation process. The additional five corridor segments include the currently instrumented freeway system. The most significant segments added were the Lodge Freeway (M-10), Greenfield to Jefferson, and the Ford Freeway (I-94) between Wyoming and Moross.

3.2 Corridor Analysis

Analyses focused on three criteria: current daily traffic volume, forecasted calendar year 2015 daily traffic volume, and reported 1992 incidents. Additionally, “incidents per lane mile” for each of the corridors were used during the assessment. Projected calendar year 2015 incident counts were not used since high fidelity incident counts can not be estimated. The length of each corridor was tabulated and compared with the number of lane miles in each corridor. The number of lanes in a freeway segment can vary and in such cases, the total number of lanes in the freeway cross section was averaged for each corridor segment.

Each of the above mentioned factors were weighted equally. The traffic volume variables were important because they reflect travel demand in the region. Freeways facilitating 100,000 vehicles per day are given priority for deployment of advanced traffic control

technologies and incident management programs over a corridor with a demand for 50,000 vehicles per day.

Improvements to facilities with a higher travel demand have a greater potential for reducing overall congestion in a region. Consideration of the location of reported incidents in 1992 aided in identifying areas where improved detection and verification would lead to a quicker removal of incidents and a corresponding reduction in travel delay caused by incidents.

The travel demand information was prepared with the assistance and coordination of the Southeast Michigan Council of Governments (SEMCOG), which is the metropolitan planning organization for the Detroit region. SEMCOG maintains a travel demand model which considers such variables as population, employment, congestion patterns, and local agency priorities and concerns. SEMCOG is also responsible for maintaining records of existing travel demand.

SEMCOG is developing a Long Range Transportation Plan for Metropolitan Detroit. This work has led to projections of corridor congestion - a factor useful in recommending a corridor for early development of advanced traffic management systems. Projections of corridor congestion incorporate forecasts of area demographics and traffic patterns based on changes in population and employment. This analysis was conducted using SEMCOG's plan and projections as a baseline.

SEMCOG has identified capacity deficient facilities and grouped them based on current and anticipated congestion. Tier A congestion facilities have volume to capacity (V/C) ratios greater than 1.25 in 1990 and 2015. Tier B contains facilities showing significant congestion in 1990 but slight improvement in 2015, due to potential improvements on these facilities or others in the same corridor. Tier C contains the remaining facilities not included in Tier A or B but showing congestion levels exceeding 0.8 in 1990 and/or 2015. Road segments which fall into each of these categories are listed in Appendix I.

In each of the corridors, travel demand was tabulated as average, minimum, and maximum for each of the freeway segments. The evaluation used the average volume for each of the segments. Once this information was tabulated, the next step was to rank each of the segments according to each of the three criteria. Segment rankings were then added and scored to develop an overall segment priority rank based on each of the three criteria, giving equal weight to each of the three criteria.

Records of 1992 incidents were obtained from MDOT's Metropolitan Transportation Center. These data were initially tabulated by the Michigan Emergency Patrol. This database was used to allocate reported incidents to the appropriate corridor segments for evaluation. Table 3-1 shows the number of reported incidents in each corridor and the nearest cross street locations within each corridor which have 35 or more reported incidents. An overall total is listed first, and then locations which incurred 35 or more reported incidents. Table 3-2 show tabulated incident data and segment demand.

**Table 3-1. Incident Tabulation By Corridor Segment
(Listing of 35 or More Incidents)**

Corridor Segment Incident Location	Incident Counts (>35)	Corridor Segment Incident Location	Incident Counts (>35)
I-75 (I-94 to 9 Mile)	Total: 779	I-275 (I-75 to I-96/M-14)	Total: 140
7 Mile	58	None	
8 Mile	89	I-96 (I-75 to I-275/M-14)	Total: 649
9 Mile	79	Davison	35
Clay	57	Greenfield	36
Davison	122	I-94	39
I-94	149	M-39	88
McNichols	36	Telegraph	47
I-696 (US-24 to I-75)	Total: 329	I-94 (Moross to M-19)	Total: 184
Greenfield	37	None	
I-75	89	I-75 (I-94 to I-375)	Total: 148
Woodward	55	Mack	63
M-10 (Greenfield to I-696)	Total: 182	I-375	Total: 56
8 Mile	44	None	
Telegraph	48	I-75 (9 Mile to Pontiac)	Total: 350
I-94 (Wyoming to I-275)	Total: 284	11 Mile	45
M-39	36	12 Mile	55
Michigan Ave	43	14 Mile	56
I-696 (I-96 to US-24)	Total: 191	Rochester	45
Orchard Lake	50	M-10 (Greenfield to Jefferson)	Total: 695
Telegraph	44	7 Mile	53
Davison	Total: 157	Davison	62
Hamilton	34	I-94	71
I-75	32	Livernois	38
M-39 (I-75 to M10)	Total: 751	Wyoming	49
6 Mile	57	I-275 (M-14 to M-102)	Total: 144
7 Mile	73	6 Mile	36
8 Mile	83	I-94 (Wyoming to Moross)	Total: 1496
Grand River	35	Chene	60
I-96	85	Conner	72
Joy	54	Gratoit	59
I-696 (I-75 to I-94)	Total: 224	I-75	160
Mound	36	I-96	90
I-75 (I-96 to I-275)	Total: 451	Linwood	36
I-96	37	Livernois	68
M-59 (BR-24 to M-53)	Total: 19	M-10	115
None		Mt. Elliot	77
		Trumbull	39
		Van Dyke	69
		W. Gran Blvd	41

Table 3-3 lists raw rankings of each evaluation category. Rankings were established based upon travel demand and total number of incidents (raw and normalized). Lower rank values depict higher priority, where a ranking of “1” has the highest priority. Composite scores were derived by totaling category rankings for each segment. Lower values are assigned higher priority rankings. Table 3-4 summarizes freeway segment priority rankings.

Table 3-2. Priority Corridor Statistics

Corridor	1990 Daily Traffic	2015 Daily Traffic	1992 Incidents	1992 Incidents per lane mi.
I-75 (I-94 to 9 Mile)	144,985	152,214	779	14.5
I-696 (US-24 to I-75)	145,362	165,375	329	4.9
M-10 (Greenfield to I-696)	125,516	117,415	182	4.9
I-94 (Wyoming to I-275)	91,555	107,279	284	3.1
I-696 (I-96 to US-24)	139,956	192,436	191	3.0
Davison (M-10 to I-75)	77,044	85,220	157	15.0
M-39 (I-75 to M10)	106,101	111,896	751	7.3
I-696 (I-75 to I-94)	156,765	165,144	224	2.7
I-75 (I-96 to I-275)	90,624	113,846	451	2.6
M-59 (BR-24 to M-53)	48,972	67,833	19	0.3
I-275 (I-75 to I-96/M-14)	58,478	79,921	140	0.8
I-96 (I-75 to I-275/M-14)	126,784	137,588	649	3.3
I-94 (Moross to M-19)	99,385	124,584	184	1.4
I-75 (I-94 to I-375)	147,616	151,991	148	11.1
I-375	67,522	82,731	56	10.7
I-75 (9 Mile to Pontiac)	119,997	143,581	350	3.2
M-10 (Greenfield to Jefferson)	94,424	95,288	695	9.2
I-275 (M-14 to M-102)	124,565	176,602	144	3.0
I-94 (Wyoming to Moross)	142,349	135,019	1496	17.4

Table 3-3. Corridor Prioritization Raw Ranking Scores

Corridor	1990 Daily Traffic	2015 Daily Traffic	1992 Incidents	1992 Incidents per lane mi.
I-75 (I-94 to 9 Mile)	4	5	2	3
I-696 (US-24 to I-75)	3	3	8	9
M-10 (Greenfield to I-696)	8	11	14	8
I-94 (Wyoming to I-275)	14	14	9	12
I-696 (I-96 to US-24)	6	1	11	14
Davison (M-10 to I-75)	16	16	15	2
M-39 (I-75 to M10)	11	13	3	7
I-696 (I-75 to I-94)	1	4	10	15
I-75 (I-96 to I-275)	15	12	6	16
M-59 (BR-24 to M-53)	19	19	19	19
I-275 (I-75 to I-96/M-14)	18	18	17	18
I-96 (I-75 to I-275/M-14)	7	8	5	10
I-94 (Moross to M-19)	12	10	12	17
I-75 (I-94 to I-375)	2	6	13	4
I-375	17	17	18	5
I-75 (9 Mile to Pontiac)	10	7	7	11
M-10 (Greenfield to Jefferson)	13	15	4	6
I-275 (M-14 to M-102)	9	2	16	13
I-94 (Wyoming to Moross)	5	9	1	1

Table 3-4. Corridor Priority Composite Scores and Relative Ranking

Corridor	Composite Scores	Overall Ranking
I-75 (I-94 to 9 Mile)	12	1
I-696 (US-24 to I-75)	15	2
M-10 (Greenfield to I-696)	27	7
I-94 (Wyoming to I-275)	40	12
I-696 (I-96 to US-24)	21	4
Davison (M-10 to I-75)	34	10
M-39 (I-75 to M10)	31	9
I-696 (I-75 to I-94)	20	3
I-75 (I-96 to I-275)	43	13
M-59 (BR-24 to M-53)	57	15
I-275 (I-75 to I-96/M-14)	54	14
I-96 (I-75 to I-275/M-14)	25	6
I-94 (Moross to M-19)	39	11
I-75 (I-94 to I-375)	12	1
I-375	39	11
I-75 (9 Mile to Pontiac)	28	8
M-10 (Greenfield to Jefferson)	34	10
I-275 (M-14 to M-102)	24	5
I-94 (Wyoming to Moross)	15	2

3.3 Priority Corridor Recommendation

Based on the results from the analysis, the I-75 corridor from I-94 to 9 Mile Road is determined to have the highest priority for ATMS/ATIS early deployment. It is recommended that this segment be identified as part of the initial deployment corridor.

This priority corridor is also adjacent to the existing instrumented freeway system. It is recommended that statistical traffic congestion and occupancy data be recorded prior to deployment of the initial early deployment system. After the deployment is complete and operational, statistical data should again be collected to determine the effectivity and performance of the ATMS/ATIS early deployment system. The difference between the “before and after” data can also be used to enhance control strategies to improve system efficiency.

Corridors identified in the priority recommendations which currently have ATMS/ATIS components should also be upgraded. These corridors were initially instrumented in the early 1980’s and are not fully instrumented with video surveillance (for incident detection/verification), changeable message signs, and highway advisory radios (for traveler information dissemination). Upgrades to these corridors will provide additional benefits in traffic management performance.

Priority corridor rankings are listed in Table 3-5 in the order of importance and urgency for deployment. As deployment funding becomes available, it is recommended that ATMS/ATIS system be deployed in the corridor priority.

However, this recommendation does not preclude spot deployment of other intermittent high demand areas which result from recreational travelers such as the area surrounding the Silverdome Stadium in Pontiac. The recommended distributed architecture (Section 4) provides flexibility to have non-linear deployment. To aid travelers in these areas, partial deployment of video surveillance and highway advisory radios (HAR) can be used to monitor and inform travelers of traffic conditions before and after special events or at times of high seasonal commercial travel. Table 3-5 lists the corridor in priority order. Further analyses are performed in the deployment strategy section (Section 3.6) to identify deployment schedules. There is a potential that lower priority corridors may be deployed earlier in order to maximize deployment benefits.

Table 3-5. Relative Ranking of Priority Corridors

Priority Ranking	Score	Corridor
1	12	I-75 (I-94 to 9 Mile Road)
1*	12	I-75 (I-94 to I-375)
2	15	I-696 (US-24 to I-75)
2*	15	I-94 (Wyoming to Moross)
3	20	I-696 (I-75 to I-94)
4	21	I-696 (I-96 to US-24)
5	24	I-275 (M-14 to M-102)
6	25	I-96 (I-75 to I-275/M-14)
7	27	M-10 (Greenfield to I-696)
8	28	I-75 (9 Mile to Pontiac)
9	31	M-39 (I-75 to M-10)
10*	34	M-10 (Greenfield to Jefferson)
10	34	Davison (M-10 to I-75)
11*	39	I-375
11	39	I-94 (Moross to M-19)
12	40	I-94 (Wyoming to I-275)
13	43	I-75 (I-96 to I-275)
14	54	I-275 (I-75 to I-96/M-14)
15	57	M-59 (BR-24 to M-53)

* Denotes existing instrumented corridors

3.4 Priority Corridor Recommendation Rationale

Results of the prioritization process show trends of high traffic volumes lead to higher incident rates. Priority corridors ranked between 1 and 6 generally accommodate average daily traffic of approximately 140,000 or more. These areas service major employment regions or service travelers traveling on corridors which are in route to major employment centers. Table 3-6 describes the top 6 priority corridors.

With high volumes of travelers within these corridors, significant fuel and travel delay savings can be realized in a short period of time. Additionally, these corridors support the

majority of travelers who are employed in the down town area of Detroit. Estimated benefit/cost ratios of deploying ATMS/ATIS on these priority corridors are shown in Section 5.

Table 3-6. Priority Corridor Service Description

Corridor	Description
I-75 (I-94 to 9 Mile Road)	<ul style="list-style-type: none"> • Major General Motors employment area • Primary corridor between Oakland County and down town Detroit
I-75 (I-94 to I-375)	<ul style="list-style-type: none"> • Primary corridor in down town Detroit
I-696 (US-24 to I-75)	<ul style="list-style-type: none"> • Primary East-West corridor which support travelers of north Detroit and south Oakland County • Services Farmington Hills and Southfield employment areas
I-94 (Wyoming to Moross)	<ul style="list-style-type: none"> • Primary corridor for North-South travelers entering down town Detroit
I-696 (I-75 to I-94)	<ul style="list-style-type: none"> • Primary East-West corridor servicing north Detroit and south Oakland County travelers • Major corridor between Oakland County, Detroit area and City of Warren employment centers
I-696 (I-96 to US-24)	<ul style="list-style-type: none"> • Supports travelers traveling between metro Detroit and Ann Arbor employment regions
I-275 (M-14 to M-102)	<ul style="list-style-type: none"> • North-South corridor servicing southern ingress point of Farmington Hills employment center
I-96 (I-75 to I-275/M-14)	<ul style="list-style-type: none"> • Major corridor which service motorists traveling between down town Detroit and western employment centers (Farmington Hills and Ann Arbor)

3.5 Initial Deployment Strategy Analysis

Four alternative deployment models were analyzed to assess which ATMS/ATIS configuration is deployable and supports initial deployment goals. Goals were established based upon the available deployment funding for the initial deployment phase. The general theme of the initial deployment activity is to deploy a subset of the ultimate 250 mile ATMS/ATIS system which demonstrates overall capabilities of the system architecture by deploying various ATMS/ATIS technologies in areas which can effectively support the infrastructure and to maximize deployment area for highest payback.

Four scenarios were developed surrounding the highest ranked priority corridor of I-75 Chrysler Freeway from I-94 to 9 Mile Road. An increase in available funding provided an opportunity to extend the initial deployment area. Therefore, various deployment models were developed to assess potential deployment areas under the increased available funding constraints.

The levels of deployment vary depending on the scenario and are described in the detailed analysis. Descriptions of each scenario are described below:

Initial Deployment Scenario #1

This configuration basically extends the high priority corridor through Oakland County to Pontiac. Segments include:

- I-75 from I-94 to 9 Mile Road (High priority corridor)
- I-75 from 9 Mile Road to I-696
- I-75 from I-696 to Big Beaver Road
- I-75 from Big Beaver Road to Squirrel Road (near Pontiac)

All four segments are fully instrumented with mainline detectors, video surveillance (including video signal multiplexers), changeable message signs (CMS), and highway advisory radios (HAR). Ramp meters were not implemented, however, certain field controllers which are located at ramp locations have the capability to be upgraded to support ramp metering functions.

Initial Deployment Scenario #2

Scenario #2 deploys a hybrid of system components to support initial functionality at particular locations. The high priority segment on I-75 between I-94 and I-696 contains the full complement of instrumentation with mainline detectors, video surveillance (with video signal multiplexers), CMS's, and HAR's. Ramp metering is included on I-75 Chrysler Freeway ramps between I-94 and I-696. The full complement is deployed to maximize the effectivity of the ATMS/ATIS system in the high priority area.

Additionally, to support the capability to integrate with arterial control mechanisms, the segment on I-75 between 14 Mile Road and Crooks Road is instrumented with the full complement (without ramp metering) instrumentation including mainline detectors. The freeway traffic information obtained from this segment can be used to aid in arterial signal control for Road Commission for Oakland County's (RCOC's) FAST-TRAC program.

I-75 between Squirrel Road and Lapeer Road is also instrumented with a full complement (without ramp metering) of instrumentation. These deployment scheme aids in incident detection around the Pontiac Silverdome. Various special events induce spurious traffic conditions before and after the special event. In order to support quick incident response and removal, mainline detectors are deployed.

Two segments, I-75 from I-696 to 14 Mile Road and I-75 from Crooks Road to Lapeer Road are partially instrumented. System components include video surveillance (with video signal multiplexers), CMS's, and HAR's. In these areas, cellular and CB call-ins are relied upon for incident detection. Historical data indicate incidents can be detected within 2 to 5 minutes with only cellular and CB call-ins. Video surveillance is used to verify incidents prior to dispatching response vehicles.

A 3 mile stretch of M59 which intersects I-75 was also included. This segment runs east and west just south of the Pontiac Silverdome. The M59 segment was added to enhance

traffic surveillance surrounding the Silverdome and contains a partial complement of video surveillance. Table 3-7 summarizes the deployment strategy:

Table 3-7. Scenario #2 Deployment Strategy

Corridor	Complement
I-75 (I-94 to 9 Mile Road)	Full*
I-75 (9 Mile Road to I-696)	Full*
I-75 (I-696 to 14 Mile Road)	Partial
I-75 (14 Mile Road to Crooks Road)	Full
I-75 (Crooks Road to Squirrel Road)	Partial
I-75 (Squirrel Road to Lapeer Road)	Full
M59 (Near the Pontiac Silverdome)	Partial

* Includes Ramp Metering

Initial Deployment Scenario #3

Scenario #3 includes the identical configuration of scenario #2 with the addition of one more segment and a different hybrid of complements. The segment is on I-696 from US24 to I-75. This segment is ranked second in the priority ranking of traffic congestion and incidents. A partial complement of video surveillance and HAR's are implemented. This segment also relies upon cellular and CB call-ins for incident detection and verification is accomplished with the deployed video surveillance equipment. Ramp metering is not implemented in these segments. Table 3-8 summarizes scenario #3's deployment strategy:

Table 3-8. Scenario #3 Deployment Strategy

Corridor	Complement
I-75 (I-94 to 9 Mile Road)	Full
I-75 (9 Mile Road to I-696)	Full
I-75 (I-696 to 14 Mile Road)	Partial
I-75 (14 Mile Road to Crooks Road)	Full
I-75 (Crooks Road to Squirrel Road)	Partial
I-75 (Squirrel Road to Lapeer Road)	Full
M59 (Near the Pontiac Silverdome)	Partial
I-696 (US24 to I-75)	Partial

Initial Deployment Scenario #4

Scenario #4 redistributes technology applications of scenario #2 while maintaining video coverage along I-696 Reuther Freeway of scenario #3. Mainline detectors in scenario #3 on I-75 Chrysler between Squirrel Road and Lapeer Road near Pontiac are removed and placed along the segment of I-75 Chrysler between I-696 Reuther Freeway and 14 Mile Road. Video detection between Squirrel Road and Lapeer road remains. Ramp metering is also deployed on I-75 Chrysler between I-94 to 14 Mile Road. Mainline detectors are retained along I-75 Chrysler between 14 Mile Road and Crooks Road. Deployment of

HARs and CMSs are identical to scenario #3. This deployment strategy maximizes the use of ramp metering at high demand locations along I-75 Chrysler while providing I-75 Chrysler traffic and incident data in the FAST-TRAC deployment region. Table 3-9 summarize scenario #4 technology deployment.

Table 3-9. Scenario #4 Deployment Strategy

Corridor	Complement
I-75 (I-94 to 9 Mile Road)	Full*
I-75 (9 Mile Road to I-696)	Full*
I-75 (I-696 to 14 Mile Road)	Full*
I-75 (14 Mile Road to Crooks Road)	Full
I-75 (Crooks Road to Squirrel Road)	Partial
I-75 (Squirrel Road to Lapeer Road)	Partial
M59 (Near the Pontiac Silverdome)	Partial
I-696 (US24 to I-75)	Partial

* Includes Ramp Metering

A high level summary of various deployment scenarios is shown in the Table 3-10.

Table 3-10. Summary of Initial Deployment Scenarios

Scenario	Deployment Cost	Total Miles	Cost per Mile
#1	\$14,446,165	21.6	\$668,804
#2	\$15,219,697	30.3	\$502,300
#3	\$15,190,342	40.5	\$375,070
#4	\$15,330,786	40.5	\$378,538

3.5.1 Initial Deployment Recommendation

It is recommended that deployment scenario #4 be implemented for initial deployment. Scenario #4 provides the largest area of coverage with concentrations of mainline detectors at those locations which require additional traffic detection and surveillance; and ramp meters at locations which require ramp control to regulate ingressing vehicles. The two highest priority corridors (I-75 from I-94 to 9 Mile Rd. and I-696 from US24 to I-75) are instrumented.

Other high traffic congestion areas such as I-75 from 9 Mile Road to I-696, I-75 from I-696 to 14 Mile Road, and I-75 from 14 Mile Road to Crooks Road are also instrumented in full complement with ramp metering from I-94 to 14 Mile Road. I-75 from Squirrel Road to Lapeer Road have video surveillance capabilities and services major traffic demands generated from the Pontiac Silverdome, Palace, Oakland University, and the

Chrysler Technology Center. This corridor can demonstrate MDOT's capability to support both sporadic (Silverdome and Palace) and recurring traffic demands (Oakland University and Chrysler Technology Park).

Additionally, the I-75 from Squirrel Road to Lapeer Road segment will be able to service freeway demands generated from travelers coming from north of Pontiac and from travelers using Square Lake Road and Business Route 24.

The I-75 from 9 Mile Road to 14 Mile Road segment provides the opportunity to demonstrate traffic coordination capabilities with FAST-TRAC. Since this freeway segment lies within the FAST-TRAC deployment region, digital traffic and incident management information can be exchanged to inform FAST-TRAC of the predicted traffic demand entering the area.

The deployment region within Oakland County can also demonstrate a tightly coupled freeway/arterial traffic control system. Potential integration with SCATS in Oakland County can demonstrate the integration and operation to two separate control systems.

Another benefit from the traffic and incident information exchange with FAST-TRAC can be realized by future SMART projects. The SMART program is currently trying to identify means to be integrated with the FAST-TRAC program. The information shared with MDOT can also aid in the route and trip planning system of the SMART program as it becomes available. Information of congestion, traffic flow, and incidents can aid SMART drivers to plan routes with minimal travel delays.

The following lists benefits realized by implementing scenario #4:

- Demonstrates the system architecture's capabilities in mainline detection, ramp metering, video surveillance, CMS's, and HAR's in areas which require the full complement of ATMS/ATIS components
- Able to provide and share digital traffic data with an arterial ATMS/ATIS (i.e. Oakland County's FAST-TRAC) programs. FAST-TRAC is the only arterial ATMS/ATIS system in the region.
- Able to support future system expansion and automated highway system (AHS) demonstrations
- Able to be operate as a future test bed for automotive manufacturers to demonstrate integrated freeway and arterial ATIS and AVCS
- Significant national visibility due to integration capability with the FAST-TRAC program

Figures 3-1 to 3-4 describe the initial deployment corridor recommendation. As shown in the figures, various levels of deployment are implemented to maximize the area of coverage and to accommodate the top two priority corridors.

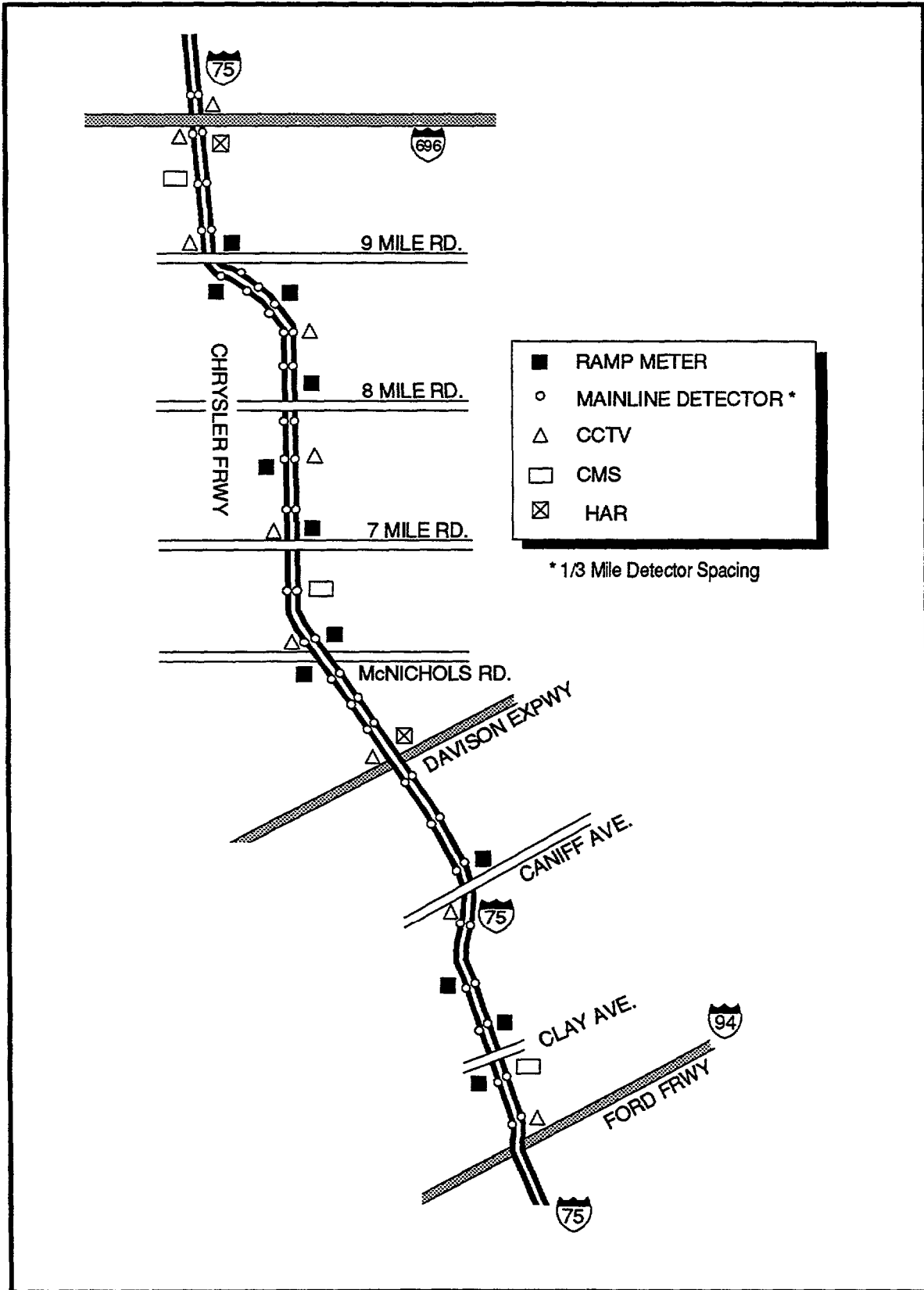


Figure 3-1. Scenario #4 Configuration - I-75 From I-94 to I-696

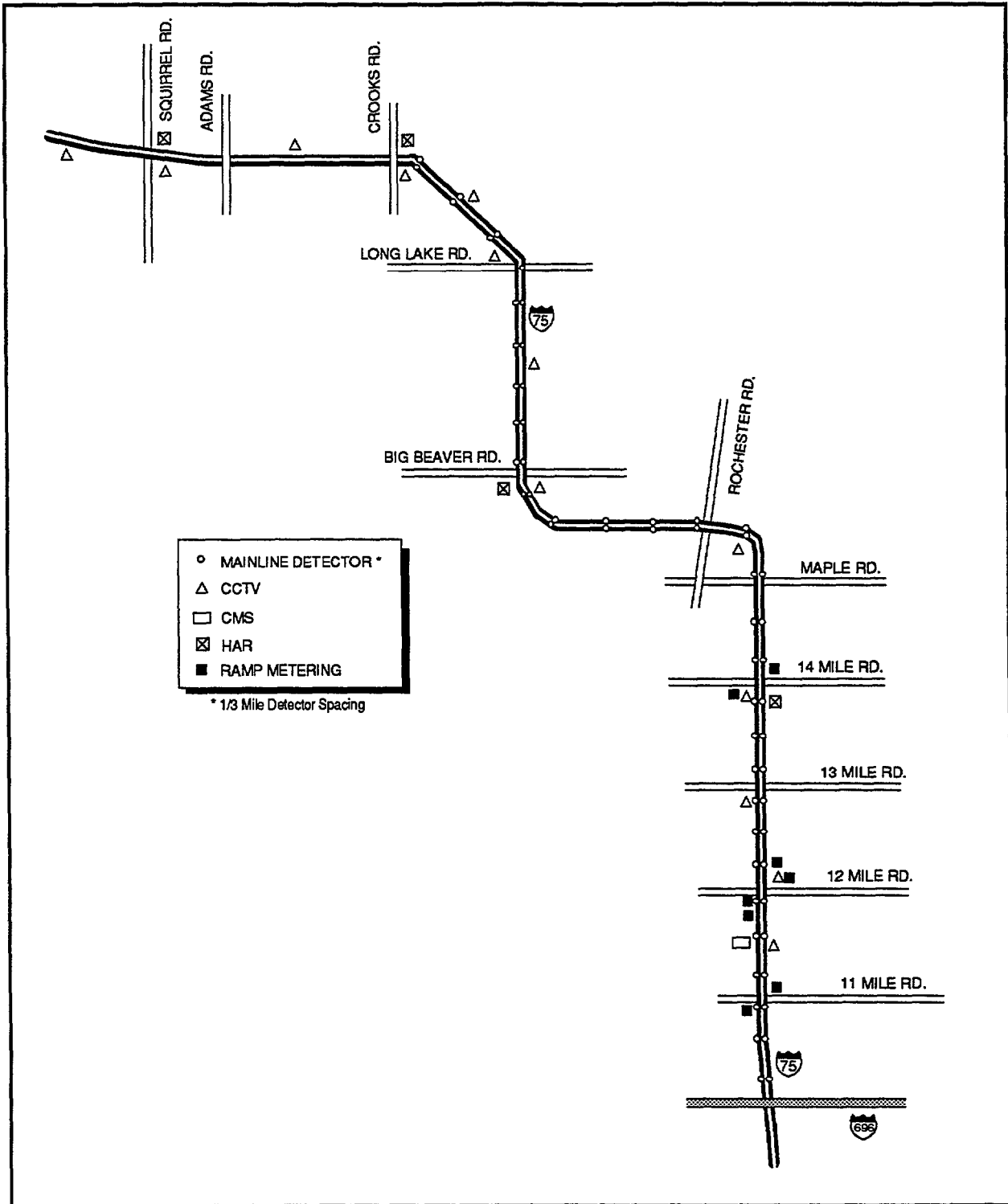


Figure 3-2. Scenario #4 Configuration - I-75 From I-696 to Squirrel Road

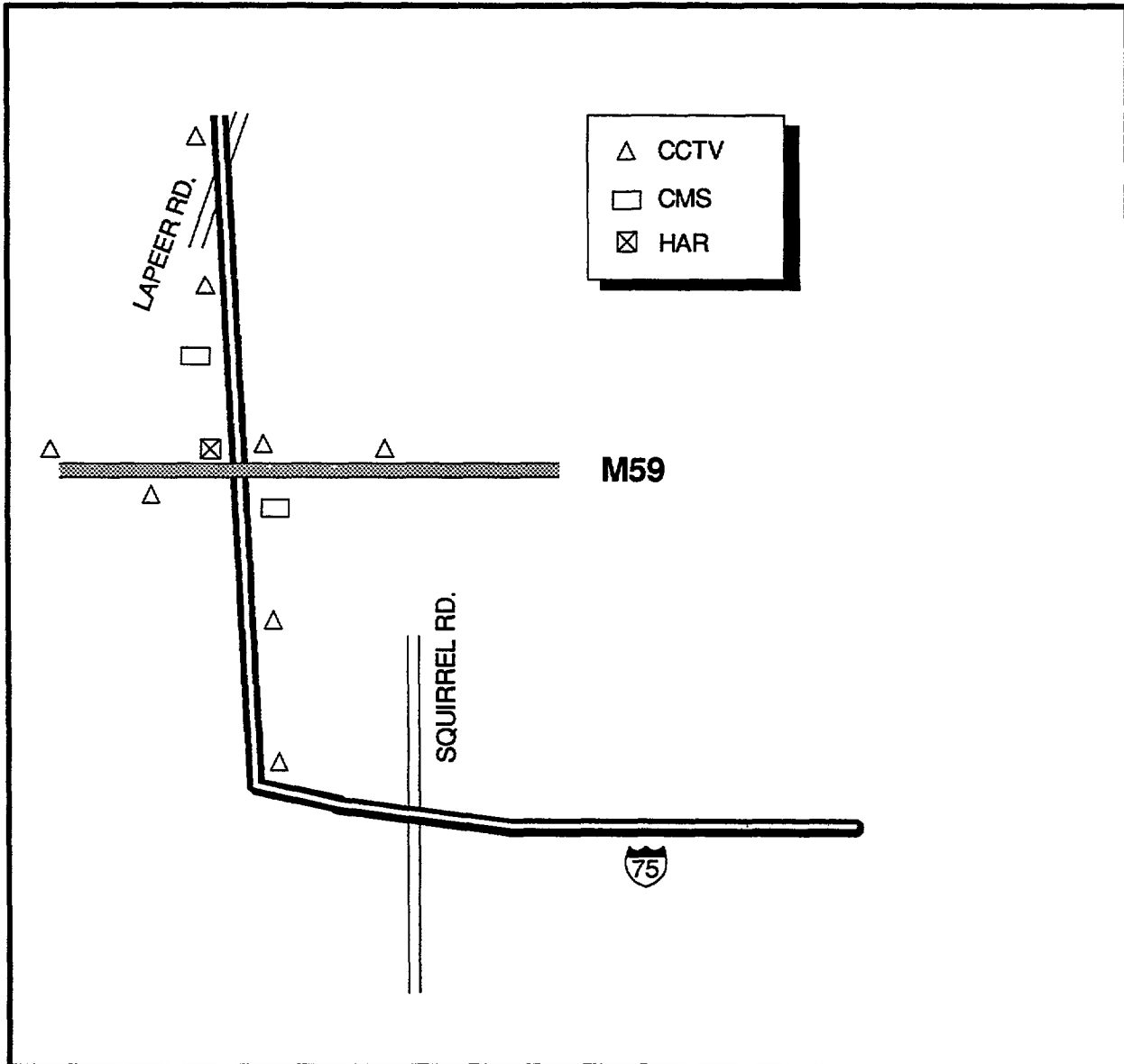


Figure 3-3. Scenario #4 - I-75 From Squirrel Road to Lapeer Road & M-59

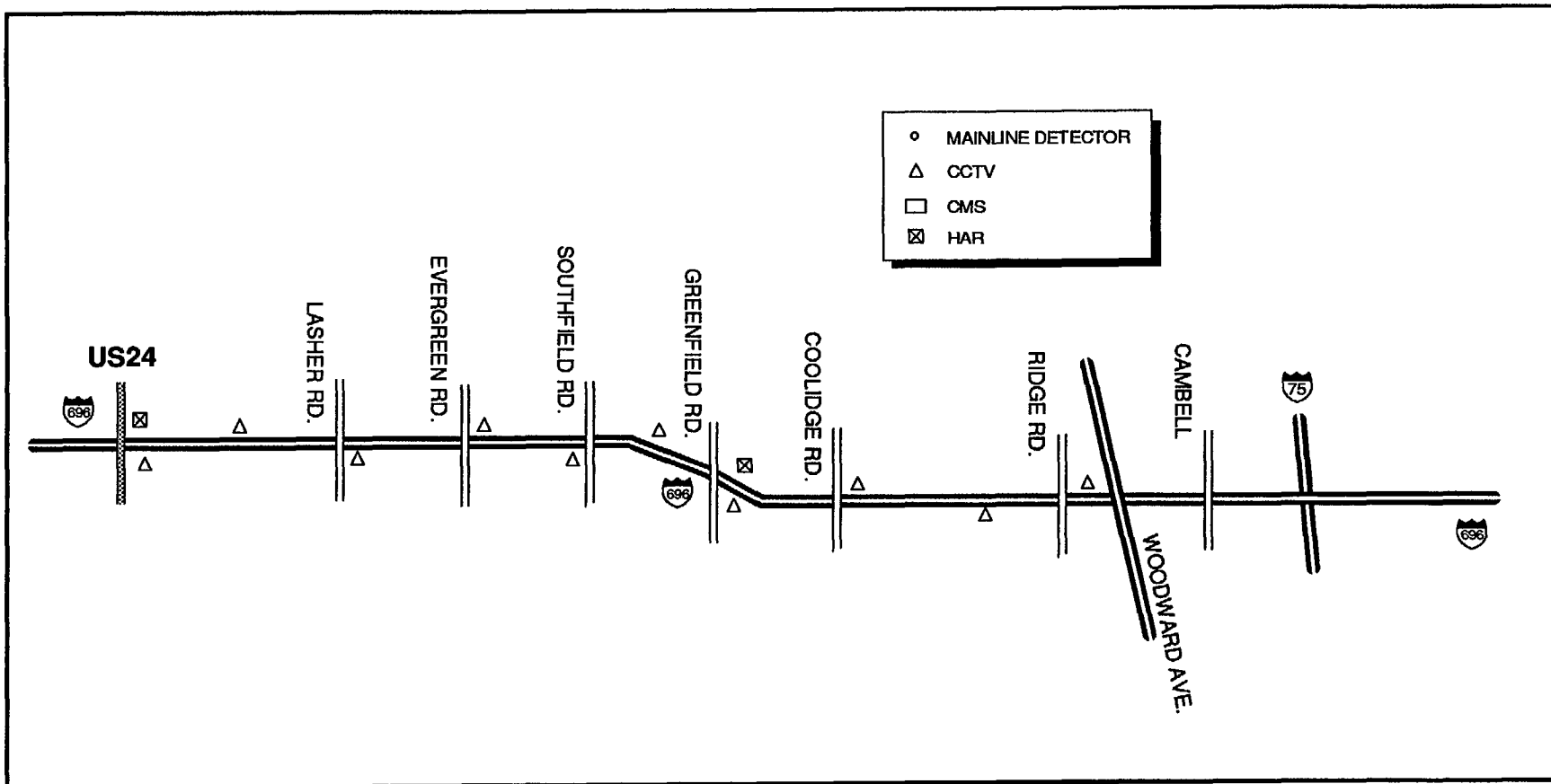


Figure 3-4. Scenario #4 - I-696 From US-24 to I-75

3.5.2 Initial Deployment Recommendation Background Analysis

Deployment estimates were based on the following rationale:

- Existing I-75 civil drawings are not currently on CADD.
- I-696 civil drawings are on CADD.
- Each deployment site for a particular equipment requires one civil design drawing.
- Drawings which are not currently on CADD require 80 hours civil design, survey, drafting, etc.
- Drawings which are on CADD require 52 hours civil design, survey, drafting, etc.
- All three configurations require additional equipment at the MTC such as video receive/control, computer processing, and communications equipment
- Each configuration also requires non-recurring system design.
- Systems integration was based on 80 hours per deployment site and includes construction project management, software loading (where required), system hardware checkout prior to application of power, local system test, integration with other system components, and overall acceptance test.

Initial Deployment Strategy Scenario #1

Table 3-11 lists corridor segments for scenario #1. ATMS/ATIS components and segment cost for this scenario are listed in Table 3-12.

Table 3-11. Initial Deployment Scenario #1 Segments

Corridor Seg. #	Corridor Segment	Length (mi.)
1	I-75 (I-94 to 9 Mile Rd)	7.4
2	I-75 (9 Mile Rd to I-696)	0.9
3	I-75 (I-696 to Big Beaver)	7.5
4	I-75 (Big Beaver to Squirrel Road)	5.8

Table 3-12. Scenario #1 Deployment Configuration and Cost Estimate

Corridor	Mainline Detector		Video Multiplexer		Video Surveillance		CMS		HAR		Total	Cost per Mile
	Seg. #	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Cost		
1	44	\$3,223,571	2	\$86,098	8	\$227,371	2	\$378,400	1	\$20,103	\$3,935,542	\$531,830
2	6	\$439,578	1	\$43,049	2	\$56,843	1	\$189,200	1	\$20,103	\$748,722	\$831,969
3	45	\$3,296,834	2	\$86,098	6	\$170,528	1	\$189,200	2	\$40,205	\$3,782,865	\$504,382
4	35	\$2,564,204	6	\$258,293	6	\$170,528	0	0	2	\$40,205	\$3,033,231	\$522,971
Total		\$9,524,186		\$473,538		\$625,271		\$756,800		\$120,615	\$11,500,410	

Estimate for civil design:

1 drawing per equipment deployment site
 includes: electrical, civil construction, pertinent utilities, roadway, right of way
 boundaries, existing structures

\$5200 per drawing
 \$8155 per site integration (project mgt., integration, test)
 Mainline Detectors: 130 Dwgs x \$5200 = \$676,000
 Video Multiplexers: 11 x 5200 = \$57,200
 Video Surveillance: 22 x 5200 = \$114,400
 CMS: 4 x 5200 = \$20,800
 HAR: 6 x 5200 = \$31,200

Total Civil Design:	\$899,600
MTC Video Equipment:	\$36,705
MTC Computer Equipment:	\$59,125
MTC Communications Equipment:	\$10,524
Systems Design:	\$528,986
Systems Integration:	\$1,410,845
Hardware and Installation:	\$11,500,410
Scenario #1 Deployment Total:	\$14,446,165

Initial Deployment Strategy Scenario #2

Table 3-13 lists corridor segments for scenario #2. ATMS/ATIS components and segment cost for this scenario are listed in Table 3-14.

Table 3-13. Initial Deployment Scenario #2 Segments

Corridor Seg. #	Corridor Segment	Length (mi.)
1	I-75 (I-94 to 9 Mile Rd)	7.4
2	I-75 (9 Mile Rd to I-696)	0.9
3	I-75 (I-696 to 14 Mile Rd)	4.0
4	I-75 (14 Mile Rd to Crooks Rd)	5.7
5	I-75 (Crooks Rd to Squirrel Rd)	3.6
6	I-75 (Crooks Rd to Lapeer Rd)	5.7
7	I-75/M59 (Near Silverdome)	3.0

MDOT Early Deployment of ATMS/ATIS

Table 3-14. Scenario #2 Deployment Configuration and Cost Estimate

Corridor	Mainline Detector		Video Multiplexer		Video Surveillance		CMS		HAR		Ramp Metering		Total	Cost per Mile
	Seg. #	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Cost
1	44	\$3,223,571	2	\$86,098	8	\$227,371	2	\$378,400	1	\$20,103	12	\$495,685	\$4,431,227	\$598,814
2	6	\$439,578	1	\$43,049	2	\$56,843	1	\$189,200	1	\$20,103	0	0	\$748,772	\$831,969
3	0	0	2	\$86,098	4	\$113,686	1	\$189,200	1	\$20,103	0	0	\$409,086	\$102,271
4	35	\$2,564,204	4	\$172,196	6	\$170,528	0	0	2	\$40,205	0	0	\$2,947,133	\$517,041
5	0	0	2	\$86,098	3	\$85,264	0	0	1	\$20,103	0	0	\$191,464	\$53,185
6	35	\$2,564,204	1	\$43,049	5	\$142,107	2	\$378,400	1	\$20,103	0	0	\$3,147,862	\$552,257
7	0	0	2	\$86,098	3	\$85,264	0	0	0	0	0	0	\$171,362	\$57,121
Total		\$8,791,556		\$602,685		\$881,063		\$1,135,200		\$140,718		\$495,685	\$12,046,907	

Estimate for civil design:

1 drawing per equipment deployment site
 includes: electrical, civil construction, pertinent utilities, roadway, right of way
 boundaries, existing structures

\$5200 per drawing (I-75)
 \$8155 per site integration (project mgt., integration, test)
 Mainline Detectors: 120 Dwgs x \$5200 = \$624,000
 Ramp Metering: 12 x 5200 = 62,400
 Video Multiplexers: 14 x 5200 = \$72,800
 Video Surveillance: 31 x 5200 = \$161,200
 CMS: 6 x 5200 = \$31,200
 HAR: 7 x 5200 = \$36,400

Total Civil Design:	\$988,000
MTC Video Equipment:	\$36,705
MTC Computer Equipment:	\$59,125
MTC Communications Equipment:	\$10,524
Systems Design:	\$528,986
Systems Integration:	\$1,549,450
Hardware and Installation:	\$12,046,907

Scenario #2 Deployment Total: \$15,219,697

Initial Deployment Strategy Scenario #3

Table 3-15 lists corridor segments for scenario #3. ATMS/ATIS components and segment cost for this scenario are listed in Table 3-16.

Table 3-15. Initial Deployment Scenario #3 Segments

Corridor Seg. #	Corridor Segment	Length (mi.)
1	I-75 (I-94 to 9 Mile Rd)	7.4
2	I-75 (9 Mile Rd to I-696)	0.9
3	I-75 (I-696 to 14 Mile Rd)	4.0
4	I-75 (14 Mile Rd to Crooks Rd)	5.7
5	I-75 (Crooks Rd to Squirrel Rd)	3.6
6	I-75 (Squirrel Rd to Lapeer Rd)	5.7
7	I-75/M59 (Near Silverdome)	3.0
8	I-696 (US24 to I-75)	10.2

MDOT Early Deployment of ATMS/ATIS

Table 3-16. Scenario #3 Deployment Configuration and Cost Estimate

Corridor	Mainline Detector		Video Multiplexer		Video Surveillance		CMS		HAR		Total Cost	Cost per Mile
	Seg. #	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty		
1	44	\$3,223,571	2	\$86,098	8	\$227,371	2	\$378,400	1	\$20,103	\$4,431,227	\$598,814
2	6	\$439,578	1	\$43,049	2	\$56,843	1	\$189,200	1	\$20,103	\$748,772	\$831,969
3	0	0	2	\$86,098	4	\$113,686	1	\$189,200	1	\$20,103	\$409,086	\$102,271
4	35	\$2,564,204	4	\$172,196	6	\$170,528	0	0	2	\$40,205	\$2,947,133	\$517,041
5	0	0	2	\$86,098	3	\$85,264	0	0	1	\$20,103	\$191,464	\$53,185
6	35	\$2,564,204	1	\$43,049	5	\$142,107	2	\$378,400	1	\$20,103	\$3,147,862	\$552,257
7	0	0	2	\$86,098	3	\$85,264	0	0	0	0	\$171,362	\$57,121
8	0	0	3	129,147	10	\$284,214	0	0	2	\$40,205	\$453,566	\$44,467
Total		\$8,791,556		\$731,832		\$1,165,277		\$1,135,200		\$180,923	\$12,004,787	

Estimate for civil design:

1 drawing per equipment deployment site
 includes: electrical, civil construction, pertinent utilities, roadway, right of way
 boundaries, existing structures

\$5200 per drawing (I-75), \$3380 per drawing (I-696)

\$8155 per site integration (project mgt., integration, test)

I-75

I-696

Mainline Detectors: 120 Dwgs x \$5200 = \$624,000

Video Multiplexers: 14 x 5200 = \$72,800

3 x 3380 = \$10,140

Video Surveillance: 31 x 5200 = \$161,200

10 x 3380 = \$33,800

CMS: 6 x 5200 = \$31,200

HAR: 7 x 5200 = \$36,400

2 x 3380 = \$6,760

Total Civil Design (I-75): \$925,600

Total Civil Design (I-696): \$50,700

MTC Video Equipment: \$36,705

MTC Computer Equipment: \$59,125

MTC Communications Equipment: \$10,524

Systems Design: \$528,986

Systems Integration: \$1,573,915

Hardware and Installation: \$12,004,787

Scenario #3 Deployment Total: \$15,190,342

Initial Deployment Strategy Scenario #4

Table 3-17 lists corridor segments for scenario #4. ATMS/ATIS components and segment cost for this scenario are listed in Table 3-18.

Table 3-17. Initial Deployment Scenario #4 Segments

Corridor Seg. #	Corridor Segment	Length (mi.)
1	I-75 (I-94 to 9 Mile Rd)	7.4
2	I-75 (9 Mile Rd to I-696)	0.9
3	I-75 (I-696 to 14 Mile Rd)	4.0
4	I-75 (14 Mile Rd to Crooks Rd)	5.7
5	I-75 (Crooks Rd to Squirrel Rd)	3.6
6	I-75 (Squirrel Rd to Lapeer Rd)	5.7
7	I-75/M59 (Near Silverdome)	3.0
8	I-696 (US24 to I-75)	10.2

MDOT Early Deployment of ATMS/ATIS

Table 3-18. Scenario #4 Deployment Configuration and Cost Estimate

Corridor	Mainline Detector		Video Multiplexer		Video Surveillance		CMS		HAR		Ramp Metering		Total Cost	Cost per Mile
	Seg. #	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty		
1	44	\$3,223,571	2	\$86,098	8	\$227,371	2	\$378,400	1	\$20,103	12	\$495,685	\$4,431,227	\$598,814
2	6	\$439,578	1	\$43,049	2	\$56,843	1	\$189,200	1	\$20,103	0	0	\$748,772	\$831,969
3	24	\$1,758,311	2	\$86,098	4	\$113,686	1	\$189,200	1	\$20,103	8	\$330,457	\$2,497,854	\$624,463
4	35	\$2,564,204	4	\$172,196	6	\$170,528	0	0	2	\$40,205	0	0	\$2,947,133	\$517,041
5	0	0	2	\$86,098	3	\$85,264	0	0	1	\$20,103	0	0	\$191,464	\$53,185
6	0	0	1	\$43,049	5	\$142,107	2	\$378,400	1	\$20,103	0	0	\$583,658	\$102,396
7	0	0	2	\$86,098	3	\$85,264	0	0	0	0	0	0	\$171,362	\$57,121
8	0	0	3	129,147	10	\$284,214	0	0	2	\$40,205	0	0	\$453,566	\$44,467
Total		\$7,985,664		\$731,832		\$1,165,277		\$1,135,200		\$180,923		\$826,142	\$12,025,036	

Estimate for civil design:

1 drawing per equipment deployment site
 includes: electrical, civil construction, pertinent utilities, roadway, right of way
 boundaries, existing structures

\$5200 per drawing (I-75), \$3380 per drawing (I-696)

\$8155 per site integration (project mgt, integration, test)

I-75

I-696

Mainline Detectors: 109 Dwgs x \$5200 = \$566,800

Ramp Metering: 20 x 5200 = \$104,000

Video Multiplexers: 14 x 5200 = \$72,800

3 x 3380 = \$10,140

Video Surveillance: 31 x 5200 = \$161,200

10 x 3380 = \$33,800

CMS: 6 x 5200 = \$31,200

HAR: 7 x 5200 = \$36,400

2 x 3380 = \$6,760

Total Civil Design (I-75): \$972,400

Total Civil Design (I-696): \$50,700

MTC Video Equipment: \$36,705

MTC Computer Equipment: \$59,125

MTC Communications Equipment: \$10,524

Systems Design: \$528,986

Systems Integration: \$1,647,310

Hardware and Installation: \$12,025,036

Scenario #4 Deployment Total: \$15,330,786

3.6 Overall System Deployment Strategy

3.6.1 Follow-on Deployment Criteria

After initial deployment of ATMS/ATIS has been completed (or near completion), design and build phases for the remaining priority corridors should be performed to realize maximum benefits from continued, non-disrupted deployment. Goals for ATMS/ATIS implementation for follow-on phases differ from the initial deployment phase. Recommended goals for phases subsequent to initial deployment concentrate on ATMS/ATIS deployment of priority corridors based upon demand and number of incidents and in areas which provide maximum benefit in order to enhance user services. Such criterion was used in prioritizing corridors earlier in this section.

Additional criteria for follow-on phases are established in order to maximize realized benefits from the ATMS/ATIS deployment. Criteria used in establishing the follow-on deployment strategy include:

- Emphasize on corridors which user services are mostly needed
- Deploy ATMS/ATIS components in order of the recommended priorities in Section 3.3; Table 3-5 (including remaining portions of initial deployment segments).
- Upgrade original 32.5 mile corridors as they are identified in the priority corridor listing.
- Deploy any corridor segments which complete geographical coverage to maximize regional implementation benefits (e.g. Davison Freeway and M- 10)
- Move up segments with a high benefit/cost ratio
- Move up small segments which can be completed quickly to take advantage of funding availability.
- Coordinate with existing roadway construction schedules to minimize costs associated with lane closures.

3.6.2 Identification of Remaining Priority Corridor Segments

Table 3-19 shows which priority corridors and associated quantities of components remain after implementation of the initial deployment corridor segments. Using the criteria identified in Section 3.6.1, remaining portions of I-75 from I-94 to 9 Mile Road, specifically an additional video multiplexer should be implemented first. This multiplexer will enable additional surrounding video signals to benefit from multiplexed transmission. Ramp metering, mainline detectors, and installation of changeable message signs on I-696 (US 24 to I-75) should also be implemented as first priorities in the follow-on deployment

phase. It is recommended that “backfilling” of the I-75 (9 Mile Road to Pontiac) be implemented after deployment of other higher priority corridors are completed since other areas can realize higher benefits from such deployment. The I-75 from 9 Mile Road to Pontiac segment is recommended to be deployed as part of phase III. This deployment time tie will coincide with the FAST-TRAC Phase IIA deployment west of Troy. This region includes the cities of Pontiac, Auburn Hills, and Rochester Hills. These communities are also home to the Palace of Auburn Hills, the Oakland Technology Park with the 3.5 million square foot Chrysler Technology Center, Oakland University, and the Pontiac Silverdome. These areas are major demand generators, and deployment coordination between MDOTs early deployment activities with Oakland County’s Phase IIA and IIB time frames will maximize benefits achieved in the region.

Following the prioritization criteria of Section 3.6.1, M-10 (Greenfield to I-696) should be included in the first phase after initial deployment to complete geographic coverage. This segment also has a high benefit/cost ratio of 7.9. Also, the Davison Freeway, which has a benefit/cost ratio of 11.1, should also be completed in Phase II.

When the implementation of this segment is completed, regions bounded by I-696 from US 24 to I-75, I-75 from I-696 to M-10, M-10 from I-75 to I-696, and Davison Freeways will be fully instrumented to provide contiguous regional coverage. Benefits from this deployment method include increase in coordinated segment performance and complete regional monitoring and control. Remaining corridor segments should be deployed in the order of prioritization identified previously.

Deployment prioritization should be reviewed annually to assess any change in funding availability and funding sources.

Coordination With Construction Activities

Near term construction schedules of the Davison Freeway (some time during Phase II implementation) will allow the deployment of technologies on this segment to be accomplished at the same time. By initiating deployment concurrent to construction activities, costs associated to lane closures at different times can significantly be reduced. In addition to the Davison Freeway, I-94 will be undergoing major construction during Phase II deployment. Again, with careful timing, the construction activities and the deployment of ATMS/ATIS components can be accomplished simultaneously.

Other construction activities identified in MDOT production schedules do not effect deployment of other corridors in phase the initial deployment and phase II activities. Construction schedules between phase III and VI are still in the planning stages. As detailed construction plans are released, appropriate scheduling of deployment activities is recommended.

Table 3-19. Remaining Corridors After Initial Deployment

Corridor Segment	Length	# Ramp Control**	# Detector Stations	# of HARs	# of CCTV	# CCTV MUX.	# of CMSs	Deployment Cost	Sys. Integ./ Civil Design	Segment Total
I-75 (I-94 to 9 Mile Road)	7.4	0	0	0	0	1	0	\$43,049	\$13,355	\$56,404
I-75 (I-94 to I-375)	1.0	0	0	0	2	1	0	\$99,892	\$40,065	\$139,957
I-696 (US 24 to I-75)	10.2	12	62	2	10	3	3	\$5,605,589	\$1,028,335	\$6,633,924
I-94 (Wyoming to Moross)*	13.6	0	0	2	11	4	4	\$1,281,836	\$280,455	\$1,562,291
I-696 (I-75 to I-94)	9.8	16	60	2	10	4	6	\$6,688,506	\$1,308,790	\$7,997,296
I-696 (I-96 to US 24)	9.1	5	56	2	10	4	2	\$5,184,276	\$1,055,045	\$6,239,321
I-275 (M-14 to M-102)	7.5	11	46	2	8	3	4	\$4,977,997	\$988,270	\$5,966,257
I-96 (I-75 to I-275/M-14)	19.0	33	114	4	19	7	6	\$11,772,071	\$2,443,965	\$14,216,036
M-10 (Greenfield to I-696)	6.0	9	36	1	6	2	2	\$3,664,359	\$747,880	\$4,412,239
I-75 (9 Mile Road to Pontiac)	19.9	23	55	0	3	2	0	\$5,150,888	\$1,108,455	\$6,259,353
M-39 (I-75 to M-10)	10.5	28	64	2	11	4	8	\$7,884,065	\$1,562,535	\$9,446,600
M-10 (Greenfield to Jefferson)*	17.0	0	0	3	9	3	3	\$1,012,847	\$240,390	\$1,253,237
Davison (M-10 to I-75)	2.0	4	12	0	2	1	2	\$1,522,678	\$280,455	\$1,803,131
I-375*	1.0	0	0	0	2	1	0	\$99,892	\$40,065	\$139,957
I-94 (Moross to M-19)	23.0	26	138	5	23	8	6	\$13,418,070	\$2,751,130	\$16,169,200
I-94 (Wyoming to I-275)	16.0	25	96	3	16	6	6	\$9,974,466	\$2,029,960	\$12,004,426
I-75 (I-96 to I-275)	29.9	44	180	6	30	10	6	\$17,543,792	\$3,685,960	\$21,229,772
I-275 (I-75 to I-96/M-14)	29.0	30	174	6	29	10	9	\$17,065,094	\$3,445,590	\$20,510,684
M-59 (BR-24 to M-53)	14.8	14	90	3	12	3	2	\$8,080,877	\$1,656,020	\$9,736,897
Subtotals	246.7	280	1183	41	203	74	69		\$24,706,750	\$145,776,993
Total Hardware		\$11,565,965	\$86,670,094	\$824,203	\$5,769,542	\$3,185,619	\$13,054,800	\$121,070,243		
Total Civil Engineering		\$1,456,000	\$6,151,600	\$213,200	\$1,055,600	\$384,800	\$358,800	\$9,620,000		
Total System Integration		\$2,283,400	\$9,647,365	\$334,355	\$1,656,465	\$603,470	\$562,695	\$15,086,750		
Total		\$15,305,385	\$102,469,059	\$1,371,758	\$8,480,607	\$4,173,889	\$13,976,295	\$145,776,993		

* Existing instrumented system. Augmentation of functionality as required.

** Cost associated with ramp control only reflect additional equipment to detector stations since controllers at detector station sites perform dual functions

3.6.3 Follow-on Deployment Phases

Table 3-20 lists the order of recommended deployment strategy using the criteria listed in Section 3.6.1. Two priority corridor segments have moved up the priority listing due to the geographic coverage criteria. The M-10 from Greenfield to I-696 priority corridor was moved up in the listing from the 9th position to the 7th position. The Davison Freeway also moved up from 10th to 8th position on the priority list.

The phased approach deploys ATMS/ATIS technologies in areas which require incident and traffic management in order of priorities based on average daily traffic, projected average daily traffic, number of incidents, and normalized number of incidents per lane-mile. Realized benefits from earlier phases provide significant benefit/cost ratios (as shown in Section 5) which aid in the justification of ATMS/ATIS deployment. Phases are divided into deployment costs of approximately \$30 million and 50 miles each in length.

Due to the priority analysis method and the criteria used in the analysis, deployment priorities reflect areas which require immediate attention to improve user services. Implementation priorities as identified in the phased approach of Table 3-20 generally support high traveler demand regions and areas which have high number of incidents. Deploying ATMS and ATIS technologies in these areas will provide improvements to the level of service, increase capacity, and reduce travel delay times.

The period of each deployment phase is approximately 36 months and includes the necessary systems/civil design, procurement, installation, and integration tasks. Each phase period is executed on a yearly basis with overlapping activities in each phase. Table, 3-20 also shows suggested start and completion dates. Figure 3-5 is a schedule representing deployment phases.

3.7 Operational Plan

One of the elements of the ATMS/ATIS Deployment Study is the Operational Plan. The purpose of the Operational Plan is to document what the rest of the system process will involve, to identify any necessary institutional arrangements, to indicated the personnel and budget resources required for the proposed system, and to provide a time table for the system process. A stand-alone Operational Plan is included in Appendix II.

MDOT Early Deployment of ATMS/ATIS

Table 3-20. Phased Deployment Strategy

Phase	Corridor Segment	Length	Deployment Cost	Sys. Integ./ Civil Design	Segment Total	B/C Ratio**	Phase Length	Cost of Phase	Start Date	Complete Date
II	I-75 (I-94 to 9 Mile Road)***	7.4	\$43,049	\$13,355	\$56,404	18.4			10/1/95	10/1/98
	I-75 (I-94 to I-375)*	1.0	\$99,892	\$40,065	\$139,957	-				
	I-696 (US24 to I-75)***	10.2	\$5,605,589	\$1,028,335	\$6,633,924	7.6				
	I-94 (Wyoming to Moross)*	13.6	\$1,281,836	\$280,455	\$1,562,291	-	59.1	\$28.8M		
	I-696 (I-75 to I-94)	9.8	\$6,688,506	\$1,308,790	\$7,997,296	6.0				
	I-696 (I-96 to US 24)	9.1	\$5,184,276	\$1,055,045	\$6,239,321	6.4				
	M-10 (Greenfield to I-696 Davison (M-10 to I-75))	6.0	\$3,664,359	\$747,880	\$4,412,239	7.9				
		2.0	\$1,522,676	\$280,455	\$1,803,131	11.1				
III	I-275 (M-14 to M-102)	7.5	\$4,977,997	\$988,270	\$5,966,267	5.3			10/1/96	10/1/99
	I-96 (I-75 to I-275/M-14)	19	\$11,772,071	\$2,443,965	\$14,216,036	5.4	46.4	\$26.4M		
	I-75 (9 Mile Road to Pontiac)***	19.9	\$5,150,888	\$1,108,465	\$6,259,353	3.2				
IV	M-39 (I-75 to M-10)	10.5	\$7,884,065	\$1,562,535	\$9,446,600	7.5			10/1/97	10/1/00
	M-10 (Greenfield to Jefferson)*	17.0	\$1,012,847	\$240,390	\$1,253,237	-	51.5	\$27.0M		
	I-375*	1.0	\$99,892	\$40,065	\$139,957	-				
	I-94 (Moross to M-19)	23.0	\$13,418,070	\$2,751,130	\$16,169,200	1.8				
V	I-94 (Wyoming to I-275)	16.0	\$9,974,466	\$2,029,960	\$12,004,426	2.7	45.9	\$33.2M	10/1/98	10/1/01
	I-75 (I-96 to I-275)	29.9	\$17,543,792	\$3,685,980	\$21,229,772	2.0				
VI	I-275 (I-75 to I-96/M-14)	29.0	\$17,065,094	\$3,445,590	\$20,510,684	0.8	43.8	\$30.2M	10/1/99	10/1/02
	M-59 (BR-24 to M-53)***	14.8	\$8,080,877	\$1,656,020	\$9,736,897	0.9				
							246.7	\$145.8M		

* Existing instrumented system. Augmentation of functionality as required.

** Benefit/Cost (B/C) ratios reflect full deployment of IVHS technologies in each corridor.

*** "Backfilling" of system components which were not deployed during the initial deployment phase.

MDOT Early Deployment of ATMS/ATIS

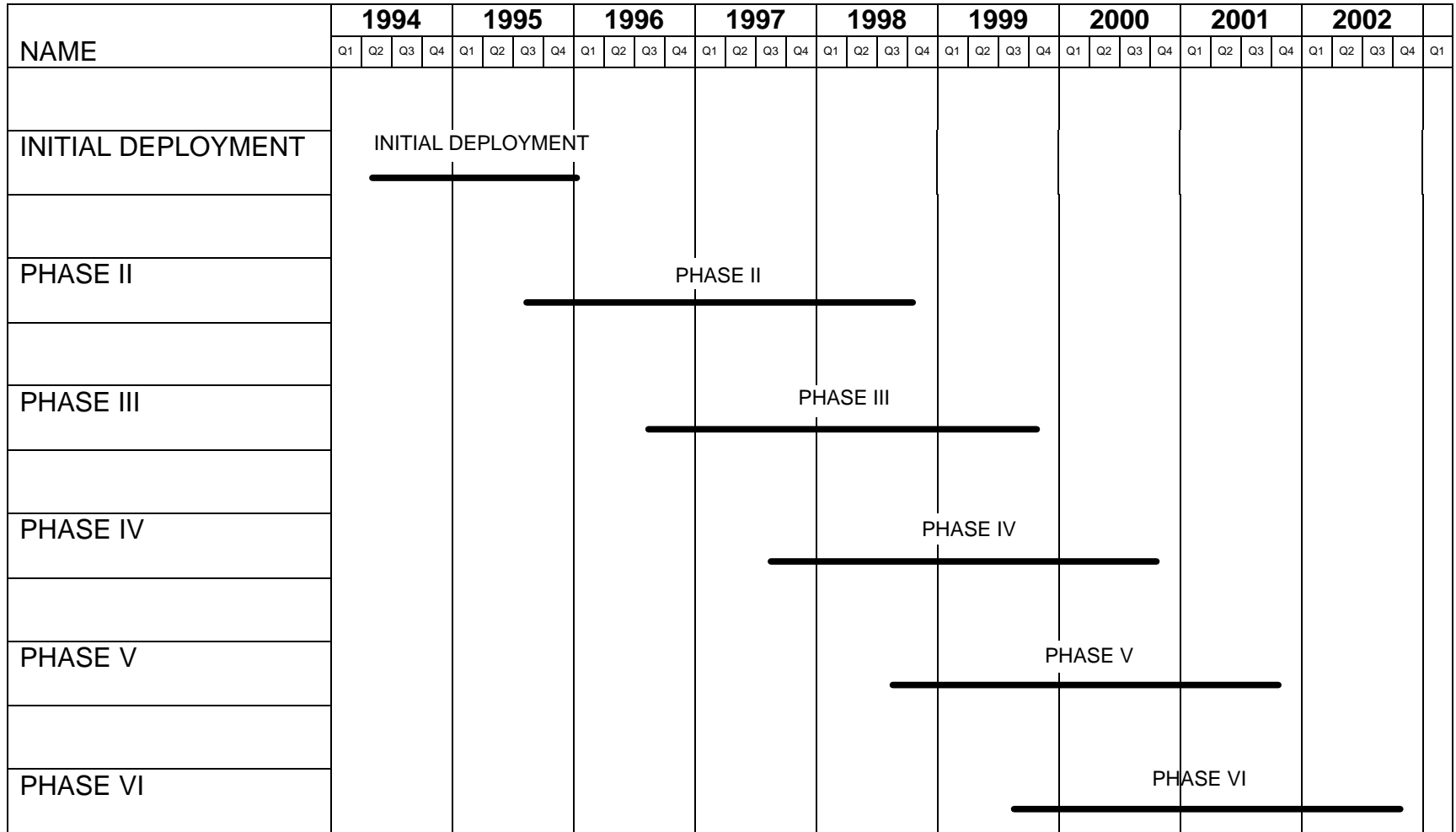


Figure 3-5. Phased Deployment of ATMS/ATIS Schedule

4.0 System Description

This section describes the system requirements and architecture for the Michigan Department of Transportation (MDOT) Michigan Intelligent Transportation System (MITS), hereinafter referred to as the system.

System requirements were developed from current freeway operations and future capabilities identified by MDOT Detroit Freeway Operations Unit (DFOU) personnel based at the MITS Center (MITSC) in downtown Detroit. These requirements identify and define system interfaces, functional processes, operational performance, system characteristics, processing resources, and logistical support which will be used as a basis for system/subsystem design and implementation. Section 4.1 summarizes the current system and resources, Section 4.2 summarizes the identified system operations, Section 4.3 contains the system requirements, and Section 4.4 contains architecture approach evaluations, and Section 4.5 documents the Baseline System Architecture.

The architecture was developed from the requirements to support effective freeway operations and to provide technological compatibility, openness, and adaptability. Commonality between requirements (functions) have been grouped into subsystems to promote synergism among operational tasks.

For the Initial Deployment option, an expansion of the current traffic surveillance and control capabilities of the current system will be the primary focus. Enhanced capabilities to provide traveler information to roadway users and other traffic centers will also be included. The Initial Deployment approach is a subset of the overall architecture to define general component-level functions, and specifies the manner in which the new corridor instrumentation interfaces with the current system and accommodates future ATMS/ATIS deployments. Requirements specifically identified for the Initial Deployment option are identified in Section 4.6.

4.1 Current Resource Usage

The Early Deployment approach concentrates on an initial deployment to expand the surveillance and control capabilities of the current system. This extension uses all in-place equipment to the maximum extent possible, modified as appropriate and includes the following:

- a. Concurrent 3280MPS processor system and existing algorithms,
- b. Vicon VPS-1300 video switcher and associated controls,
- c. Vultron CMS control console and software,
- d. DOS and GDS graphic processor subsystem,
- e. Existing cable resources.

Use of existing equipment and software does not preclude development of new interface software, addition of new features to existing software, or internal database changes

needed to accommodate an extension to the existing system. Addition of the extension utilizes current system capacities to the maximum extent possible.

As future corridor deployments begin to exceed current capabilities and capacities (and operator workload capabilities), the MITS will be upgraded and enhanced to accommodate the expanded freeway network system and streamline operator tasks and workloads.

To support the Initial Deployment program expansion, the existing CCU/RCU communications system shall be augmented, but not replaced, to accommodate the additional surveillance and control coverage. Direct extension of the CCU and RCU channel implementation will not be a requirement, and is discouraged due to potential command/response delay problems that could result in propagation delays or other communications-related problems when the physical cable/ communications path is extended beyond the current system bounds.

4.2 System Operations

Detroit Freeway Operations are managed from the MITSC located in the Greyhound Bus Building at 1050 6th Street, 2nd Floor, Detroit, MI. All freeway operation system functions are managed from the operations center.

The following describes the freeway operations capabilities to be provided by the new system (MITS). The purpose of this identification is to define the corresponding system functions required to support freeway operations. In addition, distinction between those functions or tasks performed by MITS personnel and those performed by the system can be made. From this identification, these operations can be distilled into requirement components (i.e., interfaces, functional processes, operational performance, system characteristics, system processing resources, and logistical support), to form the basis on which system/subsystem designs and implementations take their operational form; i.e., hardware, software, and support components.

The system supports three major operations (with major subtasks). These include the following:

- Traffic Management Operations
 - Manage Recurrent Congestion
 - Facilitate Incident Management

- Traveler Information Management Operations
 - Collect Traveler Information
 - Manage Traveler Information
 - Disseminate Traveler Information

- System Performance Monitoring Operations

- Monitor System Performance
- Perform Malfunction Management

4.2.1 Perform Traffic Management Operations

Traffic management encompasses a spectrum of DFO activities to minimize traffic delays and congestion; while providing improved safety, and effective utilization of roadway capacity; thus, promoting economic productivity and growth, and operational efficiency of the freeway network. Traffic management is accomplished through surveillance of mainline and surface street vehicle flow and adjustment of traffic control parameters and sequences to balance, optimize, or reroute/divert traffic flow on the metropolitan Detroit freeway network. The system manages traffic flow for both recurrent (routine congestion) and non-recurrent (incident) traffic conditions.

4.2.1.1 Manage Recurrent Congestion

Routine, recurrent traffic congestion is managed through mainline and entrance/exit ramp surveillance, ramp meter control, changeable message signing and information delivery, and area-wide coordination. Surveillance sensors collect raw traffic flow data (i.e., vehicle counts {for volume} and timing gate time differentials {for speed}) for processing into operational MOE's (average occupancy {% time detector is actuated by a vehicle}, total volume {vehicles for a given period of time}, and average speed (mph)). These MOE's are used by the system to adjust entrance ramp metering or other flow controls (e.g., moveable barriers), and display and report the freeway network status to MITS personnel through graphical displays and reports. The freeway network status is used in conjunction with information databases (i.e., CMS and HAR/AHAR) for message delivery to motorists, other TOCs, commercial dispatchers/fleets, and other roadway users via CMS, HAR/AHAR, and electronic data links. Freeway network status is overlaid, in graphical form, on an enhanced version of the current GDS map display for the entire metropolitan Detroit freeway network. These enhanced map displays include advanced graphical user interfaces (GUIs) which integrate system/subsystem-operator interfaces, and capabilities to predict traffic flow patterns (based on road closures and construction, scheduled events and activities); and calculate appropriate traffic control strategies.

- a. The current GDS platform could potentially serve as an intermediate host in parallel with an advanced GUI host for the expanded system. The advanced GUI will ergonomically integrate system displays and operator control interfaces for most system functions (traffic management operations, traveler information management operations, and system performance monitoring operations) into single operator work areas. Some tasks may still require manual attention. Operators will have the capability to cancel or override any operator-initiated commands at any time before system execution.
- b. For recurrent congestion, the system will provide the capability to "smooth" traffic flow through ramp metering, variable speed recommendations, information to motorists (i.e., congestion forewarning, approximate delay time, etc.). The system will

- use these management controls in response to the recurrent excessive volume demands on the roadway's capacity.
- c. For corridor traffic volume demands resulting from scheduled events and diversions due to planned work zones, the system will provide the capability to predict flow patterns and calculate traffic control strategies and tactics in anticipation to the increased demand or the presence of work/construction zones. These strategies and tactics include alternate routing, speed recommendations, lane control, roadway signing and ramp metering.
 - d. The system will also coordinate traffic flow throughout the geographic Metropolitan Detroit area (areawide). This coordination consists of integrated traffic information exchanges to manage traffic flow between surface arterials and the freeways and trunklines. This operation is envisioned to be accomplished between surface arterial TOCs and the MITS.

4.2.1.2 Facilitate Incident Management

Incident Management consists of a series of coordinated activities performed by various freeway operations, law enforcement, emergency service, public, private, and government agencies. Incident Management involves location detection, verification, response, removal, traffic management, and dissemination of incident information to the general public. The system provides the technological infrastructure on which DFOU personnel can effectively detect, verify, determine, respond and coordinate clearing activities, provide quick and accurate roadway incident information to motorists, and provide incident record keeping on a 24-hour, 7-day/week basis. Features to automate operator activities and tasks are facilitated by advanced GUTS. Common operator tasks are organized in a manner to minimize physical operator movement throughout the MITSC.

Application of the MDOT Incident Management Plan for Metropolitan Detroit will be supported by the system to the maximum extent possible to promote incident management coordination, reduce travel delays and potentials for secondary incidents, and improve travel safety and air quality (through minimized delays and reduced emissions). Principal incident management activities include the following:

- Incident Detection
- Incident Verification
- Response Formulation and Coordination
- Removal Coordination
- Incident Traffic Management
- Incident Information Dissemination (to motorists and others)

Incident Detection

The system facilitates detection of incidents through monitoring and processing of traffic flow MOEs (i.e., occupancy, volume, speed) along mainline corridors and interchanges.

That is, while the system calculates, monitors, and displays the different levels of traffic flow on the freeway network, an MDOT-approved incident detection algorithm measures the flow data against pre-determined thresholds and compares them to incident condition parameters. If traffic flow conditions indicate that there is an incident, the system identifies the suspected incident location (to the nearest 1/3 mile) on status display(s) and issues an alarm to the operator. The status display(s) identifies 1/3 mile segments for each instrumented mainline corridor.

Incident Verification

The system supports facilitation of incident verification tasks by providing the operator with multiple incident-reporting sources. These sources include:

- a. Identification and control of appropriate CCTV camera(s) (if available).
- b. Verification by facilitating incident correlation from multiple sources via the traffic surveillance subsystem, electronic links, or manual reports (i.e., MSP dispatcher, city police, MEP data, Metro Traffic Control, MDOT field/road crews, courtesy or service patrols, and other sources).
- c. Once the operator verifies that there is an incident (via CCTV, MSP) and declares the incident (through procedures), an electronic form is displayed and used for entries into an incident log. If correlation data is available (i.e., MEP, Metro Traffic, etc.), correlation entries will also be made available.

Response Formulation and Coordination

The system supports facilitation of incident response tasks in accordance with the approved Incident Management Plan for Metropolitan Detroit. These tasks include:

- a. If the MSP is not aware of the incident, the system offers notification assistance. If a video image is also available, the system configures appropriate video links for the MSP (or Metro Traffic Control, or other incident reporting services).
- b. If the cause of the incident can be determined, additional information is offered to the MSP (or appropriate removal agencies {i.e., courtesy patrols, towing companies, etc.}) so that appropriate removal efforts can be identified.

Removal Coordination

The system also supports coordination and execution of incident removal tasks based upon the incident cause. These tasks potentially include:

- a. Coordination with the MSP, or appropriate removal agencies, for any additional support to on-site authorities.
- b. If the cause of the incident consists of roadway debris, the system provides for notification and dispatch of MDOT agency field/road crews for removal.

- c. Provisions to coordinate and report the clearance of an incident.

Incident Traffic Management

The system provides for traffic management around incident locations by facilitating deployment of incident information to upstream motorists and activation and metering of local upstream ramps, if necessary. In addition, the system also performs the following tasks:

- a. Identification of the appropriate Incident Management Plan alternate routes (based upon the local area corridor status). Alternate routes are identified through the following priority identification criteria in accordance with MDOT criteria, AASHTO and MMUTCD engineering requirements, standards, and guidelines. Principal priority criteria (in descending order) include:
- Freeways without service drives.
 - Freeways with service drives.
 - Selected arterial surface streets.
- b. Information exchanges with arterial TOCs to adjust alternate route signal timing plans for selected arterial alternate routes.
- c. Identification of the appropriate upstream CMS locations and corridor HAR/AHAR transmitters, and selects and displays candidate CMS and/or HAR/AHAR message options to the operator. Once the operator selects and commands message deployment, the system configures the appropriate message packets, and issues the appropriate commands to the target CMS(s) or HAR/AHAR, or other ATIS functions.

Incident Information Dissemination

The system facilitates compilation of more detailed incident data, records the deployed information (i.e., CMS, HAR/AHAR, etc.) into an incident log, and provides other operator-selectable information dissemination options (i.e., fax, inter-TOC electronic links, freeway network status displays/kiosks, call-in traffic messaging systems, MEP and Metro Traffic Control communications links, etc.). Sources of incident data include:

- MDOT traffic surveillance and control system
- Michigan State Police/local city police
- MDOT field/road crews
- MEP reports
- Metro Traffic Control reports
- Manual observations from CCTV surveillance
- CB channel monitoring (i.e., CB channel 9)

Throughout activities surrounding the management of incidents, the system provides a graphical user interface (GUI) which controls and interfaces nearly all operator functions

into single-operator position(s). These functions potentially include “hands-free”, wireless telephone, radio communications, and other features to minimize operator transit within the MITSC.

4.2.2 Perform Traveler Information Management Operations

To better serve travelers using the metropolitan Detroit freeway network, traffic status and road condition information provides the motoring public informative benefits for travel decision making and route selection. Information availability leads to a more informed roadway user and potentially improves travel safety, economic productivity and efficiency, and improved environmental air quality. This service is provided in the form of travel-related information collection, management, and dissemination to freeway network users. The system supports this service through traffic surveillance and information management with technologies and techniques which provide timely and accurate information delivery to freeway users and interfacing agencies (public, commercial and private).

The system collects travel-related information from traffic surveillance capabilities and external providers (i.e., MSP dispatcher, MEP printouts, MDOT field units, other TOCs and other interfacing entities). This information includes freeway network status, roadway conditions and closures, weather conditions, and other relevant travel or traffic-related information. Relevant information is integrated, or fused, into an organized information database for monitoring, display and dissemination to roadway users and requesting entities. Dynamic traveler information dissemination techniques and technologies include roadway CMS, HAR/AHAR, video images, graphic displays, TV and AM/FM radio broadcasts, facsimile and other messages, dial-up telephone service and information delivery through third-party providers. The system provides the capabilities to collect, manage, and disseminate all relevant traffic-related information to users of the metropolitan Detroit freeway network.

4.2.2.1 Collect Traveler Information

The system collects accurate information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, work zone/construction conditions, and other relevant travel or traffic-related information for database management. The system collects this information from both infrastructure and non-infrastructure-based sources. For the metropolitan Detroit area, traffic information is generally collected from (but not limited to) the following sources:

- MDOT traffic surveillance and control subsystem
- Michigan State Police
- Local Police (cellular calls)
- Metro Traffic Control (cellular calls)
- Michigan Emergency Patrol (CB and cellular calls)
- MDOT field/road crews
- Other TOCs

- Roadway travelers/general public (cellular call-ins)
- State and local public works agencies
- Visual sighting by traffic reporting aircraft
- CB radio monitoring

4.2.2.2 Manage Traveler Information

The system integrates, or fuses, information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway conditions (i.e., work zones), and other relevant travel or traffic-related information collected from multiple sources into an organized database. Traveler information is organized (as a minimum) into four databases: Incident/Advisories; Freeway Network Status; Historical Data; and Roadway Conditions.

As with any modern information processing system, the value of the information contained on the system potentially becomes a target for unauthorized access or malicious activities. To prevent these activities from causing irreparable loss of data or service, the system monitors and controls information access to ensure data and system integrity are maintained.

DFOU personnel manage this information through administrative tasks; such as, information entry/input and archiving, database management, access management, and information system monitoring, troubleshooting, and built-in test (BIT)/built-in test equipment (BITE) diagnostic capabilities.

4.2.2.3 Disseminate Traveler Information

The system provides open and broad dissemination of traveler information through a wide variety of channels and techniques to promote travel safety and traffic flow management. Information dissemination to freeway network users can be achieved with a variety of technologies. Some of these technologies are included below:

- Roadway Signing (i.e., CMS, portable CMS, variable speed signs, fixed signs)
- Electronic Links (i.e., data links, fax service)
- Radio Frequency Broadcast (HAR/AHAR, broadcast radio (AM/FM), private radio (amateur), FM subcarrier, RDBS)
- Passive Visual Aides (printed material, broadcast TV, CATV)
- Passive Information Services (broadcast TV, remote traffic status displays - passive kiosks, broadcast radio (AM/FM))
- Interactive Information Services (call-in message service, PCS, public/office kiosks, in-vehicle guidance, computer bulletin board service (BBS), CB radio, amateur radio, modem data link, mobile data terminal)
- Third-party traffic reporting services (i.e., Metro Traffic Control, broadcast TV, CATV, and radio)

The primary objective for information dissemination is to inform freeway network users of travel and traffic conditions, preferably, to those motorists who are directly affected and can benefit from the information by altering their travel routes and/or departure times. When understanding the behavior that not all users opt to alter their travel routes even though the information is delivered, the system must still provide a level of service to achieve overall freeway network management improvements for travel safety and traffic flow facilitation. Potential users include the following:

- General Public (through broadcast TV/radio, CATV, CMS, HAR/AHAR, kiosks in major commercial centers, etc.)
- Metro Traffic Control
- Michigan Emergency Patrol
- Law enforcement/emergency services (i.e., police, fire, medical, HAZMAT, others)
- County Road Commissions/Department of Roads
- Other Traffic Operations Centers
- American Automobile Association (AAA) of Michigan
- Greyhound Bus Lines
- Detroit Department of Transportation
- SMART Regional Transit Bus
- United Parcel Service
- Commuter Transportation Service
- Other fleet services
- Third-party traffic reporting services (i.e., local broadcast TV/radio, CATV, etc.)

4.2.3 System Performance Monitoring Operations

Monitoring of system performance and system/subsystem operations is performed through on-line performance and status interrogating, health checks, and operator-commanded requests. System malfunction monitoring includes all system and subsystems functions where integrated diagnostic capabilities can identify abnormal operating states to the replaceable component level. Reports which indicate the status of functional parameters of the system or any malfunctioning subsystem component(s) are available upon operator request. These include performance reports, daily tallies, malfunction/failure logs, repair orders, etc.

4.2.3.1 Monitor Systems Performance

Monitoring of system operations provides an on-line performance assessment of MOEs for the metropolitan Detroit freeway network. This capability provides a overall performance view of the traffic control system strategies and tactics, and identifies any areas which need specific operator attention. On-line MOEs include corridor throughput/volume flow, flow speed, delay time, total travel times, total minute-miles of congestion, and other measures. Through data reduction, other MOEs (e.g., accident rate reduction, number/percentage of stopping flow, etc.) can be derived to further assess

system performance. Single-position operator workstations provide MITSC personnel the capability to operate and monitor system operations and performance.

4.2.3.2 Perform Malfunction Management

A system malfunction management capability provides the operator with on-line system monitoring, diagnostics, and record keeping to determine the extent of system malfunctions and failures. All system or subsystem functions provide a level of status which identifies their health. When a malfunction or component failure occurs, the system or subsystem status monitoring function determines the nature of the problem and isolates the level (to the replaceable component level), generates a malfunction or failure message, and displays an indicator at the MITSC to capture the operator's attention. Capabilities to interrogate and diagnose system/subsystem components are also operator-commandable from the MITSC or local on-site. Record keeping of malfunctions and repairs are integrated into the system through a maintenance log. Information contained in the log include system/subsystem failure reports, work orders, maintenance forms, repair status and disposition.

4.3 System Requirements

Primary operations considered for this system consist of traffic management, traveler information management, and system monitoring. The system shall support these operations through the following major functions:

- Perform Traffic Network Surveillance and Control
- Display Traffic Network Status
- Perform Traveler Information Management
- Perform System Performance and Status Monitoring

The operational needs and objectives are analyzed to identify system requirements. System requirements identify the functions and characteristics which form the basis on which the system hardware, software, and operations and maintenance (O&M) support are designed or specified. In general, functions specify the "tasks" performed by the system, where characteristics specify the design attributes reflected in the system hardware, software, and support components. These categories are listed below:

- System Interfaces
- Functional Processes
- Operational Performance
- System Characteristics
- System Processing Resources
- Logistical (Operations and Maintenance) Support

To develop a Baseline Architecture, system interfaces, functional processes, and operational performance were the primary considerations used to develop the functional and communication allocations which form the underlying architecture framework.

System characteristics, processing resources and logistical support provide the specific design criteria from which the system is constructed.

4.3.1 System Interfaces

System interfaces consist of DFOU operators and maintenance personnel, external government agencies, external commercial and private businesses, the travelers or users of the freeway network, the current traffic surveillance. Control and communications subsystems, and the local metropolitan Detroit freeway network and environment. Interface descriptions include the entity and the type of information, transferred (i.e., network status, traffic coordination information, incident information, physical features, environmental effects, etc.). Figure 4-1 illustrates a top-level interface diagram which provides a “context” in which these external interfaces interact with the system.

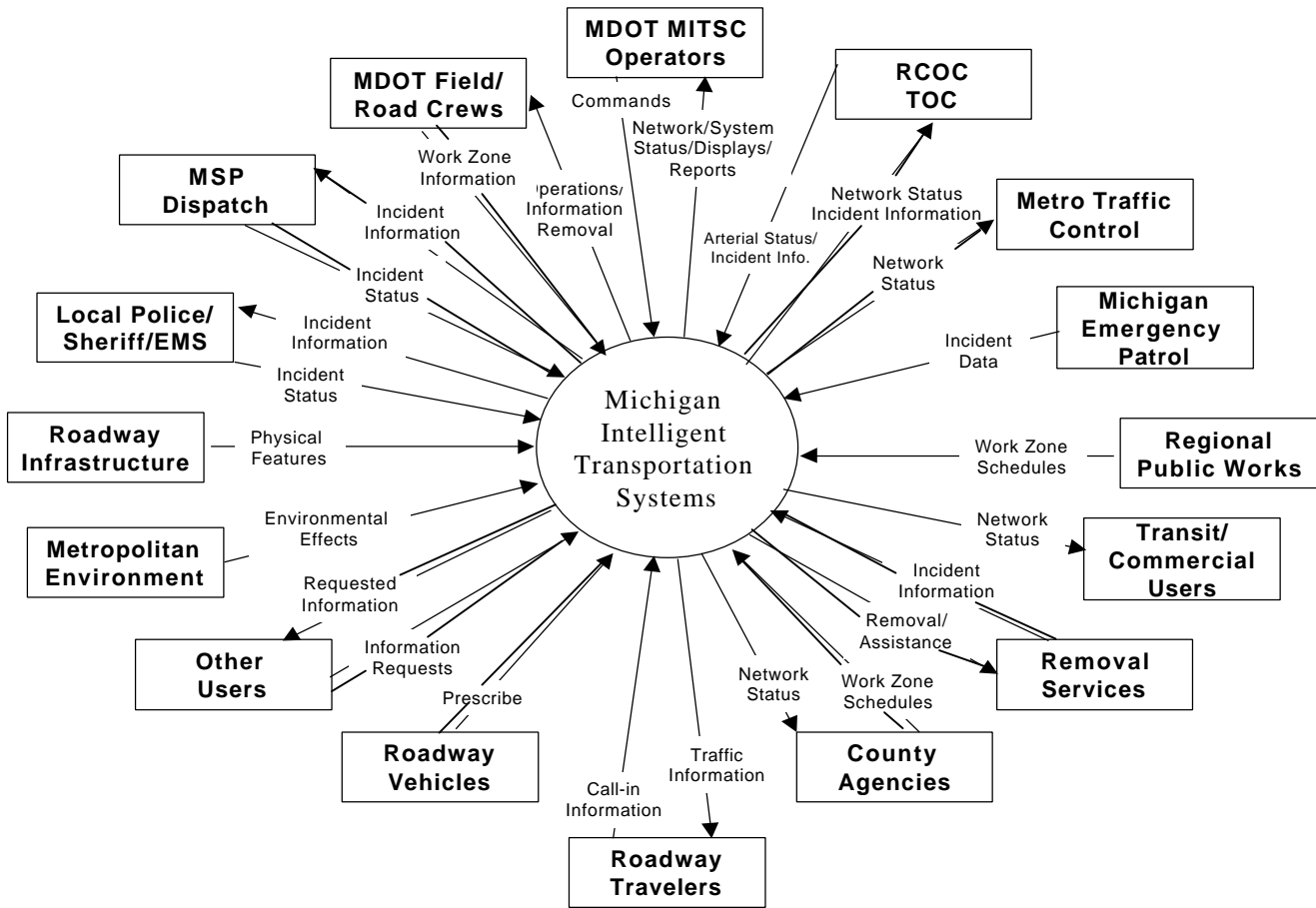


Figure 4-1. Top-Level System Interfaces.

4.3.1.1 MITSC Personnel Interfaces

MITSC operator interfaces provide system commands, freeway network status displays and reports, and system status displays and reports.

DFO maintenance/road crews provide an interface for operations information, maintenance information, and work zone information.

4.3.1.2 External Government Agencies

Federal government agencies include the US Department of Transportation (USDOT) Federal Highway Administration (FHWA) and the United States Border Patrol.

State government agencies include the Michigan Department of Management and Budget, Michigan Department of Transportation - Highway Maintenance Division, and Michigan Department of Transportation - District Maintenance, Freeway Lighting.

Law enforcement/emergency services include Michigan State Police (MSP), various County Sheriff/Fire Departments (and Rescue, etc.), and various Local City Police/Fire Departments (and Rescue, etc.), Emergency Medical services, serving the counties and cities of the following:

Counties

- Macomb County
- Monroe County
- Oakland County
- Wayne County

Cities

- Auburn Hills
- Bloomfield Hills
- Dearborn
- Detroit
- Farmington Hills
- Ferndale
- Flat Rock
- Hazel Park
- Huntington Woods
- Lincoln Park
- Livonia
- Madison Heights
- Mt. Clemens
- Oak Park
- Pontiac
- Romulus
- Roseville
- Royal Oak

- Southgate
- Woodhaven

County Agencies include the following:

- Various County Road Commissions/Department of Roads
- Southeast Michigan Council of Governments (SEMCOG)
- Other Traffic Operations Centers
- Wayne County Departments
- Monroe County Departments
- Macomb County Departments
- Oakland County Departments
- Various City/County Public Works Departments (e.g., power & lighting, water, refuse, etc.)
- Detroit Metropolitan Wayne County Airport

City Departments include the following:

- City of Detroit Department of Transportation
- Public Works (e.g., power, public lighting, water, refuse, etc.)
- Other city departments

4.3.1.3 External Commercial and Private Entities

Public Utilities include Detroit Edison Company, Michigan Bell/Ameritech Telephone Company, Consumers Power Company, and various cable television companies (i.e., Continental Cable, etc.).

External commercial and private entities include Metro Traffic media services, American Automobile Association (AAA), United Parcel Service (UPS), Michigan Emergency Patrol, Other fleet services, and third-party traffic reporting services (i.e., broadcast TV/radio - WDIV, WJR, CATV, etc.).

Removal Services include MDOT-contracted towing service providers and courtesy patrols.

Transit services include Greyhound Bus Lines, Smart Regional Transit Bus, Commuter Transportation Service.

4.3.1.4 Freeway Network Users

Roadway travelers using the freeway network include the general public, commercial users, and other users.

Roadway vehicles include passenger cars, commercial trucks, transit vehicles, and motorcycles.

4.3.1.5 Roadway infrastructure

Roadway infrastructures include roadway features, bridges/overpasses, conduit structures, electrical power, and lighting.

4.3.1.6 Local Metropolitan Detroit Freeway Environment

All fielded subsystem equipment and components shall provide protection features against the local metropolitan Detroit urban environment. Equipment and components to be procured shall make maximum use of readily available, multiple source, commercial off-the-shelf (COTS) equipment.

- a. General environment: System components shall be designed to function year-round (i.e., rain, ice, snow, etc.) in the local metropolitan Detroit urban environment. These components shall be modular in design, promote ease of maintenance, and include integrated environmental conditioning features (i.e., defogger, cooling, etc.).
- b. Outside Ambient Air Temperature (operation or storage): -25°F to +140°F (-32°C to +60°C).
- c. Humidity: up to 95 percent, non-condensing.
- d. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in the fielded configuration.
- e. Radio Frequency Interference RFI/Electromagnetic Interference (EMI): All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI which will interfere with other MITSC and localized fielded equipment.
- f. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment.
- g. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and the local metropolitan Detroit weather conditions.

4.3.2 Functional Processes

The system shall perform the following functional processes to support freeway operations in the metropolitan Detroit area.

- Perform Traffic Network Surveillance and Control
- Display Traffic Network Status
- Perform Traveler Information Management
- Perform System Performance and Malfunction Monitoring

The existing system shall be an integral part of initial new system deployments. The new system shall interface with existing equipment through currently available channel and processing capacities. In general, new subsystem equipment and components will provide capabilities to communicate with both the existing and new systems through industry-standard interfaces (i.e., NEMA, EIA, CCITT, SAE, ANSI, VME, SCSI, NTSC, etc.). The current infrastructure and equipment will be maintained as the primary system for the Early Deployment corridor. Current MJTSC operator interfaces will be augmented (where needed) to manage traffic operations capabilities for the new corridor (i.e., network status displays, ramp control, etc.).

Subsequent deployment phases shall utilize the existing system to the maximum extent possible for continued operations in concert with new system and subsystem equipment. DFOU operation of both systems shall be integrated to minimize differences in operator interface(s) and tasks. As new freeway corridors are instrumented and brought on-line, corresponding operator interfaces shall also be integrated and reflect the additional system capabilities.

4.3.2.1 Perform Traffic Network Surveillance and Control

The system shall provide DFOU personnel the capability to perform recurrent and non-recurrent traffic congestion management through mainline flow surveillance, mainline flow control, coordination of incident management tasks, and area-wide traffic coordination. Additionally, the system shall have the capability to manage mainline work zones, and calculate mainline volume demand and predict traffic flow patterns for scheduled events, planned work/construction zones, and other special events. Specific functional and performance requirements are specified in the following paragraphs. Table 4-1 identifies the designated mainline corridors (freeway network) for traffic surveillance and control.

Table 4-1. Freeway Corridor Priorities

Corridor Description	Priority Corridor	Begin Point	End Point
1	I-75 Chrysler	I-94 Ford	9 Mile Rd.
2	I-696 Reuther	US-24 Telegraph	I-75 Chrysler
3*	I-94 Ford	Wyoming I-96	Moross Rd.
3	I-696 Reuther	I-75 Chrysler	I-94 Ford
4	I-696 Reuther	Jefferies Ave.	US-24 Telegraph
5	I-96 Jefferies	I-75 Fisher	I-275/M-14
6*	I-75 Chrysler	I-375	I-94 Ford
7	I-75 Chrysler	9 Mile Rd.	to Pontiac, MI
8	M-39 Southfield	I-75 Fisher	M-10 Lodge
8	I-275	M-14	M-102
9*	M-10 Lodge	Jefferson Ave.	Greenfield Rd.
10	I-75	I-96 Jefferies	I-275
10	M-10 Lodge	Greenfield Rd.	I-696 Reuther
11	I-94 Ford	Moross Rd.	M-19
12	I-94 Ford	Wyoming Ave.	I-275
13	Davison Freeway	M-10 Lodge	I-75 Chrysler
14*	I-375	Jefferson Ave.	I-75 Chrysler
15	I-275	I-75 Fisher	I-96/M-14
16	M-59 Auburn/Hall Rd	BR-24	M-53

* - current SCANDI corridors

4.3.2.1.1 Perform Mainline Flow Surveillance

The system shall perform mainline traffic flow surveillance for the designated corridors in the metropolitan Detroit area. The system shall perform the following functions:

- a. Calculate Corridor MOEs. The system shall have the capability to capture vehicle presence counts and detection time differentials (speed traps) for passenger cars; commercial vehicles; transit vehicles; motorcycles; and other roadway vehicles.
 - 1. Vehicle detection points (stations) along the mainline corridor(s) shall be separated by roadway distances of 1/3 mile increments plus or minus 10%. If roadway characteristics in certain areas preclude using this increment tolerance, the next available location shall be selected.
 - 2. Vehicle detection stations shall be located immediately upstream of mainline entrance ramps in accordance with MDOT standards. These stations shall provide traffic flow data to determine ramp metering activation and metering rates.
 - 3. Vehicle detection points (stations) for mainline entrance and exit ramps shall conform to MDOT standards for ramp queue, demand, and passage locations, merge occupancy, and corresponding mainline locations to detect and calculate upstream demand and downstream capacity.
 - 4. System vehicle detection accuracy shall be within 10% of actual vehicle counts. Performance is based upon MDOT metering activation/deactivation threshold levels.

- b. Calculate Corridor MOEs. The system shall compute mainline corridor MOEs (average occupancy, total volume, and average speed) from collected vehicle detection data for each detection station.
- c. Perform Incident Detection. The system shall utilize an MDOT-approved incident detection capability to identify potential mainline capacity-reducing non recurrent incidents.
- d. Manage Corridor MOEs. The system shall maintain traffic flow MOE's in an integrated freeway network status database. This information shall be made available for use with other traffic operations functions (i.e., area-wide traffic coordination, work zone management, traffic demand management and flow prediction, incident management, and traveler information dissemination).
- e. Display Corridor MOEs. Mainline corridor MOE data shall be made available for freeway network status displays, entrance ramp status displays, information management, and other DFO activities.
- f. Collect Video Images. The system shall capture NTSC broadcast quality color or black and white TV video images at identified locations along mainline freeway corridors and communicate images and control data to the MITSC for traffic flow assessments and incident verification by DFOU personnel.
 - 1. Full color (daylight)/low light black and white (dawn/dusk/night) capability: 0.1 lux (1.0×10^{-2} FC)
 - 2. Automatic/manual bright/low light compensation and transition
 - 3. Image resolution (minimum): 500 lines horizontal, 400 lines vertical
 - 4. Lens system: Minimum 6: 1 image zoom ratio with a minimum angular field of view of 20° horizontal (15° vertical) at the wide angle position at f1.2, with manual focus, remotely controlled.
 - 5. TV video image resolution and modulation shall be compatible with NTSC TV standard.
 - 6. TV video image modulation shall be compatible with current MITSC TV monitors.
 - 7. Platform mounting shall allow for attachments to poles, buildings, on/under bridges, or other roadway fixtures.
 - 8. Deployed cameras shall be mounted in locations which provide effective viewing of the freeway segment under surveillance. Viewing height shall be a minimum of 40 ft above the roadway surface and minimize occlusion effects of roadway overpasses and curves.
- g. Control Video Images. The system shall provide remote video image viewing control from the MITSC. Control functions shall include the following:

1. Remote control viewing direction (i.e., horizontal pan and vertical tilt) and image quality (i.e., focus, color, zoom, intensity, etc.) adjustments shall be provided.
 2. Video camera platforms shall provide pan-tilt mounting surfaces. Specifications for the pan-tilt platforms shall be:
 - Rotation: Pan: 0 to 355 degrees
 - Tilt: +/-90 degrees horizontal.
 - Speed: 3 to 11 degrees/second
 3. Pan and tilt stops to prevent over rotation.
 4. Automatic or manual camera(s) selection control.
 5. Manual his control (light intensity control).
- h. Display Video Images. The system shall capture video images for viewing at the MITSC (and other locations). The system shall also accept video images from external sources (i.e., RCOC TOC, Metro Traffic Control, local TV stations {e.g., WDIV, WJR}, etc.)

4.3.2.1.2 Perform Mainline Flow Control

The system shall control mainline traffic flow through adaptive entrance ramp management and traffic flow diversion techniques (e.g., message signing, variable speed, lane signing).

- a. Determine Ramp Control Mode. The system shall support the following ramp control modes: clear mode; rain/wet mode; and snow/ice mode. These modes are defined as follows:
 1. Clear mode - normal mode of operations.
 2. Rain/Wet mode - pre-defined metering rates to account for hazardous roadway conditions.
 3. Snow/Ice mode - ramp metering is disabled.
- b. Provide Ramp Metering Options. The system shall support the following ramp metering modes: pre-timed metering (i.e., operator-defined TOD); and traffic-responsive (adaptive) metering, and occupancy mode metering.
 1. Pre-timed metering mode provides ramp metering with predefined metering parameters (i.e., activation thresholds or time-of-day metering rates, etc.)
 2. Traffic responsive metering mode provides ramp metering with adaptive activation in response to mainline MOEs.
 3. Occupancy mode metering mode provides activation/deactivation based upon mainline occupancy. Default activation/deactivation is TOD (due to local gore detector failures).
- c. Provide Ramp Metering Activation Control. The system shall provide the capability to perform entrance ramp metering control. Mainline traffic flow surveillance (detection

stations) immediately upstream and downstream from an entrance ramp shall support ramp metering control functions.

1. Mainline surveillance MOEs (ave. occupancy, total volume and ave. speed) and ramp exit vehicle counts shall be collected to determining ramp meter activation and metering rates.
 2. The system shall activate ramp metering by time-of-day scheduling; response to mainline gore MOEs (traffic-responsive and occupancy thresholds); or, DFOU operator command.
 3. The system shall provide the capability to set ramp meter activation and metering rates via local, on-site control; corridor processor (for integrated ramp control), or remote download from the MITSC under system or operator control.
- d. Provide Ramp Control. Entrance ramp control stations shall provide the following vehicle control capabilities in accordance with established MDOT standards:
1. The system shall determine ramp metering rates by manual operator presets; or, calculated from mainline MOEs (e.g., upstream demand/downstream capacity).
 2. The system shall support metering rates of 240 vehicles-per-hour (4 vpm) to 900 vph (15 vpm) for single lane ramps. Metering adjustment capabilities to support two-lane ramps shall also be provided.
 3. Advanced ramp control warning indicator for ramp meter operation.
 4. Vehicle queue detection
 5. Vehicle demand (checkin) detection
 6. Vehicle passage (checkout) detection
 7. Vehicle merge lane occupancy (where possible)
 8. Two-section ramp meter signal indicator for ramp traffic control.
 9. Exit ramp vehicle detection
- e. Provide Integrated Corridor Ramp Control. The system may support enhanced capabilities to perform integrated ramp control for designated ramps along a mainline corridor segment. This capability provides integrated ramp control along a designated corridor roadway. Coordinated ramp metering is conducted in sequence using upstream demand and metering data, and downstream capacity along a designated corridor length.
- f. Display and Control Changeable Messages. The system shall provide a variable roadway signing capability which supports display of traffic diversion/status information for routing of traffic flow onto alternate mainline or trunkline corridors. Traffic diversion shall be accomplished through variable signing (i.e., CMS, HAR/AHAR, speed, lanes). Corridor and status-specific messages shall be developed using MDOT-approved criteria and stored in a message database. Due to sensitive legal, operational, and jurisdictional issues, the system shall protect the database against unauthorized access and modification.

4.3.2.1.3 Facilitate Incident Management Tasks

The system shall facilitate operator actions for logical decision making and integrate execution of the following incident management activities: incident detection, operator verification and declaration, response, removal, and traffic coordination, information dissemination, and incident log record keeping in accordance with the approved Incident Management Plan for Metropolitan Detroit. The system shall provide the capability for the operator to cancel or override any system command at any point in the process, and manually operate the system.

- a. Perform Incident Detection. The system shall process and measure data (MOEs) collected from roadway traffic surveillance sensors against MDOT-established incident thresholds and check for potential incident conditions using a MDOT-approved incident detection algorithm.
 1. The system shall identify a potential incident within 30 seconds after the receipt of the collected surveillance data.
 2. The MDOT-approved incident detection algorithm shall be capable of identifying potential incidents (minimum 60% detection rate) from the traffic flow data collected from the surveillance sensors with relatively low number of false alarms (0.1%).
 3. If traffic flow conditions (multiple detection stations) and the incident detection algorithm indicate that a potential incident exists, the system shall issue an incident alarm indicator to capture the operator's attention for subsequent actions.

- b. Provide Incident Verification. The system shall provide operator-preferred verification methods. At a minimum, the system shall provide the capability to graphically identify and display incident locations on the freeway network map and configure appropriate CCTV camera(s) and video images corresponding to the identified incident location. The system shall assist the operator to correlate incident reports with incident information. The system shall support facilitation of other verification methods to the maximum extent possible in accordance with the approved Incident Management Plan for Metropolitan Detroit.

- c. Record and Manage Incident Information. System-assisted incident declaration and record keeping shall be stored in an incident database and include the following:
 - Date of the incident
 - Time start/declaration
 - Severity level
 - Time cleared

- Location (freeway, direction, lane [lane #, shoulder, median, ramp], nearest cross-street or fractional mile marker)
 - Incident category (accident, debris, fire, stalled vehicle, flood, other)
 - Number of vehicles involved
 - Truck involved?
 - Incident remarks and comments
 - Incident response actions employed (i.e., notification, traffic controls, etc)
 - Logging operator
- d. Facilitate Incident Notification. The system shall assist the operator to notify the Michigan State Police dispatcher and to inform other traffic-related agencies and organizations. These tasks include:
1. Contact with MSP dispatch center. If the MSP is not aware of the incident, the system shall facilitate notification assistance. Information for notification and transmission methods includes:
 - Incident location via available communications media (i.e., telephone, fax, graphical display, CCTV video image, etc.)
 - Additional information such as diagnosis of the incident cause.
 2. If a video image is available, the system configures the appropriate video links for transmission to the MSP dispatch post, Metro Traffic Control, and other capable incident reporting services.
- e. Facilitate Incident Response and Coordination. The system shall support incident removal through communications and coordination with the MSP, on-site authorities, MDOT field crews, and emergency and removal services. The system shall facilitate operator monitoring response and coordination
- f. Perform Incident Traffic Management. The system shall provide traffic management controls for the incident location. The system shall prepare information and system controls for traffic diversion around the incident (where possible) through alternate route information delivery, metering controls, and other techniques in accordance with the approved Incident Management Plan for Metropolitan Detroit.
1. The system shall identify appropriate Incident Management Plan alternate routes (based upon the local area corridor status).
 2. The system shall identify appropriate upstream roadway signing locations, corridor HAR/AHAR transmitters, metered ramps, and other traffic controls for operator option selection(s).
 3. The system shall select and display candidate roadway signs, HAR/AHAR messages, system-calculated metering rates, and other control options for operator-commanded selection and deployment. These message options shall be displayed to the operator for final selection and operator-commanded deployment. Once selected and commanded, the system configures the appropriate message packets to the selected target traffic management controls.

- g. Disseminate Incident Information. The system shall facilitate information dissemination through available information dissemination links. These links include roadway message signing, in-vehicle delivery, freeway network status update and delivery to interfacing information agencies, and other dissemination channels.
1. Once detailed incident resolution information is compiled, the system shall record the deployed information (i.e., CMS, HAR/AHAR, etc.) into the incident log and action database.
 2. The system shall provide operator-selectable information dissemination options (i.e., fax, inter-TOC digital links, graphical status displays/kiosks, etc.) for information delivery.
 3. Upon operator command, the system shall notify other traffic-related or emergency agencies through real-time communications media (i.e., telephone, **fax**, graphical display, CCTV video, etc.). Potential agencies include:
 - Michigan State Police
 - Michigan Emergency Patrol
 - Metro Traffic Control
 - Radio traffic reporting services
 - Local Police/Sheriff
 - Local road agencies (per incident jurisdiction)
 - Medical emergency services
 - Hazardous Material (HAZMAT) services
 4. The system shall also provide alternate routing information for other traveler information agencies. This information could be potentially used for:
 - Alternate route development and planning
 - Alternate route message deployment, where possible
 - General public education on alternate routes
 - Coordination with local police/sheriff and road agencies

4.3.2.1.4 Perform Area-Wide Traffic Coordination

The system shall provide MITSC personnel the capability to coordinate freeway network status/traffic flow and incident data and traffic control data for the greater metropolitan Detroit freeway network with other transportation centers (TOCs) in the three-county area (Wayne, Macomb, Oakland) through information and data exchanges. Expansion to include the five-county area (Wayne, Macomb, Oakland, Washtenaw, Monroe) is envisioned in subsequent phases.

- a. Exchanged traffic data includes video images, and digital, electronic, facsimile, and graphical formats.
- b. Exchanged control data includes recommendations for metering and arterial signal timing cycles/offsets.

4.3.2.1.5 Perform Work Zone Management

The system shall provide MITSC personnel the capability to configure traffic management controls to account for work zones, temporary roadway impairments, and roadway closures.

- a. The system shall collect and manage schedule information for use with freeway network surveillance and control, area-wide traffic coordination, traffic demand management and flow prediction, incident management, and traveler information dissemination.
- b. The system shall accept schedule information from manual operator inputs or formatted electronic media.

4.3.2.1.6 Perform Demand Management

The system shall provide MITSC personnel the capability to develop demand and flow controls (metering) based upon traffic demands detected from mainline gore occupancies. Demand management capabilities include:

- a. Modeling and predicting traffic flow patterns based upon known demand generator locations, incidents, and scheduled events, and reductions in roadway capacity due to scheduled roadway construction or maintenance events.
- b. Storage of results for use with traffic surveillance and control, area-wide traffic coordination, work zone management, incident management, and traveler information dissemination functions.

4.3.2.2 Display Traffic Network Status

The system shall display a graphical representation of the current corridor mainline traffic flow network status of the metropolitan Detroit freeway system. These displays shall include mainline MOE status, mainline interchange status, ramp metering at entrance ramps, and corresponding exit ramps (if applicable).

- a. The system shall support display of a minimum of three hierarchical views. These views will be hierarchical in the sense that the operator can view the entire freeway network, an operator-selected subnetwork, or a specific mainline or entrance ramp interface (i.e., ramp status, metering control, MOEs, and reports) in a single view, as a minimum. These views shall each be capable of occupying the entire graphical display area. The system shall also provide a windowing capability to display multiple subnetwork views within a single display. The full mainline freeway network view shall be the default view.
- b. Resolution of the graphics display area shall be a minimum of 1024 x 768 pixels and support a simultaneous display of at least 16 colors.

- c. The network status shall consist of different contrasted color levels which represent different levels of traffic occupancy for each mainline detection station segment. These levels shall be consistent at all view levels. Except for the full network view, the displays shall also include volume and speed indicators for each detection station segment. Color representations for occupancy levels are specified in Table 4-2.

Table 4-2. Graphic Display Status Definitions

Display Color	Occupancy (%)	Volume (veh/min)	Speed (mph)	Equipment Icon Status
Green	0-9	0-9	over 49	All Operational, On-line
Yellow	10-14	10-19	34-49	Partially Operational, On-line
Orange	15-20	20-29	20-33	
Red	over 20	over 29	0-19	Non-Operational, On-line
Grey	-	-	-	Off-line

- d. Network status information shall have a data latency no greater than 1 minute.
- e. The system shall also support views of other system operations displays, such as those for:
 1. Subsystem control (i.e., video camera control, video monitor switching, CMS control and verification, HAR/AHAR control, etc.)
 2. Incident management and coordination (i.e., incident location tagging, reports, and untagging)
 3. System performance monitoring
 4. System malfunctions
 5. Information management and dissemination
 6. System administration, archiving, audits, and record keeping
 7. Surface street operations (i.e., intersection controller status (graphic of intersection traffic flow) and control, surface street CCTV image, and surface street/freeway ramp coverage { CCTV, sensors, etc.}).

4.3.2.3 Perform Traffic and Traveler Information Management

The system shall collect relevant travel-related information from system traffic surveillance capabilities and external providers. This information shall be integrated, or fused, into an organized information database for monitoring and dissemination to roadway users and requesting entities. Dynamic traveler information dissemination techniques and technologies shall provide the capability to deliver relevant travel-related information to users of the metropolitan Detroit freeway network. These techniques and technologies include roadway signing (i.e., CMS, HAR/AHAR, speed, etc.), electronic data links (i.e., modem, fax, video), and graphical displays of the freeway network status.

4.3.2.3.1 Collect Traffic and Travel Information

The system shall collect accurate information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway conditions (i.e., work zones), and other relevant travel or traffic-related information for database management. The system shall collect this information from both infrastructure and non-infrastructure-based sources.

For the metropolitan Detroit area, traffic information is generally collected from (but not limited to) the following sources:

1. Metropolitan Detroit traffic surveillance system
2. Michigan State Police
3. Michigan Emergency Patrol
4. MDOT divisional field units
5. Other TOCs
6. Roadway travelers/general public (cellular call-ins)
7. State and local public works agencies

4.3.2.3.2 Manage Traffic and Travel Information

The system shall provide information management for all traveler-related data. The system shall organize the collected information for storage, viewing on system displays, and dissemination to freeway network users.

- a. The system shall integrate, or fuse, collected information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway conditions (i.e., work zones), and other relevant travel or traffic-related information collected from multiple sources into organized databases. Candidate databases include:
 1. Traffic Surveillance
 2. Traffic Control
 3. Traffic Demand
 4. CMS Message
 5. Communications Link Management
 6. Incident Log
 7. Traffic Network Status
 8. Historical Data
 9. Roadway Conditions
 10. System Map Data
 11. System Status Data
- b. The system shall store the information in a manner which can be retrieved for viewing on system displays and dissemination to users.

- c. The system shall monitor and control information access to ensure data and system integrity are not corrupted or compromised. The system shall manage information for administrative tasks, such as, information entry/input and archiving, database management, access management, and information system monitoring, malfunction troubleshooting, and built-in test (BIT)/built-in test equipment (BITE) diagnostic capabilities.

4.3.2.3.3 Disseminate Traffic and Travel Information

The system shall disseminate traffic and travel information to the general public, government agencies, transit services, requesting users, media reporting services, and other roadway users. Information dissemination and access to users shall be accomplished through roadway signing (i.e., CMS), HAR/AHAR transmissions, electronic data links (i.e., modem, fax, video), and graphical displays of the freeway network status.

- a. Provide Dissemination and Access Control. The system shall disseminate and allow access to traffic and travel information in primarily three modes: dissemination to roadway users through system facilities; dissemination and access to government agencies and users; and dissemination and access to requesting entities. The system shall monitor and control information access and integrity to prevent corruption and destruction of system information, facilities, and resources. The system shall provide simultaneous operation of the dissemination and access modes.
 - 1. The system shall disseminate traffic and travel information to roadway users through system-operated dissemination media (i.e., CMS, HAR/AHAR, public kiosks, etc.).
 - 2. The system shall disseminate and allow access of traffic and travel information to government agencies and user through interagency communications media (i.e., electronic links, video links, facsimile, voice, data, etc.).
 - 3. The system shall disseminate and allow access of traffic and travel information to requesting entities through system-operated and third-party dissemination media (i.e., Metro Traffic, local TV, CATV, and radio, call-up telephone, etc.).
- b. Support Information Clearinghouse Activities. The system shall support information management and coordination capabilities for a traffic and travel information clearinghouse. Through these capabilities, the system shall provide open and broad dissemination and access of traffic and travel information through a wide variety of methods and delivery channels. Candidate methods and channels are listed below:
 - 1. Roadway Signing (i.e., CMS, portable CMS, variable speed signs, fixed signs)
 - 2. Electronic Links (i.e., data links, fax service)
 - 3. Radio Frequency Broadcast (HAR/AHAR, commercial AM/FM radio, private radio (amateur), FM subcarrier, RDBS, CB radio)
 - 4. Passive Visual Aides (printed material, commercial TV, CATV)

5. Passive Information Services (commercial TV, remote traffic status displays – passive kiosks, commercial AM/FM radio)
6. Interactive Information Services (call-in message service, PCS, public/office kiosks, in-vehicle guidance, computer bulletin board service (BBS), CATV, CB radio, amateur radio, modem data link, mobile data terminal)
7. Third-party traffic reporting services (i.e., Metro Traffic Control, MEP, commercial TV, CATV, and commercial AM/FM radio)

4.3.2.4 Perform System Performance and Malfunction Monitoring

The system shall monitor operational performance and system / subsystem status operations through on-line interrogation, health checks, and operator-commanded requests. The system shall monitor detectable malfunctions in all system and subsystems functions and components. These functions and components shall integrate diagnostic capabilities which identify abnormal operating states to the replaceable component level. Reports which indicate the status of functional parameters of the system or any malfunctioning subsystem component(s) shall be available upon operator request. These include performance reports, daily tallies, malfunction/failure logs, repair orders, etc.

4.3.2.4.1 Monitor Traffic Network Performance

The system shall monitor traffic network to ensure proper and effective traffic controls promote travel mobility. The system shall perform on-line operational performance assessments of MOEs for the metropolitan Detroit freeway network. This capability shall provide a overall performance view of traffic control system strategies and tactics to optimize traffic flow controls, and identify any operational function which may need specific operator attention. On-line MOEs include corridor throughput/volume flow, flow speed, delay time, total travel times, total minute-miles of congestion, and other measures. Through data reduction, other MOEs (e.g., accident rate reduction, number/percentage of stopping flow, etc.) may be derived to further assess system performance. Single-position operator stations shall provide MITSC personnel the capability to operate and monitor integrated system operations and performance.

4.3.2.4.2 Perform System Malfunction Monitoring

The system shall integrate malfunction monitoring, reporting, and diagnostics functions. As a minimum, failures and malfunctions shall be reportable to the lowest replaceable component level (i.e., mainline detectors, ramp controllers, etc.). Failure and malfunction status shall be maintained and dispositioned for appropriate action. Failures and malfunctions shall also be reported on the system map display in accordance with Table 4-6.

4.3.2.4.2.1 Perform Routine Status Monitoring

The system shall monitor system operations for malfunctions or abnormal conditions or states through built-in test (BIT) during startup (power-on) and routinely during

operations (background processing). The system shall provide the DFOU operator with an integrated, on-line system monitoring, diagnostic trouble shooting, maintenance management, and record keeping for system malfunctions and failures. All system or subsystem functions shall determine and provide health status to the MITSC.

4.3.2.4.2.2 Determine System Malfunction

When a malfunction or component failure occurs, the system monitoring function shall determine the nature of the anomaly and isolate the level to the replaceable component level, generate a malfunction or failure message, and display an indicator at the MITSC to capture the operator's attention. The system shall provide the capability to interrogate and diagnose system/subsystem components upon operator command from the MITSC or locally on-site. The system shall maintain record keeping information of malfunctions and repairs in a maintenance log. This information shall include system/subsystem failure reports, work orders, maintenance forms, repair status and disposition.

4.3.3 Operational Performance

The approach used in these assessments consist of a logical framework of analyses to define low-level performance and timeline requirements which are used to provide a basis to partition and organize functional processing and communication requirements into a system architecture.

Specifically, this assessment framework consists of a series of supporting analyses which, individually, define detailed functional performance requirements for specific processing tasks/aspects of the traffic management and information systems, and collectively determine performance interdependencies between processing tasks. The individual requirements are analyzed and correlated to identify interdependencies between tasks and whether these interdependencies directly influence performance aspects of the operational system. These interdependencies are then used to determine appropriate operational and cost-efficient performance ranges.

Functional performance and timeline requirements are derived from analyses of freeway traffic surveillance and control operations, incident management operations, and techniques used in the management and dissemination of traffic information. Traffic management objectives and philosophies adopted by the MDOT Detroit Freeway Operations Unit will be used as the model to conduct these assessments.

Minimum, or worst case, performance requirements are defined through analysis and correlation (and parametric studies) of operational system capabilities and traffic flow behavior (e.g., nominal traffic flow relationship models and observed incident flow characteristics) to establish performance baselines. These baselines will be used to establish interdependencies between performance parameters; such as, vehicle presence detection and accuracy, MOE processing timelines supporting incident detection, mainline ramp control, freeway network status displays, and traffic network performance evaluations. Cost considerations in terms of loss of operations fidelity, equipment

required, communication timeline Penalties and constraints, and corresponding architecture constraints are also examined.

These assessments correlate performance requirements and functional processes with functional allocations and partitions in order to specify operationally-efficient subsystem groupings. These subsystem groupings and their interdependencies are then configured into a system architecture (framework). This architecture configuration provides a high-level, functional baseline or point of departure (POD) design basis where more detailed subsystem, interface, and communications designs and implementations can be defined and developed. Functional allocations and partitions are used to balance operational effectiveness and cost-efficiency drivers, while incorporating MDOT-desired architecture attributes (i.e., flexibility, adaptability, and operations efficiency). Application of “functional modularity” and interface standardization helps to promote interchangeable, modular design implementations.

The following specific performance analyses were conducted and are summarized in the following paragraphs. Full analysis details are contained in Appendix IV.

Traffic Surveillance Performance

- Traffic Flow Sensor Adequacy Analysis
- Vehicle Presence Collection Performance Analysis
- Traffic Surveillance/Incident Detection/Control Period Analysis
- MOE Monitoring and Display

Traffic Control Processing Performance

- Entrance Ramp Control Performance
- Mainline Control Performance
- Integrated Corridor Control Performance

Information Management and Dissemination Processing

- Traffic and Travel Information Collection
- Traffic and Travel Information Organization and Management
- Traffic and Travel Information Dissemination and Control

System Monitoring Performance

- Equipment/System Health and Status Monitoring
- Traffic Flow Performance Monitoring

4.3.3.1 Traffic Flow Surveillance Performance

Traffic flow surveillance provides critical information for effective traffic management. Not only does surveillance provide current flow conditions necessary to assess roadway status for incident detection, traffic control, or other functions, it also provides a feedback capability to assess the effectiveness of deployed controls and traffic network performance along monitored traffic corridors. The fidelity of surveillance data (MOEs) depends upon

the application for which it is used. MOEs can be obtained for a single lane of traffic flow to monitor and control mainline ramps, or averaged over multiple lanes to yield surveillance zone “**averages**” for network statusing traffic flow characteristics and throughput at a particular detection station. Care must be taken to define the methods and data collection frequency used to derive these MOEs so that accurate flow conditions are represented and collection cycles are balanced with system operations, capacities, and resources. Adherence to maintaining system operational effectiveness and cost-efficiency is a paramount objective when defining and developing these performance measures. Surveillance performance requirements for low-level functional processes (i.e., vehicle detection , ramp control, etc.) need to provide a wide fidelity range to support higher-level functions (i.e., traffic network surveillance, incident management, traffic control, etc.) and to balance operational effectiveness (e.g., area-wide traffic management) and efficiency. The following analyses were conducted to aid in this determination:

- Traffic Flow Sensor Adequacy Analysis
- Vehicle Presence Collection Performance Analysis
- Traffic Surveillance/Incident Detection/Control Period Analysis
- MOE Monitoring and Display

4.3.3.1.1 Traffic Flow Sensor Adequacy Analysis

A worst-case analysis is performed to determine whether sensor latency impacts affect detector output signals. In this case, the widely-used and accepted inductive loop detector technology is used as the candidate sensing technology to establish this minimum performance baseline.

This analysis determines the minimum speed at which vehicles passing through a sensing zone begin to exceed minimum detection capabilities. This analysis examines minimum vehicle detection performance requirements for two loop detector orientations: traditional square (or rectangular); and MDOTs diamond shape. Figure 4-2 illustrates these orientations for both configurations.

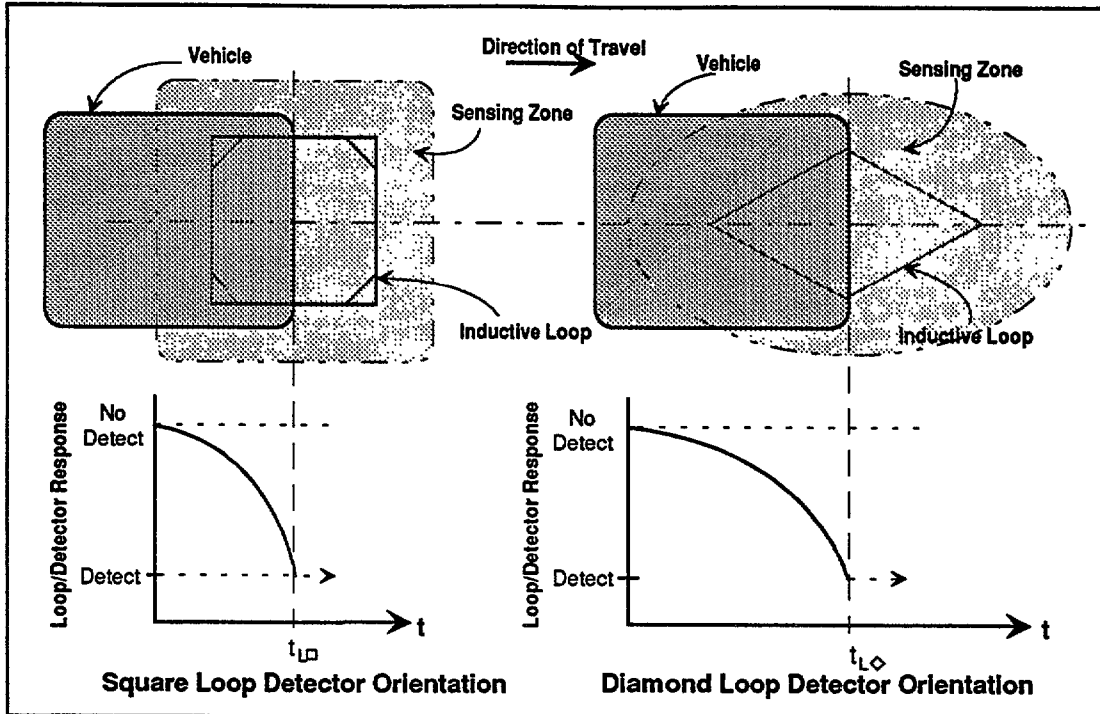


Figure 4-2. Loop Sensor Detection Latency

Assumptions:

- Nominal vehicle: $L_s = L_e = 12$ ft. (physical sensing length); Class 3 car
- Sensor latency: $t_L = 50$ ms (worst-case excitation time)
- Sensing Zone = max. 36" outside loop perimeter
- Loop excitation/relaxation (rise and fall) times are approximately equal
- Sensitivity: Detect @ 50% sensing zone area (worst-case)
- Loop dimensions: 6 ft. x 6 ft.
- Orientation: square or diamond configuration
- Sense speed range: $5 \text{ mph} \leq v_i \leq 80 \text{ mph}$; $v_n = 60 \text{ mph}$
- Detector output delay: Negligible (typical ≤ 0.1 ms.)

Find:

Using the stated assumptions, the following are determined:

- [1] v_L (min) = minimum vehicle speeds where loop sensor latency begin to impact detection capabilities; and,
- [2] whether sensor latency impacts the timeliness of detector outputs.

Analysis:

Based upon the loop sensor configurations shown in Figure 4-3, minimum impact speeds are calculated using the formula:

$$(\text{latency velocity: } v_{L\text{min}}) \times (\text{latency time: } t_L) = 50\% \text{ sensing zone traveled}$$

$$v_L \text{ (min)} = (50\% \text{ sense zone traveled}) / (t_L)$$

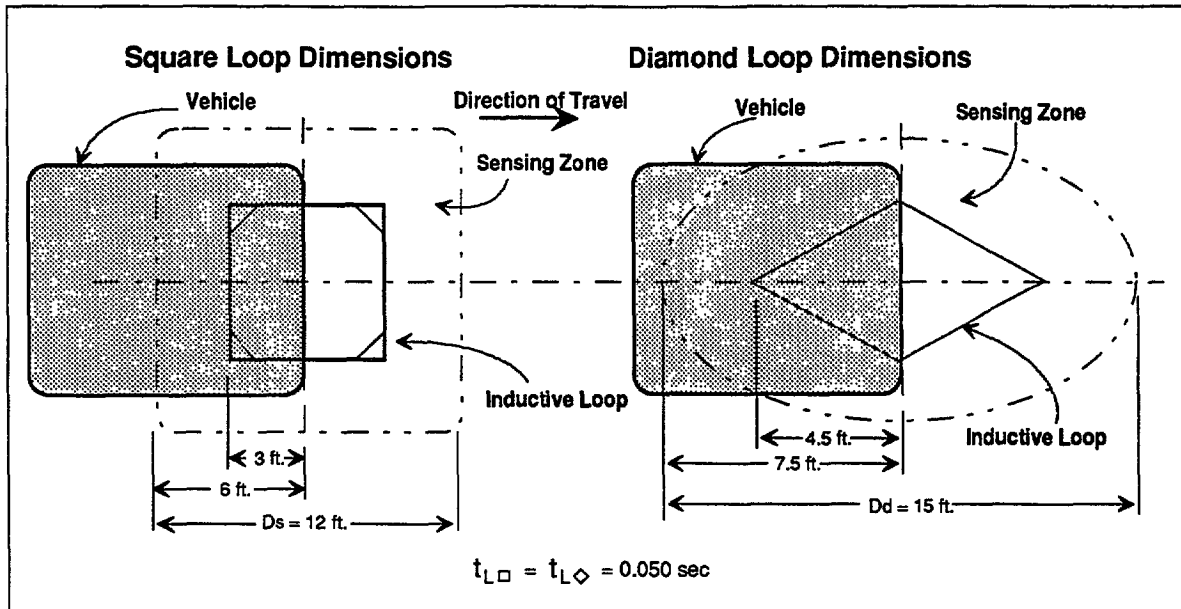


Figure 4-3. Loop Sensor Configurations

For the square loop configuration: $D_s = 3 \text{ ft.} + 3 \text{ ft.} = 6 \text{ ft.}$

$$v_{Ls} (\text{min}) = (50\% \text{ sense zone traveled: } D_s) / (t_L)$$

$$v_{Ls} (\text{min}) = (6 \text{ ft.}) / (0.050 \text{ sec.}) \times (0.681818 \text{ mph-sec./ft.})$$

$$v_{Ls} (\text{min}) = \underline{81.8 \text{ mph}}$$

For the diamond loop configuration: $D_d = 3 \text{ ft.} + 4.5 \text{ ft.} = 7.5 \text{ ft.}$

$$v_{Ld} (\text{min}) = (50\% \text{ sense zone traveled: } D_d) / (t_L)$$

$$v_{Ld} (\text{min}) = (7.5 \text{ ft.}) / (0.050 \text{ sec.}) \times (0.681818 \text{ mph-sec./ft.})$$

$$v_{Ld} (\text{min}) = \underline{102.3 \text{ mph}}$$

Conclusions:

- [1] Minimum threshold speeds where loop sensor latency (for both square and diamond loop configurations) begin to impact detector excitation, reaction, and output measurements are estimated as follows:

Square loop configuration: $v_{Ls} (\text{min}) = \underline{81.8 \text{ mph}}$

Diamond loop configuration: $v_{Ld} (\text{min}) = \underline{102.3 \text{ mph}}$

- [2] Worst case loop sensor latency errors due to electrical properties (50 ms excitation/relaxation transition delays) begin to migrate into MOE calculations when these speed thresholds are reached. At nominal freeway speeds (60-70 mph), latency impacts for both square and diamond-shaped inductive loop

detectors should not affect the accuracy of MOEs for vehicle detection applications.

Inductive loop sensors and detectors are still the foremost and most widely preferred vehicle sensor technology in use today; although, this detector technology still presents drawbacks and disadvantages associated with maintenance activities and associated costs. Establishment of minimum vehicle detection performance standards using the loop detector technology provides a baseline for new traffic flow sensors and data collection methods to maintain an upward operational compatibility and interchangeability for evolving advanced traffic management techniques and other IVHS user services. Maintenance aspects are also considered in this baseline to provide measurement criteria for new, reliable, low-cost, low-maintenance alternative traffic sensors.

4.3.3.1.2 Vehicle Presence Collection Performance Analysis

As a vehicle passes through a sensing zone, presence data (and other information: speed, vehicle type, vehicle ID, etc.) can be collected as a measurement of traffic flow conditions at a particular detection station within a surveillance zone. Presence data is currently used to calculate a variety of MOEs such as: total vehicle counts, average occupancies (%), average speeds, vehicle lengths and classifications, etc. Traditional inductive loop detector technologies are designed to output a discrete signal, when a vehicle is sensed, to a separate processor or controller for measurement of the output signal to collect presence data and cumulative calculation of corresponding MOEs for a given surveillance period. New vehicle detector technologies can collect and also process MOE information (along with other traffic flow parameters) in an integrated fashion using a variety of techniques. These techniques include integrated detector state sampling, detector state change timers, image frame sampling, composite data sampling, infrared and low power RF (radar/microwave) measurements, laser tracking and range sensing, and acoustic sensing. For the purpose of this analysis, these technologies are acknowledged as potential replacements to the inductive loop detector and must satisfy the minimum detection requirements.

This analysis provides a performance and timeline baseline for the collection and calculation of traffic flow MOEs using the minimum sensing capabilities of inductive loop detector sampling techniques.

For inductive loop detector sampling, the detector output signal is typically read on a continuous time basis, independent of vehicle presence (location). When a vehicle passes over a loop sensor, the inductance in the loop wire(s) sensor decreases and is measured by a detector unit. The detector unit generates a corresponding output signal when the inductance signal recognition thresholds are reached. Based upon detector output performance requirements (NEMA), the electrical output state transition properties (identified for detector input-output latency) are considered negligible when compared to the minimum dwell time for recognized vehicle presence (< 0.1 ms transition [NEMA] vs.

> 30 ms dwell, or 0.3%). Therefore, detector sampling errors can be assumed to not be attributed from detector input-output latency. Therefore, loop sensor states are essentially “passed through” to the detector output for processor/controller data sampling. In addition, current detectors have been designed to filter loop sensor “noise” to minimize output sensitivity and false detection errors.

Detector states are typically sampled for presence data by an local processor and/or controller, regional corridor/node processor, or central system master/host on a continuous “real-time” basis. Sampling rates can vary, but are typically read in 10 ms cycles. Presence data are typically collected and “averaged” over a larger time scale (30-60 seconds) to derive traffic flow MOEs and other parameters.

For this analysis, minimum (general) data collection performance requirements (and timelines) for calculation of traffic flow MOEs are defined from worst case (acceptable) data collection/sampling rates and traffic flow characteristics. Inductive loop detector output sampling is examined as the baseline measurement technique to provide compatibility and familiarity with current collection methods, and to provide minimum performance requirements for emerging vehicle detection technologies.

Assumptions:

Nominal vehicle:	$L_s = L_e = 12$ ft. (physical sensing length): Class 3 car
Sensing Zone =	max. 36” outside loop perimeter
Sensitivity:	Detect @ 50% sensing zone coverage (worst-case)
Loop dimensions:	6 ft. x 6 ft., square or diamond configuration
Sense speed range:	5 mph # v_i # 80 mph; also up to 120 mph
Vehicle time on loop:	$t_i = L_e/v_i = (8.1818 \text{ sec-mph})/v_i$; where: i = speed range index; t_i in seconds (use 60 mph/88 fps conversion factor)

Find:

- [1] Minimum acceptable sampling rate to detect vehicle presence; and,
- [2] an acceptable sampling error tolerance.

Analysis:

Based upon the loop sensor configurations shown in Figure 4-3, the number of samples that can be read for vehicle dwell time (t_i) over the loop are tabulated in Table 4-3 for a defined speed range. The following relationship is used to calculate vehicle presence (dwell) time over the sensing zone for worst case loop sensor sensitivity (50% coverage).

$$\text{distance traveled} = (\text{rate of speed}) \times (\text{travel time}); \text{ or rearranging,}$$

$$\text{travel time} = (\text{distance traveled}) / (\text{rate of speed});$$

$$t_i = L_e/V_i = \text{vehicle dwell time over loop sensor}$$

(for 50% coverage - worst case)

$t_i = (8.1818 \text{ sec-mph})/v_i$: includes conversion factor for feet-miles and hour-seconds

Table 4-3. Detector Sampling Rates per Vehicle Speed

Vehicle Speed v_i (mph)	Vehicle Dwell Time t_i (sec)	Number of Samples				
		@ 1 ms	@ 5 ms	@ 10 ms	@ 25 ms	@ 100 ms
5	1.636	1636	327	163	65	16
10	0.818	818	163	81	32	8
20	0.409	409	81	40	16	4
30	0.272	272	54	27	10	2/3
40	0.205	205	41	20	8	2
50	0.164	164	33	16	6	1/2
60	0.136	136	27	13	5	1
70	0.117	117	23	11	4	1
80	0.102	102	20	10	4	1
90	0.091	91	18	9	3/4	1/0
100	0.082	82	16	8	3	1/0
110	0.074	74	14	7	2/3	1/0
120	0.068	68	13	6	2	1/0

Conclusions:

[1] For the defined vehicle speed range, acceptable sampling (in worst case detection conditions) can be accomplished every 10 ms, as indicated by the shaded column in Table 4-3. Data samples read at higher rates provide a more accurate measure and greater fidelity of vehicle presence dwell time; however, the increased frequency of data collection may adversely impact processing performance and operational efficiency (i.e., processor throughput requirements, software executive (kernel) task scheduling complexity, communication requirements, etc.).

Specifically, the processor (or subsystem) allocated to perform this function needs to provide adequate processing capacity and reserves to operationally-support current and future processing and communication timeline needs. The executive kernel must be able to schedule not only detector data sampling, but other functions and tasks as well (i.e., MOE calculation, incident detection, ramp control, communications, health and status checks, data housekeeping, etc.). Data samples collected at lower rates may cause a reduction in data fidelity; potentially causing significant collection errors to propagate into MOEs, generation of incident detection false alarms, and premature activation/deactivation of traffic control functions.

The performance of current inductive loop sensor and detector technology still provide adequate fidelity for collection of surveillance data based upon careful application and data interpretation. These minimum performance requirements

(standards) provide a reasonable baseline for new sensor technology and vehicle presence collection techniques, and maintains operational compatibility for advanced traffic management strategies and other IVHS user services.

- [2] The margin of error calculated for a 10 ms sampling rate (@ 80 mph) equates to +1 (one) data sample. This could be translated into a nominal 10% error tolerance assuming excessive speeds (< 80 mph) are not encountered. In actuality, the electronic vehicle length tends to be longer than the physical length due to inductive loop sensor sensitivities having the capability to “detect” vehicle presence before actual vehicle presence or worst case detection conditions (50% sensing zone coverage). This effect actually enables a greater vehicle dwell time detected by the loop sensor, whereby, a greater number of data samples can be collected, and thus, effectively reducing the sampling error.

New vehicle detection technologies could minimize these errors from occupancy calculations (and other MOEs) directly-measured from detection zone/state dwell time. Average occupancies, speeds (timing gate), and travel times, and total volumes can be directly calculated from detector output actuation time, electronic vehicle length adjustments, and actuation differential times. Average occupancies can then be more accurately calculated for accumulated detector/zone actuation time for a given surveillance period/cycle. These measurements would then be dependent upon clock accuracies used for the trigger and state measurement functions. These methods can also provide a more accurate measure for calculating average speed and other MOEs for traffic-responsive functions.

4.3.3.1.3 Traffic Surveillance/Incident Detection/Control Period Analysis

Periodic traffic data and information collection and MOE processing performance must support traffic operations on a timely basis to enable effective and efficient traffic management. A balance between accuracy and frequency of MOE measurements (i.e., average lane occupancies, vehicle/volume counts, average flow speeds, etc.) is critical to traffic control strategy effectiveness. If sensor technologies are assumed to provide adequate accuracy, then determination of surveillance/control periods tend to define the data collection frequency and functional processing performance required to service traffic control, demand prediction, incident detection, and system monitoring and housekeeping tasks.

Traffic surveillance, incident detection, traffic control periods need to accommodate both maximum traffic flow rates and high congestion conditions. The basic traffic control model illustrated in Figure 4-4, organizes traffic flow surveillance, demand calculation, control strategies, and network behavior into a sequential/cyclic process, and also includes the effect of driver perceptions (behavior) provided as a reactive influence to traffic network status. Identification of these two process cycles provide the means to bound the traffic flow model and identify the functions needed to effectively manage this traffic flow environment. Effective and efficient traffic mobility relies upon the system’s ability to

provide appropriate traffic controls and adequate feedback mechanisms to manage traffic flow and solicit driver behavioral responses or reactions consistent with management strategies. This feedback arrangement enables the surveillance function to provide traffic flow conditions and status to the demand prediction and control functions, and support driver influence mechanisms to solicit driver behavior consistent with traffic management strategies. Since driver behavior is not a directly controllable system function, this analysis will focus on traffic flow behavior to identify and determine surveillance and control performance parameters.

Surveillance performance requirements are defined for traffic flow conditions encountered at extreme flow conditions: free-flow speeds, and congested flow (e.g., incidents). These requirements are also balanced with other interdependent functions (e.g., incident detection, traffic control) to provide the data feedback necessary for operational efficiency.

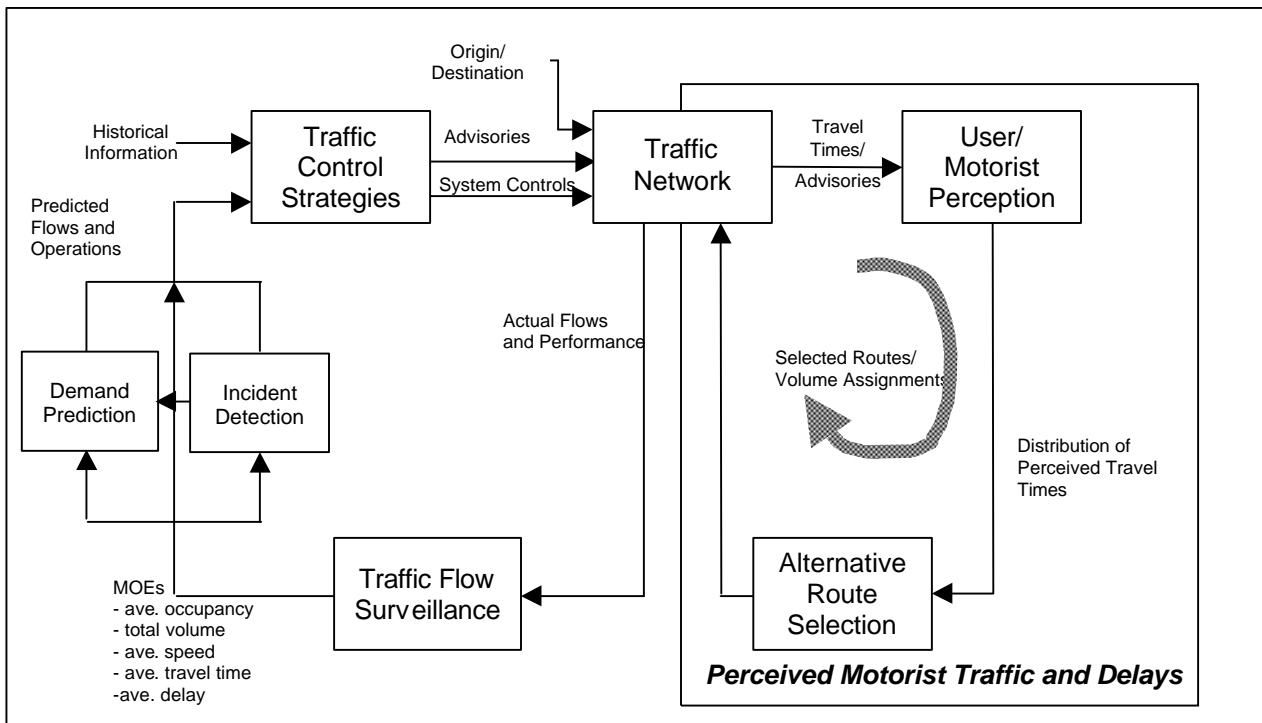


Figure 4-4. Basic Traffic Control Model

Traffic flow behavior is examined to characterize the relationships between these extreme flow regions. Free-flow traffic conditions are analyzed to determine the maximum surveillance performance required to maintain effective and efficient flow monitoring at high flow rates. Congested flow conditions are analyzed to determine congestion development effects and functional interdependencies between surveillance performance and other processes (i.e., demand prediction, traffic control, incident detection, etc.).

The following related analyses document a methodology to determine traffic surveillance, incident detection, and traffic control periods which are functionally interdependent to achieve a balance in operational performance.

Assumptions:

Traffic Flow: Greenshield's Linear Model Hypothesis: steady-state stable flow - ideal traffic flow conditions
Driver demographics: Commuter traffic: cars only – no trucks
Roadway terrain: Level - no hills/grades

Nominal vehicle: $L_o = 16$ ft. (total physical length), NEMA Class 3 passenger car

Roadway dimensions $W_m = 12$ ft. (nominal mainline lane width)
 $W_s = 6$ ft. (min. mainline median/shoulder width)
70 mph design speed - 8 lane freeway
Maximum lane capacity - 2000 pcphpl (vphpl)

Vehicle sensor: Minimum capability - loop detector
Detection orientation: Longitudinal, no lane transitions

References:

1. McShane, W. R. & Roess, R. P., Traffic Engineering, Prentice-Hall 1990, pp 68, 285-306,603-632.
2. *Secondary to reference 1:* Drake, Schofer, and May, A Statistical Analysis of Speed-Density Hypotheses, Highway Research Record 154, TRB 1967
3. A Policy on Geometric Design of Highways and Streets, AASHTO 1990, Chapter II, pp19-116
4. Traffic Engineering Handbook, ITE 1992, Chapter 5, pp 117-131
5. Chassiakos, A.P., Stephanedes, YJ, Smoothing Algorithms for Incident Detection,
6. *Secondary to reference 5:* Payne, H.J. and Tignor, S.C., Freeway Incident Detection Algorithms Based on Decision Trees with States, in Transportation Research Record 682, TRB, National Research Council, Washington DC., 1978, pp30-37

Find:

Related analyses are conducted to determine the following:

- [1] Ideal freeway traffic flow characteristics;
- [2] Required flow surveillance performance for the ideal traffic flow case;
- [3] Minimum acceptable traffic flow surveillance performance driven by associated system functions (i.e., incident detection)

Analysis: General Discussion

Let us examine traffic flow using an analogy with viscous fluid flow through a pipe. A surveillance system can be thought of a network of flow monitoring sensors (along a pipe) used to follow the movements of given particles of fluid as they flow down a pipe in a laminar fashion (i.e., fastest flow occurs at the pipe

centerline; slower flow occurs at the fluid/pipe wall interface). The ideal surveillance system monitors all fluid particles and their longitudinal and lateral (spatial) translations within the pipe for given temporal conditions.

Unfortunately, traffic flow is not uniform and real surveillance systems cannot monitor temporal and spatial conditions of all vehicles moving down a roadway corridor, nor, do they operationally need to. However, this analogy provides a surveillance framework from which spatial and temporal characteristics can be used for application to traffic flow.

Vehicle detection sensors have enabled collection of traffic flow data; however, the data only depicts point characteristics of traffic flow as vehicles pass through the sensor. To obtain true flow characteristics, sensors could be positioned in tandem along a roadway, one after another, to obtain a microscopic view of the flow; however, this approach proves to be unfeasible from a deployment perspective (e.g., MOE processing, operations resource, communications, costs, etc.) when considering the enormity of roadway miles for a given freeway network. Therefore, a balance between sensor spacing and MOE processing frequency must be determined.

Surveillance operations and processing economy must be balanced to achieve an operationally-efficient system. A macroscopic approach (instead of microscopic) is examined in this analysis to use flow “averages” to represent temporal and spatial traffic conditions within given roadway segments, or “zones” to provide manageable MOE parameters and to filter traffic flow effects of one-time events.

Current surveillance systems have adopted the use of “detection zones” or “surveillance zones” to represent the networked series of roadway segments on which traffic flow conditions are reported. “Detection stations” provide the sensor(s) implementation location within a zone for the measurement of point traffic flow conditions. For certain areas, weather conditions may also need to be collected to adjust traffic controls. Surveillance of traffic flow by zones tend to be more manageable from an operations and cost perspective due to averaging of flow parameters and the operations and maintenance costs associated with implementation of system components.

Detection or surveillance zones can vary in size and length based upon the traffic application (e.g., arterial versus freeway mainline). Arterial surveillance tends to require tightly-coupled zones (by lane) to measure right-of-way demands and queue lengths at signalized intersections. In this case, surveillance provides a “demand” indicator for signal control functions and operate on a real-time, cyclic basis due to the nature of intersection signal timing (offsets) and control. On the other hand, mainline freeway surveillance require zones, aligned in tandem to encompass extended lengths of roadway, are used to provide traffic flow status, incident detection, ramp metering, and other traffic functions. In these cases,

surveillance provides “averaged” traffic flow (and weather) data used for traffic network monitoring and activation/deactivation of real-time control operations (e.g., traffic-responsive ramp metering).

This analysis examines the relationship between zone lengths and corresponding surveillance periods to define surveillance performance requirements. Intuitively, maintaining surveillance of a vehicle as it moves downstream requires the system to “hand-off” the implicit surveillance task to adjacent zones as vehicles move downstream. Using basic traffic flow relationships, zone lengths and period lengths are directly proportional.

Analysis [1]: Ideal Traffic Flow Characteristics

In large-scale ideal (freeway) traffic flow models, vehicles can be viewed as constituents of a flow body that move down a section of roadway, at a steady rate of speed, similar to the manner in which a body of incompressible fluid flows through a length of pipe. Traffic flow surveillance along equal-length roadway segments (surveillance zones) yields collection, processing, and reporting of traffic flow conditions (MOEs) as vehicles travel from one segment to the next. The frequency at which MOEs are collected and updated can impact the structure of the system architecture, communications media, methods, and required performance, and functional processing timelines. The following describes a method to determine surveillance periods required to monitor freeway traffic flow.

Traffic flow surveillance must measure changes in traffic flow conditions as a result of behavioral reactions from perceived conditions exhibited by drivers traveling on the roadway. Due to the practical nature of sensor deployments and traffic management strategies, flow measurements cannot be collected from a continuous stream of sensors along a roadway; instead, traffic flow conditions and characteristics are collected at specific points (detection stations) to represent flow conditions for each surveillance zone.

The surveillance period for measuring temporal and spatial traffic flow conditions are dependent upon flow rates and the spacing between detection stations. Since the level of surveillance fidelity tends to be limited primarily by processing limitations and costs associated with deployment, operations, maintenance, and administrative decisions, a means to define performance characteristics are derived from traffic flow itself. At a minimum, surveillance performance periods need to accommodate traffic operations when traffic flow is ideal and traveling at free-flow speeds, and also when flow conditions are congested and other system functions predominate. The following assessment summarizes ideal traffic flow.

Ideal Traffic Flow Behavior. To better understand traffic flow behavior, several mathematical expressions have been hypothesized² to describe speed-flow-density relationships for data collected from actual observations. These observations are mapped as flow vs. speed, flow vs. density, and speed vs. density. These

expressions are calibrated to minimize the differences between the mathematical expressions and observed data. This analysis uses these hypotheses with ideal traffic flow parameters instead of observed data to determine the upper flow limits for the surveillance function. Figure 4-5 illustrates these flow-speed-density relationships with the following definitions:

- c = capacity, the maximum rate of flow (vph or vphpl or pcphpl);
Ideal = 2000 vphpl or pcphpl
- S_f = free-flow speed; theoretical speed when density = zero (mph);
Ideal conditions: = 85% of roadway design!
*= (0.85)*70 mph = 59.5 mph*
- S_c = critical speed, the speed at which capacity occurs (mph) - mathematically derived
- D_c = critical density, the density at which capacity occurs (vpm or vpmpl) - mathematically derived
- D_j = jam density, the density at which all movement stops, i.e., $S = 0$ mph (vpm or vpmpl) - mathematically derived

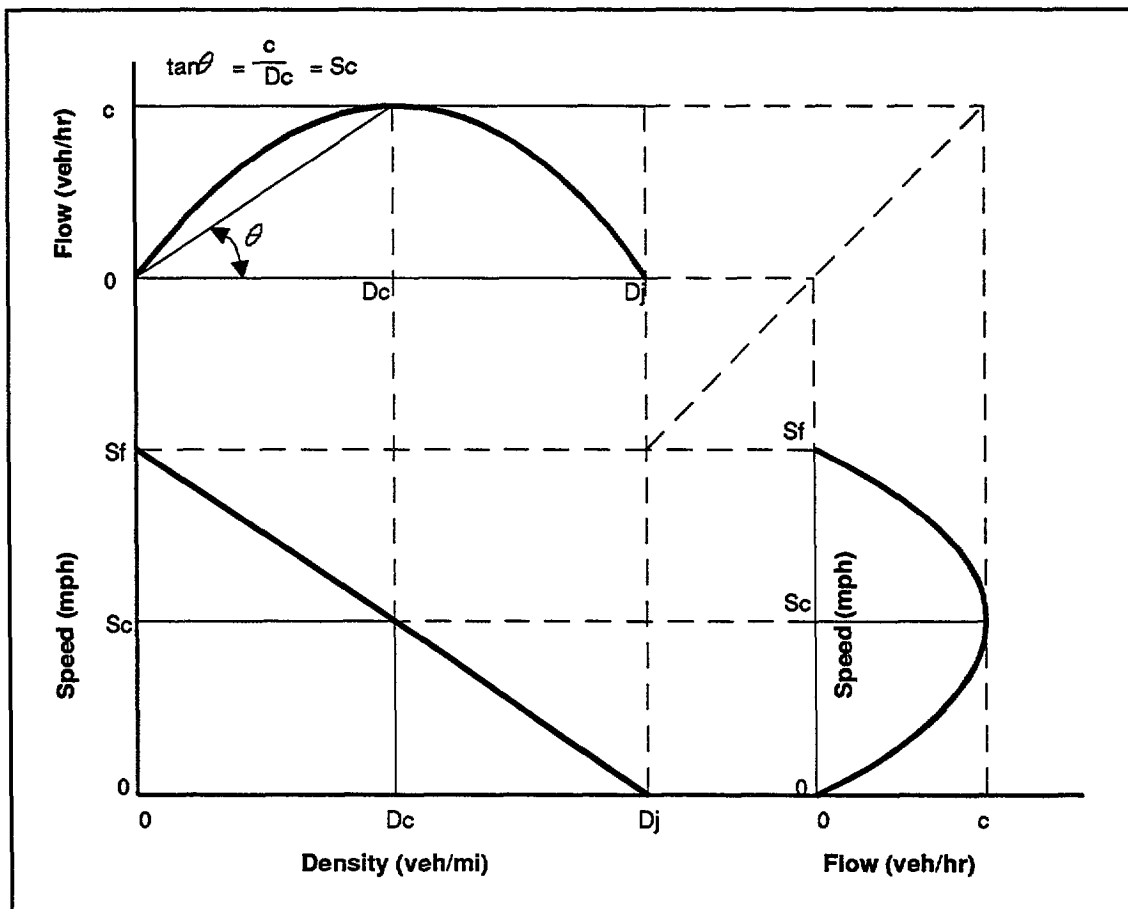


Figure 4-5. Basic Form of Speed-Flow-Density Relationships

Understanding the limits of the speed-flow-density relationships provide a mathematical approach to describe specific relationship interactions. In this case, ideal traffic flow conditions are used in place of observed data. The general mathematical expression relating flow, speed, and density* is:

$$F = S \times D;$$

where: F = rate of flow (vph or vphpl)
 S = space mean speed (or average running speed in mph)
 D = vehicle density (vpm or vpmpl)

Conclusions [1]:

Flow constants corresponding to ideal flow conditions are defined as follows:

Maximum flow (volume) rate: $c = 2000$ vphpl or pcphpl
 Maximum free-flow speed: $S_f = 59.5$ mph
 Critical density (@ capacity): $D_c = 67.2$ vpmpl
 Jam density ($S = 0$ mph): $D_j = 134.5$ vpmpl
 Critical speed (@ capacity): $S_c = 29.8$ mph

Substitution of these constants into the ideal speed-flow-density equations yield the following:

Speed – Density Equation:

$$S = (59.5 \text{ mph}) - [(59.5 \text{ mph}) / (134.5 \text{ vpmpl})] D ;$$

$$S = (59.5 \text{ mph}) - (0.44 \text{ vphpl}) D ;$$

Flow-Density Equation:

$$F = (59.5 \text{ mph}) D - [(59.5 \text{ mph}) / (134.5 \text{ vpmpl})] D^2 ;$$

$$F = (59.5 \text{ mph}) D - (0.44 \text{ mph/vpmpl}) D^2 ;$$

Flow-Speed Equation:

$$F = (134.5 \text{ vpmpl}) S - [(134.5 \text{ vpmpl}) / (59.5 \text{ mph})] S^2 ;$$

$$F = (134.5 \text{ vpmpl}) S - (2.26 \text{ vpmpl/mph}) S^2 ;$$

For calibration purposes, surveys of moderately-traveled interurban freeways (c 10% occupancy on 55-mph posted speed limits) were taken and found that travel speeds actually exceed the assumed free-flow speed of 59.5 mph. Observed speeds ranged between 61-65 mph (e.g., I-96 Jefferies Freeway), and for freeways

with posted 65mph speed limits, observed travel speeds ranged between 64-69 mph (e.g., I-275). Thus, using a simple average of these two ranges as a “calibrated” free-flow speed value, S_f , (65 mph), the resulting speed-flow-density equations become the following:

<u>Speed-Density Equation;</u>	$S = (65 \text{ mph}) - (0.528 \text{ vphpl}) D ;$
<u>Flow-Density Equation;</u>	$F = (65 \text{ mph}) D - (0.528 \text{ mph / vphpl}) D^2 ;$
<u>Flow-Speed Equation;</u>	$F(123.1 \text{ vpmpl})S - (1.89 \text{ vpmpl / mph}) S^2$

Analysis [2] : Flow Surveillance Performance (Periods)

Efficient traffic flow surveillance must enable non-duplicated coverage of flow movement between zones on a periodic basis. This requires a detection station to “hand-off” flow surveillance to an adjacent detection station as vehicles move downstream. Figure 4-6 illustrates a layout of this model. The timing of each flow surveillance period (1,2,3, etc.) is such that traffic data is collected, processed, and reported for a given flow body for a particular detection station (1,2,3, etc.) until the leading edge of that body reaches the next downstream detection station (zones A, B, C, etc.). At this point, the cycle is re-initiated starting with the next traffic flow body. This period or cycle length depends upon the traffic body flow speed and the separation distance between detection stations (surveillance zones).

Since maximum traffic monitoring performance is required when roadway and travel conditions are ideal and the theoretical free-flow speed is at its maximum, the surveillance system (detection station spacing and processing period) must maintain a monitoring cycle consistent with the free-flow speed. In other words, the (maximum) surveillance period must be consistent with the vehicle flow travel time required to cover the distance between detection stations. All flow conditions are measured/ collected, calculated, and reported within this period.

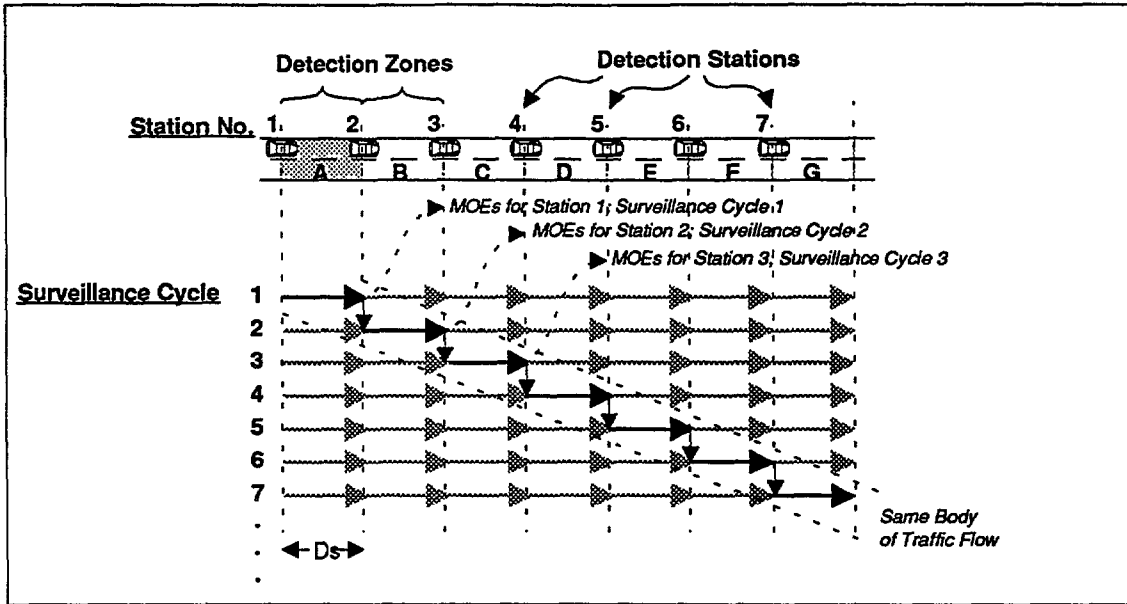


Figure 4-6. Ideal Surveillance Flow Model

Given these conditions, the maximum free flow speed, S_f , for ideal conditions (59.5 mph) is used as a determining factor to define detection station spacings (D_s) and corresponding maximum surveillance periods (P_s). The following equation illustrates this relationship and is used to develop the parametric values listed in Table 4-5. The calibrated free-flow speed value (65 mph) is also calculated and used as a basis for comparison..

$$D_s = S_f \times P_s ;$$

solving for the surveillance period P_s yields:

$$P_s = D_s / S_f = D_s / (59.5 \text{ mph}) \times (3600 \text{ sec/hr}) ;$$

and substituting:

$$P_s = D_s / (59.5 \text{ mph}) \times (3600 \text{ sec/hr}) ;$$

	$P_s = D_s \times (60.5 \text{ sec})$; for $S_f = 59.5 \text{ mph}$
and;	$P_s = D_s \times (55.38 \text{ sec})$; for $S_f = 65 \text{ mph}$

where:

- D_s distance between detection stations points (mi)
- S_f traffic flow speed (mph)
- P_s surveillance period (sec)

Table 4-5. Flow Surveillance Periods

Detection Station Separation Distance D_c (mi)	Maximum Surveillance Period (@ $S_f = 59.5$ mph) P_s (sec)*	Maximum Surveillance Period (@ $S_f = 59.5$ mph) P_s (sec)*
0.10	6.06	5.54
0.20	12.11	11.08
0.25	15.13	13.85
0.33	19.97	18.28
0.50	30.26	27.70
0.66	39.94	36.56
0.75	45.38	41.53
0.90	54.46	49.85
1.00	60.51	55.39
1.25	75.64	69.24
1.50	90.76	83.08
2.00	121.01	110.77

* values have been rounded up to the nearest 0.01 sec.

Conclusions [2]:

Further parametric analysis could define a endless range of periods due to the proportional nature of the distance-speed-time relationship. Based only on traffic surveillance functions, operations administrators could simply choose a desired detection station/surveillance period pair and develop an operations strategy around them. If simple traffic monitoring (no control functions) is desired, the surveillance period could be chosen based upon available budget, communications, and computing platforms and resources. This approach, taken in isolation, tends to be influenced by administrative preferences rather than true operational needs, and does not specify or “bound” *real* traffic operation performance requirements. Therefore, other determining factors must be used to identify a balance between operational needs and administrative preference.

Analysis [3]: Minimum Surveillance Performance Determinants,

This analysis employs the relationships defined in the traffic control model (refer to Figure 4-4) to determine surveillance performance limits required to support interdependent traffic operations for ideal flow conditions. In the model, the surveillance function provides traffic network status “feedback” to demand prediction and traffic control functions. The previous analysis identifies maximum performance required to maintain flow surveillance for “ideal” traffic flow conditions. For degraded traffic flow, as found in traffic congestion, maximum performance surveillance periods can still provide operationally-relevant traffic flow data, however, the data now represents segments of contiguous traffic flow bodies.

Determining a range of operationally-efficient surveillance periods/cycles are introduced in this analysis using other interdependent functions and system aspects.

Freeway traffic demand prediction, entrance ramp metering control, and incident detection functions are considered the primary determinants to define these operationally-efficient surveillance periods.

Diagnosis of incident traffic patterns must be balanced with respect to the rate at which traffic congestion develops. There may be instances when incidents occur during off-peak hours. In these cases, traffic densities can be very low with substantial time required for congestion to build up to the point where the queue spans multiple detection stations before sensing incident congestion patterns. The probability of incident occurrence at low densities tends to be much less than during peak-hour traffic, and thus does not provide a viable determinant. Surveillance performance must then be related to the scale of congestion (incidents) impact and the time interval required for detection and recognition of incident patterns. Thus, this analysis uses incident traffic flow conditions; namely, queue buildup, to determine surveillance performance requirements (periods/cycles).

Performance Limit Determination. This method will employ traffic and system characteristics observed during roadway incidents to focus on definition of operational surveillance performance limits to support incident detection processing. Implementation costs are considered to determine the minimum number of detection stations (maximum spacing) required to support overall traffic flow monitoring (free-flow traffic and incident detection). Characterization of the congestion development rate and incident detection capabilities are used as specific determinants to define surveillance periods and detection station spacing.

When traffic flows at or around its maximum/ideal rate, the surveillance function must update flow data (MOEs) at a corresponding rate. When traffic becomes heavily congested, the same relationship may not apply to be operationally-efficient. In this flow region, incident detection becomes a more prevalent function and relies heavily upon the periodic traffic MOEs provided by the surveillance function.

The incident detection/surveillance relationship is examined further to develop a means for specifying and balancing free-flow surveillance performance (i.e., periods and detection station spacing) with incident detection processing timelines.

First, the observed rate of congestion development will be used to calculate the time and distance required for the leading edge of a compression wave to travel upstream through the traffic flow. Tabulation of these times and distances are presented in Table 4-6. The worst case distance a compression wave must travel in order to be detected can be defined as the distance between adjacent detection stations (i.e., incident location is immediate upstream from a detection station to the next upstream station). These propagation times will be used with baseline incident detection processing timeline limits to identify detection station spacing.

Table 4-6. Compression Wave Propagation Times

Travel Distance (miles)	Propagation Time of Compression Wave @ 10 mph (seconds)
0.00	N/A
0.10	36
0.20	72
0.30	108
0.40	144
0.50	180
0.60	216
0.70	252
0.80	288
0.90	324
1.00	360
1.10	396
1.20	432
1.30	468
1.40	504
1.50	540
1.60	576
1.70	612
1.80	648
1.90	684
2.00	720

Secondly, a baseline for incident detection performance (detection time) is established through assessments of various (comparative) algorithms in current operation or test. This baseline requires definition of acceptable detection and false alarm rates, corresponding detection assumptions, and the number of (MOE) data samples required for processing. For most algorithms, detection and false alarm rates tend to follow a similar trend; that is, as the detection rate increases, the false alarm rate also increases. Some algorithms have developed improvements to minimize false alarm rates through the use of statistical smoothing of the surveillance data⁵. Others use multiple algorithms which process the same MOE data to look for different patterns and examine algorithm results through a comparator.

To determine appropriate incident detection time performance, most detection algorithms (e.g., California, time series, etc.) compare sequences of processed temporal and spatial traffic flow data to determine incident conditions or patterns. These algorithms adopt the objectives to maximize the probability of detection and to minimize the mean-time-to-detection⁵ (MTD) and corresponding false alarm rates. In the referenced study, MTDs are based from the time an incident is reported into the operator’s log. From a system performance perspective, this data

may be insufficient due to time omitted between actual occurrence and entry into a log. The following analysis provides an estimation of the overall detection time.

Detection accuracy and traffic management center (TMC) operator perspectives are examined to define thresholds for incident detection and false alarm rates; that is, high detection with a low false alarms. From the operator's perspective, low false alarm rates are emphasized due to the tendency to ignore frequent alarms within short time periods. Based upon studies⁵, acceptable rates are considered to begin at 60% detection (ratio of detections of all identified incidents) with corresponding 0.1% false alarm rates (percent of false alarm decisions to all decisions). This can be interpreted as approximately 1 false alarm per peak hour traffic at a minimum 60% detection rate for all incidents.

Higher detection rates from single algorithms potentially carry a timeliness penalty; in that, these algorithms use a larger data sample set over time to statistically "smooth" the surveillance data for filtering out data noise, or to check the persistency of an incident pattern. For these algorithms⁵, corresponding MDTs (@ 60% detection/0.1% false alarm rates) range from 1.1 minutes (DELOS3.3) up to 2.1 minutes (DELOS 1.1). However, these time values were measured from the time reports are entered into the operator's "incident log". These mean times are considered offsets to the actual occurrence-to-incident log reporting time and do not provide an adequate performance value for this analysis.

Another method to determine actual detection time could be obtained from the number of data samples required to perform incident processing. Through examination of the same algorithms, study data samples, and assumptions⁵, a baseline incident detection performance range can be determined by summing the number of sample collection time (surveillance periods) required for detections. As a minimum (no detection time offsets), the modified California algorithm (Los Angeles) requires three data samples to initiate detection processing for comparison of occupancy thresholds, and two additional samples to check for incident pattern persistency. As a maximum, the DELOS1.1 algorithm⁵ uses up to ten-samples to perform statistical smoothing and threshold/history comparisons. These incident detection algorithms were calibrated using 30-second data samples. Therefore, a baseline minimum incident detection processing interval requires five surveillance periods, or 150 seconds (2.5 minutes); and a baseline maximum interval requires ten surveillance periods, or 300 seconds (5 minutes).

Determine Operational Surveillance Period. To determine operationally-compatible surveillance periods, minimum and maximum detection times (intervals), corresponding number of data samples, and compression wave travel distances are used to calculate the required detection station spacing and corresponding minimum surveillance period lengths (for $S_f = 59.5$ mph and 65 mph) to support incident detection.

The most prominent incident flow characteristic is identified as the compression wave of vehicles (as their speed slows to a stop) which moves in an upstream direction at a rate of approximately 10 mph^{5,6} and persists over an extended period. The data from Table 4-6 is plotted in Figure 4-7 with minimum and maximum incident detection time limits to derive the corresponding travel distances of the compression wave.

The intersections at which the compression wave propagation line crosses the incident detection time limits depict the range in which the surveillance function must perform. These intersection points also identify corresponding compression wave travel distances which can be used to derive a detection station spacing; hence, the corresponding operational surveillance period.

Mathematical derivation of propagation distances corresponding to the detection limits can be obtained from the following relationship:

$$\textit{propagation distance} = (\textit{compression wave travel rate}) \times (\textit{detection time})$$

or expressed as: $P_{cw} = S_{cw} \times T_d$

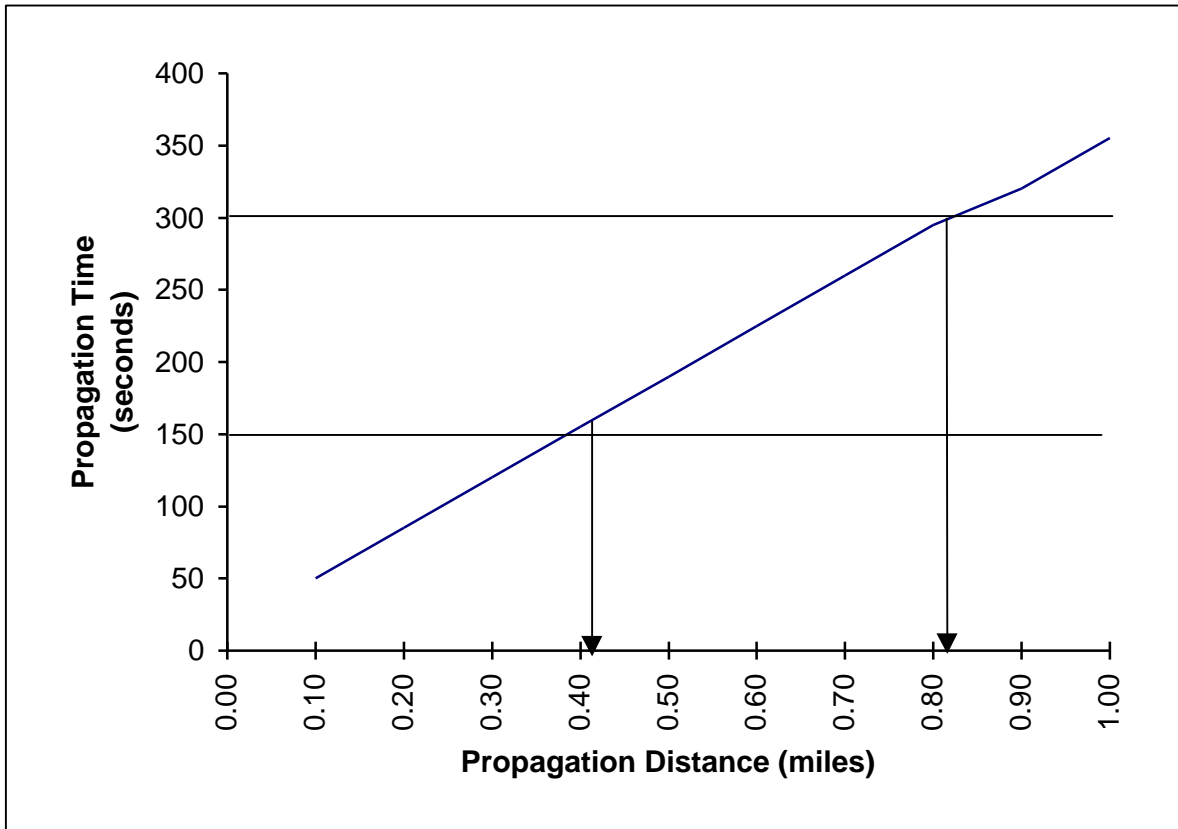


Figure 4-7. Incident Compression Wave Propagation

The following values are used for propagation speed and incident detection times:

$$S_{cw} = 10 \text{ mph}; \quad T_{dmin} = 150 \text{ seconds (minimum)}$$
$$T_{dmax} = 300 \text{ seconds (maximum)}$$

Thus, compression wave propagation distances corresponding to incident detection time limits are:

$$P_{cwmin} = 0.42 \text{ mile}; \text{ and, } P_{cwmax} = 0.83 \text{ mile}$$

These distances do not directly correspond to detection station spacing, but can be used to derive spacings based upon the number of data samples used for incident detection.

To find the detection station spacing for the minimum detection time, the worst case situation (incident immediately upstream) is assumed. For minimum detection time (modified California algorithm), 5 data samples were required to signal a detection alarm, of which 2 samples were used for persistency checks. Therefore, when the alarm is issued, the compression wave, or queue length, has traveled 2/5 of 0.42 mile, or 0.17 mile passed the first adjacent upstream detection station. Thus, detection stations are spaced at 3/5 of 0.42 mile, or at 0.25 mile intervals.

A similar derivation can be performed for the maximum detection time where 10 data samples were required, of which 6 samples were used as a historical base and 4 samples used for measurement and persistency. Similar ratios are used on the corresponding maximum propagation distance of 0.83 mile. In this case, detection station spacing results in 0.50 mile intervals (6/10ths of 0.83 mi.).

Conclusions [3]:

Improvements in automated incident detection accuracy and false alarm rate reductions are consistently being studied. Given that short surveillance periods can always support long detection intervals, the maximum surveillance performance required to support incident detection processing needs correspond to a period length which supports traffic data collection at both low density, free flowing speeds, and at high density - low speed, unstable traffic flow.

Correlation of detection station spacing derived from incident detection processing is linked to spacing derived from the free flow/ideal traffic flow model ($S_f = 59.5$ mph). Spacing values yield a surveillance period range of 15.1 seconds to 30.3 seconds. These values correspond to detection station spacings of 0.25 mile and 0.50 mile. If the observed free flow traffic speeds ($S_f = 65$ mph) are used, the surveillance period range reduces to 13.9 seconds to 27.7 seconds. Also, since the surveillance function is closely coupled with the traffic control and demand functions, the same (surveillance) processing cycle/period would also apply to

those functions to ensure the latest information is used within the control cycle and the system feedback path is maintained.

Actual detection station location placement and spacing for surveillance zones along freeway mainlines can vary based upon a number of conditions. Entrance and exit ramp spacing, weaving areas, roadway curvatures, communications media access, and demand and average daily traffic volumes all provide input into the layout and frequency of detection station spacing and surveillance zones. Overall, typical detection station location selection ranges between +/- 0.2 mile of the desired spacing distance.

Recommendations. As a guideline for system implementation based on performance and cost, detection stations should be spaced between 0.25 mile to 0.50 mile apart. Within this range, If system incident detection performance is a priority, 0.25 mile spacing of surveillance zones is recommended. If budgetary constraints do not allow a close spacing, then up to 0.50 mile spacing intervals should be sufficient to provide adequate surveillance and incident detection performance.

4.3.3.1.4 MOE Monitoring and Display

As traffic surveillance flow data is collected and processed, traffic MOEs and system performance information must be made available to other system-level functions for traffic control performance monitoring, traffic network status management, information dissemination, and operator feedback. MOE updates are dependent upon the collection rate of the surveillance system. Information access to MOEs should be available on demand

4.3.3.1.4.1 MOE Monitoring

Traffic flow MOEs provide the principal measures for traffic management performance. MOEs are used at different processing levels within the traffic management system and are required in three primary timeline categories: [1] “on-line” processing functions (i.e., traffic control feedback and incident detection processing); [2] “routine” processing functions (i.e., traffic network management and status displays); and [3] “off-line” functions (i.e., traffic network information management, access, and dissemination). Figure 4-8 illustrates these levels and corresponding timeline scales for MOEs are use and application.

MOEs for traffic control and incident detection processing need to be directly provided by the surveillance function. The surveillance function tends to be closely-coupled with these processes to provide the timely feedback needed to support control activities and monitoring functions. This coupling also ensures the MOE data is representative of up-to-date traffic conditions and minimizes latency conditions which could trigger inappropriate controls and alarms. Functions which use MOEs in this “on-line” fashion typically operate on a near real-time timeline (seconds to minutes). For example, integrated corridor flow control collects and processes MOE data at the corridor level. In these applications, MOE

Value is measured more by the recency of the data in order to assess proper system responses.

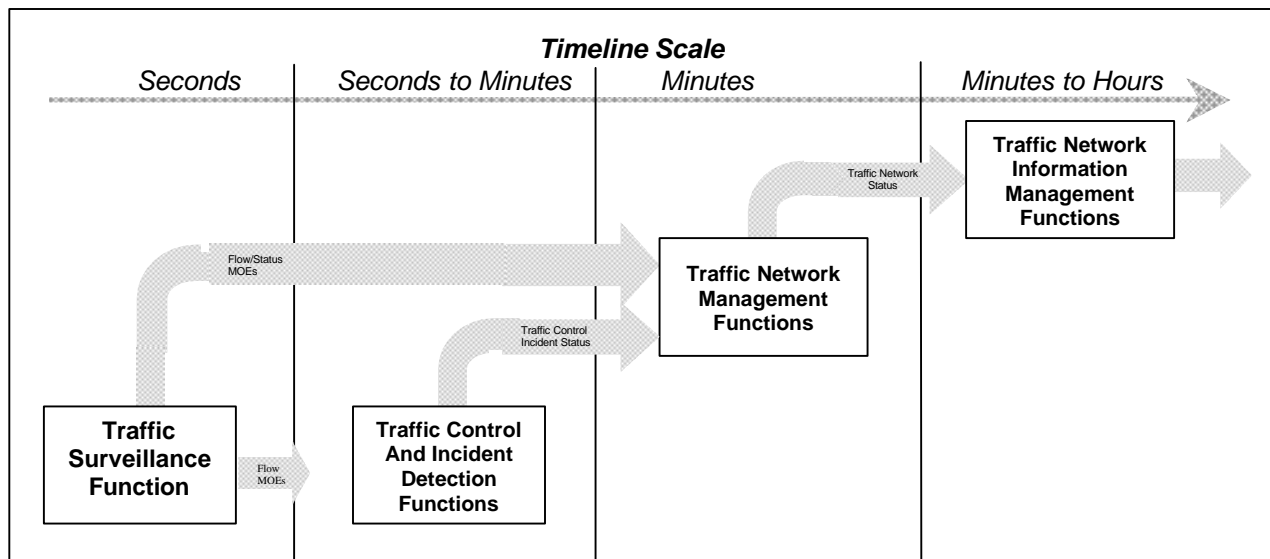


Figure 4-8. MOE Processing Application Levels

MOEs used for traffic network management and status displays need to be readily available (on demand) for traffic control functions and operator presentation and feedback. MOEs available on demand are defined as the latest reported status (within the last surveillance cycle – typically 20-30 seconds) retained by the system. On demand performance minimizes latency effects and operator frustration when having to wait for system feedback and status displays.

MOE processing and availability at this level require periodic updates to support ongoing “strategic” management activities, or possibly “tactical” traffic views (i.e., mainline section, entrance ramp status, etc.). Where traffic control and incident detection functions involve more critical MOE processing timelines (direct access), monitoring activities are more involved with the organization, interpretation, and presentation of the MOEs on a system status display in an operations center environment to conduct routine traffic management and information dissemination activities.

Off-line functions, such as, traffic network information management, information access control, and information dissemination, tend not to require stringent MOE update timelines. The term “off-line” is used to make reference to information processing performed external to the traffic surveillance and control subsystems. This processing is primarily oriented towards information services to provide traffic status to external (to traffic operations) entities. MOEs used in this capacity are processed into more relevant travel information involving corridor congestion, incidents travel times, and delays. This information can be disseminated to outside parties or to individuals for independent traffic reporting services, assessments and reports.

4.3.3.1.4.2 Traffic Network Status Displays

Traffic network surveillance status displays include overall traffic network flow (system map), corridor-level flow (mainline segment - multiple surveillance zones), sub-corridor-level (i.e., single surveillance zone, entrance/exit ramps), video surveillance, and traffic management subsystems status. Control of the data displays and media are processed through two basic functions: [1] the traffic surveillance and control subsystems; and [2] the TMC operator interface(s). Organization of user/operator interface controls need to be self-contained where all pertinent information is available to aid operator selection. The latter function focuses the operator's attention to a single interface to promote ease of use and operator productivity. System-generated response actions (decision aids) need to automate repetitive tasks and actions (standard operating procedures) to streamline operator workload. User presentations should incorporate graphical forms to maximize operational utility, control, and user friendliness.

Status displays processed through the traffic management subsystems should automatically collect and update traffic status on a routine (periodic) basis. These displays include the following:

- Overall traffic network status including roadway congestion status and incident detection processing
- Traffic surveillance and control subsystems status
- System/component health status
- Information system maintenance

Control and data displays commanded by the TMC operator should be processed through an integrated and interactive user interface for display and control functions (e.g., function selection, scale, data types, etc.). These displays need to be available on-demand for the following management functions.

- Traffic surveillance and control monitoring
 - Traffic surveillance (plus environmental data)
 - Mainline/Ramp control
 - Changeable message control (CMS/HAR)
 - Network performance monitoring
 - Database maintenance
- Incident management
 - Detection/Prediction (e.g., special events, work/construction zones, etc.)
 - Verification
 - Notification
 - Response and removal coordination
 - Incident traffic management
 - Incident information dissemination
 - Incident database maintenance

- Video surveillance and control
 - Image selection (camera) and control (PTZ)
 - Image display control (monitor)
- Information management
 - Information collection and management
 - Dissemination and access control
 - Database maintenance
- Malfunction monitoring
 - System status monitoring
 - System/component health checks and diagnostics
 - Database maintenance
- System administration
 - Housekeeping
 - Database maintenance

4.3.3.2 Traffic Control Performance

Traffic control systems provide the flow control facilitation mechanisms to collect, calculate and execute traffic management strategies. The FHWA Traffic Control Systems Handbook, FHWA-IP-8511, defines traffic control as the regulation, warning, and guidance of traffic for the purpose of improving the safety and efficiency of moving people and goods. Implementing this control process involves the installation, operation, and maintenance of various traffic control strategies and control devices, such as signs, signals, and lane barriers.

The MDOT ATMS/ATIS will primarily involve management of traffic on freeways and expressways surrounding the metropolitan Detroit area. Freeway Operations will include mainline flow management and control, incident management, driver/traveler information dissemination, and system maintenance. Mainline flow management and control activities include entrance ramp activation and metering control, mainline flow control, and integrated corridor management and control. Evolution of mainline flow management can extend into integrated surface street/mainline flow controls to optimize traffic flow between high capacity trunklines/arterials and freeways during peak traffic periods.

The following assessments are intended to identify levels of control processing to support allocation of those processes and functions into the system architecture. Detailed performance characteristics are defined where possible.

4.3.3.2.1 Traffic Control Assumptions

Assumptions associated with this assessment involve behavioral aspects of traffic flow, metropolitan Detroit roadway characteristics, and MDOT DFO traffic control modes and strategies. These assumptions reflect the perspective from which the system will be designed, implemented, operated, and maintained. Operational-efficiency objectives (i.e., operational-effectiveness and cost-efficiency) are incorporated into this analysis to define feasible performance requirements consistent with DFO strategies.

Traffic Flow Behavior. The traffic model illustrated in Figure 4-4 depicts a closed process relationship between traffic flow surveillance, demand prediction, incident detection, traffic control, and the traffic network. Driver perceptions result in reactions to the traffic controls and network status and are displayed in driver behaviors. These behaviors are a result of route re-evaluation and the exercising alternative route choices. These perceptions tend to be accounted for through the collection of traffic MOEs, however, may modify traffic strategies to adapt to the changes in traffic flow and routes taken. The traffic control system must formulate and execute these strategies in response to flow changes measured by the surveillance system and predicted by potential traffic demands and incidents.

Metropolitan Detroit Roadway Characteristics. Traffic control for metropolitan Detroit roadways, more specifically freeway mainlines, will include entrance ramp controls, mainline controls, and corridor controls. Portions of freeway mainlines exhibit non-capacity-reducing bottleneck characteristics. These characteristics include sight-occluded curves, narrow roadways, weaving sections (e.g., transition lanes), and severe roadway surface inconsistencies. Seasonal weather conditions tend to amplify the effects of these bottleneck characteristics with heavy rain and transitional snow/ice roadway surface conditions. The traffic control system needs to sense and adjust traffic controls for these conditions.

MDOT Traffic Control Strategies. Traffic control strategies for metropolitan Detroit currently consist of entrance ramp control and variable message signing (i.e., CMS, HAR/AHAR). Current control strategies use the freeway mainlines as the primary conduits for traffic movement. Limited deployment of traffic surveillance and control infrastructure has constrained the system's ability to effectively manage traffic flow. Strategies for the future system will enable areawide integrated corridor management with coordinated operations, variable mainline speed signing, integrated ramp control, and integrated surface arterial/mainline control. In addition, traffic information will be available and disseminated to other TMCs, media reporting services, and roadway users to provide improved traffic awareness and travel planning capabilities.

Reference Sources. The following references are used in this assessment:

1. Wilshire, R., Black, R., Grochoske, R. & Higinbotham, J., Traffic Control Systems Handbook. Revised Edition - 1985, FHWA-IP-85-11, USDOT FHWA, pp 4.3-4.70.
2. Pline, J. L., Traffic Engineering Handbook, Institute of Transportation Engineers, pp 360-390, 391-418

4.3.3.2.2 Traffic Control Performance Assessments

Traffic control performance needs to be responsive to control strategies and appropriately scaled to be effective. The traffic control functions to be assessed include mainline ramp control, variable mainline speed signing, integrated corridor control, and coordinated areawide traffic operations.

4.3.3.2.2.1 Entrance Ramp Control Performance

Limiting the volume rate of vehicles entering a freeway mainline is the most widely used form of freeway traffic control. The primary objective of entrance ramp control is to eliminate, or at least reduce, traffic flow problems resulting from mainline congestion. In principle, the ramp control function limits the number of vehicles which enter the mainline by modulating the (entering) traffic demand with the mainline’s downstream capacity. In consequence, vehicles may need to wait at the ramp before entering the mainline; queues may develop and cause spillover onto surface arterials; drivers may be diverted to other downstream ramps, avoid traveling on the mainline altogether, use surface arterials, or avoid traveling at that time; or ultimately, use another travel mode (i.e., transit bus, light rail, etc.). In any case, entrance ramp control helps promote smooth and efficient mainline traffic flow by deferring the travel delay onto the ramp and helps improve safety resulting from smoother traffic flow.

Performance for entrance ramp controls are summarized in Table 4-7 and described in the following paragraphs.

Table 4-7. Entrance Ramp Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Ramp Closure	signing	scheduled	real-time	real-time	enabled	enabled	enabled
	barriers	scheduled	real-time	real-time	enabled	enabled	enabled
Ramp Metering	pre-timed	scheduled	real-time	real-time	enabled	enabled+	disabled
	traffic resp.	scheduled	real-time	real-time	enabled	enabled+	disabled
Intgr. Rmp Cntl	interconnection	scheduled	real-time	real-time	enabled	enabled	disabled

+ - modified normal mode

Control Strategies. Ramp control strategies are categorized as diversionary or non-diversionary. Diversionary strategies specify ramp control parameters so that entering traffic demand is diverted to another ramp, to an alternate route or travel period, or to an alternate mode. Non-diversionary strategies service, or assimilate, the entire traffic demand at the ramp.

Activation Modes. Activation modes are those control processes which determine the conditions in which ramp control is activated and deactivated. For most systems, ramp control activation is determined by a fixed schedule (time-of-day, day-of-week), response

to mainline traffic conditions (traffic responsive), or through direct operator commands (operator override). When activation conditions are no longer valid, controls should be deactivated to promote motorist trust in the system.

Control Modes. Like other areas with a very diverse climate, the metropolitan Detroit area occasionally experiences inclement weather conditions which degrades the roadway surface and visibility. The system must provide the capability to determine local environmental conditions. These conditions include adverse roadway surface conditions due heavy rain (flooding) and snow and ice. The system will enable, disable, and modify ramp controls as weather conditions vary. Normal mode is the default mode and applied for clear weather and roadway surface conditions. Rain mode is applied when significant (rain) precipitation is experienced. Metering rates are also modified to increase the intervals (spacings) between vehicles to allow more merging space. Snow/ice mode is applied when snow or ice conditions are experienced on the roadways and ramps. This mode deactivates ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers.

Ramp Control Implements. Three methods of ramp control include [1] Ramp Closure; [2] Ramp Metering; and [3] Integrated Ramp Metering.

1. Ramp Closure is utilized to restrict entrance ramp access for congestion elimination or safety reasons. Ramp closure must be applied with care due to its inflexibility to accommodate mainline access. Ramp closure is applied when roadway capacity immediately upstream from the ramp is at capacity, inadequate vehicle queue storage capacity on the ramp, major incidents downstream from the ramp, and severe weaving problems exist at the ramp gore. Methods to implement ramp closure include message signing and moveable barriers. Specific infrastructure accommodations also need to be in place in order to utilize the ramp closure method. These include adequate alternate routes and alternate ramps.
2. Ramp Metering is the most widely used method of ramp control. Ramp metering is normally applied to alleviate mainline congestion and/or to improve the safety of merging operations.
 - a. Activation control is determined by a fixed schedule (TOD/DOW), in response to mainline traffic conditions, or by operator command (override).
 - b. Metering methods used for metropolitan Detroit include pre-timed and traffic responsive metering (see Table 4-7). Pre-timed ramp metering typically uses preset metering rates (not directly influenced by mainline traffic conditions). Traffic responsive metering calculates metering rates based upon a mainline demand-capacity relationship whereby real-time upstream demand and downstream capacity determines the rate.
 - c. Single-entry metering rates are varied from 180-900 vehicles per hour (vph), and platoon metering rates are used when > 900 vph are required.
 - d. Control implements used for ramp metering include a standard 3-section (red-yellow-green) or 2 section (red-green) metering signal head, an advance ramp

control warning sign with a flashing beacon or “blank-out” (“METER ON”) sign, a local ramp controller, environmental sensors (optional), and vehicle sensors to detect vehicles at the complementary ramp exit, at the ramp entrance, at the stop line (check-in), just passed the stop line (check-out), and optionally in the primary merging area of the ramp and freeway mainline.

3. Integrated Ramp Control applies the principles of ramp metering to a series of adjacent ramps. Integrated pre-timed metering and integrated traffic responsive metering consists of coordinated control where adjacent ramp controllers adjust metering rates based upon traffic conditions throughout an entire corridor. Typical processing calculations use the demand-capacity traffic relationship for metering rates at each ramp, with implementation options which use a central system master a corridor (node) master; or logically-interconnected controllers coordinating metering rates.

4.3.3.2.2 Mainline Control Performance

Mainline control provides a means to [1] improve the stability and uniformity of traffic flow; [2] disseminate pertinent traffic information directly to roadway users to provide warnings and promote awareness; [3] divert traffic to alternate routes make better use of corridor capacity; [4] facilitate incident clearance and recovery by diverting traffic to alternate routes; and [5] change the directional capacity of the freeway mainlines by using reversible lanes. Performance of mainline controls vary depending upon the type of operation. Performance parameters are summarized in Table 4-8 and described in the following paragraphs.

Table 4-8. Mainline Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Variable Speed (Restriction)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
Info. Dissemin, (Restriction)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Altern. Routing (Diversion)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Lane Control (Restriction/ Diversion)	signing	scheduled	real-time thresholds	real-time	enabled	enabled+	enabled+
	barriers	scheduled	real-time thresholds	real-time	enabled	enabled+	enabled+

+ - modified normal mode

Control Strategies. Mainline control strategies are applied to regulate, warn, and guide mainline traffic to achieve more stable and uniform traffic flow. The primary strategy is to detect impending congestion and hazardous roadway conditions and deploy mainline controls to facilitate smoother traffic flow.

Activation Modes. Activation modes are those control processes which determine the conditions in which mainline controls are activated or deactivated. Activation modes include fixed (scheduled), traffic responsive, or operator commanded (override). Except for lane controls established for recurrent traffic patterns (reversible lanes), all mainline controls are activated through pre-defined thresholds based upon real-time traffic conditions and operator concurrence. When activation conditions are no longer valid controls should be deactivated to promote motorist trust in the system. Controls for reversible lanes are scheduled (with operator concurrence) to conform with established recurrent traffic patterns. Scheduling enables predictability for drivers and roadway availability.

Control Modes. The system must provide the capability to determine local environmental conditions and adjust mainline controls to appropriate levels. These conditions include adverse roadway surface conditions due heavy rain (flooding) and snow and ice. The system will enable, disable, and modify mainline controls as weather conditions vary.

1. Normal mode is the default mode and applies to clear weather and roadway surface conditions. This mode specifies mainline controls (speed, mainline demand, integrated ramp demand, alternate routing) to promote system-wide traffic flow stability and uniformity.
2. Rain mode is applied when significant (rain) precipitation is experienced. Controls are modified/adjusted to account for degraded roadway surface conditions and cautious motorist behavior.
3. Snow/ice mode is applied when snow or ice conditions are present on the roadways and ramps. This mode provides similar adjustments as Rain Mode with the addition of deactivating ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers. This mode may specify closure of designated ramps and mainline interchanges due to hazardous roadway conditions.

Mainline Control Implements. Four methods of mainline control applicable to the metropolitan Detroit area include [1] Variable Speed Control; [2] Driver Information Dissemination; [3] Alternate Routing; and [4] Lane Control. Mainline metering could also be applied in the future if the use toll roads become evident as a means to fund new roadway infrastructure developments.

1. Variable Speed Control is utilized to reduce the speed of the mainline traffic during peak-flow conditions so that the flow is adjusted to mainline capacity. At best, variable speed control may delay congestion occurrence. Speed control improves the stability and uniformity of traffic flow during peak-flow periods, thus helping reduce the occurrence of rear-end collisions as congestion develops. Speed control can also be applied as an advance warning system when downstream incidents are detected. Care must be used with speed control to ensure traffic flow conditions warrant use, i.e., control activation to anticipate peak-flow conditions, and deactivation once

congestion conditions are prevalent. Methods to implement speed controls include specific speed signing or integrated with general messages.

2. Driver Information Dissemination is utilized to provide pertinent, real-time traffic information directly to roadway users. Information dissemination is normally applied when abnormal traffic conditions exist and warnings for roadway, traffic, and incident conditions, speed reductions, and route diversions. Methods to disseminate information include variable message signing, variable speed signing, and lane control signals.
 - a. Variable message signing direct to roadway drivers using overhead and roadside equipment (CMS/HAR/AHAR).
 - b. Variable speed signing to provide advance warning for downstream roadway and traffic conditions.
 - c. Lane control indicator to identify lane closures and diversions from typical lane use.
3. Alternate Routing Control is applied when traffic congestion, roadway conditions, and major incidents warrant diversion of mainline traffic to other under-utilized corridors. Methods to provide alternate routing include variable message signing (CMS/HAR/AHAR) and lane control indicators.
4. Lane Control is applied to improve the efficiency and safety of mainline traffic flow. Use of lane control is usually warranted for advance warning of lane blockage, for improvement of ramp merging operations, mainline traffic diversion, mainline tunnel control, and construction/work zones. Methods to provide lane control include variable message signing and permanent/moveable barriers.

4.3.3.2.2.3 Integrated Corridor Control Performance

Integrated corridor control provides a means to improve the stability and uniformity of traffic flow within a corridor through management of all available regulatory traffic controls on both the freeway mainline, service roads, and parallel surface arterials. The fundamental system requirement to achieve integrated corridor control is surveillance and control of both freeway mainlines and surface arterials through coordinated management.

Performance of integrated corridor controls vary depending upon the type and extend of operations. Performance parameters are summarized in Table 4-9 and described in the following paragraphs.

Table 4-9. Integrated Corridor Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Ramp Closure	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
	barriers	N/A	real-time	real-time	enabled	enabled+	enabled+
Intgr. Rmp Cntl	interconnection	N/A	real-time	real-time	enabled	enabled	disabled
Variable Speed (Restriction)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
Info. Dissemin, (Restriction)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Altern. Routing (Diversion)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Lane Control (Restriction/ Diversion)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
	barriers	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+

+ - modified normal mode

Control Strategies. Integrated corridor control strategies are placed into two categories: [1] restriction; and [2] diversion. Restriction limits corridor traffic demand to below corridor capacity levels to stall congestion levels and promote traffic throughput. Restriction strategies are accomplished through regulatory controls, such as, ramp, mainline, and mainline/surface arterial intersections. Diversion transfers excess traffic demand onto alternate corridors with excess capacity. Diversion strategies are also accomplished through regulatory controls with the addition of driver information signing. System integration of these control elements will provide the means to implement the following techniques:

1. Coordination of traffic signals on frontage/service roads and parallel alternate routes
2. Coordination of traffic signals at freeway interchanges with surface arterials (i.e., diamond interchange).
3. Coordination of the ramp control queue-override feature with frontage/service road intersection control to prevent queuing across the intersection.
4. Provisions for turning phases at frontage/service road and alternate route intersections with cross-streets that lead to freeway ramps.
5. Detection of incidents and provisions for rapid response and removal to minimize capacity impacts.

Activation Modes. Activation modes are those control processes which determine the conditions in which corridor controls are activated. Activation modes are traffic responsive or operator commanded (override). All corridor controls are determined by

the system and activated through pre-defined thresholds based upon real-time traffic conditions and operator concurrence. Controls for reversible lanes are determined (with operator concurrence) to conform with established recurrent corridor traffic patterns.

Control Modes. The system must provide the capability to determine local environmental conditions and adjust mainline controls to appropriate levels. These conditions include adverse roadway surface conditions due heavy rain (flooding) and snow and ice. The system will enable, disable, and modify mainline controls as weather conditions vary.

1. Normal mode is the default mode and applies to clear weather and roadway surface conditions. This mode specifies corridor controls (speed, mainline demand, integrated ramp demand, alternate routing, and surface signals) to promote corridor traffic flow stability, uniformity, and roadway efficiency.
2. Rain mode is applied when significant (rain) precipitation is experienced. Controls are modified/adjusted to account for degraded roadway surface conditions and cautious motorist behavior.
3. Snow/ice mode is applied when snow or ice conditions are experienced on the roadways and ramps. This mode provides similar adjustments as Rain Mode with the addition of deactivated ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers. This mode may specify closure of designated ramps and mainline interchanges due to hazardous roadway conditions.

Corridor Control Implements. The control implements use for integrated corridor management coordinate the traffic responsive controls for ramp and mainline controls and integrate the control coordination with surface arterial signal timing and control. Integration with the surface arterial signal network requires real-time coordination with the surface arterial TMC and jurisdictional agreements. In addition, corridor controls need to be directly integrated with incident management plans to provide rapid response coordination and incident traffic diversion deployment.

4.3.3.3 Information Management and Dissemination Processing

Advanced Traveler Information Subsystems (ATIS), in conjunction with Advanced Traffic Management Subsystems (ATMS), will provide a variety of information services to assist travelers in arriving at their destinations whether the mode is via private vehicles, law enforcement, commercial dispatchers, public transportation, and intermodal travel systems. The ATIS will collect travel and traffic information from the ATMS, coalesce and manage the information into presentable forms, and disseminate the information in a variety of methods, to a variety of users. For the metropolitan Detroit area, this ATIS will be integrated with the Michigan Department of Transportation (MDOT) ATMS located at the MITSC. ATMS/ATIS operations are envisioned to be managed from the MITSC.

Disseminated information includes congested and incident locations, alternate routing, roadway/freeway network status, weather and road conditions, roadway limitations and closures, and speed recommendations. Dissemination of traffic information will evolve over several phases, beginning with currently available communications media (i.e., AM/FM radio, variable message signing, printed material, etc.), then to more specialized telecommunications devices (i.e., personal communication devices, intelligent terminals and kiosks, roadway infrastructure devices, full featured call-up services, and other interactive information services), and finally to autonomous, in-vehicle navigation systems, pre-trip planning services from homes, offices, and roadside kiosks, and portable personal data assistants which interact with the infrastructure for real-time traffic and traveler information.

This evaluation examines the performance required to manage and disseminate traveler and traffic information from within the ATIS. Performance for information delivery to users will vary depending upon the telecommunications device and the service used, and is considered beyond the scope of this evaluation.

4.3.3.3.1 Information Management and Dissemination Assumptions

Traffic and roadway information has the potential to be collected from a variety of sources. These include the ATMS, MDOT highway maintenance/construction crews, weather service bureaus, other TMCs, local and state government agencies (i.e., MSP, Detroit Police, Sheriff departments), courtesy patrols, public volunteer services, and local businesses. The following list represents a candidate list of the sources and users that may provide or receive traffic, weather, and roadway status information.

- ATMS traffic surveillance subsystems
- Michigan Emergency Patrol
- Michigan Department of Transportation (MDOT) divisions
- Michigan State Police (MSP)
- Metropolitan Detroit cities and counties public works (i.e., city/county road departments, etc.)
- Edison electric, Ameritech/Michigan Bell
- Local/national weather bureaus
- Roadway commuters and travelers (i.e., cellular call-ins)

4.3.3.3.2 Information Management and Dissemination Processing Assessments

Before any information can be effectively disseminated, it has to be collected, validated, and organized into a form that can be identified, processed (if necessary), and logged. Management of this information needs to occur in an efficient manner in order for effective MDTs operations and to provide timely, valid traffic information and status to outside users. In addition, the operators must be able to easily manage the information and system functions from a integrated work station which minimizes excessive operator actions. This information subsystem interfaces with the various subsystems (i.e., traffic surveillance and control subsystem [ATMS], CMSS, etc.). Figure 4-9 illustrates a

candidate information systems architecture which manages traffic information flow into and from the system.

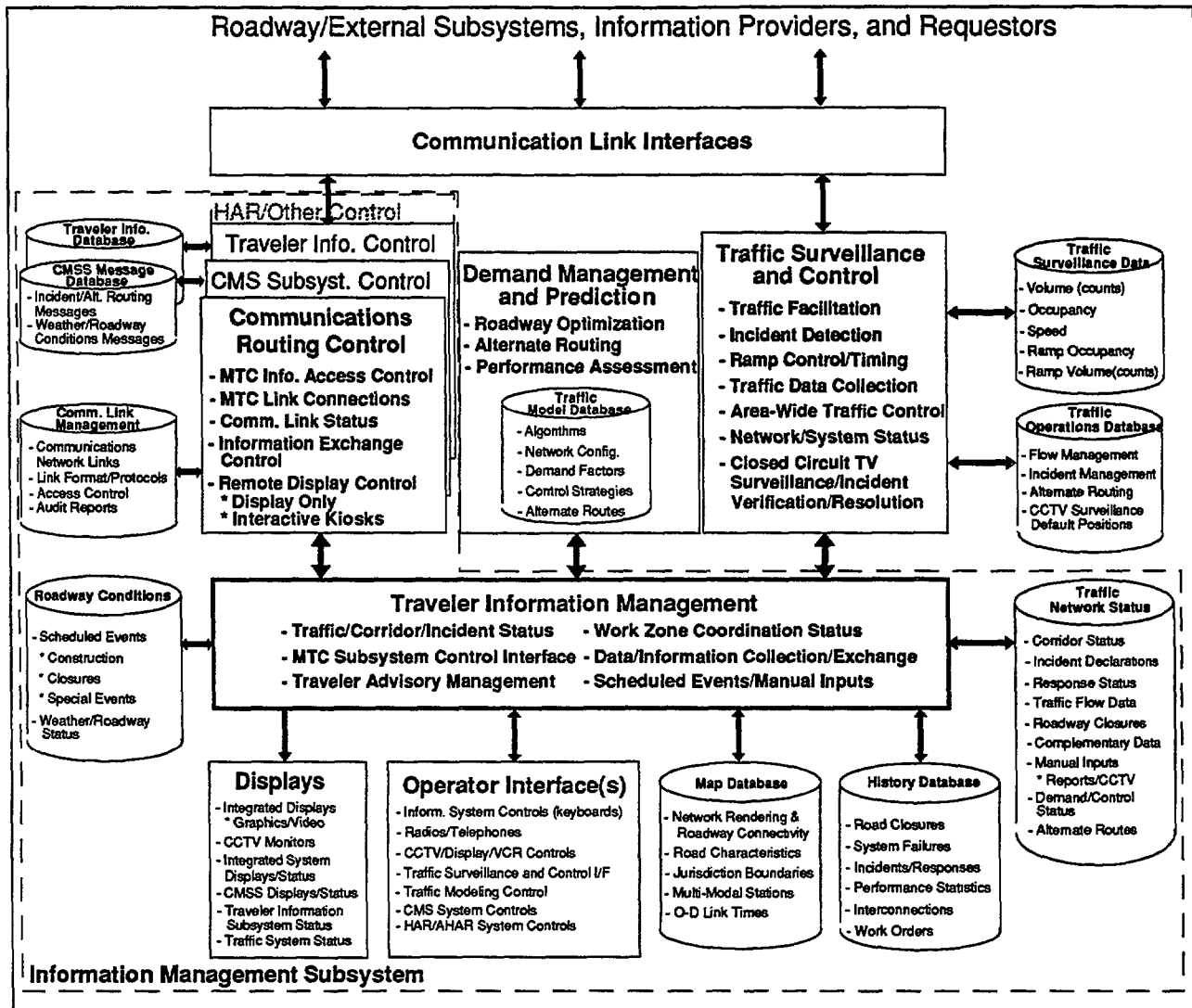


Figure 4-9. ATMS/ATIS Information Management Architecture

4.3.3.3.2.1 Traffic and Travel Information Collection

The traffic and roadway information will be collected by the ATIS from many sources. The primary sources are summarized in Table 4-10 and described below.

Table 4-10. Information Management Subsystem Inputs

Input Information	Source	Input Method	Destination/Database
Traffic Conditions - Traffic Flow Data - Corridor Status - Demand/Control Status - TOC Data Exchanges	- MDTs traffic surveillance subsystems (ATMS) - Michigan State Police (MSP) - Operator - Roadway commuters and travelers (i.e., cellular call-ins)	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions Database
Incident Declarations - CMS messages - Advisories - Alternate Routing	- Operator - MSP - MEP	- Manual	- Traffic Network Database - History Database
Incident Response Status	- Operator - MSP - MEP - Removal Service	- Manual	- Traffic Network Status Database - History Database
Maintenance Work Orders	- Operator	- Manual	- Traffic Network Status Database - History Database
Scheduled Events - Sports - Conventions - Public Works	- Operator - Data Exchange Link - Metropolitan Detroit cities and counties public works (i.e., city/county highway departments, Edison electric, Ameritech)	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions - Traffic Operations Database
Weather Reports	- Operator - Local weather bureaus/reports	- Manual	- Traffic Network Status Database - History Database - Roadway Conditions - Traffic Operations Database - CMSS - Traveler Ino. Subsystem
Roadway Closures - Construction - Maintenance	- Operator - Data Exchange Link	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions - CMSS Message Database - Traveler Ino. Subsystem
System Status - Performance Statistics - System Failures - Work Orders	- Operator - ATMS - MITSC Subsystems	- Manual - Electronic	- History Database - Roadway Conditions
System Configuration - Comm. Network Links - Access Control	- Operator	- Manual	Comm Link Management
Operator Control Commands - ATMS - Traffic Modeling - CMSS - Communications - Traveler Information - Information System Administration	- Operator	- Manual	- Traffic Operations Database - Traffic Modeling Database - CMSS Message Database - Comm Link Management - Traveler Info. Subsystem - System Database

1. The ATMS will provide traffic flow statistics, potential incidents displays/alarms, system status (i.e., Failure Status, Controller Status, Traffic Page, and Incident Page), and CCTV video signals.
2. MITSC operators monitor the ATMS displays/status, MSP dispatcher radio frequencies, MEP printouts, DFOU field crews, weather reports, and perform other MITSC duties (i.e., secretarial) to input and log incidents, system failures, repair work orders, weather and road conditions, and daily summaries

3. Information from local and state government agencies, public services, and sporting and special event organizers, and businesses may provide schedules for events which could impact traffic flow. Information regarding these pre-planned events may be input (by MITSC operators) into the information management subsystem to provide traffic advisories through advanced equipment (i.e., CMS displays, HAR/AHAR announcements, etc.) and implementing traffic control strategies.

4.3.3.3.2.2 Traffic and Travel Information Organization and Management

The Information Management Subsystem (IMS) provides the ‘virtual’ database for management of all system and subsystem data. The IMS will fuse data received from multiple sources, both internal and external to the system. The IMS will serve as a centralized information clearinghouse for up-to-date traffic information. Information access is provided through roadway signing devices, media reporting services, dial-up, and point-to-point/electronic information exchanges.

Operator commands and controls will be routed through the IMS to electronically interface to other subsystems. The information management subsystem must provide timely information upon operator request. System responses and requested information should be provided to the operator without disrupting the continuity of the task (e.g., respond within 10 seconds of the request). CCTV camera controls will be routed through the MITSC operator interface and must be an integrated station where all freeway operations can be managed. Traffic information management and control displays will be integrated to handle [1] overall system status, [2] freeway network surveillance and control, [3] subsystem displays and controls, [4] administrative management (i.e., operator inputs, incident reports, system status reports, work orders, communications link access control. etc.), and [5] software and system updates.

At a minimum, information will be organized into the following categories:

Table 4-11. Database Organization

Database	Data Types (examples)
Traffic Flow Surveillance	Congestion levels/MOEs
	Link times/delays
	Incident detection locations
Traffic Operations	Current control operations
	Incident Management
	Control modes
	Control plans
	System status
Demand Management	Control strategies
	Traffic Demand factors
	System performance statistics
	Predictive control plans
Traffic Network Status	Corridor status/Coalesced MOEs
	Link times/delays
	Incident declarations/locations
	Road closures
	Manual Reports
	Alternate route data
History Database	Compiled traffic MOEs/Congestion levels
	Link times
	Incident Data
	System status/failures
	System work requests/status
Incident Management	Incident Data
	Responding agencies
	Jurisdictions
Map Database	Displays/Map coordinates
	Equipment location
	Surveillance zones
	Jurisdiction boundaries
	Roadway characteristics
Roadway Conditions	Scheduled events
	Weather condition status
	Roadway condition status
Message Signing Database	Changeable Message Signs
	Highway Advisory Radio/Automatic HAR
	Other signing
Communications Management	Network connections
	Communications protocols
	Access controls
	Audit reports

4.3.3.2.3 Traffic and Travel Information Dissemination and Control

The IMS will provide MITSC personnel with an integrated station from which to monitor and control all ATMS/ATIS subsystems. Outputs from the IMS consist of electronic data and information exchanges with subsystems, and also administrative reports for the

purpose of record keeping, traffic studies, data reduction, and maintenance work orders. Table 4-12 identifies information and corresponding output methods used for dissemination to freeway network users.

Table 4-12. Information Management Subsystem Outputs

Output Information	Output Method	Destination
Traffic Conditions - Traffic Flow Data - Corridor Status - Incidents/Response Status	ATIS - CMSS - HAR/AHAR Syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Roadway Conditions - Weather - Closures	ATIS - CMSS - HAR/AHAR Syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Traffic Modeling and Prediction	ATMS - Electronic - Printouts	- Traffic Operations Database - History Database
MDTS Work Orders	- Hard Copy Printouts - Electronic Storage	- MITSC Personnel - History Database
System Reports - Traffic Data - Weather Reports - System Performance Reports - Incident/Response Reports -	- Hard Copy Printouts - Electronic Storage	- MITSC Personnel - System Archives
Operator Control Commands - ATMS - Traffic Modeling - CMSS - HAR/AHAR Subsystem - Communications - Traveler Information - System Administration	- Electronic Storage	- Traffic Operations Database - Traffic Modeling Database - CMSS - HAR/AHAR Subsystem - Communications Routing - Traveler Information Subsystem - Information Management Subsystems

4.3.3.4 System Monitoring Performance

The ATMS/ATIS must be capable of evaluating subsystem components for performance effectiveness and malfunction conditions. Two types of monitoring functions are evaluated in this assessment: [1] Traffic Control Effectiveness; and [2] System Health Status. Monitoring could be accomplished at various levels; however, reports must be delivered to the TMC for evaluation and disposition.

4.3.3.4.1 System Monitoring Assumptions

Assumptions used in this performance assessment encompass the following:

1. Traffic Control Effectiveness is measured from reported surveillance MOEs and compared with current traffic control plans.
2. System Health Status is monitored for all surveillance and control components. Each component has the capability for built-in test (BIT) and executes BIT/self test upon power-on, periodically consistent with MOE reporting periods, and on operator command (local or from MITSC).
3. Central monitoring functions have the capability to further interrogate each component for diagnostic testing to identify malfunctions to the removable module level. Diagnostic testing is commandable through MITSC system operator interfaces.

4.3.3.4.2 System Monitoring Assessments

Real-time system monitoring shall be accomplished from the MITSC through available subsystem equipment. These equipment are primarily the collection points for traffic MOE data and field equipment status. In addition, these equipment also provide the means to assess traffic control effectiveness (via comparison of control plans with MOE data) and malfunction diagnostics (i.e., operator commanded self test).

4.3.3.4.2.1 Traffic Flow Performance Monitoring

Traffic flow performance monitoring is conducted to evaluate the effectiveness of traffic control plans. The primary goal of this function is to ensure the traffic control system is properly configured to meet the traffic demand and does not inadvertently cause traffic congestion problems.

This monitoring function can be thought of as a traffic demand/control assessment function where deployed traffic control plans are used with measured flow volumes to model calculated traffic flow MOEs. These “modeled” MOEs are then compared with measured MOEs and evaluated for consistency (compared to thresholds). Inconsistent values are analyzed and correlated with other data to identify the cause for the inconsistency. If traffic controls or detected incidents are determined as the cause, the system provides the operator with recommended responses (traffic control plan changes, incident responses) and resolution. The performance of this function requires real-time access to MOE data and current traffic control plans (ramp metering, closures, etc.). Statistical results are compiled (per hour) and stored to document the system’s performance.

4.3.3.4.2.2 Equipment/System Health and Status Monitoring

Equipment/system health and status monitoring is conducted to maintain a current view of the system health and operational status. The primary goal of this function is to ensure the system is operating properly and malfunctions are identified and dispositioned. This function requires real-time access to complementary equipment status data (which is reported with traffic flow MOEs). Monitoring of this data also requires interfaces to system status displays and an interrupt capability to perform ancillary operator-commanded functions (diagnostics).

Malfunction indicators shall be automatically issued through visual or audible alarms. The system should automatically issue an initial self test command to ensure the malfunction is not an occasional anomaly. If frequent malfunctions are detected within a short period of time (once every 10 cycles or 10% - approximately every 3 - 5 minutes), the system should automatically flag the anomaly and issue an alarm to the operator.

The system should automatically manage system malfunction information and maintain a historical database for malfunction type, time of malfunction, equipment ID, disposition (i.e., work order issued), operation restoration status, and other pertinent maintenance information.

4.4 Architecture Approach Assessment

The baseline architecture shall be designed from requirements and characteristics derived and analyzed from MDOT operational goals, objectives, and needs to provide a safe, efficient, and cost-effective freeway network infrastructure for the surrounding metropolitan Detroit area. The preferred architecture needs to provide a balance of the following MDOT-defined criteria: [1] supports all current functional processes and open to future desired capabilities and capacities; [2] adaptable to evolving technologies; [3] flexible (modular) in operational configuration; [4] cost-efficient to implement, operate and maintain. Table 4-13 defines evaluation weights corresponding to each of these criteria. This architecture provides the design framework on which hardware, software and support functions (designed from system requirements) are implemented and integrated into an operational ATMS/ATIS.

Table 4-13. Architecture Evaluation Weights

Criteria	Weight Factor
Supports current and future functional capabilities	10
Cost-efficient to implement, operate, and maintain	10
Supports growth capabilities	9
Flexible to configure (modular)	8
Adaptable to evolving technologies	8

To support current MDOT efforts, ATMS/ATIS architecture development has been separated into two levels: Baseline Architecture and Early Deployment Architecture. The Baseline Architecture development includes a broader system design that incorporates the Initial Deployment architecture and provides a general framework on which subsequent phased deployments shall expand integrated system operation for management of traffic flow and roadway information for the entire network of MDOT-defined freeway corridors serving the metropolitan Detroit area. The Initial Deployment architecture development primarily focuses on a design to support the addition of surveillance and control capabilities on a currently uninstrumented priority corridor.

4.4.1 Top Level Architecture Approaches

Architecture configurations tend to be based upon trade-off factors consisting of operational considerations, technological feasibility, growth/evolutionary characteristics, and costs associated with construction/implementation, operation, and maintenance of the configured system. Operational command hierarchies, technological feasibility, and implementation cost considerations primarily influence partitioning and location of functional processing; while, growth and evolutionary characteristics and operations and maintenance cost considerations influence the structure or framework in which these functions are integrated.

As a means to determine a preferred top-level architecture approach, a trade analysis was conducted using the stated MDOT criteria and several candidate architecture configurations. Architecture configurations considered include [1] centralized command and control of system functions, [2] centralized command/decentralized control, and [3]

distributed processing and control. For centralized command and control configurations, all command and control of the system is performed from a central location. For centralized command/ decentralized control configurations, commands originate from a central location down to decentralized locations where the commands are executed and system elements execute local control. For distributed processing and control, strategies are established and distributed to local processors; where local processors execute command coordination and local control of system elements between local processors.

These configurations each have the potential to support ATMS/ATIS applications (i.e., traffic surveillance and control and information management and dissemination). Table 4-14 summarizes general advantages and disadvantages of each architecture configuration approach.

Table 4-14. Architecture Configuration Features

Architecture Configuration	Traditional Application	Advantages	Disadvantages
Centralized Command and Control	Traffic Control Systems Fleet Management Systems Military Command Centers	<ul style="list-style-type: none"> - Raw surveillance data available at operations center for reduction. - Real-time supervisory command and control over all field functions. - Simple field components/sensors. 	<ul style="list-style-type: none"> - Large communications requirement for data collection and control. - Large processing capacity required at central master to coordinate data collection. - Limited growth capability (function of processing/ communication capacity @ central master). - Relatively high implementation and recurrent costs.
Centralized Command/ Decentralized Control	Traffic Control Systems Air Traffic Control Systems Automated Assembly Lines Military Strategic Missile Systems	<ul style="list-style-type: none"> - Real-time supervisory command over all distributed functions. - Localized control processing. - Preprocessed MOEs to central master. - Broad range of communication link options due to lower bandwidth requirements. - Modular growth capability. 	<ul style="list-style-type: none"> - Complex field components/ sensors. - Limited central control. - Complex field processing functions.
Distributed Processing and Control	Automated Factory / Inventory Systems Modern Electronic Manufacturing	<ul style="list-style-type: none"> - Supervisory command over all distributed functions – non real-time. - Localized command and control processing. - Preprocessed MOEs to central master. - Modular growth capability. 	<ul style="list-style-type: none"> - Complex field components/ sensors. - Complex field processing functions. - Relatively high development and implementation costs. - Limited non real-time central control. - High inter-node communications.

Trends of typical and anticipated traffic subsystem procurement costs are illustrated in Figure 4-10. These trends identify costs related to implementation of subsystem equipment and hardware. Operations and maintenance costs of system are directly related to the structure of the architecture (i.e., communications) and types of hardware used.

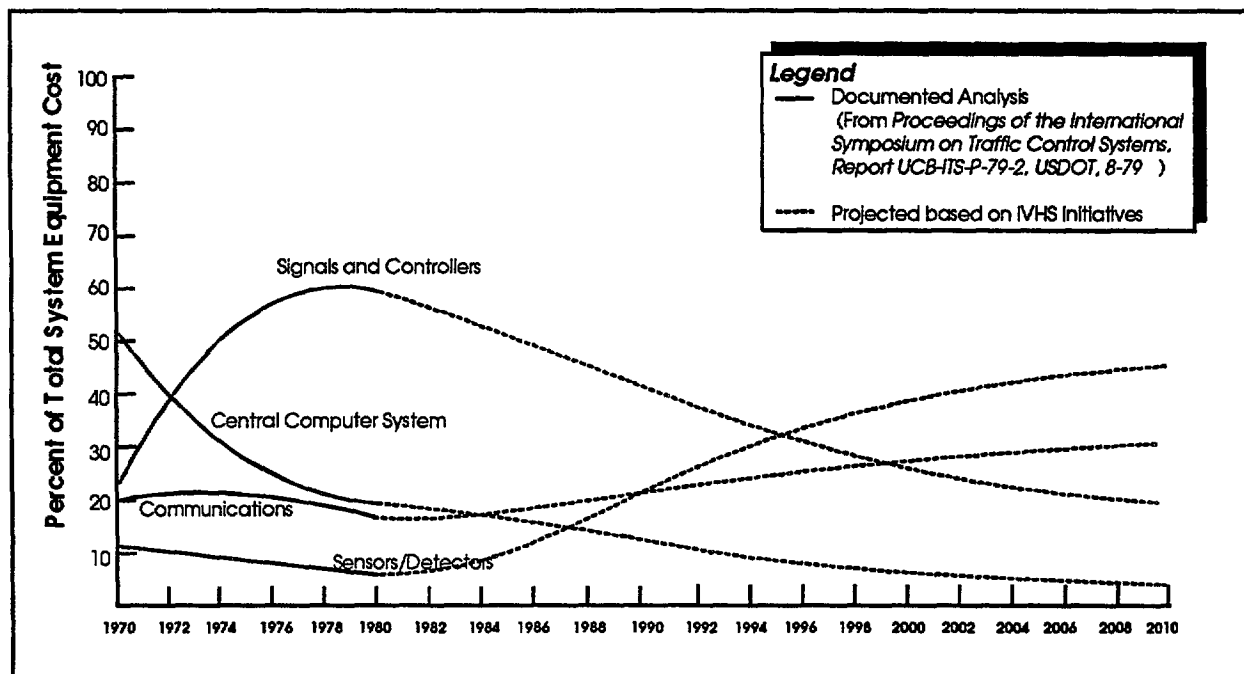


Figure 4-10. Relative Procurement Costs for Major TMS Subsystems

4.4.2 Evaluation of Architecture Approaches

The three basic architecture configuration approaches were evaluated based upon the criteria listed in Table 4-13. In general, the architectures were evaluated in terms of relative assessments for computer processing, communications bandwidth, hardware and software complexity, technology adaptability, configuration expandability, and implementation, operations and maintenance cost. A relative assessment approach was chosen in order to be consistent with the qualitative nature of the architecture attributes as specified by the system goals and objectives. This qualitative approach provides a comparative measure without detailing implementation-specific architecture configurations. In this fashion, architecture attributes are used in conjunction with the functional processes and performance requirements to define the architecture partitioning drivers. An architecture that is implementation-neutral provides modularity in functional processing and operation while offering adaptability through defined (standardized) interfaces, and flexibility and expandability in configuration. Modularity and standardization in architecture design also promotes cost-effective operations and maintenance.

Table 4-15 identifies and compares each architecture configuration relative to system processing capacities, openness, technology adaptability, flexibility, expandability, and cost-efficiency (i.e., implementation, operations, and maintenance).

Table 4-15. Architecture Configuration Approach Comparisons

Architecture Attributes	Centralized Command and Control	Centralized Command / Decentralized Control	Distributed Processing and Control
Required Processing Capacities	@ central master	@ central master and local nodes	@ central master and local nodes
Surveillance MOE Processing	high @ central master	medium @ local nodes	high @ local nodes
Traffic Control Processing	high @ central master	low @ local nodes or central master	medium @ local node to node coordination
Communications Bandwidth	high – critical timing for central communications	medium – sensor to local node. medium – local node to central master	medium – sensor to local node medium – node to node coordination low – local nodes to central master
System Complexity			
- Hardware	high- central master computing capacity	medium – central master medium – local nodes	medium – central master medium – local nodes
- Software	medium – time critical communications management	medium – central master medium – local nodes	medium – central master low – local nodes
Technology Adaptability	limited to central master capacity	good – based on modularity	good – based on modularity
- surveillance	limited – modular component	good – modular component	good – modular component
- communications	limited	good – modular component	good – modular component
- motorist information	limited	good – modular component	good – modular component
- incident mgmt.	good – data and capacity availability	good – integrated @ central master	good – integrated between local nodes and central master
- information mgmt.	limited to central master capacity	good – modular component to central master	good – modular component to local nodes or central master
Configuration Flexibility (Modularity)	limited due to centralized processing and critical communications	good – modular components - sensors - communications - processing platforms - data management platforms	good – modular components - sensors - communications - processing platforms - data management platforms
Costs			
- Implementation	medium	medium	high
- Operations	high	low	low
- Maintenance	medium	low	low

Institutional Issues Relating To ATMS/ATIS Deployment

Additional considerations which influence the architecture approach and deployment exist within the non-technical area and may provide reasons to avoid certain conditions or situations to enhance system acceptance and inter-agency cooperation. (Suggested roles and responsibilities of other agencies are also discussed in Section 4.2; System Operations.) These considerations are identified in following paragraphs.

- a. ATMS/ATIS Technology Deployment. Advanced technologies in computer processing and communications can significantly reduce travel delays, provide coordinated incident management, and improve safety. However, the acceptance of deployment of these technologies has been proceeding slower than implementation of high technology components into automobiles. This action can potentially be attributed to the fact that implementation of ATMS/ATIS components on roadways are almost exclusively the responsibility of the public sector.

Streets and highways which are deployed with ATMS and ATIS technologies are under the jurisdiction and control of state and local governments. In most cases, more than one government jurisdiction is involved. Therefore, the cooperation and coordination among various level of government and different departments within government is necessary.

- b. Inter-agency Coordination. Negotiations and institutional arrangements is actually a larger task than the technology implementation phase itself. However, the task of developing inter-agency relationships and cooperation must precede the installation and operations of ATMS and ATIS. The metropolitan Detroit area participants have taken the first step in creating such relationships by assembling the Metropolitan Detroit Incident Management Coordinating Committee. Monthly Early Deployment of ATMS/ATIS status meeting are also convened to keep various agencies within deployment jurisdictions of the progress abreast of the implementation architecture, operations, and deployment corridor selection. A draft memorandum of understanding is included in Appendix III.
- c. Technology Barriers. Key aspects of ATMS/ATIS technology deployment are not only system design, technology selection, and installation; but are also operations and maintenance. Traffic engineers who are employed by state and local governments have a significant role in making ATMS/ATIS deployment a success. These traffic engineers, most of whom had early training as civil engineers, may not have complete understanding of deploying advanced technologies of computers and communications. However, they do have the knowledge and understanding of traffic operations needed to assure that new technologies be applied to solve current operational problems. Even though the electrical and computer engineers designed the ATMS/ATIS using system components of advanced technologies, it is traffic engineers who have the understanding of the traffic system that will apply these technologies. Therefore, cooperation and understanding between system designers and system users must be strictly maintained.

- d. IVHS Application. Not all Intelligent Vehicle-Highway Systems (IVHS) components face the level of institutional barriers. Advanced traveler information systems, advanced public transportation, and commercial vehicle operations are examples of IVHS components which have minimal institutional ties. Decisions to purchase in-vehicle navigation systems can be decided by a single person and the decision to deploy advanced communication systems on board commercial vehicle operations or public transportation can be made by fleet managers. Decisions involving the use of public road, however, are more difficult since responsibilities are spread among different levels of government and different agencies within government.

An example of such difficulties are areas where ATMS are deployed among state controlled highway systems and city or local government controlled arterial systems. Highway ATMS may divert significant volumes of traffic onto arterial streets to support highway incident management strategies. Many local agencies view that their role is to provide the adjacent street system to absorb diverted traffic. A truly integrated ATMS would integrate freeway operations and the arterial street traffic control systems so both operations benefit. Such integration, however, may be difficult due to different agency priorities of utilizing public funds to support the inevitable increase in traffic demand.

- e. Incident Management. Incident management can be considered one of the most important aspect of ATMS. Incident management activities must be coordinated among agencies to properly respond to motorist emergencies, accidents, and other travel delay causing events. Some institutional issues involving the incident management component of ATMS are:
- Legislative encouragement is needed to remove vehicles from immediate accident scenes for accident reporting
 - Who takes control of an incident scene
 - Removal of abandoned vehicles must be accomplished in a timely manner (faster than the current 48 hour requirement)
 - Budgets for or means to recover over-time pay for responding personnel
 - Standardize jurisdictional boundaries
 - Elevate incident management to a higher level priority for responding agencies
 - Make funds available to upgrade and maintain alternate routes
 - Require periodic vehicle safety inspections to help prevent incidents
 - Enforce a minimum speed limit on freeways to reduce congestion
 - Cite motorist for running out of fuel on major freeways
 - Allocate a common communications channel or frequency for inter-agency communications (i.e. state, local, and international access)
 - Search for means of compensating service patrols (tax credits, public funding, fuel tax, etc.)
 - Coordination of any construction projects which may impact system capacity
 - Benefits from cooperative participation should be advertised

- f. Other Institutional Functions. Other government administrative departments such as human resources, accounting, information systems, finance, purchasing, and legal departments are other groups who need to participate in ATMS/ATIS deployment. These organizations are important in providing operational support and planning.

Functional Relationship to USDOT FHWA National IVHS Architecture User Services

In addition to the attribute and non-technical assessments, the architecture and functional constituents were also compared against the USDOT FHWA National IVHS Architecture User Services Requirements (dated October 13, 1993). The table maps currently-identified low-level MITS (architecture) functions into the structure of identified National IVHS Architecture User Services. The objective of this mapping is to identify synergism between MITS functionality and the 27 identified user services. But, due to the high-level nature of the IVHS User Services, multiple low-level functions were found to be contained within the scope of a single service, or fragmented over several services. Table 4-16 provides an index for each of the 27 user services. A summary of this comparison is illustrated in Table 4- 17.

Table 4-16. National IVHS Architecture User Service Index

#	USER SERVICE
1	Pre-Trip Planning
2	Driver Information
3	En Route Transit Advisory
4	Traveler Service Information
5	Route Guidance
6	Ride Matching and Reservation
7	Incident Management
8	Travel Demand Management
9	Traffic Control
10	Electronic Payment Services
11	Commercial Vehicle Preclearance
12	Automated Roadside Safety Inspection
13	Commercial Vehicle Administrative Process
14	On-Board Safety Monitoring
15	Commercial Fleet Management
16	Public Transportation Management
17	Personalized Public Transit
18	Emergency Notification and Personal Security
19	Public Travel Security
20	Emergency Vehicle Management
21	Longitudinal Collision Avoidance
22	Lateral Collision Avoidance
23	Intersection Collision Avoidance
24	Vision Enhancement for Crash Avoidance
25	Safety Readiness
26	Pre-Crash Restraint Deployment
27	Automated Vehicle Operation

Table 4-17. IVHS User Service Mapping

Low-Level Function	IVHS USER SERVICE																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1.2.1.1.1								✓																			
1.2.1.1.2								✓																			
1.2.1.1.3							✓	✓																			
1.2.1.1.4								✓																			
1.2.1.1.5.1							✓	✓																			
1.2.1.1.5.2							✓	✓																			
1.2.1.1.5.3				✓			✓	✓																			
1.2.1.2.1.1							*	✓																			
1.2.1.2.1.2								✓																			
1.2.1.2.1.3							*	✓																			
1.2.1.2.1.4							*	✓																			
1.2.1.2.1.5							*	✓																			
1.2.1.2.2		✓					✓	✓																			
1.2.1.3.1							✓														✓						
1.2.1.3.2							✓																				
1.2.1.3.3							✓																				
1.2.1.3.4							✓														✓						
1.2.1.3.5							✓									*					✓						
1.2.1.3.6	✓	✓	*	✓	*		✓	✓	✓																		
1.2.1.3.7		✓		✓			✓	✓	✓																		
1.2.1.4				✓			✓	✓							✓	✓					✓						
1.2.1.5				✓	*		✓	✓							*												
1.2.1.6								✓							*	*	*				✓						
1.2.2	✓			✓				✓																			
1.2.3.1				✓																							
1.2.3.2				✓																							
1.2.3.3.1	✓	✓		✓			✓	✓																			
1.2.3.3.2	✓	✓	✓	✓			✓																				
1.2.4.1								✓	✓																		
1.2.4.2.1				✓				✓																			
1.2.4.2.2				✓				✓																			

✓ - denotes direct service support; * - denotes indirect service support

Each architecture configuration is assessed against the criteria listed in Table 4-13 and assigned scores using a scale of 10 to 1; where 10 completely satisfies the criteria, and 1 does not satisfy any aspect of the criteria. Scores are assessed based upon currently known capabilities and application maturity. Table 4-18 defines the evaluation scoring guidelines for assessing each architecture configuration approach.

Table 4-18. Evaluation Assessment Guidelines

Level of Evaluation	Score
Exceeds Criteria	10
Fully Satisfies Criteria	9
Good Compliance with Criteria	8
Above Average	7
Average Compliance	6
Minimum Requirement Satisfied	5
Marginal Satisfaction	4
Partial Satisfaction	3
Poor Satisfaction	2
Does Not Satisfy	1

Once individual attribute categories are scored, each score is multiplied by its corresponding weight factor to obtain a weighted score. All weighted scores are then summed for a total score. The largest score identifies the best approach/option based upon current technology capabilities and related costs. Evaluation scores for this trade analysis are summarized in Table 4-19.

Table 4-19. Architecture Approach Trade-off Summary

Evaluation Criteria	Weight Factor	Scores		
		Central Command and Control	Central Command/Decentral Control	Distributed Processing and Control
Supports current and future functional capabilities	10	score = 6 subtotal = 60	score = 9 subtotal = 90	score = 9 subtotal = 90
Cost-efficient to implement, operate, and maintain	10	score = 7 subtotal = 70	score = 9 subtotal = 90	score = 7 subtotal = 70
Supports growth capabilities	9	score = 6 subtotal = 54	score = 9 subtotal = 81	score = 9 subtotal = 81
Flexible to Configure (Modular)	8	score = 7 subtotal = 56	score = 9 subtotal = 72	score = 10 subtotal = 80
Adaptable to evolving technologies	8	score = 7 subtotal = 56	score = 8 subtotal = 64	score = 8 subtotal = 64
TOTAL SCORES		296	397	385

For this assessment, a centralized command, decentralized control architecture approach indicates the best balance for an ATMS/ATIS serving Metropolitan Detroit. This approach allows the system to be commanded from a central location (DFOC), and those commands are executed by local controllers/processors within the corridors.

4.5 Baseline Architecture Description

The objective of the Baseline Architecture is to develop the system framework on which to implement traffic sensors, instrumentation, and controls, controllers, communications, operations command and control, and traffic information processing and management for the greater Metropolitan Detroit freeway network. This system will expand MDOT's current traffic management capabilities to priority corridors to promote traffic mobility and highway safety on the freeway network

With the centralized command, decentralized control architecture approach, certain system constraints are levied. The communications path between the central facility and field locations require only command and summary data traffic. An assumption is made that pre-processing and local control takes place in the field to allow for a lower communications bandwidth requirement with the central facility. Only summary data and status-type reports are returned to the central facility for further processing.

With the use of these processing constraints, an allocation was developed for all identified functions. Three levels of processing were defined to accommodate central processes, node-level processes, and line processes. Central processes interface with a system operator, provide "strategic" level commands to nodes and field components, and provides the functions to manage traffic and travel information. Node-level processes provide the collection point for data, and execute commands issued from the central processes. Node-level processes also perform data processing to "package" data summaries and monitor equipment status. Line processes provide the "tactical" controls for the traffic manager.

Based upon performance levels, the functions identified in section 4.3.2 have been analyzed and allocated to different processing levels as listed in Table 4-20. It is noted that some functions are allocated to multiple levels. In those cases, the functions have been identified to potentially reside in more than one level based upon potentially different implementation approaches. This characteristic supports the architecture attribute for flexibility to allow implementation of varying degrees of technical capability.

This allocation provides the basis on which to examine processing and communication requirements for the system. A goal to minimize the amount of "raw" traffic surveillance data required at the central facility was the primary criteria used in this examination. An illustration of this allocation is depicted in Figure 4-11.

Table 4-20. ATMS/ATIS Functional Allocation

Function Name	Central Process	Corridor Process	Line Process
Perform Traffic Network Surveillance and Control	N/A	N/A	N/A
Perform Mainline Flow Surveillance	N/A	N/A	N/A
Perform Vehicle Detection			✓
Calculate Corridor MOEs		✓	✓
Manage Corridor MOEs	✓		
Display Corridor MOEs	✓		
Perform Video Surveillance	N/A	N/A	N/A
Collect Video Images			✓
Video Image Control	✓	✓	✓
Display Video Images	✓		
Perform Mainline Flow Control	N/A	N/A	N/A
Perform Mainline Ramp Control	N/A	N/A	N/A
Determine Ramp Control Mode	✓		
Provide Ramp Metering Mode Options	✓		
Provide Ramp Metering Activation Control	✓		✓
Provide Ramp Control			✓
Provide Integrated Corridor Ramp Control	✓	✓	
Display and Control Changeable Messages	✓	✓	
Facilitate Incident Management Tasks	N/A	N/A	N/A
Perform Incident Detection	✓	✓	
Provide Incident Verification Capabilities	✓		
Record and Manage Incident Information	✓		
Facilitate Incident Notification and Response	✓		
Facilitate Incident Response and Removal Coordination	✓		
Perform Incident Traffic Management	✓	✓	
Disseminate Incident Information	✓		
Perform Area-Wide Traffic Coordination	✓		
Perform Work Zone Management	✓		
Perform Traffic Demand Management	✓		
Display Traffic Network Status	✓		
Perform Traffic and Travel Information Management	N/A	N/A	N/A
Collect Traffic and Travel Information	✓		
Manage Traffic and Travel Information	✓		
Disseminate Traffic and Travel Information	N/A	N/A	N/A
Provide Dissemination and Access Mode Control	✓		
Support Information Clearinghouse Activities	✓		
Perform System Performance and Malfunction Monitoring	N/A	N/A	N/A
Monitor Traffic Network Performance	✓	✓	✓
Perform System Malfunction Monitoring	N/A	N/A	N/A
Perform Routine Status Monitoring	✓	✓	✓
Determine System Malfunction	✓	✓	✓

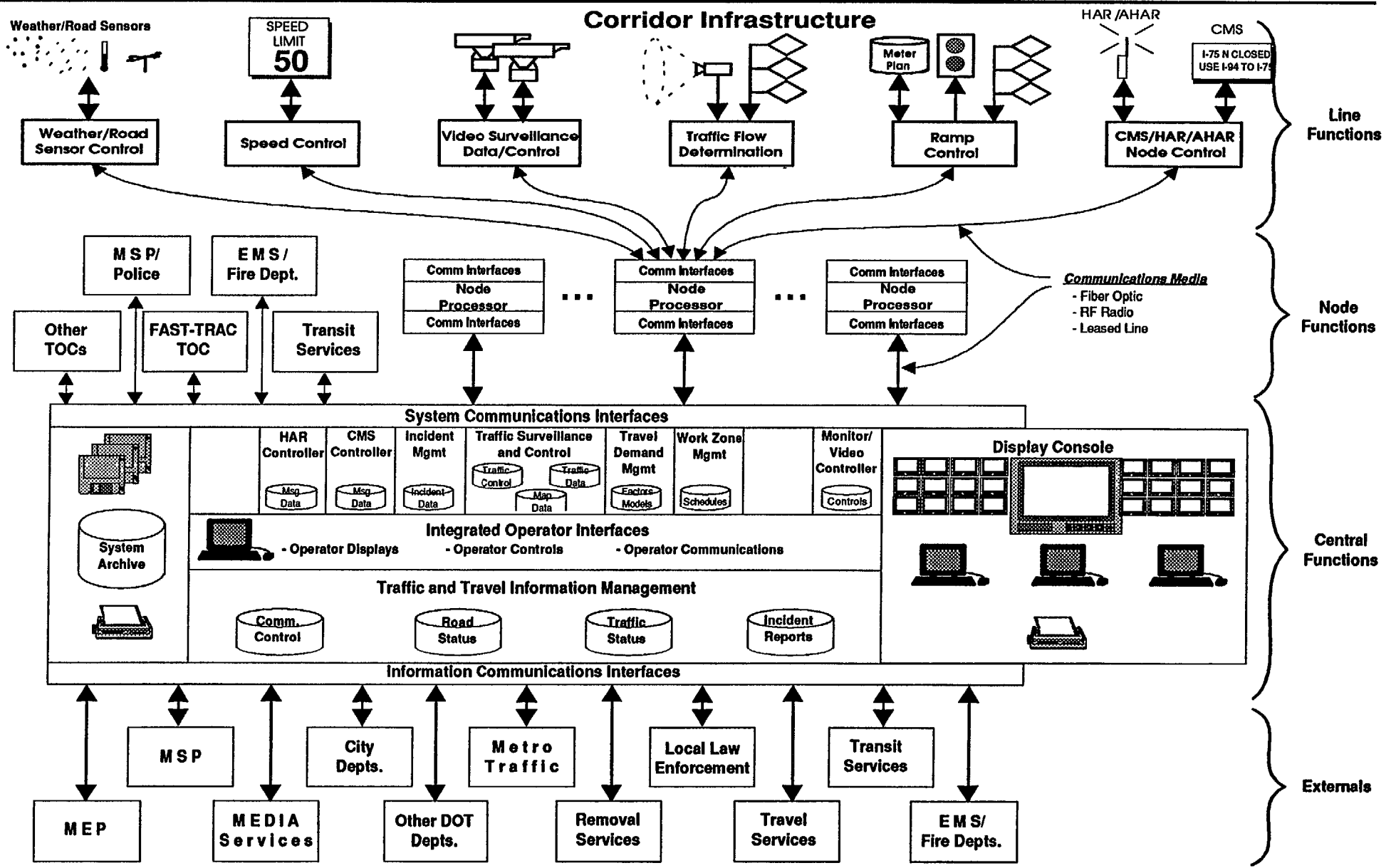


Figure 4-11. Baseline Architecture Configuration

During the period where new corridors are being instrumented and brought on-line, the architecture must be able to accommodate a coexistence of existing SCANDI equipment and new equipment. A transition period will provide the operational changeover from SCANDI to the new system.

DFOC operations will require integration of the different existing traffic subsystems (i.e., CMSS, HAR/AHAR, SCANDI, CCTV, and system operations) and new subsystems HAR control. The approach to integrate these subsystems relies upon a modification of the current operations. This is meant to functionally integrate those functions which are currently operated on an individual basis. In addition, the new DFOC operations environment will include an additional capability to collect, manage, and disseminate traveler information.

Integration of new corridors the inputs and outputs of the three relatively independent subsystems, (i.e., video monitor/camera, CMS, and traffic surveillance and control), must be isolated for independent communications and routing control; however, Tie-Division Multiplexing (TDM) of the various controls and status will accomplish the modulation required to interface with the current RF cable system. Selection of where TDM is performed is based primarily on implementation cost and minimizing impacts to existing resources. Candidate locations for TDM include locations where the existing SCANDI system is used as a communications link to the DFOC headend.

4.5.1 Modifications to Current Subsystems and Additional Equipment

Deployment of the Baseline Architecture shall require equipment modifications and additions to provide traffic surveillance and control and information capabilities to the priority corridors. The following paragraphs describe the nature of these modifications and additions.

General Hardware Modifications. Additional headend communications hardware and DFOC information server equipment will be required to implement the Baseline Architecture. These primarily involve new communications and modulation equipment to receive traffic data and equipment status from field controllers and transmit traffic control commands to the same controllers.

New instrumentation to be installed in the corridor infrastructure includes controllers, communications equipment, vehicle detection sensors, signal heads, variable speed signs, changeable message signs, highway advisory radio transmitters, and other ancillary equipment.

General Software Modifications. The Concurrent computer will remain the central computing resource in the DFOC, however, it will no longer be required to collect and calculate individual vehicle detection station MOEs, and control entrance ramp operations. The Concurrent computer will provide the command platform to conduct overall traffic operations ranging from corridor link performance and status monitoring, areawide

incident detection, and areawide traffic control strategy development. In addition, the computer may be used to perform traffic demand prediction through the use of scheduling data received from traffic generators such as employment sites, special events, or highway maintenance and construction zones. The current GDS system will be augmented and modified to display the entire Metropolitan Detroit freeway and trunkline network and provide an integrated user interface platform for the entire ATMS/ATIS.

Software will be developed to interface the additional sensors, ramp controllers, video cameras, and CMS and HAR resources to provide, as a minimum, the same capabilities in the current system.

The current Graphic Display Subsystem (GDS) software and database shall be modified to process traffic network and system status on a more operator-timely basis. Waiting time for new map screens, lower-level mainline flow details, and traffic flow updates will be reduced to display the current traffic and system status at the time of the request.

Due to the decentralized command approach, it is noted that when intelligent remote ramp controllers are used (as opposed to central control of the ramp activities on a 250 ms basis), it may not be possible to provide the low-level vehicle passage and ramp signal on/off information for real-time display, and that this capability, when weighed against communications and other costs, may not provide much value-added benefits. If low-level operations are needed, monitoring of vehicle passage may be obtained through CCTV. If the ramp display capability is important for diagnosis of incidents and system faults, generation of the necessary GDS inputs at 250 ms intervals for a specified ramp may be provided by software simulation on the Concurrent central computer, based on the ramp flow volume, metering rate, queue and demand information received from the ramp controller during the last reporting interval.

4.5.1.1 Sensor Requirements

Additional sensors to monitor traffic volume and occupancy shall be compatible with existing inductive loop resources. The sensors shall cover all lanes of the freeway in both directions. The sensors shall be capable of sensing all vehicle types from motorcycles to multiple-trailer trucks traveling at speeds from 0 to 100 mph. The sensors shall provide reliable detection under all environmental conditions possible in southeast Michigan including rain, snow, ice, fog (with visibility greater than 25 feet) and clear conditions at air temperatures from -25 to +120 degrees Fahrenheit.

4.5.1.2 Sensor Processing

Local processing of sensor information shall be provided in the roadway infrastructure to yield total volume, average occupancy, and average speed (using “timing gates”, where required) at a minimum interval of 10 seconds and a maximum interval of 20 seconds. The resulting data shall preserve individual lane information consistent with current system formats. The data shall contain all required information, including time tagging, so that it is usable (possibly after conversion / combination) by the existing 3280MPS algorithms to provide data fusion into 1 minute periods at 20 second intervals.

Status of the remote sensor subsystems shall be provided at the same interval as the sensor information to enable fault isolation to the field replaceable unit (Line Replaceable Unit {LRU}) level. The subsystems shall be capable of maintaining and outputting additional status information, upon request, to isolate malfunctions and faults to the lowest circuit card / shop replaceable unit (SRU).

4.5.1.3 Ramp Control Processing

Local autonomous entrance ramp control shall be provided at those ramps which are designated for that purpose. The ramp control shall be operational without the need for any special commands from the DFOC to provide, as a minimum, a (pre-set) vehicle entrance rate of from 4 to 15 vehicles per minute (vpm) at a minimum of 2 (pre-set) time of day (TOD) intervals. Metering rates and TOD schedules shall be downloadable from the DFOC.

- a. The ramp control subsystem shall accept commands from the DFOC to modify the time and rate settings within specified intervals including full start-up and shut-down override operations.
- b. The ramp control subsystem shall maintain occupancy and volume information, even when flow is not being regulated. The ramp control subsystem shall be capable of sending status information to the DFOC at a rate of 10 seconds minimum to 20 seconds maximum containing, at a minimum, the following:
 1. Ramp identification
 2. Ramp occupancy
 3. Ramp traffic volume
 4. Current metering rate
 5. Time tagging information / sequence number
 6. Subsystem status which allows fault isolation down to the LRU
- c. The ramp control subsystem shall be capable of maintaining and outputting additional status information upon request to isolate faults down to the lowest circuit card / shop replaceable unit (SRU).

4.5.1.4 Changeable Message Sign Processing

New CMS resources will be added to the system. They shall be compatible with the existing CMS monitor and control subsystem. Software changes to the CMS control system to incorporate the new CMS shall be limited to database updates necessary to bring the new CMS on-line. Operator command will be enabled through an integrated user interface.

4.5.1.5 Video Surveillance

Full-motion video shall be provided at those locations designated for surveillance. The infrastructure shall accommodate a 6 MHz video bandwidth using standard NTSC video. The video signal(s) shall be routed to the MDOT DFOC at the nearest junction point to the new equipment using spare existing cable capacity wherever possible.

4.5.1.6 Communications

Communications between corridor processing and the DFOC shall be designed to provide the following capabilities for each corridor (as a minimum):

- a. Sufficient communications bandwidth capability shall be designed into the each deployment corridor to provide full-motion NTSC video signals and bi-directional data transfer.
- b. Communications facilities shall be provided for one-way video transfer to the DFOC, remote camera Pan-Tilt-Zoom (PTZ) and camera switching, communication with entrance ramp meter controllers on a 10 second minimum interval, processed (volume, occupancy, speed, status) inputs from mainline detectors on a 10 second (minimum) interval, and control / status collection from Changeable Message Signs (CMSs).
- c. Sufficient processing capacity shall be available for control of Highway Advisory Radio (HAR) transmitters.

Each corridor deployment shall not require more than 50 percent of the design communications capacity. The remainder is reserved for future expansion. Alternative temporary communication facilities, such as wireless radio or leased lines, may be considered to enable quick deployment.

The Baseline Architecture will use an entirely new communications networking system to cover the extended ranges required to communicate with field components. This new system is required to accommodate the vast expanse through the Metropolitan Detroit areas with additional growth and expansion capabilities. When a communications “backbone” media is embedded on one side of a roadway, the use of short-distance wireless communication from equipment cabinets located on the backbone side to equipment cabinets located on the opposite side of the roadway shall be weighed against the life-cycle cost (LCC) of trenching across the freeway for the installation of fixed wire/fiber link required to reach the backbone. Similarly, the life cycle costs of using wireless

communication methods from video cameras to a nearby cabinet shall be weighed against the installation of fixed lines for both video signal return and camera PTZ controls.

Because pre-processing of sensor inputs and autonomous operation of ramp controllers is specified, the communication bandwidth for these functions will be quite low and well within the capability of UHF, VHF packet or spread-spectrum radios. CMS communications could also be handled within this bandwidth or the current CMSS. The primary communication difficulty is with the full-motion video. Even using compression techniques, a minimum of 1.5 MHz bandwidth (T1 Carrier) is currently required.

Commercially-available means for communicating with cameras using short-distance wireless radio is available. Further evaluation of these means are required based upon system requirements and cost considerations. It is also possible to avoid costly trenching operations between ramp controllers on the opposite side of a roadway to the communications backbone cable or fiber using wireless radio.

4.5.1.7 Baseline Architecture DFOC / MTC Headend

Figure 4-12 shows the DFOC headend interfaces. At the DFOC, video inputs will use the existing blonder-tongue (B-T) demodulator / Vicon Switcher and video control architecture. It is envisioned that additional B-T video demodulator(s) will be required for additional corridor cameras or as the system expands beyond the current design capacity, the unit will be replaced altogether.. The Vicon equipment currently provides a sufficient number of spare ports for camera video inputs and monitor outputs.

Similarly, new camera controllers will remain compatible with the current camera control system. Some modifications may be required to the PC database to accommodate new cameras and addressing, but there should be adequate spare margin for additional cameras. The same cable frequency modulator will be used as for all other cameras, operating at a frequency of 18.1 MHz with a 56KB B da a rate during the transition phase, and then the entire system may be replaced to better accommodate CCTV operations on a wider scale.

The details of the new Vultron CMS controller interfaces are unclear at this time, but it is believed that the standard “modem” type of interface (TCP/IP, RS-232, RS-422) can be used as for existing wireline-connected CMS facilities. To conserve cable resources, however, this infrequent control information will be multiplexed in a straightforward manner with the (also infrequent) new ramp control parameter overrides and ramp / loop status requests. The multiplexing may be as simple as controlling the Clear-to-send (CTS) line(s) going back to the Vultron CMS controller and new Concurrent serial interface to assure that only one device is sending data at a time with a digital selector used to route the appropriate input to the output. Responses coming back from the remote CMS controllers will be routed to the Vultron CMS controller by a demultiplexing process based on a simple algorithm such as received data parity. The throughput of the 56KB RF cable modem should be adequate to satisfy the currently-programmed response requirements of the Vultron software operating on a 2400 bps wireline modem.

Since the remote ramp controllers and loop controllers contain intelligent processing, they do not need to be polled to return the ramp MOE's (occupancy, queue, and demand, flow volume, metering rate, time, status) or the loop MOE's (volume, occupancy, speed). The remote controllers are expected to send this data at their pre-set rates once commanded "on" without further polling. Commands to the ramp controllers to change metering rates or activate / deactivate metering may also be sent. The capability to poll the controllers for additional status (primarily faults) is also provided.

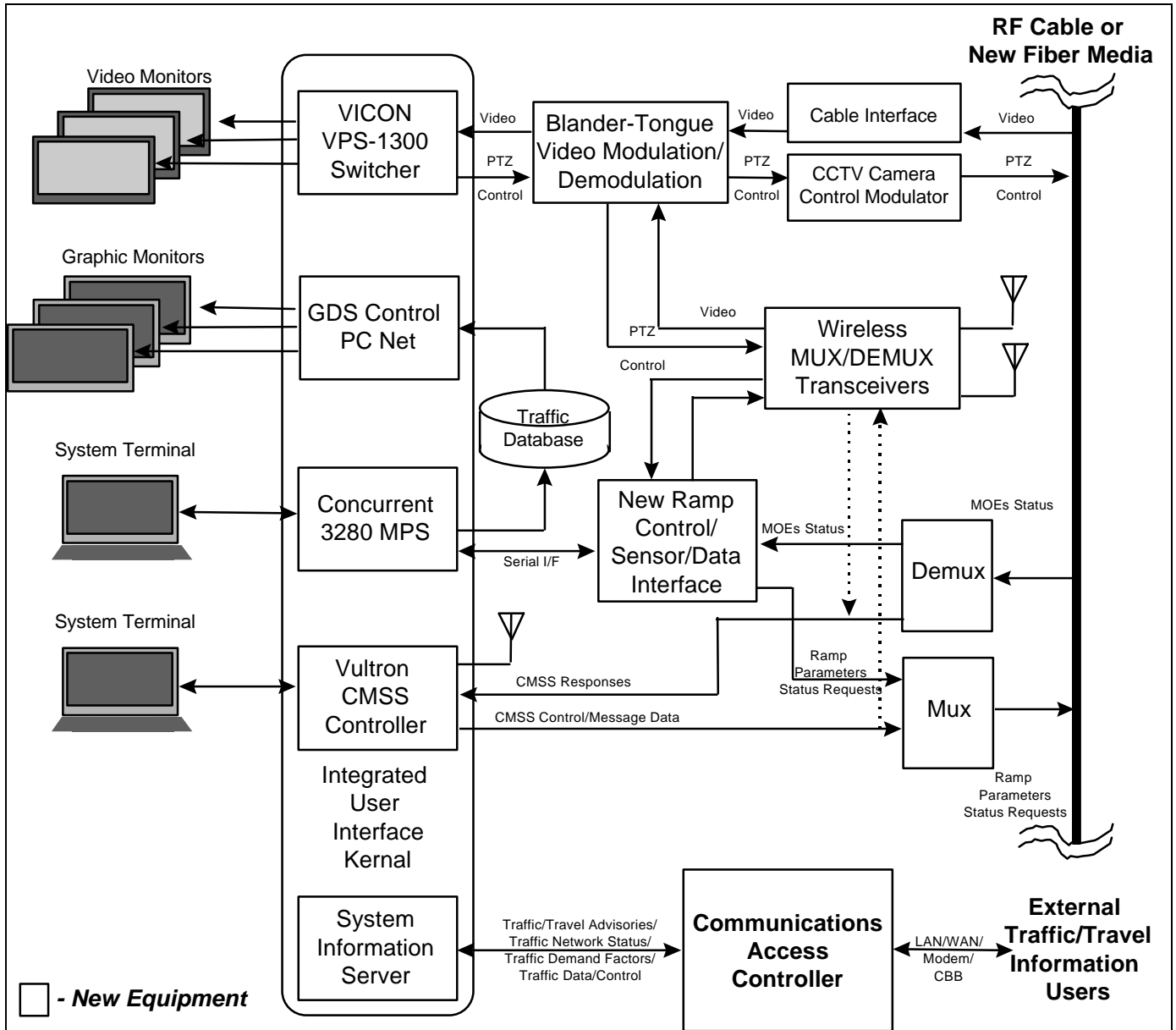


Figure 4-12. Baseline Architecture MTC/DFOC Headend Detail

4.5.1.8 Communications Media Junction

Figure 4-13 shows the internal detail for a "junction box" which will provide the interface between differing communications media. The equipment converts between any of 3 possible communications media to media for a given node controller..

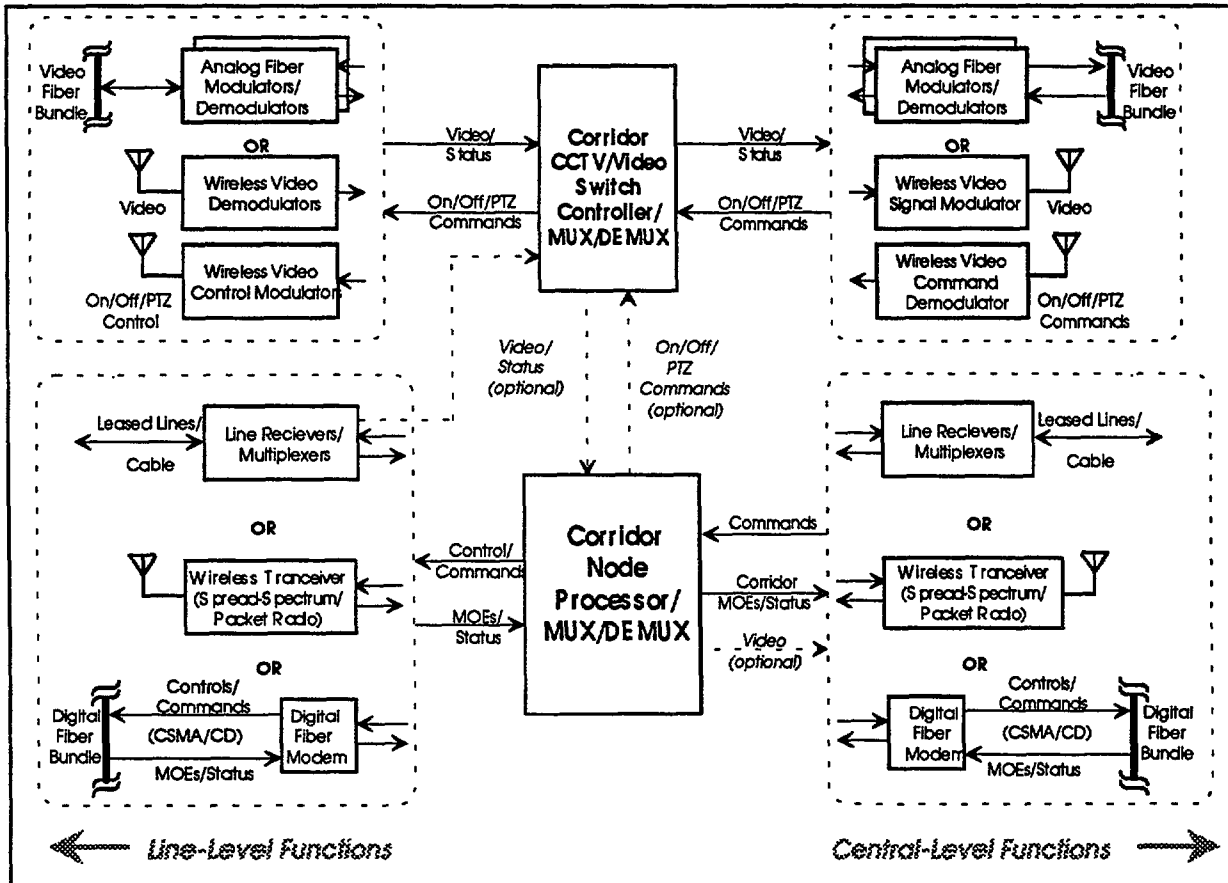


Figure 4-13. Communications Junction Node Detail

Camera video will require either fiber-optic transmission line or wireless video transmitters from remote locations or leased cable facilities. If trenching must be performed to install cable, the additional cost to use fiber-optic bundles is negligible.

Normal fiber LAN architecture details include a fiber "backbone" with "spurs" that connect with this backbone (Star configuration) at hub locations. The "spurs" run on a separate fiber bundle (or even wireline cable) to somewhere between 8 and 15 nodes. This type of architecture usually has a hub every 4 or 5 miles along the fiber backbone so that a smaller number of nodes will be impacted should there be a break in the spur (or in the event a cabinet is damaged by maintenance crews knocking it over, as sometimes happens). Since some corridors already have conduits for the SCANDI system, it is proposed to dispense with the expense of a backbone / hub architecture and simply run the fiber through the conduit for those corridors with a conduit run.

Since remote sensors, CMS, and ramp controllers require a much smaller bandwidth, the option exists to use wireless media such as spread-spectrum radios or packet radios as well as leased (or switched) voice-grade wirelines. This is reflected in the figure, where options exist for bringing in data (or sending data) via radio, leased line, or a fiber digital modem (if fiber is used for the video).

4.5.1.8.1 Video Signal Return

When fiber-optic cable is available, the most cost-effective use is to allocate one fiber of a bundle for each camera chain (more than 1 camera can be in a chain) with standard COTS analog modulation / demodulation equipment. This avoids costly digitization and/or multiplexing of the signal. A camera chain consists of one or more cameras whose modulator and camera are all capable of being switched off or on via remote command. Only 1 modulator at a time (using simple LED's) may be carried on the fiber. Note that COTS equipment is available which will multiplex 4 or more NTSC video signals on a single fiber. This is useful for co-located cameras, and would be an exception to the "single camera chain, single fiber" approach. The group of cameras would then be treated as a single camera for switching on or off the chain.

Multiple fibers in a bundle are used to accommodate multiple camera chains for simultaneous viewing of several locations. This technique will cover 99% of the real-time surveillance requirements where incidents statistically happen frequently at only 1 location on a chain and infrequently at others. The high-incident location would normally be selected for viewing with the others switched in or out as indicated by the received MOE's from the field sensors. This switching could even be done automatically on a round-robin basis to present (for example) 10 seconds of a given camera view before switching to the next camera on the chain. This would, however, require significantly more software modifications than a simple operator-commanded switch mechanism. It would also result in a fraction of a second of "black" on the monitor before the next camera were switched on, which could be aesthetically disturbing.

Demodulated video, either from the fiber or leased cable, is presented to a video chain switcher, if required, prior to being sent to a standard cable modulator for frequency-division multiplexing on the existing cable. The video switcher is required only if there are fewer cable video channels available than there are camera chains on the fibers. At the switcher, a second level switching occurs to select the chain to be sent back to the DFOC. Control for the secondary switcher will be time multiplexed with other control functions at the DFOC.

4.5.1.8.2 Video Camera Control

The camera PTZ control that is currently sent on the 18.1 MHz digital channel from the DFOC will be demodulated at junction nodes and input to a 2-way multiplexer (effectively a packet switch). The control commands occur infrequently, and can easily be combined with ramp control and status requests.

4.5.1.8.3 Ramp Control and Status Requests

These signals are demodulated from the new cable control channel (see Figure 4-5), and include both CMS control and new ramp parameter commands (and possible camera chain switching commands) from the Concurrent system. They are combined with command packets from the camera control using simple time multiplexing (store and forward packet switching) and then sent to one of the 3 optional media for output along the designated corridor.

4.5.1.8.4 MOE and Status Return:

The ramp MOE's (occupancy, traffic volume, flow rate, time, status), and loop MOE's (volume, occupancy, speed) are passed through from the corridor node link to the DFOC. While this is shown as passing through the multiplexer / demultiplexer, little needs to be done beyond packet relay from the remote sensors to the cable. Again, this data could arrive from any one of the three possible media, also at a nominal 56 KB rate (although data throughput would be much less due to the burst nature of the reports).

4.5.1.8.5 Communications Protocols

There are cost-effective parts available which will completely handle a Carrier-Sense-Multiple-Access / Collision-Detection (CSMA/CD) fiber access for multiple devices on the same fiber with little additional intelligence required (i.e. no separate CPU). It is envisioned that the Control Processor will be fabricated using a COTS single-board computer (possibly VME-Bus) assembly and add-on COTS I/O cards. This processor could easily handle the set-up of the CSMA/CD LSI chip, which would then take care of all transmission and reception from the fiber. The Intel standard CSMA/CD controllers are available in several configurations. No custom hardware should be necessary, but semi-custom (modified) software will certainly be required.

A single fiber in the bundle can be used to carry ALL status and MOE information from the remote intelligent controllers. These controllers would simply send a packet when data were available at their predefined collection rates. The CSMA/CD protocol would allow each remote to determine if it had been interfered with and needed to retransmit the packet. At the junction box, outgoing commands are multiplexed in the same manner on the bidirectional cable transceiver. This scheme is a form of optical LAN access which has equal applicability to leased lines or coaxial cable.

For packet radio, a modified type of access protocol would be required. Packet radio, operating at 9600 bps, could support all communication within an extended 6 mile range. The packet radio mechanism uses not only collision avoidance (i.e., listen before transmit), but also reverse acknowledgment of received data. Some modification of the AX.25 protocol could be performed to enhance throughput and connectivity, but is easily avoided with multiple-session packet Terminal Node Controllers (TNC's) located at junction nodes.

Spread spectrum protocols generally work better with a poll-response type of approach. To use this type of radio, a frame time would have to be enforced by the junction control processor (on a 10-20 second basis). Polls to all remote detection stations would be generated and the responses collected and relayed to the cable modulator. This approach is less desirable due to the larger amount of custom software development that would be required. It could be needed to support larger bandwidths (up to 250,000 bps), however, than packet radio (using the available UHF frequencies and 9600 bps speeds) can accommodate.

4.5.1.9 Inductive Loop / Other Detectors

Figure 4-14 shows a representative loop detection station node. All optional communication mechanisms are also shown for completeness. Again, only 1 of the 3 will be required in the final system (which will most likely be the fiber interface). For interim quick deployment, the optional leased line or wireless modes are also to be considered.

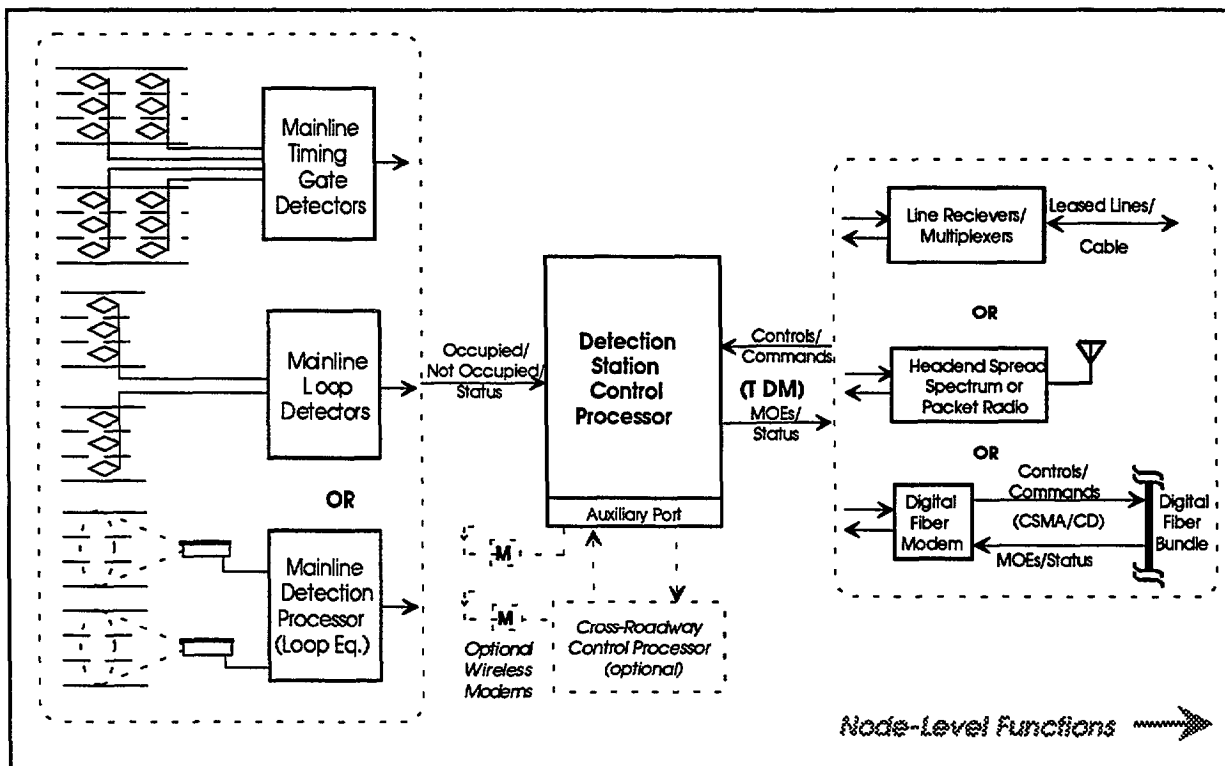


Figure 4-14. Detection Station Node Detail

This architecture is for a simple loop set from both sides of the roadway where there is no nearby ramp controller or camera. There does not need to be a co-located speed trap. If the site supports a speed trap, an additional set of loop drivers will be required to cover an 8 lane highway. For a speed trap, the processor should be programmed to also supply normal MOE's from a single set of loops (either set remotely commandable to compensate for temporary faults) along with the speed information.

Note that provision has also been made to replace some loop detectors with an equivalent system should it be necessary in certain locations due to roadway condition or other factors. The control processor should be able to handle raw loop on/off or processed data from the other detector types.

4.5.1.10 Ramp Controllers

Figure 4-15 shows the architecture within a cabinet housing a ramp control station node. This architecture is similar to that for a detection station node, but some additional I/O capabilities are required for lamp drivers, and less loop measurement capacity is required.

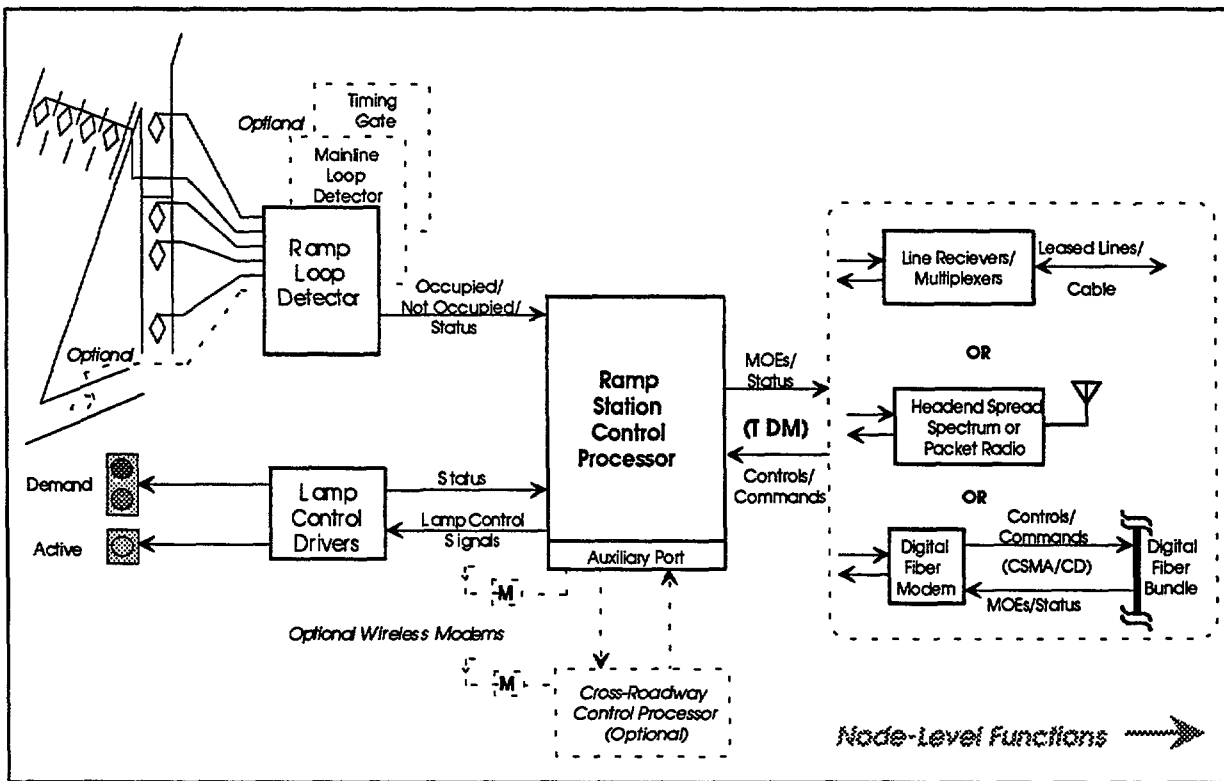


Figure 4-15. Ramp Control Station Node Detail

Additionally, since ramps are located on both sides of the roadway, and the cable/fiber will be on one side only, a wireless method is shown for passing information to and from a nearby cabinet located on the LAN. This is obviously not needed for the radio connection

or a leased line. The wireless modems are simply UHF radios (such as a Motorola unit) with integral data modem. They require very little power (less than 100 milliwatts typically), so could be unlicensed if they are in the proper spectrum. However, since MDOT has a license for several UHF and VHF frequencies, it would be better to use that allocation to assure relative immunity from interference. With low power and a simple antenna (a quarter wave length of wire at the side of a cabinet would work), a single frequency could be used for all inter-cabinet cross-roadway connections.

The radios are shown under the assumption that it is cheaper to buy, install, and maintain them over a 15 year time span than it is to trench under the roadway to run a fiber / wireline extension to the backbone.

Some detail is omitted from the diagram for clarity in the use of the optional wireless modems. The fiber digital modem may require special control from a processor for setup. To avoid extra processors, it is best to provide an auxiliary port on the processor used for ramp control and detection nodes to accept input from a cross-roadway wireless modem. The processor would be responsible for receiving information for its own function as well as that of the cross-roadway “cousin”. It would be responsible for multiplexing the received data onto the single fiber interface along with its own. This is also less costly than having separate fiber transceivers for each function. The detailed architecture is shown in Figure 4-16.

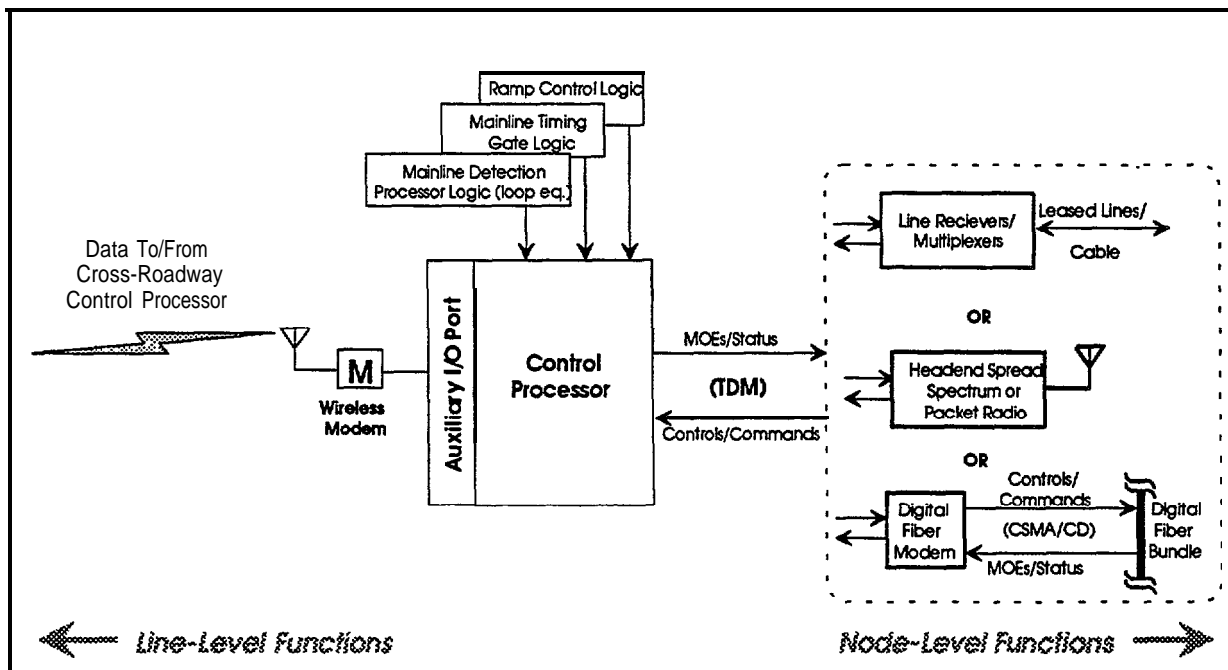


Figure 4-16. Cross-Roadway Wireless Communications Detail

4.5.1.11 CCTV Video Surveillance

This node is different than the other types since the wide video bandwidth required dictates the use of a fiber, cable, specialized wireless connection. Figure 4-17 illustrates a CCTV video / camera control node architecture. For this reason, it is assumed that the cabinet containing the control processor will be located on the fiber LAN or contain the wireless communications equipment for the video/camera control link. However, there is no reason why there cannot be a ramp controller on the opposite roadway side that uses the facilities of the control processor.

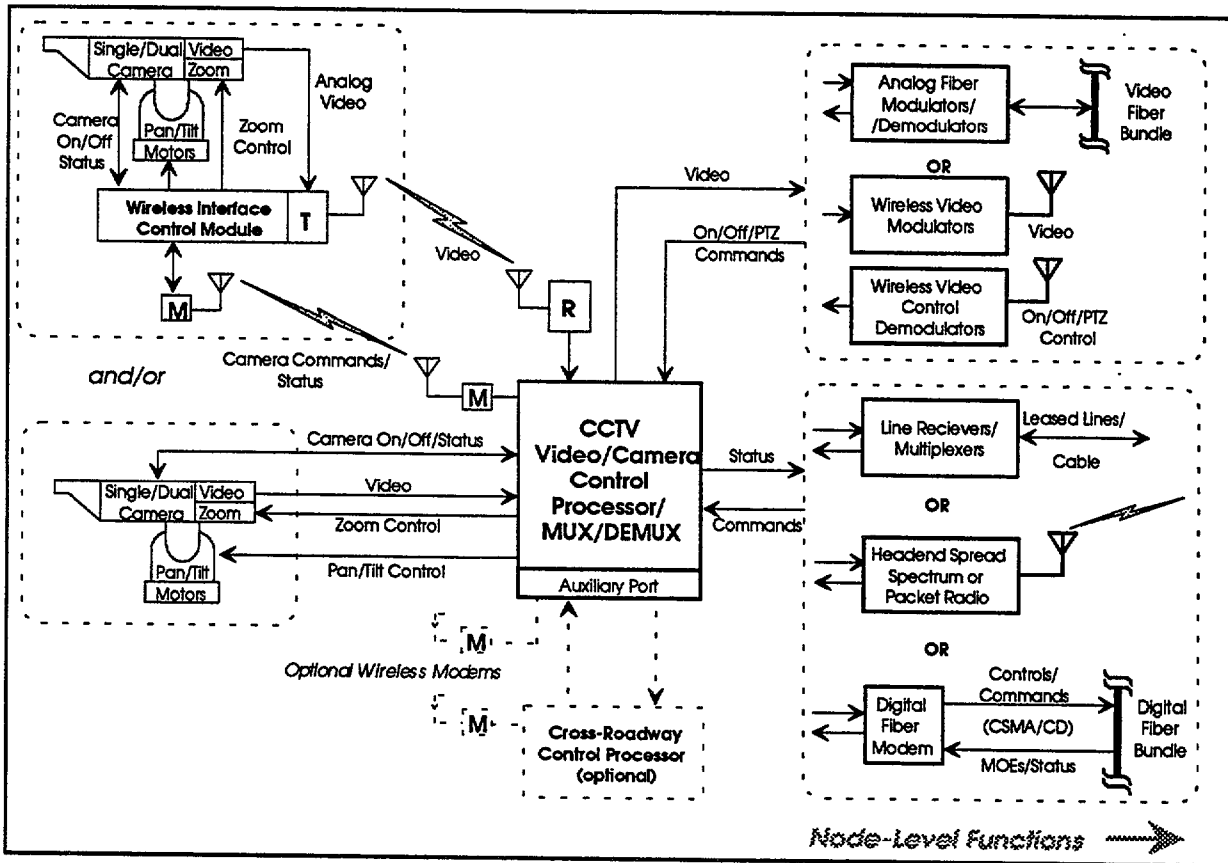


Figure 4-17. CCTV Video / Camera Control Node Detail

Provisions have been made for wireless modem and video modulator usage to link the control cabinet to the camera assembly in lieu of trenching and laying control lines and video cable. COTS wireless video transmitters (unlicensed) are available to handle the video transfer. A standard wireless modem of the type used for cross-highway links will also be required to transfer the camera PTZ commands and receive status from the remote side unless supplied with the wireless video link. If not, camera control will most likely require a special interface card to isolate the various PTZ commands from the digital data stream and route them to the proper control mechanism. A separate processor should not be required -- a control sequencer type of ASIC design will probably suffice.

If the camera is “hard wired” to the control cabinet, then separate lines will be run from the control processor I/O card for control of the PTZ functions as well as receipt of status. Video transfer will require a coax cable (to carry the baseband video signal) to the video-fiber modulator. The control processor interface software will be slightly different depending on the camera control interface type.

It should also be noted, although it is not shown in the figure, that multiple cameras could be handled by a single cabinet junction when they are located in close proximity to each other (such as on more than one side of freeway interchanges). In this case, one of the multi-channel video multiplexers will be required ahead of the video-fiber modulator and multiple camera command ports will be required from the control processor. Control processor software must be designed in a modular manner to support the decoding and routing of commands to multiple camera addresses from the common DFOC control port.

4.5.1.12 CMS / HAR Interface

The interface and control architecture for a CMS or HAR link is almost the same as that for a camera PTZ control link. There is no video interface, but the command / response interface is generically the same as shown in Figure 4-9, replacing the camera with the CMS or HAR control module. Control processor software can also be common as long as it is concerned only with command address recognition and speed buffering (i.e., packet switching) to a serial interface type. It is also conceivable that a single common control processor could handle either multiple cameras, or cameras and a CMS or HAR command / response port. The function could also be combined with a ramp or loop interface.

4.5.2 Representative Control Processor Architecture

4.5.2.1 Processor and I/O Hardware

The control processor needed to satisfy the Baseline Architecture requirements should be selected for its capacity for growth potential as well as the availability of off-the-shelf modular CPU and peripheral cards. It is highly recommended that a modular chassis (e.g., VME-bus and standard card format) architecture be used. The NEMA 170 types of systems are evolving toward this standard, and interfaces from the 170 to VME configurations currently exist. However, use of a 170-type controller is probably not cost effective since growth and processing capacities are marginal in current configurations. Multiple vendors support the 680x0 VME standard, to which the NEMA 170 6800 CPU software is readily convertible. Allen Bradley has VME configuration processors and I/O cards. Many other vendors also have these, and it is probable that traffic-type operations (such as lamp drivers) and certainly fiber or cable LAN interface modules are readily available.

Figure 4-18 shows a representative recommended internal control processor architecture. The figure shows all required modules for the Early Deployment architecture

implementation. Since a VME bus is used, many other peripheral cards for varying functions needed in the future are also easily added when required.

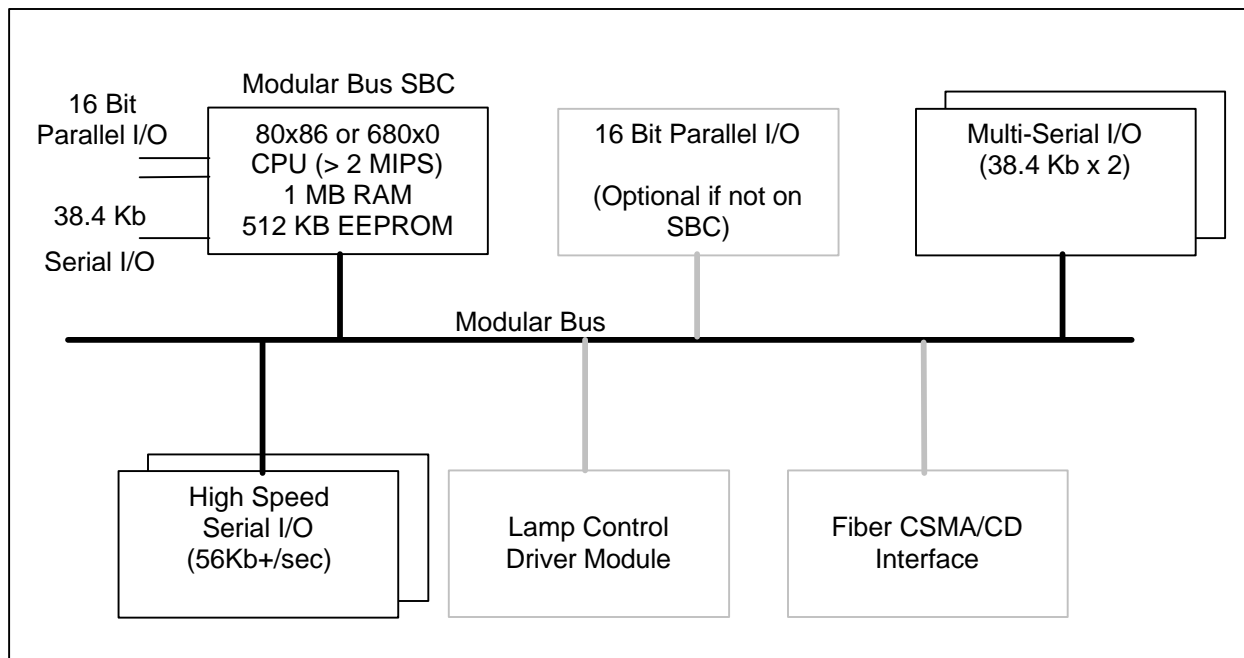


Figure 4-18. Representative Modular Control Processor Architecture

This type of architecture can be used to satisfy the requirements for Junction Nodes, Detection Nodes, Ramp Control Nodes, and Video nodes. Not all peripheral cards are required in all applications. A brief synopsis of each module follows:

4.5.2.2 Modular Single Board Computer (SBC) Module:

A large variety of modular chassis (e.g., VME-bus compatible) SBC's are currently available using both the Intel 80x86 types of processors and the Motorola 680x0 processor types. The 680x0 is preferred for commercial applications because of its compatible interface to the VME standard and upward compatibility with the current NEMA 6800 standard processor type. Abundant vendors for C compilers and 680x0 assemblers exist.

The selected SBC should have a minimum of 2 Million Instructions per Second (MIPS) throughput (easily satisfied by even the slowest 68000 board), 1 Megabyte of on-board RAM (expandable to at least 4 MB), and a minimum of 512 K bytes of Flash EEPROM for program and constant / parameter storage for non-volatility and unattended operation/ automatic restart on power fault.

In addition, the board should have a general asynchronous serial I/O port with a speed rating of 1200 to 19,200 bps for connection of a local diagnostic console. A few bits of parallel I/O for general control and/or loop detector inputs should also be provided. A

minimum of 16 bits is recommended, although an external (possibly multi-function) VME card could also provide these functions if not available on a cost-effective SBC. For future supportability and easy card interchange / upgrade, it is probably best to avoid dense, multi-function VME cards in favor of more modular systems which can be upgraded or repaired using “mix and match” techniques with full interchangeability from different vendors. This will also assure MDOT of easy repair / replacement in the future without the need to repeat their custom development efforts for new replacement parts when a sole-source vendor goes out of business.

The board should support full VME Direct Memory Access and control functions for high speed transfer from one port to another. Multiple DMA channels are required for simultaneous transfer of data for at least 4 ports. This is used for data packet switching and multiplexing / demultiplexing, particularly at the Junction Node (or possibly LAN hubs). Finally, the board should support at least 2 programmable counter/timers (3 is standard) for implementing a “real time” clock and other temporary timing loops for various functions.

4.5.2.3 16 to 24 Bit Parallel I/O:

This card would be used for handling inputs from standard loop detectors if used. It is required only if the SBC does not have at least 16 bits of parallel I/O. Each bit should be software configurable as either input or output, although if the majority are fixed at inputs with only a few outputs, that is sufficient.

4.5.2.4 Multi-Serial I/O:

This should be a general-purpose synchronous / asynchronous (USART or DUSART) serial I/O module with at least 2 ports on the same card. Both ports should provide, as a minimum, RS-232 drivers and receivers with RS-422 (balanced) provided as either a hardware strap option or software configurable item. Each port should have a set of RS-232 style control signals (RTS / CTS, DSR, DTR) and possibly also RING for potential use in dial-up line applications. Each port should support from 75 bps to 38.4 Kbps as a software configurable option.

These serial I/O cards (up to 2 should be provided for in the architecture) are used for the following:

- Radio Interface (spread-spectrum or packet) option,
- Leased line demodulator / demux option,
- Auxiliary Cross-Roadway wireless Modem port,
- Loop detector substitute (e.g., Autoscope, vision sensor,) input ports,
- Camera commands / status port for wireless node to camera link.

Full DMA capability is optional, but interrupt capability is mandatory.

4.5.2.5 High Speed Serial I/O:

These cards are similar to the multi-port serial I/O cards except they should have full DMA control capability. They are used only in the junction node for Camera demodulator input and Control / MOE / Status modem I/O at speeds of 56 Kbps. Up to 2 cards should be provided for in the architecture.

4.5.2.6 Lamp Control Driver Module:

This card is used only in the ramp controller applications for driving the red / green lamps. It is not necessary if an external solid-state or electromechanical switch which accepts TTL inputs is used, since the generic parallel I/O card can easily produce the required control signals.

4.5.2.7 Fiber CSMA/CD Interface:

This card will contain the fiber-optic LAN control logic (and also possibly the actual fiber modulator / demodulator logic). The LAN protocol must use a Carrier-Sense-Multiple-Access / Collision Detection scheme in order to multiplex multiple nodes on the same physical fiber. An LSI chip, such as the Intel 82592, is capable of several megabits of throughput and provides nearly all control and buffering necessary, as long as DMA is available from the processor to/from memory. It is intended that the processor configure this chip during initialization (configuration is quite complex due to the many options available). Any other equivalent function LAN control LSI chip would also be acceptable.

The card is needed only when a fiber-optic LAN architecture is used (in lieu of the packet radio or spread spectrum radio options).

4.5.3 Software Functions

There are many real-time operating systems available for use with VME bus types of processors. The Early Deployment tasks to be performed do not necessarily require a sophisticated Operating System (OS). They could all be easily implemented with a simple "activity loop polling" scheme in the software working from interrupt or DMA queue indicators to determine what action to take next. This simple approach saves on some types of costs but often results in higher software development costs than if a standard COTS operating system is selected. This must be carefully traded before making a final decision. Any COTS OS selected should be mature and likely to remain on the market for many years to come, support C and assembler programming, full debugging tools, and preemptive multi-tasking for future growth.

Whether or not an OS is used, the software functions should still be partitioned into tasks. A modular approach must be used to enhance re-usability and also flexibility in implementing multiple functions within a single control processor. The best way to specify the functions required in the software is on a task basis for each node type, as will be done in subsequent subsections.

4.5.3.1 Junction Node

The control processor at the junction node is primarily concerned with switching data from one port to another. It will require a store-and-forward packet switch type of software protocol. This is most easily implemented by defining a task to handle each exchange. DMA transfers should be used and a modular protocol interpreter (to determine packet start / end or to format new packets) should be provided.

The following major tasks are defined:

- a. Receive and process ramp control and status requests. Inputs come from the cable demodulator. The software must interpret each command received, determine that it is valid, and then format and queue it for transfer per the output option (Fiber, Radio, or Leased Line driver). The actual output of the data is a separate task. This task is also responsible for recognizing Video Chain switching commands that may arrive in the input stream and sending them to the local switcher.
- b. Camera control PTZ command processing. Inputs come from the Camera Control cable demodulator. The software must interpret the input data, determine it is valid, and then format and queue it for transfer per the output option (Fiber, Radio, or Leased line). This is similar to task (a) except for the different format and different interrupt port. The same software should be usable beyond the input data interpretation differences.
- c. Output commands to remote device. This task is responsible for managing and coordinating the time-division output of data that arrives from tasks (a) and (b). It contains the specific drivers necessary for the selected output option (Fiber, Radio, or Leased line). This is little more than a queue management task and device driver.
- d. Input of MOE and Status information from remote devices. This task is responsible for accepting the returned data packets from remote devices, verifying them, reformatting where required, and queuing them for output via the Cable Modulator back to the DFOC. Input protocol will vary depending on the selected option (Fiber, Radio, or Leased Line).
- e. Output Remote Responses to DFOC. This task handles the protocol necessary to output CMS responses, MOE's, and Status information back to the DFOC via the Cable Modulator. It must also multiplex local processor status (including video chain switcher command acknowledgment) with the data stream received from the remote devices. Speed buffering and storage is provided to match potentially higher (megabit) burst rates from fiber to the slower 56KB steady stream to the DFOC.

4.5.3.2 Detection Node

The control processor in the detection node shares some common functions with the junction node. It also has additional required capabilities. The following major tasks are defined:

- a. Receive control commands. Inputs come from the Fiber / Radio / Leased Line interface (as applicable) and consist of BIT status requests, node configuration change commands such as addresses of associated linked controllers), commands to a (possibly linked) cross-roadway ramp controller, and synchronization information to control sorting of detector derived MOE's. The commands must be validated by the software and then acted upon.

Control commands change the internal software configuration and operation. These should be stored in some sort of non-volatile (e.g., Flash EEPROM) for power fail recovery purposes. There should also be an acknowledgment of the command queued for output back to the DFOC.

Commands addressed to the cross-roadway controller should be queued for output to the auxiliary port.

Commands addressed to nodes other than this one or the associated cross-roadway controller should be discarded.

- b. Calculation of MOE's. Depending on the configuration of the node, several sub-tasks could be defined. The software is responsible for collecting inputs from the loop detector (or alternate loop equivalent) devices at nominal 10 millisecond intervals, determining vehicle presence or non-presence, and accumulating volume and occupancy, using the same algorithm as currently implemented in the Concurrent mainframe for processing CCU inputs from the loop RCU's. This data must be accumulated on a lane-by-lane basis for reporting back.

When a tuning gate is implemented in the node, the software shall calculate the average speed of traffic flow using the same algorithm as in the Concurrent system. Alternatively, speed shall be derived based upon vehicle classification and adjustments received from the Concurrent mainframe for adjacent nodes when a single loop arrangement exists at the node.

Provisions should be made to clear all internal counters upon command of the Concurrent control program.

- c. Reporting of MOE's and Algorithm Reset. The merged / calculated volume, occupancy, and speed shall be queued for output to the (Fiber, Radio, or Leased Line as applicable) port at the interval configured in the program ROM or the interval commanded from the headend Concurrent control program. This data will be sent at a nominal rate of once each 20 seconds for fusion with previous node data.

Since the Concurrent contains the logic to “smooth” and “average” the collected MOE’s at the 20 second interval into larger 1 minute intervals, it should not be necessary to perform any filtering of data at the node. Once a set of MOE’s is calculated, the counters should be reset to zero and the software will start all over again.

- d. Accept responses from auxiliary node. The software must accept inputs from the Cross-roadway node via the auxiliary port for combination with its own responses and queuing for output back to the DFOC.
- e. Output queue handling. The software must time-division multiplex the outputs resulting from tasks a, c, and d, format them, and output them to the selected communication medium (Fiber, Radio, or Leased Line). The appropriate device drivers and data protocol formatting should be implemented independently to preserve as much device-independence as possible. This is primarily a store-and-forward message switch task.

The software must also format and output the commands received for the Cross-roadway node to the auxiliary port.

- f. Built-in test. The software shall detect on-line faults in the control processor (as evidenced by erroneous operation of any control port) and report them along with the MOE’s to the DFOC.

The software shall support the capability to perform an “off-line” self test (and a startup self test) of processor logic and interface logic that more rigorously tests each subsystem and reports the results so that faults may be isolated down to the lowest LRU (or group). Consideration should also be given to diagnostics that will isolate parts down to the lowest SRU, although this may be something that is loaded and run only in the shop environment.

4.5.3.3 Ramp Control Node

The control processor in the ramp control node shares many common functions with the detection node. It also has additional required capabilities for ramp metering. The following major tasks are defined:

- a. Receive control commands. Inputs come from the Fiber / Radio / Leased Line interface (as applicable) and consist of BIT status requests, node configuration change commands (such as addresses of associated linked controllers, metering on/off control or time-of-day segment for metering, or red/green timing sequence changes), commands to a (possibly linked) cross-roadway ramp controller, and synchronization information to control reporting of the ramp’s loop detector derived MOE’s. The commands must be validated by the software and then acted upon.

Control commands change the internal software configuration and operation. These should be stored in some sort of non-volatile (e.g., Flash EEPROM) for power fail recovery purposes. There should also be an acknowledgment of the command queued for output back to the DFOC.

Commands addressed to the cross-roadway controller should be queued for output to the Auxiliary port.

Commands addressed to nodes other than this one or the associated cross-roadway controller should be discarded.

- b. Calculation of MOE's. The software should calculate MOE's based on the ramp loop inputs whether or not ramp control is in progress. The software is responsible for collecting inputs from the loop detector (or alternate loop equivalent) devices at nominal 10 millisecond intervals, determining vehicle presence or non-presence at each of the Queue, Presence, and Passage loops, and accumulating the following, using the same algorithm as currently implemented in the Concurrent mainframe for processing CCU inputs from the ramp RCU's. This data must be accumulated on a lane-by-lane basis for reporting back in the event there is more than one entrance lane on a given ramp:
1. Ramp occupancy
 2. Ramp queue and demand
 3. Ramp traffic volume (vehicles per minute)
 4. Metering rate (i.e., vehicles per minute, vehicles per hour)
 5. Detected metering violations (if metering in progress)

Provisions should be made to clear all internal counters upon command of the Concurrent control program.

- c. Reporting of MOE's. The merged / calculated ramp volume and occupancy shall be queued for output to the (Fiber, Radio, or Leased Line as applicable) port at the interval configured in the program ROM or the interval commanded from the headend Concurrent control program. This data will be sent at a nominal rate of once each 20 seconds for fusion with previous node data. Exact interface with the Concurrent algorithm is will be determined.

Unlike the detection nodes, the Concurrent probably does not contain logic to "smooth" and "average" the collected MOE's at the 20 second interval into larger 1 minute intervals. The software should continue to update the current MOE's with newly recorded inputs, smoothing the data from one 20 second (or other, depending on configuration) to the next. The number of 20 second intervals to be used in the smoothing algorithm is will be determined, but should be a minimum of 2 and probably a maximum of 5 minute's worth. Detected violations should be cleared after each

reporting period, but the data maintained so that a violation in progress at the reporting interval is not lost, but instead reported during the next interval. Traffic data will also be collected on an hourly basis and then archived for each 24-hour period.

- d. Accept responses from Auxiliary node. The software must accept inputs from the Cross-roadway node via the Auxiliary port for combination with its own responses and queuing for output back to the DFOC.
- e. Output queue handling. The software must time-division multiplex the outputs resulting from tasks a, c, and d, format them, and output them to the selected drivers and data protocol formatting should be implemented independently to preserve as much device-independence as possible. This is primarily a store-and-forward message switch task.

The software must also format and output the commands received for the Cross-roadway node to the Auxiliary port.

- f. Built-in test. The software shall detect on-line faults in the control processor (as evidenced by erroneous operation of any control port) and report them along with the MOE's to the DFOC.

The software shall support the capability to perform an "off-line" self test (and a startup self test) of processor logic and interface logic that more rigorously tests each subsystem and reports the results so that faults may be isolated down to the lowest LRU (or group). Consideration should also be given to diagnostics that will isolate parts down to the lowest SRU, although this may be something that is loaded and run only in the shop environment.

- g. Meter ramp. The software shall provide the control signals to the red/green signal lamps independently for each lane in a multi-lane entrance ramp (or simultaneously to both, dependent on configuration). These signals shall be provided only during time-of-day intervals pre-set in the configuration PROM or upon command of the Concurrent control program at the DFOC.

Prior to starting metering or upon termination of metering, the software should hold the signals at a steady state of "green" for 30 seconds. When metering is not in progress, the signal lamp should both be dark (off).

The software shall support vehicle entrance rates from 4 to 15 vehicles per minute with the metering algorithm, using demand and passage detection points to aid in red/green signal switching.

The software should be initially configured to release a vehicle each 4 seconds in the absence of other commands from the DFOC during initial deployment. This results in a 15 vehicle per minute metering rate.

4.5.3.4 Video Node

The control Processor in the video node has the fewest required functions of all node types since it is not involved in processing the video signal and it is assumed a video node is located on the LAN and thus does not need to be concerned with remote radio operation across the freeway. It is possible that a ramp control node may use the video node's LAN hookup, however. Additionally, provision is made for use of a wireless interface to the PTZ camera interface.

- a. Receive control commands. Inputs come from the Fiber / Radio / Leased Line interface (as applicable) and consist of BIT status requests, node configuration change commands (such as addresses of associated linked controllers), commands to a (possibly linked) cross-roadway ramp controller, and Pan / Tilt / Zoom commands to be sent to the camera. The commands must be validated by the software and then acted upon.

Control commands change the internal software configuration and operation. These should be stored in some sort of non-volatile (e.g., Flash EEPROM) for power fail recovery purposes. There should also be an acknowledgment of the command queued for output back to the DFOC.

Commands addressed to the cross-roadway controller should be queued for output to the Auxiliary port.

Commands addressed to this node's camera control mechanism must be passed to the camera controller. The method of doing this, and the ports used will vary depending on whether the camera is linked via wireless or wired connections. The commands should be queued to a generic output device handler to minimize software differences.

Commands addressed to nodes other than this one or the associated cross-roadway controller should be discarded.

- b. Reporting of status. The software should acknowledge all commands sent to the camera PTZ mechanism. The software should also report internal node status periodically so that the health of the node may be monitored by the DFOC processor to enable fault detection as soon as possible. The software should send a status report back to the DFOC at least once each 5 minutes, even if no control or other commands have been received. Since responses from an auxiliary node are handled transparently back to the DFOC, the presence or absence of such a node has no bearing on this requirement.

- c. Accent responses from Auxiliary node. The software must accept inputs from the Cross-roadway node via the Auxiliary port for combination with its own responses and queuing for output back to the DFOC.
- d. Output queue handling. The software must time-division multiplex the outputs resulting from tasks a, b, and c, format them, and output them to the selected communication medium (Fiber, Radio, or Leased Line). The appropriate device drivers and data protocol formatting should be implemented independently to preserve as much device-independence as possible. This is primarily a store-and-forward message switch task.

The software must format and output the commands received for the Cross-roadway node to the Auxiliary port.

The software must format commands for the camera PTZ mechanism received from the DFOC and output them to the camera control. Both wireless communication (with status return) and wired communication (possibly via different ports) must be supported. Note that translation of the DFOC camera control device into a different form or content may be required to accommodate new camera control logic. This translation is the responsibility of the node control processor.

- e. Built-in test. The software shall detect on-line faults in the control processor (as evidenced by erroneous operation of any control port) and report them to the DFOC as soon as they are detected. Once a fault is detected, there is no need to continuously send the status to the DFOC at an interval more frequent than specified above for normal status reports.

The software shall support the capability to perform an “off-line” self test (and a startup self test) of processor logic and interface logic that more rigorously tests each subsystem and reports the results so that faults may be isolated down to the lowest LRU (or group). Consideration should also be given to diagnostics that will isolate parts down to the lowest SRU, although this may be something that is loaded and run only in the shop environment.

4.5.3.5 CMS/HAR Interface

The functions of the CMS/HAR interface node are nearly identical to those for the video node when the camera control port’s interface is replaced by the CMS or HAR controller.

The control processor software in a CMS or HAR interface node shall “transparently” (without modifying the commands or responses) switch the packets to and from the attached CMS or HAR. This may be done using either a regular port (such as the camera port equivalent) or the auxiliary port.

Self test requirements and support for a cross-roadway ramp node also apply.

4.5.4 DFOC Headend Software Modifications

Software modifications will be required to the headend computer equipment. It is hoped that the scope of these modifications has been minimized through the careful interface design. The following sections discuss only the nature of the changes, not the specific changes, since the internals of each computer are not specifically known at this time. Most of the information herein is based on discussions with of MDOT.

4.5.4.1 Vicon VPS-1300

The Vicon video switcher should require no special modifications other than possible table modifications to accommodate additional camera inputs and additional monitor outputs.

4.5.4.2 Camera Control PC

The current video and camera control should not require modifications beyond possibly enabling additional camera addresses, by simple table updates.

4.5.4.3 Vultron CMS Controller

The Vultron CMS controller should not require any modifications beyond adding new CMS addresses to its internal tables. An interface protocol will need to be investigated to remotely control the controller through the integrated user interface.

4.5.4.4 Concurrent 3280MPS

It has been confirmed with MDOT personnel that there should be no problem with merging new detector inputs at the 20 second data fusion point in its processing. It is estimated that all that will be required is to expand some working arrays which hold the data (and also store it on disk) along with the associated array index limits. A new task to perform this function as the data is received from remote nodes is required.

- a. Serial I/O handling. A new serial I/O handler is required to manage data input and output via the new control / status return interface. The standard Concurrent common serial port protocol driver will most likely be capable of handling the actual device-level interface.
- b. Detector failure to report and reported faults. A new software task to handle faults and also internally generated fault indications when detection nodes fail to report new information (detected when the data is needed for merging) will be required.

A new software task to format and display these faults (or merge the reports in with the existing fault reporting subsystem) will be required.

- c. Operator Interface. The existing operator interface will require modification to accept commands for ramp overrides, node configuration changes, and commands for node off-line self test for the new node types. This capability goes beyond the current operator interface, but should be compatible with it.
- d. Graphic Display Subsystem interface. The Concurrent sends volume, occupancy, and speed on a 1 minute update basis to the GDS (without the GDS requesting it). The scope of this data must be increased to include the newly instrumented sections of roadway.

The Concurrent also polls the GDS at 250 millisecond intervals to receive and transfer incident and construction information from one GDS station to another. If any of the GDS systems are displaying a metered ramp detailed view, the Concurrent also sends information about the state of the loops and metering lamps. A new subroutine will be required in the Concurrent to “simulate” generation of the passage and metering data based on the last reported volume, occupancy, and passage information to the mainframe from the remote “intelligent” ramp controller. The computations will produce an “average” vehicle entry rate and generate the required sequence of queue, presence, and passage indications synchronized to the fixed lamp on/off cycle time. This will provide a graphical display of the vehicle moving along the ramp in synchronized with the lamps, as it now does in real-time. The graphical display essentially is the equivalent of the statistical numbers, but is easier for an operator to “get a feel” for the actual flow rate.

4.5.4.5 Graphic Display Subsystem

The Graphic Display Subsystem interface will remain the same except additional volume, occupancy, and speed, and ramp control information must be sent on the 1 minute update basis. It is hoped that the GDS map displays are table driven so that minimal software (just table) updates are required to add the new corridors. Based upon the current map coverage, significant changes to the GDS database will be required to cover the entire Metropolitan Detroit freeway and trunkline network.

Adding new ramp controller detailed views is also a database modification task. There are probably existing ramp views that can be copied and modified to include the new ramps. The internal tables of ramps will need to be updated. Software modifications should be minimal provided that sufficient software documentation is available for the current system.

The low-level interface from the Concurrent for the ramp metering view should remain the same, although a new concurrent subroutine will be generating the data.

4.5.5 Interface Data Definitions

Table 4-21 lists each of the interfaces and the top-level data types that are passed on them.

Table 4-21. Deployment Interfaces

From	To	Data Types	Comm Method
<i>MTC/DFOC Headend</i>			
3280 MPS	Junction Nodes (Detection, Ramp, and Video Nodes)	Ramp Parameters Status Requests Node Configuration Commands	56Kb Cable Modulator (multiplexed with CMS data)
Vultron CMS Controller	New CMSs	CMS Control / Configuration Data (via “modem” port)	56Kb Cable Modulator/ RF -trunked radio
Camera Control PC	Video Nodes	Camera Pan/Tilt/Zoom Commands	Camera 18.1 MHz Cable Modulator wireless FM
I-94 Junction Nodes (Detection, Ramp, and Video Nodes)	3280MPS	Detector: Volume, Occupancy, Speed, Time, Node Status Ramp: Volume, Occupancy, Flow Rate, Time, Node Status Video: Camera and Node Status	56Kb Cable Demodulator (Multiplexed with CMS return data) or fiber or wireless
Video Node	VICON VPS-1300	NTSC Video	Blonder-Tongue Cable Video Demod.
CMS	Vultron CMS Controller	CMS Status Responses (via “modem” port)	56Kb Cable Demodulator/ RF -trunked radio
<i>Junction Node</i>			
Video Node	Cable Video Modulators	NTSC Video from Camera(s)	Fiber Bundle or Leased Lines to Cable Conversion
Detection, Ramp, Video Nodes	Headend	MOE’s, Node Status	Fiber, Radio, or Leased line to 56Kb Cable Modulator
Camera Control Demod	Video Nodes	Pan/Tilt/Zoom commands	Cable Demod to Fiber, Radio, or Leased Line Conversion
Node & CMS Command Demodulator	Detection, Ramp, Video Nodes	Ramp Parameters Status Requests Node Configuration Commands	56Kb Cable Demod to Fiber, Radio, or Leased Line Conversion
<i>Detection Station Node</i>			
DFOC Headend	Node Control Processor	Node Configuration Commands Self test Requests Time Synchronization Commands (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator

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Node Control Processor	DFOC Headend	Volume, Occupancy, and Speed MOE's Node Status and Time Tags Node Off-line BIT Status (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Modulator
Loop Detector (or equivalent)	Node Control Processor	Loop Detect / No Detect Status	Wireline inside cabinet
Ramp Control Node			
DFOC Headend	Node Control Processor	Node Configuration Commands Self test Requests Time Synchronization Commands (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Volume, Occupancy, Flow Rate MOE's Node Status and Time Tags Node Off-line BIT Status (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Loop Detector	Node Control Processor	Loop Detect/No Detect Status for ramp loops	Wireline inside cabinet
Node Control Processor	Lamp Control Drivers	Red / Green / Off signals	Wireline
Video Node			
DFOC Headend	Node Control Processor	Node Configuration Commands Self Test Requests Time Synchronization Commands Camera Pan / Tilt / Zoom Commands Fiber Video Modulator On/Off (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Node Status and Time Tags Node Off-line BIT Status Camera / Modulator Command Acknowledgements (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	Camera Control Logic	Pan, Tilt and Zoom Commands	Wireless modem or wireline
Camera Control Logic	Node Control Processor	Camera subsystem status	Wireless modem or wireline

Camera Video	DFOC Headend	NTSC Video	Fiber, Leased Line or wireless
<i>CMS or HAR Node</i>			
DFOC Headend	Node Control Processor	Node Configuration Commands Self Test Requests Time Synchronization Commands CMS and HAR commands (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Node Status and Time Tags Node Off-line BIT Status CMS and HAR subsystem Acknowledgments and status (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Modulator
CMS or HAR	Node Control Processor	CMS or HAR Control Commands	Wireless modem or wireline
Node Control Processor	CMS or HAR	CMS or HAR Subsystem acknowledgements and status	Wireless modem or wireline

The following subsections define the format for data packets passed over the major interfaces in more detail. Note that camera control commands and CMS / HAR commands remain the same as they are now, but they will be “wrapped” in a packet with destination identified for routing over the selected communication system.

4.5.5.1 Headend to Remote Nodes

Commands to the remote nodes are already defined in the case of camera controls and CMS commands. It is intended that these be “wrapped” in some sort of digital envelope at the DFOC headend, which is then converted, if required, at junction nodes. Both CMS and CCTV camera controls carry their own node addressing information, which will have to be checked at each CMS / Video node. The general format is shown in Table 4-22 below:

Table 4-22. CCTV Camera / CMS Commands

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization
Data Identifier (Apply ONLY at Junction, Not Headend)	16 Nominal	Identifies the source of the data -- Camera Controller or CMS / HAR Controller. This is applied ONLY at junction nodes by the Control Processor there since these commands arrive over different cable channels from the headend.
Camera Information or CMS Command	Predefined	Identifies the camera address (8 bits) and the function (16 bits) as documented already at the DFOC -or- identifies the CMS and its function, as documented by Vultron
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

Commands from the 3280MPS to the Detection, Ramp, and Video Nodes should all be formatted into a standard packet which is easily distinguished from camera control packets. The general format is shown in Table 4-23. Note that 16 bit words are defined for nearly all entries. This should be done to make the software easier and memory access faster, even when only 8 bits are used. 16 bits is also the granularity of some types of LAN controllers.

Table 4-23. 3280MPS Commands

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization. Should be different than Packet Header used for Camera Control.
Packet ID	16 Nominal	Identifies the function of this packet (for example Set Node Time)
Node Address	16 Nominal	Identifies the node to which the command is addressed. Provision should be made for an “all call” or “all nodes” address (such as all ones except the LS bit)
Packet Word Count	16	Number of significant 16-bit words following this entry, excluding the check word
Control Information	Varies	Each control item (e.g., date, hour, minute, second) needed for the particular control function
Check Word	16	16- bit add-and-left-rotate (discard carry) checksum over all data in the packet following the packet header and excluding the check word itself.
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

4.5.5.2 Remote Nodes to Headend

The format of the packets from the remote nodes to the headend are similar to those from the headend to the nodes. The data is different, of course. The node control processors will generate the packets. The junction control processor may strip off certain information in the case of the CMS responses to maintain compatibility with current formats. The Demux at the headend may also have to strip off some identifying information in order to present the CMS Controller with the exact format of a response as it would get from a direct wireline modem hookup. Table 4- 24 illustrates this.

Table 4-24. CMS Responses

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization (strip at headend demux)
Data Identifier	16 Nominal	Identifies the data as CMS / HAR Controller response. This must also be stripped by the headend demux after it is used to route the received data.
CMS Response	Predefined	Identifies the CMS response function as documented by Vultron
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization (junction node before sending to headend demux)

BIT responses and node MOE's and status must be packetized by the node controllers. The format is similar to that for the 3280 MPS headend commands, as shown in Table 4-25.

Table 4-25. Node Controller Responses

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization. Should be different than Packet Header used for CMS Responses.
Packet ID	16 Nominal	Identifies the function of this packet (for example, Detector MOE Report)
Node Address	16 Nominal	Identifies the node from which the response is sent
Packet Word Count	16	Number of significant 16-bit words following this entry, excluding the check word
Control Information	Varies	Each item (e.g., volume, occupancy, speed, minute, second, node status) needed for the particular response
Check Word	16	16-bit add-and-left-rotate (discard carry) checksum over all data in the packet following the packet header and excluding the check word itself.
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

4.5.5.3 Remote Video to Headend

Video will be standard NTSC carried via fiber analog modulators, cable analog modulators, or wireless video modulators. Leased line will require CODEC equipment to digitize the video and send it with reduced (T1 carrier -- 1.5 MHz) bandwidth. Formats will depend on the CODEC vendor.

4.6 Initial Deployment Architecture

This section describes the system requirements and architecture descriptions for the Initial Deployment option. The Initial Deployment option emphasizes timely traffic system expansion improvements which provide increased visibility to both MDOT and the motoring public. The objective of the Initial Deployment architecture is to expand current DFOU traffic management capabilities to a priority corridor without changing current system operations, while preserving compatibility with future deployment capabilities.

The Initial Deployment architecture is a subset of the Baseline System Architecture and is designed as a modular corridor component. This approach expands the capabilities of the current system, with the corridor infrastructure design being a component of the new system. The architecture primarily uses existing equipment to provide traffic surveillance monitoring and control. Maximum use of all existing equipment is made with SCANDI RF cable system junction conversions and modulation to take advantage of the current cable system network to the DFOC. Other alternative communication options may be considered for connectivity between the new corridor and the DFOC.

4.6.1 Initial Deployment Architecture Functions

The system shall interface with existing equipment through currently available channel and processing capacities. In general, new subsystem equipment and components will provide capabilities to communicate with both the existing and new systems through industry-standard interfaces (i.e., NEMA, EIA, CCITT, SAE, ANSI, VME, SCSI, NTSC, etc.). The current infrastructure and equipment will be maintained as the primary system for the Initial Deployment corridor. Current DFOC operator interfaces will be augmented (where needed) to manage traffic operations capabilities for the new corridor (i.e., network status displays, ramp control, etc.). The new system shall perform the following primary functions to support freeway operations in the metropolitan Detroit area.

- Perform Traffic Network Surveillance and Control
- Display and Control Changeable Messages
- Display Traffic Network Status
- Perform System Malfunction Monitoring

Subsequent deployment phases shall utilize the existing system to the maximum extent possible for continued operations in concert with new system and subsystem equipment. DFOU operation of both systems shall be integrated to minimize & differences in operator interface(s) and tasks. As new freeway corridors are instrumented and brought on-line, corresponding operator interfaces shall also be integrated and reflect the additional system capabilities. Specific functional processes are identified as follows:

4.6.1.1 Perform Mainline Flow Surveillance

The system shall provide the capability to perform mainline traffic flow surveillance for the Initial Deployment corridor.

4.6.1.1.1 Perform Vehicle Detection

The system shall have the capability to capture vehicle presence counts and detection time differentials (speed traps) for passenger cars; commercial vehicles; transit vehicles; motorcycles; and other roadway vehicles.

1. Vehicle detection points (stations) along the mainline corridor(s) shall be separated by roadway distances of minimum 1/3 mile increments plus or minus 10%. If roadway characteristics in certain areas preclude using this increment tolerance, the next available location shall be selected.
2. Vehicle detection stations shall be located immediately upstream of mainline entrance ramps in accordance with MDOT standards. These stations shall provide traffic flow data to determine ramp metering activation and metering rates.
3. Vehicle detection points (stations) for mainline entrance and exit ramps shall conform to MDOT standards for ramp queue, demand, and passage locations, merge occupancy, and corresponding mainline locations to detect and calculate upstream demand and downstream capacity.
4. System vehicle detection accuracy shall be within 10% of actual vehicle counts. Performance is based upon MDOT metering activation/deactivation threshold levels.

4.6.1.1.2 Calculate Corridor MOEs

The system shall compute mainline corridor MOEs (min. average occupancy, total volume, and average speed) for each detection station from the vehicle detection data.

4.6.1.1.3 Manage Corridor MOEs

The system shall maintain traffic flow MOE's in an integrated freeway network status database. This information shall be made available for use with other traffic operations functions (i.e., area-wide traffic coordination, work zone management, traffic demand management and flow prediction, incident management, and traffic and travel information dissemination).

4.6.1.1.4 Display Corridor MOEs

Mainline corridor MOE data shall be made available for freeway network status displays, entrance ramp status displays, information management, and other DFO activities.

4.6.1.1.5 Perform Video Surveillance

The system shall capture NTSC broadcast quality color or black and white TV video images at identified locations along mainline freeway corridors and communicate images and control data to the DFOC for traffic flow assessments and incident verification by DFOU personnel for up to 24-hour surveillance.

4.6.1.1.5.1 Collect Video Images

The system shall collect NTSC broadcast quality video images (color; black and white) of designated freeway corridors for display on the MDTS DFOC video monitors. Image characteristics shall include the following:

1. Full color (daylight)/low light black and white (dawn/dusk/night) capability: 0.1 lux (1.0x10⁻² FC)
2. Automatic/manual bright/low light compensation and transition
3. Image resolution (minimum): 500 lines horizontal, 400 lines vertical
4. Image zoom/telephoto: Minimum effective zoom/telephoto of the video image shall be 25-150 mm @ f1.2, with manual focus, remotely controlled.
5. TV video image resolution and modulation shall be compatible with NTSC TV standard.
6. TV video image modulation shall be compatible with current DFOC TV monitors.

4.6.1.1.5.2 Video Image Control

The system shall provide remote video image viewing control from the DFOC. Control functions shall include the following:

1. Remote control viewing direction (i.e., horizontal pan and vertical tilt) and image quality (i.e., focus, color, zoom, intensity, etc.) adjustments shall be provided.
2. Video camera platforms shall provide pan-tilt mounting surfaces. Specifications for the pan-tilt platforms shall be:
Rotation: Pan: 0 to 355 degrees
Tilt: +/-90 degrees horizontal.
Speed: 3 to 11 degrees/second
3. Pan and tilt stops to prevent over rotation.
4. Platform mounting shall allow for attachments to poles, buildings, on/under bridges, or other roadway fixtures.
5. Deployed cameras shall be mounted in locations which provide effective viewing of the freeway segment under surveillance. Viewing height shall be a minimum of 40 ft above the roadway surface and minimize occlusion effects of roadway overpasses and curves.

4.6.1.1.5.3 Display Video Images

The system shall capture video images for viewing and display at the DFOC (and other locations) through the current video monitors. The system shall provide operator control to monitor video images collected from any field camera to a designated video monitor in the DFOC.

4.6.1.2 Perform Mainline Flow Control

The system shall control mainline traffic flow through traffic flow diversion techniques (e.g., message signing).

4.6.1.2.1 Display and Control Changeable Messages

The system shall provide a variable roadway signing capability which supports display and radio transmission of traffic diversion/status information for traffic alerts and routing of traffic flow onto alternate mainline or trunkline corridors. Corridor and status-specific messages shall be developed using MDOT-approved criteria and stored in a message database for use with the CMS or HAR (or AHAR) systems.

Dissemination of traveler information for Initial Deployment shall be consistent with current capabilities. CMS/HAR placement included in the Initial Deployment program shall be consistent with MDOT criteria and offer diversion and information delivery opportunities on existing MDOT mainlines and trunklines.

4.6.1.3 Display Traffic Network Status

The system shall provide traffic data collected from the Initial Deployment corridor to the current SCANDI (with modifications) and the GDS for traffic status displays. This data shall include mainline traffic MOEs and system status.

4.6.1.4 Perform System Malfunction Monitoring

The system shall monitor operational performance and system/subsystem status operations through on-line interrogation, health checks, and operator-commanded requests. The system shall monitor detectable malfunctions in the Initial Deployment system and subsystems functions and components. These functions and components shall integrate diagnostic capabilities which identify abnormal operating states to the replaceable component level. Reports which indicate the status of functional parameters of the system or any malfunctioning subsystem component(s) shall be available through the SCANDI system. At a minimum, failures and malfunctions shall be reportable to the lowest replaceable component level (i.e., mainline detectors, ramp controllers, etc.). Failures and malfunctions shall also be reported on the system map display consistent with the existing GDS system.

4.6.1.4.1 Perform Routine Status Monitoring

The system shall monitor system operations for malfunctions or abnormal conditions, modes, or states through built-in test (BIT) during startup (power-on) and routinely during operations (background processing).

4.6.1.4.2 Determine System Malfunction

When a malfunction or component failure occurs, the system monitoring function shall determine the nature of the anomaly and isolate the level to the replaceable component level, generate a malfunction or failure message, and display an indicator at the MTC/DFOC to capture the operator's attention. The system shall provide the capability to interrogate and diagnose system/subsystem components locally on-site.

4.6.2 Initial Deployment Architecture Description

For integration of the new corridor, the inputs and outputs of the three relatively independent subsystems, (i.e., video monitor/camera, CMS, and traffic surveillance and control), must be isolated for independent communications and routing control; however, Time-Division Multiplexing (TDM) of the various controls and status will accomplish the modulation required to interface with the current RF cable system. Selection of where TDM is performed is based primarily on implementation cost and minimizing impacts to existing resources. Candidate locations for TDM include the I-75/I-94 cable junction and the DFOC headend.

To support the Initial Deployment program extension, the existing CCU/RCU communications system shall be augmented, but not replaced, to accommodate the additional surveillance and control coverage. Direct extension of the CCU and RCU channel implementation will not be a requirement, and is discouraged due to potential command/response delay problems that could result in propagation delays or other communications-related problems when the physical cable/ communications path is extended beyond the current system bounds.

The top-level Initial Deployment architecture is shown in Figure 4-19 This shows the roadway infrastructure-based components, the DFOC-based components, and their interconnections. Although the headend RF cable equipment is at the DFOC, it has been split out separately to emphasize changes and additions required to implement the Initial Deployment corridor functions.

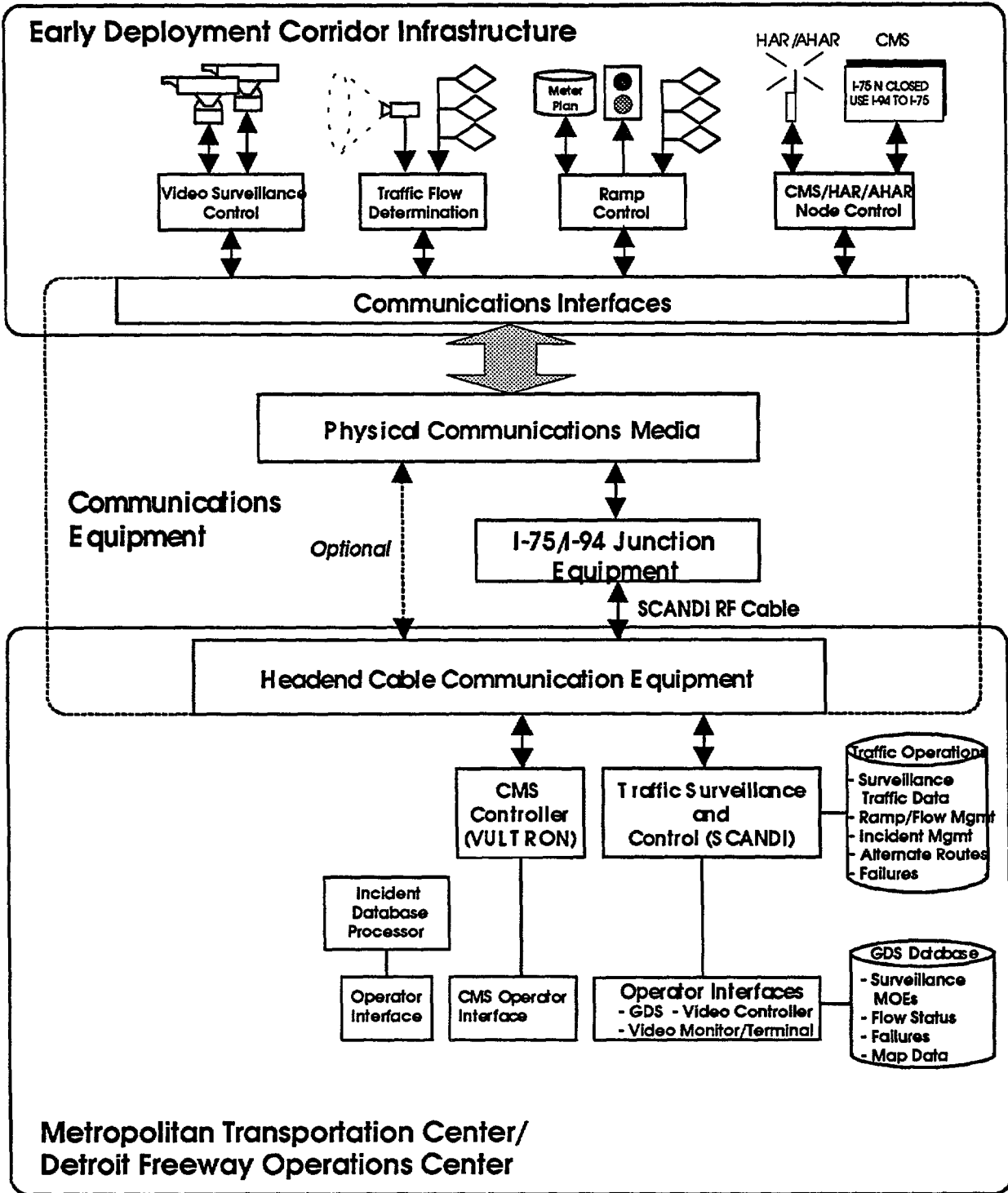


Figure 4-19. Top-Level Initial Deployment Architecture

4.6.2.1 Current Subsystems Modifications and Additions

The Initial Deployment program shall require equipment modifications and additions to provide traffic surveillance and control and information dissemination capabilities on the priority corridor. The following paragraphs describe these modifications and additions in more detail.

General Hardware Modifications. Addition of the corridor surveillance shall require a minimum of hardware changes to the MTC, being limited to augmentation of the existing hardware and addition of new communications interfaces to it.

General Software Modifications. Additions to the current system shall not require extensive changes to existing software. Software shall be developed to interface additional inductive loop (or equivalent) sensors, ramp controllers, video cameras, and CMS and HAR resources to provide, as a minimum, the same capabilities in the current system.

The existing Graphic Display Subsystem (GDS) software and database shall be expanded to include the new freeway segment in its map display capabilities.

Note that when intelligent remote ramp controllers are used (as opposed to central control of the ramp activities on a 250 ms basis), it may not be possible to provide the low-level vehicle passage and ramp signal on/off information for real-time display, and that this capability, when weighed against communications and other costs, may not provide much value-added benefits. If low-level operations are needed, monitoring of vehicle passage may be obtained through CCTV. If the ramp display capability is important for diagnosis of incidents and system faults, generation of the necessary GDS inputs at 250 ms intervals for a specified ramp may be provided by software simulation on the Concurrent central computer, based on the ramp flow volume, metering rate, queue and demand information received from the ramp controller during the last reporting interval.

4.6.2.1.1 Sensor Requirements

Additional sensors to monitor traffic volume and occupancy shall be compatible with existing inductive loop resources. The sensors shall cover all lanes of the freeway in both directions. The sensors shall be capable of sensing all vehicle types from motorcycles to multiple-trailer trucks traveling at speeds from 0 to 100 mph. The sensors shall provide reliable detection under all environmental conditions possible in southeast Michigan including rain, snow, ice, fog (with visibility greater than 25 feet) and clear conditions at air temperatures from -20 to +120 degrees Fahrenheit.

4.6.2.1.2 Sensor Processing

Local processing of sensor information shall be provided in the roadway infrastructure to yield total volume, average occupancy, and average speed (using “timing gates”, where required) at a minimum interval of 10 seconds and a maximum interval of 20 seconds. The resulting data shall preserve individual lane information consistent with current system formats. The data shall contain all required information, including time tagging, so that it is usable (possibly after conversion / combination) by the existing 3280MPS algorithms to provide data fusion into 1 minute periods at 20 second intervals.

Status of the remote sensor subsystems shall be provided at the same interval as the sensor information to enable fault isolation to the field replaceable unit (Line Replaceable Unit {LRU}) level. The subsystems shall be capable of maintaining and outputting additional status information, upon request, to isolate malfunctions and faults to the lowest circuit card / shop replaceable unit (SRU).

4.6.2.1.3 Changeable Message Sign Processing

Any new CMS resources added to the system shall be compatible with the existing CMS monitor and control subsystem. Software changes to the CMS control system to incorporate the new CMS shall be limited to database updates necessary to bring the new CMS on-line.

4.6.2.1.4 Video Surveillance

Full-motion video shall be provided at those locations designated for surveillance. The infrastructure shall accommodate a 6 MHz video bandwidth using standard NTSC video. The video signal(s) shall be routed to the MDOT DFOC at the nearest junction point to the new equipment using spare existing cable capacity wherever possible.

4.6.2.1.5 Communications

Communications between corridor processing and the DFOC shall be designed to provide the following capabilities:

- a. Sufficient communications bandwidth capability shall be designed into the Initial Deployment corridor to provide full-motion NTSC video signals and bi-directional data transfer.
- b. Communications facilities shall be provided for one-way video transfer to the DFOC, remote camera Pan-Tilt-Zoom (PTZ) and camera switching, communication with processed (volume, occupancy, speed, status) inputs from mainline detectors on a 10 second (minimum) interval, and control / status collection from Changeable Message Signs (CMSs).

- c. Sufficient processing capacity shall be available for control of Highway Advisory Radio (HAR) transmitters.

The Initial Deployment shall not require more than 50 percent of the design communications capacity. The remainder is reserved for future expansion. Alternative temporary communication facilities, such as wireless radio or leased lines, may be considered to enable earlier deployment.

When a communications “backbone” media is embedded on one side of a roadway, the use of short-distance wireless communication from equipment cabinets located on the backbone side to equipment cabinets located on the opposite side of the roadway shall be weighed against the life-cycle cost (ICC) of trenching across the freeway for the installation of fixed wire / fiber link required to reach the backbone. Similarly, the life cycle costs of using wireless communication methods from video cameras to a nearby cabinet shall be weighed against the installation of fixed lines for both video signal return and camera PTZ controls.

Because pre-processing of sensor inputs and autonomous operation of ramp controllers is specified, the communication bandwidth for these functions will be quite low and well within the capability of UHF (or VHF) packet or spread-spectrum radios, CMS communications could also be handled within this bandwidth or the current CMSS. The primary communication difficulty is with the full-motion video. Even using compression techniques, a minimum of 1.5 MHz bandwidth (T1 Carrier) is currently required.

Commercially-available means for communicating with cameras using short-distance wireless radio is available. Further evaluation of these means are required based upon system requirements and cost considerations. It is also possible to avoid costly trenching operations between ramp controllers on the opposite side of a roadway to the communications backbone cable or fiber using wireless radio.

4.6.2.1.7 DFOC / MTC Headend

Figure 4-20 shows the DFOC headend interfaces. At the DFOC, video inputs will use the existing blonder-tongue (B-T) demodulator / Vicon Switcher and video control architecture. It is envisioned that additional B-T video demodulator(s) will be required for the additional corridor cameras. The Vicon equipment currently provides a sufficient number of spare ports for camera video inputs and monitor outputs.

Similarly, the camera controllers will remain common with the current camera control system. Some modifications may be required to the PC database to accommodate new cameras and addressing, but there should be adequate spare margin for Initial Deployment camera additions. The same cable frequency modulator will be used as for all other cameras, operating at a frequency of 18.1 MHz with a 56KB data rate.

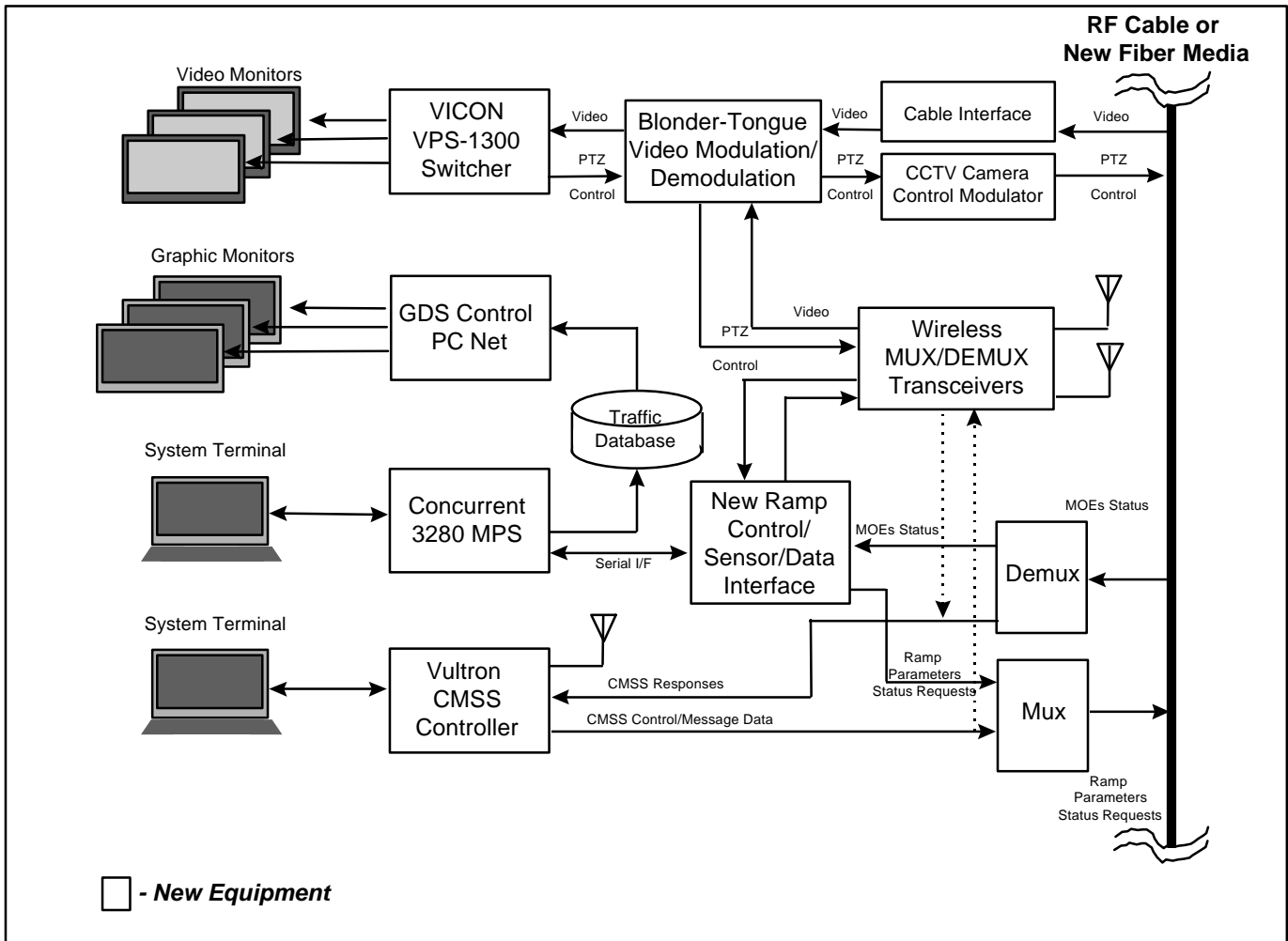


Figure 4-19. Initial Deployment MTC/DFOC Headend Detail

The details of the new Vultron CMS controller interfaces are not known at this time, but it is believed that the standard “modem” type of interface can be used as for existing wireline-connected CMS facilities. To conserve cable resources, however, this infrequent control information will be multiplexed in a straightforward manner with the (also infrequent) new ramp control parameter overrides and ramp / loop status requests. The multiplexing may be as simple as controlling the Clear-to-send (CTS) line(s) going back to the Vultron CMS controller and new Concurrent serial interface to assure that only one device is sending data at a time with a digital selector used to route the appropriate input to the output. Responses coming back from the remote CMS controllers will be routed to the Vultron CMS controller by a demultiplexing process based on a simple algorithm such as received data parity. The throughput of the 56KB RF cable modem should be adequate to satisfy the currently-programmed response requirements of the Vultron software operating on a 2400 bps wireline modem.

Since the remote ramp controllers and loop controllers contain intelligent processing, they do not need to be polled to return the ramp MOE’s (occupancy, queue, and demand, flow volume, metering rate, time, status) or the loop MOE’s (volume, occupancy, speed). The

remote controllers are expected to send this data at their pre-set rates once commanded "on" without further polling. Commands to the ramp controllers to change metering rates or activate / deactivate metering may also be sent. The capability to poll the controllers for additional status (primarily faults) is also provided.

Two additional narrow band 56KB cable frequency interface devices (or a single dual-frequency modem) may be required, as shown in Figure 4-20.

4.6.2.1.8 I-94 Junction

Figure 4-21 shows the internal detail for the "junction box" located in the I-94 / I-75 area. The equipment is required to convert between any of 3 possible communications media to the existing cable media.

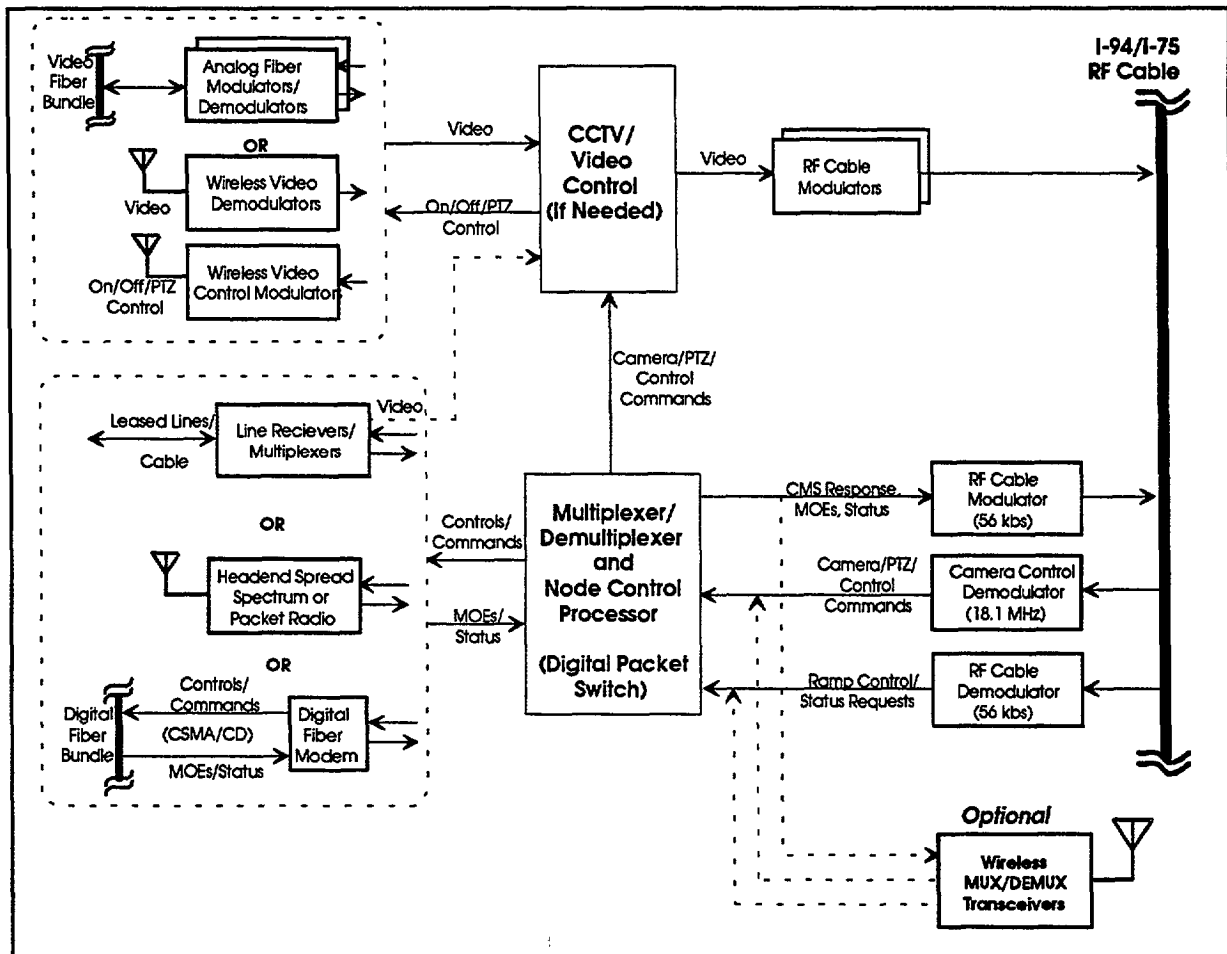


Figure 4-21. Initial Deployment I-75/I-94 Junction Detail

Camera video will require either fiber-optic transmission line from remote I-75 locations, wireless video transmission, or leased cable facilities. If trenching must be performed to install cable, the additional cost to use fiber-optic bundles is negligible.

Note that the architecture in this document is for Initial Deployment only, and omits the normal fiber LAN architecture details. In particular, a fiber “backbone” is normally installed. There are then “spurs” that connect with this backbone (Star configuration) at hub locations. The “spurs” then run on a separate fiber bundle (or even wireline cable) to somewhere between 8 and 15 nodes. This type of architecture usually has a hub every 4 or 5 miles along the fiber backbone so that a smaller number of nodes will be impacted should there be a break in the spur (or in the event a cabinet is damaged by maintenance crews knocking it over, as sometimes happens).

For the Initial Deployment architecture, since the entire run is only about the length of a single spur, it is proposed to dispense with the expense of a backbone / hub architecture and simply run the fiber from the I-94 junction to all nodes for the (approximately) 6 mile run. However, the fiber backbone cable (if used) should be installed in the conduit alongside the spur cable during initial installation, even though it will not be used until the ATMS system is extended beyond the Initial Deployment corridor.

Since remote sensors, CMS, and ramp controllers require a much smaller bandwidth, the option exists to use wireless media such as spread-spectrum radios or packet radios as well as leased (or switched) voice-grade wirelines. This is reflected in the figure, where options exist for bringing in data (or sending data) via radio, leased line, or a fiber digital modem (if fiber is used for the video).

4.6.2.1.8.1 Video Signal Return

When fiber-optic cable is available, the most cost-effective use is to allocate one fiber of a bundle for each camera chain (more than 1 camera can be in a chain) with standard COTS analog modulation / demodulation equipment. This avoids costly digitization and/or multiplexing of the signal. A camera chain consists of one or more cameras whose modulator and camera are all capable of being switched off or on via remote command. Only 1 modulator at a time (using simple LED's) may be carried on the fiber. Note that COTS equipment is available which will multiplex 4 or more NTSC video signals on a single fiber. This is useful for co-located cameras, and would be an exception to the “single camera chain, single fiber” approach. The group of cameras would then be treated as a single camera for switching on or off the chain.

Multiple fibers in a bundle are used to accommodate multiple camera chains for simultaneous viewing of several locations. This technique will cover 99% of the real-time surveillance requirements where incidents statistically happen frequently at only 1 location on a chain and infrequently at others. The high-incident location would normally be selected for viewing with the others switched in or out as indicated by the received MOE's from the field sensors. This switching could even be done automatically on a round-robin basis to present (for example) 10 seconds of a given camera view before switching to the next camera on the chain. This would, however, require significantly more software modifications than a simple operator-commanded switch mechanism. It would also result

in a fraction of a second of “black” on the monitor before the next camera were switched on, which could be aesthetically disturbing.

Demodulated video, either from the fiber or leased cable, is presented to a video chain switcher, if required, prior to being sent to a standard cable modulator for frequency-division multiplexing on the existing cable. The video switcher is required only if there are fewer cable video channels available than there are camera chains on the fibers. At the switcher, a second level switching occurs to select the chain to be sent back to the DFOC. While this should not be needed for the Initial Deployment implementation, it is shown for future expansion of video coverage. Control for the secondary switcher will be time multiplexed with other control functions at the DFOC.

4.6.2.1.8.2 Camera Control:

The camera PTZ control that is currently sent on the 18.1 MHz digital channel from the DFOC will be demodulated at the junction box and input to a 2-way multiplexer (effectively a packet switch). The control commands occur infrequently, and can easily be combined with ramp control and status requests.

4.6.2.1.8.3 CMS Control and Status Requests:

These signals are demodulated from the new cable control channel (if used) and include both CMS control where applicable and possible camera chain switching commands from the Concurrent system. They are combined with command packets from the camera control using simple time multiplexing (store and forward packet switching) and then sent to one of the 3 optional media for output along the Initial Deployment corridor.

4.6.2.1.8.4 MOE and Status Return:

Mainline MOE's (volume, occupancy, speed) are passed through from the link directly to an additional 56Kb cable modulator for relay to the DFOC. While this is shown as passing through the multiplexer / demultiplexer, little needs to be done beyond packet relay from the remote sensors to the cable. Again, this data could arrive from any one of the three possible media, also at a nominal 56 KB rate (although data throughput would be much less due to the burst nature of the reports).

4.6.2.1.8.5 Communications Protocols:

There are cost-effective parts available which will completely handle a Carrier-Sense-Multiple-Access / Collision-Detection (CSMA/CD) fiber access for multiple devices on the same fiber with little additional intelligence required (i.e. no separate CPU). It is envisioned that the Control Processor will be fabricated using a COTS single-board computer (possibly VME-Bus) assembly and add-on COTS I/O cards. This processor could easily handle the set-up of the CSMA/CD LSI chip, which would then take care of

all transmission and reception from the fiber. The Intel standard CSMA/CD controllers are available in several configurations. No custom hardware should be necessary, but semi-custom (modified) software will certainly be required.

A single fiber in the bundle can be used to carry ALL status and MOE information from the remote intelligent controllers. These controllers would simply send a packet when data were available at their predefined collection rates. The CSMA/CD protocol would allow each remote to determine if it had been interfered with and needed to retransmit the packet. At the junction box, outgoing commands are multiplexed in the same manner on the bidirectional cable transceiver. This scheme is a form of optical LAN access which has equal applicability to leased lines or coaxial cable.

For packet radio, a modified type of access protocol would be required. Packet radio, operating at 9600 bps, could support all communication for the junction link. The packet radio mechanism uses not only collision avoidance (i.e., listen before transmit), but also reverse acknowledgment of received data. Some modification of the AX.25 protocol could be performed to enhance throughput and connectivity, but is easily avoided with multiple-session packet Terminal Node Controllers (TNC's) located at the junction.

Spread spectrum protocols generally work better with a poll-response type of approach. To use this type of radio, a frame time would have to be enforced by the junction control processor (on a 10-20 second basis). Polls to all remote detection stations would be generated and the responses collected and relayed to the cable modulator. This approach is less desirable due to the larger amount of custom software development that would be required. It could be needed to support larger bandwidths (up to 250,000 bps), however, than packet radio (using the available UHF frequencies and 9600 bps speeds) can accommodate.

4.6.2.1.9 Inductive Loop / Other Detectors

Figure 4-22 shows a representative mainline detection station node. All optional communication mechanisms are also shown for completeness. Again, only 1 of the 3 will be required in the final system. For initial deployment, wireless modes shall be used.

This architecture is for a simple detector set from both sides of the roadway where there is no nearby ramp controller or camera. There does not need to be a co-located speed trap. If the site supports a speed trap, an additional set of loop drivers will be required to cover an 8 lane highway, if loops are to be used. For a speed trap, the processor should be programmed to also supply normal MOE's from a single set of loops (either set remotely commandable to compensate for temporary faults) along with the speed information.

Note that provision has also been made to replace some loop detectors with an equivalent system should it be necessary in certain locations due to roadway condition or other factors. The control processor should be able to handle raw loop on/off or processed data from the other detector types.

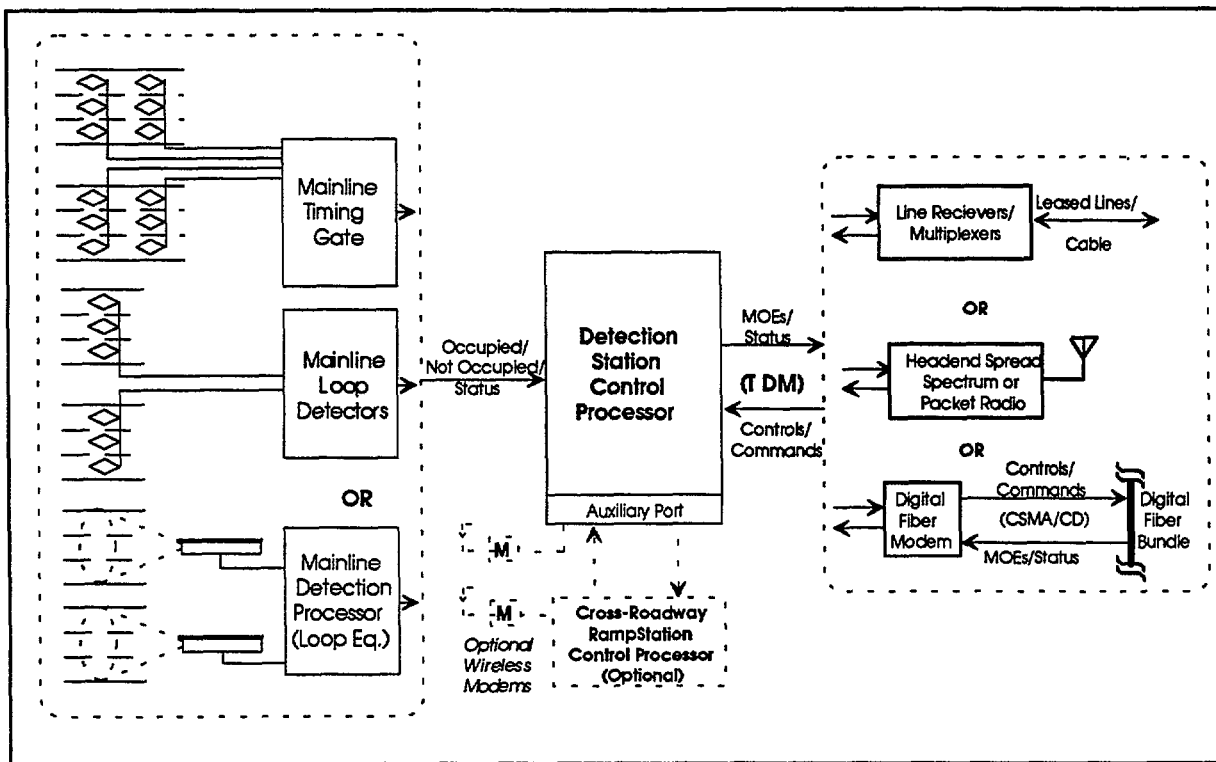


Figure 4-22. Initial Deployment Detection Station Node Detail

4.6.2.1.10 CCTV Video Surveillance

This node is different than the other types since the wide video bandwidth required dictates the use of a fiber, cable, specialized wireless connection. Figure 4-23 illustrates a CCTV video / camera control node architecture. For this reason, it is assumed that the cabinet containing the control processor will be located on the fiber LAN or contain the wireless communications equipment for the video/camera control link. However, there is no reason why there cannot be a detector controller on the opposite roadway side that uses the facilities of the control processor.

Provisions have been made for wireless modem and video modulator usage to link the control cabinet to the camera assembly in lieu of trenching and laying control lines and video cable. COTS wireless video transmitters (unlicensed) are available to handle the video transfer. A standard wireless modem of the type used for cross-highway links will also be required to transfer the camera PTZ commands and receive status from the remote side unless supplied with the wireless video link. If not, camera control will most likely require a special interface card to isolate the various PTZ commands from the digital data stream and route them to the proper control mechanism. A separate processor should not be required -- a control sequencer type of ASIC design will probably suffice.

If the camera is "hard wired" to the control cabinet, then separate lines will be run from the control processor I/O card for control of the PTZ functions as well as receipt of status.

Video transfer will require a coax cable (to carry the baseband video signal) to the video-fiber modulator. The control processor interface software will be slightly different depending on the camera control interface type.

It should also be noted, although it is not shown in the figure, that multiple cameras could be handled by a single cabinet junction when they are located in close proximity to each other (such as on more than one side of freeway interchanges). In this case, one of the multi-channel video multiplexers will be required ahead of the video-fiber modulator and multiple camera command ports will be required from the control processor. Control processor software must be designed in a modular manner to support the decoding and routing of commands to multiple camera addresses from the common DFOC control port.

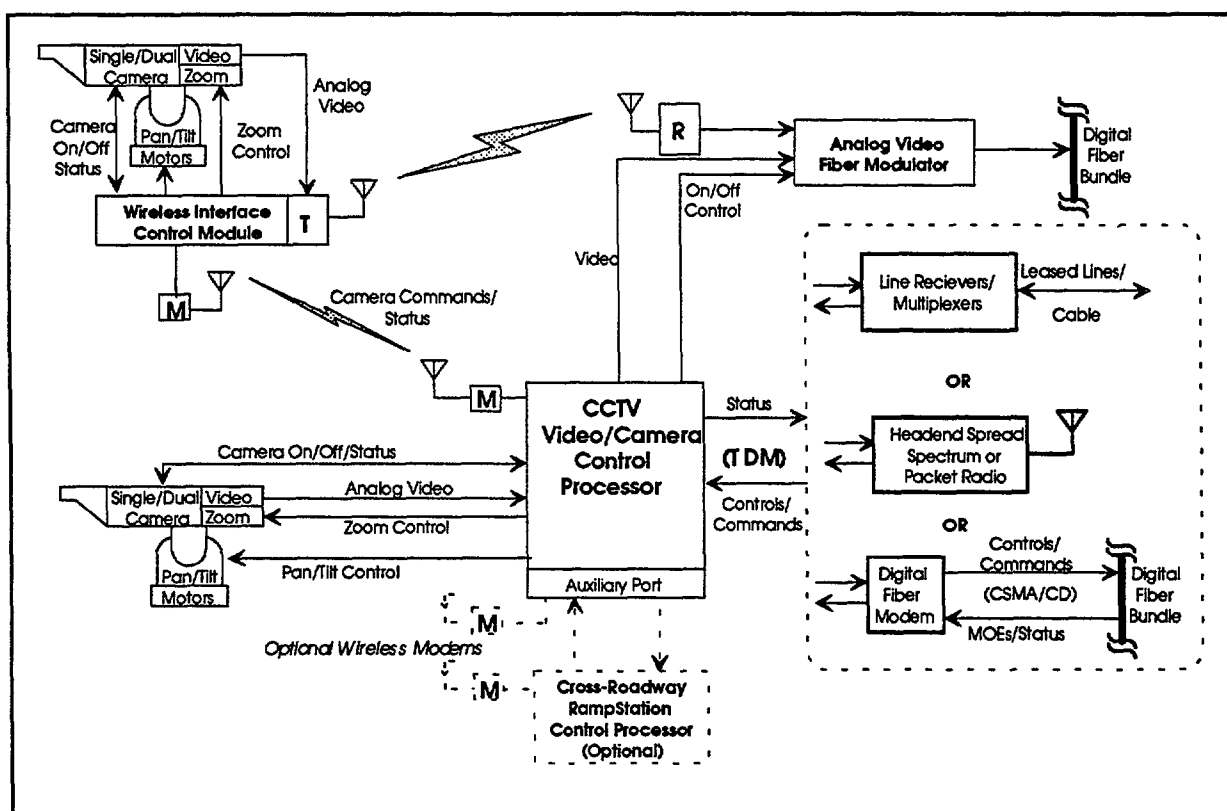


Figure 4-23. Initial Deployment CCTV Video / Camera Control Node Detail

4.6.2.1.11 CMS / HAR Interface

The interface and control architecture for a CMS or HAR link is almost the same as that for a camera PTZ control link. There is no video interface, but the command / response interface is generically the same as shown in Figure 4-23, replacing the camera with the CMS or HAR control module. Control processor software can also be common as long as it is concerned only with command address recognition and speed buffering (i.e., packet switching) to a serial interface type. It is also conceivable that a single common control

processor could handle either multiple cameras, or cameras and a CMS or HAR command / response port. The function could also be combined with a detector station controller.

4.6.2.2 Representative Control Processor Architecture

4.6.2.2.1 Processor and I/O Hardware

The control processor needed to satisfy Initial Deployment and future MDOT requirements should be selected for its capacity for growth potential as well as the availability of off-the-shelf modular CPU and peripheral cards. It is highly recommended that a modular chassis (e.g., VME-bus and standard card format) architecture be used. The NEMA 170 types of systems are evolving toward this standard, and interfaces from the 170 to VME configurations currently exist. However, use of a 170-type controller is probably not cost effective since growth and processing capacities are marginal in current configurations. Multiple vendors support the 680x0 VME standard, to which the NEMA 170 6800 CPU software is readily convertible. Allen Bradley has VME configuration processors and I/O cards. Many other vendors also have these, and it is probable that traffic-type operations (such as lamp drivers) and certainly fiber or cable LAN interface modules are readily available.

Figure 4-24 shows a representative recommended internal control processor architecture. The figure shows all required modules for the Initial Deployment architecture implementation. Since a VME bus is used, many other peripheral cards for varying functions needed in the future are also easily added when required.

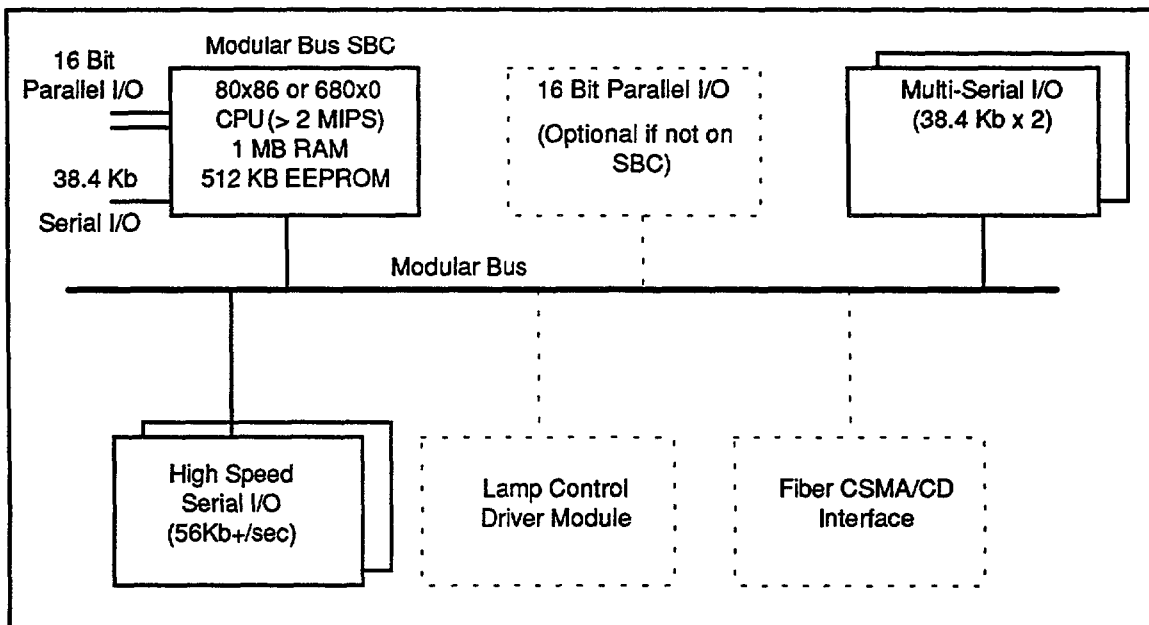


Figure 4-24. Representative Modular Control Processor Architecture

This type of architecture can be used to satisfy the requirements for the Junction, Detection Nodes, and Video nodes. Not all peripheral cards are required in all applications. A brief synopsis of each module follows:

4.6.2.2.2 Modular Single Board Computer (SBC) Module:

A large variety of modular chassis (e.g., VME-bus compatible) SBC's are currently available using both the Intel 80x86 types of processors and the Motorola 680x0 processor types. The 680x0 is preferred for commercial applications because of its compatible interface to the VME standard and upward compatibility with the current NEMA 6800 standard processor type. Abundant vendors for C compilers and 680x0 assemblers exist.

The selected SBC should have a minimum of 2 Million Instructions per Second (MIPS) throughput (easily satisfied by even the slowest 68000 board), 1 Megabyte of on-board RAM (expandable to at least 4 MB), and a minimum of 512 K bytes of Flash EEPROM for program and constant /parameter storage for non-volatility and unattended operation / automatic restart on power fault.

In addition, the board should have a general asynchronous serial I/O port with a speed rating of 1200 to 19,200 bps for connection of a local diagnostic console. A few bits of parallel I/O for general control and/or loop detector inputs should also be provided. A minimum of 16 bits is recommended, although an external (possibly multi-function) VME card could also provide these functions if not available on a cost-effective SBC. For future supportability and easy card interchange / upgrade, it is probably best to avoid dense, multi-function VME cards in favor of more modular systems which can be upgraded or repaired using "mix and match" techniques with full interchangeability from different vendors. This will also assure MDOT of easy repair / replacement in the future without the need to repeat their custom development efforts for new replacement parts when a sole-source vendor goes out of business.

The board should support full VME Direct Memory Access and control functions for high speed transfer from one port to another. Multiple DMA channels are required for simultaneous transfer of data for at least 4 ports. This is used for data packet switching and multiplexing / demultiplexing, particularly at the Junction Node (or possibly LAN hubs). Finally, the board should support at least 2 programmable counter/timers (3 is standard) for implementing a "real time" clock and other temporary timing loops for various functions.

4.6.2.2.3 16 to 24 Bit Parallel I/O:

This card would be used for handling inputs from standard loop detectors. It is required only if the SBC does not have at least 16 bits of parallel I/O. Each bit should be software configurable as either input or output, although if the majority are fixed at inputs with only a few outputs, that is sufficient.

4.6.2.2.4 Multi-Serial I/O:

This should be a general-purpose synchronous / asynchronous (USART or DUSART) serial I/O module with at least 2 ports on the same card. Both ports should provide, as a minimum, RS-232 drivers and receivers with RS-422 (balanced) provided as either a hardware strap option or software configurable item. Each port should have a set of RS-232 style control signals (RTS / CTS, DSR, DTR) and possibly also RING for potential use in dial-up line applications. Each port should support from 75 bps to 38.4 Kbps as a software configurable option.

These serial I/O cards (up to 2 should be provided for in the architecture) are used for the following:

- Radio Interface (spread-spectrum or packet) option,
- Leased line demodulator / demux option,
- Auxiliary Cross-Roadway wireless Modem port,
- Loop detector substitute (e.g., Autoscope) input ports,
- Camera commands / status port for wireless node to camera link.

Full DMA capability is optional, but interrupt capability is mandatory.

4.6.2.2.5 High Speed Serial I/O:

These cards are similar to the multi-port serial I/O cards except they should have full DMA control capability. They are used only in the junction for Camera demodulator input and Control / MOE / Status modem I/O at speeds of 56 Kbps. Up to 2 cards should be provided for in the architecture.

4.6.2.2.6 Fiber CSMA/CD Interface:

This card will contain the fiber-optic LAN control logic (and also possibly the actual fiber modulator / demodulator logic). The LAN protocol must use a Carrier-Sense-Multiple-Access / Collision Detection scheme in order to multiplex multiple nodes on the same physical fiber. An LSI chip, such as the Intel 82592, is capable of several megabits of throughput and provides nearly all control and buffering necessary, as long as DMA is available from the processor to/from memory. It is intended that the processor configure this chip during initialization (configuration is quite complex due to the many options available). Any other equivalent function LAN control LSI chip would also be acceptable.

The card is needed only when a fiber-optic LAN architecture is used (in lieu of the packet radio or spread spectrum radio options).

4.6.2.3 Software Functions

There are many real-time operating systems available for use with VME bus types of processors. Initial Deployment tasks to be performed do not necessarily require a sophisticated OS. They could all be easily implemented with a simple “activity loop polling” scheme in the software working from interrupt or DMA queue indicators to determine what action to take next. This simple approach saves on some types of costs but often results in higher software development costs than if a standard COTS operating system is selected. This must be carefully traded before making a final decision. Any COTS OS selected should be mature and likely to remain on the market for many years to come, support C and assembler programming, full debugging tools, and preemptive multi-tasking for future growth.

Whether or not an OS is used, the software functions should still be partitioned into tasks. A modular approach must be used to enhance re-usability and also flexibility in implementing multiple functions within a single control processor. The best way to specify the functions required in the software is on a task basis for each node type, as will be done in subsequent subsections.

4.6.2.3.1 Junction Node

The control processor at the junction node is primarily concerned with switching data from one port to another. It will require a store-and-forward packet switch type of software protocol. This is most easily implemented by defining a task to handle each exchange. DMA transfers should be used and a modular protocol interpreter (to determine packet start / end or to format new packets) should be provided.

The following major tasks are defined:

- a. Receive and process MOE and status requests. Inputs come from the cable demodulator. The software must interpret each command received, determine that it is valid, and then format and queue it for transfer per the output option (Fiber, Radio, or Leased Line driver). The actual output of the data is a separate task. This task is also responsible for recognizing Video Chain switching commands that may arrive in the input stream and sending them to the local switcher.
- b. Camera control PTZ command processing. Inputs come from the Camera Control cable demodulator. The software must interpret the input data, determine it is valid, and then format and queue it for transfer per the output option (Fiber, Radio, or Leased line). This is similar to task (a) except for the different format and different interrupt port. The same software should be usable beyond the input data interpretation differences.
- c. Output commands to remote devices. This task is responsible for managing and coordinating the time-division output of data that arrives from tasks (a) and (b). It

- contains the specific drivers necessary for the selected output option (Fiber, Radio, or Leased line). This is little more than a queue management task and device driver.
- d. Input of MOE and Status information from remote devices. This task is responsible for accepting the returned data packets from remote devices, verifying them, reformatting where required, and queuing them for output via the Cable Modulator back to the DFOC. Input protocol will vary depending on the selected option (Fiber, Radio, or Leased Line).
 - e. Output Remote Responses to DFOC. This task handles the protocol necessary to output CMS responses, MOE's, and Status information back to the DFOC via the Cable Modulator. It must also multiplex local processor status (including video chain switcher command acknowledgment) with the data stream received from the remote devices. Speed buffering and storage is provided to match potentially higher (megabit) burst rates from fiber to the slower 56KB steady stream to the DFOC.

4.6.2.3.2 Detection Node

The control processor in the detection node shares some common functions with the junction node. It also has additional required capabilities. The following major tasks are defined:

- a. Receive control commands. Inputs come from the Fiber / Radio / Leased Line interface (as applicable) and consist of BIT status requests, node configuration change commands such as addresses of associated linked controllers), commands to a (possibly linked) cross-roadway ramp controller, and synchronization information to control sorting of detector derived MOE's. The commands must be validated by the software and then acted upon.

Control commands change the internal software configuration and operation. These should be stored in some sort of non-volatile (e.g., Flash EEPROM) for power fail recovery purposes. There should also be an acknowledgment of the command queued for output back to the DFOC.

Commands addressed to the cross-roadway controller should be queued for output to the auxiliary port.

Commands addressed to nodes other than this one or the associated cross-roadway controller should be discarded.

- b. Calculation of MOE's. Depending on the configuration of the node, several sub-tasks could be defined. The software is responsible for collecting inputs from the loop detector (or alternate loop equivalent) devices at nominal 10 millisecond intervals, determining vehicle presence or non-presence, and accumulating volume and occupancy, using the same algorithm as currently implemented in the Concurrent

mainframe for processing CCU inputs from the loop RCU's. This data must be accumulated on a lane-by-lane basis for reporting back.

When a timing gate is implemented in the node, the software shall calculate the average speed of traffic flow using the same algorithm as in the Concurrent system. Alternatively, speed shall be derived based upon vehicle classification and adjustments received from the Concurrent mainframe for adjacent nodes when a single loop arrangement exists at the node.

Provisions should be made to clear all internal counters upon command of the Concurrent control program.

- c. Reporting of MOE's and Algorithm Reset. The merged / calculated volume, occupancy, and speed shall be queued for output to the (Fiber, Radio, or Leased Line as applicable) port at the interval configured in the program ROM or the interval commanded from the headend Concurrent control program. This data will be sent at a nominal rate of once each 20 seconds for fusion with previous node data.

Since the Concurrent contains the logic to "smooth" and "average" the collected MOE's at the 20 second interval into larger 1 minute intervals, it should not be necessary to perform any filtering of data at the node. Once a set of MOE's is calculated, the counters should be reset to zero and the software will start all over again.

- d. Accept responses from auxiliary node. The software must accept inputs from the Cross-roadway node via the auxiliary port for combination with its own responses and queuing for output back to the DFOC.
- e. Output queue handling. The software must time-division multiplex the outputs resulting from tasks a, c, and d, format them, and output them to the selected communication medium (Fiber, Radio, or Leased Line). The appropriate device drivers and data protocol formatting should be implemented independently to preserve as much device-independence as possible. This is primarily a store-and-forward message switch task.

The software must also format and output the commands received for the Cross-roadway node to the auxiliary port.

- f. Built-in test. The software shall detect on-line faults in the control processor (as evidenced by erroneous operation of any control port) and report them along with the MOE's to the DFOC.

The software shall support the capability to perform an "off-line" self test (and a startup self test) of processor logic and interface logic that more rigorously tests each subsystem and reports the results so that faults may be isolated down to the lowest

LRU (or group). Consideration should also be given to diagnostics that will isolate parts down to the lowest SRU, although this may be something that is loaded and run only in the shop environment.

4.6.2.3.3 Video Node

The control processor in the video node has the fewest required functions of all node types since it is not involved in processing the video signal and it is assumed a video node is located on the LAN and thus does not need to be concerned with remote radio operation across the freeway. It is possible that a ramp control node may use the video node's LAN hookup, however. Additionally, provision is made for use of a wireless interface to the PTZ camera interface.

- a. Receive control commands. Inputs come from the Fiber / Radio / Leased Line interface (as applicable) and consist of BIT status requests, node configuration change commands (such as addresses of associated linked controllers), commands to a (Possibly linked) cross-roadway ramp controller, and Pan / Tilt / Zoom commands to be sent to the camera. The commands must be validated by the software and then acted upon.

Control commands change the internal software configuration and operation. These should be stored in some sort of non-volatile (e.g., Flash EEPROM) for power fail recovery purposes. There should also be an acknowledgment of the command queued for output back to the DFOC.

Commands addressed to the cross-roadway controller should be queued for output to the Aux port.

Commands addressed to this node's camera control mechanism must be passed to the camera controller. The method of doing this, and the ports used will vary depending on whether the camera is linked via wireless or wired connections. The commands should be queued to a generic output device handler to minimize software differences.

Commands addressed to nodes other than this one or the associated cross-roadway controller should be discarded.

- b. Reporting of status. The software should acknowledge all commands sent to the camera PTZ mechanism. The software should also report internal node status periodically so that the health of the node may be monitored by the DFOC processor to enable fault detection as soon as possible. The software should send a status report back to the DFOC at least once each 5 minutes (), even if no control or other commands have been received. Since responses from an auxiliary node are handled transparently back to the DFOC, the presence or absence of such a node has no bearing on this requirement.

- c. Accept responses from Aux node. The software must accept inputs from the Cross-roadway node via the Aux port for combination with its own responses and queuing for output back to the DFOC.
- d. Output queue handling. The software must time-division multiplex the outputs resulting from tasks a, b, and c, format them, and output them to the selected communication medium (Fiber, Radio, or Leased Line). The appropriate device drivers and data protocol formatting should be implemented independently to preserve as much device-independence as possible. This is primarily a store-and-forward message switch task.

The software must format and output the commands received for the Cross-roadway node to the Aux port.

The software must format commands for the camera PTZ mechanism received from the DFOC and output them to the camera control. Both wireless communication (with status return) and wired communication (possibly via different ports) must be supported. Note that translation of the DFOC camera control device into a different form or content may be required to accommodate new camera control logic. This translation is the responsibility of the node control processor.

- e. Built-in test. The software shall detect on-line faults in the control processor (as evidenced by erroneous operation of any control port) and report them to the DFOC as soon as they are detected. Once a fault is detected, there is no need to continuously send the status to the DFOC at an interval more frequent than specified above for normal status reports.

The software shall support the capability to perform an “off-line” self test (and a startup self test) of processor logic and interface logic that more rigorously tests each subsystem and reports the results so that faults may be isolated down to the lowest LRU (or group). Consideration should also be given to diagnostics that will isolate parts down to the lowest SRU, although this may be something that is loaded and run only in the shop environment.

4.6.2.3.4 CMS/HAR Interface

The functions of the CMS/HAR interface node are nearly identical to those for the video node when the camera control port’s interface is replaced by the CMS or HAR controller.

The control processor software in a CMS or HAR interface node shall “transparently”. (without modifying the commands or responses) switch the packets to and from the attached CMS or HAR. This may be done using either a regular port (such as the camera port equivalent) or the auxiliary port.

4.6.2.4 DFOC Headend Software Modifications

Software modifications will be required to the headend computer equipment. It is hoped that the scope of these modifications has been minimized through the careful interface design. The following sections discuss only the nature of the changes, not the specific changes, since the internals of each computer are not specifically known at this time. Most of the information herein is based on discussions with of MDOT.

4.6.2.4.1 Vicon VPS-1300

The Vicon video switcher should require no special modifications other than possible table modifications to accommodate additional camera inputs and additional monitor outputs.

4.6.2.4.2 Camera Control PC

The current video and camera control should not require modifications beyond possibly enabling additional camera addresses, by simple table updates.

4.6.2.4.3 Vultron CMS Controller

The Vultron CMS controller should not require any modifications beyond adding new CMS addresses to its internal tables.

4.6.2.4.4 Concurrent 3280MPS

It has been confirmed with MDOT personnel that there should be no problem with merging new detector inputs at the 20 second data fusion point in its processing. It is estimated that all that will be required is to expand some working arrays which hold the data (and also store it on disk) along with the associated array index limits. A new task to perform this function as the data is received from remote nodes is required.

- a. Serial I/O handling. A new serial I/O handler is required to manage data input and output via the new control / status return interface. The standard Concurrent common serial port protocol driver will most likely be capable of handling the actual device-level interface.
- b. Detector failure to report and reported faults. A new software task to handle faults and also internally generated fault indications when detection nodes fail to report new information (detected when the data is needed for merging) will be required.

A new software task to format and display these faults (or merge the reports in with the existing fault reporting subsystem) will be required.

- c. Operator Interface. The existing operator interface will require modification to accept commands for ramp overrides, node configuration changes, and commands for node

off-line self test for the new node types. This capability goes beyond the current operator interface, but should be compatible with it.

- d. Graphic Display Subsystem interface. The Concurrent sends volume, occupancy, and speed on a 1 minute update basis to the GDS (without the GDS requesting it). The scope of this data must be increased to include the newly instrumented sections of roadway.

4.6.2.4.5 Graphic Display Subsystem

The Graphic Display Subsystem interface will remain the same except additional volume, occupancy, and speed, and ramp control information must be sent on the 1 minute update basis. It is hoped that the GDS map displays are table driven so that minimal software (just table) updates are required to add the new I-75 corridor (which now appears in “grey” on the map up to 8 Mile Road). If the instrumentation is extended beyond 8 Mile Road, it will not be covered by the current map, and far more significant changes to the GDS database will be required to include it.

Adding new ramp controller detailed views is also a database modification task. There are probably existing ramp views that can be copied and modified to include the new ramps. The internal tables of ramps will need to be updated. Software modifications should be minimal provided that sufficient software documentation of the existing system is available.

4.6.2.5 Interface Data Definitions

Table 4-26 lists each of the interfaces and the top-level data types that are passed on them.

Table 4-26. Initial Deployment Interfaces

From	To	Data Types	Comm Method
<i>MTC/DFOC Headend</i>			
3280 MPS	I-94 Junction (Detection, Ramp, and Video Nodes)	Ramp Parameters Status Requests Node Configuration Commands	56Kb Cable Modulator (multiplexed with CMS data)
Vultron CMS Controller	New CMS	CMS Control / Configuration Data (via “modem” port)	56Kb Cable Modulator
Camera Control PC	Video Nodes	Camera Pan/Tilt/Zoom Commands	Camera 18.1 MHz Cable Modulator
I-94 Junction (Detection, Ramp, and Video Nodes)	3280 MPS	Detector: Volume, Occupancy, Speed, Time, Node Status Ramp: Volume, Occupancy, Flow Rate, Time, Node Status Video: Camera and Node Status	56Kb Cable Demodulator (Multiplexed with CMS return data)
Video Node	VICON VPS-1300	NTSC Video	Blonder-Tongue Cable Video Demod.
CMS	Vultron CMS Controller	CMS Status Responses (via “modem” port)	56Kb Cable Demodulator

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<i>Junction</i>			
Video Node	Cable Video Modulators	NTSC Video from Camera(s)	Fiber Bundle or Leased Lines to Cable Conversion
Detection, Video Nodes	Headend	MOE's, Node Status	Fiber, Radio, or Leased line to 56Kb Cable Modulator
Camera Control Demod	Video Nodes	Pan/Tilt/Zoom commands	Cable Demod to Fiber, Radio, or Leased Line Conversion
Node & CMS Command Demodulator	Detection, Video Nodes	Ramp Parameters Status Requests Node Configuration Commands	56Kb Cable Demod. To Fiber, Radio, or Leased Line Conversion
<i>Detection Station Node</i>			
DFOC Headend	Node Control Processor	Node Configuration Commands Self test Requests Time Synchronization Commands (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Volume, Occupancy, and Speed MOE's Node Status and Time Tags Node Off-line BIT Status (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Modulator
Loop Detector (or equivalent)	Node Control Processor	Loop Detect / No Detect Status	Wireline inside cabinet
<i>Video Node</i>			
DFOC Headend	Node Control Processor	Node Configuration Commands Self test Requests Time Synchronization Commands Camera Pan/Tilt/Zoom Commands Fiber Video Modulator On/Off (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Node Status and Time Tags Node Off-line BIT Status Camera/Modulator Command Acknowledgements (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Modulator

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Node Control Processor	Camera Control Logic	Pan, Tilt, and Zoom Commands	Wireless modem or wireline
Camera Control Logic	Node Control Processor	Camera subsystem status	Wireless modem or wireline
Camera Video	DFOC Headend	NTSC Video	Fiber, wireless, or Leased Line
<i>Video Node</i>			
DFOC Headend	Node Control Processor	Node Configuration Commands Self test Requests Time Synchronization Commands CMS or HAR Commands (Also Node Configuration Commands and self test requests to cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Demodulator
Node Control Processor	DFOC Headend	Node Status and Time Tags Node Off-line BIT Status CMS or HAR subsystem Acknowledgements and status (Also Node MOE's and Status for cross-roadway interfaced ramp controller)	Fiber, Radio, or Leased Line Modulator
CMS or HAR	Node Control Processor	CMS or HAR Control Commands	Wireless modem or wireline
Node Control Processor	CMS or HAR	CMS or HAR Subsystem Acknowledgements and status	Wireless modem or wireline

The following subsections define the format for data packets passed over the major interfaces in more detail. Note that camera control commands and CMS / HAR commands remain the same as they are now, but they will be “wrapped” in a packet with destination identified for routing over the selected communication system.

4.6.2.5.1 Headend to Remote Nodes

Commands to the remote nodes are already defined in the case of camera controls and CMS commands. It is intended that these be “wrapped” in some sort of digital envelope at the DFOC headend, which is then converted, if required, at the junction. Both CMS and CCTV camera controls carry their own node addressing information, which will have to be checked at each CMS / Video node. The general format is shown in Table 4-27 below:

Table 4- 27. CCTV Camera / CMS Commands

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization.
Data Identifier (Apply ONLY at Junction, Not Headend)	16 Nominal	Identifies the source of the data – Camera Controller or CMS/HAR Controller. This is applied ONLY at the I-95/75 junction by the Control Processor there since these commands arrive over different cable channels from the headend.
Camera Information or CMS Command	Predefined	Identifies the camera address (8 bits) and the function (16 bits) as documented already at the DFOC -or- identifies the CMS and its function as documented by Vultron.
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

Commands from the 3280MPS to the Detection, Ramp, and Video Nodes should all be formatted into a standard packet which is easily distinguished from camera control packets. The general format is shown in Table 4-28. Note that 16 bit words are defined for nearly all entries. This should be done to make the software easier and memory access faster, even when only 8 bits are used. 16 bits is also the granularity of some types of LAN controllers.

Table 4-28. 3280MPS Commands

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization. Should be different than Packet Header used for Camera Control.
Packet ID	16 Nominal	Identifies the function of this packet (for example Set Node Time)
Node Address	16 Nominal	Identifies the node to which the command is addressed. Provision should be made for an “all call” or “all nodes” address (such as all ones except the LS bit)
Packet Word Count	16	Number of significant 16-bit words following this entry, excluding the check word
Control Information	Varies	Each control item (e.g., date, hour, minute, second) needed for the particular control function
Check Word	16	16- bit add-and-left-rotate (discard carry) checksum over all data in the packet following the packet header and excluding the check word itself.
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

4.6.2.5.2 Remote Nodes to Headend

The format of the packets from the remote nodes to the headend are similar to those from the headend to the nodes. The data is different, of course. The node control processors will generate the packets. The junction control processor may strip off certain information in the case of the CMS responses to maintain compatibility with current formats. The Demux at the headend may also have to strip off some identifying information in order to

present the CMS Controller with the exact format of a response as it would get from a direct wireline modem hookup. Table 4-29 illustrates this.

Table 4-29. CMS Responses

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization (strip at headend demux)
Data Identifier	16 Nominal	Identifies the data as CMS / HAR Controller response. This must also be stripped by the headend demux after it is used to route the received data.
CMS Response	Predefined	Identifies the CMS response function as documented by Vultron
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization (junction node before sending to headend demux)

BIT responses and node MOE' s and status must bepacketized by the node controllers. The format is similar to that for the 3280 MPS headend commands, as shown in Table 4- 30.

Table 4-30. Node Controller Responses

Field	Number of Bits	Usage
Packet Header	16 Nominal	Identifies start of a new packet for synchronization. Should be different than Packet Header used for CMS Responses.
Packet ID	16 Nominal	Identifies the function of this packet (for example, Detector MOE Report)
Node Address	16 Nominal	Identifies the node from which the response is sent
Packet Word Count	16	Number of significant 16-bit words following this entry, excluding the check word
Control Information	Varies	Each item (e.g., volume, occupancy, speed, minute, second, node status) needed for the particular response
Check Word	16	16-bit add-and-left-rotate (discard carry) checksum over all data in the packet following the packet header and excluding the check word itself.
Packet Trailer	16 Nominal	Identifies end of a packet for synchronization

4.6.2.5.3 Remote Video to Headend

Video will be standard NTSC carried via fiber analog modulators, cable analog modulators, or wireless video modulators. Leased line will require CODEC equipment to digitize the video and send it with reduced (T1 carrier -- 1.5 MHz) bandwidth. Formats will depend on the CODEC vendor.

5.0 Engineering Design For Deployment

5.1 Deployment Cost Breakdown

Individual cost estimates for each ATMS/ATIS component are assessed to determine overall system deployment cost. Detailed cost estimate breakdowns are provided for each system component which include material and labor for the procurement and installation of such equipment. Table 5-1 summarize deployment system cost categorized by priority corridor. Estimated quantities for each deployed system component are included along with estimates of system integration and civil design.

Civil design engineering is to include one drawing per deployment site and is \$5200. These activities include site surveys for each specific site, civil design for system component installation, coordination with the local utility agency, and development of as-built drawings.

System integration (estimated at \$8155 per site) are conducted for each site and includes project management, loading of application software, integration of sub-system components (processors, communication, power, host system, etc.), system check out, and system test. Overall system cost per deployment mile calculates to \$749,992 compared to a national average of \$1 million per mile. This savings is due to the system integrator procurement method and application of new technologies and distributed processing architecture. Calculated system cost per mile only includes costs associated with ATMS/ATIS deployment of new corridor segments and does not include costs associated with upgrade instrumentation on the existing system.

The cost figures in Table 5-1 only reflect field deployed equipment costs. Additional non-recurring system design costs of \$528,986 and miscellaneous operations center equipment cost of \$106,354 must be added. System design activities include:

- System requirements analysis
- System requirements documentation
- Data flow analysis and diagrams
- System software design and code
- Field equipment software design and code
- Communications systems design
- Software documentation (data flow diagrams, program design language (PDL))
- System operation training

Table 5-2 categorizes the cost into labor and material. Labor content for the implementation portion of the project calculates to approximately 15.7 percent. Material content equates to approximately 67.2% while systems integration and civil design calculate to 17.1%. Data from the Los Angeles corridor project show operations and maintenance (O&M) costs associated with ATMS/ATIS deployment is approximately 10 percent of the deployment cost. A similar figure of 10 percent is used in this analysis.

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Table 5-1 System Deployment Cost Breakdown Summary

Corridor Segment	Length	# Ramp Control**	# Detector Stations	# of HARs	# of CCTV	# CCTV MUX.	# of CMSs	Deployment Cost	Sys. Integ./ Civil Design	Segment Total
I-75 (I-94 to 9 Mile Road)	7.4	12	44	1	8	3	2	\$4,474,276	\$934,850	\$5,409,126
I-75 (I-94 to I-375)	--	--	--	--	2	1	0	\$99,892	\$40,065	\$139,957
I-696 (US 24 to I-75)	10.2	12	62	2	10	3	3	\$6,059,155	\$1,228,660	\$7,287,815
I-94 (Wyoming to Moross)*	13.6	0	0	2	11	4	4	\$1,281,836	\$280,455	\$1,562,291
I-696 (I-75 to I-94)	9.8	16	60	2	10	4	6	\$6,688,506	\$1,308,790	\$7,997,296
I-696 (I-96 to US 24)	9.1	5	56	2	10	4	2	\$5,184,276	\$1,055,045	\$6,239,321
I-275 (M-14 to M-102)	7.5	11	46	2	8	3	4	\$4,977,997	\$988,270	\$5,966,257
I-96 (I-75 to I-275/M-14)	19.0	33	114	4	19	7	6	\$11,772,071	\$2,443,965	\$14,216,036
M-10 (Greenfield to I-696)	6.0	9	36	1	8	2	2	\$3,664,359	\$747,880	\$4,412,239
I-75 (9 Mile Road to Pontiac)	19.9	31	120	6	23	12	4	\$12,119,770	\$2,617,580	\$14,737,350
M-39 (I-75 to M-10)	10.5	28	64	2	11	4	8	\$7,884,065	\$1,562,535	\$9,446,600
M-10 (Greenfield to Jefferson)*	17.0	0	0	3	9	3	3	\$1,012,847	\$240,390	\$1,253,237
Davison (M-10 to I-75)	2.0	4	12	0	2	1	2	\$1,522,678	\$280,455	\$1,803,131
I-375	--	--	--	--	2	1	0	\$99,892	\$40,065	\$139,957
I-94 (Moross to M-19)	23.0	26	138	5	23	8	6	\$13,418,070	\$2,751,130	\$16,169,200
I-94 (Wyoming to I-275)	16.0	25	96	3	16	6	6	\$9,974,466	\$2,029,960	\$12,004,426
I-75 (I-96 to I-275)	29.9	44	180	6	30	10	6	\$17,543,792	\$3,685,960	\$21,229,772
I-275 (I-75 to I-96/M-14)	29.0	30	174	6	29	10	9	\$17,065,094	\$3,445,590	\$20,510,684
M-59 (BR-24 to M-53)	14.8	14	90	3	15	5	2	\$8,252,239	\$1,722,795	\$9,975,034
Subtotals	246.7	300	1292	50	244	91	75		\$27,404,460	\$160,499,739
Total Hardware		\$12,392,127	\$94,655,757	\$1,005,125	\$6,934,819	\$3,917,451	\$14,190,000	\$133,095,279		
Total Civil Engineering		\$1,560,000	\$6,718,400	\$260,000	\$1,268,800	\$473,200	\$390,000	\$10,670,400		
Total System Integration		\$2,446,500	\$10,536,260	\$407,750	\$1,989,820	\$742,105	\$611,625	\$16,734,060		
Total		\$16,398,627	\$111,910,417	\$1,672,875	\$10,193,439	\$5,132,175	\$15,191,625	\$160,499,739		
Total Deployment Cost Per Mile For New Freeway Segments Only								\$749,648		

* Existing instrumented system. Augmentation of functionality as required.

** Cost associated with ramp control only reflect additional equipment to detector stations since controllers at detector station sites perform dual functions

Table 5-1 System Deployment Cost Breakdown Summary

Corridor Segment	Material Total	Labor Total	Deployment Total	Sys. Integ./ Civil Design	Segment Total	Estimated Annual O & M
I-75 (I-94 to 9 Mile Road)	\$3,591,121	\$883,155	\$4,474,276	\$934,850	\$5,409,126	\$540,913
I-75 (I-94 to I-375)	\$77,411	\$22,481	\$99,892	\$40,065	\$139,957	\$13,996
I-696 (US 24 to I-75)	\$4,937,623	\$1,121,532	\$6,059,155	\$1,228,660	\$7,287,815	\$728,781
I-94 (Wyoming to Moross)*	\$1,073,521	\$208,315	\$1,281,836	\$280,455	\$1,562,291	\$156,229
I-696 (I-75 to I-94)	\$5,421,347	\$1,267,160	\$6,688,506	\$1,308,790	\$7,997,296	\$799,730
I-696 (I-96 to US 24)	\$4,299,705	\$884,571	\$5,184,276	\$1,055,045	\$6,239,321	\$623,932
I-275 (M-14 to M-102)	\$4,046,376	\$931,622	\$4,977,997	\$988,270	\$5,966,257	\$596,627
I-96 (I-75 to I-275/M-14)	\$9,439,256	\$2,332,816	\$11,772,071	\$2,443,965	\$14,216,036	\$1,421,604
M-10 (Greenfield to I-696)	\$2,958,712	\$705,648	\$3,664,359	\$747,880	\$4,412,239	\$441,224
I-75 (9 Mile Road to Pontiac)	\$9,740,229	\$2,379,541	\$12,119,770	\$2,617,580	\$14,737,350	\$1,473,735
M-39 (I-75 to M-10)	\$6,252,319	\$1,631,745	\$7,884,065	\$1,562,535	\$9,446,600	\$944,660
M-10 (Greenfield to Jefferson)*	\$849,480	\$163,366	\$1,012,847	\$240,390	\$1,253,237	\$125,324
Davison (M-10 to I-75)	\$1,231,433	\$291,243	\$1,522,678	\$280,455	\$1,803,131	\$180,313
I-375	\$77,411	\$22,481	\$99,892	\$40,065	\$139,957	\$13,996
I-94 (Moross to M-19)	\$10,936,713	\$2,481,357	\$13,418,070	\$2,751,130	\$16,169,200	\$1,616,920
I-94 (Wyoming to I-275)	\$8,048,958	\$1,925,507	\$9,974,466	\$2,029,960	\$12,004,426	\$1,200,443
I-75 (I-96 to I-275)	\$14,131,128	\$3,412,665	\$17,543,792	\$3,685,960	\$21,229,772	\$2,122,977
I-275 (I-75 to I-96/M-14)	\$13,965,216	\$3,099,878	\$17,065,094	\$3,445,590	\$20,510,684	\$2,051,068
M-59 (BR-24 to M-53)	\$6,746,799	\$1,505,440	\$8,252,239	\$1,722,795	\$9,975,034	\$997,503
Total	\$107,824,755	\$25,270,524	\$133,095,279	\$27,404,460	\$160,499,739	\$16,049,974

5.1.1 Traffic Detector Station

The mainline traffic detector station estimate is based on available machine vision sensors and associated processing and communications equipment. Table 5-3 show the itemized breakdown of components which are required. Items include both required material and labor associated with installation of the material. Mainline traffic detector stations also have the capability to support the additional functionality of ramp metering with minimal addition of hardware and modification of application software. The cost estimate for each mainline traffic detector station is \$73,263 which includes a 20 percent maintenance and protection of traffic cost.

Table 5-3. Mainline Detector Site Cost Estimate

Detector Station Only				
	Units	Unit Cost	Quantity	Total Cost
Trench & Backfill	LF	\$11. 83	100	\$1, 182. 50
F&I 3" PVC Conduit	LF	\$4. 73	100	\$473. 00
F&I Cabinet	EA	\$5, 084. 75	1	\$5, 084. 75
F&I Foundation	EA	\$946. 00	1	\$946. 00
F&I Controller	EA	\$9, 460. 00	1	\$9, 460. 00
F&I Detectors	EA	\$29, 562. 50	1	\$29, 562. 50
F&I Cameras	EA	\$2, 956. 25	1	\$2, 956. 25
F&I Mounting Pole	EA	\$4, 730. 00	1	\$4, 730. 00
F&I Pull Boxes	EA	\$1, 005. 13	1	\$1, 005. 13
Power Service	EA	\$2, 956. 25	1	\$2, 956. 25
F&I Radio Unit	EA	\$946. 00	1	\$946. 00
F&I Environ. Sensors	EA	\$236. 50	1	\$236. 50
F&I Antenna	EA	\$94. 60	1	\$94. 60
Coax Cable	LF	\$2. 37	400	\$946. 00
F&I Modem	EA	\$236. 50	1	\$236. 50
F&I TNC	EA	\$236. 50	1	\$236. 50
				\$61, 052. 48
Maintenance and Protection of Traffic	0. 20			\$12, 210. 50
				\$73, 262. 97

5.1.2 Traffic Detector Station / Ramp Controller

The detector station / ramp controller component includes the basic configuration of the mainline traffic detector station with additional hardware for ramp metering functions. An off-ramp detector (one inductive loop detector) is also included in the estimate. Additional signage, signal cables, stop bar striping, and meter signal head are some of the additional material included. Table 5-4 summarizes the cost estimate.

Table 5-4. Mainline Controller Site Cost Estimate

Detector Station & Ramp Controller				
	Units	Unit Cost	Quantity	Total Cost
Trench & Backfill	LF	\$11. 83	1, 040	\$12, 298. 00
Jacking	LF	\$59. 13	30	\$1, 773. 75
F&I 3" PVC Conduit	LF	\$4. 73	530	\$2, 506. 90
F&I 1" PVC Conduit	LF	\$3. 55	510	\$1, 809. 23
F&I 3" Steel Conduit	LF	\$29. 56	30	\$886. 88
F&I Cabinet	EA	\$5, 084. 75	1	\$5, 084. 75
F&I Foundation	EA	\$946. 00	1	\$946. 00
F&I Controller	EA	\$9, 460. 00	1	\$9, 460. 00
F&I Detectors	EA	\$29, 562. 50	1	\$29, 562. 50
F&I Cameras	EA	\$2, 956. 25	2	\$5, 912. 50
F&I Mounting Pole	EA	\$4, 730. 00	1	\$4, 730. 00
F&I Pull Boxes	EA	\$1, 005. 13	5	\$5, 025. 63
Loop Electronics	EA	\$147. 81	1	\$147. 81
Sawcut & Seal Loops	LF	\$11. 83	108	\$1, 277. 10
F&I Loop Wire	LF	\$1. 48	200	\$295. 63
F&I Lp Lead in Wire	LF	\$1. 48	1, 000	\$1, 478. 13
Signal	EA	\$2, 956. 25	1	\$2, 956. 25
Additional Signage	EA	\$1, 478. 13	1	\$1, 478. 13
Signal Cables	LF	\$2. 37	690	\$1, 631. 85
Pavement Stripe	LF	\$0. 59	30	\$17. 74
Power Service	EA	\$2, 956. 25	1	\$2, 956. 25
F&I Radio Unit	EA	\$946. 00	1	\$946. 00
F&I Eviron. Sensors	EA	\$236. 50	1	\$236. 50
F&I Antenna	EA	\$94. 60	1	\$94. 60
Coax Cable	LF	\$2. 37	630	\$1, 489. 95
F&I Modem	EA	\$236. 50	1	\$236. 50
F&I TNC	EA	\$236. 50	1	\$236. 50
				\$95, 475. 05
Maintenance and Protection of Traffic	0. 20			\$19, 095. 01
				\$114, 570. 06

5.1.3 Video Surveillance

Video surveillance sites include a dual camera (low light B/W and daylight color) system enclosed in a single housing. This system also includes an automatic camera switch over system which monitor ambient light conditions and switches over to the appropriate camera. Additionally, the video surveillance site cost estimate includes camera mounting hardware and pole. The cost of bringing in power service and associated conduit, trenching, and cable are included. Table 5-5 summarizes the cost estimate for video surveillance.

Table 5-5. Video Surveillance Site Cost Estimate

Camera Site				
	Units	Unit Cost	Quantity	Total Cost
F&I Camera & Housing	EA	\$7,095.00	1	\$7,095.00
F&I PTZ	EA	\$2,956.25	1	\$2,956.25
F&I Foundation	EA	\$946.00	1	\$946.00
F&I Mounting Pole	EA	\$4,730.00	1	\$4,730.00
Trench & Backfill	LF	\$11.83	175	\$2,069.38
F&I 2" Conduit	LF	\$4.14	250	\$1,034.69
Power Cable	LF	\$2.37	250	\$591.25
Power Service	EA	\$2,956.25	1	\$2,956.25
F&I PTZ Driver	EA	\$2,956.25	1	\$2,956.25
F&I Video Transmitter	EA	\$3,547.50	1	\$3,547.50
F&I 12 VDC P. S.	EA	\$94.60	1	\$94.60
F&I 24 VAC P. S.	EA	\$94.60	1	\$94.60
Coax Cable	LF	\$2.37	25	\$59.13
F&I Pole Mount	EA	\$118.25	1	\$118.25
				\$28,421.39

5.1.4 Video Multiplexer / Concentrator

The video multiplexer / concentrator site is similar to the video surveillance site. This system, however, deploys video receivers capable of receiving 4 to 5 video signals and multiplexes video signals. Signals are multiplexed or switched (cost of equipment is similar) remotely and transmits reduced number of video channels back to the MTC. Associated cable, transmitters, receivers, and power supply are included in the estimate. Table 5-6 shows the cost breakdown for the multiplexer / concentrator site.

Table 5-6. Video Multiplexer / Concentrator Site Cost Estimate

Video Multiplexor / Concentrator Site				
	Units	Unit Cost	Quantity	Total Cost
F&I Foundation	EA	\$946.00	1	\$946.00
F&I Mounting Pole	EA	\$4,730.00	1	\$4,730.00
Trench & Backfill	LF	\$11.83	175	\$2,069.38
F&I 2" Conduit	LF	\$4.14	250	\$1,034.69
Power Cable	LF	\$2.37	250	\$591.25
Power Service	EA	\$2,956.25	1	\$2,956.25
F&I Video Receiver	EA	\$4,138.75	1	\$16,555.00
F&I Video Transmitter	EA	\$3,547.50	1	\$3,547.50
F&I 12 VDC P. S.	EA	\$94.60	5	\$473.00
F&I 24 VAC P. S.	EA	\$94.60	1	\$94.60
F&I Multiplexer	EA	\$1,182.50	1	\$1,182.50
F&I Control Xmitter	EA	\$1,773.75	4	\$7,095.00
F&I Control Interface	EA	\$827.75	1	\$827.75
Coax Cable	LF	\$2.37	150	\$354.75
F&I Pole Mount	EA	\$118.25	5	\$591.25
				\$43,048.91

5.1.5 Highway Advisory Radio

Highway advisory radio cost estimates include a solar powered unit mounted on a standard utility pole. The HAR equipment installation primarily includes cost associated with vendor installation and associated hardware. Table 5-7 shows the cost breakdown.

Table 5-7. Highway Advisory Radio Site Cost Estimate

HAR Sites				
	Units	Unit Cost	Quantity	Total Cost
F&I Mounting Pole	EA	\$532.13	1	\$532.13
F&I HAR	EA	\$19,570.38	1	\$19,570.38
				<u>\$20,102.51</u>

5.1.6 Changeable Message Sign

Associated changeable message sign costs include a worst case scenario where a separate mounting structure is required. The CMS cost includes the changeable sign cost, enclosure, and associated labor to install the unit. Mounting structure cost include the structure itself, labor to install, and protection/maintenance of traffic. Table 5-8 lists the cost components of CMS sites.

Table 5-8. Changeable Message Sign Site Cost Estimate

CMS Sites				
	Units	Unit Cost	Quantity	Total Cost
F&I Mounting Structure	EA	\$59,125.00	1	\$59,125.00
F&I CMS	EA	\$130,075.00	1	\$130,075.00
				<u>\$189,200.00</u>

5.1.7 Traffic Operations Center (TOC)

Equipment associated with ATMS/ATIS deployment in the operations center include communications, video surveillance, and computer processing equipment. Table 5-9 show the breakdown of cost estimates for each component. The communications equipment is to be used to receive process data from field controllers. The same unit can also be used to communicate with changeable message signs. Video surveillance equipment support reception of video signals. This equipment also includes an additional camera control unit, power supplies, receiver, and associated receiver mounting hardware. An assumption is made that digital and video data will be received on top of the State building across the street from the MTC. The computer equipment estimate is basically the cost of an additional serial interface board to the Concurrent 3280MPS mainframe computer. The cost also includes an additional personal computer to provide any data distribution within the MTC. This computer will be used to provide a transparent interface to other TOC equipment where processed digital data is required.

Table 5- 9. TOC Equipment Cost Estimate

Digital Communications Equipment				
	Units	Unit Cost	Quantity	Total Cost
F&I Radio Unit	EA	\$1,182.50	2	\$12,365.00
F&I Power Supply	EA	\$236.50	1	\$236.50
F&I Antenna	EA	\$354.75	1	\$354.75
Coax Cable	LF	\$2.37	1,500	\$3,547.50
F&I Modem	EA	\$236.50	1	\$236.50
F&I TNC	EA	\$236.50	1	\$236.50
F&I Antenna Mast	EA	\$3,547.50	1	\$3,547.50
				\$10,524.25
Video Communications Equipment				
	Unit	Unit Cost	Quantity	Total Cost
F&I Video Receiver	EA	\$4,138.75	1	\$16,555.00
F&I 12 VDC P.S.	EA	\$94.60	5	\$473.00
F&I 24 VAC P.S.	EA	\$94.60	3	\$283.80
F&I Multiplexer	EA	\$1,182.50	1	\$1,182.50
F&I Control Transmitter	EA	\$1,773.75	4	\$7,095.00
F&I Control Interface	EA	\$827.75	2	\$1,655.50
Coax Cables	LF	\$2.37	3,000	\$7,095.00
F&I Pole Mount	EA	\$118.25	5	\$591.25
PTZ Controller	EA	\$1,773.75	1	\$1,773.75
				\$36,704.80
Computer Equipment				
	Units	Unit Cost	Quantity	Total Cost
Serial I/O & PC	EA	\$59,125.00	1	\$59,125.00

5.2 Priority Corridor Benefit/Cost Analysis

Estimating potential benefits from ATMS/ATIS deployment provides the means to determine if implementation of traffic management programs are cost effective. Various methods of applying traffic management techniques are available to reduce the number of incidents, travel delay times, vehicle emissions, fuel usage, and even increase traffic flow. Demand in metropolitan Detroit continue to increase as shown in Table 5-10 which describe annual vehicle miles in the region.

Table 5-10. Metropolitan Detroit Annual Vehicle-Miles

Corridor Segment	1990 ADT	1990 Annual Vehicle-Miles	2015 ADT	2015 Annual Vehicle-Miles
I-75 (I-94 to 9 Mile Road)	144,985	391,604,485	152,214	411,130,014
I-75 (I-94 to I-375)	147,616	53,879,840	151,991	55,476,715
I-696 (US 24 to I-75)	145,362	541,182,726	165,375	615,691,125
I-94 (Wyoming to Moross)*	142,349	706,620,436	135,019	670,234,316
I-696 (I-75 to I-94)	156,765	560,748,405	165,144	590,720,088
I-696 (I-96 to US 24)	139,956	464,863,854	192,436	639,176,174
I-275 (M-14 to M-102)	124,565	340,996,688	176,602	483,447,975
I-96 (I-75 to I-275/M-14)	126,784	879,247,040	137,588	954,172,780
M-10 (Greenfield to I-696)	125,516	274,880,040	117,415	257,138,850
I-75 (9 Mile Road to Pontiac)	119,997	871,598,210	143,581	1,042,900,594
M-39 (I-75 to M-10)	106,101	406,632,083	111,896	428,841,420
M-10 (Greenfield to Jefferson)*	94,424	585,900,920	95,288	591,262,040
Davison (M-10 to I-75)	77,044	56,242,120	85,220	62,210,600
I-375*	67,522	24,645,530	82,731	30,196,815
I-94 (Moross to M-19)	99,385	834,337,075	124,584	1,045,882,680
I-94 (Wyoming to I-275)	91,555	534,681,200	107,279	626,509,360
I-75 (I-96 to I-275)	90,624	989,025,024	113,846	1,242,458,321
I-275 (I-75 to I-96/M-14)	58,478	618,989,630	79,921	845,963,785
M-59 (BR-24 to M-53)	48,972	264,546,744	67,833	366,433,866
Total	2,108,000	9,401 (in millions)	2,405,963	10,960 (in millions)

* Existing instrumented system

Three categories of traffic management techniques are studied to determine benefit/cost ratios for each priority corridor. Freeway incident detection / management, motorist information systems, and effects of ramp metering are evaluated.

Freeway Incident Detection and Management Systems

A freeway incident detection and management system consist of a combination of various traffic management components. Most obvious are ATMS/ATIS infrastructure components such as mainline traffic detectors, changeable message signs, highway advisory radios, video surveillance, communications system, ramp metering, and a central computing platform to manage the system. The ability to remotely monitor traffic conditions throughout the freeway system is one of the primary contributors in motorist benefits. The means to detect and verify incidents quickly can significantly reduce travel delay times. The reduction in travel delay time in turn reduces fuel usage and vehicle emissions. Additionally, the means to disseminate incident information provides motorist opportunities to modify their route to avoid the congestion. The “system” operating in an integrated manner can provide the highest benefit/cost ratios.

Regions surrounding metropolitan Detroit have benefited from additional sources of incident detection. Motorist participation in incident detection in the greater Detroit

region has been accomplished through the use of cellular phones and citizen band radios. Detection / reporting times have been on the average of 2-3 minutes.

Motorist Information Systems

Dissemination of traffic congestion information to motorist is an important component of a traffic management system. Changeable message signs, highway advisory radios, and/or in-vehicle navigation and information systems are examples of such information systems. The ITE Toolbox for Alleviating: Traffic Congestion indicates that in the 14 years of experience in the Los Angeles area, Caltrans has seen several beneficial features by implementing changeable message signs. These features include:

- Changeable message signs which inform motorist of up coming congestion spots provided earlier opportunities to reduce the speeds of vehicles approaching a queue, which resulted in reduced secondary accidents and related delays. Deceleration rates tend to be less severe into congested spots.
- Early warnings and signing increased off-ramp diversion which were greater than one half mile upstream from incidents.
- Early warning of lane blockages induced drivers to change lanes away from affected lanes.
- Signs upstream from major freeway-to-freeway interchanges are highly efficient in reducing travel delay times.

Highway advisory radio is another method of disseminating congestion and incident information to motorist. Radio messages are transmitted within a local region informing motorists of downstream traffic conditions. This technique has been used on corridors approaching regional airports to advise on parking availability and recently airline flight schedules. Highway advisory radios have been used in several areas as portable transmitters near freeway construction sites and mobile incident management teams. However, areas such as Los Angeles and Seattle have been deploying highway advisory radios as a permanent system component.

The San Francisco Bay area is planning to deploy several highway advisory radios as part of an area-wide traffic management system. Transmitters will be located in intervals of approximately 4 miles in the 216 mile network to allow continuous coverage. This motorist information technique is relatively inexpensive when compared to other system elements and can provide more timely information to motorist.

Ramp Metering

Ramp metering has proven to be one of the most cost-effective techniques for improving traffic flow on freeways. Although additional delay may be seen by the ramp traffic, mainline freeway capacities are maintained and the overall efficiency is improved. High occupancy bypass lanes on metered ramps have also been used to provide incentives for carpooling.

Ramp metering alone cannot provide the ultimate benefit/cost ratio to an ATMS/ATIS system. However, it is a key factor in providing an overall cost effective system solution. A FHWA survey of seven ramp metering systems in the United States and Canada revealed significant benefits from ramp meter, although not in the same magnitude of a total system implementation.

Average highway speeds shown an increase of 29 percent after installing a ramp metering system. When including ramp delays, average freeway speeds still increased 20 percent and decreased travel time 16.5 percent. Data collected from the FLOW system in Seattle indicated that deployment of ramp metering increased highway volumes from 12 to 40 percent. An additional benefit seen from ramp meter deployment was a decrease in ramp-mainline merging accidents. Reductions of 20 to 58 percent have been achieved through improved merging operations.

Various levels of ramp metering have been implemented across the country. Two ramp meter locations measured increases of 1.6% in volume and 114% in speed (27 to 59.9 mph) at one location and increases of 11.6% in volume with 64% increase speed (35.2 to 58.0 mph) at another. These two sites were metered to simply improve the conditions at specific problem merge areas. A few states have implemented ramp metering system wide, notably California and Texas. Average speed increases of 30 percent commonly result in this implementation technique. During the 14 years of system operation, a 16 percent increase in average peak hour freeway speeds (37 to 43 mph) and a 25 percent increase in average peak period volumes has been seen.

Real-time adaptive ramp metering systems has produced results that are generally 5 to 10 percent greater than those of pretimed ramp metering. In Los Angeles, a 100 percent increase in average speed (25 to 52 mph), a 20 percent decrease in ramp wait times, a 3 percent increase in freeway volumes have been measured. Although this is probably a best case example, it points to the greater flexibility of adaptive ramp control and potential impacts.

5.2.1 Analysis Techniques and Assumptions

Two separate analyses are conducted to assess benefit/cost ratios for recurring congestion and congestion created by incidents. A 1986 FHWA study revealed that a 30 percent reduction in recurring congestion travel delay times can be realized from implementation of an incident detection and management system. Further studies have shown that in the Los Angeles area reported approximately 50-65 percent reduction in incident induced travel delay times. For this analysis, the following travel time delay reductions due to incident detection and management systems are assumed:

Recurring congestion: 30%
Incident congestion: 40%

In both analysis models, average vehicle fuel efficiencies are assumed to be:

City: 15 miles per gallon of fuel (<35 mph)
Highway: 25 miles per gallon of fuel (>35 mph)

The cost of fuel is \$1.20 per gallon for calendar years 1994 and 2015.

Average speed during the delay period:

Recurring congestion: 12.5 mph (unstable flow)
Incident congestion: 10 mph (unstable flow)

The average speed is a function of vehicle volumes. Volume is inversely proportional to speed. For example when volume increases, the speed decreases. A representative average queue length of 7.5 miles is used. During times of congestion, the average queue length is assumed to be the same, however flow rates differ.

It is assumed that only 20 percent of the average daily traffic (ADT) will encounter peak time congestion. It is also assumed that only 20 percent of the average daily traffic will encounter time delaying incidents.

5.2.2 Analysis

Analyses are conducted for two separate scenarios; 1) normal congestion and 2) incident congestion. The following sections describe detailed analysis techniques used in calculating benefits derived from implementing an incident detection and traffic management system as a whole using mainline detectors, video surveillance, ramp metering, and various modes of information dissemination (CMS, HAR, public radio, etc.).

5.2.2.1 Travel Delay Time

Travel Delay Savings Due to Recurring Congestion

Assuming the average queue length of 7.5 miles, the travel delay time can be calculated by using the following equation:

$$\begin{aligned} \text{Travel Delay Time} &= (\text{average queue length} / \text{average delay velocity}) \times 60 \\ &= (7.5 \text{ miles} / 12.5 \text{ mph}) \times 60 \text{ min/hour} \end{aligned}$$

$$\text{Travel Delay Time} = 36 \text{ minutes}$$

Implementing an incident detection and traffic management system produces a 30 percent reduction in delayed travel time (similar to the Los Angeles corridor study). This calculates to:

$$\text{Travel Delay Time} = 36 \text{ minutes} \times (1 - .30)$$

Travel Delay Time = 25.2 minutes

Using the two travel delay times of 36 minutes (no ATMS/ATIS implementation) and 25.2 minutes (with ATMS/ATIS implementation), travel delay time benefits can be determined by using the following equation:

Annual Travel Delay Time (hrs) = $ADT \times 0.2 \times 36 \text{ minutes} \times 365 \text{ days} / 60$
(no ATMS/ATIS implementation)

Annual Travel Delay Time (hrs) = $ADT \times 0.2 \times 25.2 \text{ minutes} \times 365 \text{ days} / 60$
(with ATMS/ATIS implementation)

Benefits and savings can be calculated by taking the difference of the two results. Table 5-11 shows the breakdown of benefits in travel delay time savings for each corridor segment. Recorded 1990 average daily traffic counts are used as a baseline. Furthermore, projected calendar year 2015 ADTs are used to project potential travel delay time savings.

Table 5-11. Travel Delay Time Savings Under Recurring Congestion Conditions

Corridor Segment	Total Delay (hrs) (No Controls)	Total Delay (hrs) (With Controls)	Total Annual Delay Savings (hrs)	Total 2015 Delay (hrs) (No Controls)	Total 2015 Delay (hrs) (With Controls)	Total 2015 Annual Delay Savings (hrs)
I-75 (I-94 to 9 Mile Road)	6,350,343	4,445,240	1,905,103	6,666,973	4,666,881	2,000,092
I-696 (US 24 to I-75)	6,366,856	4,456,799	1,910,057	7,243,425	5,070,398	2,173,028
I-696 (I-75 to I-94)	6,866,307	4,806,415	2,059,892	7,233,307	5,063,315	2,169,992
I-696 (I-96 to US 24)	6,130,073	4,291,051	1,839,022	8,428,697	5,900,088	2,528,609
I-275 (M-14 to M-102)	5,455,947	3,819,163	1,636,784	7,735,168	5,414,617	2,320,550
I-96 (I-75 to I-275/M-14)	5,553,139	3,887,197	1,665,942	6,026,354	4,218,448	1,807,906
M-10 (Greenfield to I-696)	5,497,601	3,848,321	1,649,280	5,142,777	3,599,944	1,542,833
I-75 (9 Mile Road to Pontiac)	5,255,869	3,679,108	1,576,761	6,288,848	4,402,193	1,886,654
M-39 (I-75 to M-10)	4,647,224	3,253,057	1,394,167	4,901,045	3,430,731	1,470,313
Davison (M-10 to I-75)	3,374,527	2,362,169	1,012,358	3,732,636	2,612,845	1,119,791
I-94 (Moross to M-19)	4,353,063	3,047,144	1,305,919	5,456,779	3,819,745	1,637,034
I-94 (Wyoming to I-275)	4,010,109	2,807,076	1,203,033	4,698,820	3,289,174	1,409,646
I-75 (I-96 to I-275)	3,969,331	2,778,532	1,190,799	4,986,455	3,490,518	1,495,936
I-275 (I-75 to I-96/M-14)	2,561,336	1,792,935	768,401	3,500,540	2,450,378	1,050,162
M-59 (BR-24 to M-53)	2,144,974	1,501,482	643,492	2,971,085	2,079,760	891,326
Total	72,536,698	50,775,689	21,761,009	85,012,909	59,509,036	25,503,873

Travel Delay Savings Due to Incident Congestion

Assuming the average queue length of 7.5 miles, the travel delay time can be calculated by using the following equation:

$$\begin{aligned} \text{Travel Delay Time} &= (\text{average queue length} / \text{average delay velocity}) \times 60 \\ &= (7.5 \text{ miles} / 10 \text{ mph}) \times 60 \text{ min/hour} = 45 \text{ minutes} \end{aligned}$$

Historical figures from the Los Angeles system show that implementing an incident detection and traffic management system can produce a 50-65 percent reduction in delayed travel time. In this analysis, a conservative figure of 40 percent savings is assumed. This calculates to:

$$\text{Travel Delay Time} = 45 \text{ minutes} \times (1 - .40) = 27 \text{ minutes}$$

It is assumed that only 20 percent of the ADT encounters the overall total number of incidents as posted in calendar year 1990 and that the number of incident will be unchanged during the deployment year. Table 5-12 shows ADT values for each corridor segment and their associated number of reported incidents in 1990. (NOTE: Approximately 70% of actual incidents are actually reported.)

Table 5-12. Corridor Segment ADT and 1990 Recorded Incidents

Corridor Segment	1990 ADT	1990 Recorded Incidents
I-75 (I-94 to 9 Mile Road)	144,985	779
I-75 (I-94 to I-375)	147,616	148
I-696 (US 24 to I-75)	145,362	329
I-94 (Wyoming to Moross)*	142,349	1,496
I-696 (I-75 to I-94)	156,765	224
I-696 (I-96 to US 24)	139,956	191
I-275 (M-14 to M-102)	124,565	144
I-96 (I-75 to I-275/M-14)	126,784	649
M-10 (Greenfield to I-696)	125,516	182
I-75 (9 Mile Road to Pontiac)	119,997	350
M-39 (I-75 to M-10)	106,101	751
M-10 (Greenfield to Jefferson)*	94,424	695
Davison (M-10 to I-75)	77,044	157
I-375	67,522	56
I-94 (Moross to M-19)	99,385	184
I-94 (Wyoming to I-275)	91,555	284
I-75 (I-96 to I-275)	90,624	451
I-275 (I-75 to I-96/M-14)	58,478	140
M-59 (BR-24 to M-53)	48,972	19
Total	2,108,000	7,229

* Existing ATMS system coverage

Using the two travel delay times of 45 minutes (no ATMS/ATIS implementation) and 27 minutes (with ATMS/ATIS implementation), travel delay time benefits can be determined by using the following equation:

$$\text{Annual Travel Delay Time (hrs) (no ATMS/ATIS implementation)} = \text{ADT} \times 0.2 \times 45 \text{ minutes} \times (\# \text{ of incidents}) / 60$$

$$\text{Annual Travel Delay Time (hrs) (with ATMS/ATIS implementation)} = \text{ADT} \times 0.2 \times 27 \text{ minutes} \times (\# \text{ of incidents}) / 60$$

Benefits and savings can be calculated by taking the difference of the two results. Table 5-13 shows the breakdown of benefits in travel delay time savings for each corridor segment induced by incident congestion. Recorded 1990 average daily traffic counts are used as a baseline.

Table 5-13. Travel Delay Time Savings Under Incident Congestion Conditions

Corridor Segment	Total Delay (hrs) (No Controls)	Total Delay (hrs) (With Controls)	Total Annual Delay Savings (hrs)
I-75 (I-94 to 9 Mile Road)	16,941,497	10,164,898	6,779,599
I-696 (US 24 to I-75)	7,173,615	4,304,169	2,869,446
I-696 (I-75 to I-94)	5,267,304	3,160,382	2,106,922
I-696 (I-96 to US 24)	4,009,739	2,405,844	1,603,896
I-275 (M-14 to M-102)	2,690,604	1,614,362	1,076,242
I-96 (I-75 to I-275/M-14)	12,342,422	7,405,453	4,936,969
M-10 (Greenfield to I-696)	3,426,587	2,055,952	1,370,635
I-75 (9 Mile Road to Pontiac)	6,299,843	3,779,906	2,519,937
M-39 (I-75 to M-10)	11,952,278	7,171,367	4,780,911
Davison (M-10 to I-75)	1,814,386	1,088,632	725,754
I-94 (Moross to M-19)	2,743,026	1,645,816	1,097,210
I-94 (Wyoming to I-275)	3,900,243	2,340,146	1,560,097
I-75 (I-96 to I-275)	6,130,714	3,678,428	2,452,285
I-275 (I-75 to I-96/M-14)	1,228,038	736,823	491,215
M-59 (BR-24 to M-53)	139,570	83,742	55,828
Total	86,059,866	51,635,919	34,423,946

5.2.2.2 Fuel Usage

Fuel Savings Due to Recurring Congestion

Further calculations can be made to calculate average vehicle velocities upon implementing the ATMS/ATIS system.

Average speed to travel 7.5 mi. = (average queue length / travel delay time) x 60

Average speed to travel 7.5 mi. = (7.5 miles / 25.2 minutes) x 60

Average speed to travel 7.5 miles = 17.9 mph

Using the established fuel efficiency ratings at 17.9 mph, fuel use can be calculated:

Fuel use = queue length / fuel efficiency

Fuel use = 7.5 miles / 15 mpg

Fuel use = 0.5 gallons

Assuming that the fuel burn rate at 12.5 mph and 17.9 mph are the same, a fuel rate factor can be calculated as follows:

RF = Fuel Use / Delay Travel Time

RF = 0.5 gal. / 25.2 min.

RF = 0.020 gal. / min.

Using the calculated rate factor RF, the amount of fuel use can be calculated for the for conditions in which ATMS/ATIS are not implemented

Fuel use = 36 minutes x 0.020 gal./min

Fuel use = 0.72 gallons

Total fuel use under recurring congestion conditions can be calculated using the following equation:

Total fuel use (no ATMS/ATIS implementation) = ADT x 0.2 x 0.72 x 365 gals.

Total fuel use (with ATMS/ATIS implementation) = ADT x 0.2 x 0.50 x 365 gals.

Table 5-14 shows the fuel savings in gallons using the above calculations as applied to each corridor segment.

Savings in fuel cost can be calculated by multiplying the fuel cost per gallon (\$1.20) by the number of gallons used annually. Table 5-15 uses annual fuel saving values from Table 5-14 to determine the approximate fuel savings in dollars.

Table 5-14. Annual Fuel Use Under Recurring Congestion

Corridor Segment	Total Fuel Use (gal) (No Controls)	Total Fuel Use (gal) (With Controls)	Total Annual Fuel Savings (gal)	Total 2015 Fuel Use (gal) (No Controls)	Total 2015 Fuel Use (gal) (With Controls)	Total 2015 Annual Fuel Savings (gal)
I-75 (I-94 to 9 Mile Road)	7,620,412	5,291,953	2,328,459	8,000,368	5,555,811	2,444,557
I-696 (US 24 to I-75)	7,640,227	5,305,713	2,334,514	8,692,110	6,036,188	2,655,922
I-696 (I-75 to I-94)	8,239,568	5,721,923	2,517,646	8,679,969	6,027,756	2,652,213
I-696 (I-96 to US 24)	7,356,087	5,108,394	2,247,693	10,114,436	7,023,914	3,090,522
I-275 (M-14 to M-102)	6,547,136	4,546,623	2,000,514	9,282,201	6,445,978	2,836,223
I-96 (I-75 to I-275/M-14)	6,663,767	4,627,616	2,036,151	7,231,625	5,021,962	2,209,663
M-10 (Greenfield to I-696)	6,597,121	4,581,334	2,015,787	6,171,332	4,285,648	1,885,684
I-75 (9 Mile Road to Pontiac)	6,307,042	4,379,891	1,927,152	7,546,617	5,240,707	2,305,910
M-39 (I-75 to M-10)	5,576,669	3,872,687	1,703,982	5,881,254	4,084,204	1,797,050
Davison (M-10 to I-75)	4,049,433	2,812,106	1,237,327	4,479,163	3,110,530	1,368,633
I-94 (Moross to M-19)	5,223,676	3,627,553	1,596,123	6,548,135	4,547,316	2,000,819
I-94 (Wyoming to I-275)	4,812,131	3,341,758	1,470,373	5,638,584	3,915,684	1,722,900
I-75 (I-96 to I-275)	4,763,197	3,307,776	1,455,421	5,983,746	4,155,379	1,828,367
I-275 (I-75 to I-96/M-14)	3,073,604	2,134,447	939,157	4,200,648	2,917,117	1,283,531
M-59 (BR-24 to M-53)	2,573,968	1,787,478	786,490	3,565,302	2,475,905	1,089,397
Total	87,044,038	60,447,249	26,596,789	102,015,491	70,844,091	31,171,400

Table 5-15 Annual Fuel Cost Savings Under Recurring Congestion Conditions

Corridor Segment	Total Fuel Use (\$) (No Controls)	Total Fuel Use (\$) (With Controls)	Total Annual Fuel Savings (\$)	Total 2015 Fuel Use (\$) (No Controls)	Total 2015 Fuel Use (\$) (With Controls)	Total 2015 Annual Fuel Savings (\$)
I-75 (I-94 to 9 Mile Road)	\$9,144,494	\$6,350,343	\$2,794,151	\$9,600,441	\$6,666,973	\$2,933,468
I-696 (US 24 to I-75)	\$9,168,272	\$6,366,856	\$2,801,416	\$10,430,532	\$7,243,425	\$3,187,107
I-696 (I-75 to I-94)	\$9,887,482	\$6,866,307	\$3,021,175	\$10,415,962	\$7,233,307	\$3,182,655
I-696 (I-96 to US 24)	\$8,827,305	\$6,130,073	\$2,697,232	\$12,137,323	\$8,428,697	\$3,708,627
I-275 (M-14 to M-102)	\$7,856,564	\$5,455,947	\$2,400,617	\$11,138,641	\$7,735,168	\$3,403,474
I-96 (I-75 to I-275/M-14)	\$7,996,520	\$5,553,139	\$2,443,381	\$8,677,950	\$6,026,354	\$2,651,596
M-10 (Greenfield to I-696)	\$7,916,545	\$5,497,601	\$2,418,944	\$7,405,599	\$5,142,777	\$2,262,822
I-75 (9 Mile Road to Pontiac)	\$7,568,451	\$5,255,869	\$2,312,582	\$9,055,941	\$6,288,848	\$2,767,093
M-39 (I-75 to M-10)	\$6,692,002	\$4,647,224	\$2,044,778	\$7,057,505	\$4,901,045	\$2,156,460
Davison (M-10 to I-75)	\$4,859,319	\$3,374,527	\$1,484,792	\$5,374,996	\$3,732,636	\$1,642,360
I-94 (Moross to M-19)	\$6,268,411	\$4,353,063	\$1,915,348	\$7,857,762	\$5,456,779	\$2,400,983
I-94 (Wyoming to I-275)	\$5,774,557	\$4,010,109	\$1,764,448	\$6,766,301	\$4,698,820	\$2,067,481
I-75 (I-96 to I-275)	\$5,715,837	\$3,969,331	\$1,746,506	\$7,180,495	\$4,986,455	\$2,194,040
I-275 (I-75 to I-96/M-14)	\$3,688,324	\$2,561,336	\$1,126,968	\$5,040,777	\$3,500,540	\$1,540,238
M-59 (BR-24 to M-53)	\$3,088,762	\$2,144,974	\$943,788	\$4,278,363	\$2,971,085	\$1,307,278
Total	\$104,452,845	\$72,536,698	\$31,916,147	\$122,418,589	\$85,012,909	\$37,405,680

Fuel Savings Due to Incident Congestion

Further calculations can be made to calculate average vehicle velocities upon implementing the ATMS/ATIS system

$$\text{Average speed to travel 7.5 mi.} = (\text{average queue length} / \text{travel delay time}) \times 60$$

$$\text{Average speed to travel 7.5 mi.} = (7.5 \text{ miles} / 27 \text{ minutes}) \times 60$$

$$\text{Average speed to travel 7.5 miles} = 16.6 \text{ mph}$$

Using the established fuel efficiency ratings at 16.6 mph, fuel use can be calculated:

$$\text{Fuel use} = \text{queue length} / \text{fuel efficiency}$$

$$\text{Fuel use} = 7.5 \text{ miles} / 15 \text{ mpg}$$

$$\text{Fuel use} = 0.5 \text{ gallons}$$

Assuming that the fuel burn rate at 10 mph and 16.6 mph are the same, a fuel rate factor can be calculated as follows:

$$R_F = \text{Fuel Use} / \text{Delay Travel Time}$$

$$R_F = 0.5 \text{ gal.} / 27 \text{ min.}$$

$$R_F = 0.019 \text{ gal.} / \text{min.}$$

Using the calculated rate factor R_F , the amount of fuel use can be calculated for the conditions in which ATMS/ATIS are not implemented.

$$\text{Fuel use} = 45 \text{ minutes} \times 0.019 \text{ gal./min}$$

$$\text{Fuel use} = 0.86 \text{ gallons}$$

Total fuel use under recurring congestion conditions can be calculated using the following equation:

$$\text{Total fuel use (no ATMS/ATIS implementation)} = \text{ADT} \times 0.2 \times 0.86 \times \# \text{ of incidents}$$

$$\text{Total fuel use (with ATMS/ATIS implementation)} = \text{ADT} \times 0.2 \times 0.50 \times \# \text{ of incidents}$$

Table 5-16 shows the fuel savings in gallons using the above calculations as applied to each corridor segment.

Table 5-16. Annual Fuel Use under Incident Congestion

Corridor Segment	Total Fuel Use (gal) (No Controls)	Total Fuel Use (gal) (With Controls)	Total Annual Fuel Savings (gal)
I-75 (I-94 to 9 Mile Road)	19,426,250	11,294,332	8,131,919
I-696 (US 24 to I-75)	8,225,745	4,782,410	3,443,335
I-696 (I-75 to I-94)	6,039,842	3,511,536	2,528,306
I-696 (I-96 to US 24)	4,597,835	2,673,160	1,924,675
I-275 (M-14 to M-102)	3,085,226	1,793,736	1,291,490
I-96 (I-75 to I-275/M-14)	14,152,644	8,228,282	5,924,363
M-10 (Greenfield to I-696)	3,929,153	2,284,391	1,644,762
I-75 (9 Mile Road to Pontiac)	7,223,819	4,199,895	3,023,924
M-39 (I-75 to M-10)	13,705,278	7,968,185	5,737,093
Davison (M-10 to I-75)	2,080,496	1,209,591	870,905
I-94 (Moross to M-19)	3,145,336	1,828,684	1,316,652
I-94 (Wyoming to I-275)	4,472,279	2,600,162	1,872,117
I-75 (I-96 to I-275)	7,029,885	4,087,142	2,942,743
I-275 (I-75 to I-96/M-14)	1,408,150	818,692	589,458
M-59 (BR-24 to M-53)	160,040	93,047	66,994
Total	98,681,979	57,373,244	41,308,736

Savings in fuel cost can be calculated by multiplying the fuel cost per gallon (\$1.20) by the number of gallons used annually. Table 5-17 uses annual fuel saving values from Table 5-16 to determine the approximate fuel savings in dollars.

Table 5-17. Annual Fuel Cost Savings Under Incident Congestion Conditions

Corridor Segment	Total Fuel Use (\$) (No Controls)	Total Fuel Use (\$) (With Controls)	Total Annual Fuel Savings (\$)
I-75 (I-94 to 9 Mile Road)	\$23,311,500	\$13,553,198	\$9,758,302
I-696 (US 24 to I-75)	\$9,870,894	\$5,738,892	\$4,132,002
I-696 (I-75 to I-94)	\$7,247,810	\$4,213,843	\$3,033,967
I-696 (I-96 to US 24)	\$5,517,401	\$3,207,792	\$2,309,610
I-275 (M-14 to M-102)	\$3,702,271	\$2,152,483	\$1,549,788
I-96 (I-75 to I-275/M-14)	\$16,983,173	\$9,873,938	\$7,109,235
M-10 (Greenfield to I-696)	\$4,714,983	\$2,741,269	\$1,973,714
I-75 (9 Mile Road to Pontiac)	\$8,668,583	\$5,039,874	\$3,628,709
M-39 (I-75 to M-10)	\$16,446,334	\$9,561,822	\$6,884,512
Davison (M-10 to I-75)	\$2,496,595	\$1,451,509	\$1,045,086
I-94 (Moross to M-19)	\$3,774,404	\$2,194,421	\$1,579,983
I-94 (Wyoming to I-275)	\$5,366,734	\$3,120,194	\$2,246,540
I-75 (I-96 to I-275)	\$8,435,862	\$4,904,571	\$3,531,291
I-275 (I-75 to I-96/M-14)	\$1,689,780	\$982,430	\$707,350
M-59 (BR-24 to M-53)	\$192,049	\$111,656	\$80,392
Total	\$118,418,375	\$68,847,893	\$49,570,483

5.2.2.3 Loss of Productivity

Loss of productivity can also be directly related to travel delay time induced by recurring and incident congestion. Every hour spent on congested highways can directly influence loss of wages, and production of material goods and services. In 1972, an approximate loss of \$3.00 per congested hours was reported in the metropolitan Detroit area. Factoring cost of money increase, economic inflation, and increase in wages, a \$10.00 per congested hour is used in determining loss of productivity dollars. *The Traffic Engineering Handbook* of 1992 also validates this figure. Table 5-18 and 5-19 show the dollars associated in loss of productivity for recurring and incident congestion, respectively.

Table 5-18. Productivity Loss Due To Recurring Congestion

Corridor Segment	Total 1990 Prod Loss (\$) (No Controls)	Total 1990 Prod Loss (\$) (With Controls)	Total 1990 Prod Savings (\$)	Total 2015 Prod Loss (\$) (No Controls)	Total 2015 Prod Loss (\$) (With Controls)	Total 2015 Prod Savings (\$)
I-75 (I-94 to 9 Mile Road)	\$ 63,503,430	\$ 44,452,401	\$ 19,051,029	\$ 66,669,732	\$ 46,668,812	\$ 20,000,920
I-696 (US 24 to I-75)	\$ 63,668,556	\$ 44,567,989	\$ 19,100,567	\$ 72,434,250	\$ 50,703,975	\$ 21,730,275
I-696 (I-75 to I-94)	\$ 68,663,070	\$ 48,064,149	\$ 20,598,921	\$ 72,333,072	\$ 50,633,150	\$ 21,699,922
I-696 (I-96 to US 24)	\$ 61,300,728	\$ 42,910,510	\$ 18,390,218	\$ 84,286,968	\$ 59,000,878	\$ 25,286,090
I-275 (M-14 to M-102)	\$ 54,559,470	\$ 38,191,629	\$ 16,367,841	\$ 77,351,676	\$ 54,146,173	\$ 23,205,503
I-96 (I-75 to I-275/M-14)	\$ 55,531,392	\$ 38,871,974	\$ 16,659,418	\$ 60,263,544	\$ 42,184,481	\$ 18,079,063
M-10 (Greenfield to I-696)	\$ 54,976,008	\$ 38,483,206	\$ 16,492,802	\$ 51,427,770	\$ 35,999,439	\$ 15,428,331
I-75 (9 Mile Road to Pontiac)	\$ 52,558,686	\$ 36,791,080	\$ 15,767,606	\$ 62,888,478	\$ 44,021,935	\$ 18,866,543
M-39 (I-75 to M-10)	\$ 46,472,238	\$ 32,530,567	\$ 13,941,671	\$ 49,010,448	\$ 34,307,314	\$ 14,703,134
Davison (M-10 to I-75)	\$ 33,745,272	\$ 23,621,690	\$ 10,123,582	\$ 37,326,360	\$ 26,128,452	\$ 11,197,908
I-94 (Moross to M-19)	\$ 43,530,630	\$ 30,471,441	\$ 13,059,189	\$ 54,567,792	\$ 38,197,454	\$ 16,370,338
I-94 (Wyoming to I-275)	\$ 40,101,090	\$ 28,070,763	\$ 12,030,327	\$ 46,988,202	\$ 32,891,741	\$ 14,096,461
I-75 (I-96 to I-275)	\$ 39,693,312	\$ 27,785,318	\$ 11,907,994	\$ 49,864,548	\$ 34,905,184	\$ 14,959,364
I-275 (I-75 to I-96/M-14)	\$ 25,613,364	\$ 17,929,355	\$ 7,684,009	\$ 35,005,398	\$ 24,503,779	\$ 10,501,619
M-59 (BR-24 to M-53)	\$ 21,449,736	\$ 15,014,815	\$ 6,434,921	\$ 29,710,854	\$ 20,797,598	\$ 8,913,256
Total	\$ 725,366,982	\$ 507,756,887	\$ 217,610,095	\$ 850,129,092	\$ 595,090,364	\$ 255,038,728

Table 5-19. Productivity Loss Due to Incident Congestion

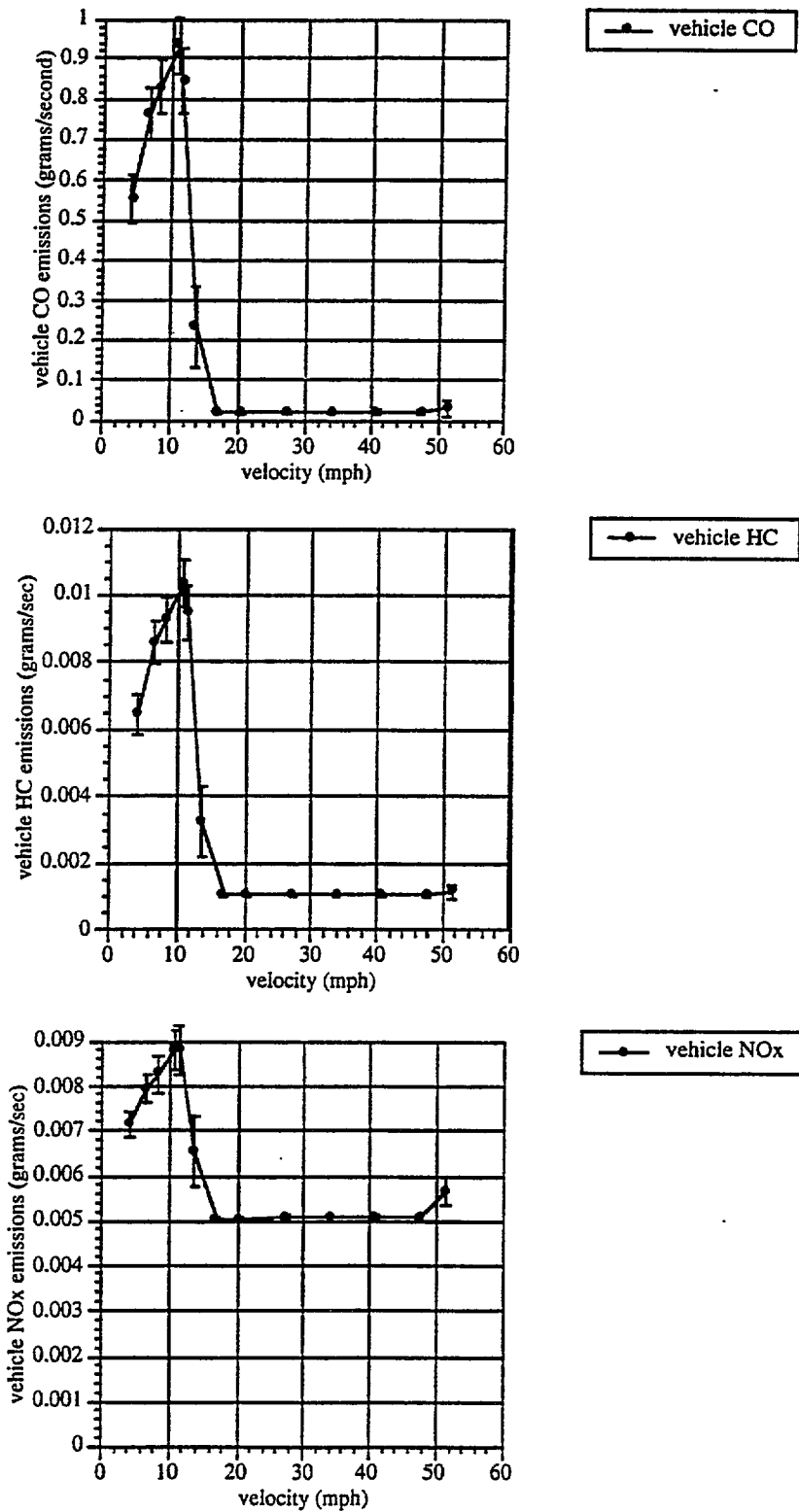
Corridor Segment	Total Prod Loss (\$) (No Controls)	Total Prod Loss (\$) (With Controls)	Total Prod Savings (\$)
I-75 (I-94 to 9 Mile Road)	\$ 169,414,973	\$ 101,648,984	\$ 67,765,989
I-696 (US 24 to I-75)	\$ 71,736,147	\$ 43,041,688	\$ 28,694,459
I-696 (I-75 to I-94)	\$ 52,673,040	\$ 31,603,824	\$ 21,069,216
I-696 (I-96 to US 24)	\$ 40,097,394	\$ 24,058,436	\$ 16,038,958
I-275 (M-14 to M-102)	\$ 26,906,040	\$ 16,143,624	\$ 10,762,416
I-96 (I-75 to I-275/M-14)	\$ 123,424,224	\$ 74,054,534	\$ 49,369,690
M-10 (Greenfield to I-696)	\$ 34,265,868	\$ 20,559,521	\$ 13,706,347
I-75 (9 Mile Road to Pontiac)	\$ 62,998,425	\$ 37,799,055	\$ 25,199,370
M-39 (I-75 to M-10)	\$ 119,522,777	\$ 71,713,666	\$ 47,809,111
Davison (M-10 to I-75)	\$ 18,143,862	\$ 10,886,317	\$ 7,257,545
I-94 (Moross to M-19)	\$ 27,430,260	\$ 16,458,156	\$ 10,972,104
I-94 (Wyoming to I-275)	\$ 39,002,430	\$ 23,401,458	\$ 15,600,972
I-75 (I-96 to I-275)	\$ 61,307,136	\$ 36,784,282	\$ 24,522,854
I-275 (I-75 to I-96/M-14)	\$ 12,280,380	\$ 7,368,228	\$ 4,912,152
M-59 (BR-24 to M-53)	\$ 1,395,702	\$ 837,421	\$ 558,281
Total	\$ 860,598,657	\$ 516,359,194	\$ 344,239,463

5.2.2.4 Reduction of Emissions

Vehicle exhaust emissions can be reduced due to the reduction of recurring and incident congestion. Research which was conducted by Partners for Advanced Transit and Highways (PATH) and the South Coast Air Quality Management District shows that vehicle emits various amounts of CO, HC, and NOx emissions. Figure 5-1 describe the amounts of emissions versus velocities generated by vehicles on the average. From the graphs, the following emission rates were extrapolated:

Emission	Recurring Congestion	Incident Congestion
CO	0.8 grams / sec	0.9 grams / sec
HC	0.009 grams / sec	0.1 grams / sec
Nox	0.008 grams / sec	0.0085 grams / sec

Table 5-20 and 5-21 show reductions in vehicle emissions per corridor,



SOURCE: University of California, Riverside

Figure 5-1. Velocity vs. Emissions Curves

MDOT Early Deployment of ATMS/ATIS

Table 5-20. Emission Reduction Under Recurring Congestion Conditions

Corridor Segment	Total CO Emissions Savings (tons)	Total HC Emissions Savings (tons)	Total NOx Emissions Savings (tons)	Total 2015 CO Emissions Savings (tons)	Total 2015 HC Emissions Savings (tons)	Total 2015 NOx Emissions Savings (tons)
I-75 (I-94 to 9 Mile Road)	6,048	68	60	6,350	71	63
I-696 (US 24 to I-75)	6,064	68	61	6,899	78	69
I-696 (I-75 to I-94)	6,539	74	65	6,889	78	69
I-696 (I-96 to US 24)	5,838	66	58	8,027	90	80
I-275 (M-14 to M-102)	5,196	58	52	7,367	83	74
I-96 (I-75 to I-275/M-14)	5,289	59	53	5,739	65	57
M-10 (Greenfield to I-696)	5,236	59	52	4,898	55	49
I-75 (9 Mile Road to Pontiac)	5,006	56	50	5,989	67	60
M-39 (I-75 to M-10)	4,426	50	44	4,668	53	47
Davison (M-10 to I-75)	3,214	36	32	3,555	40	36
I-94 (Moross to M-19)	4,146	47	41	5,197	58	52
I-94 (Wyoming to I-275)	3,819	43	38	4,475	50	45
I-75 (I-96 to I-275)	3,780	43	38	4,749	53	47
I-275 (I-75 to I-96/M-14)	2,439	27	24	3,334	38	33
M-59 (BR-24 to M-53)	2,043	23	20	2,830	32	28
Total	69,084	777	691	80,966	911	810

Table 5-21. Emission Reduction Under Incident Congestion Conditions

Corridor Segment	Total CO Emissions Savings (tons)	Total HC Emissions Savings (tons)	Total NOx Emissions Savings (tons)
I-75 (I-94 to 9 Mile Road)	24,203	269	229
I-696 (US 24 to I-75)	10,248	114	97
I-696 (I-75 to I-94)	7,525	84	71
I-696 (I-96 to US 24)	5,728	64	54
I-275 (M-14 to M-102)	3,844	43	36
I-96 (I-75 to I-275/M-14)	17,632	196	167
M-10 (Greenfield to I-696)	4,895	54	46
I-75 (9 Mile Road to Pontiac)	9,000	100	85
M-39 (I-75 to M-10)	17,075	190	161
Davison (M-10 to I-75)	2,592	29	24
I-94 (Moross to M-19)	3,919	44	37
I-94 (Wyoming to I-275)	5,572	62	53
I-75 (I-96 to I-275)	8,758	97	83
I-275 (I-75 to I-96/M-14)	1,754	19	17
M-59 (BR-24 to M-53)	199	2	2
Total	122,945	1,366	1,161

5.2.3 Benefit/Cost Summary

Benefit/cost ratios of ATMS/ATIS implementation for each priority corridor are tabulated and shown in Table 5-22. It is assumed that benefit/cost analyses were performed on existing instrumented corridors of I-75 (I-94 to I-365), I-94 (Wyoming to Moross), M-10 (Greenfield to Jefferson), and I-375. Additional ATMS/ATIS instrumentation such as CMS's and video surveillance components will only enhance incident detection, verification, and traffic management functions; and improve benefit/cost ratios of these corridors.

Values listed in Table 5-22 use cost factors based on costs associated with current implementation and projected calendar year 2015 benefits were not used. ATMS/ATIS deployment cost only included costs associated design, procurement, installation, integration, and test of field equipment. Overall system benefit/cost reflect a 4.1:1 ratio with several individual corridors having greater than a 5:1 benefit/cost ratio. Current implementation of the two least priority corridors, I-275 (I-75 to I-96/M-14) and M-59 (BR-24 to M-53), show benefit/cost ratios of less than one (0.8:1 and 0.9:1, respectively). However, projecting to calendar year 2015, these ratios increase to 0.9:1 and 1.1:1, respectively. These ratios have been calculated using reported incident figures. Studies have shown that up to 30 percent of incidents go unreported. If these figures are included, the benefit/cost ratio for these two segments will be over 1:1. These two

corridor segments should remain with the overall ATMS/ATIS project since benefit/cost ratios of adjacent corridors can only be improved.

A 1986 FHWA study revealed that associated benefit/cost ratios realized from ATMS/ATIS implementation average 4:1 in urban areas. The overall 4.1:1 ratio of the metropolitan Detroit system fall within the study average. Corridor segment benefit/cost ratios of 5:1 or 6:1 have been seen based on over ten years' experience in the Los Angeles system Benefit/cost ratios of over 5:1

have been calculated for nine of the fifteen evaluated corridors. Based on comparison, implementation of the metropolitan Detroit system returns comparable benefits to regional residents and businesses.

Table 5-22. Benefit/Cost Ratio of Priority Corridors

Corridor Segment	Recurring Congestion Fuel Savings	Incident Congestion Fuel Savings	Recurring Productivity Loss Savings	Incident Productivity Loss Savings	Total Savings (Dollars)	ATMS/ATIS Deployment Cost	Overall Benefit/Cost Ratio
I-75 (I-94 to 9 Mile Road)	\$2,794,151	\$9,758,302	\$ 19,051,029	\$ 67,765,989	\$ 99,369,471	\$ 5,409,126	10.4
I-696 (US 24 to I-75)	\$2,801,416	\$4,132,002	\$ 19,100,567	\$ 28,694,459	\$ 54,728,444	\$ 7,287,815	7.6
I-696 (I-75 to I-94)	\$3,021,175	\$3,033,967	\$ 20,598,921	\$ 21,069,216	\$ 47,723,279	\$ 7,997,296	6.0
I-696 (I-96 to US 24)	\$2,697,232	\$2,309,610	\$ 18,390,218	\$ 16,038,958	\$ 39,436,017	\$ 6,239,321	6.4
I-275 (M-14 to M-102)	\$2,400,617	\$1,549,788	\$ 16,367,841	\$ 10,762,416	\$ 31,080,662	\$ 5,966,267	5.3
I-96 (I-75 to I-275/M-14)	\$2,443,381	\$7,109,235	\$ 16,659,418	\$ 49,369,690	\$ 75,581,724	\$ 14,216,036	5.4
M-10 (Greenfield to I-696)	\$2,418,944	\$1,973,714	\$ 16,492,802	\$ 13,706,347	\$ 34,591,808	\$ 4,412,239	7.9
I-75 (9 Mile Road to Pontiac)	\$2,312,582	\$3,628,709	\$ 15,767,606	\$ 25,199,370	\$ 46,908,267	\$ 14,737,350	3.2
M-39 (I-75 to M-10)	\$2,044,778	\$6,884,512	\$ 13,941,671	\$ 47,809,111	\$ 70,680,072	\$ 9,446,600	7.5
Davison (M-10 to I-75)	\$1,484,792	\$1,045,086	\$ 10,123,582	\$ 7,257,545	\$ 19,911,005	\$ 1,803,131	11.1
I-94 (Moross to M-19)	\$1,915,348	\$1,579,983	\$ 13,059,189	\$ 10,972,104	\$ 27,526,624	\$ 16,169,200	1.8
I-94 (Wyoming to I-275)	\$1,764,448	\$2,246,540	\$ 12,030,327	\$ 15,600,972	\$ 31,642,287	\$ 12,004,426	2.7
I-75 (I-96 to I-275)	\$1,746,506	\$3,531,291	\$ 11,907,994	\$ 24,522,854	\$ 41,708,645	\$ 21,229,772	2.0
I-275 (I-75 to I-96/M-14)	\$1,126,968	\$707,350	\$ 7,684,009	\$ 4,912,152	\$ 14,430,499	\$ 20,510,684	0.6
M-59 (BR-24 to M-53)	\$943,788	\$80,392	\$ 6,434,921	\$ 558,281	\$ 8,017,382	\$ 9,975,034	0.9
Total	\$31,916,147	\$49,570,483	\$ 217,610,095	\$ 344,239,463	\$ 643,336,187	\$ 157,404,298	4.1

5.3 Alternative Contracting Procedures

Alternative contracting procedures for the deployment of the ATMS/ATIS system are reviewed to identify the most beneficial approach in terms of cost, schedule, and risk. All phases of deployment, which include system design, component procurement, installation, test, and warranty, are reviewed.

As new technologies and implementation approaches emerge, traditional contracting methods may not be appropriate due to the complexity level and integration efforts of advanced traffic management and traveler information systems.

5.3.1 Identification of Alternative Contracting Procedures

Three types of contracting procedures were reviewed to assess their applicability to the deployment of advanced technology components and distributed system architecture. These contracting methods are:

- Design / Build
- Design / Bid/Build
- Design / Build / Install / Integrate (Systems Integrator)

Design / Build

The design/build approach most closely represents the approach used for the original SCANDI procurement. In this approach, a single contract is awarded for both the design and construction phase. Because of project staging, it may be that different contractors will implement the various stages. In order to be assured that the specifications are acceptable and being met, it is likely that a separate consultant may be engaged to review: 1) plans and specifications, 2) test plans, 3) documentation to perform construction inspection and supervision (the state may elect to do the majority of this activity with their won manpower), 4) witness tests and 5) recommend system acceptance.

Because the contractor must develop engineering plans, specifications, software and data bases, it may be required to technically pre-qualify prospective contractors. If this is not done, MDOTs resources could be wasted reviewing and assessing proposals from contractors who cannot comply with the complexity of these tasks. Figure 5-2 represents a typical process flow of the design / build approach.

Design /Bid / Build

The design / bid / build approach can be considered as the traditional approach. Under this approach, a consultant develops plans and specifications which are then let for advertising. A separate contractor would furnish and install the system, and provide software. During the construction phase, the consultant would provide services similar to those described previously for the design/build option. Figure 5-3 shows the process flow of the design / bid / build approach. This technique, which has probably been used for the largest number of traffic system procurements, is between the design/build approach and the systems integrator approach.

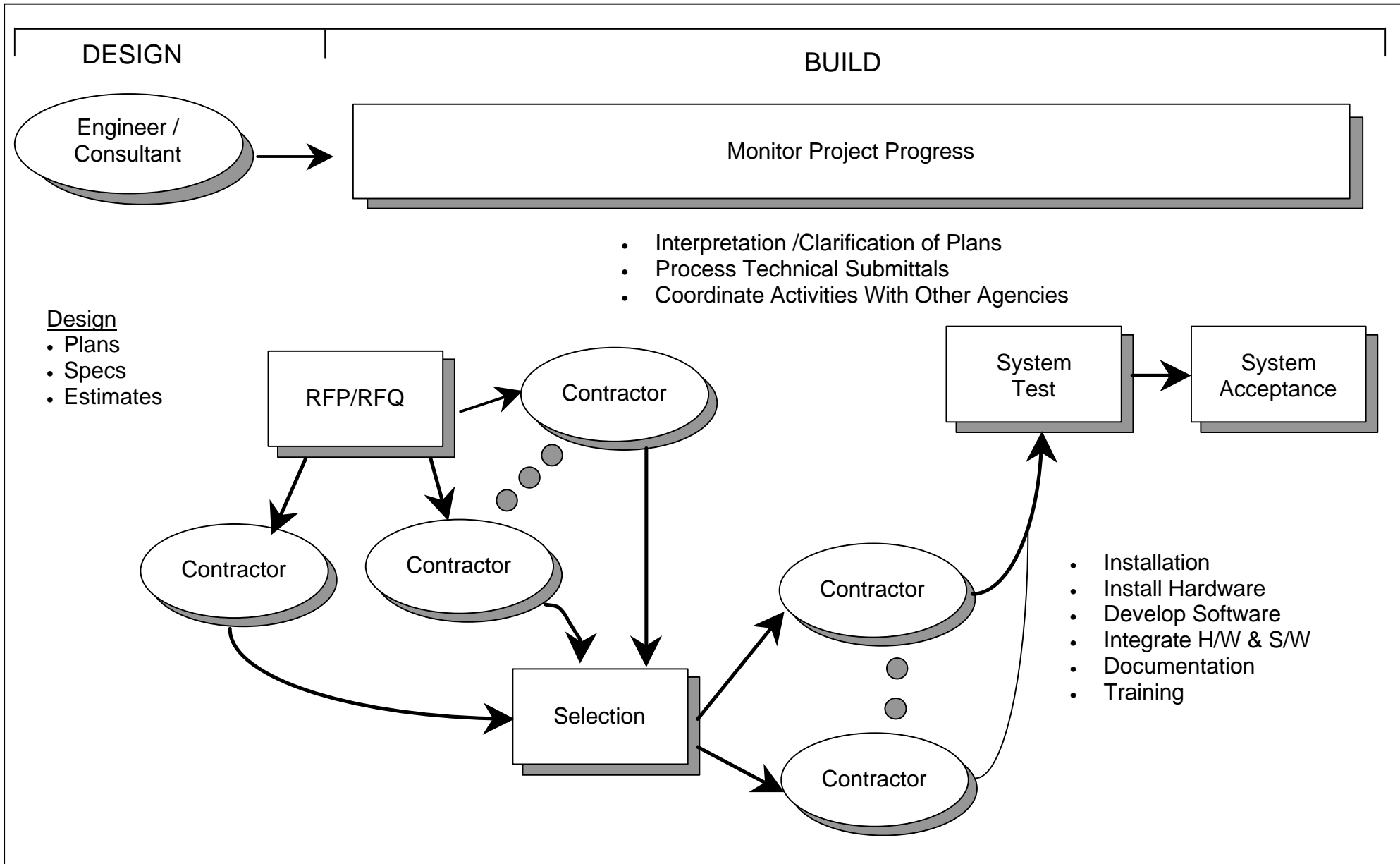


Figure 5-2. Design Build Process Flow

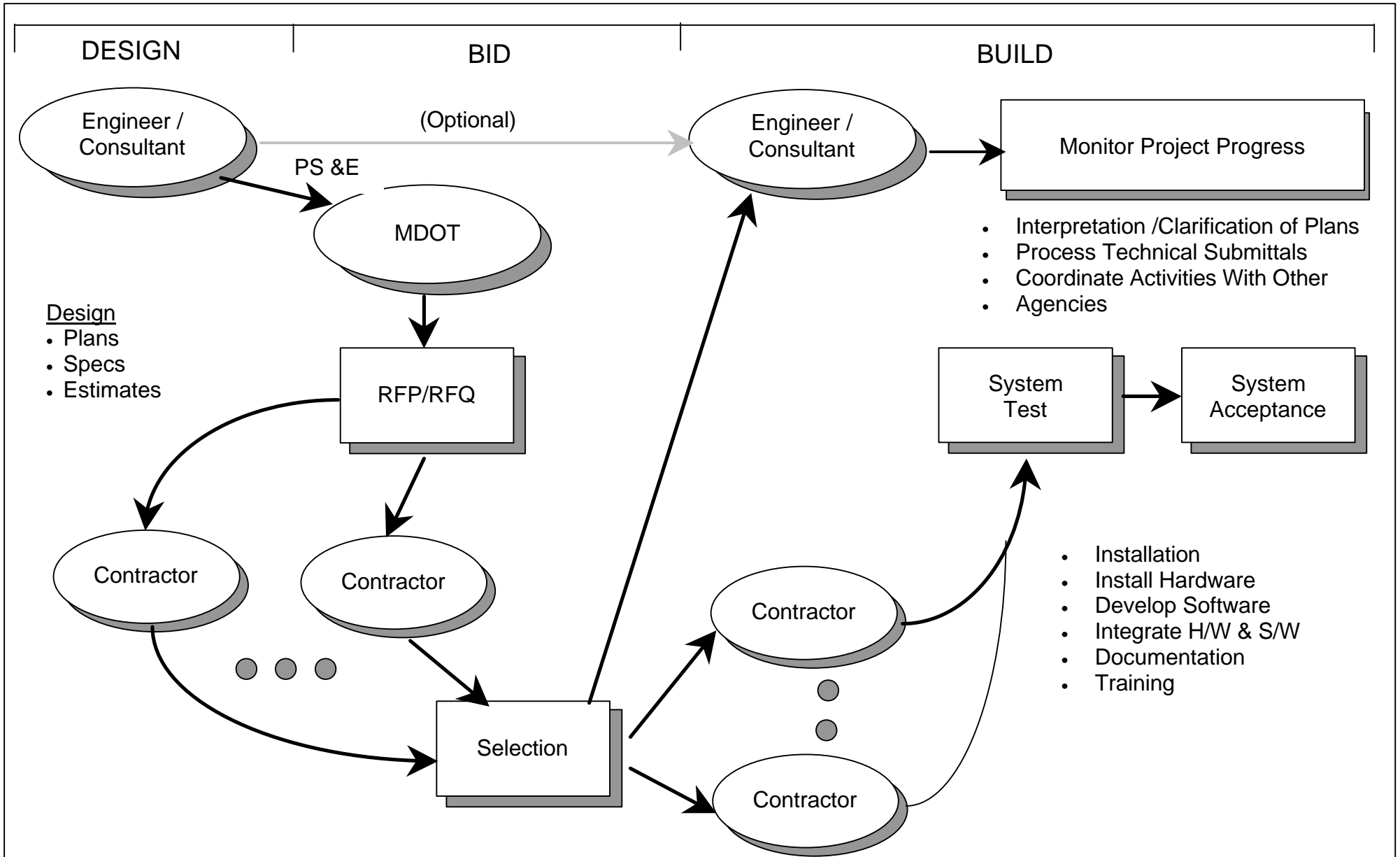


Figure 5-3. Design / Bid / Build Process Flow

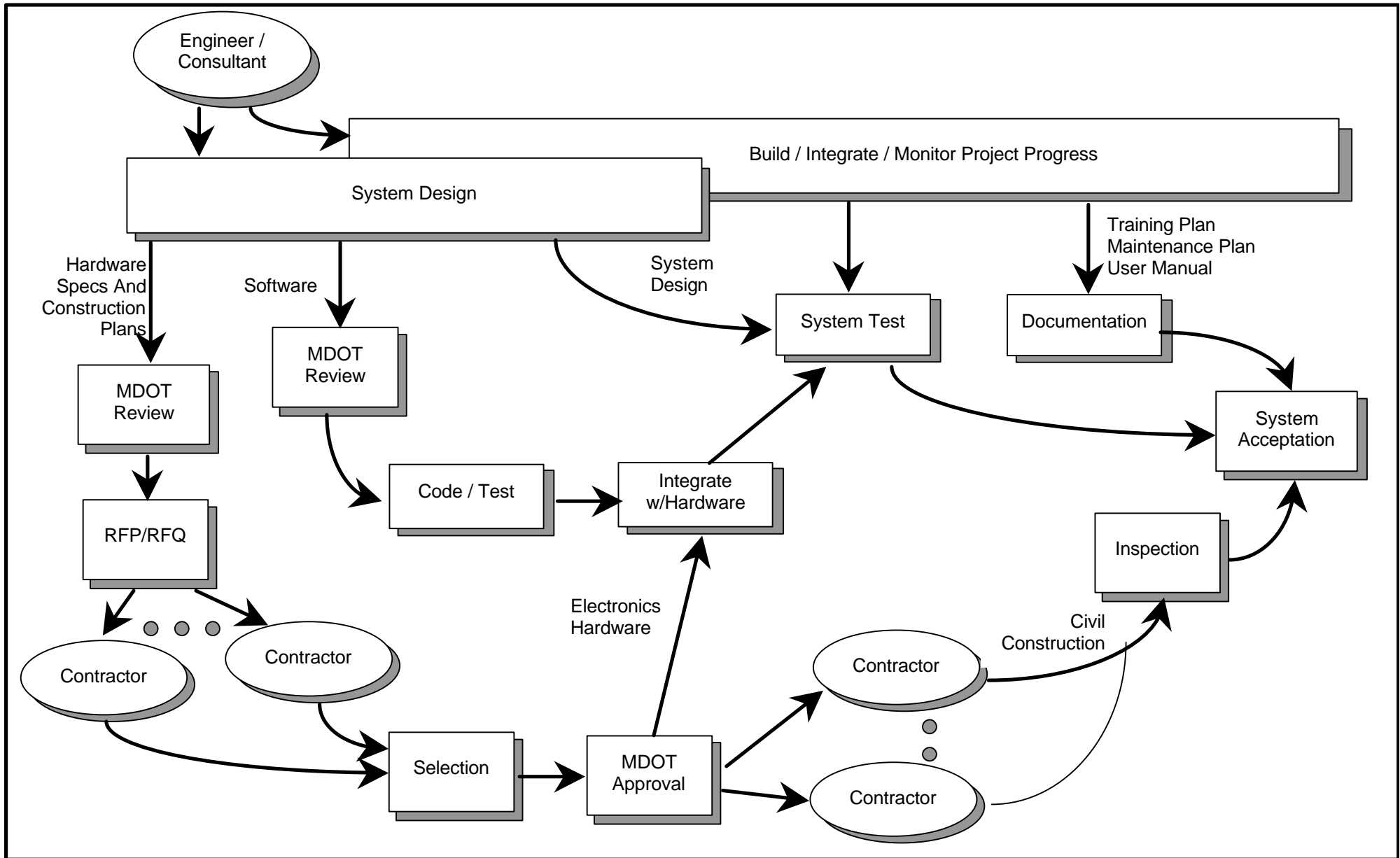


Figure 5-4. Design / Build / Install / Integrate (Systems Integrator) Process Flow

Design / Build / Install / Integrate (Systems Integrator)

The design/build/install/integrate or systems integrator approach is similar in nature to the design/build approach. This approach relies on a system integrator to provide the client a turnkey system in which the system integrator is responsible for all aspects of system design, system component procurement, installation, and most important, system integration. Figure 5-4 shows the detailed process of the systems integrator approach.

This approach allows client involvement in the overall process by allowing client approval prior to major hardware procurement and subcontracting. The system integrator has the overall responsibility to provide an operational system and is responsible for all work performed, including work performed by other subcontractors.

5.3.2 Comparison of Alternative Procedures

All three alternative contracting procedures have unique advantages, and conversely, disadvantages. Various facets of ATMS/ATIS deployment contracting are reviewed. Deployment schedule, material procurement, and performance responsibility factors are assessed.

Deployment Schedule

Each alternative differs significantly in overall performance time frame. The traditional design/bid/build approach requires a minimum of three phases. After the design phase is complete, the client reviews design-procurement specifications and releases the specifications for bid. A predetermined period of time is allocated to allow responses from qualified bidders to be returned. Once responses are received, bids are reviewed and an award is given to a successful bidder. After contracting documents are finalized, the build phase can begin.

The design/build approach allows one contract to be let to the design consultant. As specifications are completed by the consultant, the bidding process similar to the traditional design/bid/build begins. This process somewhat reduces the period between the design and bid phase, however, the overall process still operates in a serial manner.

The system integrator approach differs in a way which allows incremental design specifications to be let while other parts of the system are being designed. For example, once preliminary site surveys have been conducted, certain build activities such as facility power installation, controller cabinet foundation installation, and video surveillance pole installation can commence. This approach also allows certain system components such as video surveillance equipment to be installed and integrated prior to mainline detector stations. Other components which do not physically require support from communications and data processing infrastructures (i.e. cellular phone based HAR's) can also be deployed before other ATMS/ATIS system components. The actual deployment time frame can significantly be reduced.

Material Procurement

Both design/build and design/bid/build require full participation from the client to procure deployed material. These approaches require that the client manage bid and procurement processes to the point where full time personnel resources are required to evaluate outgoing bid packages, evaluate incoming bids, conduct bid evaluation, and execute bid awards. The design/bid/build approach however has an advantage which allows selected deployment activities to be incrementally funded by only allowing certain bid packages to be let.

The system integrator approach primarily relies upon the prime system integrator to manage material and service procurement activities. A minimum procurement threshold can be established to allow client review prior to procurement. In such cases, recommendations are made by the system integrator and procurement cycle continues upon client approval. This process keeps the client in concert with the progress of procurement activities while maintaining a role in system deployment.

Performance Responsibility

Responsibility of system operations can be a key factor in creating a successful deployment program. Design/build and design/bid/build approaches do not have a single participating party responsible for overall system performance. In both cases, the design consultant is normally retained to consult the client at times where specification clarification is needed. However, the system integration and proper operation of the system are not part of the design consultant's obligations.

The system integrator approach requires the system integrator to integrate, test, and be responsible for overall system operation and performance. The system integrator must also be significantly experienced in integrating various components which are designed at different technology levels. System level software, which may require custom development, also requires in-depth knowledge of system requirements, operations, and have data fusion experience. System integrator activities generally include incremental design reviews which enable the client to be abreast of all phases of system design and deployment,

5.3.3 Recommendation

It is recommended that a design/build/install/integrate (system integrator) procurement approach be used for the design and implementation of ATMS/ATIS technologies. There are significant advantages in executing this procurement approach. They are:

- The system integrator is fully responsible for system deployment and operation.
- Delays due to selecting a separate design and build consultants are eliminated.
- Provides significant reduction in project schedule.
- Material and service procurement handled by the system integrator.
- Competitiveness is still maintained in which significant amount of the contract value is competitively awarded

- Client risk is considerably reduced while maintaining client involvement in the design, bidding, installation, and integration phases.

5.4 Prototype Request For Proposal

A prototype request for proposal (RFP) is included in Appendix V. This prototype RFP will enable MDOT to migrate from the system infrastructure study phase to the design/deployment phase. The prototype RFP is written to allow various levels of implementation to be deployed on selected priority corridors. Sections which require specific corridor details are identified to allow the basic prototype RFP to be used for different ATMS/ATIS deployment procurements.

5.5 Design Plans For Implementation

System deployment planning enables preliminary planning to be accomplished. Details of functional requirements, which are addressed in Section 4, were used in determining implementation approaches. Design plans for implementation takes these functional requirements and deploys specific technologies at required locations.

5.5.1 Video Surveillance

To have immediate visualization of the technology deployment regions, video surveillance may be the first of the technologies to be deployed. Video surveillance equipment can be installed and integrated separate from mainline detector and ramp metering controllers. Depending upon the type of wireless transmission techniques used, FCC license preparation must begin as soon as possible. Video surveillance cameras are deployed at approximately one mile intervals to provide roadway surveillance coverage of over 80 percent. At these intervals, incidents can be verified on majority of the freeway segments prior to initiating response vehicles or teams.

5.5.2 Changeable Message Signs

Figure 5-5 show the various deployment of CMS and video surveillance cameras. Areas of existing instrumentation are indicated by using a different icon on the map. Changeable message signs are strategically located to provide motorist opportunity to take diversionary routes in the event of delay causing incidents. CMS locations are shown on the deployment map with associated cross streets as reference. CMS's are generally mounted on existing overpasses to reduce installation costs. Construction schedules were reviewed and it was determined that none of the CMS deployment sites had any pending construction projects.

5.5.3 Highway Advisory Radios

Highway advisory radios operating at approximately 10 watts of output power can cover a radius of up to 5 miles. As new methods of implementing HAR and automatic HAR (AHAR) become available, placement of HAR/AHAR equipment can be reduced from a

recommended 5 mile increment to approximately 1 mile increment. Since the interval is generally fixed in relation to the freeway segment, HAR equipment are not shown in the deployment map of Figure 5-5. The current architecture provides the flexibility of modifying deployment schemes in order to accommodate future IVHS technology applications. As the DIRECT program is implemented on corridors such as I-94, equipment associated with this project can be integrated into the overall system architecture. Standard electrical interfaces at these sites can be used in conjunction with minimal special software to integrate the systems together.

5.5.4 Ramp Metering and Mainline Detectors

Ramp meters which provide high benefits in providing mainline flow control, are implemented throughout the system. Each ramp meter has the capability to provide ramp meter control using pre-timed ramp metering or by real-time adaptive ramp metering by monitoring adjacent mainline MOE's. It is assumed that all ramps will be metered within the deployment region, therefore specific ramp metering locations are not included in the deployment map. Mainline detectors are located at 1/3 mile increments, and are also not shown on the deployment map. The 1/3 mile increment of mainline detector locations also provides the capability to expand the controller's functions to support any future tasks, such as automated highway systems (AHS) infrastructure support. These functions may include vehicle to roadside communications in order to provide additional infrastructure data to moving vehicles.

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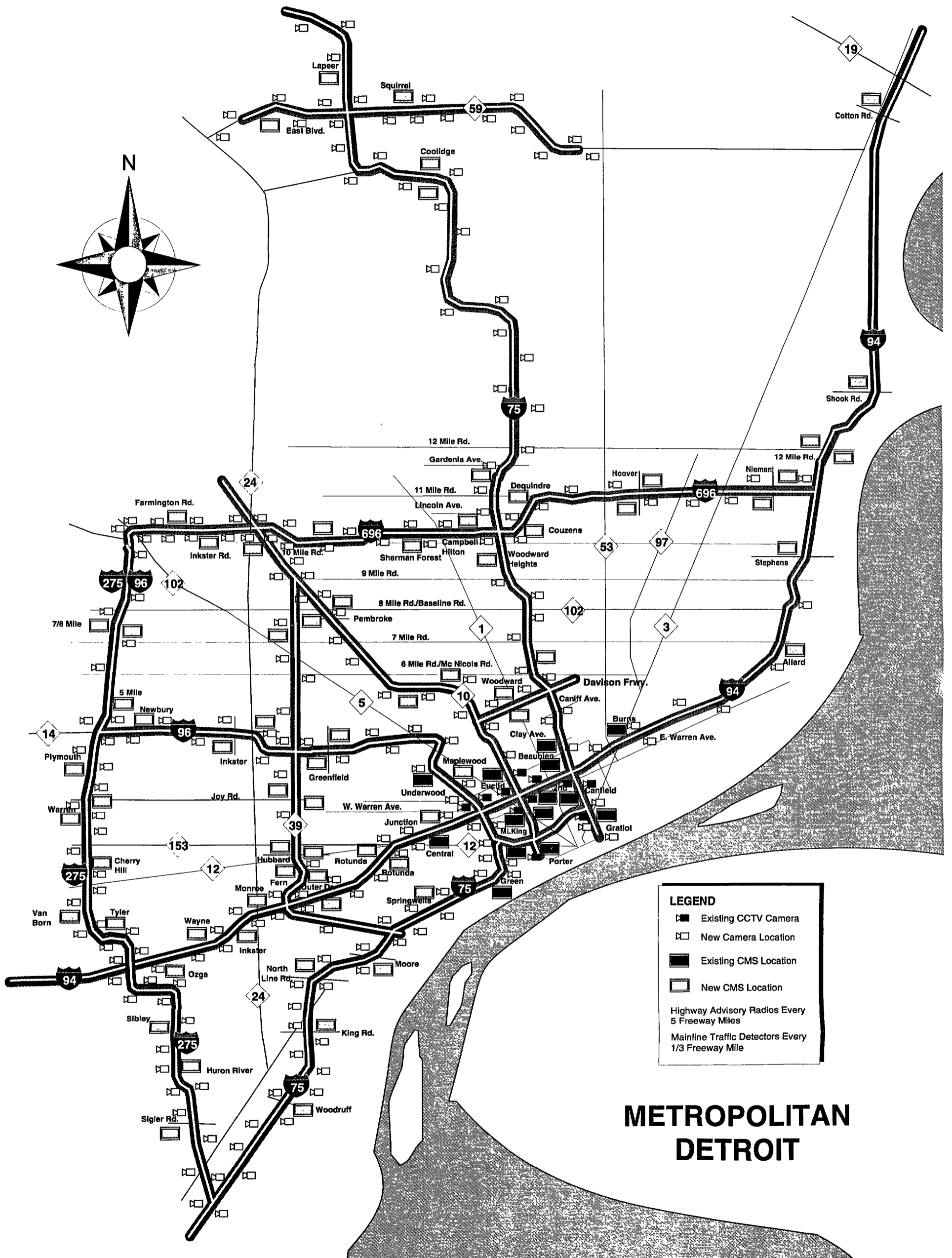


Figure 5-5. Metro Detroit Early Deployment of ATMS/ATIS Technologies

APPENDIX - I

**Southeast Michigan Highway Facilities by County and City of Detroit
2015 Long Range Transportation Plan**

Tier A Traffic Congestion

April 28,1993

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
CITY OF DETROIT	M39 FWY	8 MILE	WARREN	1.26	1.29	153,800	160,300
	TELEGRAPH	8 MILE	FENKELL	1.26	1.34	60,000	64,500
MACOMB	16 MILE	MOUND	UTICA	1.27	1.37	36,100	39,000
	23 MILE	M53 FWY	NORTH	1.27	1.58	18,100	22,400
	23 MILE	NORTH	I94 FWY	1.29	1.60	21,100	26,400
	23 MILE	I94 FWY	JEFFERSON	1.49	1.71	27,000	32,200
	DEQUINDRE	I696 FWY	16 MILE	1.36	1.27	29,000	37,500
	HALL	GROESBECK	JEFFERSON	1.36	2.21	29,200	36,400
	HALL	GROESBECK	HAYES	1.77	1.36	19,100	19,000
	HALL	HAYES	M53 FWY	1.43	1.53	42,100	56,400
	HALL	M53 FWY	MOUND	1.31	1.93	37,400	55,000
	HAYES	HALL	UTICA	1.36	1.36	18,700	22,909
	UTICA	16 MILE	18 MILE	1.55	1.66	21,400	21,500
	VAN DYKE	SIXTEEN MILE	I696 FWY	1.43	1.65	61,600	71,400
OAKLAND	BALDWIN	I75 FWY	OAKLAND	1.26	1.62	17,900	23,000
	BIG BEAVER	WOODWARD	UVERNOIS	1.42	1.89	34,900	42,600
	CROOKS	M59	AVON	1.50	1.89	20,700	20,100
	FRANKLIN	TELEGRAPH	WOODWARD	1.35	1.49	17,100	18,700
	HAGGERTY	12 MILE	RICHARDSON	1.46	2.11	20,700	30,000

Tier A Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	HAGGERTY	8 MILE	12 MILE	1.68	2.40	23,900	34,200
	I275 FWY	6 MILE	M102	1.26	1.77	150,400	210,500
	I696 FWY	DEQUINDRE	175 FWY	1.27	1.32	186,000	194,109
	I75 FWY	BIG BEAVER	I696 FWY	1.53	1.72	171,390	189,409
	I75 FWY	I696 FWY	8 MILE	1.65	1.62	181,500	178,309
	MIDDLEBELT	ORCHARD LAKE	8 MILE	1.26	1.54	17,600	21,500
	NORTHWESTERN	M10 FWY	ORCHARD LAKE	1.41	1.71	42,500	61,200
	ORTONVILLE	DIXIE	RATTALLEE LAKE	1.29	1.25	18,500	23,600
	ROCHESTER	I76 FWY	M59	1.28	1.48	38,700	42,000
	SILVER LAKE	DIXIE	WALTON	1.29	1.80	17,800	24,500
	SOUTHFIELD	MAPLE	I696 FWY	1.45	1.26	32,500	27,600
	TELEGRAPH	FRANKLIN	I696 FWY	1.42	1.54	67,700	73,600
	TELEGRAPH	I696 FWY	8 MILE	1.32	1.47	75,200	83,500
FORT HURON UAZ	PINE GROVE	I94 CONN	24 TH	1.46	1.61	41,900	46,300
WAYNE	EIGHT MILE	I275 FWY	CENTER	1.38	1.53	22,500	33,300
	WEST	TELEGRAPH	I75 FWY	1.33	1.75	20,700	27,300

**Southeast Michigan Highway Facilities by County and City of Detroit
2015 Long Range Transportation Plan**

Tier B Traffic Congestion

April 28,1993

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
CITY OF DETROIT	DAVISON	CONANT	MOUND	0.65	1.00	18,500	29,500
	EIGHT MILE	M10 FWY	M39 FWY	1.10	1.00	46,900	42,800
	EIGHT MILE	MOUND	WOODWARD	1.20	1.29	65,000	66,306
	EIGHT MILE	WOODWARD	M10 FWY	1.16	1.02	85,300	49,000
	I75 FWY	8 MILE	I375 FWY	1.11	1.16	162,600	170,600
	I94 FWY	MOROSS	MT ELLIOTT	1.10	1.01	121,500	111,700
	I94 FWY	MT ELLIOTT	WARREN	1.30	1.24	148,200	140,200
	M10 FWY	FOREST	WYOMING	1.23	1.20	130,000	126,600
LIVINGSTON	GRAND RIVER	I96 FWY/NIXON	PINCKNEY	0.97	1.48	80,700	46,600
	GRAND RIVER	FOWLerville	COUNTY LINE	0.73	1.11	10,709	16,490
	I96 FWY	US23 FWY	GRAND RIVER	0.62	1.08	54,900	95,600
	M59	US23 FWY	OAK GROVE	0.76	1.05	11,600	16,200
	US23 FWY	M59	I96 FWY	0.51	1.06	36,400	75,300
	US23 FWY	WASHTENAW CO	I96 FWY	0.64	1.29	45,506	91,400
MACOMB	13 MILE	DEQUINDRE	VAN DYKE	0.60	1.06	21,306	27,903
	13 MILE	GROESBECK	HARPER	1.12	1.34	16,900	19,600
	14 MILE	DEQUINDRE	VAN DYKE	0.64	1.04	26,406	32,700
	14 MILE	UTICA	HARPER	0.65	1.24	15,200	21,606
	16 MILE	VAN DYKE	GROESBECK	0.66	1.06	17,300	23,300
	16 MILE	UTICA	GROESBECK	1.23	1.32	36,000	37,400

**Tier B Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
MACOMB (cont)	16 MILE	GROESBECK	I94 FWY	1.05	1.24	29,800	35,200
	17 MILE	DEQUINDRE	VAN DYKE	1.12	1.24	15,500	23,100
	18 MILE	DEQUINDRE	VAN DYKE	1.10	1.25	15,200	17,209
	19 MILE	CLINTON RIVER	ROMEO PLANK	0.73	1.07	10,166	14,700
	21 MILE	VAN DYKE	SCHEONHERR	0.66	1.43	11,500	16,800
	22 MILE	VAN DYKE	SCHEONHERR	0.57	1.19	7,800	15,500
	23 MILE	DEQUINDRE	M53 FWY	1.13	1.30	18,600	21,700
	CASS	HALL	GROESBECK	1.02	1.14	16,206	18,306
	DEQUINDRE	16 MILE	AVON	1.69	1.25	15,500	17,800
	DEQUINDRE	AVON	26 MILE	0.65	1.36	12,106	18,500
	DODGE PARK	UTICA	15 MILE	0.91	1.23	12,500	17,000
	GARFIELD	HALL	UTICA	1.02	1.15	25,000	27,766
	GRATIOT	23 MILE	NEW HAVE	1.69	1.17	14,200	16,600
	GRATIOT	HALL	23 MILE	0.98	1.30	28,000	37,100
	GRATIOT	16 MILE	HALL	0.66	1.19	30,500	41,500
	GRATIOT	I696 FWY	16 MILE	0.69	1.15	50,900	65,200
	GROESBECK	UTICA	I696 FWY	0.96	1.03	48,100	61,600
	GROESBECK	UTICA	16 MILE	1.02	1.13	35,600	39,700
	I696 FWY	GROESBECK	VAN DYKE	1.65	1.18	154,600	172,900
	I696 FWY	VAN DYKE	DEQUINDRE	1.16	1.17	159,566	172,000
	I94 FWY	13 MILE	SNOVER	0.73	1.26	79,800	131,690
	I94 FWY	SNOVER	23 MILE	0.60	1.17	28,100	92,600
	I94 FWY	13 MILE	6 MILE	1.13	1.24	124,000	136,060
	M19	MEMPHIS RIDGE	I94 FWY	0.60	1.32	11,500	19,000
	MEMPHIS RIDGE	GRATIOT	BORDMAN	0.66	1.18	9,800	17,166

Tier B Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
MACOMB (cont)	MOUND	I696 FWY	13 MILE	1.12	1.26	35,400	40,760
	MOUND	17 MILE	13 MILE	0.62	1.07	48,406	60,900
	MOUND	28 MILE	24 MILE	0.64	1.22	11,666	16,900
	RYAN	16 MILE	16 MILE	1.09	2.05	15,000	28,300
	RYAN	15 MILE	I696 FWY	1.13	1.07	20,900	24,788
	SCHOENHERR	MORAVIAN	I696 FWY	1.01	1.08	28,500	30,500
	SCHOENHERR	23 MILE	HALL	0.77	1.23	13,200	22,000
	UTICA	16 MILE	14 MILR	1.48	1.23	19,306	30,200
	VAN DYKE	26 MILE	M59	1.07	1.45	21,500	29,200
	VAN DYKE	M59	SIXTEEN MILE	1.23	1.51	45,100	55,769
MONROE	M50	TELEGRAPH	MACOMB	0.96	1.12	18,300	16,566
	TELEGRAPH	STEWART	M50	0.87	1.19	25,186	34,500
OAKLAND	10 MILE	GRAND RIVER	TELEGRAPH	0.91	1.29	13,366	18,868
	12 MILE	NORTHWESTERN	I96 FWY	0.83	1.48	15,100	24,466
	13 MILE	WOODWARD	NOVI	1.14	1.72	16,500	25,568
	14 MILE	NORTHWESTERN	PONTIAC	1.04	1.42	14,106	19,468
	14 MILE	DEQUINDRE	I75 FWY	1.31	1.13	45,400	39,496
	9 MILE	WOODWARD	TELEGRAPH	0.81	2.17	18,300	24,666
	ADAMS	DULTON	M59 FWY	1.83	1.47	14,500	21,900
	ADAMS	M59 FWY	I75 FWY	0.88	1.16	12,608	15,600
	ADAMS	I75 FWY	WOODWARD	0.82	1.00	14,200	17,500
	AUBURN	OPDYKE	DEQUINDRE	0.96	1.31	13,300	18,100
	AVON	DEQUINDRE	ADAMS	0.77	1.64	10,966	14,608
	BALDWIN	CLARKSTON	I75 FWY	0.75	1.49	10,866	26,660
	BECK	MAPLE	8 MILE	0.62	1.83	8,500	14,266

**Tier B Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	BENSTEIN	SLEETH	MAPLE	0.89	1.28	12,300	17,700
	BOGIE LK	M59	COMMERCE	0.61	1.75	15,900	24,800
	CASS LK	ORCHARD LK	M59	1.12	1.00	8,500	13,800
	COMMERCE	MILFORD	UNION LK	0.53	1.28	7,300	17,900
	COMMERCE	UNION LK	ORCHARD LK	0.76	1.17	10,900	16,700
	COOLIDGE	SOUTH	14 MILE	0.78	1.17	16,700	23,600
	CRESCENT LK	ELIZABETH LK	HATCHERY	0.80	1.23	11,000	17,000
	DECKER	S COMMERCE	13 MILE	0.96	1.44	13,200	19,900
	DIXIE	DAVISBURG	TELEGRAPH	0.83	1.13	25,300	34,800
	DRAKE	15 MILE	9 MILE	0.72	1.19	9,400	15,200
	ELIZABETH LK	WILLIAMS LK	M59	0.02	1.17	15,600	20,800
	FARMINGTON	16 MILE	8 MILE	0.87	1.32	13,400	19,800
	GRAND RIVER	M102	10 MILE	0.80	1.25	22,100	34,600
	GREENFIELD	14 MILE	I696 FWY	0.93	1.52	24,800	40,400
	GREENFIELD	I696 FWY	8 MILE	0.97	1.22	34,800	43,300
	HALSTED	14 MILE	8 MILE	0.77	1.29	10,200	17,300
	HICKORY RIDGE	STOBART	BAKER	0.51	1.06	7,300	15,200
	I696 FWY	I75 FWY	TELEGRAPH	1.13	1.33	151,100	177,100
	I696 FWY	TELEGRAPH	I275/I96 FWY	0.72	1.05	106,200	159,400
	I75 FWY	BIG BEAVER	LONG LAKE	1.06	1.50	116,300	165,300
	I75 FWY	M59	LONG LAKE	0.96	1.27	120,600	106,400
	I96 FWY	I696 FWY	KENSINGTON LK	0.79	1.22	89,700	138,000
	JOHN R	AUBURN	TECHNOLOGY	0.96	1.19	16,400	19,600
	LIVERNOIS	BIG BEAVER	TIENKEN	1.16	1.47	16,400	20,900
	LONG LAKE	TELEGRAPH	ADAMS	1.05	1.49	15,600	22,500

**Tier B Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	LONG LAKE	MIDDLEBELT	TELEGRAPH	0.98	1.02	13,900	14,400
	M10 FWY	EIGHT MILE	SOUTHFIELD FWY	1.15	1.06	118,500	109,300
	M10 FWY	NORTHWESTERN	SOUTHFIELD FWY	1.15	1.42	118,500	114,300
	M24	SEYMOUR LK	I75 FWY	1.08	1.38	32,000	42,100
	M39	I696 FWY	M39 FWY		1.42	61,400	60,000
	M59	WIDE WILLIAMS	WILLIAMS LK	1.14	1.10	35,400	44,400
	M59	WOODWARD	TIPSICO LK	1.07	1.42	32,900	33,300
	MAPLE	TRACK LK	DEQUINDRE	1.65	1.06	26,700	39,900
	MAPLE	WOODWARD	PONTIAC TRAIL	1.18	1.49	20,100	25,100
	MEADOWBROOK	14 MILE	8 MILE	0.77	1.14	6,700	12,900
	MILFORD	CLYDE	10 MILE	0.91	1.58	12,900	22,600
	NOVI	8 MILE	13 MILE	1.15	1.67	22,300	33,000
	ORCHARD LAKE	GRAND RIVER	8 MILE	0.96	1.09	13,300	15,000
	ORCHARD LAKE	TELEGRAPH	PONTIAC TRAIL	1.06	1.24	22,900	27,100
	ORCHARD LAKE	PONTIAC TRAIL	NORTHWESTERN	1.03	1.23	81,600	38,400
	ORCHARD LAKE	NORTHWESTERN	I696 FWY	0.78	1.03	24,300	32,100
	ORTONVILLE	GENESSEE CO.	RATTALLEE LAKE	0.97	1.14	14,000	16,400
	PONTIAC TRAIL	8 MILE	I96 FWY	0.68	1.02	9,500	14,400
	QUARTON	TELEGRAPH	WOODWARD	1.13	1.11	15,600	15,300
	ROCHESTER	M59	SNELL	1.95	1.28	32,500	39,900
	SASHABAW	SEYMOUR LK	DIXIE	0.80	1.21	11,200	17,000
	SOUTH BLVD	TELEGRAPH	ADAMS	0.81	1.02	11,200	14,100
	SQUARE LK	MIDDLEBELT	I75 RAMP	1.93	1.17	34,500	38,100
	STEPHENSON	ROCHESTER	12 MILE	1.05	1.17	28,900	32,400
	TIENKEN	ADAMS	ROCHESTER	1.18	3.99	15,100	53,200

Tier B Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	UNION LK/ELIZABETH	RICHARDSON	M59	0.71	1.25	10,000	17,400
	VOORHEIS	M59	ORCHARD LK	1.02	1.18	14,100	16,300
	WALTON BLVD	SILVER LAKE	OPDYKE	0.85	1.07	17,100	22,500
	WALTON BLVD	OPDYKE	SQUIRREL	0.83	1.13	13,300	18,000
	WALTON BLVD	SQUIRREL	ROCHESTER	0.79	1.06	23,600	31,900
	WILLIAMS LK	M59	DIXIE HWY	0.88	1.37	14,600	23,600
	WIXOM	COMMERCE	GRAND RIVER	0.56	1.10	9,300	18,500
	WOODWARD	LONE PINE	I696 FWY	1.01	1.21	67,400	69,000
FORT HURON UAZ	10 TH	LAPEER	M25	0.88	1.23	24,100	34,160
	GRATIOT	M29	I94 FWY	0.73	1.02	10,500	14,500
	I94/M25 CONN	I94 FWY	M25	1.93	1.42	30,000	40,800
	LAPEER	RANGE	I94 CONN	0.64	1.01	10,600	16,400
	M25	LAKESHORE	JEDDO	1.10	1.24	15,700	17,700
	RANGE	I94 FWY	GRATIOT	0.61	1.63	10,300	21,200
	WADHAMS	I69 FWY	N RIVER	0.91	1.46	12,600	20,400
ST CLAIR	M29	COUNTY LINE	PALMS	1.16	1.33	16,100	19,100
	MARINE CITY	COUNTY LINE	PALMS	0.74	1.16	10,700	16,700
	MARINE CITY	PALMS	KING	0.90	1.22	13,600	17,600
WASHTENAW	BAKER	CENTRAL	DEXTER-AA	0.52	1.60	7,500	21,500
	MICHIGAN	US23 FWY	HARRIS	1.08	1.30	19,600	23,600
	US23 FWY	N TERRITORIAL	6 MILE	0.62	1.59	58,500	112,560

**Tier B Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
WAYNE	6 MILE	BRADNER	NORTHVILLE	0.73	1.16	12,700	18,200
	ALLEN	WEST	VAN HORN	1.99	1.13	30,300	34,400
	ANN ARBOR	PLYMOUTH	JOY	1.16	1.64	25,600	33,800
	BELLEVILLE	ECORSE	I94 FWY	0.87	1.20	12,400	17,100
	CANTON CENTER	JOY	MICHIGAN	0.99	1.39	14,000	19,700
	EDWARD HINES	FORD	OUTER DR	1.01	1.47	14,300	20,900
	EIGHT MILE	FARMINGTON	I275 FWY	1.96	1.65	18,300	33,400
	EIGHT MILE	GRAND RIVER	FARMINGTON	0.94	1.93	25,800	29,300
	EUREKA	I275 FWY	I75 FWY	1.00	1.09	22,700	25,300
	FARMINGTON	I96 FWY	JOY	0.94	1.14	21,900	25,600
	FORD	WYOMING	INKSTER	1.11	1.12	49,200	49,300
	FORD	INKSTER	I275 FWY	1.05	1.35	33,200	28,600
	FORD	I275 FWY	BECK	0.90	1.56	25,500	29,100
	FORT	EUREKA	PENNSYLVANIA	1.17	1.24	35,600	37,800
	GROSSE ILE PKWY	JEFFERSON	RIVER	0.82	1.02	11,300	14,000
	HAGGERTY	7 MILE	8 MILE	0.84	1.24	11,500	17,100
	HAGGERTY	ANN ARBOR TRAIL	JOY	0.85	1.46	11,800	20,100
	I275 FWY	M14 FWY	MICHIGAN	0.94	1.18	105,800	132,200
	I275/I96 FWY	8 MILE	M14 FWY	1.11	1.50	172,200	232,200
	I94 FWY	MOROSS	8 MILE	1.12	1.07	123,100	117,500
	I96 FWY	TELEGRAPH	WYOMING	0.99	1.16	145,600	169,900
	INKSTER	WARREN	FORD	1.09	1.20	15,100	16,600
	JOY	NEWBURGH	ANN ARBOR	1.00	2.35	13,800	32,500
	LILLEY MILL	ANN ARBOR TRAIL	CHERRY HILL	0.97	1.55	11,500	18,700
	M14	NAPIER	I96 FWY	0.74	1.05	59,300	84,500

**Tier B Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
WAYNE	M39 FWY	WARREN	I94 FWY	1.23	1.30	126,700	134,000
	MAIN	ANN ARBOR TRAIL	JOY	0.93	1.42	15,200	22,500
	MICHIGAN	HOLMES	BELLEVILLE	0.94	1.99	26,600	31,100
	MICHIGAN	I275 FWY	BECK	1.05	1.26	29,900	36,000
	NEWBURGH	6 MILE	I96 FWY	0.87	1.21	24,100	33,400
	NORTHLINE	HURON RIVER DR	WAYNE	0.96	1.03	13,200	14,200
	PENNSYLVANIA	ALLEN	FORT	1.09	1.24	15,000	17,100
	PLYMOUTH	MIDDLEBELT	ANN ARBOR TRAIL	1.05	1.25	30,400	36,100
	RAWSONVILLE	I94 FWY	HURON RIVER DR	1.42	1.16	19,600	31,900
	SHELDON	JOY	FORD	1.13	1.72	15,100	22,900
	SUMPTER	I94 FWY	WILLIS	0.87	1.30	53,000	55,300
	TELEGRAPH	WARREN	NORTHLINE	1.24	1.03	12,300	14,600
	TELEGRAPH	NEWBURGH	WARREN	0.92	1.22	61,500	64,000
	WARREN	FENKELL	HIX	1.23	1.26	12,600	16,900
	WAYNE	FORD	PALMER	1.07	1.06	33,600	33,900

**Southeast Michigan Highway Facilities by County and City of Detroit
2015 Long Range Transportation Plan**

Tier C Traffic Congestion

April 28,1993

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
CITY OF DETROIT	7 MILE	LAHSER	WYOMING	0.87	0.93	26,400	28,200
	DAVISON	WYOMING	ROSA PARKS	0.78	0.96	38,900	50,600
	EIGHT MILE	HAYES	MOUND	0.80	0.72	44,700	39,900
	EIGHT MILE	M39 FWY	GRAND RIVER	1.05	0.97	44,800	41,300
	I94 FWY	WYOMING	WARREN	0.99	0.98	108,700	107,700
	I96 FWY	TELEGRAPH	WYOMING	0.76	0.86	140,100	157,200
	JEFFERSON	M10 FWY	ALTER	0.59	0.83	29,900	41,300
	M10 FWY	FOREST	JEFFERSON	0.76	0.91	77,600	94,200
	M10 FWY	8 MILE	WYOMING	0.96	0.89	98,900	92,000
	MCNICHOLS	OUTER DRIVE	SCHAEFER	0.68	0.70	25,100	19,800
LIVINGSTON	I96 FWY	BURKHARDT	FOWLerville	0.46	0.87	35,400	67,100
	I96 FWY	OAKLAND CO	US23 FWY	0.53	0.86	61,400	100,100
	M36	US23 FWY	CHILSON	0.49	0.98	7,300	14,700
	OAKGROVE	MASON	MARR	0.52	0.88	7,300	12,400
	PINCKNEY	I96 FWY	COON LAKE	0.46	0.94	6,600	13,600
		US23 FWY	GENESSEE CO	M59	0.48	0.86	34,000
MACOMB	12 MILE	DEQUINDRE	VAN DYKE	0.84	0.87	26,200	27,100
	14 MILE	VAN DYKE	UTICA	0.70	0.87	21,600	27,200
	15 MILE	DEQUINDRE	VAN DYKE	0.80	0.98	24,200	29,900
	AUBURN	DEQUINDRE	WOODALL	0.93	0.96	12,800	13,300

**Tier C Traffic Congestion
(Continued)**

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
MACOMB (cont)	CANAL	HALL	GARFIELD	0.69	0.88	9,600	12,200
	DEQUINDRE	8 MILE	I696 FWY	0.82	0.82	23,400	23,300
	GROESBECK	16 MILE	HALL	0.84	0.91	26,200	28,600
	HOOVER	14 MILE	10 MILE	0.97	0.66	27,100	23,900
	I696 FWY	GROESBECK	I94 FWY	0.83	0.92	121,300	135,300
	M53 FWY	VAN DYKE	M59	0.62	0.88	42,800	60,700
	MORAVIAN	SCHEONHERR	HARRINGTON	0.71	0.99	9,700	13,700
	SCHEONHERR	HALL	UTICA	1.01	0.75	16,600	17,000
	SHELBY	22 MILE	HALL	0.77	0.88	10,600	12,200
	UTICA	GRATIOT	14 MILE	0.64	0.89	18,100	25,300
	UTICA	18 MILE	M59	0.84	0.74	10,600	9,300
	UTICA	M59	AUBURN	0.91	0.99	11,300	12,400
	VAN DYKE	26 MILE	32 MILE	1.12	0.72	16,600	10,100
	VAN DYKE	32 MILE	EBELING	0.83	0.30	12,400	4,400
MONROE	STERNS	SECOR	M125	0.38	0.82	5,000	11,400
OAKLAND	10 MILE	DEQUINDRE	JOHN R	0.72	0.81	16,400	18,400
	11 MILE	GREENFIELD	DEQUINDRE	0.75	0.91	21,700	26,200
	11 MILE	LASHER	TELEGRAPH	1.09	0.97	15,600	13,800
	13 MILE	DEQUINDRE	WOODWARD	0.87	0.92	25,000	26,500
	14 MILE	I76 FWY	M39	0.94	0.93	26,300	26,000
	9 MILE	TELEGRAPH	GRAND RIVER	0.73	0.94	11,900	15,000
	9 MILE	FARMINGTON	HAGGERTY	0.74	0.83	20,400	22,900
	BIG BEAVER	LIVERNOIS	DEQUINDRE	0.83	0.89	35,400	38,000
COOLEY LK	ELIZABETH LK	UNION LK	0.56	0.94	13,600	23,200	
	CROOKS	MAIN	M50	0.82	0.85	20,200	21,206

Tier C Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	FARMINGTON	8 MILE	I96 FWY	0.85	0.84	26,400	28,000
	FORD BLVD	MICHIGAN	US12	0.77	0.94	10,700	13,000
	FORT	PENNSYLVANIA	VAN HORN	0.96	0.91	27,300	25,800
	FORT	M39	NORTHLINE	0.82	0.78	37,500	35,400
	GOLFVIEW	FORD	MILITARY	0.81	0.52	9,200	5,906
	HAGGERTY	PLYMOUTH	5 MILE	0.53	0.83	7,300	11,400
	HAGGERTY	VAN HORN	SAVAGE	0.50	0.97	6,900	13,300
	I94 FWY	WYOMING	INKSTER	0.96	0.65	93,700	106,200
	JOY	MIDDLEBELT	FARMINGTON	0.90	0.82	11,300	12,400
	KING	ALLEN	FORT	0.89	0.80	12,200	11,000
	MACK	CADIEUX	6 MILE	0.84	0.76	23,800	21,500
	MERRIMAN	8 MILE	I96 FWY	0.97	0.96	16,900	15,800
	MICHIGAN	WYOMING	INKSTER	0.91	0.63	42,600	39,000
	MIDDLEBELT	I96 FWY	CHERRY HILL	0.84	0.92	26,700	31,700
	MIDDLEBELT	GRAND RIVER	I96 FWY	0.99	0.96	30,700	29,800
	MILITARY	OUTER DRIVE	MICHIGAN	0.86	0.64	12,700	9,800
	NEWBURGH	I96 FWY	FORD	0.65	0.93	18,900	27,100
	NEWBURGH	FORD	MICHIGAN	0.85	0.97	15,000	17,700
	PLYMOUTH	TELEGRAPH	INKSTER	0.81	0.75	23,100	21,400
	SIBLEY	TELEGRAPH	FORT	0.94	0.96	12,900	15,900
	TELEGRAPH	NORTHLINE	SIBLEY	0.91	0.86	29,900	28,500
	TRENTON	DIX	FORT	0.96	0.85	13,100	11,800
	VAN HORN	ALLEN	FORT	0.67	0.98	12,000	13,560
	VERNIER	I94 FWY	LAKESHORE	0.89	0.73	24,600	20,100
	WAYNE	PLYMOUTH	FORD	0.88	0.99	28,266	31,700

Tier C Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
OAKLAND (cont)	FRANKLIN	NORTHWESTERN	QUARTON	0.77	0.97	9,900	12,300
	HAMLIN	ADAMS	DEQUINDRE	0.60	0.93	8,700	13,900
	I76 FWY	DIXIE HWY	M59 FWY	0.56	0.94	71,200	119,000
	INKSTER	GRAND RIVER	WALNUT LK	0.48	0.61	6,600	11,100
	JOSLYN	CLARKSTON	I75 FWY	0.51	0.89	9,900	17,200
	LAHSER	SQUARE LK	I696 FWY	0.98	0.90	15,100	14,100
	LAHSER	I696 FWY	6 MILE	0.76	0.91	12,600	15,200
	LIVERNOIS/MAIN	I696 FWY	BIG BEAVER	0.70	0.88	20,300	25,400
	M102 FWY	GRAND RIVER	I96 FWY	0.39	0.80	27,200	22,100
	M39 FWY	10 MILE	6 MILE	0.87	0.91	69,900	94,300
	M59 FWY	I75 FWY	DEQUINDRE	0.80	0.91	54,800	74,300
	MASONIC	KELLY	GRATIOT	0.62	0.84	16,700	19,100
	OPDYKE	WOODWARD	M24	0.71	0.95	15,800	20,400
	PONTIAC TRAIL	ORCHARD LK	EAST LK	0.77	0.99	11,400	14,900
	PONTIAC TRAIL	MAPLE	MILFORD	0.40	0.86	6,600	12,200
	S COMMERCE	COMMERCE	PONTIAC TRAIL	0.67	1.00	9,000	13,300
	TELEGRAPH	DIXIE HWY	FRANKLIN	0.86	0.92	34,509	37,500
	UNIVERSITY	WIDE TRACK	SQUIRREL	0.64	0.03	16,200	23,300
	WALNUT LK	FRANKLIN	PONTIAC TRAIL	0.55	0.03	7,200	11,000
	WALTON	DIXIE	SILVER LAKE	0.65	0.86	20,300	27,700
	WATTLES	DEQUINDRE	WOODWARD	0.80	0.92	11,100	12,700
	WHITE LK	MILFORD	ROSE CENTER	0.34	0.82	4,900	11,700
	WILLIAMS LK	COOLEY LK	M59	0.71	0.95	10,000	13,500
	WOODWARD	I696 FWY	6 MILE	0.64	0.98	41,600	48,700

Tier C Traffic Congestion

(Continued)

COUNTY/CITY	ROADNAME	LOCATION		AVG EST V/C RATIO		ESTIMATED ADT	
		FROM STREET	TO STREET	1990	2015	1990	2015
FORT HURON UAZ	10 TH	GRISWOLD	LAPEER	0.76	0.90	21,000	24,800
	24 TH	M136	KEEWAHDIN	1.05	0.98	33,000	30,800
	24 TH	GRISWOLD/OAK	LAPEER	0.65	0.80	18,000	22,200
	I94 FWY	M25 CONN	LAPEER CONN	0.58	0.66	42,300	64,700
	I94/LAPEER CONN	I94 FWY	LAPEER	0.63	0.81	9,000	11,606
	M136	STATE	M25	0.37	0.60	4,600	11,000
	M25	KEEWAHON	LAKESHORE	0.98	0.95	14,000	18,500
	M29	BEARD	M25/GRATIOT	0.93	0.93	20,000	26,400
	M29	HURON	RANGE/COX	0.66	0.98	9,100	13,600
	PINE GROVE	BLUE W.BRIDGE	M25 CONN	0.84	0.96	24,060	27,400
	RATTLE RUN	COX	M29	0.77	0.96	10,600	13,500
	WATER	I94 FWY	16 TH	0.43	0.86	11,000	24,400
WASHTENAW	DEXTER	CENTRAL	MILLER	0.60	0.85	9,400	13,500
	M52	I94 FWY	STOCKBRIDGE	0.61	0.92	9,900	15,400
	MICHIGAN	CHELSEA	MAPLE	0.77	0.98	11,500	14,700
WAYNE	7 MILE	NEWBURGH	FARMINGTON	0.72	0.90	21,100	26,900
	7 MILE	NEWBURGH	HAGGERTY	0.70	0.95	19,700	26,600
	ALLEN	MOORE	EUREKA	0.82	0.95	25,700	29,700
	BELLEVILLE	I94 FWY	HURON RIVER DR	1.27	0.79	17,600	15,000
	CHERRY HILL	MIDDLEBELT	RIDGE	0.70	0.83	13,500	15,300
	CHERRY HILL	TELEGRAPH	MILITARY	0.86	0.93	13,100	12,500
	DIX-TOLEDO	M39	NORTHLINE	0.78	0.81	35,000	36,400
	EDWARD HINES	OUTER DR	INKSTER	1.02	0.84	14,400	11,900
	EDWARD HINES	MERRIMAN	NEWBURGH	0.79	0.84	11,200	11,900
EUREKA	I75 FWY	JEFFERSON	0.90	0.96	27,700	29,800	

APPENDIX - II

Operations Plan
for the
Metropolitan Detroit
Advanced Traffic Management/
Advanced Traveler Information
System

February 2, 1994

Prepared for
Michigan Department of Transportation

1. Introduction

Planning for the system funding, procurement, design, construction management, system startup, and operations and maintenance of a traffic management system is critical to the system's funding, development, effectiveness, and acceptance. This plan describes the process and activities necessary for a successful program.

1.1 Purpose

This operations plan provides the planning and programmatic activities necessary to carry out system funding, award, design, deployment/construction management, operations, and maintenance planning of a new Metropolitan Detroit Advanced Traffic Management System (ATMS)/Advanced Traveler Information System (ATIS). These planning activities include conformance with applicable legislation and establishment of inter-agency agreements, program bid/award process, system design, system construction and implementation, system integration and start-up, system operations, system maintenance, the overall schedule for these activities, and commitment to this operations plan.

1.2 Background

The Michigan Department of Transportation (MDOT) presently manages a traffic management system designed to improve and facilitate traffic flow on selected freeway corridors within the City of Detroit. This system, currently known as the Surveillance Control AND Driver Information (SCANDI) system, provides traffic and video surveillance, entrance ramp control, incident detection, message signing, and traffic coordination to roadway users for on 32.5 corridor miles.

Since SCANDI's implementation in the mid-70s, population growth and demographic changes in the southeast Michigan region have enhanced the need for an area wide traffic management system serving the metropolitan Detroit freeway network. Whereas the present SCANDI system has surveillance and control over 32.5 miles using older technology, this plan, when complete, will implement a new system managing 244 freeway miles spanning Wayne, Oakland, Monroe, and Macomb counties. This new system will integrate advanced technologies for freeway traffic surveillance, control and traffic coordination, streamline traffic operations and maintenance through computer-assisted decision aids and record keeping, and enhance the collection, management, coordination, and dissemination of traffic and travel-related information to roadway users, law enforcement agencies, fire and emergency services, media reporting services, and others. The new system will highlight the following capabilities:

- Expand the geographic range of closed circuit video to assist detection and clearance of incidents.
- Automate incident management procedures to assist operator decision making.
- Coordinate control with surface street traffic managers to optimize signal timing cycles of intersections near freeway entrance and exit ramps.
- Provide up-to-the-minute traffic and travel information to emergency and transportation agencies, media reporting services (e.g., commercial TV/radio stations, cable TV traffic

channel, etc.), and other users (e.g., private businesses, individuals, agencies, etc.) for travel planning and route diversion guidance.

Planning for the new Metropolitan Detroit ATMS/ATIS embraces the goals and objectives of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) through development of a program which pursues the application of advanced technologies for enhancement of vehicle traffic mobility and throughput, improvement of highway travel safety, and the reduction of environmental pollutants (through improved mobility) and energy/fuel consumption by minimizing travel delays, optimizing highway capacity utilization, and diverting traffic around congested roadways.

At present, an early deployment study for definition of advanced traffic management and advanced traveler information systems (ATMS/ATIS) is being conducted to assess traffic management needs, candidate technologies, system architecture configurations, and implementation options for deployment to establish the technical foundation to design an advanced, area wide freeway traffic management system for the metropolitan Detroit area.

2. Laws, Regulations, Policies, and Agreements

This plan identifies the applicable laws, regulations, policies, and agreements for the planning, development, construction, operations, and maintenance of the system. This plan is designed to conform with Michigan Department of Transportation Construction and Maintenance Contract provisions and requirements, State Administrative Board provisions and approvals, and provide the identification process for modification and changes to state legislation, regulations, policies, and memorandums of agreement.

2.1 Applicable Documents

The following documents are applicable to the planning, development, construction, operations, and maintenance of the system. Required documents identify applicable statutes, specifications, regulations, and policies for successful execution of this plan. Guidance documents provide reference sources and supplementary information to aide the execution of this plan.

2.1.1 Required Documents

Documents required to execute this plan are identified as follows:

- Michigan Department of Transportation Statement of Work for the Initial Deployment
- Michigan Department of Transportation Standard Specifications for Construction, 1990
- State of Michigan Administrative Board Resolution of 1979 for Michigan Department of Transportation Construction and Maintenance Contracts, State Administrative Board
- Michigan Manual of Uniform Traffic Control Devices, Revision 2, dated December 1985.
- Manual of Traffic Signal Design, ITE, 1982
- Michigan Department of Transportation Detroit Freeway Operations Unit Operations Manual

2.1.2 Guidance Documents

Documents to be used for guidance for the execution of this plan are identified as follows:

- USDOT Manual of Uniform Traffic Control Devices, 1988
- A Policy on Geometric Design of Highways and Streets, AASHTO, 1990
- National Program Plan for IVHS, IVHS America, Draft October 1993
- Highway Capacity Manual, TRB Special Report 209, Second Edition, 1992

2.2 Required Legislation and Agreements

Required legislation, regulation, policies, and memorandums of agreement are identified as follows:

2.2.1 Required Legislation and Regulations

This plan involves the expansion of MDOT Metropolitan Freeway Operations and shall conform with current laws and regulations. There are no legislative requirements currently identified.

2.2.2 Required Policies and Memorandum of Agreements

Successful operation and effectiveness of the new system require the participation and coordination between a variety of public, private, and commercial entities that currently do not exist or are inactive.

2.2.2.1 Policies and Memorandums Needs and Changes

New policies and memorandums with the MDOT Transportation Systems Section, Traffic and Safety Division, Detroit Freeway Operations need to be established for public inter-agency information exchange and coordination, and authorization for public/private/commercial cooperation. In addition, policy requirements for the handling and commercial value of traffic information collected by the system may need to be addressed as a result of potential market demand and cost-effective advancements in communications and information technologies.

2.2.2.2 Participating Agencies/Entities

Memorandums (of Agreement) need to be established with the following public agencies, private organizations, and commercial entities.

Public Agencies:

- US Department of Transportation (USDOT) Federal Highway Administration (FHWA)
- Michigan Department of Management and Budget
- Michigan State Police
- Various Local City Police and Sheriff Departments
- Various Local City/County Fire Departments (and Rescue, EMS, HAZMAT, etc.)
- Various City/County Public Works Departments (e.g., Edison electric, power & lighting, water, refuse, etc.)
- Wayne County Departments

- Monroe County Departments
- Macomb County Departments
- Oakland County Departments
- Road Commission for Oakland County
- City of Detroit Department of Transportation
- City of Detroit Departments
- Wayne County Department of Roads
- Border Patrol
- Detroit Metropolitan Wayne County Airport
- Southeast Michigan Council of Governments (SEMCOG)
- Detroit Edison

Private:

- Michigan Emergency Patrol
- Contract Towing Service Providers

Commercial:

- Metro Traffic
- American Automobile Association (AAA)
- United Parcel Service (UPS)
- Greyhound Bus Lines
- SMART Regional Transit
- Commuter Transportation Service
- Michigan Bell/Ameritech

2.3 Responsibilities

Responsibility for establishing the legislative, policy, and agreement vehicles are identified as follows:

2.3.1 Draft

Drafting of legislation, policies, and agreements shall be generated by MDOT for matters concerning the funding, bid/award, system design, construction, and operations and maintenance of the system. MDOT shall also review existing statutes to identify avenues for establishing cooperative agreements between public and private entities. Full disclosure of roles and responsibilities shall be identified and agreed-to by appropriate authorities.

2.3.2 Legal Review

Legal review shall be conducted by the State of Michigan.

2.3.3 Enactment

Enactment of agreements shall be executed by the affected entities.

3. Contract Bid/Award Process

The contract bid/award process to be used for initiation of the system implementation project shall comprise an invitation to bid (advertisement), pre-bid activities, bid proposal, project bond, agreement, terms and conditions to contract, and contractor qualifications.

3.1 Responsibility to Advertise

Advertisement of projects retains the open opportunity of qualified prospective bidders to publicly-funded highway projects. This initiates the bidding process to award the project.

3.2 Advertisement

Advertisement for project bids provides an announcement to prospective bidders about the existence of the project and enables them to decide whether the project is within their capabilities and interest. The announcement also contains information for directing interested bidders to the source of bid documents.

3.2.1 Journals/Publications

Advertisement for contract bids shall be placed in Michigan Contractor and Builder and Michigan Roads and Construction periodicals at a minimum.

3.2.2 Announcement Content

The advertisement is usually a one-page document which contains a brief summary of the project, its bidding and system implementation procedures, and bidder qualification requirements.

3.3 Pre-bid Activities

The pre-bid activities are primarily designed to provide proposal/bid instructions to prospective qualified bidders, provide guidance to questions about the bid package, and to identify the procedures and staff required to evaluate the proposals/bids.

3.3.1 Pre-bidders Conference and Attendance Requirements

Proposal/bid instructions are usually provided with the request for proposal (RFP) which also includes the scope of the project, the requirements of the system. The conference is primarily designed to summarize the expectations of the project, answer questions about the general RFP and proposal format, and other proposal-related items. Attendance is typically required to ensure all prospective bidders receive the same information for purposes of competitiveness.

3.3.2 Prequalification Procedures

Prospective bidders are usually required to provide general experience and financial data with their request for a bid package. This ensures prospective bidders have proper qualifications with respect to the nature and scope of the project. In addition, the prospective bidder must be in compliance with the following Federal regulations:

- Title VI, Civil Rights Act of 1964
- Minority Business Enterprise Guidelines

- Equal Employment Opportunity Guidelines
- Non-discrimination on the Basis of Handicap (Section 504)

3.4 Evaluation of Proposals

Evaluation of the received proposals shall be conducted in accordance to procedures defined by MDOT (with FHWA requirements (if applicable)). Each proposal shall be evaluated against minimum requirements and weighting criteria. These criteria usually consist of the following items and corresponding weights:

Content of Technical Proposal	30 points
Experience of Bidder/Project Leader/Team Members	20 points
Content of Cost Proposal	20 points
Completeness of Proposal	10 points
Availability of Key Personnel	10 points
Schedule for Successful Project Completion	10 points
Total	100 points

In addition, the bidder's cost proposal shall be evaluated for cost realism with relation to the scope of the project.

The following information shall be included with each bidder's submitted proposal.

3.4.1 Business Organizations

Each bidder shall state the full name and address of the business organization and, if applicable, the branch office or subordinate element that will perform or assist in performing the tasks delineated in the statement of Work. Each bidder shall indicate whether the organization is an individual, partnership, or corporation. If a corporation, the bidder shall include the state in which incorporated. Also, each bidder shall provide information regarding the organization's minority business enterprise (MBE), or disadvantaged business enterprise (DBE) status.

3.4.2 Project Statement

Each bidder shall provide a project statement, in succinct terms, of the bidder's understanding of the scope and effort required to complete this project presented in the RFP.

3.4.3 Work Plan

Each bidder shall include, with their proposal, a work plan for completion of this project. The work plan shall identify major project milestones (e.g., reviews requiring MDOT participation and approval, major task completion, etc.), major tasks (outlined in the statement of work), and corresponding task schedules. In addition, the work plan shall identify the key personnel associated with each major task.

3.4.4 Proposed System Design

Each bidder shall provide a proposed system design based upon the technical requirements (i.e., scope, functional and performance requirements) identified in the statement of work. Each bidder shall define their development approach for the successful design and implementation of the system. Alternative design approaches shall be identified. Trade-off studies and analyses shall be summarized to support the bidder's proposed system design. In addition, a deployment and integration approach corresponding to the system design, and provisions for system start-up, acceptance testing, and initial maintenance shall be included.

3.4.4 Bidder's Qualifications and Prior Experience

Each bidder shall include a brief statement concerning the recent experience of key personnel of the firm who will be actively engaged in the proposed efforts. Do not include firm experience unless personnel who participated in that experience will also be directly engaged in this project. Emphasis should be placed on experience directly applicable to project requirements. Firm experience shall also include a summary of firm involvement with the activities of IVHS America and IVHS-related projects and operational tests.

3.4.5 Personnel

Each bidder shall include specific background information for each key individual who will be directly engaged in this project. The background information shall emphasize their experience related to project requirements. A general resume is not a satisfactory substitute for this information. Personnel information on key individuals shall also include their involvement with IVHS America committee activities.

3.4.6 Authorized Negotiators

Each bidder shall include the name(s) and phone number(s) for personnel authorized to negotiate the proposed contract with MDOT.

3.4.7 Cost Proposal

Each bidder shall provide a comprehensive cost proposal for the project. The cost proposal shall include project management, fee schedule for key personnel, and rough orders of magnitudes (ROMs) for the proposed system design (and components). In addition, labor hours and other costs for work plan tasks shall be identified. Other costs include, but not limited to, profit materials and travel (number of trips, days of diem, etc.).

3.5 Approval Authority

MDOT and FHWA shall provide the approval authority to award this project.

3.6 Bid Analysis and Award

Proposals shall be analyzed in accordance to the identified evaluation criteria with award given to the proposal that provides the best overall benefits to MDOT per delineated costs.

3.6.1 Involved Parties

The involved parties for this agreement shall include MDOT Transportation Systems Section – Traffic and Safety Division (in concurrence with the USDOT Federal Highway Administration) and the winning bidder.

3.6.2 Concurrence

The project award shall be coordinated with and concurred upon by the following agencies:

- Michigan Department of Management and Budget
- Wayne County Departments
- Wayne County Department of Roads
- Road Commission for Oakland County
- City of Detroit Department of Transportation
- Oakland County Departments
- Macomb County Departments
- Monroe County Departments
- Detroit Metropolitan Wayne County Airport
- Southeast Michigan Council of Governments (SEMCOG)

3.6.3 Award Authority

The Michigan Department of Transportation shall be the awarding authority.

3.6.4 Contract Bond

The winning contractor may be required to provide a contract bond equal to the amount of the contract for the period up to contract completion based upon the contractor’s financial stability.

3.6.5 Contract Terms and Conditions

Contract terms and conditions shall identify detailed contractual relationships and procedures relative to the project. These conditions include specific requirements for information to be provided by the contracting agency in order for the contractor adequately execute the agreement; including MDOT approval of all subcontractors to provide services under the contract. Supplementary conditions shall define the specific details for specific project modifications. These terms and conditions and specific conditions shall be documented as part of the contract documents.

3.6.6 Contractor Qualifications

Contractors and subcontractors shall be evaluated for their qualifications in order to bid for the project. Qualifications for this project include experience in designing and managing large-scale systems which involve numerous subcontractors. Considerations will be given for contractors and subcontractors actively involved in current IVHS-oriented projects and operational tests. In addition, subcontractors must be qualified to perform their respective services.

3.6.7 Document Precedence

Document precedence shall be clearly defined to establish the hierarchy of precedence for contractual documents. In the case of conflicting requirements, this hierarchy serves as the governing order to which requirements will be applied. For this project, the following document precedence shall apply:

- Agreement
- Design Plans
- Special (technical) Specifications
- Standard Specifications
- Supplementary Conditions
- General Terms and Conditions

4. System Design

The system design for this project shall incorporate new technologies, operational strategies, and contracting approaches to develop an expansion of freeway traffic surveillance and control capabilities for identified early deployment corridors. In addition, this project shall incorporate a system design which provides compatibility, adaptability, and expandability with current and future IVHS-related technologies. Tasks to be performed under this procurement shall include system design, design plans, specifications, and estimates (PS&E) preparation, subcontract bid preparation and evaluation, system construction/implementation, system integration, and system start-up, acceptance testing, documentation and training.

4.1 Type of Procurement

This procurement shall be a cost reimbursable/fixed fee contract.

4.2 Responsibilities

Responsibilities are identified for MDOT, concurring agencies, other agencies, and the project contractor.

4.2.1 MDOT Project Manager and Supporting Staff

MDOT shall dedicate a project manager to this project to ensure satisfactory progress of contractor system development and deployment tasks and adherence to project schedules. The project manager shall have the responsibility to transform MDOT needs into reality in a controlled fashion by ensuring key reviews and project milestones are satisfactorily accomplished with MDOT approval, and proper MDOT supporting staff are available for project reviews. These reviews include system design, design plans, specifications, and estimates (PS&E), subcontract bid preparation and evaluation, system construction/implementation, system integration, and system start-up, acceptance testing, documentation and training. Supporting staff shall provide project administration, subcontractor approval, and technical assistance (reviews).

Specific attention is given to visibility to project actions, establishment of orderly procedures to attain project goals and objectives, and centralization of responsibility and accountability.

The MDOT project manager shall oversee the management of schedules, contractor performance, and project resources and costs. Management responsibility shall encompass diverse technologies (including IVHS developments), coordination with various agencies, project schedule interrelationships, resource and cost considerations, and operational considerations (i.e., user support, training, maintenance, and system documentation). Additionally, management responsibilities shall involve many disciplines including traffic engineering, systems engineering, electrical engineering, civil engineering, software engineering, field installation, integration and inspection, equipment/material procurement, and contract administration

4.2.2 Parties Involved in Development of Design Plans and Specifications

MDOT shall be the approving authority of all project design plans and specifications. Timely reviews shall be conducted to ensure plans and specifications reflect MDOT requirements. Other MDOT departments shall provide support to expedite development and review of the design plans and specifications. Project design plans and specifications shall have concurrence with FHWA, applicable county Road Commissions, and other affected government agencies.

4.2.3 Other Agencies and Organizations

Other government agencies with responsibilities associated with this project include:

- Michigan Department of Management and Budget
- Wayne County Departments
- Wayne County Department of Roads
- Road Commission for Oakland County
- City of Detroit Department of Transportation
- Oakland County Departments
- Macomb County Departments
- Monroe County Departments
- Detroit Metropolitan Wayne County Airport
- Southeast Michigan Council of Governments (SEMCOG)

4.2.4 Project Contractor

The project contractor shall be responsible for system design; development of plans, specifications, and estimates (PS&E); subcontract bid preparation and evaluation and system construction/implementation, integration, and startup; and system documentation preparation and training. The project contractor shall directly interface and coordinate with the MDOT project manager for necessary reviews, approvals, and construction changes.

4.3 Standards and Specifications

The system shall be designed and constructed in accordance with MDOT-approved specifications and design and construction standards as related to highway and traffic operations.

4.3.1 Required State Specifications

The following State of Michigan specifications and standards shall apply to this project.

Michigan Department of Transportation Standard Specifications for Construction, 1990
Michigan Department of Transportation Bureau of Highways - various facilities specifications
State of Michigan Administrative Board Resolution of 1979 for Michigan Department of Transportation Construction and Maintenance Contracts, State Administrative Board
Michigan Manual of Uniform Traffic Control Devices, Revision 2, dated December 1985.

4.3.2 Required Federal Specifications

USDOT Manual of Uniform Traffic Control Devices, 1988

4.3.3 Other Specifications

Manual of Traffic Signal Design, ITE, 1982
Highway Capacity Manual, TRB Special Report 209, Second Edition, 1992
A Policy on Geometric Design of Highways and Streets, AASHTO, 1990

4.4 Data and Information Sources

MDOT shall maintain a data and information source library for all current freeway traffic operations and available SCANDI documentation. This information shall be made available for contractor use and review.

4.4.1 Plans, Maps, and Inventories

Information concerning existing plans (drawings), maps, and system inventories shall be maintained in the library.

4.4.2 System Equipment

Information concerning existing system equipment shall be maintained within the library.

4.4.3 Utilities

Information concerning utility coordination and availability shall be maintained within the library.

4.5 Design Plans, Specifications, and Estimates - Reviews and Approvals

Design plans (or drawings), specifications, and estimates (PS&E) provide the construction contract documents which define the system to be deployed. Design plans provide the physical relationships of materials on which the contract is based. Specifications define the quality and types of workmanship and materials required to implement the system. Specifications provide the (minimum) acceptable requirements for system equipment, interfaces, materials, and installation requirements (if necessary) in such a manner to support competitive bidding. Care must be taken to ensure the content of plans and specifications are clear, concise, and consistent and void of redundancy. Content of plans and specifications shall include, but not limited to, the following:

Plans:

- Title sheet
- Summary of quantities
- General notes
- Roadway/Ramp/Interchange/Intersection layout
- Conduit, cable, and controller/processor tables
- Wiring diagrams
- Control Mode/Timing Plans
- Construction design drawings
- Work zone traffic control plan
- Traffic control detail layouts
- Diagram of (underground) utilities
- Standard plans

Technical Specifications:

- General descriptions
- Detailed interface requirements
- Functional and performance requirements
- Physical (material) requirements/characteristics
- Standard component specifications
- Materials to be furnished by the contractor
- Power connection
- Conduit
- Wiring
- Grounding and bonding
- Sealing
- Concrete
- Concrete foundations
- Paint and painting
- Preservation of landscaping
- Removal and replacement of curbs and roadway shoulder
- Disposition of controller cabinet items (i.e., keys, instructions, etc.)

Material/Equipment Specifications:

- System master requirements
- Controller requirements
- Pole assemblies (i.e., pedestal, strain, etc.)
- Signal heads and conductors
- Cabling (i.e., signal, communications)
- Vehicle sensors/detectors
- Communications equipment (i.e., modems, transceivers, multiplexers, etc.)
- Computer requirements
- Software requirements
- Geographic information systems
- Monitors

- Hardcopy devices (i.e., printers)
- Memory storage devices
- Operator consoles
- Closed-circuit video surveillance equipment (i.e., cameras, pan-tilt units, etc.)
- Special software processing (i.e., incident detection algorithms, ramp metering, database management, etc.)

Review and approval of design plans, specifications and estimates shall be conducted by MDOT prior to proceeding with subcontract bidding, system construction / implementation and integration.

4.5.1 Comments

MDOT shall provide timely and specific comments to the project contractor. Comments may be binding or non-binding. Binding comments shall consist of changes or recommendations necessary in order for satisfactory acceptance and approval by MDOT and initiation of subcontract bid preparation, and system construction/implementation and integration. Non-binding comments shall consist of suggestions and guidance applicable to documents which are satisfactory and acceptable in their current state.

4.5.2 Concurrence and Approval

Concurrence and approval of PS&E documentation shall involve approval by MDOT and concurrence from participating project agencies.

5. Construction Management

For this project, construction management shall be conducted by the contractor as part of the awarded contract. This project shall use a modified design/build contracting approach to also include system development, construction/installation, integration, start-up, acceptance, training, and initial maintenance.

5.1 Project Engineer

The project engineer shall serve as the individual responsible for inspection of day-to-day construction activities, witness to acceptance testing, and other technically-oriented duties. In addition, the project engineer shall conduct record keeping of all construction development in accordance with State of Michigan and FHWA requirements. These include review (and approval) of design plans and shop drawings, identification of change orders (including negotiations with MDOT on changes and compensation), and obtaining the necessary reviews and approvals with MDOT and other agencies prior to authorization.

The MDOT project manager shall provide the counterpart point of contact for the project engineer.

5.2 Others on the Construction Management Team

Other disciplines shall support the construction of the system. These include the following utility coordinators, technical specialists (i.e., systems engineers, civil engineers, electrical and hardware engineers, software engineers, field technicians, contract administrators, financial accountants, etc.).

5.3 Involved Entities

Entities involved with this project may include the following:

Public Utilities:

- Detroit Edison Company
- Michigan Bell/Ameritech Telephone Company
- Consumers Power Company
- Various Cable Television Companies (i.e., Continental Cable, etc.)

Law Enforcement Agencies:

- Michigan State Police
- County Sheriff Departments including:
 - Macomb County
 - Monroe County
 - Oakland County
 - Wayne County
- City Police Departments including:
 - Auburn Hills
 - Bloomfield Hills
 - Dearborn
 - Detroit
 - Farmington Hills
 - Ferndale
 - Flat Rock
 - Hazel Park
 - Huntington Woods
 - Lincoln Park
 - Livonia
 - Madison Heights
 - Mt. Clemens
 - Oak Park
 - Pontiac
 - Romulus
 - Roseville
 - Royal Oak
 - Southgate
 - Woodhaven

Other:

Fire Emergency Services

Signal Maintenance

Local Cable Operators

5.4 Utility Coordination/Underground Clearance Process

Underground clearance shall be conducted in accordance with MDOT-approved procedures. These procedures shall apply to, but not limited to, utility coordination, other contractor coordination, and exploratory trenching, and include the following procedures to be carried out by the Contractor (in conformance of Public Act 53):

- Notify the appropriate utility owners a minimum of three full working days (including Saturdays, Sundays, and holidays) prior to beginning excavation in areas where public utilities have not been previously located.
 - MDOT Freeway System agencies
 - MDOT District Maintenance, Freeway Lighting . coordinator (313) 569-3993
 - MDOT Freeway Operations Center, MDOT SCANDI System - (313) 256-9800
 - Public Lighting Department, Lighting and Traffic Signal Cables (Detroit) - (313) 224-0500
 - Michigan Consolidated Gas Company (MICHCON) - (313) 595-1000
 - Call 1-800-482-7171 (“MISS DIG” alert system) - Members will alert utility owners.
- Owners of existing service facilities (within grading or structure limits) will move them to locations designated by the Project Engineer, or remove them entirely from the highway right-of-way.
- Owners of Public Utilities will not be required (by the City/County) to move additional poles or structures in order to facilitate the operation of construction equipment unless it is determined by the Project Engineer that such poles or structures constitute a hazard to the public or are extraordinarily dangerous to the Contractor’s operations.
- No additional compensation will be paid to the Contractor for delays due to material shortages or other reasons beyond the control of the County/City, or for delays on construction due to the encountering of existing utilities that are, or are not, shown on the plans.
- Work stoppages by employees of utility companies which results in a delay of utility revisions on any portion of this project may be considered on the basis for a claim for an extension of time for completion, but will not be considered the basis for a claim for extra compensation or a judgment in contract unit prices.

5.5 Inspections

Inspections shall be conducted through testing, observation, demonstration or analysis of the system or subsystem under inspection. Criteria for inspection shall be defined by corresponding design plans and technical and equipment/material specifications.

5.5.1 Lead Responsibility

Lead responsibility for inspections shall be the project engineer with concurrence from MDOT representative(s).

5.5.2 Other Parties Involved

Other parties involved in the inspection process shall include MDOT representative(s) (at a minimum), and concurring agencies.

5.5.3 Training

Inspection training shall be conducted by the Contractor.

5.6 Design Plans, Specifications, Other Documentation

Design plans, specifications and other documentation shall be developed by the Contractor for review and approval by the MDOT Project Manager. Other documentation includes work plans, schedules, and acceptance test procedures.

5.6.1 Approval/Concurrence Responsibility and Authority

All design plans, specifications, and applicable documents shall be reviewed and approved by the MDOT Project Manager prior to subcontract bid preparation and evaluation, and system construction/implementation and integration, and acceptance testing.

5.7 Change Orders

Change orders shall be prepared when the project engineer determines that design plans, drawings, or specifications need to be revised due to errors or overly constraining requirements.

5.7.1 Approval Hierarchy

The hierarchy for approvals shall consist of the following:

- MDOT Project Manager has final approval authority for all change orders and their cost considerations.
- Contractor Project Engineer has approval authority for identification and preparation of change order and cost considerations documentation.
- Participating Agencies have concurrence authority for change orders which affect operations under their jurisdiction.

5.7.2 Information Requirements for Approvals

Typical information requirements for change orders shall include, but not limited to, the following:

- Change request identification
- Affected document (i.e., design plans/drawings, specification, other)
- Originator
- Nature of change
- Rationale
- Effectivity

- Other documentation affected

5.7.3 Approval Schedule

Approval of change orders shall be conducted within 45 days of receipt.

5.8 Acceptance Testing

Acceptance testing is an integral part of a system's development and operations and should follow successful system integration testing conducted by the Contractor. Acceptance testing shall be conducted at various levels based upon the requirements for development and installation. In general, acceptance testing shall be conducted for equipment and subsystems installed by subcontractors or other service providers.

5.8.1 Test Procedure Development Responsibility

Acceptance testing procedures shall be developed by the Contractor (and approved by MDOT) to verify all physical characteristics and operational/functional and performance aspects of the system, subsystem(s), or components installed by the Contractor, subcontractor, or service supplier. These procedures shall consist of the following types of testing:

- Equipment Checkout Tests. Each major system component shall be tested on an individual basis to verify its operation. This shall include the diagnostic testing of each functional feature of items, such as controller units and sensor electronics, and environmental testing of components and subsystems. Testing can be conducted on a sampling basis, but full testing is recommended for each delivered item.
- System Electrical Tests. Electrical continuity tests shall be conducted to verify conductors satisfy identified specifications. These tests shall apply to each conductor, including spares.
- Computer Software Tests. System software functionality shall be tested to verify the operation and performance of each functional feature.
- System Operational Tests. The installed system shall be tested to verify the overall system's performance and reliability. These tests shall be conducted as the basis for system acceptance by MDOT.

5.8.2 Testing Conduct Responsibility

For the overall system, MDOT shall conduct acceptance testing at the highest level for testing of the installed system. The Contractor may conduct acceptance testing of subsystems and components installed by subcontractors to ensure subsystem/component specifications are satisfied.

5.8.3 Testing Site(s)

Testing facilities shall consist of (but not limited to) controlled Contractor development environments, field locations, and MDOT facilities.

5.8.4 Equipment Required

Any equipment required to conduct testing shall be provided by the Contractor for the duration of the test.

5.9 Claim Procedures

Established State of Michigan procedures shall be maintained in the event Contractor claims.

5.10 Training

Training shall be conducted by the Contractor (or designated entities) to provide the technical skills required to effectively utilize, operate, and maintain all the features and components of the system. Training shall be structured to specifically address the needs of individual levels of MDOT staff. These include management/supervisory staff, system operators, and maintenance technicians.

Training shall be conducted to foster acceptance of the system and promote utilization of all its features.

5.10.1 Types of Training

Training shall be conducted to address the needs of MDOT management/supervisory staff, system operators, and maintenance technicians. Training shall be designed such that cross-training of MDOT staff shall be promoted to the maximum extent possible. Training shall be conducted for three phases: [1] pre-installation; [2] system installation; and [3] post-acceptance/system operations. These phases consist of the following:

- Pre-installation. Pre-installation training offers an early opportunity for MDOT staff to gain familiarity and insight (in an informal environment) into the details and considerations of the system. These include:
 - Equipment configuration
 - System capabilities and features
 - System operations
 - Maintenance support requirements
 - Software programming concepts and design
 - Database types, organization, and preparation
- System Installation. Training during system installation shall provide MDOT staff the opportunity for hands-on experience with the detailed operations and maintenance (preventative/routine and corrective/trouble shooting) procedures for each equipment component.
- Post-acceptance/System Operations. Training after the system has been accepted and the period during extended operations, training manuals, on-line training, and refresher training may be conducted to address personnel cross-training and turnover.

5.10.2 Training Schedule

A training schedule shall be established by the Contractor as part of the scope of work in the deployment of system components.

5.10.3 Training Responsibility/Attendance

The Contractor shall be responsible for conducting system training at facilities selected by the MDOT project manager. Attendance of these training sessions shall include, but not limited to:

- Operations Systems Manager
- Advanced Technology Manager
- System Operators
- System Maintenance Personnel

5.10.4 Training Site Travel

Training shall be conducted within MDOT facilities and the metropolitan Detroit area. Travel for training shall be minimized to preserve operations budgets.

5.10.5 Training Budget Requirements

MDOT training budgets shall be allocated for pre-installation, during system installation, and post-system acceptance. Additional training budgets (in-house or contracted) shall be identified and allocated within the MDOT budgeting process.

5.11 Documentation

System documentation is an absolute necessity for successful system operation. Documentation shall provide sufficient detail to reflect as-build plans and specifications, and fully describe the methods of operations, maintenance, modification, and expansion of the system or any of its individual components. Manufacturer-supplied documentation shall be provided to satisfy these requirements in lieu of specially-prepared material.

5.11.1 Types of Documentation Required

Hardware, software, and control system documentation shall consist of the following (at a minimum):

- Hardware Documentation
 - General Description
 - Theory of Operation
 - Normal Operating Procedures
 - Maintenance
 - Installation
 - Parts List
 - Cable Routing/Wiring Schematic Diagrams
 - Maps and Drawings

- Software Documentation
 - Software Specifications
 - Software Design Descriptions/Narratives (including executive, utility, and library programs)
 - Source Listings
 - Software Programmer/User's Manual
 - Software Rights

- Control System Specifications
 - Control Parameters
 - Timing/Phase Sequences

5.11.2 Submittal Requirements

Submittals of documentation shall be in accordance the minimum standards identified by the Michigan Department of Transportation as listed in the solicitation.

5.11.3 Submittal Schedule(s)

Documentation shall be submitted according to the schedule established by the Michigan Department of Transportation.

5.12 Test Equipment

Test equipment shall be identified for periodic maintenance and tuning, and system diagnostics (trouble shooting).

6. System Integration and Start-up

System integration and start-up usually consist of the period of initial system operation where system operational and maintenance problems are usually experienced due to the full exercise of hardware and any remaining unfamiliarity. Software problems may be identified along with the refinement of the control system and system databases. In addition, operator skills and day-to-day operational skills are developing. Contractor support during system start-up shall be required to ensure smooth transition of the newly installed system.

6.1 System Pick-up Procedures

System pick-up procedures shall be established by the Contractor upon the request of the Michigan Department of Transportation.

6.2 Timing and Database Development

Initial timing and database development shall be conducted prior to system acceptance. This initial development provides the basic parameters to operate the system. Subsequent development

shall be conducted by MDOT operators to tune control parameters and customize database formats. System safeguards to prevent unintentional database damage or corruption may be included. As a minimum, database backups shall be provided and maintained along with the capabilities for updates.

6.2.1 Development Responsibility

Initial database development shall be required by the Contractor for system acceptance. Subsequent development shall be conducted by MDOT.

6.2.2 Database Formats

Existing database formats shall be used whenever possible. If such formats are deemed to be inefficient due to the growth of recurring data, the Contractor shall recommend an alternative format to improve efficiency.

6.2.3 Database Development Schedule

New database shall be developed in accordance with schedules agreed upon by the Michigan Department of Transportation and the Contractor.

6.2.4 Database Types

Database types shall include the following (but not limited to):

- System Inventory Data
- Traffic Surveillance Data
- System Status Data
- Incident Data
- Traffic Control Data
- Dissemination Data

6.2.5 Database Encoding and Control Timing Test

The Contractor shall be responsible the development and execution of database encoding and control timing tests. Tests shall be conducted to verify and validate the integrity of the encoding mechanization.

6.2.6 Control Timing Test Review

Control timing tests shall be conducted by the Contractor to ensure that specific control timing constraints have been maintained.

6.2.7 Install Encoded Databases

Any newly developed encoded databases shall be installed by the Contractor.

6.2.8 Evaluation Control Timing

The Contractor shall be responsible for evaluation tests which are conducted to validate control timing.

6.3 Acceptance Test

After installation and debugging of all central control equipment, local controllers, vehicle sensors, communications links, and other system hardware and software elements, the system shall be required to satisfactorily complete a thirty (30) day period of acceptable operation.

6.3.1 Exercise System Functions

The intent of this System Acceptance Test is to demonstrate that the total system of hardware, software, materials and construction is properly installed; free from identified problems; complies with the specifications; and has exhibited the stable, reliable performance level required for the management of traffic. The System Acceptance Test shall fully and successfully demonstrate all system functions using live vehicle sensor data and controlling all system-controlled components.

6.3.1.1 Action in the Event of Hardware Failure

Failure in any hardware item during the test period with the exception of expendable items such as bulbs and fuses, shall necessitate restarting the 30-day test period for its full 30-day duration for that item after its repair.

6.3.1.2 Action in the Event of Software Failure

Any failure of system software, or discovery of a software deficiency which causes a system malfunction, or discovery of software operation which is not in compliance with the specifications, shall cause the 30-day test to be halted and repeated in its entirety for the software element, after correction of the software problem. If no further software problems are discovered, and if no software problems are introduced, as a result of the correcting the initial deficiency, the Project Engineer may reduce the restarted test period for software to not less than 15 days. In no case shall the total test period be reduced under 30 days.

6.3.1.3 Uncertain Causes of Failures

In the event a problem is discovered for which it is uncertain whether the cause is hardware or software related, the 30-day test restart and repeat shall follow the procedure in paragraph 6.3.1.2 for software. If the failure is induced by an interfacing subsystem or component that is not part of the system under test, but is supporting the test, the test period shall be suspended and the subsystem or component shall be replaced and independently checked. Once the subsystem or component has passed independent test, the subsystem or component shall be re-integrated and tested as part of the system per paragraph 6.3.1.5.

6.3.1.4 Persistent Intermittent Failures

No intermittent hardware, software, communications, or control operation, or other malfunctions not related to a specific hardware or software malfunction shall be permitted to persist during the test period. If such problems are encountered, the test shall be suspended until the problem is corrected.

6.3.1.5 System Shutdown for Testing/Correction

While it is the intent that the system be fully operational during the entire System Acceptance Test, the possibility for system shutdown for purposes of testing and correcting identified deficiencies is acknowledged. During any period that the system operation is restricted or limited in any way as a result of testing, the 30-day System Acceptance Test shall be halted and shall not continue until a period of 72 to 168 hours of successful performance, as determined by the MDOT Project Manager, has proven that any correction or modifications made are valid, the problem corrected, and no new system problem or deficiency created as a result of the change. Diagnostic testing which does not result in changes to system hardware or software shall result only in the loss of acceptance test time.

6.3.1.6 Maximum Down Time

Total system downtime in excess of 72 hours during the 30-day test period shall cause the system Acceptance Test to be restarted. System downtime is defined as a condition which, due to central control hardware, software, or communications equipment malfunctions, causes the system to operate in a standby mode, causes the central system to cease operations, or causes any subsystem to revert to its locally-generated standby timing program.

6.3.1.7 Documentation Updates

All system documentation having errors, omission, or changes which may have been detected or occurred as a result of system modifications or other reasons during the 30-day test period, shall be corrected and resubmitted before final system approval is granted.

6.3.2 Contractor Assistance

The Contractor shall assist in all System Acceptance Test activities.

6.4 System Performance Evaluation

Final system acceptance shall not be granted until the level of performance for each hardware item and for system software as defined by System Acceptance Test has been reached, and all other contractual elements (excluding operational support and maintenance) have been met to the reasonable satisfaction of the MDOT Project Manager.

6.4.1 Data Gathering

The Contractor shall be responsible for the collection of data for evaluation.

6.4.2 Data Analysis

The Michigan Department of Transportation shall analyze the data obtained during the test period for independent evaluation.

6.4.3 Draft Evaluation Report

The Contractor shall review the test data collected during the test period and generate a final report summarizing the results of the System Acceptance Test. The report shall include the system test configuration, acceptance test procedures, a record of anomalies experienced during

the test period, a record of failures during the test period, and a record of corrective actions taken during the test period.

6.4.4 Review Draft Evaluation Report

Michigan Department of Transportation shall review the result of the final report and provide comments within 30 working days.

6.4.5 Acceptance of Final Report

The Contractor shall incorporate or disposition (per MDOT) comments to the final report and resubmit the final report within 30 days of receipt of comments. MDOT shall accept the final report after all comments have been incorporated or dispositioned.

6.4.6 Final Report Distribution

MDOT shall define the requirements for Final Report Distribution.

6.4.7 Public Brochure

Any public brochures or advertisement by the Contractor of the early deployment system shall require prior written approval from the Michigan Department of Transportation prior to release.

7. System Operations

Detroit Freeway Operations Unit (DFOU) through the operations center provides benefits to the motorist by: 1) Quickly identifying or verifying lane blocking incidents through the detection loop, surveillance cameras, Michigan Emergency Patrol (MEP) reports, or the State Police Dispatcher. With accurate information, quick response and removal of the incident relieves congestion and the potential for additional incidents to occur, 2) Operating traffic signals on entrance ramps of freeways, called ramp meters, which break up platoons of vehicles entering into an already slow peak freeway. This prevents additional, “Stop and Go” waves from occurring which often causes accidents, 3) Provide accurate traffic information to motorist via the changeable message sign system (CMS). This information could assist additional congestion by providing information to motorists so they may divert away from the problem.

Detroit Freeway Operations are managed from the MTC located in the Greyhound Bus Building at 1050 6th Street, 2nd Floor, Detroit, MI. All freeway operation system functions are managed from the operations center.

The following describes the freeway operations capabilities to be provided by the new system. The purpose of this identification is to define the corresponding system functions required to support freeway operations. In addition, distinction between those functions or tasks performed by DFOU personnel and those performed by the system can be made. From this identification, these operations can be distilled into requirement components (i.e., interfaces, functional processes, operational performance, system characteristics, system processing resources, and logistical support), to form the basis on which system/subsystem designs and implementations take their operational form; i.e., hardware, software, and support components.

The system supports three major operations (with major subtasks). These include the following:

- Traffic Management Operations
 - Manage Recurrent Congestion
 - Facilitate Incident Management

- Traveler Information Management Operations
 - Collect Traveler Information
 - Manage Traveler Information
 - Disseminate Traveler Information

- System Performance Monitoring Operations
 - Monitor System Performance
 - Perform Malfunction Management

Traffic Management Operations

Traffic management encompasses a spectrum of DFO activities to minimize traffic delays and congestion; while providing improved safety, and effective utilization of roadway capacity; thus, promoting economic productivity and growth, and operational efficiency of the freeway network. Traffic management is accomplished through surveillance of mainline and surface street vehicle flow and adjustment of traffic control parameters and sequences to balance, optimize, or reroute/divert traffic flow on the metropolitan Detroit freeway network. The system manages traffic flow for both recurrent (routine congestion) and non-recurrent (incident) traffic conditions.

Manage Recurrent Congestion

Routine, recurrent traffic congestion is managed through mainline and entrance/exit ramp surveillance, ramp meter control, changeable message signing and information delivery, and area-wide coordination. Surveillance sensors collect raw traffic flow data (i.e., vehicle counts {for volume} and timing gate time differentials (for speed)) for processing into operational MOE's (average occupancy {% time detector is actuated by a vehicle}, total volume {vehicles for a given period of time}, and average speed {mph}). These MOE's are used by the system to adjust entrance ramp metering or other flow controls (e.g., moveable barriers), and display and report the freeway network status to DFOU personnel through graphical displays and reports. The freeway network status is used in conjunction with information databases (i.e., CMS and HAR/AHAR) for message delivery to motorists, other TOCs, commercial dispatchers/fleets, and other roadway users via CMS, HAR/AHAR, and electronic data links. Freeway network status is overlaid, in graphical form, on an enhanced version of the current GDS map display for the entire metropolitan Detroit freeway network. These enhanced map displays include advanced graphical user interfaces (GUIs) which integrate system/subsystem-operator interfaces, and capabilities to predict traffic flow patterns (based on road closures and construction, scheduled events and activities); and calculate appropriate traffic control strategies.

- a. The current GDS platform could potentially serve as an intermediate host in parallel with an advanced GUI host for the expanded system. The advanced GUI will ergonomically integrate system displays and operator control interfaces for most system functions (traffic management operations, traveler information management operations, and system performance monitoring operations) into single operator work areas. Some tasks may still require manual attention. Operators will have the capability to cancel or override any operator-initiated commands at any time before system execution.
- b. For recurrent congestion, the system will provide the capability to “smooth” traffic flow through ramp metering, variable speed recommendations, information to motorists (i.e., congestion forewarning, approximate delay time, etc.). The system will with these management controls in response to the recurrent excessive volume demands on the roadway’s capacity.
- c. For corridor traffic volume demands resulting from scheduled events and diversions due to planned work zones, the system will provide the capability to predict flow patterns and calculate traffic control strategies and tactics in anticipation to the increased demand or the presence of work/construction zones. These strategies and tactics include alternate routing, speed recommendations, lane control, roadway signing and ramp metering.

Facilitate Incident Management

Incident Management consists of a series of coordinated activities performed by various freeway operations, law enforcement, emergency service, public, private, and government agencies. Incident Management involves location detection, verification, response, removal, traffic management, and dissemination of incident information to the general public. The system provides the technological infrastructure on which DFOU personnel can effectively detect, verify, determine, respond and coordinate clearing activities, provide quick and accurate roadway incident information to motorists, and provide incident record keeping on a 24-hour, 7-day/week basis. Features to automate operator activities and tasks are facilitated by advanced GUIs. Common operator tasks are organized in a manner to minimize physical operator movement throughout the DFOC.

Application of the MDOT Incident Management Plan for Metropolitan Detroit will be supported by the system to the maximum extent possible to promote incident management coordination, reduce travel delays and potentials for secondary incidents, and improve travel safety and air quality (through minimized delays and reduced emissions). Principal incident management activities include the following:

- Incident Detection
- Incident Verification
- Response Formulation and Coordination
- Removal Coordination
- Incident Traffic Management
- Incident Information Dissemination (to motorists and others)

Incident Detection

The system facilitates detection of incidents through monitoring and processing of traffic flow MOEs (i.e., occupancy, volume, speed) along mainline corridors and interchanges. That is, while the system calculates, monitors, and displays the different levels of traffic flow on the freeway network, an MDOT-approved incident detection algorithm measures the flow data against pre-determined thresholds and compares them to incident condition parameters. If traffic flow conditions indicate that there is an incident, the system identifies the suspected incident location (to the nearest 1/3 mile) on status display(s) and issues an alarm to the operator. The status display(s) identifies 1/3 mile segments for each instrumented mainline corridor.

Incident Verification

The system supports facilitation of incident verification tasks by providing the operator with multiple incident-reporting sources. These sources include:

- a. Identification and control of appropriate CCTV camera(s) (if available).
- b. Verification by facilitating incident correlation from multiple sources via the traffic surveillance subsystem, electronic links, or manual reports (i.e., MSP dispatcher, city police, MEP data, Metro Traffic Control, MDOT field/road crews, courtesy or service patrols, and other sources).
- c. Once the operator verifies that there is an incident (via CCTV, MSP) and declares the incident (through procedures), an electronic form is displayed and used for entries into an incident log. If correlation data is available (i.e., MEP, Metro Traffic, etc.), correlation entries will also be made available.

Response Formulation and Coordination

The system supports facilitation of incident response tasks in accordance with the approved Incident Management Plan for Metropolitan Detroit. These tasks include:

- a. If the MSP is not aware of the incident, the system offers notification assistance. If a video image is also available, the system configures appropriate video links for the MSP (or Metro Traffic Control, or other incident reporting services).
- b. If the cause of the incident can be determined, additional information is offered to the MSP (or appropriate removal agencies {i.e., courtesy patrols, towing companies, etc.}) so that appropriate removal efforts can be identified.

Removal Coordination

The system also supports coordination and execution of incident removal tasks based upon the incident cause. These tasks potentially include:

- a. Coordination with the MSP, or appropriate removal agencies, for any additional support to on-site authorities.

- b. If the cause of the incident consists of roadway debris, the system provides for notification and dispatch of MDOT agency field/road crews for removal.
- c. Provisions to coordinate and report the clearance of an incident.

Incident Traffic Management

The system provides for traffic management around incident locations by facilitating deployment of incident information to upstream motorists and activation and metering of local upstream ramps, if necessary. In addition, the system also performs the following tasks:

- a. Identification of the appropriate Incident Management Plan alternate routes (based upon the local area corridor status). Alternate routes are identified through the following priority identification criteria in accordance with MDOT criteria, AASHTO and MMUTCD engineering requirements, standards, and guidelines. Principal priority criteria (in descending order) include:
 - Freeways without service drives.
 - Freeways with service drives.
 - Selected arterial surface streets.
- b. Information exchanges with arterial TOCs to adjust alternate route signal timing plans for selected arterial alternate routes.
- c. Identification of the appropriate upstream CMS locations and corridor HAR/AHAR transmitters, and selects and displays candidate CMS and/or HAR/AHAR message options to the operator. Once the operator selects and commands message deployment, the system configures the appropriate message packets, and issues the appropriate commands to the target CMS(s) or HAR/AHAR, or other ATIS functions.

Incident Information Dissemination

The system facilitates compilation of more detailed incident data, records the deployed information (i.e., CMS, HAR/AHAR, etc.) into an incident log, and provide other operator-selectable information dissemination options (i.e., fax, inter-TOC electronic links, freeway network status displays/kiosks, call-in traffic messaging systems, MEP and Metro Traffic Control communications links, etc.). Sources of incident data include:

- MDOT traffic surveillance and control system
- Michigan State Police/local city police
- MDOT field/road crews
- MEP reports
- Metro Traffic Control reports
- Manual observations from CCTV surveillance
- CB channel monitoring (i.e., CB channel 9)

Throughout activities surrounding the management of incidents, the system provides a graphical user interface (GUI) which controls and interfaces nearly all operator functions into single-operator position(s). These functions potentially include “hands-free”, wireless telephone, radio communications, and other features to minimize operator transit within the DFOC.

Perform Traveler Information Management Operations

To better serve travelers using the metropolitan Detroit freeway network, traffic status and road condition information provide the motoring public informative benefits for travel decision making and route selection. Information availability leads to a more informed roadway user and potentially improves travel safety, economic productivity and efficiency, and improved environmental air quality. This service is provided in the form of travel-related information collection, management, and dissemination to freeway network users. The system supports this service through traffic surveillance and information management with technologies and techniques which provide timely and accurate information delivery to freeway users and interfacing agencies (public, commercial and private).

The system collects travel-related information from traffic surveillance capabilities and external providers (i.e., MSP dispatcher, MEP printouts, MDOT field units, other TOCs and other interfacing entities). This information includes freeway network status, roadway conditions and closures, weather conditions, and other relevant travel or traffic-related information. Relevant information is integrated, or fused, into an organized information database for monitoring, display and dissemination to roadway users and requesting entities. Dynamic traveler information dissemination techniques and technologies include roadway CMS, HAR/AHAR, video images, graphic displays, TV and AM/FM radio broadcasts, facsimile and other messages, dial-up telephone service and information delivery through third-party providers. The system provides the capabilities to collect, manage, and disseminate all relevant traffic-related information to users of the metropolitan Detroit freeway network.

Collect Traveler Information

The system collects accurate information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, work zone/construction conditions, and other relevant travel or traffic-related information for database management. The system collects this information from both infrastructure and non-infrastructure-based sources. For the metropolitan Detroit area, traffic information is generally collected from (but not limited to) the following sources:

- MDOT traffic surveillance and control subsystem
- Michigan State Police
- Local Police (cellular calls)
- Metro Traffic Control (cellular calls)
- Michigan Emergency Patrol (CB and cellular calls)
- MDOT field/road crews

- Other TOCs
- Roadway travelers/general public (cellular call-ins)
- State and local public works agencies
- Visual sighting by traffic reporting aircraft
- CB radio monitoring

Manage Traveler Information

The system integrates, or fuses, information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway conditions (i.e., work zones), and other relevant travel or traffic-related information collected from multiple sources into an organized database. Traveler information is organized (as a minimum) into four databases: Incident/Advisories; Freeway Network Status; Historical Data; and Roadway Conditions.

As with any modern information processing system, the value of the information contained on the system potentially becomes a target for unauthorized access or malicious activities. To prevent these activities from causing irreparable loss of data or service, the system monitors and controls information access to ensure data and system integrity are maintained.

DFOU personnel manage this information through administrative tasks; such as, information entry/input and archiving, database management, access management, and information system monitoring, troubleshooting, and built-in test (BIT)/built-in test equipment (BITE) diagnostic capabilities.

Disseminate Traveler Information

The system provides open and broad dissemination of traveler information through a wide variety of channels and techniques to promote travel safety and traffic flow management. Information dissemination to freeway network users can be achieved with a variety of technologies. Some of these technologies are included below:

- Roadway Signing (i.e., CMS, portable CMS, variable speed signs, fixed signs)
- Electronic Links (i.e., data links, fax service)
- Radio Frequency Broadcast (HAR/AHAR, broadcast radio (AM/FM), private radio (amateur), FM subcarrier, RDBS)
- Passive Visual Aides (printed material, broadcast TV, CATV)
- Passive Information Services (broadcast TV, remote traffic status displays – passive kiosks, broadcast radio (AM/FM))
- Interactive Information Services (call-in message service, PCS, public/office kiosks, in-vehicle guidance, computer bulletin board service (BBS), CB radio, amateur radio, modem data link, mobile data terminal)
- Third-party traffic reporting services (i.e., Metro Traffic Control, broadcast TV, CATV, and radio)

The primary objective for information dissemination is to inform freeway network users of travel and traffic conditions, preferably, to those motorists who are directly affected and can benefit from the information by altering their travel routes and/or departure times. When understanding the behavior that not all users opt to alter their travel routes even though the information is delivered, the system must still provide a level of service to achieve overall freeway network management improvements for travel safety and traffic flow facilitation. Potential users include the following:

- General Public (through broadcast TV/radio, CATV, CMS, HAR/AHAR, kiosks in major commercial centers, etc.)
- Metro Traffic Control
- Michigan Emergency Patrol
- Law enforcement/emergency services (i.e., police, fire, medical, HAZMAT, others)
- County Road Commissions/Department of Roads
- Other Traffic Operations Centers
- American Automobile Association (AAA) of Michigan
- Greyhound Bus Lines
- Detroit Department of Transportation
- Smart Regional Transit Bus
- United Parcel Service
- Commuter Transportation Service
- Other fleet services
- Third-party traffic reporting services (i.e., local broadcast TV/radio, CATV, etc.)

System Performance Monitoring Operations

Monitoring of system performance and system/subsystem operations is performed through on-line performance and status interrogating, health checks, and operator-commanded requests. System malfunction monitoring includes all system and subsystems functions where integrated diagnostic capabilities can identify abnormal operating states to the replaceable component level. Reports which indicate the status of functional parameters of the system or any malfunctioning subsystem component(s) are available upon operator request. These include performance reports, daily tallies, malfunction/failure logs, repair orders, etc.

Monitor Systems Performance

Monitoring of system operations provides an on-line performance assessment of MOEs for the metropolitan Detroit freeway network. This capability provides an overall performance view of the traffic control system strategies and tactics, and identifies any areas which need specific operator attention. On-line MOEs include corridor throughput/volume flow, flow speed, delay time, total travel times, total minute-miles of congestion, and other measures. Through data reduction, other MOEs (e.g., accident rate reduction, number/percentage of stopping flow, etc.) can be derived to further assess system performance. Single-position operator workstations provide DFOC personnel the capability to operate and monitor system operations and performance.

Perform Malfunction Management

A system malfunction management capability provides the operator with on-line system monitoring, diagnostics, and record keeping to determine the extent of system malfunctions and failures. All system or subsystem functions provide a level of status which identifies their health. When a malfunction or component failure occurs, the system or subsystem status monitoring function determines the nature of the problem and isolates the level (to the replaceable component level), generates a malfunction or failure message, and displays an indicator at the DFOC to capture the operator's attention. Capabilities to interrogate and diagnose system/subsystem components are also operator-commandable from the DFOC or local on-site. Record keeping of malfunctions and repairs are integrated into the system through a maintenance log. Information contained in the log include system/subsystem failure reports, work orders, maintenance forms, repair status and disposition.

7.1 System Operators and Responsibilities

An operator performs many tasks that are essential to the Metropolitan Detroit ATMS/ATIS System's performance. The operator is at the center of a large-scale traffic surveillance and control and information processing system that is used to promote smooth flowing freeway traffic.

The operator plays an intricate part of this system. The operator must know the functions of the components, know when components fail, and how to request repairs from DFO's dedicated technical staff. The operator must listen and recognize incidents at freeway locations from the traffic data sources: System graphics display, MEP printout, state police dispatch radio, and from personnel in the field. After possible verification from the closed circuit TV's (CCTV), alert the State Police and M.E.P. (if they are not aware of the incident). Where possible, the operator must inform the motorist of traffic problems on the changeable message signs in a timely manner. In addition, the operator maintains logs, performs studies, collects data, substitutes with secretarial duties, and acts as a radio system dispatch for field technicians.

A freeway surveillance operations center without an operator present at all times, cannot function properly. In order for DFOU to provide the best service possible, the operations center must always be occupied by an operator during regular working hours. This is of course, with prudent discretion. (except for special occurrences such as when there is only one operator at the desk, they can leave the desk to distribute phone messages, going to the restroom, etc, for a minimal time without abuse). MEP printouts, state police dispatch information, radio call from field technicians or incidents can occur at any random moment. Therefore, it is imperative the operation room is covered at all times.

General operator responsibilities include:

- Incident Detection
- Failure Monitoring
 - System Failures
 - Cable Failures
- Daily Tally
- Ramp Metering Operation

- CMSS Operation
- Radio Responding
- CRT Functions
- Other Responsibilities:
 - Secretarial Duties
 - Desk Coverage (hours)
 - Special Studies
 - Others
- System Failure
- Emergencies

7.1.1 Operations Staff Required (Assigned and Reserve)

Operation staff requirements for the early deployment system shall consist of the following, as a minimum:

- Systems Manager
- Operations Supervisor
- System Operators (Quantify of 2 for each shift)
- Operations Systems Engineer
- Operations Systems Engineering Support

7.1.2 Operations Staff Qualification Requirements (by Positions)

- Systems Manager - Degreed Civil Engineer with a minimum of 10 years experience in operations, budgeting, and scheduling
- Operations Supervisor - Degreed Civil Engineer with emphasis on Traffic Operations
- System Operators - High School Graduate with traffic operations experience
- Operations Systems Engineer - Degreed engineer with a minimum of 10 years of computer science experience to maintain system operations software and hardware
- Operations Systems Engineering Support - A minimum of an Associate degree with 2 years experience with computer software and hardware

7.1.3 Operations Staff Recruitment (Schedule)

The Michigan Department of Transportation shall develop a staff recruitment schedule to fill un-staffed positions. Operations center shall be fully staffed by the time of system acceptance test.

7.1.4 Operations Staff Training

Operations staff training of the newly deployed system shall be provided by the Contractor in accordance with the terms and conditions of the design/build agreement. If additional training is required, additional training courses shall be negotiated.

7.1.5 Operations Working Hours

The Operation Center shall operate between the hours 6:00 AM and 7:00 PM weekdays.

7.1.5.1 Operations Working Hours for Special Events and Emergencies

The Operation Center shall operate between the hours 6:00 AM and 7:00 PM weekdays and any additional hours to cover special events and emergencies.

7.2 System Timing Plan and Control Strategy Updates

The Operations Systems Engineer shall be responsible for identifying the need for system timing plan and control strategy updates.

7.2.1 Traffic Flow Analysis and Optimization

The Operations Systems Engineer shall be responsible for conducting traffic flow analysis with the aid of the Operations Supervisor. Analysis shall be conducted to identify areas which are in need of specific optimizations.

7.2.2 Timing Plan/Control Strategy Development

The Operations Systems Engineer shall be responsible for timing plans/control strategies with the aid of the Operations Supervisor.

7.2.3 Encode Timing Plans/Control Strategy

The Operations Systems Engineer shall be responsible for the encoding of timing planed and implementation of control strategies.

7.2.4 System Tuning

System Tuning shall be conducted by the Operations Systems Engineer whenever necessary to maintain system performance requirements.

8. Systems Maintenance

MDOT shall provide system maintenance through in-house staff and contracted services. Based upon maintenance requirements specified by system documentation, MDOT shall conduct routine maintenance (preventative) and remedial (corrective) maintenance services. The system incorporates maximum use of standardized, modular, commercial-off-the-shelf (COTS) products and technical services. Standard is defined as modular products and technical services which provide a service function through industry-standard interfaces. The system supports maintainability factors and constraints associated with a system maintenance program, including OEM/licensed vendor technical support, funding, budgeting, and staffing resources. These factors provide general requirements for a system maintenance concept, types of maintenance, and maintenance services.

The system supports a modular maintenance concept. The system shall incorporate technologies, equipment, components, and subsystems which support modular designs for ease of maintenance and accessibility by MDOT maintenance personnel or contracted maintenance service providers.

8.1 Types of Maintenance

MDOT shall provide multiple functional and system maintenance categories corresponding with different maintenance levels. Functional maintenance consists of activities associated with functional operation of the system (i.e., recurring database updates, timing plan updates, etc.). System maintenance consists of activities associated with system hardware and software maintenance and remedial repair actions.

For hardware, three levels of maintenance priority are addressed: (1) remedial maintenance to restore operations due to equipment malfunctions and failures; (2) preventive maintenance to minimize the probability of failure during the product design life; and (3) modification/reconstruction maintenance to remedy manufacturing or design flaws or to incorporate hardware improvements to enhance overall equipment characteristics and performance.

For software, a continuous level of maintenance shall be performed to maintain, improve, and enhance system operations. System software shall incorporate, as a minimum, the following characteristics to minimize software failures and problems, and reduce their impact to manageable proportions.

- Employ verified or proven software packages
- Utilize software packages which are written in a compiler-level language
- Complete set of accurate software documentation, including user's manuals and source listings

8.1 Contract Maintenance

The system shall incorporate commercial-off-the-shelf (COTS) modules, equipment, components, and subsystems that can be maintained through MDOT maintenance organizations or alternative maintenance approaches whereby maintenance tasks may be performed through contracted services.

8.1.1 Development of Specifications

MDOT shall identify and determine which maintenance tasks are to be performed in-house and contracted to maintenance service vendors.

8.1.2 Specification Review Process

MDOT shall review and approve maintenance services specifications for those aspects of system maintenance which will be contracted.

8.2 Agency Maintenance Staff

8.2.1 Maintenance Staff Required (Assigned and Reserve)

The following staff shall be a minimum to maintain the system:

- Maintenance Supervisor
- Maintenance Lead
- Maintenance Technician (5)

8.2.2 Maintenance Staff Qualification Requirements (by Position)

- Maintenance Supervisor - Minimum of Associate degreed with a minimum of 10 years technician experience and a minimum of 5 years experience with incident management, communications, and traffic control devices
- Maintenance Lead - Minimum of Associate degree with 5 years experience with incident management, communications, and traffic control devices
- Maintenance Technician - Minimum of an associate degree with 2 years experience in computer hardware, test equipment, incident management devices, communications, and traffic control devices

8.2.3 Maintenance Staff Recruitment (Schedule)

The Michigan Department of Transportation shall develop a staff recruitment schedule to fill un-staffed positions. Operations center shall be fully staffed by the time of system acceptance test.

8.2.4 Maintenance Staff Training

Operations staff training of the newly deployed system shall be provided by the Contractor in accordance with the terms and conditions of the design/build agreement. If additional training is required, additional training courses shall be negotiated.

8.2.5 System Spares Inventory

The Contractor shall recommend the level of system spares inventory based upon the life cycle and availability of the procured hardware.

9. Overall Schedule of System Process

The system deployment schedule is shown in Figure 9-1. Maintenance funding requirements are shown in Table 9- 1.

MDOT Early Deployment of ATMS/ATIS

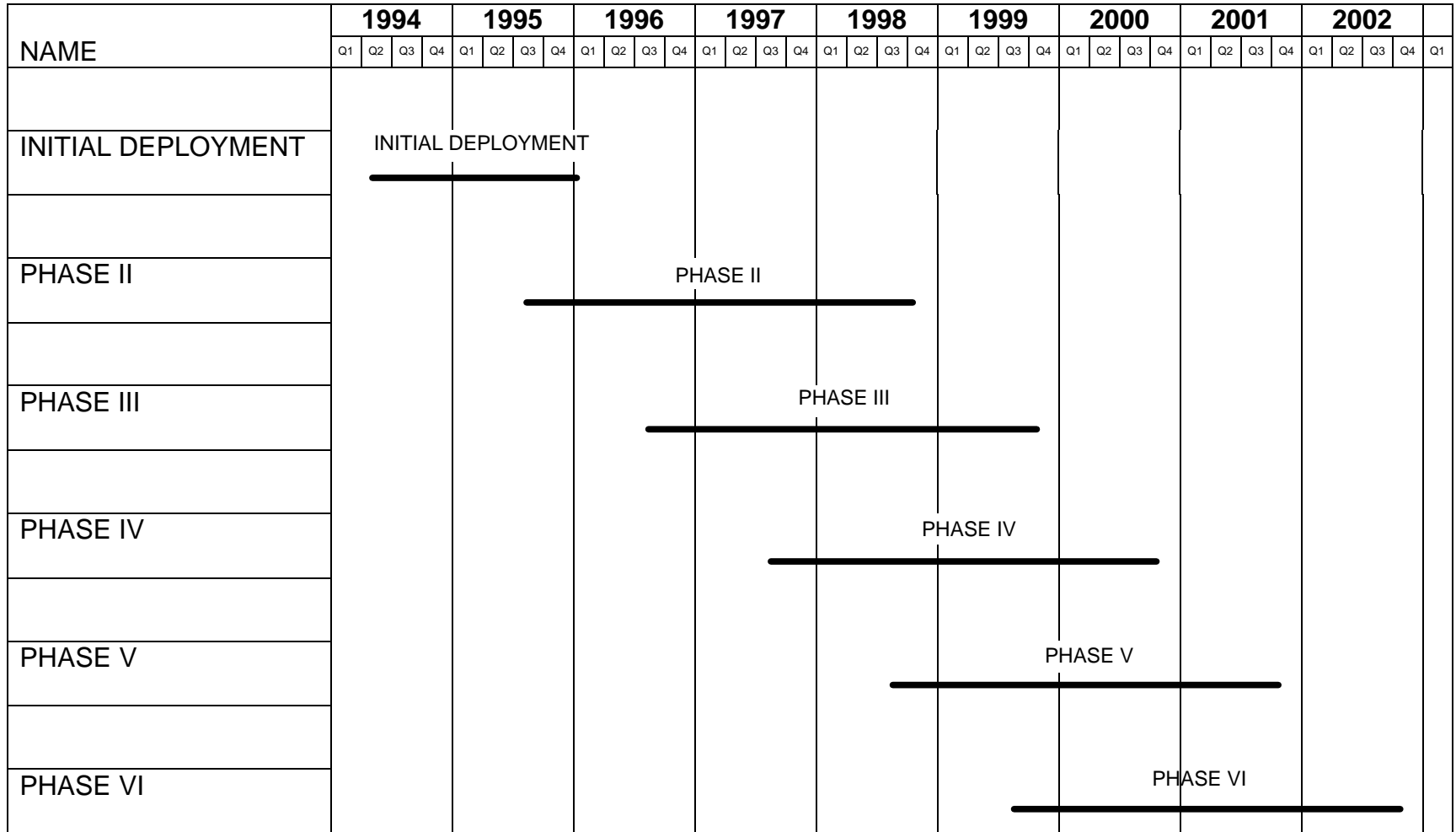


Figure 3-5. Phased Deployment of ATMS/ATIS Schedule

Table 9-1. Phased Deployment Cost Breakdown

Phase	Corridor Segment	Length	Deployment Cost	Sys. Integ./ Civil Design	Segment Total	B/C Ratio**	Phase Length	Cost of Phase	Start Date	Complete Date
Initial	I-75 (I-94 to 9 Mile Road)****	7.4	\$4,431,227	\$921,495	\$5,988,062	16.5	40.5	\$15.3M	5/1/94	11/1/95
	I-75 (9 Mile Road to Pontiac)	19.9	\$6,968,881	\$1,509,115	\$8,477,996	3.2				
	I-75 M-59	3.0	\$171,362	\$66,775	\$238,137	0.9				
	I-696 (US24 to I-75)	10.2	\$456,566	\$173,025	\$626,591	7.6				
II	I-75 (I-94 to 9 Mile Road)***	7.4	\$43,049	\$13,355	\$56,404	-	59.1	\$28.8M	10/1/95	10/1/98
	I-75 (I-94 to I-375)*	1.0	\$99,892	\$40,065	\$139,957	-				
	I-696 (US24 to I-75)***	10.2	\$5,605,589	\$1,028,335	\$6,633,924	-				
	I-94 (Wyoming to Moross)*	13.6	\$1,281,836	\$280,455	\$1,562,291	-				
	I-696 (I-75 to I-94)	9.8	\$6,688,506	\$1,308,790	\$7,997,296	6.0				
	I-696 (I-96 to US 24)	9.1	\$5,184,276	\$1,055,045	\$6,239,321	6.4				
	M-10 (Greenfield to I-696)	6.0	\$3,664,359	\$747,880	\$4,412,239	7.9				
	Davison (M-10 to I-75)	2.0	\$1,522,676	\$280,455	\$1,803,131	11.1				
III	I-275 (M-14 to M-102)	7.5	\$4,977,997	\$988,270	\$5,966,267	5.3	46.4	\$26.4M	10/1/96	10/1/99
	I-96 (I-75 to I-275/M-14)	19	\$11,772,071	\$2,443,965	\$14,216,036	5.4				
	I-75 (9 Mile Road to Pontiac)***	19.9	\$5,150,888	\$1,108,465	\$6,259,353	-				
IV	M-39 (I-75 to M-10)	10.5	\$7,884,065	\$1,562,535	\$9,446,600	7.5	51.5	\$27.0M	10/1/97	10/1/00
	M-10 (Greenfield to Jefferson)*	17.0	\$1,012,847	\$240,390	\$1,253,237	-				
	I-375*	1.0	\$99,892	\$40,065	\$139,957	-				
	I-94 (Moross to M-19)	23.0	\$13,418,070	\$2,751,130	\$16,169,200	1.8				
V	I-94 (Wyoming to I-275)	16.0	\$9,974,466	\$2,029,960	\$12,004,426	2.7	45.9	\$33.2M	10/1/98	10/1/01
	I-75 (I-96 to I-275)	29.9	\$17,543,792	\$3,685,980	\$21,229,772	2.0				
VI	I-275 (I-75 to I-96/M-14)	29.0	\$17,065,094	\$3,445,590	\$20,510,684	0.8	43.8	\$30.2M	10/1/99	10/1/02
	M-59 (BR-24 to M-53)***	14.8	\$8,080,877	\$1,656,020	\$9,736,897	-				
\$133,095,278								\$161.1M		

* Existing instrumented system. Augmentation of functionality as required.

** Benefit/Cost (B/C) ratios reflect full deployment of IVHS technologies in each corridor.

*** "Backfilling" of system components which were not deployed during the initial deployment phase.

**** Includes non-recurring system design and MTC equipment

10. Commitment to Operations Plan

With adoption of this operational plan, the Michigan Department of Transportation is committed to uphold the detailed plan as described in this document. Deviations of this plan shall will not be taken lightly. Each change request will be vigorously reviewed to determine if circumstances or advances in technologies, or newly adopted procedures. When circumstances change, this Operations plan shall be revised accordingly and resubmitted to all involved entities for review.

APPENDIX - III

MEMORANDUM OF UNDERSTANDING

For The Early Deployment of Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) in Metropolitan Detroit

THIS MEMORANDUM OF UNDERSTANDING entered into by and among the Michigan Department of Transportation, Wayne County, Macomb County, Oakland County, Michigan State Police, and the United States Department of Transportation, Federal Highway Administration (FHWA), sets forth mutually agreeable terms and documents their intent to engage in a cooperative effort for the early deployment of an Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) for Metropolitan Detroit freeway corridors.

WITNESSETH:

WHEREAS, the parties to this Memorandum of Understanding are concerned with making more efficient use of existing facilities through the application of advanced traffic surveillance, control, and motorist communication systems to improve the efficiency and quality of transportation along Metropolitan Detroit freeway corridors, and

WHEREAS, the parties to this Memorandum of Understanding concur in and support the following overall, basic objectives of the ATMS/ATIS facility: a) to improve traffic operations by real-time provision of routing information, incident detection and management, ramp access control, and emergency and other motorist aids, b) that the design and operation of the system shall be predicated on integration of the functions so that all aspects of the system are operated in concert; c) that the ATMS/ATIS facility shall be operated to optimize the person and goods flow of the entire facility (without, however, excessively penalizing any one part of the system in favor of any other part), and

WHEREAS, the parties to this Memorandum of Understanding, furthermore, desire to promote the implementation of such a facility to solve existing operational problems, to serve as a demonstration of what can be done, to serve as a National training ground, and to provide a facility on which research and development testing can be performed to advance the state of the art.

NOW, THEREFORE, it is understood between the parties that:

1. The Michigan Department of Transportation, Wayne County, Macomb County, Oakland County, Michigan State Police, and FHWA will expedite all activities which are required of the appropriate jurisdiction for completion of the early deployment project (subject to the availability of funds) and to provide data required, within their ability; this would include cooperating with the Michigan Department of Transportation prime contractor, as necessary, to permit the contractor to carry out his tasks under the early deployment contract.

2. All parties will make a reasonable effort to come to an agreement on any question within a time period that will be short enough to assure the furtherance of the general objectives of the ATMS/ATIS facility and of the spirit of cooperation evidenced in the creation of this Memorandum of Understanding.
3. A Steering Committee will be established to expedite and coordinate the activities involved in, and review, approve, and evaluate the plans and the progress of, the overall ATMS/ATIS project. The Steering Committee shall consist of one member from each of involved parties.
4. With respect to the ATMS/ATIS facility, any public statements, press or media releases, etc., shall give appropriate and adequate recognition to the respective roles and contributions of all agencies involved. No dissemination of data or results generated under this Memorandum of Understanding shall be made by any party of its contractors without the approval of the Michigan Department of Transportation.

In signing this Memorandum of Understanding, the undersigned recognize that the complexity of the project and the necessary involvement of multiple public agencies (Federal, State and Local) mandate an integrated planning process within Metropolitan Detroit are freeway corridors. The undersigned will ensure that all personnel involved in their respective jurisdictions will cooperate fully in carrying out the intent and provisions of this Memorandum of Understanding.

Signed,

Michigan Department of Transportation

Date: _____

Federal Highway Administration

Date: _____

Michigan State Police

Date: _____

Wayne County

Date: _____

Macomb County

Date: _____

Oakland County

Date: _____

APPENDIX - IV

Working Paper

Traffic Management

Performance Assessment

January 30, 1994

**Early Deployment of ATMS/ATIS
For Metropolitan Detroit**

Contract No. 93-0580-DAB

May 14, 1993

Prepared for
Michigan Department of Transportation

**Autonetics Electronic Systems Division
Rockwell International Corporation
3370 Miraloma Avenue
Anaheim, California 92803-4192**

Dunn Engineering Associates

HUBBELL, ROTH & CLARK, INC.

Working Paper

Traffic Management Performance Assessment

1. Introduction

Traffic management (surveillance and control) performance needs to support overall freeway traffic operations in a timely, effective and cost-efficient manner. This assessment examines the functional performance required by system processing functions to collect, process, monitor, coordinate, and report traffic surveillance MOEs; and to develop, execute, and coordinate traffic control strategies for the conduct of freeway traffic operations and management.

2. Assessment Methodology

The approach used in these assessments consist of a logical framework of analyses to define low-level performance and timeline requirements which are used to provide a basis to partition and organize functional processing and communication requirements into a system architecture.

Specifically, this assessment framework consists of a series of supporting analyses which, individually, define detailed functional performance requirements for specific processing tasks/aspects of the traffic management and information systems, and collectively determine performance interdependencies between processing tasks. The individual requirements are analyzed and correlated to identified interdependencies between tasks and whether these interdependencies directly influence performance aspects of the operational system. These interdependencies are then used to determine appropriate operational and cost-efficient performance ranges. These analyses are organized into the following assessments:

Traffic Surveillance Performance

- Traffic Flow Sensor Adequacy Analysis (3.1.2.1)
- Vehicle Presence Collection Performance Analysis (3.1.2.2)
- Traffic Surveillance/Incident Detection/Control Period Analysis (3.1.2.3)
- MOE Monitoring and Display (3.1.2.4)

Traffic Control Processing Performance

- Entrance Ramp Control Performance (3.2.2.1)
- Mainline Control Performance (3.2.2.2)
- Integrated Corridor Control Performance (3.2.2.3)

Information Management and Dissemination Processing

- Traffic and Travel Information Collection (3.3.2.1)
- Traffic and Travel Information Organization and Management (3.3.2.2)
- Traffic and Travel Information Dissemination and Control (3.3.2.3)

System Monitoring Performance

- Equipment/System Health and Status Monitoring (3.4.2.1)
- Traffic Flow Performance Monitoring (3.4.2.2)

Working Paper

Traffic Management Performance Assessment

3. Operational Performance Analyses

Functional performance and timeline requirements are derived from analyses of freeway traffic surveillance and control operations, incident management operations, and techniques used in the management and dissemination of traffic information. Traffic management objectives and philosophies adopted by the MDOT Detroit Freeway Operations Unit will be used as the model to conduct these assessments.

Minimum, or worst case, performance requirements are defined through analysis and correlation (and parametric studies) of operational system capabilities and traffic flow behavior (e.g., nominal traffic flow relationship models and observed incident flow characteristics) to establish performance baselines. These baselines will be used to establish interdependencies between performance parameters; such as, vehicle presence detection and accuracy, MOE processing timelines supporting incident detection, mainline ramp control, freeway network status displays, and traffic network performance evaluations. Cost considerations in terms of loss of operations fidelity, equipment required, communication timeline penalties and constraints, and corresponding architecture constraints are also examined.

These assessments correlate performance requirements and functional processes with functional allocations and partitions in order to specify operationally-efficient subsystem groupings. These subsystem groupings and their interdependencies are then configured into a system architecture (framework). This architecture configuration provides a high-level, functional point of departure (POD) design basis where more detailed subsystem, interface, and communications designs and implementations can be defined and developed. Functional allocations and partitions are used to balance operational effectiveness and cost-efficiency drivers, while incorporating MDOT-desired architecture attributes (i.e., flexibility, adaptability, and operations efficiency). Application of “functional modularity” and interface standardization helps to promote interchangeable, modular design implementations.

Specific performance analyses are documented in the following paragraphs.

3.1 Traffic Flow Surveillance Performance

Traffic flow surveillance provides critical information for effective traffic management. Not only does surveillance provide current flow conditions necessary to assess roadway status for incident detection, traffic control, or other functions, it also provides a feedback capability to assess the effectiveness of deployed controls and traffic network performance along monitored traffic corridors. The fidelity of surveillance data (MOEs) depends upon the application for which it is used. MOEs can be obtained for a single lane of traffic flow to monitor and control mainline ramps, or averaged over multiple lanes to yield surveillance zone “averages” for network status using traffic flow characteristics and throughput at a particular detection station. Care must be taken to define the methods and data collection frequency used to derive these MOEs so that accurate flow conditions are represented and collection cycles are balanced with system operations, capacities, and

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Traffic Management Performance Assessment

resources. Adherence to maintaining system operational effectiveness and cost-efficiency is a paramount objective when defining and developing these performance measures. Surveillance performance requirements for low-level functional processes (i.e., vehicle detection, ramp control, etc.) need to provide a wide fidelity range to support higher-level functions (i.e., traffic network surveillance, incident management, traffic control, etc.) and to balance operational effectiveness (e.g., area-wide traffic management) and efficiency. In other words, vehicle presence dwell time, or occupancy (collected from vehicle detector output states), need to be measured on a “real-time” basis (by data sampling or state changes) to ensure accurate collection of traffic flow information (e.g., vehicle occupancy, vehicle classification, weigh-in-motion, electronic vehicle tags, etc.). If accuracy of flow measurements deteriorate or become latent to the extent that they no longer represent actual flows, traffic controls and management strategies become ineffective and potentially cause more congestion than the natural flow of traffic. Conversely, if flow measurements provide a very high degree of fidelity, “noisy” data could result and potentially produce an unnecessary processing burden on the system, thus creating potential impacts to other functions (e.g., incident detection, traffic controls/ramps, etc.). The level at which “real-time” traffic flow information is collected and processed needs to be assessed against their operational use and the behavioral characteristics of traffic flow.

Surveillance MOEs (i.e., average % occupancy, average speed, and total vehicle counts, delay time, travel time, etc.) need to be calculated on a periodic basis to ensure up-to-date representations of traffic flow. This data is only as accurate as the source (raw) data and the manner in which they are collected. The following paragraphs describe an analysis to determine the minimum performance required for the collection of traffic surveillance data.

3.1.1 Surveillance Assumptions

As a starting point, certain assumptions are made to determine the parametric bounds for determination of worst-case, surveillance performance requirements. These assumptions are listed below:

<i>Nominal vehicle type:</i>	NEMA Class 3 - passenger car
<i>Nominal vehicle dimensions:</i>	$L_s = L_e = 12$ ft. (physical sensing length – conductive material; also equals electronic length - worst case) $L_o = 16$ ft. (total physical length)
<i>Nominal Roadway dimensions:</i>	$W_m = 12$ ft. (nominal mainline lane width) $W_s = 6$ ft. (min. mainline median/shoulder width)
<i>Standard vehicle detector:</i>	Inductive wire loop type - analog sense; digital signal output Loop sensor dimensions: 6 ft. x 6 ft. Orientation: square or diamond configuration Loop wire: AWG #14, 3 turns

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Traffic Management Performance Assessment

Lead-in wire: AWG #14 twisted pair, shielded,
20-24 μ H per 100 ft.

Sensing latency: $t_L = 50$ ms (worst case)

Loop excitation/de-excitation times are identical

Sensing Zone = max. 36" outside loop perimeter

Sensitivity: Detect @ 50% coverage of sensing
zone (worst-case)

Represents minimum detector performance

Vehicle detection speed range: 5 mph # V_i # 80 mph;

$v_n = 60$ mph nominal flow speed

Detection configuration:

Longitudinal, no lane transitions

3.1.2 Surveillance Performance Analyses

Performance requirements for traffic flow (MOEs) data collection and processing are dependent upon numerous deployment factors. The frequency at which MOEs are collected and updated clearly dictate the accuracy of traffic flow conditions and potentially determine the resultant performance and effectiveness of traffic controls and management strategies. MOEs can be collected, processed, and monitored by either local processors for corridor traffic management, and/or by a traffic operations center (TOC) for central management for the overall freeway network system. These factors tend to be centered around sensor capabilities and adequacy, data collection frequency, detection station (surveillance zone) spacing, operational application of traffic flow MOEs, and available implementation, operations, and maintenance funds.

The following analyses provide a baseline for minimum surveillance performance requirements and document how vehicle detection supports surveillance MOE generation; and, in turn, how frequency of MOE generation correlates with traffic flow behavior and characteristics and influences other interdependent system functions (e.g., traffic control, incident detection).

3.1.2.1 Traffic Flow Sensor Adequacy Analysis

A worst-case analysis is performed to determine whether sensor latency impacts affect detector output signals. In this case, the widely-used and accepted inductive loop detector technology is used as the candidate sensing technology to establish this minimum performance baseline.

This analysis determines the minimum speed at which vehicles passing through a sensing zone begin to exceed minimum detection capabilities. This analysis examines minimum vehicle detection performance requirements for two loop detector orientations: traditional square (or rectangular); and MDOT's diamond shape. Figure 3.1.2-1 illustrates these orientations for both configurations.

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Traffic Management Performance Assessment

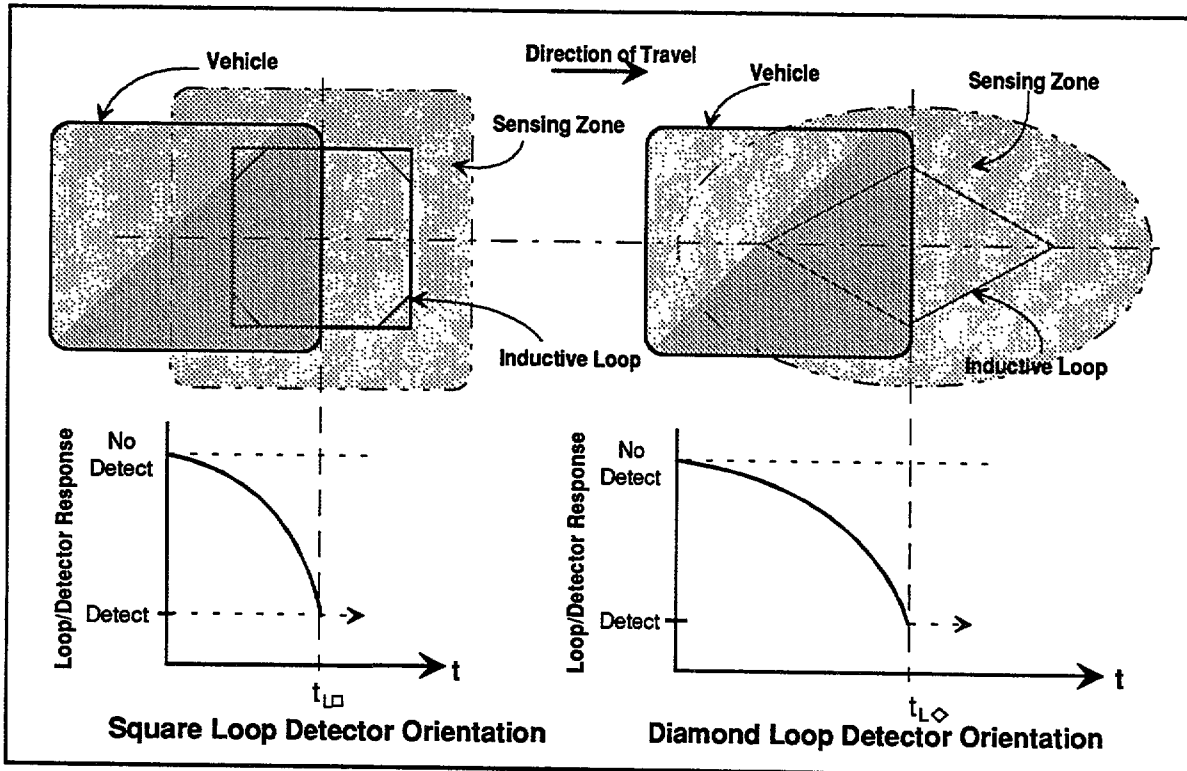


Figure 3.1.2-1. Loop Sensor Detection Latency

Assumptions:

- Nominal vehicle: $L_s = L_e = 12$ ft. (physical sensing length); Class 3 car
- Sensor latency: $t_L = 50$ ms (worst-case excitation time)
- Sensing Zone = max. 36" outside loop perimeter
- Loop excitation/relaxation (rise and fall) times are approximately equal
- Sensitivity: Detect @ 50% sensing zone area (worst-case)
- Loop dimensions: 6 ft. x 6 ft.
- Orientation: square or diamond configuration
- Sense speed range: $5 \text{ mph} \leq v_i \leq 80 \text{ mph}$; $v_n = 60 \text{ mph}$
- Detector output delay: Negligible (typical ≤ 0.1 ms.)

Find:

Using the stated assumptions, the following are determined:

- [1] v_L (min) = minimum vehicle speeds where loop sensor latency begin to impact detection capabilities; and,
- [2] whether sensor latency impacts the timeliness of detector outputs.

Analysis:

Based upon the loop sensor configurations shown in Figure 3.1.2-2, minimum impact speeds are calculated using the formula:

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Traffic Management Performance Assessment

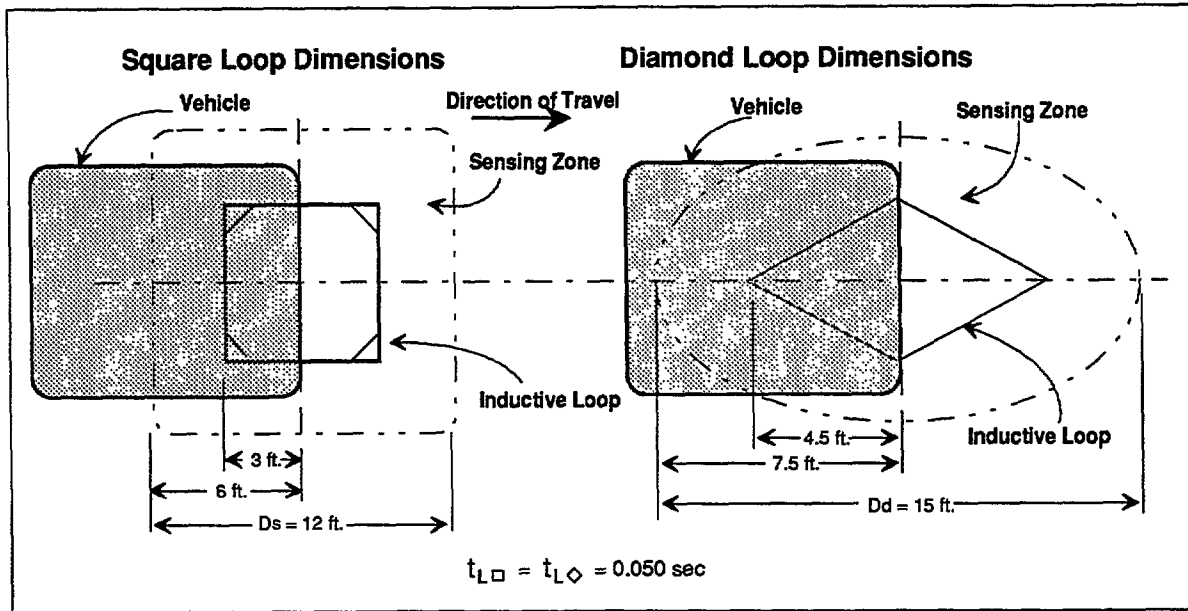


Figure 3.1.2-2. Loop Sensor Configurations

(latency velocity: v_{Lmin}) x (latency time: t_L) = 50% sensing zone traveled

$$v_L (\text{min}) = (50\% \text{ sense zone traveled}) / (t_L)$$

For the square loop configuration: $D_s = 3 \text{ ft.} + 3 \text{ ft.} = 6 \text{ ft.}$

$$v_{Ls} (\text{min}) = (50\% \text{ sense zone traveled: } D_s) / (t_L)$$

$$v_{Ls} (\text{min}) = (6 \text{ ft.}) / (0.050 \text{ sec.}) \times (0.681818 \text{ mph-sec./ft.})$$

$$v_{Ls} (\text{min}) = \underline{81.8 \text{ mph}}$$

For the diamond loop configuration: $D_d = 3 \text{ ft.} + 4.5 \text{ ft.} = 7.5 \text{ ft.}$

$$v_{Ld} (\text{min}) = (50\% \text{ sense zone traveled: } D_d) / (t_L)$$

$$v_{Ld} (\text{min}) = (7.5 \text{ ft.}) / (0.050 \text{ sec.}) \times (0.681818 \text{ mph-sec./ft.})$$

$$v_{Ld} (\text{min}) = \underline{102.3 \text{ mph}}$$

Conclusions:

- [1] Minimum threshold speeds where loop sensor latency (for both square and diamond loop configurations) begin to impact detector excitation, reaction, and output measurements are estimated as follows:

Square loop configuration: $v_{Ls} (\text{min}) = \underline{81.8 \text{ mph}}$

Diamond loop configuration: $v_{Ld} (\text{min}) = \underline{102.3 \text{ mph}}$

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Traffic Management Performance Assessment

- [2] Worst case loop sensor latency errors due to electrical properties (50 ms excitation/relaxation transition delays) begin to migrate into MOE calculations when these speed thresholds are reached. At nominal freeway speeds (60-70 mph), latency impacts for both square and diamond-shaped inductive loop detectors should not affect the accuracy of MOEs for vehicle detection applications.

Inductive loop sensors and detectors are still the foremost and most widely preferred vehicle sensor technology in use today; although, this detector technology still presents drawbacks and disadvantages associated with maintenance activities and associated costs. Establishment of minimum vehicle detection performance standards using the loop detector technology provides a baseline for new traffic flow sensors and data collection methods to maintain an upward operational compatibility and interchangeability for evolving advanced traffic management techniques and other IVHS user services. Maintenance aspects are also considered in this baseline to provide measurement criteria for new, reliable, low-cost, low-maintenance alternative traffic sensors.

3.1.2.2 Vehicle Presence Collection Performance Analysis

As a vehicle passes through a sensing zone, presence data (and other information: speed, vehicle type, vehicle ID, etc.) can be collected as a measurement of traffic flow conditions at a particular detection station within a surveillance zone. Presence data is currently used to calculate a variety of MOEs such as: total vehicle counts, average occupancies (%), average speeds, vehicle lengths and classifications, etc. Traditional inductive loop detector technologies are designed to output a discrete signal, when a vehicle is sensed, to a separate processor or controller for measurement of the output signal to collect presence data and cumulative calculation of corresponding MOEs for a given surveillance period.

New vehicle detector technologies can collect and also process MOE information (along with other traffic flow parameters) in an integrated fashion using a variety of techniques. These techniques include integrated detector state sampling, detector state change timers, image frame sampling, composite data sampling, infrared and low power RF (radar/microwave) measurements, laser tracking and range sensing, and acoustic sensing. For the purpose of this analysis, these technologies are acknowledged as potential replacements to the inductive loop detector and must satisfy the minimum detection requirements.

This analysis provides a performance and timeline baseline for the collection and calculation of traffic flow MOEs using the minimum sensing capabilities of inductive loop detector sampling techniques.

For inductive loop detector sampling, the detector output signal is typically read on a continuous time basis, independent of vehicle presence (location). When a vehicle passes over a loop sensor, the inductance in the loop wire(s) sensor decreases and is measured by a detector unit. The detector unit generates a corresponding output signal when the inductance signal recognition thresholds are reached. Based upon detector output

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performance requirements (NEMA), the electrical output state transition properties (identified for detector input-output latency) are considered negligible when compared to the minimum dwell time for recognized vehicle presence (< 0.1 ms transition [NEMA] vs. $\$ 30$ ms dwell, or 0.3%). Therefore, detector sampling errors can be assumed to not be attributed from detector input-output latency. Therefore, loop sensor states are essentially “passed through” to the detector output for processor/controller data sampling. In addition, current detectors have been designed to filter loop sensor “noise” to minimize output sensitivity and false detection errors.

Detector states are typically sampled for presence data by an local processor and/or controller, regional corridor/node processor, or central system master/host on a continuous “real-time” basis. Sampling rates can vary, but are typically read in 10 ms cycles. Presence data are typically collected and “averaged” over a larger time scale (30-60 seconds) to derive traffic flow MOEs and other parameters.

For this analysis, minimum (general) data collection performance requirements (and timelines) for calculation of traffic flow MOEs are defined from worst case (acceptable) data collection/sampling rates and traffic flow characteristics. Inductive loop detector output sampling is examined as the baseline measurement technique to provide compatibility and familiarity with current collection methods, and to provide minimum performance requirements for emerging vehicle detection technologies.

Assumptions:

Nominal vehicle:	$L_s = L_e = 12$ ft. (physical sensing length): Class 3 car
Sensing Zone =	max. 36” outside loop perimeter
Sensitivity:	Detect @ 50% sensing zone coverage (worst-case)
Loop dimensions:	6 ft. x 6 ft., square or diamond configuration
Sense speed range:	5 mph # v_i # 80 mph; also up to 120 mph
Vehicle time on loop:	$t_i = L_e / v_i = (8.18 \text{ 18 set-mph})/v_i$; where: i = speed range index; t_n in seconds (use 60 mph/88 fps conversion factor)

Find:

- [1] Minimum acceptable sampling rate to detect vehicle presence; and,
- [2] an acceptable sampling error tolerance.

Analysis:

Based upon the loop sensor configurations shown in Figure 3.1.2-2, the number of samples that can be read for vehicle dwell time (t_i) over the loop are tabulated in Table 3.1.2-1 for a defined speed range. The following relationship is used to calculate vehicle presence (dwell) time over the sensing zone for worst case loop sensor sensitivity (50% coverage).

distance traveled = (rate of speed) x (travel time); or rearranging,
travel time = (distance traveled) / (rate of speed);

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$t_i = L_e / V_i =$ vehicle dwell time over loop sensor
(for 50% coverage - worst case)

$t_i = (8.1818 \text{ sec-mph})/v_i$; includes conversion factor for feet-miles and
hour-seconds

Table 3.1.2-1. Detector Sampling Rates per Vehicle Speed

Vehicle Speed v_i (mph)	Vehicle Dwell Time t_i (sec)	Number of Samples				
		@ 1 ms	@ 5 ms	@ 10 ms	@ 25 ms	@ 100 ms
5	1.636	1636	327	163	65	16
10	0.818	818	163	81	32	8
20	0.409	409	81	40	16	4
30	0.272	272	54	27	10	2/3
40	0.205	205	41	20	8	2
50	0.164	164	33	16	6	1/2
60	0.136	136	27	13	5	1
70	0.117	117	23	11	4	1
80	0.102	102	20	10	4	1
90	0.091	91	18	9	3/4	1/0
100	0.082	82	16	8	3	1/0
110	0.074	74	14	7	2/3	1/0
120	0.068	68	13	6	2	1/0

Conclusions:

- [1] For the defined vehicle speed range, acceptable sampling (in worst case detection conditions) can be accomplished every 10 ms, as indicated by the shaded column in Table 3.1.2-1. Data samples read at higher rates provide a more accurate measure and greater fidelity of vehicle presence dwell time; however, the increased frequency of data collection may adversely impact processing performance and operational efficiency (i.e., processor throughput requirements, software executive (kernel) task scheduling complexity, communication requirements, etc.).

Specifically, the processor (or subsystem) allocated to perform this function needs to provide adequate processing capacity and reserves to operationally-support current and future processing and communication timeline needs. The executive kernel must be able to schedule not only detector data sampling, but other functions and tasks as well (i.e., MOE calculation, incident detection, ramp control, communications, health and status checks, data housekeeping, etc.). Data samples collected at lower rates may cause a reduction in data fidelity; potentially causing significant collection errors to propagate into MOEs, generation of incident detection false alarms, and premature activation/deactivation of traffic control functions.

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The performance of current inductive loop sensor and detector technology still provide adequate fidelity for collection of surveillance data based upon careful application and data interpretation. These minimum performance requirements (standards) provide a reasonable baseline for new sensor technology and vehicle presence collection techniques, and maintains operational compatibility for advanced traffic management strategies and other IVHS user services.

- [2] The margin of error calculated for a 10 ms sampling rate (@ 80 mph) equates to " 1 (one) data sample. This could be translated into a nominal 10% error tolerance assuming excessive speeds (< 80 mph) are not encountered. In actuality, the electronic vehicle length tends to be longer than the physical length due to inductive loop sensor sensitivities having the capability to "detect" vehicle presence before actual vehicle presence or worst case detection conditions (50% sensing zone coverage). This effect actually enables a greater vehicle dwell time detected by the loop sensor, whereby, a greater number of data samples can be collected, and thus, effectively reducing the sampling error.

New vehicle detection technologies could minimize these errors from occupancy calculations (and other MOEs) directly-measured from detection zone/state dwell time. Average occupancies, speeds (timing gate), and travel times, and total volumes can be directly calculated from detector output actuation time, electronic vehicle length adjustments, and actuation differential times. Average occupancies can then be more accurately calculated for accumulated detector/zone actuation time for a given surveillance period/cycle. These measurements would then be dependent upon clock accuracies used for the trigger and state measurement functions. These methods can also provide a more accurate measure for calculating average speed and other MOEs for traffic-responsive functions.

3.1.2.3 Traffic Surveillance/Incident Detection/Control Period Analysis

Periodic traffic data and information collection and MOE processing performance must support traffic operations on a timely basis to enable effective and efficient traffic management. A balance between accuracy and frequency of MOE measurements (i.e., average lane occupancies, vehicle/volume counts, average flow speeds, etc.) is critical to traffic control strategy effectiveness. If sensor technologies are assumed to provide adequate accuracy, then determination of surveillance/control periods tend to define the data collection frequency and functional processing performance required to service traffic control, demand prediction, incident detection, and system monitoring and housekeeping tasks.

Traffic surveillance, incident detection, traffic control periods need to accommodate both maximum traffic flow rates and high congestion conditions. The basic traffic control model illustrated in Figure 3.1.2-3, organizes traffic flow surveillance, demand calculation, control strategies, and network behavior into a sequential/cyclic process, and also includes the effect of driver perceptions (behavior) provided as a reactive influence to traffic network status. Identification of these two process cycles provide the means to bound the

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traffic flow model and identify the functions needed to effectively manage this traffic flow environment. Effective and efficient traffic mobility relies upon the system's ability to provide appropriate traffic controls and adequate feedback mechanisms to manage traffic flow and solicit driver behavioral responses or reactions consistent with management strategies. This feedback arrangement enables the surveillance function to provide traffic flow conditions and status to the demand prediction and control functions, and support driver influence mechanisms to solicit driver behavior consistent with traffic management strategies. Since driver behavior is not a directly controllable system function, this analysis will focus on traffic flow behavior to identify and determine surveillance and control performance parameters.

Surveillance performance requirements are defined for traffic flow conditions encountered at extreme flow conditions: free-flow speeds, and congested flow (e.g., incidents). These requirements are also balanced with other interdependent functions (e.g., incident detection, traffic control) to provide the data feedback necessary for operational efficiency.

Traffic flow behavior is examined to characterize the relationships between these extreme flow regions. Free-flow traffic conditions are analyzed to determine the maximum surveillance performance required to maintain effective and efficient flow monitoring at high flow rates. Congested flow conditions are analyzed to determine congestion development effects and functional interdependencies between surveillance performance and other processes (i.e., demand prediction, traffic control, incident detection, etc.).

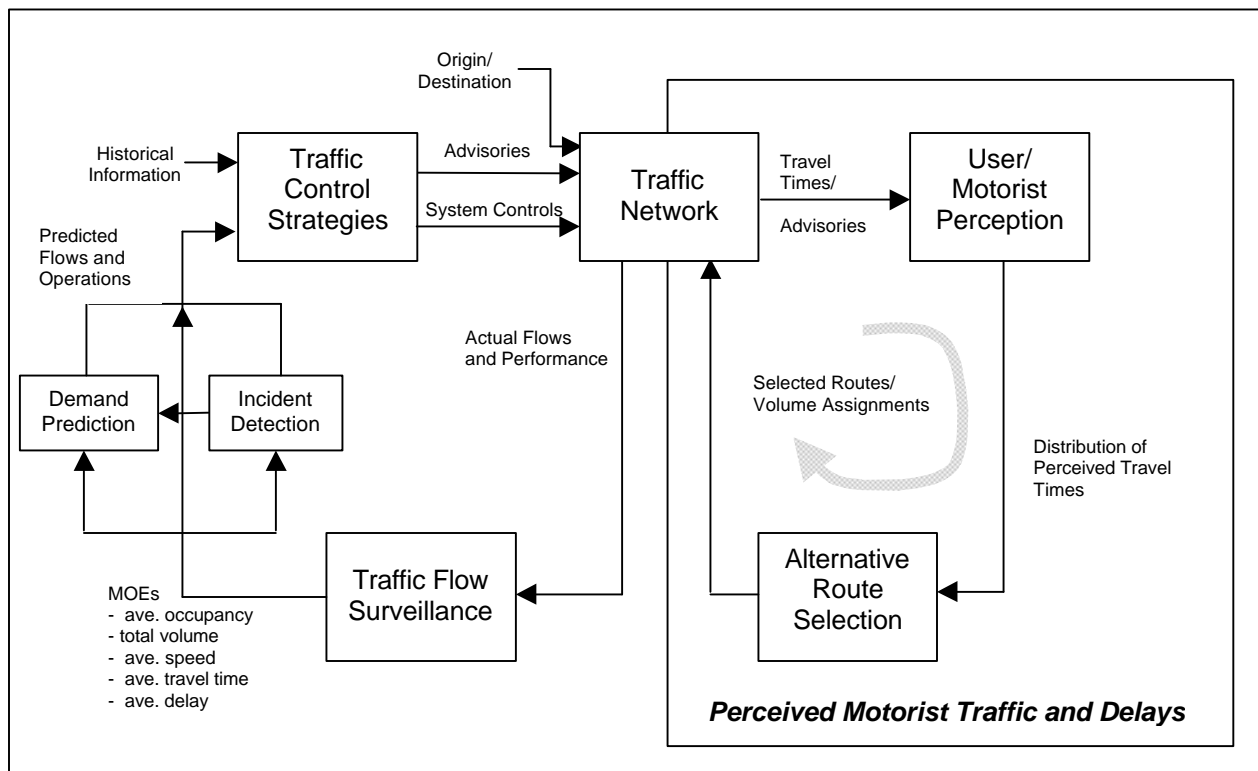


Figure 3.1.2-3. Basic Traffic Control Model

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The following related analyses document a methodology to determine traffic surveillance, incident detection, and traffic control periods which are functionally interdependent to achieve a balance in operational performance.

Assumptions:

Traffic Flow:	Greenshield's Linear Model Hypothesis: steady-state stable flow - ideal traffic flow conditions ¹ Driver demographics: Commuter traffic: cars only - no trucks Roadway terrain: Level - no hills/grades
Nominal vehicle:	$L_o = 16$ ft. (total physical length), NEMA Class 3 passenger car
Roadway dimensions	$W_m = 12$ ft. (nominal mainline lane width) $W_s = 6$ ft. (min. mainline median/shoulder width) 70 mph design speed - 8 lane freeway Maximum lane capacity - 2000 pcphpl (vphpl)
Vehicle sensor:	Minimum capability - loop detector
Detection orientation:	Longitudinal, no lane transitions

References:

1. McShane, W. R. & Roess, R. P., Traffic Engineering, Prentice-Hall 1990, pp 68, 285-306, 603-632.
2. *Secondary to reference 1*: Drake, Schofer, and May, A Statistical Analysis of Speed-Density Hypotheses, Highway Research Record 154, TRB 1967
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4. Traffic Engineering Handbook, ITE 1992, Chapter 5, pp 117-131
5. Chassiakos, A.P., Stephanedes, Y.J., Smoothing: Algorithms for Incident Detection,
6. *Secondary to reference 5*: Payne, H.J. and Tignor, S.C., Freeway Incident Detection Algorithms Based on Decision Trees with States, in Transportation Research Record 682, TRB, National Research Council, Washington D.C., 1978, pp30-37

Find:

Related analyses are conducted to determine the following:

- [1] Ideal freeway traffic flow characteristics;
- [2] Required flow surveillance performance for the ideal traffic flow case;
- [3] Minimum acceptable traffic flow surveillance performance driven by associated system functions (i.e., incident detection)

Analysis: General Discussion

Let us examine traffic flow using an analogy with viscous fluid flow through a pipe. A surveillance system can be thought of a network of flow monitoring sensors (along a pipe) used to follow the movements of given particles of fluid as they flow down a pipe in a laminar fashion (i.e., fastest flow occurs at the pipe

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centerline; slower flow occurs at the fluid/pipe wall interface). The ideal surveillance system monitors all fluid particles and their longitudinal and lateral (spatial) translations within the pipe for given temporal conditions.

Unfortunately, traffic flow is not uniform and real surveillance systems cannot monitor temporal and spatial conditions of all vehicles moving down a roadway corridor, nor, do they operationally need to. However, this analogy provides a surveillance framework from which spatial and temporal characteristics can be used for application to traffic flow.

Vehicle detection sensors have enabled collection of traffic flow data; however, the data only depicts point characteristics of traffic flow as vehicles pass through the sensor. To obtain true flow characteristics, sensors could be positioned in tandem along a roadway, one after another, to obtain a microscopic view of the flow; however, this approach proves to be unfeasible from a deployment perspective (e.g., MOE processing, operations resource, communications, costs, etc.) when considering the enormity of roadway miles for a given freeway network. Therefore, a balance between sensor spacing and MOE processing frequency must be determined.

Surveillance operations and processing economy must be balanced to achieve an operationally-efficient system. A macroscopic approach (instead of microscopic) is examined in this analysis to use flow “averages” to represent temporal and spatial traffic conditions within given roadway segments, or “zones” to provide manageable MOE parameters and to filter traffic flow effects of one-time events.

Current surveillance systems have adopted the use of “detection zones” or “surveillance zones” to represent the networked series of roadway segments on which traffic flow conditions are reported. “Detection stations” provide the sensor(s) implementation location within a zone for the measurement of point traffic flow conditions. For certain areas, weather conditions may also need to be collected to adjust traffic controls. Surveillance of traffic flow by zones tend to be more manageable from an operations and cost perspective due to averaging of flow parameters and the operations and maintenance costs associated with implementation of system components.

Detection or surveillance zones can vary in size and length based upon the traffic application (e.g., arterial versus freeway mainline). Arterial surveillance tends to require tightly-coupled zones (by lane) to measure right-of-way demands and queue lengths at signalized intersections. In this case, surveillance provides a “demand” indicator for signal control functions and operate on a real-time, cyclic basis due to the nature of intersection signal timing (offsets) and control. On the other hand, mainline freeway surveillance require zones, aligned in tandem to encompass extended lengths of roadway, are used to provide traffic flow status, incident detection, ramp metering, and other traffic functions. In these cases,

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surveillance provides “averaged” traffic flow (and weather) data used for traffic network monitoring and activation/deactivation of real-time control operations (e.g., traffic-responsive ramp metering).

This analysis examines the relationship between zone lengths and corresponding surveillance periods to define surveillance performance requirements. Intuitively, maintaining surveillance of a vehicle as it moves downstream requires the system to “hand-off” the implicit surveillance task to adjacent zones as vehicles move downstream. Using basic traffic flow relationships, zone lengths and period lengths are directly proportional.

Analysis [1]: Ideal Traffic Flow Characteristics

In large-scale ideal (freeway) traffic flow models, vehicles can be viewed as constituents of a flow body that move down a section of roadway, at a steady rate of speed, similar to the manner in which a body of incompressible fluid flows through a length of pipe. Traffic flow surveillance along equal-length roadway segments (surveillance zones) yields collection, processing, and reporting of traffic flow conditions (MOEs) as vehicles travel from one segment to the next. The frequency at which MOEs are collected and updated can impact the structure of the system architecture, communications media, methods, and required performance, and functional processing timelines. The following describes a method to determine surveillance periods required to monitor freeway traffic flow.

Traffic flow surveillance must measure changes in traffic flow conditions as a result of behavioral reactions from perceived conditions exhibited by drivers traveling on the roadway. Due to the practical nature of sensor deployments and traffic management strategies, flow measurements cannot be collected from a continuous stream of sensors along a roadway; instead, traffic flow conditions and characteristics are collected at specific points (detection stations) to represent flow conditions for each surveillance zone.

The surveillance period for measuring temporal and spatial traffic flow conditions are dependent upon flow rates and the spacing between detection stations. Since the level of surveillance fidelity tends to be limited primarily by processing limitations and costs associated with deployment, operations, maintenance, and administrative decisions, a means to define performance characteristics are derived from traffic flow itself. At a minimum, surveillance performance periods need to accommodate traffic operations when traffic flow is ideal and traveling at free-flow speeds, and also when flow conditions are congested and other system functions predominate. The following assessment characterizes ideal traffic flow.

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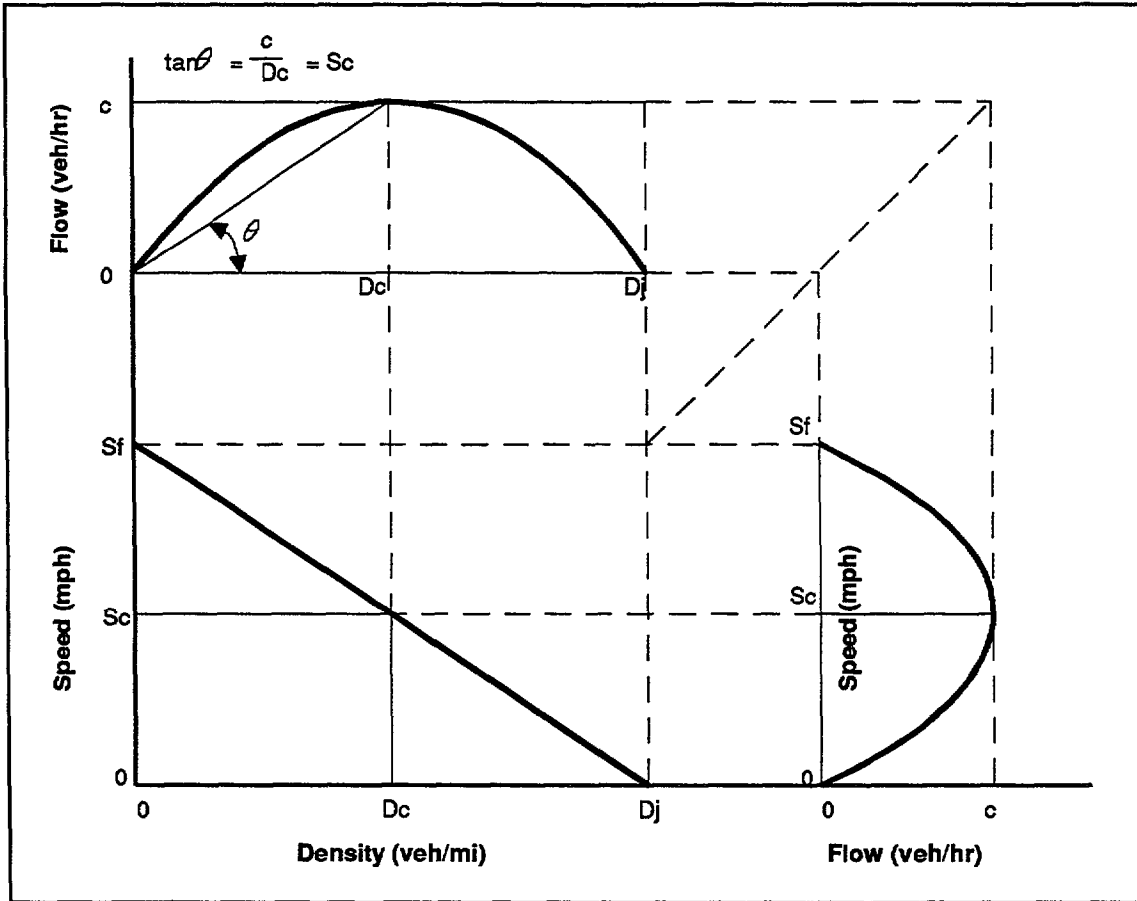


Figure 3.1.2-4. Basic Form of Speed-Flow-Density Relationships

Ideal Traffic Flow Behavior. To better understand traffic flow behavior, several mathematical expressions have been hypothesized² to describe speed-flow-density relationships for data collected from actual observations. These observations are mapped as flow vs. speed, flow vs. density, and speed vs. density. These expressions are calibrated to minimize the differences between the mathematical expressions and observed data. This analysis uses these hypotheses with ideal traffic flow parameters instead of observed data to determine the upper flow limits for the surveillance function. Figure 3.1.2-4 illustrates these flow-speed-density relationships with the following definitions:

- c = capacity, the maximum rate of flow (vph or vphpl or pcphpl);
Ideal = 2000 vphpl or pcphpl
- S_f = free-flow speed; theoretical speed when density = zero (mph);
Ideal conditions: = 85% of roadway design¹
= (0.85)*70 mph = 59.5 mph
- S_c = critical speed, the speed at which capacity occurs (mph) - mathematically derived

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- D_c = critical density, the density at which capacity occurs (vpm or vpmp) mathematically derived
- D_j = jam density, the density at which all movement stops, i.e., $S = 0$ mph (vpm or vpmp) - mathematically derived

Understanding the limits of the speed-flow-density relationships provide a mathematical approach to describe specific relationship interactions. In this case, ideal traffic flow conditions are used in place of observed data. The general mathematical expression relating flow, speed, and density¹ is:

$$F = S \times D;$$

- where: F = rate of flow (vph or vphpl)
 S = space mean speed (or average running speed in mph)
 D = vehicle density (vpm or vpmp)

Description of mathematical flow-speed-density expressions are derived from multiple linear regression analysis (minimizing the sum of least squares), and take the form:

$$y = a + bx_1 + cx_2 + \dots + zx_n;$$

- where: y = independent variable
 x_1, \dots, x_n = independent variables
 a, b, \dots, z = calibration constants

Since two flow variables are mapped in this form at any given time, the linear regression model reduces to the form:

$$y = a + bx;$$

Calibration of the mathematical equivalents of ideal speed-flow-density conditions requires three related equations expressed as: [1] flow vs. speed, [2] flow vs. density, and [3] speed vs. density. Ideal flow conditions include [a] capacity = 2000 pcphpl. Since these expressions are related through $F = S \times D$, determination of one parameter essentially derives the others.

Speed -Density Relationship, The speed versus density relationship is examined first due to a simpler analysis than the other two. The reasons for this are: [1] the mathematical expression involves a simpler form (linear), [2] this relationship follows a definitive trend with respect to the other parameter, and [3] speed-

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density curves are representative of the most basic interaction of drivers and vehicles on highways¹.

This third point is further explained from a human behavior perspective. Drivers perceive density, or the proximity of other vehicles, and adjust their speeds accordingly. Drivers cannot directly sense flow, which is a point measure, and therefore tends not to directly influence their driving behavior; rather, traffic flow tends to be a product of their behavior. Thus, calibration of the speed-density relationship is an appropriate starting point to establish the basis for the other two flow equations.

For simplicity, Greenfield's model (linear) is used to perform the following algebraic manipulations for the speed-density equation:

$$S = S_f [1 - (D/D_j)]:$$

manipulated into:

$$\underline{S = S_f - S_f / D_j) D:} \quad \text{for the form } y = a + bx;$$

$$\text{where:} \quad \begin{aligned} a &= S_f; \\ b &= - S_f / D_j; \end{aligned}$$

Flow Density Relationship. For the flow (volume)-density equation, manipulate the basic equation $F = S \times D$ into $S = F / D$ and substitute into the speed-density equation:

$$S = S_f - (S_f / D_j) D;$$

$$(F / D) = S_f - (S_f / D_j) D;$$

then solving for F :

$$\underline{F = S_f D - (S_f / D_j) D^2:}$$

where linear speed-density equations result in parabolic flow-density equations:

Flow Speed Relationship. For the flow (volume)-speed equation, manipulate the basic equation $F = S \times D$ into $D = F / S$ and substitute into the speed-density equation:

$$S = S_f - (S_f / D_j) D;$$

$$S = S_f - (S_f / D_j) (F / S);$$

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then solving for F :

$$\underline{F = D_j S - (D_j / S_f) S^2};$$

where linear speed-density equations result in parabolic flow-speed equations:

Determine Calibration Constants. Next, the following calibration constants associated with the speed-flow-density equations need to be determined using known ideal freeway traffic flow parameters:

Critical density (@ capacity):	D_c (vpmpl)
Jam density ($S = 0$ mph):	D_j (vpmpl)
Critical speed (@ capacity):	S_c (mph)
Maximum flow (volume) rate:	$c = \text{capacity} = 2000 \text{ vphpl or pcphpl}$
Maximum free-flow speed:	$S_f = 59.5 \text{ mph (based on 85\% of 70 mph design)}$.

Critical and jam densities: D_c and D_j :

Ideally, critical density occurs when capacity is at its maximum (from the stable flow region). In other words, the region (peak) of the speed-density curve where the slope is zero. Using:

$$F = S_f D - (S_f / D_j) D^2; \quad (\text{flow-density equation});$$

$$dF / dD = 0 = S_f - 2 (S_f / D_j) D;$$

solving for D ($= D_c$ @ capacity):

$$\underline{D_c = D_j / 2}; \quad \text{critical density occurs at 1/2 the jam density.}$$

Critical speed: S_c :

The corresponding critical speed occurs when maximum capacity is reached (from the stable flow region), and is derived from:

$$S = S_f - (S_f / D_j) D; \quad (\text{speed-density equation});$$

substituting: $D = D_c = D_j / 2$ into the speed-density equation:

$$S = S_c = S_f - (S_f / D_j) (D_j / 2); \text{ and simplifying}$$

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$S_c = S_f / 2$; critical speed occurs at 1/2 free-flow speed.

therefore, for $S_f = 59.5 \text{ mph}$ (theoretical free-flow speed):

$$S_c = 59.5 \text{ mph} / 2;$$

$$\underline{S_c = 29.8 \text{ mph}}$$

Jam density D_j :

Since flow is the product of speed and density, $F = S \times D$, and the maximum rate of flow occurs at capacity, c , substituting S_c and D_c into the general flow equation yields:

$$F = c = S \times D = (S_f / 2) (D_j / 2);$$

$$F = c = (S_f D_j) / 4;$$

where $c = 2000 \text{ vphpl}$; and $S_f = 59.5 \text{ mph}$;

and solving for the jam density D_j :

$$D_j = (4 c) / S_f = 4 \times (2000 \text{ vphpl}) / 59.5 \text{ mph}$$

$$\underline{D_j = 134.5 \text{ vpmpl}};$$

therefore the critical density D_c is:

$$D_c = D_j / 2 = 134.5 \text{ vpmpl} / 2$$

$$\underline{D_c = 67.2 \text{ vpmpl}}$$

Conclusions [1]:

Flow constants corresponding to ideal flow conditions are defined as follows:

Maximum flow (volume) rate: $c = 2000 \text{ vphpl}$ or $pcphpl$

Maximum free-flow speed: $S_f = 59.5 \text{ mph}$

Critical density (@ capacity): $D_c = 67.2 \text{ vpmpl}$

Jam density ($S = 0 \text{ mph}$): $D_j = 134.5 \text{ vpmpl}$

Critical speed (@ capacity): $S_c = 29.8 \text{ mph}$

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Substitution of these constants into the ideal speed-flow-density equations yield the following:

Speed – Density Equation;

$$S = (59.5 \text{ mph}) - [(59.5 \text{ mph}) / (134.5 \text{ vpmpl})] D ;$$

$$S = (59.5 \text{ mph}) - (0.44 \text{ vphpl}) D ;$$

Flow-Density Equation;

$$F = (59.5 \text{ mph}) D - [(59.5 \text{ mph}) / (134.5 \text{ vpmpl})] D^2 ;$$

$$F = (59.5 \text{ mph}) D - (0.44 \text{ mph/vpmpl}) D^2 ;$$

Flow-Speed Equation;

$$F = (134.5 \text{ vpmpl}) S - [(134.5 \text{ vpmpl}) / (59.5 \text{ mph})] S^2 ;$$

$$F = (134.5 \text{ vpmpl}) S - (2.26 \text{ vpmpl/mph}) S^2 ;$$

For calibration purposes, surveys of moderately-traveled interurban freeways (c 10% occupancy on 55-mph posted speed limits) were taken and found that travel speeds actually exceed the assumed free-flow speed of 59.5 mph. Observed speeds ranged between 61-65 mph (e.g., I-96 Jefferies Freeway), and for freeways with posted 65mph speed limits, observed travel speeds ranged between 64-69 mph (e.g., I-275). Thus, using a simple average of these two ranges as a “calibrated” free-flow speed value, S_f , (65 mph), the resulting speed-flow-density equations become the following:

Speed-Density Equation; $S = (65 \text{ mph}) - (0.528 \text{ vphpl}) D ;$

Flow-Density Equation; $F = (65 \text{ mph}) D - (0.528 \text{ mph / vphpl}) D^2 ;$

Flow-Speed Equation; $F(123.1 \text{ vpmpl})S - (1.89 \text{ vpmpl / mph}) S^2$

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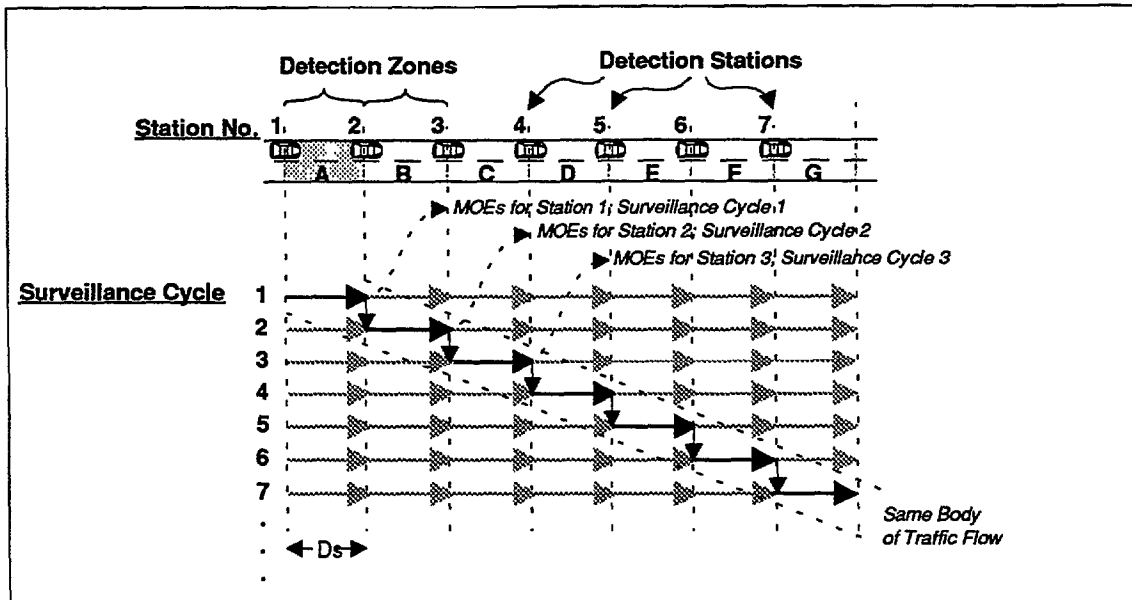


Figure 3.1.2-5. Ideal Surveillance Flow Model

Analysis [2]: Flow Surveillance Performance (Periods)

Efficient traffic flow surveillance must enable non-duplicated coverage of flow movement between zones on a periodic basis. This requires a detection station to "hand-off" flow surveillance to an adjacent detection station as vehicles move downstream. Figure 3.1.2-5 illustrates a layout of this model. The timing of each flow surveillance period (1,2,3, etc.) is such that traffic data is collected, processed, and reported for a given flow body for a particular detection station (1,2,3, etc.) until the leading edge of that body reaches the next downstream detection station (zones A, B, C, etc.). At this point, the cycle is re-initiated starting with the next traffic flow body. This period or cycle length depends upon the traffic body flow speed and the separation distance between detection stations (surveillance zones).

Since maximum traffic monitoring performance is required when roadway and travel conditions are ideal and the theoretical free-flow speed is at its maximum, the surveillance system (detection station spacing and processing period) must maintain a monitoring cycle consistent with the free-flow speed. In other words, the (maximum) surveillance period must be consistent with the vehicle flow travel time required to cover the distance between detection stations. All flow conditions are measured/ collected, calculated, and reported within this period.

Given these conditions, the maximum free flow speed, S_f , for ideal conditions (59.5 mph) is used as a determining factor to define detection station spacings (D_s) and corresponding maximum surveillance periods (P_s). The following equation illustrates this relationship and is used to develop the parametric values listed in

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Table 3.1.2-2. The calibrated free-flow speed value (65 mph) is also calculated and used as a basis for comparison..

$$D_s = S_f \times P_s ;$$

solving for the surveillance period P_s yields:

$$P_s = D_s / S_f = D_s / (59.5 \text{ mph}) \times (3600 \text{ sec/hr.}) ;$$

and substituting:

$$P_s = D_s / (59.5 \text{ mph}) \times (3600 \text{ sec/hr}) ;$$

$P_s = D_s \times (60.5 \text{ sec})$; for $S_f = 59.5 \text{ mph}$
and; $P_s = D_s \times (55.38 \text{ sec})$; for $S_f = 65 \text{ mph}$

where:

D_s distance between detection stations points (mi)
 S_f traffic flow speed (mph)
 P_s surveillance period (sec)

Table 3.1-2. Flow Surveillance Periods

Detection Station Separation Distance D_c (mi)	Maximum Surveillance Period (@ $S_f = 59.5 \text{ mph}$) P_s (sec)*	Maximum Surveillance Period (@ $S_f = 65 \text{ mph}$) P_s (sec)*
0.10	6.06	5.54
0.20	12.11	11.08
0.25	15.13	13.85
0.33	19.97	18.28
0.50	30.26	27.70
0.66	39.94	36.56
0.75	45.38	41.53
0.90	54.46	49.85
1.00	60.51	55.39
1.25	75.64	69.24
1.50	90.76	83.08
2.00	121.01	110.77

* values have been rounded up to the nearest 0.01 sec.

Conclusions [2]:

Further parametric analysis could define a endless range of periods due to the proportional nature of the distance-speed-time relationship. Based only on traffic surveillance functions, operations administrators could simply choose a desired detection station/surveillance period pair and develop an operations strategy

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around them. If simple traffic monitoring (no control functions) is desired, the surveillance period could be chosen based upon available budget, communications, and computing platforms and resources. This approach, taken in isolation, tends to be influenced by administrative preferences rather than true operational needs, and does not specify or “bound” *real* traffic operation performance requirements. Therefore, other determining factors must be used to identify a balance between operational needs and administrative preference.

Analysis [3]: Minimum Surveillance Performance Determinants.

This analysis employs the relationships defined in the traffic control model (refer to Figure 3.1.2-3) to determine surveillance performance limits required to support interdependent traffic operations for ideal flow conditions. In the model, the surveillance function provides traffic network status “feedback” to demand prediction and traffic control functions. The previous analysis identifies maximum performance required to maintain flow surveillance for “ideal” traffic flow conditions. For degraded traffic flow, as found in traffic congestion, maximum performance surveillance periods can still provide operationally-relevant traffic flow data, however, the data now represents segments of contiguous traffic flow bodies.

Determining a range of operationally-efficient surveillance periods/cycles are introduced in this analysis using other interdependent functions and system aspects. Freeway traffic demand prediction, entrance ramp metering control, and incident detection functions are considered the primary determinants to define these operationally-efficient surveillance periods.

Traffic demand for roadway capacity typically does not occur instantaneously; rather, demand develops slowly and steadily over the course of tens of minutes, at best, and sometimes hours¹ as a result of traffic generators such as special and sporting events, or large employment areas. This relatively slow development can be attributed to a limited number of egress points and routes (whether permanent or temporary) emanating from the traffic generator. This configuration, in effect, acts as a form of traffic flow metering for the volume of traffic being released onto the (monitored) roadway network. As routes diverge from the generator, traffic tends to diffuse and become absorbed into the available roadway capacity. Traffic surveillance and controls would be required to anticipate or sense this increase in volume and respond with appropriate controls (i.e., ramp metering, alternate routing, etc.); however, the duration and infrequency of capacity demand from these infrequent events tend to appear more like “incidents” and do not provide a reasonable parameter to determine surveillance periods.

Entrance ramp metering control is typically actuated by time-of-day (TOD) or traffic-responsive modes (e.g., occupancy, gap-acceptance, etc.). TOD cycles tend to be independent of surveillance periods due to their synchronization with

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recurrent traffic patterns (i.e., commuter); and do not provide a reasonable determinant. On the other hand, traffic-responsive metering is directly related to mainline volume and occupancy status and provides a viable candidate for surveillance period determination. Traffic studies have been conducted to characterize the development of mainline densities¹, and results indicate that (barring lane-blocking incidents) “measurable” traffic flow changes tend to occur over a 10 to 15 minutes. The monitoring scale for activation of traffic-responsive, ramp metering is designed to average these changes over a comparable time frame to prevent premature activation/deactivation. Thus, ramp metering and response cycles do not provide reasonable time scales to determine surveillance periods.

Incident detection also directly interfaces with the surveillance function through assessment of traffic data and location correlation. The objective of “modern” incident detection is to provide a traffic operations tool to automatically and accurately identify (detect) locations of “potential” incidents through monitoring of MOEs collected from adjacent detection stations deployed in the roadway infrastructure. The term “potential” is used due to the likelihood of the algorithms to issue false detection alarms. Standard operating procedures (SOP) require the operator to correlate incident information (e.g., CCTV) to verify the validity of an incident before declaration and notifying proper authorities.

Once an incident is declared, management responses are formulated (and executed) to coordinate with law enforcement, specialized responding agencies, and removal agencies; perform traffic control and alternate routing to divert traffic around the incident location; and provide incident information dissemination to appropriate reporting and public media agencies.

Providing timely detection and responsive measures to remove and clear incident events weighs heavily on minimizing traffic congestion (i.e., queue buildup) and clearance, and other traffic safety concerns (e.g., secondary incidents). Therefore, incident-related flow conditions and incident detection processing provide a reasonable determinant from which to determine appropriate surveillance periods. Analysis of incident detection timeliness is used as a determinant to define corresponding surveillance processing periods and detection station spacings.

To understand the basis on which incident detection algorithms operate, incident traffic flow is characterized. Lane-blocking or capacity-reducing incidents most likely occur when traffic flow becomes unstable. In other words, traffic flow is at critical density, D_c , (Figure 3.1.2-4) and corresponding flow rates and vehicle speeds become erratic.

Traffic flow characteristics in this unstable region can be illustrated as having “stop-and-go”, “accordion”, or “compression wave” vehicle flow effects. While in this flow region, a lane-blocking incident, due to an accident or stalled vehicle, can cause a congestion queue to develop at a (nominal) rate of 10 mph^{5,6} in an

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upstream direction. As an illustration, an incident-induced compression wave can develop an upstream lane queue one mile in length in approximately 6 minutes. Congestion development can cause serious traffic management problems if not detected in a timely fashion. Thus, there is significant emphasis to accurately detect, diagnose, and resolve incident traffic patterns as quickly as possible.

Diagnosis of incident traffic patterns must be balanced with respect to the rate at which traffic congestion develops. There may be instances when incidents occur during off-peak hours. In these cases, traffic densities can be very low with substantial time required for congestion to build up to the point where the queue spans multiple detection stations before sensing incident congestion patterns. The probability of incident occurrence at low densities tends to be much less than during peak-hour traffic, and thus does not provide a viable determinant. Surveillance performance must then be related to the scale of congestion (incidents) impact and the time interval required for detection and recognition of incident patterns. Thus, this analysis uses incident traffic flow conditions; namely, queue buildup, to determine surveillance performance requirements (periods/cycles).

Performance Limit Determination This method will employ traffic and system characteristics observed during roadway incidents to focus on definition of operational surveillance performance limits to support incident detection processing. Implementation costs are considered to determine the minimum number of detection stations (maximum spacing) required to support overall traffic flow monitoring (free-flow traffic and incident detection). Characterization of the congestion development rate and incident detection capabilities are used as specific determinants to define surveillance periods and detection station spacing.

When traffic flows at or around its maximum/ideal rate, the surveillance function must update flow data (MOEs) at a corresponding rate. When traffic becomes heavily congested, the same relationship may not apply to be operationally-efficient. In this flow region, incident detection becomes a more prevalent function and relies heavily upon the periodic traffic MOEs provided by the surveillance function.

The incident detection/surveillance relationship is examined further to develop a means for specifying and balancing free-flow surveillance performance (i.e., periods and detection station spacing) with incident detection processing timelines.

First, the observed rate of congestion development will be used to calculate the time and distance required for the leading edge of a compression wave to travel upstream through the traffic flow. Tabulation of these times and distances are presented in Table 3.1.2-3. The worst case distance a compression wave must travel in order to be detected can be defined as the distance between adjacent detection stations (i.e., incident location is immediate upstream from a detection

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station to the next upstream station). These propagation times will be used with baseline incident detection processing timeline limits to identify detection station spacing.

Table 3.1.2-3. Compression Wave Propagation Times

Travel Distance (miles)	Propagation Time of Compression Wave @ 10 mph (seconds)
0.00	N/A
0.10	36
0.20	72
0.30	108
0.40	144
0.50	180
0.60	216
0.70	252
0.80	288
0.90	324
1.00	360
1.10	396
1.20	432
1.30	468
1.40	504
1.50	540
1.60	576
1.70	612
1.80	648
1.90	684
2.00	720

Secondly, a baseline for incident detection performance (detection time) is established through assessments of various (comparative) algorithms in current operation or test. This baseline requires definition of acceptable detection and false alarm rates, corresponding detection assumptions, and the number of (MOE) data samples required for processing. For most algorithms, detection and false alarm rates tend to follow a similar trend; that is, as the detection rate increases, the false alarm rate also increases. Some algorithms have developed improvements to minimize false alarm rates through the use of statistical smoothing of the surveillance data⁵. Others use multiple algorithms which process the same MOE data to look for different patterns and examine algorithm results through a comparator.

To determine appropriate incident detection time performance, most detection algorithms (e.g., California, time series, etc.) compare sequences of processed temporal and spatial traffic flow data to determine incident conditions or patterns.

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These algorithms adopt the objectives to maximize the probability of detection and to minimize the mean-time-to-detection⁵ (MTD) and corresponding false alarm rates. In the referenced study, MTDs are based from the time an incident is reported into the operator's log. From a system performance perspective, this data may be insufficient due to time omitted between actual occurrence and entry into a log. The following analysis provides an estimation of the overall detection time.

Detection accuracy and traffic management center (TMC) operator perspectives are examined to define thresholds for incident detection and false alarm rates; that is, high detection with a low false alarms. From the operator's perspective, low false alarm rates are emphasized due to the tendency to ignore frequent alarms within short time periods. Based upon studies⁵, acceptable rates are considered to begin at 60% detection (ratio of detections of all identified incidents) with corresponding 0.1% false alarm rates (percent of false alarm decisions to all decisions). This can be interpreted as approximately 1 false alarm per peak hour traffic at a minimum 60% detection rate for all incidents.

Higher detection rates from single algorithms potentially carry a timeliness penalty; in that, these algorithms use a larger data sample set over time to statistically "smooth" the surveillance data for filtering out data noise, or to check the persistency of an incident pattern. For these algorithms⁵, corresponding MDTs (@ 60% detection/0.1 % false alarm rates) range from 1.1 minutes (DELOS3.3) up to 2.1 minutes (DELOS 1.1). However, these time values were measured from the time reports are entered into the operator's "incident log". These mean times are considered offsets to the actual occurrence-to-incident log reporting time and do not provide an adequate performance value for this analysis.

Another method to determine actual detection time could be obtained from the number of data samples required to perform incident processing. Through examination of the same algorithms, study data samples, and assumptions⁵, a baseline incident detection performance range can be determined by summing the number of sample collection time (surveillance periods) required for detections. As a minimum (no detection time offsets), the modified California algorithm (Los Angeles) requires three data samples to initiate detection processing for comparison of occupancy thresholds, and two additional samples to check for incident pattern persistency. As a maximum, the DELOS 1.1 algorithm⁵ uses up to ten-samples to perform statistical smoothing and threshold/history comparisons. These incident detection algorithms were calibrated using 30-second data samples. Therefore, a baseline minimum incident detection processing interval requires five surveillance periods, or 150 seconds (2.5 minutes); and a baseline maximum interval requires ten surveillance periods, or 300 seconds (5 minutes).

Determine Operational Surveillance Period, To determine operationally-compatible surveillance periods, minimum and maximum detection times (intervals), corresponding number of data samples, and compression wave travel

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distances are used to calculate the required detection station spacing and corresponding minimum surveillance period lengths (for $S_f = 59.5$ mph and 65 mph) to support incident detection.

The most prominent incident flow characteristic is identified as the compression wave of vehicles (as their speed slows to a stop) which moves in an upstream direction at a rate of approximately 10 mph^{5,6} and persists over an extended period. The data from Table 4-6 is plotted in Figure 4-7 with minimum and maximum incident detection time limits to derive the corresponding travel distances of the compression wave.

The intersections at which the compression wave propagation line crosses the incident detection time limits depict the range in which the surveillance function must perform. These intersection points also identify corresponding compression wave travel distances which can be used to derive a detection station spacing; hence, the corresponding operational surveillance period.

Mathematical derivation of propagation distances corresponding to the detection limits can be obtained from the following relationship:

$$\textit{propagation distance} = (\textit{compression wave travel rate}) \times (\textit{detection time})$$

or expressed as: $P_{cw} = S_{cw} \times T_d$

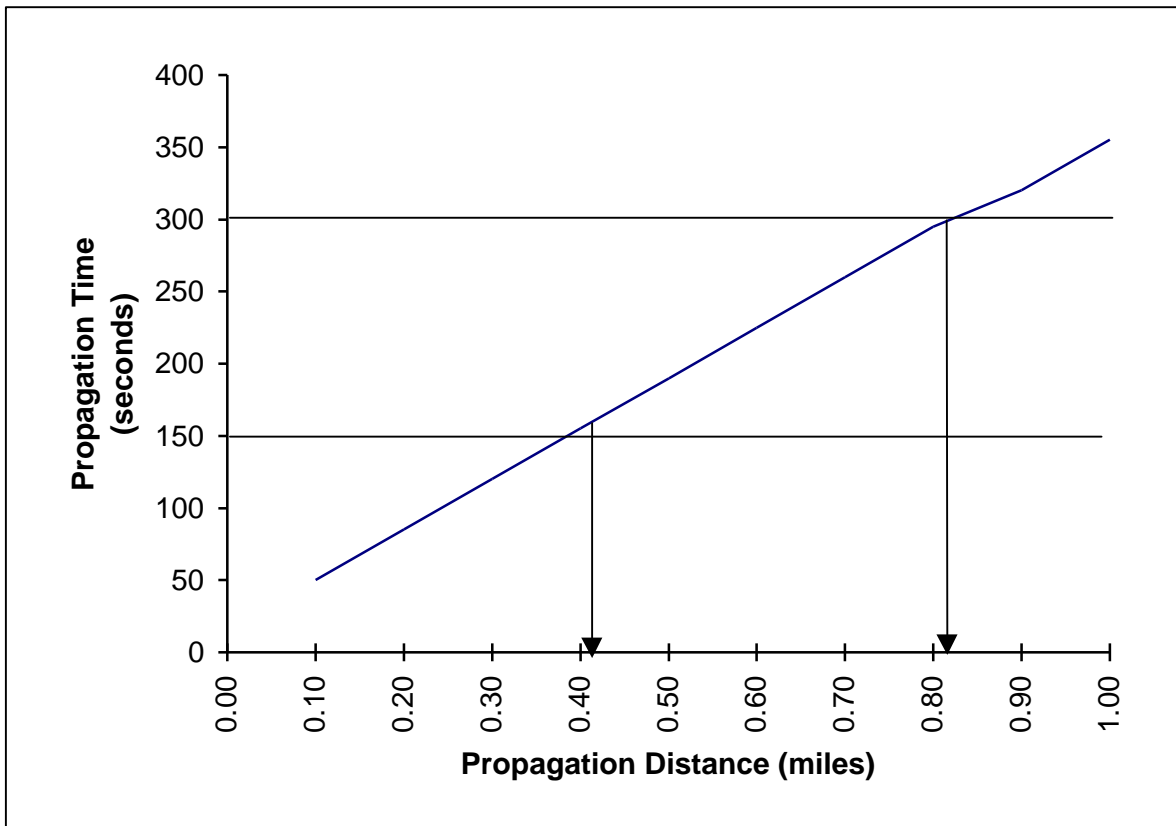


Figure 4-7. Incident Compression Wave Propagation

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The following values are used for propagation speed and incident detection times:

$$S_{cw} = 10\text{mph}; \quad T_{dmin} = 150 \text{ seconds (minimum)}$$
$$T_{dmax} = 300 \text{ seconds (maximum)}$$

Thus, compression wave propagation distances corresponding to incident detection time limits are:

$$P_{cwmin} = 0.42 \text{ mile; and,} \quad P_{cwmax} = 0.83 \text{ mile}$$

These distances do not directly correspond to detection station spacing, but can be used to derive spacings based upon the number of data samples used for incident detection.

To find the detection station spacing for the minimum detection time, the worst case situation (incident immediately upstream) is assumed. For minimum detection time (modified California algorithm), 5 data samples were required to signal a detection alarm, of which 2 samples were used for persistency checks. Therefore, when the alarm is issued, the compression wave, or queue length, has traveled 2/5 of 0.42 mile, or 0.17 mile passed the first adjacent upstream detection station. Thus, detection stations are spaced at 3/5 of 0.42 mile, or at 0.25 mile intervals.

A similar derivation can be performed for the maximum detection time where 10 data samples were required, of which 6 samples were used as a historical base and 4 samples used for measurement and persistency. Similar ratios are used on the corresponding maximum propagation distance of 0.83 mile. In this case, detection station spacing results in 0.50 mile intervals (6/10ths of 0.83 mi.).

Conclusions [3] :

Improvements in automated incident detection accuracy and false alarm rate reductions are consistently being studied. Given that short surveillance periods can always support long detection intervals, the maximum surveillance performance required to support incident detection processing needs correspond to a period length which supports traffic data collection at both low density, freeflowing speeds, and at high density - low speed, unstable traffic flow.

Correlation of detection station spacing derived from incident detection processing is linked to spacing derived from the freeflow/ideal traffic flow model ($S_f = 59.5$ mph). Spacing values yield a surveillance period range of 15.1 seconds to 30.3 seconds. These values correspond to detection station spacings of 0.25 mile and 0.50 mile. If the observed freeflow traffic speeds ($S_f = 65$ mph) are used, the surveillance period range reduces to 13.9 seconds to 27.7 seconds. Also, since the surveillance function is closely coupled with the traffic control and demand functions, the same (surveillance) processing cycle/period would also apply to

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those functions to ensure the latest information is used within the control cycle and the system feedback path is maintained.

Actual detection station location placement and spacing for surveillance zones along freeway mainlines can vary based upon a number of conditions. Entrance and exit ramp spacing, weaving areas, roadway curvatures, communications media access, and demand and average daily traffic volumes all provide input into the layout and frequency of detection station spacing and surveillance zones. Overall, typical detection station location selection ranges between +/- 0.2 mile of the desired spacing distance.

Recommendations:

As a guideline for system implementation based on performance and cost, detection stations should be spaced between 0.25 mile to 0.50 mile apart. Within this range, If system incident detection performance is a priority, 0.25 mile spacing of surveillance zones is recommended. If budgetary constraints do not allow a close spacing, then up to 0.50 mile spacing intervals should be sufficient to provide adequate surveillance and incident detection performance.

3.1.2.4 MOE Monitoring and Display

As traffic surveillance flow data is collected and processed, traffic MOEs and system performance information must be made available to other system-level functions for traffic control performance monitoring, traffic network status management, information dissemination, and operator feedback. MOE updates are dependent upon the collection rate of the surveillance system. Information access to MOEs should be available on demand

3.1.2.4.1 MOE Monitoring

Traffic flow MOEs provide the principal measures for traffic management performance. MOEs are used at different processing levels within the traffic management system and are required in three primary timeline categories: [1] “on-line” processing functions (i.e., traffic control feedback and incident detection processing); [2] “routine” processing functions (i.e., traffic network management and status displays); and [3] “off-line” functions (i.e., traffic network information management, access, and dissemination). Figure 3.1.2-7 illustrates these levels and corresponding timeline scales for MOEs are use and application.

MOEs for traffic control and incident detection processing need to be directly provided by the surveillance function. The surveillance function tends to be closely-coupled with these processes to provide the timely feedback needed to support control activities and monitoring functions. This coupling also ensures the MOE data is representative of up-to-date traffic conditions and minimizes latency conditions which could trigger inappropriate controls and alarms. Functions which use MOEs in this “on-line” fashion typically operate on a near real-time timeline (seconds to minutes). For example, integrated corridor flow

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control collects and processes MOE data at the corridor level. In these applications, MOE Value is measured more by the recency of the data in order to assess proper system responses. Details of incident detection processing are documented in paragraph 3.1.2.3. Further details of traffic control performance requirements are documented in paragraph 3.2.2.

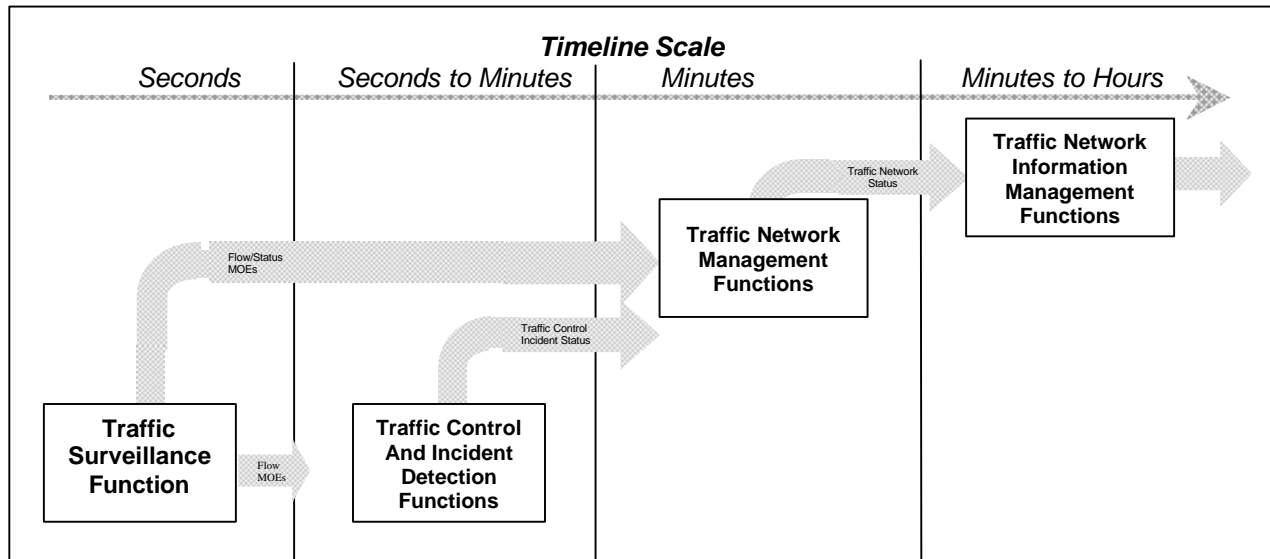


Figure 3.1.2-7. MOE Processing Application Levels

MOEs used for traffic network management and status displays need to be readily available (on demand) for traffic control functions and operator presentation and feedback. MOEs available on demand are defined as the latest reported status (within the last surveillance cycle - typically 20-30 seconds) retained by the system. On demand performance minimizes latency effects and operator frustration when having to wait for system feedback and status displays.

MOE processing and availability at this level require periodic updates to support ongoing “strategic” management activities, or possibly “tactical” traffic views (i.e., mainline section, entrance ramp status, etc.). Where traffic control and incident detection functions involve more critical MOE processing timelines (direct access), monitoring activities are more involved with the organization, interpretation, and presentation of the MOEs on a system status display in an operations center environment to conduct routine traffic management and information dissemination activities.

Off-line functions, such as, traffic network information management, information access control, and information dissemination, tend not to require stringent MOE update timelines. The term “off-line” is used to make reference to information processing performed external to the traffic surveillance and control subsystems. This processing is primarily oriented towards information services to provide traffic status to external (to

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traffic operations) entities. MOEs used in this capacity are processed into more relevant travel information involving corridor congestion, incidents travel times, and delays. This information can be disseminated to outside parties or individuals for independent traffic reporting services, assessments, and reports.

3.1.2.4.2 Traffic Network Status Displays

Traffic network surveillance status displays include overall traffic network flow (system map), corridor-level flow (mainline segment - multiple surveillance zones), sub-corridor-level (i.e., single surveillance zone, entrance/exit ramps), video surveillance, and traffic management subsystems status. Control of the data displays and media are processed through two basic functions: [1] the traffic surveillance and control subsystems; and [2] the TMC operator interface(s). Organization of user/operator interface controls need to be self-contained where all pertinent information is available to aid operator selection. The latter function focuses the operator's attention to a single interface to promote ease of use and operator productivity. System-generated response actions (decision aids) need to automate repetitive tasks and actions (standard operating procedures) to streamline operator workload. User presentations should incorporate graphical forms to maximize operational utility, control, and user friendliness.

Status displays processed through the traffic management subsystems should automatically collect and update traffic status on a routine (periodic) basis. These displays include the following:

- Overall traffic network status including roadway congestion status and incident detection processing
- Traffic surveillance and control subsystems status
- System/component health status
- Information system maintenance

Control and data displays commanded by the TMC operator should be processed through an integrated and interactive user interface for display and control functions (e.g., function selection, scale, data types, etc.). These displays need to be available on-demand for the following management functions.

- Traffic surveillance and control monitoring
 - Traffic surveillance (plus environmental data)
 - Mainline/Ramp control
 - Changeable message control (CMS/HAR)
 - Network performance monitoring
 - Database maintenance
- Incident management
 - Detection/Prediction (e.g., special events, work/construction zones, etc.)
 - Verification
 - Notification

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- Response and removal coordination
- Incident traffic management
- Incident information dissemination
- Incident database maintenance
- Video surveillance and control
 - Image selection (camera) and control (PTZ)
 - Image display control (monitor)
- Information management
 - Information collection and management
 - Dissemination and access control
 - Database maintenance
- Malfunction monitoring
 - System status monitoring
 - System/component health checks and diagnostics
 - Database maintenance
- System administration
 - Housekeeping
 - Database maintenance

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3.2 Traffic Control Performance

Traffic control systems provide the flow control facilitation mechanisms to collect, calculate and execute traffic management strategies. The FHWA Traffic Control Systems Handbook, FHWA-IP-85-11, defines traffic control as the regulation, warning, and guidance of traffic for the purpose of improving the safety and efficiency of moving people and goods. Implementing this control process involves the installation, operation, and maintenance of various traffic control strategies and control devices, such as signs, signals, and lane barriers.

The MDOT ATMS/ATIS will primarily involve management of traffic on freeways and expressways surrounding the metropolitan Detroit area. Freeway Operations will include mainline flow management and control, incident management, driver/traveler information dissemination, and system maintenance. Mainline flow management and control activities include entrance ramp activation and metering control, mainline flow control, and integrated corridor management and control. Evolution of mainline flow management can extend into integrated surface street/mainline flow controls to optimize traffic flow between high capacity trunklines/arterials and freeways during peak traffic periods.

The following assessments are intended to identify levels of control processing to support allocation of those processes and functions into the system architecture. Detailed performance characteristics are defined where possible.

3.2.1 Traffic Control Assumptions

Assumptions associated with this assessment involve behavioral aspects of traffic flow, metropolitan Detroit roadway characteristics, and MDOT DFO traffic control modes and strategies. These assumptions reflect the perspective from which the system will be designed, implemented, operated, and maintained. Operational-efficiency objectives (i.e., operational-effectiveness and cost-efficiency) are incorporated into this analysis to define feasible performance requirements consistent with DFO strategies.

Traffic Flow Behavior. The traffic model illustrated in Figure 3.1.2-3 depicts a closed process relationship between traffic flow surveillance, demand prediction, incident detection, traffic control, and the traffic network. Driver perceptions result in reactions to the traffic controls and network status and are displayed in driver behaviors. These behaviors are a result of route re-evaluation and the exercising alternative route choices. These perceptions tend to be accounted for through the collection of traffic MOEs, however, may modify traffic strategies to adapt to the changes in traffic flow and routes taken. The traffic control system must formulate and execute these strategies in response to flow changes measured by the surveillance system and predicted by potential traffic demands and incidents.

Metropolitan Detroit Roadway Characteristics. Traffic control for metropolitan Detroit roadways, more specifically freeway mainlines, will include entrance ramp controls, mainline controls, and corridor controls. Portions of freeway mainlines exhibit non-capacity- reducing bottleneck characteristics. These characteristics include sight-occluded

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curves, narrow roadways, weaving sections (e.g., transition lanes), and severe roadway surface inconsistencies. Seasonal weather conditions tend to amplify the effects of these bottleneck characteristics with heavy rain and transitional snow/ice roadway surface conditions. The traffic control system needs to sense and adjust traffic controls for these conditions.

MDOT Traffic Control Strategies. Traffic control strategies for metropolitan Detroit currently consist of entrance ramp control and variable message signing (i.e., CMS, HAR/AHAR). Current control strategies use the freeway mainlines as the primary conduits for traffic movement. Limited deployment of traffic surveillance and control infrastructure has constrained the system's ability to effectively manage traffic flow. Strategies for the future system will enable areawide integrated corridor management with coordinated operations, variable mainline speed signing, integrated ramp control, and integrated surface arterial/mainline control. In addition, traffic information will be available and disseminated to other TMCs, media reporting services, and roadway users to provide improved traffic awareness and travel planning capabilities.

Reference Sources. The following references are used in this assessment:

1. Wilshire, R., Black, R., Grochoske, R. & Higinbotham, J., Traffic Control System Handbook. Revised Edition - 1985, FHWA-IP-85-11, USDOT FHWA, pp 4.3-4.70.
2. Pline, J. L., Traffic Engineering Handbook, Institute of Transportation Engineers, pp 360-390, 391-418

3.2.2 Traffic Control Performance Assessments

Traffic control performance needs to be responsive to control strategies and appropriately scaled to be effective. The traffic control functions to be assessed include mainline ramp control, variable mainline speed signing, integrated corridor control, and coordinated areawide traffic operations.

3.2.2.1 Entrance Ramp Control Performance

Limiting the volume rate of vehicles entering a freeway mainline is the most widely used form of freeway traffic control. The primary objective of entrance ramp control is to eliminate, or at least reduce, traffic flow problems resulting from mainline congestion. In principle, the ramp control function limits the number of vehicles which enter the mainline by modulating the (entering) traffic demand with the mainline's downstream capacity. In consequence, vehicles may need to wait at the ramp before entering the mainline; queues may develop and cause spillover onto surface arterials; drivers may be diverted to other downstream ramps, avoid traveling on the mainline altogether, use surface arterials, or avoid traveling at that time; or ultimately, use another travel mode (i.e., transit bus, light rail, etc.). In any case, entrance ramp control helps promote smooth and efficient mainline traffic flow by deferring the travel delay onto the ramp and helps improve safety resulting from smoother traffic flow.

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Performance for entrance ramp controls are summarized in Table 3.2.2-1 and described in the following paragraphs.

Table 3.2.2-1. Entrance Ramp Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Ramp Closure	signing	scheduled	real-time	real-time	enabled	enabled	enabled
	barriers	scheduled	real-time	real-time	enabled	enabled	enabled
Ramp Metering	pre-timed	scheduled	real-time	real-time	enabled	enabled+	disabled
	traffic resp.	scheduled	real-time	real-time	enabled	enabled+	disabled
Intgr. Rmp Cntl	interconnection	scheduled	real-time	real-time	enabled	enabled	disabled

+ - modified normal mode

Control Strategies. Ramp control strategies are categorized as diversionary or non-diversionary. Diversionary strategies specify ramp control parameters so that entering traffic demand is diverted to another ramp, to an alternate route or travel period, or to an alternate mode. Non-diversionary strategies service, or assimilate, the entire traffic demand at the ramp.

Activation Modes. Activation modes are those control processes which determine the conditions in which ramp control is activated and deactivated. For most systems, ramp control activation is determined by a fixed schedule (time-of-day, day-of-week), response to mainline traffic conditions (traffic responsive), or through direct operator commands (operator override). When activation conditions are no longer valid, controls should be deactivated to promote motorist trust in the system.

Control Modes. Like other areas with a very diverse climate, the metropolitan Detroit area occasionally experiences inclement weather conditions which degrade the roadway surface and visibility. The system must provide the capability to determine local environmental conditions. These conditions include adverse roadway surface conditions due to heavy rain (flooding) and snow and ice. The system will enable, disable, and modify ramp controls as weather conditions vary. Normal mode is the default mode and applied for clear weather and roadway surface conditions. Rain mode is applied when significant (rain) precipitation is experienced. Metering rates are also modified to increase the intervals (spacings) between vehicles to allow more merging space. Snow/ice mode is applied when snow or ice conditions are experienced on the roadways and ramps. This mode deactivates ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers.

Ramp Control Implements. Three methods of ramp control include [1] Ramp Closure; [2] Ramp Metering; and [3] Integrated Ramp Metering.

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1. Ramp Closure is utilized to restrict entrance ramp access for congestion elimination or safety reasons. Ramp closure must be applied with care due to its inflexibility to accommodate mainline access. Ramp closure is applied when roadway capacity immediately upstream from the ramp is at capacity, inadequate vehicle queue storage capacity on the ramp, major incidents downstream from the ramp, and severe weaving problems exist at the ramp gore. Methods to implement ramp closure include message signing and moveable barriers. Specific infrastructure accommodations also need to be in place in order to utilize the ramp closure method. These include adequate alternate routes and alternate ramps.
2. Ramp Metering is the most widely used method of ramp control. Ramp metering is normally applied to alleviate mainline congestion and/or to improve the safety of merging operations.
 - a. Activation control is determined by a fixed schedule (TOD/DOW), in response to mainline traffic conditions, or by operator command (override).
 - b. Metering methods used for metropolitan Detroit include pre-timed and traffic responsive metering (see Table 3.2.2-1). Pre-timed ramp metering typically uses preset metering rates (not directly influenced by mainline traffic conditions). Traffic responsive metering calculates metering rates based upon a mainline demand-capacity relationship whereby real-time upstream demand and downstream capacity determines the rate.
 - c. Single-entry metering rates are varied from 180-900 vehicles per hour (vph), and platoon metering rates are used when > 900 vph are required.
 - d. Control implements used for ramp metering include a standard 3-section (red-yellow-green) or 2 section (red-green) metering signal head, an advance ramp control warning sign with a flashing beacon or “blank-out” (“METER ON”) sign, a local ramp controller, environmental sensors (optional), and vehicle sensors to detect vehicles at the complementary ramp exit, at the ramp entrance, at the stop line (check-in), just passed the stop line (check-out), and optionally in the primary merging area of the ramp and freeway mainline.
3. Integrated Ramp Control applies the principles of ramp metering to a series of adjacent ramps. Integrated pre-timed metering and integrated traffic responsive metering consists of coordinated control where adjacent ramp controllers adjust metering rates based upon traffic conditions throughout an entire corridor. Typical processing calculations use the demand-capacity traffic relationship for metering rates at each ramp, with implementation options which use a central system master; a corridor (node) master; or logically-interconnected controllers coordinating metering rates.

3.2.2.2 Mainline Control Performance

Mainline control provides a means to [1] improve the stability and uniformity of traffic flow; [2] disseminate pertinent traffic information directly to roadway users to provide warnings and promote awareness; [3] divert traffic to alternate routes make better use of corridor capacity; [4] facilitate incident clearance and recovery by diverting traffic to

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alternate routes; and [5] change the directional capacity of the freeway mainlines by using reversible lanes. Performance of mainline controls vary depending upon the type of operation. Performance parameters are summarized in Table 3.2.2-2 and described in the following paragraphs.

Table 3.2.2-2. Mainline Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Variable Speed (Restriction)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
Info. Dissemin, (Restriction)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Altern. Routing (Diversion)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Lane Control (Restriction/ Diversion)	signing	scheduled	real-time thresholds	real-time	enabled	enabled+	enabled+
	barriers	scheduled	real-time thresholds	real-time	enabled	enabled+	enabled+

+ - modified normal mode

Control Strategies. Mainline control strategies are applied to regulate, warn, and guide mainline traffic to achieve more stable and uniform traffic flow. The primary strategy is to detect impending congestion and hazardous roadway conditions and deploy mainline controls to facilitate smoother traffic flow.

Activation Modes. Activation modes are those control processes which determine the conditions in which mainline controls are activated or deactivated. Activation modes include fixed (scheduled), traffic responsive, or operator commanded (override). Except for lane controls established for recurrent traffic patterns (reversible lanes), all mainline controls are activated through pre-defined thresholds based upon real-time traffic conditions and operator concurrence. When activation conditions are no longer valid controls should be deactivated to promote motorist trust in the system Controls for reversible lanes are scheduled (with operator concurrence) to conform with established recurrent traffic patterns. Scheduling enables predictability for drivers and roadway availability.

Control Modes. The system must provide the capability to determine local environmental conditions and adjust mainline controls to appropriate levels. These conditions include adverse roadway surface conditions due heavy rain (flooding) and snow and ice. The system will enable, disable, and modify mainline controls as weather conditions vary.

1. Normal mode is the default mode and applies to clear weather and roadway surface conditions. This mode specifies mainline controls (speed, mainline demand, integrated ramp demand, alternate routing) to promote system-wide traffic flow stability and uniformity.

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2. Rain mode is applied when significant (rain) precipitation is experienced. Controls are modified/adjusted to account for degraded roadway surface conditions and cautious motorist behavior.
3. Snow/ice mode is applied when snow or ice conditions are present on the roadways and ramps. This mode provides similar adjustments as Rain Mode with the addition of deactivating ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers. This mode may specify closure of designated ramps and mainline interchanges due to hazardous roadway conditions.

Mainline Control Implements. Four methods of mainline control applicable to the metropolitan Detroit area include [1] Variable Speed Control; [2] Driver Information Dissemination; [3] Alternate Routing; and [4] Lane Control. Mainline metering could also be applied in the future if the use toll roads become evident as a means to fund new roadway infrastructure developments.

1. Variable Speed Control is utilized to reduce the speed of the mainline traffic during peak-flow conditions so that the flow is adjusted to mainline capacity. At best, variable speed control may delay congestion occurrence. Speed control improves the stability and uniformity of traffic flow during peak-flow periods, thus helping reduce the occurrence of rear-end collisions as congestion develops. Speed control can also be applied as an advance warning system when downstream incidents are detected. Care must be used with speed control to ensure traffic flow conditions warrant use, i.e., control activation to anticipate peak-flow conditions, and deactivation once congestion conditions are prevalent. Methods to implement speed controls include specific speed signing or integrated with general messages.
2. Driver Information Dissemination is utilized to provide pertinent, real-time traffic information directly to roadway users. Information dissemination is normally applied when abnormal traffic conditions exist and warnings for roadway, traffic, and incident conditions, speed reductions, and route diversions. Methods to disseminate information include variable message signing, variable speed signing, and lane control signals.
 - a. Variable message signing direct to roadway drivers using overhead and roadside equipment (CMS/HAR/AHAR).
 - b. Variable speed signing to provide advance warning for downstream roadway and traffic conditions.
 - c. Lane control indicator to identify lane closures and diversions from typical lane use.
3. Alternate Routing Control is applied when traffic congestion, roadway conditions, and major incidents warrant diversion of mainline traffic to other under-utilized corridors. Methods to provide alternate routing include variable message signing (CMS/HAR/AHAR) and lane control indicators.

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4. Lane Control is applied to improve the efficiency and safety of mainline traffic flow. Use of lane control is usually warranted for advance warning of lane blockage, for improvement of ramp merging operations, mainline traffic diversion, mainline tunnel control, and construction/work zones. Methods to provide lane control include variable message signing and permanent/moveable barriers.

3.2.2.3 Integrated Corridor Control Performance

Integrated corridor control provides a means to improve the stability and uniformity of traffic flow within a corridor through management of all available regulatory traffic controls on both the freeway mainline, service roads, and parallel surface arterials. The fundamental system requirement to achieve integrated corridor control is surveillance and control of both freeway mainlines and surface arterials through coordinated management. Performance of integrated corridor controls vary depending upon the type and extend of operations. Performance parameters are summarized in Table 3.2.2-3 and described in the following paragraphs.

Table 3.2.2-3. Integrated Corridor Control Operational Performance

Control Method	Control Device	Activation Mode			Control Mode		
		Fixed	Traffic Rsp	Opr-Cmd	Normal	Rain	Snow/Ice
Ramp Closure	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
	barriers	N/A	real-time	real-time	enabled	enabled+	enabled+
Intgr. Rmp Cntl	interconnection	N/A	real-time	real-time	enabled	enabled	disabled
Variable Speed (Restriction)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
Info. Dissemin, (Restriction)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Altern. Routing (Diversion)	signing	N/A	real-time	real-time	enabled	enabled+	enabled+
Lane Control (Restriction/ Diversion)	signing	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+
	barriers	N/A	real-time thresholds	real-time	enabled	enabled+	enabled+

+ - modified normal mode

Control Strategies. Integrated corridor control strategies are placed into two categories: [1] restriction; and [2] diversion. Restriction limits corridor traffic demand to below corridor capacity levels to stall congestion levels and promote traffic throughput. Restriction strategies are accomplished through regulatory controls, such as, ramp, mainline, and mainline/surface arterial intersections. Diversion transfers excess traffic demand onto alternate corridors with excess capacity. Diversion strategies are also accomplished through regulatory controls with the addition of driver information signing.

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System integration of these control elements will provide the means to implement the following techniques:

1. Coordination of traffic signals on frontage/service roads and parallel alternate routes
2. Coordination of traffic signals at freeway interchanges with surface arterials (i.e., diamond interchange).
3. Coordination of the ramp control queue-override feature with frontage/service road intersection control to prevent queuing across the intersection.
4. Provisions for turning phases at frontage/service road and alternate route intersections with cross-streets that lead to freeway ramps.
5. Detection of incidents and provisions for rapid response and removal to minimize capacity impacts.

Activation Modes. Activation modes are those control processes which determine the conditions in which corridor controls are activated. Activation modes are traffic responsive or operator commanded (override). All corridor controls are determined by the system and activated through pre-defined thresholds based upon real-time traffic conditions and operator concurrence. Controls for reversible lanes are determined (with operator concurrence) to conform with established recurrent corridor traffic patterns.

Control Modes. The system must provide the capability to determine local environmental conditions and adjust mainline controls to appropriate levels. These conditions include adverse roadway surface conditions due heavy rain (flooding) and snow and ice. The system will enable, disable, and modify mainline controls as weather conditions vary.

1. Normal mode is the default mode and applies to clear weather and roadway surface conditions. This mode specifies corridor controls (speed, mainline demand, integrated ramp demand, alternate routing, and surface signals) to promote corridor traffic flow stability, uniformity, and roadway efficiency.
2. Rain mode is applied when significant (rain) precipitation is experienced. Controls are modified/adjusted to account for degraded roadway surface conditions and cautious motorist behavior.
3. Snow/ice mode is applied when snow or ice conditions are experienced on the roadways and ramps. This mode provides similar adjustments as Rain Mode with the addition of deactivated ramp metering to account for marginal roadway surface conditions which may compromise vehicle traction in stop-start-stop maneuvers. This mode may specify closure of designated ramps and mainline interchanges due to hazardous roadway conditions.

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Corridor Control Implements. The control implements use for integrated corridor management coordinate the traffic responsive controls for ramp and mainline controls and integrate the control coordination with surface arterial signal timing and control. Integration with the surface arterial signal network requires real-time coordination with the surface arterial TMC and jurisdictional agreements. In addition, corridor controls need to be directly integrated with incident management plans to provide rapid response coordination and incident traffic diversion deployment.

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3.3 Information Management and Dissemination Processing

Advanced Traveler Information Subsystems (ATIS), in conjunction with Advanced Traffic Management Subsystems (ATMS), will provide a variety of information services to assist travelers in arriving at their destinations whether the mode is via private vehicles, law enforcement, commercial dispatchers, public transportation, and inter-modal travel systems. The ATIS will collect travel and traffic information from the ATMS, coalesce and manage the information into presentable forms, and disseminate the information in a variety of methods, to a variety of users. For the metropolitan Detroit area, this ATIS will be integrated with the Michigan Department of Transportation (MDOT) ATMS located at the Metropolitan Transportation Center (MTC). ATMS/ATIS operations are envisioned to be managed from the Detroit Freeway Operations Center (DFOC).

Disseminated information includes congested and incident locations, alternate routing, roadway/freeway network status, weather and road conditions, roadway limitations and closures, and speed recommendations. Dissemination of traffic information will evolve over several phases, beginning with currently available communications media (i.e., AM/FM radio, variable message signing, printed material, etc.), then to more specialized telecommunications devices (i.e., personal communication devices, intelligent terminals and kiosks, roadway infrastructure devices, full featured call-up services, and other interactive information services), and finally to autonomous, in-vehicle navigation systems, pre-trip planning services from homes, offices, and roadside kiosks, and portable personal data assistants which interact with the infrastructure for real-time traffic and traveler information.

This evaluation examines the performance required to manage and disseminate traveler and traffic information from within the ATIS. Performance for information delivery to users will vary depending upon the telecommunications device and the service used, and is considered beyond the scope of this evaluation.

3.3.1 Information Management and Dissemination Assumptions

Traffic and roadway information has the potential to be collected from a variety of sources. These include the ATMS, MDOT highway maintenance/construction crews, weather service bureaus, other TMCs, local and state government agencies (i.e., MSP, Detroit Police, Sheriff departments), courtesy patrols, public volunteer services, and local businesses. The following list represents a candidate list of the sources and users that may provide or receive traffic, weather, and roadway status information.

- ATMS traffic surveillance subsystems
- Michigan Emergency Patrol
- Michigan Department of Transportation (MDOT) divisions
- Michigan State Police (MSP)
- Metropolitan Detroit cities and counties public works (i.e., city/county road departments, etc.)
- Edison electric
- Ameritech/Michigan Bell

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- Local/national weather bureaus
- Roadway commuters and travelers (i.e., cellular call-ins)

3.3.2 Information Management and Dissemination Processing Assessments

Before any information can be effectively disseminated, it has to be collected, validated, and organized into a form that can be identified, processed (if necessary), and logged. Management of this information needs to occur in an efficient manner in order for effective MDTS operations and to provide timely, valid traffic information and status to outside users. In addition, the operators must be able to easily manage the information and system functions from a integrated work station which minimizes excessive operator actions. This information subsystem interfaces with the various subsystems (i.e., traffic surveillance and control subsystem [ATMS], CMSS, etc.). Figure 3.3.2-1 illustrates a candidate information systems architecture which manages traffic information flow into and from the system.

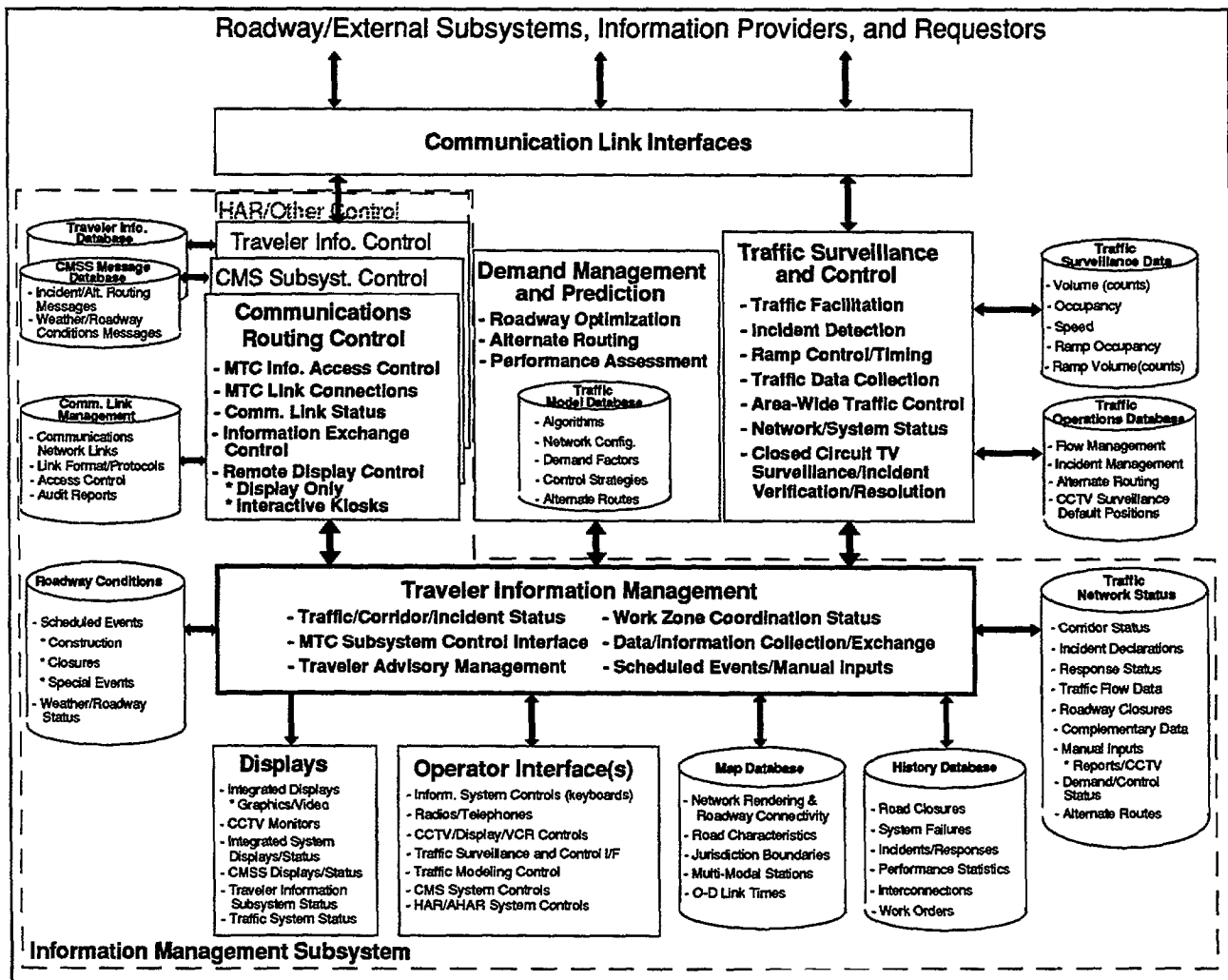


Figure 3.3.2-1. ATMS/ATIS Information Management Architecture

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3.3.2.1 Traffic and Travel Information Collection

The traffic and roadway information will be collected by the ATIS from many sources. The primary sources are summarized in Table 3.3.2-1 and described below.

Table 3.3.2-1. Information Management Subsystem Inputs

Input Information	Source	Input Method	Destination/Database
Traffic Conditions - Traffic Flow Data - Corridor Status - Demand/Control Status - TOC Data Exchanges	- MDTS traffic surveillance subsystems (ATMS) - Michigan State Police (MSP) - Operator - Roadway commuters and travelers (i.e., cellular call-ins)	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions Database
Incident Declarations - CMS messages - Advisories - Alternate Routing	- Operator - MSP - MEP	- Manual	- Traffic Network Database - History Database
Incident Response Status	- Operator - MSP - MEP - Removal Service	- Manual	- Traffic Network Status Database - History Database
Maintenance Work Orders	- Operator	- Manual	- Traffic Network Status Database - History Database
Scheduled Events - Sports - Conventions - Public Works	- Operator - Data Exchange Link - Metropolitan Detroit cities and counties public works (i.e., city/county highway departments, Edison electric, Ameritech)	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions - Traffic Operations Database
Weather Reports	- Operator - Local weather bureaus/reports	- Manual	- Traffic Network Status Database - History Database - Roadway Conditions - Traffic Operations Database - CMSS - Traveler Ino. Subsystem
Roadway Closures - Construction - Maintenance	- Operator - Data Exchange Link	- Manual - Electronic	- Traffic Network Status Database - History Database - Roadway Conditions - CMSS Message Database - Traveler Ino. Subsystem
System Status - Performance Statistics - System Failures - Work Orders	- Operator - ATMS - MITSC Subsystems	- Manual - Electronic	- History Database - Roadway Conditions
System Configuration - Comm. Network Links - Access Control	- Operator	- Manual	Comm Link Management
Operator Control Commands - ATMS - Traffic Modeling - CMSS - Communications - Traveler Information - Information System Administration	- Operator	- Manual	- Traffic Operations Database - Traffic Modeling Database - CMSS Message Database - Comm Link Management - Traveler Info. Subsystem - System Database

1. The ATMS will provide traffic flow statistics, potential incidents displays/alarms, system status (i.e., Failure Status, Controller Status, Traffic Page, and Incident Page), and CCTV video signals.

DFOC operators monitor the ATMS displays/status, MSP dispatcher radio frequencies, MEP printouts, DFOU field crews, weather reports, and perform other

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DFOC duties (i.e., secretarial) to input and log incidents, system failures, repair work orders, weather and road conditions, and daily summaries.

3. Information from local and state government agencies, public services, and sporting and special event organizers, and businesses may provide schedules for events which could impact traffic flow. Information regarding these pre-planned events may be input (by DFOC operators) into the information management subsystem to provide traffic advisories through advanced equipment (i.e., CMS displays, HAR/AHAR announcements, etc.) and implementing traffic control strategies.

3.3.2.2 Traffic and Travel Information Organization and Management

The Information Management Subsystem (IMS) provides the “virtual” database for management of all system and subsystem data. The IMS will fuse data received from multiple sources, both internal and external to the system. The IMS will serve as a centralized information clearinghouse for up-to-date traffic information. Information access is provided through roadway signing devices, media reporting services, dial-up, and point-to-point/electronic information exchanges.

Operator commands and controls will be routed through the IMS to electronically interface to other subsystems. The information management subsystem must provide timely information upon operator request. System responses and requested information should be provided to the operator without disrupting the continuity of the task (e.g., respond within 10 seconds of the request). The DFOC operator interface must provide an integrated station where all freeway operations can be managed. Traffic information management and control displays will be integrated to handle [1] overall system status, [2] freeway network surveillance and control, [3] subsystem displays and controls, [4] administrative management (i.e., operator inputs, incident reports, system status reports, work orders, communications link access control. etc.), and [5] software and system updates.

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At a minimum, information will be organized into the following categories:

Table 3.3.2-2. Database Organization

Database	Data Types (examples)
Traffic Flow Surveillance	Congestion levels/MOEs
	Link times/delays
	Incident detection locations
Traffic Operations	Current control operations
	Incident Management
	Control modes
	Control plans
	System status
Demand Management	Control strategies
	Traffic Demand factors
	System performance statistics
	Predictive control plans
Traffic Network Status	Corridor status/Coalesced MOEs
	Link times/delays
	Incident declarations/locations
	Road closures
	Manual Reports
	Alternate route data
History Database	Compiled traffic MOEs/Congestion levels
	Link times
	Incident Data
	System status/failures
	System work requests/status
Incident Management	Incident Data
	Responding agencies
	Jurisdictions
Map Database	Displays/Map coordinates
	Equipment location
	Surveillance zones
	Jurisdiction boundaries
	Roadway characteristics
Roadway Conditions	Scheduled events
	Weather condition status
	Roadway condition status
Message Signing Database	Changeable Message Signs
	Highway Advisory Radio/Automatic HAR
	Other signing
Communications Management	Network connections
	Communications protocols
	Access controls
	Audit reports

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3.3.2.3 Traffic and Travel Information Dissemination and Control

The IMS will provide DFOC personnel with an integrated station from which to monitor and control all ATMS/ATIS subsystems. Outputs from the IMS consist of electronic data and information exchanges with subsystems, and also administrative reports for the purpose of record keeping, traffic studies, data reduction, and maintenance work orders. Table 3.3.2-3 identifies information and corresponding output methods used for dissemination to freeway network users.

Table 3.3.2-3. Information Management Subsystem Outputs

Output Information	Output Method	Destination
Traffic Conditions - Traffic Flow Data - Corridor Status - Incidents/Response Status	ATIS - CMSS - HAR/AHAR Syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Roadway Conditions - Weather - Closures	ATIS - CMSS - HAR/AHAR Syst. - Traveler Info. Syst. - Electronic Data Link	- Travelers - Public/Private Kiosks - MSP - Emergency Services - Commercial Business - Public Transit
Traffic Modeling and Prediction	ATMS - Electronic - Printouts	- Traffic Operations Database - History Database
MDTS Work Orders	- Hard Copy Printouts - Electronic Storage	- MITSC Personnel - History Database
System Reports - Traffic Data - Weather Reports - System Performance Reports - Incident/Response Reports -	- Hard Copy Printouts - Electronic Storage	- MITSC Personnel - System Archives
Operator Control Commands - ATMS - Traffic Modeling - CMSS - HAR/AHAR Subsystem - Communications - Traveler Information - System Administration	- Electronic Storage	- Traffic Operations Database - Traffic Modeling Database - CMSS - HAR/AHAR Subsystem - Communications Routing - Traveler Information Subsystem - Information Management Subsystems

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3.4 System Monitoring Performance

The ATMS/ATIS must be capable of evaluating subsystem components for performance effectiveness and malfunction conditions. Two types of monitoring functions are evaluated in this assessment: [1] Traffic Control Effectiveness; and [2] System Health Status. Monitoring could be accomplished at various levels; however, reports must be delivered to the TMC for evaluation and disposition.

3.4.1 System Monitoring Assumptions

Assumptions used in this performance assessment encompass the following:

1. Traffic Control Effectiveness is measured from reported surveillance MOEs and compared with current traffic control plans.
2. System Health Status is monitored for all surveillance and control components. Each component has the capability for built-in test (BIT) and executes BIT/self test upon power-on, periodically consistent with MOE reporting periods, and on operator command (local or from DFOC).
3. Central monitoring functions have the capability to further interrogate each component for diagnostic testing to identify malfunctions to the removable module level. Diagnostic testing is commandable through DFOC system operator interfaces.

3.4.2 System Monitoring Assessments

Real-time system monitoring shall be accomplished from the MTC through available subsystem equipment. These equipment are primarily the collection points for traffic MOE data and field equipment status. In addition, these equipment also provide the means to assess traffic control effectiveness (via comparison of control plans with MOE data) and malfunction diagnostics (i.e., operator commanded self test).

3.4.2.1 Traffic Flow Performance Monitoring

Traffic flow performance monitoring is conducted to evaluate the effectiveness of traffic control plans. The primary goal of this function is to ensure the traffic control system is properly configured to meet the traffic demand and does not inadvertently cause traffic congestion problems.

This monitoring function can be thought of as a traffic demand/control assessment function where deployed traffic control plans are used with measured flow volumes to model calculated traffic flow MOEs. These “modeled” MOEs are then compared with measured MOEs and evaluated for consistency (compared to thresholds). Inconsistent values are analyzed and correlated with other data to identify the cause for the inconsistency. If traffic controls or detected incidents are determined as the cause, the

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system provides the operator with recommended responses (traffic control plan changes, incident responses) and resolution. The performance of this function requires real-time access to MOE data and current traffic control plans (ramp metering, closures, etc.). Statistical results are compiled (per hour) and stored to document the system's performance.

3.4.2.2 Equipment/System Health and Status Monitoring

Equipment/system health and status monitoring is conducted to maintain a current view of the system health and operational status. The primary goal of this function is to ensure the system is operating properly and malfunctions are identified and dispositioned. This function requires real-time access to complementary equipment status data (which is reported with traffic flow MOEs). Monitoring of this data also requires interfaces to system status displays and an interrupt capability to perform ancillary operator-commanded functions (diagnostics).

Malfunction indicators shall be automatically issued through visual or audible alarms. The system should automatically issue an initial self test command to ensure the malfunction is not an occasional anomaly. If frequent malfunctions are detected within a short period of time (once every 10 cycles or 10% - approximately every 3 - 5 minutes), the system should automatically flag the anomaly and issue an alarm to the operator.

The system should automatically manage system malfunction information and maintain a historical database for malfunction type, time of malfunction, equipment ID, disposition (i.e., work order issued), operation restoration status, and other pertinent maintenance information.

APPENDIX – V

MICHIGAN DEPARTMENT OF TRANSPORTATION

REQUEST FOR PROPOSAL

DEPLOYMENT OF ATMS/ATIS IN METROPOLITAN DETROIT

*** PROTOTYPE ***

Date of Issuance: [Issue Date]

Pre-proposal Assistance Questions Due: [Questions Due Date 1, 4:30 PM

Date Due: [Proposal Due Date]

Address: Transportation Systems
 Traffic and Safety Division
 Michigan Department of Transportation
 State Transportation Building
 425 West Ottawa Street, P.O. Box 30050
 Lansing, Michigan 48909

Contact Person: [MDOT P.O.C.]

Phone: [MDOT P.O.C. Telephone Number]

Fax: (517) 335-1815

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SECTION 1 - GENERAL INFORMATION FOR THE BIDDER

1.1 Purpose

This request for proposal (RFP) provides interested parties (hereafter referred to as “Bidder”) with the information required to prepare and submit proposals to carry out all responsibilities associated with the scope of this procurement.

This procurement includes both the design and construction necessary for deployment of Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS) in the three county (Wayne, Oakland and Macomb) Metropolitan Detroit area. Proposals submitted in response to this RFP must include system design, component design (where non-standard), software design, construction design (civil, electrical, and other related elements), procurement, production, installation, integration, test, and warranty for the entire system. The providing of a service contract, maintenance training, and other options are also included.

1.2 Issuing Office

This request for proposal is issued by the Michigan Department of Transportation (MDOT), Transportation Systems Section, Traffic and Safety Division, State Transportation Building, P.O. Box 30050, 425 West Ottawa Street, Lansing, Michigan 48909; phone (517) 373-2247, FAX (517) 335-1815.

1.3 Project Funding

MDOT plans to fund the project using Congestion Management Air Quality (CMAQ) funds. The contract award is subject to approval by MDOT and the Federal Highway Administration (FHWA).

1.4 Proposals

In order to be considered, a Bidder must submit a complete response to this RFP based on the Scope of Work in Section 2 using the System Implementation provided in Section 3. Proposals must be submitted in two parts, a technical proposal and a cost proposal. Ten (10) copies of the technical proposal under sealed cover and two (2) copies of the cost proposal under separate sealed cover must be received no later than 3:00 p.m. EST by [insert due date 1, to the address as specified in Section 1.2. Any proposal received after this time and date will be rejected. No other distribution of proposals will be made by the Bidder. Proposals must be signed by an official authorized to bind the Bidder to its provisions. For this RFP, the proposal must remain valid for at least ninety (90) days after the proposal due date. Proposals received in response to this RFP will remain the property of MDOT and will not be returned.

1.5 Addenda

In the event it becomes necessary to revise any part of the RFP, addenda will be provided to all bidders who originally requested the basic RFP. The names of the bidders will not be disclosed outside MDOT or the U.S. Department of Transportation, Federal Highway Administration.

1.6 Pre-Proposal Assistance

All questions relative to the development of a proposal are to be directed to [insert name of MDOT P.O.C. 1, Transportation Systems, Traffic and Safety Division, P.O. Box 30050, Lansing, Michigan 48909; FAX (517) 335-1 815. All questions must be in writing and submitted on or before [insert question due date] . A copy of questions and answers will be provided to all bidders who received the RFP.

A bidders conference may be scheduled if considered beneficial by MDOT. Notification of the location, date and time of the conference will be provided to all bidders who received the RFP at least five (5) working days prior to the conference. Attendance at the bidders conference (if scheduled) will be optional and will be solely at the Bidder's cost and no reimbursement for travel or any other item whatsoever will be admissible. A copy of all questions, answers, and discussions at the bidders conference will be provided to all bidders who received the RFP.

1.7 Oral Presentations

Bidders who submit a proposal may be requested to make oral presentations of their proposal to MDOT. These presentations provide opportunity for the Bidder to clarify their proposal to insure thorough, mutual understanding. MDOT will schedule these presentations. These presentations, if called upon to do so, will be solely at the Bidder's cost and no reimbursement for travel or any other item whatsoever will be admissible.

1.8 Economy of Presentation

Proposals should be prepared simply and economically, providing a straightforward, concise description of the Bidder's ability to meet the requirements of the RFP. Fancy bindings, color displays, promotional materials, and related items are not desired. Emphasis should be placed on completeness and clarity of content.

1.9 News Release

News releases pertaining to this RFP, or the service, study or project to which it relates, will not be made without prior MDOT approval, and then only in coordination with MDOT.

1.10 Compliance with Federal Regulations

The Bidder selected must be in compliance with the following federal regulations:

1. Title VI Civil Rights Act of 1964
2. Minority Business Enterprise Guidelines
3. Equal Employment Opportunity Guidelines
4. Non-discrimination on the Basis of Handicap (Section 504)
5. Prohibition of Discrimination in State Contracts (See Appendix A)

1.11 Type of Contract

The Bidder selected will be required to agree to the standard terms and conditions of a firm fixed price contract for all items excluding the procurement of the traffic sensors. Procurement of traffic sensors will be under a separate cost plus fixed fee line item.

1.12 Proposal Contract

The contract between MDOT and the Bidder shall consist of:

1. The RFP and any amendments thereto, and
2. The Bidder's proposal submitted in response to the RFP.

In the event of a conflict in language between the two documents referenced above, the provisions and requirements set forth and/or referenced in the RFP shall govern. In the event that an issue is addressed in one document that is not addressed in the other document, no conflict in language shall have been deemed to occur. However, MDOT reserves the right to clarify any contractual relationship in writing with the concurrence of the Bidder, and such written clarification shall govern in case of conflict with the applicable requirements stated in the RFP or the Bidder's proposal. In all other matters not affected by the written clarification, if any, the RFP shall govern.

This contract represents the entire agreement between the parties with respect to the subject matter hereof and supersedes all prior negotiations, representations or agreements, either written or oral, between the parties hereto relating to the subject matter hereof and shall be independent of and have no effect upon any other contracts. A record of formal contract negotiations between the contractual parties will be prepared by MDOT and will become a permanent part of the contract file.

1.13 Termination of Contract

The contract resulting from this RFP shall be subject to the following termination provisions. The contract may be terminated by MDOT for the following reasons:

1. Default
2. Bidder Bankruptcy
3. Unavailability of funds

4. Convenience

1.13.1 Termination for Default

Any bidder who is determined in writing by MDOT to be in breach of any of the terms and conditions of a contract with MDOT shall at the discretion of MDOT be declared in default and such contract may be terminated as a result of such default. MDOT shall not be liable for any further payment to the Bidder under a contract terminated for the Bidder's default after the date of such default as determined by MDOT except for commodities, supplies, equipment or services delivered and accepted on or before the date of default and for which payment had not been made as of that date. The Bidder shall be liable to MDOT for all loss, cost or damage sustained by MDOT as a result of the Bidder's default.

1.13.2 Termination for Bankruptcy

In the event of the filing of a petition of bankruptcy by or against the Bidder, MDOT shall have the right to terminate the contract upon the same terms and conditions as a termination for default.

1.13.3 Termination for Unavailability of Funds

In the event that MDOT funds of Federal funds for the contract become unavailable, MDOT shall have the right to terminate the contract without penalty and upon the same terms and conditions as a termination for convenience.

1.13.4 Termination for Convenience

MDOT shall be authorized to terminate for its own convenience all contracts for the procurement of supplies and services MDOT has determined that such termination will be in MDOT's best interests. When it has been determined that a contract should be terminated for the convenience of MDOT, MDOT shall be authorized to negotiate a settlement with the Bidder according to terms deemed just and equitable by MDOT. Compensation to the Bidder for lost profits on a contract terminated for convenience of MDOT shall not exceed an amount proportionate to the sum that the Bidder's total expected margin of profit on the contract bore to the contract price, based on the total out of pocket expense incurred by the Bidder as of the date of termination of the contract. Whenever a contract is terminated for the convenience of MDOT, the Bidder shall have the burden of establishing the amount of compensation to which he believes himself to be entitled by submission of complete and accurate cost data employed in submitting his bid or proposal for the contract and evidence of expenses paid or incurred in performance of the contract from the date of award through the date of termination. Payment of the sum agreed to in settlement of a contract terminated for convenience of MDOT shall be made from the same source of funds or account as the original contract.

1.13.5 Procedure on Termination

Upon delivery by certified mail to the Bidder of a Notice of Termination specifying the nature of the termination, the extent to which performance of work under the contract is terminated, and the date upon which such termination becomes effective, the Bidder shall:

1. Stop work under the contract on the date and to the extent specified in the Note of Termination
2. Place no further orders for materials, services, or facilities, except as may be necessary for completion of such portion of the work under the contract as is not terminated
3. Terminate all orders to the extent that they relate to the performance of work terminated by the Notice of Termination
4. Assign to MDOT all of the right, title, and interest of the Bidder under the orders so terminated, in which case MDOT shall have the right, at its discretion, to settle or pay any or all claims arising out of the termination of such orders
5. With the approval of MDOT, settle all outstanding liabilities and all claims arising out of such termination of orders, the cost of which would be reimbursable in whole or in part, in accordance with the provision of the contract
6. Transfer title, all files, processing systems, data manuals, or other documentation, in any form, that relate to the work terminated by the Notice of Termination
7. Complete the performance of such work as shall not have been terminated by the Notice of Termination

The Bidder shall proceed immediately with the performance of the above obligations notwithstanding any delay in determining or adjusting the amount of any item reimbursable price under this clause.

1.13.6 Termination Clause

After receipt of a Notice of Termination, the Bidder shall submit to MDOT any claim promptly but in no event later than six (6) months from the effective date of termination, unless an extension is granted by MDOT within the six month period. Upon failure of the Bidder to submit its termination claim within the time allowed, MDOT may determine on the basis of information available to MDOT, the amount, if any, due to the Bidder by reason of the termination and shall thereupon cause to be paid to the Bidder the amount so determined.

1.14 Changes in Scope

MDOT may, at any time by a written order, make changes within the general scope of the contract. No changes in scope are to be conducted except at the approval of MDOT. If any such change causes an increase or decrease in the cost of, or the time required for the performance of any part of the work under the contract, whether changed or not changed by any such order, a mutually satisfactory adjustment shall be made in the contract price or delivery schedule, or both, and the contract shall be modified in writing accordingly.

1.15 Incurring Costs

The successful Bidder must not commence any billable work until a valid contract has been executed. Costs of developing the proposal are solely the responsibility of the Bidder. MDOT will provide no reimbursement for such costs.

1.16 Hold Harmless

The Bidder agrees to indemnify, defend, and hold harmless MDOT, its officers, agents, and employees from:

1. Any claims or losses for service rendered by the Bidder, person or firm performing or supplying services, materials, or supplies in connection with the performance of the contract;
2. Any claims or losses to any person or firm injured or damaged by the erroneous or negligent acts of the Bidder, its officers or employees in the performance of the contract;
3. Any claims or losses resulting to any person or firm injured or damaged by the Bidder, its officers or employees by the publication, translation, reproduction, delivery, performance, use, or disposition of any data processed under the contract in a manner not authorized by the contract, or by Federal or MDOT regulations or statutes;
4. Any failure of the Bidder, its officers or employees to observe Michigan laws, including but not limited to labor laws and minimum wage laws.

1.17 Rights and Remedies

The rights and remedies of MDOT provided in Section One shall not be exclusive and are in addition to any other rights and remedies provided by law or under this contract.

1.18 Contract Variations

If any provision of the contract (including items incorporated by reference) is declared or found to be illegal, unenforceable, or void, both MDOT and the Bidder shall be relieved of all obligations arising under such provision; if the remainder of the contract is capable of performance, it shall not be affected by such declaration or finding and shall be fully performed.

1.19 Insurance

The Bidder will provide public liability, property damage and workmen's compensation insurance, insuring as they may appear, the interest of all parties of agreement against any and all claims which may arise out of Bidder operations under the terms of this contract. It is agreed that in the event any carrier of such insurance exercises cancellations, notice will be made immediately to MDOT of such cancellation.

1.20 Attorney's Fees

In the event that either party deems it necessary to take legal action to enforce any provision of the contract, and in the event MDOT prevails, the Bidder agrees to pay all expenses of such action, including attorney's fees and costs at all states of litigation as set by the court or hearing officer.

1.21 Independent Price Determination

A proposal will not be considered for award if the price in the proposal was not arrived at independently without collusion, consultation, communication, or agreement as to any matter relating to such prices with any other offeror or with any competitor.

The Bidder must include a certified statement in the proposal certifying that the price was arrived at without any conflict of interest as described above. Should conflict of interest be detected any time during the contract, the contract shall be null and void and the Bidder shall assume all costs of this project until such time that a new Bidder is selected.

1.22 Protest

MDOT shall have authority to determine protests and other controversies of actual or prospective Bidders or Offerors in connection with the solicitations or selection for award of a contract.

Any actual or prospective Bidder or Bidder who is aggrieved in connection with solicitation or selection for award of a contract, may file a protest with MDOT. A protest or notice of other controversy must be filed promptly, and in any event two calendar weeks after such aggrieved person knows or should have known of the facts giving rise thereto. AU protests or notices of other controversies must be in writing. MDOT shall promptly issue a decision in writing. A copy of that decision shall be mailed or otherwise furnished to the aggrieved party and shall state the reasons for the action taken. The decision by MDOT shall be final and conclusive.

SECTION 2 - OVERALL PROJECT DESCRIPTION

2.1 Background

The Michigan Department of Transportation has operated a freeway surveillance system on 32.5 miles of freeway in the City of Detroit since 1980. The existing system consists of 1,240 inductive vehicle detector loops, 49 ramp metering locations, 14 changeable message signs (CMS), 11 closed circuit television (CCTV) cameras, and 2 highway advisory radios (HAR).

Surveillance and control are from the Michigan Intelligent Transportation Systems (MITS) Center (MITSC). Equipment related to the MITSC includes:

1. Concurrent 3280MPS processor system and existing software
2. Vicon VPS-1300 video switcher and associated controls
3. Vultron CMS control console and software
4. Disk Operating System (DOS) and Graphic Display System (GDS) graphic processor subsystems
5. Cable resources from junction of I-94/I-75 to MITSC.

All communication between the MITSC and the field equipment is over 75 ohm coaxial cable installed along either shoulder of the freeway covered. A 25-pair copper cable is also available and is used for communication to nine of the CMS and to two of the HAR. Short distance communications from the vehicle detector stations to the superintending remote communication unit (RCU) are via the same 25 pair cable.

The existing communication equipment was designed by Sperry and Tocom in the late 1970's. In 1993, MDOT contracted with a consultant to conduct an Advanced Traffic Management System Architecture Study to determine the best and most suitable techniques and equipment currently available, or likely to become available in the next five years. This project is an outgrowth of that study as most of the new technology and methods of operation identified in this FWP are the result of that study.

Additional information on the existing system may be requested as required from the address listed in Paragraph 1.2. Information will be provided where available in its existing format.

2.2 Project Objectives

This RFP is issued for the purpose of retaining the services of a supplier for the engineering, procurement, installation, integration, and service of a system providing ATMS and ATIS on the freeways and state trunk lines in the proposed coverage area (Figure 1).

[Place specific deployment area map here]

Figure 1 - Deployment Area Map and Technology Locations

A final determination of coverage area will be dependent upon funding availability, the deployment costs, and the consistency of areas covered and functionality's performed in order to meet the objectives. Should increased funding or reduced costs permit, installation of additional instrumentation may be included.

The system shall provide MDOT personnel the capability to detect and verify recurrent and non-recurrent traffic congestion for efficient traffic management by utilizing Advanced Traveler Information Systems. Additionally, the system shall have the capability to manage mainline work zones, calculate mainline volume demand and predict traffic flow patterns for scheduled events, planned work/construction zones, and special events.

The proposed project scope will include the following tasks:

1. Project management
2. Engineering
 - a. Civil design to support installation of ATMS/ATIS instrumentation
 - b. Systems/electrical design to support installation operation and all interfaces as needed for system performance
3. Specification development for the procurement of equipment, hardware and software
4. Procurement of hardware, software, and all other equipment and services
5. Installation
6. System integration, test and evaluation of system and subsystem performance
7. Warranty, service, maintenance and training

Detailed descriptions of each of these tasks are provided in Section 3.

2.3 Scope of Work

The project to be awarded from this RFP includes both design and construction (design/build) phases. As such, it places unique demands on the prospective bidder. Firms bidding must have both design and construction capabilities, either individually, as a team, or through subcontractors. The tasks to be executed (Section 3) require the detailed design of the overall system, each site, and some specific unique equipment. In order to properly prepare a bid, it will be necessary to estimate, to some level of detail, a specific design solution corresponding to each detailed design effort that is a part of the contract.

Also to be included in this phase is all construction work associated with the installation of the equipment selected in the design process. Procurement of the equipment, or in some cases manufacture of certain pieces, is also included.

Following installation, an extensive series of integration, test, and operator training steps must be conducted in order to ensure proper operation of the system. This must include those steps necessary to make new capabilities compatible with existing traffic control capabilities. Training

necessary to make the operators fully capable of utilizing all features must also be provided. A warranty for one (1) year on all equipment, workmanship, and other items furnished must be included. This warranty must extend manufacturer's warranties where they are less than one year.

Estimates for two options are also required. These include a service policy providing up to four (4) years additional warranty (performance and repair) coverage (five years total) and a formalized maintenance training course.

2.4 System Functional Requirements

The system shall perform the following functional processes to support freeway operations in the Metropolitan Detroit area:

1. Interface to other agencies and systems
2. Perform traffic network surveillance and control
3. Display traffic network status
4. Perform traveler information management
5. Perform system performance and malfunction monitoring

Details of each of these functional requirements are provided in Section 4.

The existing system shall become an integral part of the initial deployment of the new system. General performance capabilities of the new installation shall be compatible with the current communications and operations system.

The system shall provide the MITSC the capability to monitor traffic and congestion through the use of traffic detectors and video surveillance. Traveler and motorist information shall be provided using HAR and CMS. The implementation of the ATMS/ATIS system shall provide MDOT the timely means to detect and verify incidents on selected corridors and to provide traffic operations personnel sufficient data to distinguish incidents from normal daily congestion. Mainline flow control shall be provided by ramp control devices. The system shall allow the dissemination of traffic and congestion information to motorists so they can plan or modify their traveling plans.

The newly deployed system shall be integrated in operation with the current traffic control system. This project will entail system design, installation, and integration as well as personnel training to operate and maintain the system.

2.5 Individual Component Requirements

Certain specialized equipment will be necessary in many areas of the project. These components may require additional analysis in their specification. Currently, this is expected to apply to:

1. Traffic Sensors

2. Ramp Meters
3. CCTV Equipment
4. CMS
5. HAR Equipment
6. Control and Data Processors and Software
7. Concentrator CCTV Node Equipment
8. Communications Equipment
9. MITSC Equipment and Software
10. Other System Software

Details for each of these component requirements are provided in Section 5.

Wherever possible, the system should utilize commercial off-the-shelf (COTS) equipment. Where unavoidable, these items may be special ordered, or designed and manufactured specifically for this project.

2.6 Schedule Requirements

Timely completion of the overall project within the allocated 18 month period is required. Because the detailed schedule depends on the design and construction methods selected, it has not been established for this project. The Bidder will provide a detailed time schedule for project completion, indicating milestones and reviews by MDOT.

2.7 Reporting Requirements

Documentation of all design elements, decisions, and other information is required in report, drawing or presentation format.

2.7.1 Interim Report

At the completion of each task the Bidder will provide ten (10) copies of an interim, task specific, report and related plans for MDOT review.

2.7.2 Final Report

At the completion of the project the Bidder will provide one camera ready master and fifty (50) copies of the final report and related plans for MDOT review.

2.7.3 Meetings and Presentations

The selected Bidder will be required to meet with MDOT within two weeks of the award of the contract to discuss and finalize planning and execution of specific elements of each work task. The selected Bidder will also be required to make monthly progress report presentations and a final report presentation before a committee designated by MDOT. In these presentations, the

Bidder will present the results to date and solicit comments from the committee to be addressed and incorporated in the subsequent reports and final report.

SECTION 3 - SPECIFIC TASKS

The following section discusses the design and construction for deployment of ATMS/ATIS, within the current system of traffic management at the MITSC, through a series of specific tasks. Task 2 must be completed for each major component of the system identified in Section 5 and approved by MDOT prior to the start of the installation of that component as required in task 5. Task 3 must be completed for each major component of the system identified in Section 5 and approved by MDOT prior to the procurement of that component as required in task 4.

3.1 Task 1 - Project Management

The management of this project will include direct monitoring and coordination of the project's progress by key personnel reporting to a project manager. All coordination of design activities in order to ensure proper interpretation of all hardware and software components will depend on the program manager. The project manager will be directly accountable to a committee designated by MDOT.

The project manager shall be responsible for all aspects of the project. Management and supervision responsibilities include, but are not limited to:

1. Design
2. Procurement
3. Installation
4. Integration (hardware and software, including custom developed software and integration of COTS software with custom developed software)
5. Assurance that all required FCC requirements are met when integrating communications equipment
6. Assurance that all performance specifications are met
7. Procurement and installation of hardware and software components
8. Preparation of deliverable documents
9. Coordination of civil construction project management activities
10. Coordination with local and regional government agencies
11. Acquisition of necessary permits and licenses
12. Operation and maintenance training
13. Service and repair, including correction of all anomalies identified prior to system acceptance

3.2 Task 2 - Engineering

The engineering task has been divided into civil design and systems/electrical design.

3.2.1 Task 2A - Engineering - Civil Design

Civil design shall include all standard civil design and analysis efforts in the area of deployment including:

1. Base drawings showing the location of the equipment to be installed.
2. Field survey of areas where equipment will be installed to determine if the location is appropriate given the field conditions and to locate utilities necessary for the installation and operation of the equipment.
3. Preparation of “as-built” drawings showing the location of the equipment installed, utilities required for the operation of the equipment, access required for the maintenance of the equipment, pavement, and right-of-ways.
4. Preparation of specifications and estimates for subsurface construction, pavements, and the installation of system components.

3.2.2 Task 2B - Engineering - Systems/Electrical/Software Design

Systems/electrical design shall establish requirements for the system and for each sub-system defined by the system design. From these requirements, specific sub-system and system components shall be selected, designed and integrated with other sub-systems. Sub-systems shall include at least a system host, detector station controller, ramp meter controller, video surveillance unit, information dissemination unit, and communications equipment. Strict design practices shall be used to develop the system design.

The selection of commercial software, and the design and development of custom software when required, is a subset of the engineering design described in this task. The design of custom software shall follow a formalized, standard practice designed to control errors and document results.

3.3 Task 3 - Specification Development for the Procurement of Equipment, Hardware and Software

In order to maximize system flexibility and incremental deployment strategies, a distributed modular architecture with standardized interfaces shall be used. Each system component shall be treated as an independent node capable of operating autonomously whenever possible. Distributing the functionality to the lowest level component shall be used to significantly reduce communications requirements.

A hierarchical system design shall be utilized to provide autonomous regional control and to reduce single point failures. A regional processor can be deployed to coordinate a specific region and operate without continuous interaction with the main system host computer.

3.4 Task 4 - Procurement of Hardware, Software, Other Equipment and Services

All hardware, software, other equipment and services necessary for the completion of this project shall be procured by the Bidder. The development, coding, testing, and documentation of custom software shall either be procured or performed by the Bidder. Software embedded in system hardware may either be considered as part of that hardware or as a separate item.

The procurement of each component of the system as identified in Section 5 shall not take place until the specification resulting from Task 3 is completed and approved by MDOT. Equipment and components shall make maximum use of readily available, multiple source, COTS equipment.

3.5 Task 5 - Installation

Installation of system components shall be performed within the specific corridor boundaries at locations identified in Task 2. The installation of each component of the system as identified in Section 5 shall not take place until the design resulting from Task 2 is completed and approved by MDOT. This task includes, as a minimum, construction management, all construction efforts (demolition, foundations, paving, electrical, signs, poles, structures, communications, traffic control), and other hardware and/or software installation.

3.6 Task 6 - System Integration, Test and Evaluation of System and Subsystem Performance

This task shall include, as a minimum, all efforts necessary to insure correct operation of all system elements and to demonstrate this correct operation to MDOT's satisfaction. This shall be accomplished in two phases, integration and acceptance.

3.6.1 System Integration

System integration shall be performed to ensure that deployed ATMS/ATIS components are operating within system functional specifications. Integration activities include, but are not limited to, installation of software, integration of software and hardware components, and integration of deployed system equipment.

3.6.2 Acceptance Test

There shall be an acceptance test period of thirty days after completion of installation to identify, isolate and correct any problems with the purchased hardware and software, the developed hardware and software, and all interfaces. A test procedure shall be developed by the Bidder in conjunction with MDOT and shall be approved by MDOT before a formal acceptance test may be conducted. All problems discovered by the Bidder or MDOT shall be corrected to the satisfaction of MDOT and the test successfully repeated before the acceptance test shall be adjudged as successfully completed.

The objective of acceptance testing is to provide a reasonable level of assurance to demonstrate that operation of the implemented system satisfies the approved design.

The system shall be accepted as operational only after all of the following has been achieved.

1. Successful completion of acceptance testing per the MDOT approved acceptance test procedure.
2. MDOT receipt, review, and approval of all acceptance test data and results.
3. Successful completion and delivery of all contract deliverables.

Performance criteria to be examined during acceptance test period shall include the following:

1. System operations shall be performed within current system timeline constraints (e.g., SCANDI, GDS, Vultron, other).
 - a. Traffic surveillance data collection, processing, and communications to the MITSC shall be accomplished (as appropriate) within current SCANDI timelines (e.g., 1 minute data, 20 second data, etc.).
 - b. Video signal and control from the MITSC to field components shall be in real-time. Video signals and camera controls (pan, tilt, and zoom) shall be selectable from the MITSC.
 - c. Routine system monitoring functions for field components shall be performed (as appropriate) within current SCANDI timelines (e.g., 1 minute data, 20 second data). Operator-commanded diagnostics shall also conform to SCANDI timelines (e.g., 1 minute data).
 - d. CMS and HAR (or automatic highway advisory radio (AHAR)) operations shall be performed through the SCANDI, Vultron, or HAR control systems. These operations shall be interactive and sustaining in nature.
2. SCANDI software modifications shall maintain current timeline performance. This includes assimilation of traffic flow status and volume counts.
3. Acceptance testing shall be conducted for a period of thirty (30) consecutive days from the initiation of acceptance testing. System field components shall operate continuously during the normal MDOT shift hours (6AM to 8PM). The system shall experience no major failures during this testing period (major failures include malfunctions that require longer than 1 day to repair). If a major failure occurs, the acceptance test period shall be restarted for a new 30 day period.

3.7 TASK 7 - Warranty, Service, Maintenance and Training

A one year full warranty and operational training must be provided as part of the proposal in response to this RFP. In addition, two optional additions shall be described and priced separately. These options provide:

1. A service policy extending the warranty coverage in one year increments to a maximum total of five years

2. A maintenance training program for MDOT personnel.

3.7.1 System and Subsystem Performance and Service Warranty

The Bidder shall furnish a warranty of all hardware, software and equipment for maintenance and performance for the specific period of one (1) year from the date of acceptance of work. All purchased hardware, equipment and software shall have their ownership and warranties transferred to MDOT. Where equipment is warranted for a period of less than one year by its supplier or manufacturer, the Bidder shall extend the warranty coverage to one full year.

MDOT shall withhold an amount, not to exceed five (5) percent of the total contract amount, until the conclusion of the warranty period or until the posting of a bond assuring full execution of the warranty.

Any failed equipment covered by warranty that can be repaired on-site shall be repaired by the Bidder within twenty-four (24) hours of notification of failure. Equipment requiring removal from site for repair or any equipment requiring replacement with a new unit shall be replaced by the bidder within five (5) days of notification. New replacement equipment shall continue the original warranty of the replaced unit except where the warranty provided by its supplier or manufacturer is longer. The cost of shipping of failed equipment shall be the responsibility of the Bidder even where it is removed by MDOT.

3.7.2 Operational Training

The Bidder shall provide training to state personnel in the operation (including basic theory, normal and maintenance operating modes, and basic troubleshooting) of the system. The Bidder shall provide two (2) eight-hour training sessions, accommodating up to 10 students in each session. Training materials will be prepared and provided by the Bidder and approved by MDOT. By utilizing the training received, state personnel will be able to utilize all features of the system and to operate it to meet all functional requirements as specified in Section 4.

For a period of five (5) years from the date of acceptance of work, when state personnel who have completed this operational training are unable to operate any feature, component or other part of the system, the Bidder shall respond to the site with 24 hours of notification and shall provide such information as required to allow proper operation and full system performance. All labor, travel and related costs associated with responding to system failures during this five year period shall be the responsibility of the Bidder.

3.7.3 System and Subsystem Performance and Service Policy Option

The Bidder shall provide, priced separately, the option of extending all warranty terms (parts and service) in consecutive one (1) year increments to a period of five (5) full years from the date of acceptance of work (four years of extension options). MDOT may select any number of additional consecutive years of extension (including zero) without other impact on this project.

MDOT shall withhold an amount, not to exceed fifty (50) percent of the optional service contract amount, until the conclusion of the service contract period or until the posting of a bond assuring full execution of the service contract. The balance of the optional service contract amount shall be payable in equal amounts divided over the number of years of the service contract selected. Payment will be made at the end of each year on the same date as the completion of acceptance testing.

This service policy will provide repair or replacement of all hardware, software and equipment due to defects in operation or performance. Where equipment is warranted for a period of less than the number of selected years by its supplier or manufacturer, the Bidder shall extend the warranty coverage for the full period without additional cost to MDOT. Any failed equipment covered by warranty that can be repaired on-site shall be repaired by the Bidder within twenty-four (24) hours of notification of failure. Equipment requiring removal from site for repair or any equipment requiring replacement with a new unit shall be replaced by the bidder within five (5) days of notification. New replacement equipment shall continue the original warranty of the replaced unit except where the warranty provided by its supplier or manufacturer is longer. The cost of shipping of failed equipment shall be the responsibility of the Bidder even where it is removed by MDOT.

3.7.4 Maintenance Training Option

The Bidder shall provide, priced separately, the option of providing training to state personnel in the operation, maintenance, troubleshooting, and repairs of the system. The Bidder shall provide two (2) eight-hour training sessions, accommodating up to 10 students in each session. Training materials will be prepared and provided by the Bidder and approved by MDOT. By utilizing the training received, state personnel will troubleshoot any failures, attempt to identify the, location of the failure, and attempt to restore the system to proper operation. Payment for this optional course will be made when overall system acceptance is complete and payment is made.

For a period of five (5) years from the date of acceptance of work, when state personnel who have completed this maintenance training are unable to return the system to proper operation, the Bidder shall respond to the site with 24 hours of notification and shall return the equipment to proper operation within 72 hours of notification. All labor, travel and related costs associated with responding to system failures during this five year period shall be the responsibility of the Bidder.

SECTION 4 - SYSTEM FUNCTIONAL REQUIREMENTS

This project will entail system design, installation, and integration as well as personnel training to operate and maintain the system. The system (Figure 2) shall perform the following functional processes to support freeway operations in the Metropolitan Detroit area:

1. Interface to other agencies and systems
2. Perform traffic network surveillance and control
3. Display traffic network status
4. Perform traveler information management
5. Perform system performance and malfunction monitoring

The system shall provide the MITSC the capability to monitor traffic and congestion through the use of traffic detectors and video surveillance. Traveler and motorist information shall be provided via HAR and CMS. The implementation of the ATMS/ATIS system shall provide MDOT the timely means to detect and verify incidents on selected corridors and to provide traffic operations personnel sufficient data to distinguish incidents from normal daily congestion. Mainline flow control shall be provided by ramp control devices. The system shall allow the dissemination of traffic and congestion information to motorist so they can plan or modify their traveling plans.

The existing system shall be an integral part of initial new system deployments. General performance capabilities shall be compatible with the current communications and operations system. Additions to the existing system shall not require extensive changes to the current software or hardware. Software shall be developed to interface additional sensors, ramp controllers, video cameras, and CMS and HAR resources to provide, as a minimum, the same capabilities as in the current system. Changes to the existing hardware will be limited to the augmentation of the existing hardware and addition of new interfaces to it.

4.1 System Interfaces

System interfaces consist of Detroit Freeway Operations Unit (DFOU) operators and maintenance personnel, external government agencies, external commercial and private businesses, the travelers or users of the freeway network, the current traffic surveillance, control and communications subsystems, and the local metropolitan Detroit freeway network and environment. Interface descriptions include the entity and the type of information transferred (e.g., network status, traffic coordination information, incident information, physical features, environmental effects, etc.).

4.1.1 DFOU Personnel Interfaces

Detroit Freeway Operations Center (DFOC) operator interfaces include operator commands, freeway network status displays and reports, and system status displays and reports.

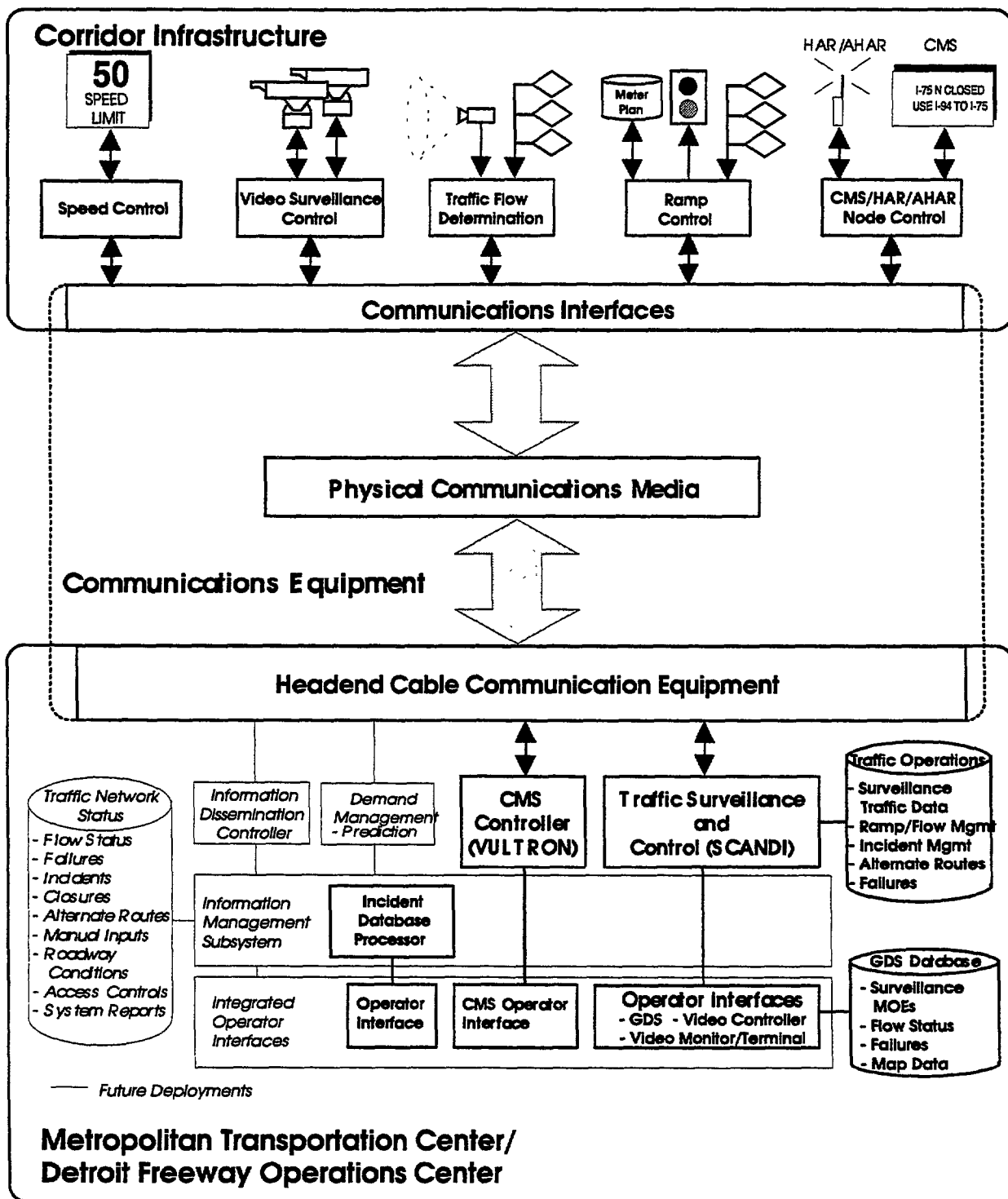


Figure 2 - System Functional Architecture

DFOC field/road crew interfaces include operations information, work/construction zone information and status.

4.1.2 External Government Agencies

Law enforcement/emergency service interfaces include Michigan State Police (MSP), local police/sheriff, fire departments, medical services, HAZMAT, and others.

County Agency interfaces include County Road Commissions/Department of Roads, Southeast Michigan Council of Governments (SEMCOG), other Traffic Operations Centers, and other county agencies

City Department interfaces include Detroit Department of Transportation, Public Works departments, and other city departments.

4.1.3 External Commercial and Private Businesses

External commercial and private business interfaces include Metro Traffic, AAA, United Parcel Service, other fleet services, and third-party traffic reporting services (e.g., broadcast TV/radio, CATV, etc.).

Removal Service interfaces include towing/wrecking companies and contracted courtesy patrols. Transit service interfaces include Greyhound Bus Lines, Smart Regional Transit Bus, and Commuter Transportation Service.

4.1.4 Freeway Network Users

Roadway travelers using the freeway network include the general public and other users. Roadway vehicles include passenger cars, commercial trucks, transit vehicles, and motorcycles. Roadway infrastructure interfaces include roadway features, bridges/overpasses, conduit structures, electrical power, and lighting.

4.1.5 Standard Interfaces

The system shall interface with existing equipment through currently available channel and processing capacities. In general, new subsystem equipment and components will provide capabilities to communicate with both the existing and new systems through industry-standard interfaces (e.g., NEMA, EIA, CCITT, SAE, ANSI, VME, SCSI, NTSC, etc.). The current infrastructure and equipment will be maintained as the primary system for other corridor deployment. Current DFOC operator interfaces will be augmented (where needed) to manage

traffic operations capabilities for the new corridor (e.g., network status displays, ramp control, etc.).

Subsequent deployment phases shall utilize the existing system to the maximum extent possible for continued operations in concert with new system and subsystem equipment. DFOU operation of both systems shall be integrated to minimize differences in operator interface(s) and tasks. As new freeway corridors are instrumented and brought on-line, corresponding operator interfaces shall also be integrated and reflect the additional system capabilities. Specific functional processes are identified as follows:

4.2 Perform Traffic Network Surveillance and Control

The system shall provide DFOU personnel the capability to perform recurrent and non-recurrent traffic congestion management through mainline flow surveillance, mainline flow control, coordination of incident management tasks, and area-wide traffic coordination. Additionally, the system shall have the capability to manage mainline work zones, and calculate mainline volume demand and predict traffic flow patterns for scheduled events, planned work/construction zones, and other special events. Specific functional and performance requirements are specified in the following paragraphs.

4.2.1 Perform Mainline Flow Surveillance

The system shall provide the capability to perform mainline traffic flow surveillance for the designated corridors in the metropolitan Detroit area.

4.2.1.1 Perform Vehicle Detection

The system shall have the capability to capture vehicle presence counts and detection time differentials (speed traps) for passenger cars; commercial vehicles; transit vehicles; motorcycles; and other roadway vehicles using vehicle detection stations meeting the following:

1. Vehicle detection stations along the mainline corridor(s) shall be separated by roadway distances of 1/3 mile increments plus or minus 10%. If roadway characteristics in certain areas preclude using this increment tolerance, the next available location shall be selected.
2. Vehicle detection stations shall be located immediately upstream of mainline entrance ramps in accordance with MDOT standards. These stations shall provide traffic flow data to determine ramp metering activation and metering rates.
3. Vehicle detection points (stations) for mainline entrance and exit ramps shall conform to MDOT standards for ramp queue, demand, and passage locations, merge occupancy, and corresponding mainline locations to detect and calculate upstream demand and downstream capacity.
4. System vehicle detection accuracy shall be within 10% of actual vehicle counts. Performance is based upon MDOT metering activation/deactivation threshold levels.

4.2.1.2 Calculate Corridor MOEs

The system shall compute mainline corridor measures of effectiveness (MOE: average occupancy, total volume, and average speed) for each detection station from the vehicle detection data.

4.2.1.3 Manage Corridor MOEs

The system shall maintain traffic flow MOEs in an integrated freeway network status database. This information shall be made available for use with other traffic operations functions (e.g., area-wide traffic coordination, work zone management, traffic demand management and flow prediction, incident management, and traffic and travel information dissemination).

4.2.1.4 Display Corridor MOEs

Mainline corridor MOE data shall be made available for freeway network status displays, entrance ramp status displays, information management, and other DFOC activities.

4.2.1.5 Monitor Mainline MOEs for Incidents

The system shall utilize an MDOT-approved incident detection capability to identify potential mainline capacity-reducing non recurrent incidents.

4.2.1.6 Perform Video Surveillance

The system shall capture NTSC broadcast quality color or monochrome TV video images at identified locations along mainline freeway corridors and communicate images and control data to the DFOC for traffic flow assessments and incident verification by DFOU personnel for 24-hour surveillance. Average intervals shall be 1 mile.

4.2.1.6.1 Collect Video Images

The system shall provide NTSC broadcast quality video images (color and monochrome) of designated freeway corridors for display at the Metropolitan Detroit Transportation System (MDTS) DFOC. Image characteristics shall include the following:

1. Full color (daylight) capability
2. Low light monochrome (dawn/dusk/night) capability to a minimum of 0.1 lux (1.0×10^{-2} FC)
3. Automatic/manual bright/low light compensation and transition
4. Image resolution (minimum): 500 lines horizontal, 400 lines vertical
5. Lens systems providing a minimum 6:1 zoom ratio with a minimum angular field of view of 20° horizontal (15° vertical) at the wide angle position at f1.2, with manual focus, remotely controlled.
6. TV video image resolution and modulation shall be compatible with NTSC TV standard.

7. TV video image modulation shall be compatible with current DFOC TV monitors.

4.2.1.6.2 Video Image Control

The system shall provide remote video image viewing control from the DFOC. Control functions shall include the following:

1. Remote control viewing direction (e.g., horizontal pan and vertical tilt) and image quality (e.g., focus, color, zoom, intensity, etc.) adjustments shall be provided.
2. Video camera platforms shall provide pan-tilt mounting surfaces. Specifications for the pan-tilt platforms shall be:
 - a. Rotation: Pan: 0 to 355 degrees
 - b. Tilt: +/-90 degrees vertical.
 - c. Speed: 3 to 11 degrees/second
3. Pan and tilt stops to prevent over rotation.
4. Platform mounting shall allow for attachments to poles, buildings, on/under bridges, or other roadway fixtures.
5. Cameras shall be mounted in locations that provide effective viewing of the freeway segment under surveillance. Viewing height shall be a minimum of 40 feet above the roadway surface and minimize occlusion effects of roadway overpasses and curves.

4.2.1.6.3 Display Video Images

The system shall capture video images for viewing and display at the DFOC (and other locations). The system shall provide the capability to accept video images from external sources (e.g., Road Commission for Oakland County (RCOC) Transportation Operation Centers (TOC), Metro Traffic Control, local television stations). The system shall provide operator control to monitor video images collected from any field camera to a designated video monitor in the DFOC.

4.2.2 Perform Mainline Flow Control

The system shall control mainline traffic flow through adaptive entrance ramp management and traffic flow diversion techniques (e.g., message signing).

4.2.2.1 Perform Mainline Ramp Control

The system shall perform mainline freeway ramp control for designated freeway corridors. Ramp control shall consist of control modes and metering modes.

4.2.2.1.1 Determine Ramp Control Mode

The system shall support the following ramp control modes: clear mode; rain/wet mode; and snow/ice mode. These modes are defined as follows:

1. Clear mode - normal mode of operations.
2. Rain/Wet mode - pre-defined metering rates to account for hazardous roadway conditions.
3. Snow/Ice mode - ramp metering is disabled.

4.2.2.1.2 Provide Ramp Metering Mode Options

The system shall support the following ramp metering modes: pre-timed metering (e.g., operator-defined, time-of-day (TOD)), traffic-responsive (adaptive) metering, and occupancy mode metering.

1. Pre-timed metering mode provides ramp metering with predefined metering parameters (e.g., activation thresholds or time-of-day metering rates, etc.)
2. Traffic responsive metering mode provides ramp metering with adaptive activation to mainline MOEs, and adaptive or predefined metering rates.
3. Occupancy mode metering mode provides activation/deactivation based upon mainline occupancy. Default activation/deactivation is TOD (due to local gore detector failures).

4.2.2.1.3 Provide Ramp Metering Activation Control

The system shall provide the capability to perform entrance ramp metering control. Mainline traffic flow surveillance (detection stations) immediately upstream and downstream from an entrance ramp shall support ramp metering control functions.

1. Mainline surveillance MOEs (average occupancy, total volume and average speed) and ramp exit vehicle counts shall be collected to determine ramp meter activation and metering rates.
2. The system shall activate ramp metering by time-of-day scheduling; response to mainline gore MOEs (traffic-responsive and occupancy thresholds); or, DFOU operator command.
3. The system shall determine ramp metering rates by manual operator presets; or, calculated from mainline MOEs (e.g., upstream demand/downstream capacity).
4. The system shall support metering rates of 240 vehicles-per-hour (vph, equivalent to 4 vehicles per minute (vpm)) to 900 vph (15 vpm) for single lane ramps. Metering adjustment capabilities to support two-lane ramps shall also be provided.
5. The system shall provide the capability to set ramp meter activation and metering rates via local, on-site control; corridor processor (for integrated ramp control), or remote download from the DFOC under system or operator control.

4.2.2.1.4 Provide Ramp Control

Entrance ramp control stations shall provide the following capabilities in accordance with established MDOT standards:

1. Advanced ramp control warning indicator for ramp meter operation.

2. Vehicle queue detection
3. Vehicle demand (check-in) detection
4. Vehicle passage (checkout) detection
5. Vehicle merge lane occupancy (where possible)
6. Two-section ramp meter signal indicator for ramp traffic control.
7. Exit ramp vehicle detection

4.2.2.1.5 Provide Integrated Corridor Ramp Control

The system shall support enhanced capabilities to perform integrated ramp control for designated ramps along a mainline corridor segment. This capability provides integrated ramp control along a designated corridor roadway. Coordinated ramp metering is conducted in sequence along a corridor using upstream demand and metering data, and downstream capacity.

4.2.2.2 Display and Control Changeable Messages

The system shall provide a variable roadway signing capability that supports display of traffic diversion/status information for routing of traffic flow onto alternate mainline or trunk line corridors. Corridor and status-specific messages shall be developed using MDOT-approved criteria and stored in a diversion (CMS) message database. Due to sensitive legal, operational, and jurisdictional issues, the system shall protect the database against unauthorized modification.

4.2.3 Facilitate Incident Management Tasks

The system shall facilitate operator actions for logical decision making and integrate execution of the following incident management activities: incident detection, operator verification and declaration, response, removal, and traffic coordination, information dissemination, and incident log record keeping in accordance with the approved Incident Management Plan for Metropolitan Detroit. The system shall provide the capability for the operator to cancel or override any system command at any point in the process, and manually operate the system.

4.231 Perform Incident Detection

The system shall process and measure data collected from roadway traffic surveillance sensors against established incident thresholds and check for potential incident conditions using multiple MDOT-approved incident detection algorithms.

1. The system shall identify a potential incident within 180 seconds after the receipt of initial collected surveillance data indicating incident conditions.
2. The system shall employ a minimum of three (3) incident detection algorithms to concurrently process traffic flow data for every corridor surveillance cycle. The selected algorithms shall be subject for approval by MDOT prior to employment.
3. The MDOT-approved incident detection algorithms shall be capable of identifying potential incidents from the traffic flow data collected from the surveillance sensors.

4. Incident detection algorithm decision outputs shall be compared for detection consensus. A majority vote for detection shall be used to issue an incident detection alarm indicator.
5. If traffic flow conditions (multiple detection stations) and the incident detection consensus indicate that a potential incident exists, the system shall issue an incident alarm indicator to capture the operator's attention.

4.2.3.2 Provide Incident Verification Capabilities

The system shall provide for operator-preferred verification methods. At a minimum, the system shall provide the capability to graphically identify and display incident locations on the freeway network map and appropriate CCTV camera(s) corresponding to the identified incident location. The system shall support facilitation of other verification methods (e.g., report correlation) to the maximum extent possible in accordance with the approved Incident Management Plan for Metropolitan Detroit.

4.2.3.3 Record and Manage Incident Information

System assisted incident declaration and record keeping shall be stored in an incident database and include the following:

1. Date of the incident
2. Time start/declaration
3. Time cleared
4. Location (freeway, direction, lane (lane number, shoulder, median, ramp), nearest cross-street or fractional mile marker)
5. Incident category (accident, debris, fire, stalled vehicle, flood, HAZMAT, scheduled event, other)
6. Expected duration
7. Responding agency notified
8. Number of vehicles involved
9. Truck involvement
10. Weather conditions (temperature, rain/fog/snow/ice/dust, wind, other)
11. Incident remarks and comments
12. Logging operator identification

4.2.3.4 Facilitate Incident Notification and Response

The system shall assist the operator to notify the Michigan State Police dispatcher and to inform other incident response/traffic-related agencies and organizations. These tasks include:

1. Contact with MSP dispatch center. If the MSP is not aware of the incident, the system shall facilitate notification assistance. Information for notification and transmission methods includes:

- a. Incident location via available communications media (e.g., telephone, FAX, graphical display, CCTV video image, etc.)
 - b. Additional information such as diagnosis of the incident cause.
2. If a video image is available, the system configures the appropriate video links for transmission to the MSP dispatch post, Metro Traffic Control, and other capable incident reporting services.

4.2.3.5 Facilitate Incident Response and Removal Coordination

The system shall support incident removal through communications and coordination with the MSP, on-site authorities, MDOT field crews, and emergency and removal services. The system shall monitor response and coordination activities and document responding agencies, notified agencies, and incident resolution status in an incident information database.

4.2.3.6 Perform Incident Traffic Management

The system shall provide traffic management controls for the incident location. The system shall prepare information and system controls for traffic diversion around the incident (where possible) through alternate route information delivery, metering controls, and other techniques in accordance with the approved Incident Management Plan for Metropolitan Detroit.

1. The system shall identify appropriate Incident Management Plan alternate routes (based upon the local area corridor status).
2. The system shall identify appropriate upstream roadway signing locations, corridor HAR/AHAR transmitters, metered ramps, and other traffic controls for operator option selection(s).
3. The system shall select and display candidate roadway signs, HAR/AHAR messages, system-calculated metering rates, and other control options for operator-commanded selection and deployment. These message options shall be displayed to the operator for final selection and operator-commanded deployment. Once selected and commanded, the system configures the appropriate message packets to the selected target traffic management controls.

4.2.3.7 Disseminate Incident Information

The system shall facilitate incident information dissemination through available information dissemination links. These links include roadway message signing, in-vehicle delivery, freeway network status update and delivery to interfacing information agencies, and other dissemination channels.

1. Once detailed incident resolution information is compiled, the system shall record the deployed information (e.g., CMS, HAR/AHAR, etc.) into the incident log and action database.

2. The system shall provide operator-selectable information dissemination options (e.g., FAX, inter-TOC digital links, graphical status displays/kiosks, etc.) for information delivery.
3. Upon operator command, the system shall notify other traffic-related or emergency agencies through real-time communications media (e.g., telephone, FAX, graphical display, CCTV video, etc.). Potential agencies include:
 - a. Michigan State Police
 - b. Michigan Emergency Patrol
 - c. Metro Traffic Control
 - d. Radio traffic reporting services
 - e. Local Police/Sheriff
 - f. Local road agencies (per incident jurisdiction)
 - g. Medical emergency services
 - h. Hazardous Material (HAZMAT) services
4. The system shall also provide alternate routing information for other traveler information agencies. This information could be potentially used for:
 - a. Alternate route development and planning
 - b. Alternate route message deployment, where possible
 - c. General public education on alternate routes
 - d. Coordination with local police/sheriff and road agencies

4.2.4 Perform Area-Wide Traffic Coordination

The system shall provide DFOC personnel the capability to coordinate freeway network status/traffic flow and incident data and traffic control data for the greater metropolitan Detroit freeway network with other TOCs in the three-county area (Wayne, Macomb, Oakland) through information and data exchanges. Expansion to include the five-county area (Wayne, Macomb, Oakland, Washtenaw, Monroe) is envisioned in subsequent phases.

1. Exchanged traffic data includes video images, and digital, electronic, facsimile, and graphical formats.
2. Exchanged control data includes recommendations for metering and arterial signal timing cycles/offsets.

4.2.5 Perform Work Zone Management

The system shall provide DFOC personnel the capability to coordinate traffic management controls to account for work zones, temporary roadway impairments, and roadway closures.

1. The system shall collect and manage schedule information for use with freeway network surveillance and control, area-wide traffic coordination, traffic demand management and flow prediction, incident management, and traffic and travel information dissemination.
2. The system shall accept work schedule information from manual operator inputs or formatted electronic media.

4.2.6 Perform Traffic Demand Management

The system shall provide DFOC personnel the capability to calculate and develop traffic demand and flow controls based upon potential capacity demands induced by scheduled events, environmental conditions, work zones, or other recurring events.

1. The system shall model and predict traffic flow patterns based upon known demand generator locations and scheduled events, and reductions in roadway capacity due to scheduled roadway construction or maintenance events.
2. The system shall store demand results for use with traffic surveillance and control, area-wide traffic coordination, work zone management, incident management, and traffic and travel information dissemination functions.

4.3 Display Traffic Network Status

The system shall display a graphical representation of traffic network status of the metropolitan Detroit freeway system. These displays shall include mainline MOE status, mainline interchange status, ramp metering status, and corresponding exit ramps (if applicable). Displays consist of the entire interconnected system of identified corridors as the system (freeway network) map, and also support detailed corridor displays..

1. The system shall support display of a minimum of three hierarchical views. These views shall be hierarchical in the sense that the operator can view the entire freeway network, an operator-selected sub-network, or a specific mainline or entrance ramp interface (e.g., ramp status, metering control, MOEs, and reports) in a single view, as a minimum. These views shall each be capable of occupying the entire graphical display area. The system shall also provide a windowing capability to display multiple sub-network views within a single display. The full mainline freeway network view shall be the default view.
2. Resolution of the graphics display area shall be a minimum of 1024 x 768 pixels and support a simultaneous display of at least 16 colors.
3. The network status shall consist of different contrasted color levels that represent different levels of traffic occupancy for each mainline detection station segment. These levels shall be consistent at all view levels. Except for the full network view, the displays shall also include volume and speed indicators for each detection station segment. Color representations for occupancy levels are specified in Table 1.

Table 1 - Graphic Display Status Definitions

Display Color	Occupancy (%)	Volume (vehicles/min.)	Speed (mph)	Equipment Icon Status
Green	0-9	0-9	over 49	All Operational, On-line
Yellow	10-14	10-19	34-49	Partially Operational, On-line
Orange	15-20	20-29	20-33	Partially Operational, On-line
Red	over 20	over 29	0-19	Non-Operational, On-line
Gray	-	-	-	Off-line

4. Network status information shall have a data latency no greater than 1 minute.
5. The system shall also support views of other system operations displays, such as those for:
 - a. Subsystem control (e.g., video camera control, video monitor switching, CMS control and verification, HAR/AHAR control, etc.)
 - b. Incident management and coordination (e.g., incident location tagging, reports, and untagging)
 - c. System performance monitoring
 - d. System malfunctions
 - e. Information management and dissemination
 - f. System administration, archiving, audits, and record keeping
 - g. Surface street operations (e.g., intersection controller status (graphic of intersection traffic flow) and control, surface street CCTV image, and surface street/freeway ramp coverage (CCTV, sensors, etc.)).

4.4 Perform Traffic and Travel Information Management

The system shall collect relevant travel-related information from system traffic surveillance and controls capabilities and external providers. This information shall be integrated into an organized information database for monitoring and dissemination to roadway users, reporting services, and requesting entities. Dynamic traffic and travel information dissemination techniques and technologies shall provide the capability to deliver relevant travel-related information to users of the metropolitan Detroit freeway network in a secure and reliable fashion.

4.4.1 Collect Traffic and Travel Information

The system shall collect accurate information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway use status (e.g., work zones), and other relevant travel or traffic-related information for database management. The system shall collect this information from both infrastructure and non-infrastructure-based sources. The system shall accept information from operator inputs (manual means) and electronic media (e.g., data, video, voice, etc.). For the metropolitan Detroit area, traffic information is generally collected from (but not limited to) the following sources:

1. Metropolitan Detroit traffic surveillance system
2. Michigan State Police
3. Michigan Emergency Patrol
4. MDOT divisional field units
5. Other TOCs
6. Roadway travelers/general public (cellular call-ins)
7. State and local public works agencies

4.4.2 Manage Traffic and Travel Information

The system shall provide information management for all traffic and travel-related data. The system shall organize the collected information for storage, viewing on system displays, and dissemination to freeway network users. The system shall incorporate information access and integrity controls to protect the information system. Management of traffic and travel information shall be consistent with current capabilities and procedures.

1. The system shall integrate, or fuse, collected information on traffic conditions, freeway network status, roadway conditions and closures, weather conditions, other roadway conditions (e.g., work zones), and other relevant travel or traffic-related information collected from multiple sources into organized databases. Candidate databases include:
 - a. Traffic Operations
 - b. Traffic Modeling
 - c. CMS Message
 - d. Communications Link Management
 - e. Incident Log
 - f. Traffic Network Status
 - g. Historical Data
 - h. Roadway Conditions
 - i. System Map Data
 - j. System Status Data
2. The system shall store the information in a manner which can be retrieved for viewing on system displays and dissemination to users.
3. The system shall monitor and control information access to ensure data and system integrity are not corrupted or compromised. The system shall manage information for administrative tasks, such as, information entry/input and archiving, database management, access management, and information system monitoring, malfunction troubleshooting, and built-in test (BIT)/built-in test equipment (BITE) diagnostic capabilities.

4.4.3 Disseminate Traffic and Travel Information

The system shall disseminate traffic and travel information to the general public, government agencies, transit services, requesting users, media reporting services, and other roadway users.

Information dissemination and access to users shall be accomplished through roadway signing (e.g., CMS), HAR/AHAR transmissions, electronic data links (e.g., modem, FAX, video), and graphical displays of the freeway network status.

4.4.3.1 Provide Information Dissemination and Access Modes

The system shall disseminate and allow access to traffic and travel information in primarily three modes: dissemination to roadway users through system facilities; dissemination and access to government agencies and users; and dissemination and access to requesting entities. The system shall monitor and control information access and integrity to prevent corruption and destruction of system information, facilities, and resources. The system shall provide simultaneous operation of the information and access modes.

1. The system shall disseminate traffic and travel information to roadway users through system-operated dissemination media (e.g., CMS, HAR/AHAR, public kiosks, etc.).
2. The system shall disseminate and allow access of traffic and travel information to government agencies and user through interagency communications media (e.g., electronic links, video links, facsimile, voice, data, etc.).
3. The system shall disseminate and allow access of traffic and travel information to requesting entities through system-operated and third-party dissemination media (e.g., Metro Traffic, local TV, CATV, and radio, call-up telephone, etc.).

4.4.3.2 Support Information Clearinghouse Activities

The system shall support information management and coordination capabilities for a traffic and travel information clearinghouse. Through these capabilities, the system shall provide open and broad dissemination and access of traffic and travel information through a wide variety of methods and delivery channels. Candidate methods and channels are listed below:

1. Roadway Signing (CMS, portable CMS, variable speed signs, fixed signs)
2. Electronic Links (data links, FAX service)
3. Radio Frequency Broadcast (HAR/AHAR, broadcast AM/FM radio, private radio (amateur), FM subcarrier, radio data broadcast system (RDBS), CB radio)
4. Passive Visual Aides (printed material, broadcast TV, CATV)
5. Passive Information Services (broadcast TV, remote traffic status displays - passive kiosks, broadcast AM/FM radio)
6. Interactive Information Services (call-in message service, personal communications service (PCS), public/office kiosks, in-vehicle guidance, computer bulletin board system (BBS), CB radio, amateur radio, modem data link, mobile data terminal)
7. Third-party traffic reporting services (Metro Traffic Control, Michigan Emergency Patrol (MEP), broadcast TV, CATV, and broadcast AM/FM radio)

4.5 Perform System Performance and Malfunction Monitoring

The system shall monitor operational performance and system / subsystem status operations through on-line interrogation, health checks, and operator-commanded requests. The system shall monitor detectable malfunctions in all system and subsystems functions and components. These functions and components shall integrate diagnostic capabilities that identify abnormal operating states to the replaceable component level. Reports that indicate the status of functional parameters of the system or any malfunctioning subsystem component(s) shall be available upon operator request. These include performance reports, daily tallies, malfunction/failure logs, repair orders, etc.

4.5.1 Monitor Traffic Network Performance

The system shall monitor traffic network to ensure proper and effective traffic controls promote travel mobility. The system shall perform on-line operational performance assessments of MOEs for the metropolitan Detroit freeway network. This capability shall provide an overall performance view of traffic control system strategies and tactics to optimize traffic flow controls, and identify any operational function that may need specific operator attention. On-line MOEs include corridor throughput/volume flow, flow speed, delay time, total travel times, total minute-miles of congestion, and other measures. Through data reduction, other MOEs (e.g., accident rate reduction, number/percentage of stopping flow, etc.) may be derived to further assess system performance. Single-position operator stations shall provide DFOC personnel the capability to operate and monitor integrated system operations and performance.

4.5.2 Perform System Malfunction Monitoring

The system shall integrate malfunction monitoring, reporting, and diagnostics functions. As a minimum, failures and malfunctions shall be reportable to the lowest replaceable component level (e.g., mainline detectors, ramp controllers, etc.). Failure and malfunction status shall be maintained and dispositioned for appropriate action. Failures and malfunctions shall also be reported on the system map display.

4.5.2.1 Perform Routine Status Monitoring

The system shall monitor system operations for malfunctions or abnormal conditions or states through built-in test (BIT) during startup (power-on) and routinely during operations (background processing). The system shall provide the DFOU operator with an integrated, on-line system monitoring, diagnostic trouble shooting, maintenance management, and record keeping for system malfunctions and failures. All system or subsystem functions shall determine and provide health status to the DFOC.

4.5.2.2 Determine System Malfunction

When a malfunction or component failure occurs, the system monitoring function shall determine the nature of the anomaly and isolate the level to the replaceable component level, generate a

malfunction or failure message, and display an indicator at the DFOC to capture the operator's attention. The system shall provide the capability to interrogate and diagnose system/subsystem components upon operator command from the DFOC or locally on-site. The system shall maintain record keeping information of malfunctions and repairs in a maintenance log. This information shall include system/subsystem failure reports, work orders, maintenance forms, repair status and disposition.

SECTION 5 - COMPONENT REQUIREMENTS

Specific requirements for certain component parts of the system are contained in this section. It is expected, but not required, that these components will require specific or unique design efforts and may be specially ordered or manufactured for this project. Other components may also be designed specifically for this project.

5.1 Traffic Sensors

Traffic sensors based on above-ground machine vision technology shall be used. Machine vision sensors are defined as systems that have the capability to detect licensed vehicles using image processing or similar techniques. Machine vision sensors shall calculate five to sixty second aggregate traffic parameters that include average vehicle velocities, flow rate (derived from vehicle counts) and occupancy.

In addition to aggregate traffic parameters, machine vision sensors shall be capable of generating discrete outputs of vehicle presence and non-presence in ramp metering applications. These parameters shall be accumulated on a per-lane basis. Machine vision traffic sensors shall have the capability to calculate the aggregate vehicle velocities, lane flow rates, and lane occupancies on local computing processing hardware to support distributed processing techniques as required by the system architecture defined in the “Early Deployment of ATMS/ATIS Study Report”.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All traffic sensors shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.

5. Radio Frequency Interference (RFI)/Electromagnetic Interference (EMI): All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

5.2 Ramp Meters

Ramp metering shall be provided to maximize mainline traffic flow. Metering techniques shall include, but not limited to, time of day metering and real-time adaptive metering rates. External signage and control mechanisms associated with ramp control shall also be provided. Ramp meter control hardware shall also have the capability to accommodate the function of mainline traffic detection.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All ramp meters shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.

2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI / EMI All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

5.3 CCTV Equipment

Example locations for closed circuit television cameras are indicated in Figure 1. Closed circuit television shall be provided by dual color and monochrome television camera installations. These dual cameras are to be contained in a common housing and have separate zoom lens assemblies. Determination of which camera to use will be through an integral light sensitive switch that automatically switches from color to monochrome when the ambient light level falls below a preset threshold, and vice versa. The camera switching circuitry shall also switch the zoom lens control signals to the appropriate zoom lens. The inactive camera's zoom lens shall remain motionless. Remote manual override of this automatic feature is desirable. Image characteristics shall include the following:

1. Full color (daylight) capability
2. Low light monochrome (dawn/dusk/night) capability to a minimum of 0.1 lux (1.0×10^{-2} FC)
3. Automatic/manual bright/low light compensation and transition
4. Image resolution (minimum): 500 lines horizontal, 400 lines vertical
5. Lens systems providing a minimum 6:1 zoom ratio with a minimum angular field of view of 20° horizontal (15° vertical) at the wide angle position at f1.2, with manual focus, remotely controlled.
6. TV video image resolution and modulation shall be compatible with NTSC TV standard.
7. TV video image modulation shall be compatible with current DFOC TV monitors.

Control functions shall include the following:

1. Remote control viewing direction (e.g., horizontal pan and vertical tilt) and image quality (e.g., focus, color, zoom, intensity, etc.) adjustments shall be provided.
2. Video camera platforms shall provide pan-tilt mounting surfaces. Specifications for the pan-tilt platforms shall be:
 - a. Rotation: Pan: 0 to 355 degrees
 - b. Tilt: +/-90 degrees vertical.
 - c. Speed: 3 to 11 degrees/second
3. Pan and tilt stops to prevent over rotation.
4. Platform mounting shall allow for attachments to poles, buildings, on/under bridges, or other roadway fixtures.
5. Cameras shall be mounted in locations that provide effective viewing of the freeway segment under surveillance. Viewing height shall be a minimum of 40 feet above the roadway surface and minimize occlusion effects of roadway overpasses and curves.

Pan and tilt capabilities shall be controlled by operators at the MITSC. The dual camera video surveillance system shall provide video images in NTSC format. CCTV signals may be multiplexed or switched to reduce the number of simultaneous video channels that are to be transmitted back to the MITSC. It is not required to have all live video signals present at the MITSC simultaneously.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All CCTV equipment shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.

4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

5.4 Changeable Message Signs

Example locations for the CMS are shown in Figure 1. CMS shall be clearly visible from a distance of 750 feet under the environmental conditions mentioned. The sign shall be able to display sufficient data to convey traffic information without imposing any traffic hazard. Characters shall be a minimum of 16" high. The CMS shall be capable of displaying three lines of text with at least 18 characters per line.

The CMS shall be mounted on overpass bridges, whenever possible. Bridge mounting designs shall be prepared by a licensed structural engineer, completely detailed by the fabricating firm, and approved by MDOT prior to installation. Where bridge mounting is not possible, an approved post and foundation shall be provided.

Each sign shall be enclosed in a walk-in cabinet with all necessary ventilation, heating and lighting for use in the environment specified below. Equipment shall be designed for simplified maintainability. All maintenance functions shall be able to be accomplished from inside the cabinet. Maintainability design shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures. Protective Lexan or similar covers shall be provided to protect the display mechanism from adverse environmental effects.

Communication with the CMS shall be by either networked spread spectrum radios, wide area (packet) radios or the existing GE digital Trunking radio system.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

All CMSs shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MJTSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

5.5 Highway Advisory Radio Equipment

HAR using the normal broadcast band shall be provided. Each radio shall be capable of operating at any frequency in the normal AM band, including the latest additions to the standard AM band. Change of broadcast frequency shall be possible either through crystal controlled frequency synthesis or through changing a crystal. Control of the HAR station and transmission of the message to broadcast shall be by cellular telephone. The HAR station shall achieve a minimum four (4) mile transmission zone. Innovative design techniques can be used to reduce the interference. The HAR system shall have the capability to store prerecorded messages and allow voice messages to be recorded from the operations center.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All HAR Equipment shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding- MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

The Bidder is responsible for determining the most suitable frequencies to use and for obtaining all necessary licenses for the State to operate this equipment. Operation of HAR equipment shall meet all Federal Communications Commission (FCC) laws and regulations.

It is envisioned that deployment intervals will be reduced in the future to support localized information dissemination. Therefore, the HAR system shall have the capability to vary the output power to support more closely spaced HAR deployment.

5.6 Control and Data Processors and Software

The defined system architecture requires raw traffic data to be preprocessed at remote locations prior to transmitting aggregate data back to the central computing platform at the MITSC. Control and data processors will also be used (depending on site locations) to process data and control other system components such as ramp metering whenever necessary. Communications protocol handling and processing shall be supported by remote control and data processors.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

Field installed control and data processors shall be enclosed in cabinets. All control and data processors installed in cabinets shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/Eml conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants

emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.

7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to these effects, consideration shall be given to equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

In order to maximize data through-put and minimize the number of communication channels, the use of a robust Carrier Sense Multiple Access/Collision Detection (CSMA/CD) protocol scheme is required. Therefore, the processing equipment shall have sufficient computing capability to support the CSMA/CD protocol scheme.

A modular processor architecture shall be used to enable various field configurations. As a minimum, there shall be processor and input/output (I/O) modules, hosted on an industry standard backplane (e.g., VME, ISA, EISA). The minimum capabilities of the modules shall include:

1. 80x86 or 680x0 CPU board with general purpose serial and parallel I/O
 - a. 3 million instructions per second (MIPS) minimum
 - b. 1 MByte of random access memory (RAM) (expandable to 4 MBytes)
 - c. 512 KBytes Non-volatile memory (EEPROM or battery backed RAM)
 - d. 4 serial I/O ports
 - e. 16 discrete parallel lines
2. Multi-serial I/O with at least 38.4 Kbps maximum data rate capacity using industry standard electrical interface (EIA-232, EIA-422, or EIA-485)
3. Communications specific interface module (If required by the final design)

The processor backplane shall also have the expansion capability to accept a minimum of 2 additional multi-function circuit boards to support future IVHS applications.

Software shall be an optimum combination of commercially available packages (where usable) and custom development. The design of all custom software shall follow a formalized, standard practice designed to control errors and document results. The output of the design process shall include sufficient information to begin coding.

Detailed software requirements, software modules and routine level descriptions shall be provided in the software design document described in Section 6.4. Custom software developed for existing equipment shall use existing software development tools and languages. Custom software developed for newly acquired equipment shall use the high level language "C" or

“C++.” The use of assembly language is permissible for applications or routines that are time critical and require execution time optimization. Structured programming techniques shall be maintained using data flow diagrams, data dictionaries, structure charts, and source code comments.

5.7 Concentrator CCTV Node Equipment

The concentrator node for CCTV shall be capable of handling simultaneous NTSC transmissions. The concentrator node shall multiplex signals onto a common wireless transmission channel for transmission back to the Control Center. Alternatively, several concentrator nodes may transmit their composite signal to another concentrator node for a higher level of multiplexing for the link back to the Control Center. The choice of the option to use shall be determined by the Bidder in consultation with MDOT.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All concentrator CCTV node equipment shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants

emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.

7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to weather effects, considerations shall be given for equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

The Bidder is responsible for assuring compliance with all FCC requirements and for obtaining all necessary licenses for the State to operate this equipment.

5.8 Communications Equipment

Digital data communications shall use area wide wireless radio. Available MDOT frequencies shall be used whenever possible. Wireless data modem equipment shall support a minimum of 9600 bits per second and support CSMA/CD communication protocol schemes. The electrical interface between the communication equipment and processors shall be industry standard EIA-RS-232, EIA-RS-422, or EIA-RS-485. The radio configuration shall allow data to be exchanged at distances of 30 miles, minimum. The use of repeater stations is permissible to achieve the required data transmission distance.

Wireless video surveillance communications shall be provided. Separate communications links shall be established for both incoming video and reverse control functions. The communication medium shall support NTSC live color video of 30 frames per second (interlaced) at resolutions of 500 lines horizontal and 400 vertical. Video channels may be multiplexed onto a single wide band wireless to minimize the number of video channels to the MITSC. A maximum of five video channels may be multiplexed for transmission. Narrow beam antennas shall be used to minimize external and environmental transmission interference. The output of the video communications equipment at the MITSC shall be compatible with existing VICON display equipment.

Equipment and components to be procured shall make maximum use of readily available, multiple source, COTS equipment.

Equipment shall be designed for simplified maintainability. This shall include simplified access (within security considerations), use of modular components, elimination of the need for special tools or unique test equipment, inclusion of self-test capabilities and/or built-in test equipment, and inclusion of connection diagrams within the equipment enclosure. Systems shall be designed to allow safe access by maintenance personnel having the required skill and knowledge for normal operations. Safety guards, warning signs and labels, and interlocks shall be used where

required. Ventilation and/or lighting for maintenance personnel shall be included in large enclosures.

All communications equipment shall provide protection features against the local metropolitan Detroit urban environment. System components shall operate under environments specified below.

1. General Environment: System components shall be designed to function in the local metropolitan Detroit urban environment.
2. Outside Ambient Air Temperature (Operation or Storage): -25°F to +140°F (-32°C to +60°C).
3. Humidity: Up to 95 percent, non-condensing.
4. Lightning/Electrostatic discharge: All subsystem equipment shall be incorporate features to prevent damage from transient electrical discharges in fielded configurations.
5. RFI/EMI: All subsystem electronic equipment shall not be affected by normal RFI/EMI conditions emanating from the surrounding MITSC office and Metropolitan Detroit urban environments. Correspondingly, all electronic equipment shall not emanate RFI/EMI that will interfere with other MITSC and localized fielded equipment.
6. Wind/salt/sand/dust/contaminants: Subsystem components shall be protected from the effects of wind, salt, sand, dust, and other organic and inorganic contaminants emanating from roadway vehicles and the surrounding environment for a period no less than 10 years from field deployment or exposure.
7. Other environmental effects: Subsystem components shall be insulated from other (direct or induced) environmental effects. Other effects include acceleration/shock, vibration, acoustics, heating due to solar radiation, etc. due to normal vehicle travel and regional weather conditions.

In addition to weather effects, considerations shall be given for equipment vandalism and theft. Features such as non-valuable materials, camouflage (or neutral colors), and low-profile equipment mountings (or locations) shall be considered to aid against damage.

The Bidder is responsible for ensuring compliance with all FCC requirements and for obtaining all necessary licenses for the State to operate this equipment.

5.9 MITSC Equipment and Software

Digital traffic data received at the MITSC shall be integrated with existing system processing equipment, whenever possible. The level of data integration and processed data, as described in Task 3 shall be provided. A Concurrent 3280MPS mainframe computer is the primary computing platform. Traffic data shall also be displayed using the existing GDS. The use of existing operator interface systems shall be maximized. Information input and processing of new data items shall be transparent at the system level and at the operator interface to maintain existing operating procedures.

Software shall be an optimum combination of commercially available packages (where usable) and custom development. The design of all custom software shall follow a formalized, standard practice designed to control errors and document results. The output of the design process shall include sufficient information to begin coding.

Detailed software requirements, software modules and routine level descriptions shall be provided in the software design document described in Section 6.4. Custom software developed for existing equipment shall use existing software development tools and languages. Custom software developed for newly acquired equipment shall use the high level language “C” or “C++.” The use of assembly language is permissible for applications or routines that are time critical and require execution time optimization. Structured programming techniques shall be maintained using data flow diagrams, data dictionaries, structure charts, and source code comments.

5.10 Other System Software

Software shall be an optimum combination of commercially available packages (where usable) and custom development. The design of all custom software shall follow a formalized, standard practice designed to control errors and document results. The output of the design process shall include sufficient information to begin coding.

Detailed software requirements, software modules and routine level descriptions shall be provided in the software design document described in Section 6.4. Custom software developed for existing equipment shall use existing software development tools and languages. Custom software developed for newly acquired equipment shall use the high level language “c” or “C++.” The use of assembly language is permissible for applications or routines that are time critical and require execution time optimization. Structured programming techniques shall be maintained using data flow diagrams, data dictionaries, structure charts, and source code comments.

SECTION 6 - DELIVERABLES

The Bidder shall deliver, as a minimum requirement but not limited to, the following:

6.1 Reports

1. Interim and final reports, as specified in Section 2.5, for each task.
2. Monthly written progress reports to the MDOT project manager.

6.2 Attendance at Meetings

1. Attendance at project kick-off meeting and monthly program meetings.

6.3 Plans, Specifications and Estimates

1. Final plans, specifications and estimates for implementation of the expanded ATMS system. Detailed documentation shall be provided for civil construction activities in the focused locations needed for the project. Construction as-built drawings for each deployment site shall be included to provide specific electrical and structural details. A minimum of 50 scale (1" = 50') shall be used. Specific plan details shall be a minimum of 10 scale (1" = 10'). Additionally, specifications for civil construction and estimates shall be provided to MDOT to allow appropriate deployment funding to be allocated. Plans shall be on magnetic media in Autocad (DWG) format or MicroStation (DGN) format, as well as in printed sets, Specifications shall be on magnetic media in Word Perfect format, as well as printed sets. Estimates may be on magnetic media in either Word Perfect or Quattro Pro format, as well as printed sets.
2. A System Integration Plan which describes the processes and methods to integrate both hardware and software will be required.
3. A System Acceptance Test Plan shall be developed to document test procedures and evaluation criteria used for system acceptance. The document shall identify resources, both equipment and personnel, which are necessary to complete the acceptance test.

6.4 Documentation

1. Minutes to monthly status meetings which include Bidder briefings and updated monthly schedules.
2. Complete documentation of all hardware and software developed by the Bidder, including source code, and any necessary libraries and compilers.
3. Complete documentation for all purchased hardware and software, including all manuals, diskettes and other documentation obtained with the hardware or software.
4. A System Requirements Document containing all high level system requirements individually analyzed to determine specific data interchange and data flow requirements.
5. A System Design Description Document containing a system level block diagram, required data flow diagrams, system level functionality, specific interface design descriptions, system component requirements, communications requirements, and individual sub-

system requirements. Sufficient design margins shall be provided to enable migration into the final 250 mile coverage of the Metropolitan Detroit area with minimal or no modification to application software or system hardware. As system components are identified, detailed deployment maps shall be generated to provide visual means of determining actual placement of field equipment and to show the area of coverage.

6. An Interface Protocol Design Document containing specific interface protocol universal to all system components to maintain an open architecture and modular configuration. It will include protocol design details such as message handling, timing requirements, and data formats. It shall also provide details to enable the seamless implementation of the interface protocol.
7. A Software Design Document containing detailed software design for each sub-system. Data flow diagrams for each sub-system shall be provided in addition to English-like Program Design Language (PDL) enabling implementation of the software design to code directly from the design description with no further interpretation. Algorithms and procedures defined in the sub-system requirements section of the System Design Description and Interface Protocol Design documents shall be extensively detailed to enable software code development to occur without additional software design.
8. A Procurement Specifications Document containing specifications for each individual system component shall be developed to allow system component procurements to occur. All required hardware and software components shall be identified and specific performance, mechanical, and functional requirements shall be documented in a manner that allow open-bidding to occur during the hardware procurement cycle.

6.5 Warranties

1. A written warranty for all hardware, software and equipment for the appropriate terms specified earlier in this contract.
2. All warranty documentation, including date of purchase documentation, for all purchased hardware and software.

SECTION 7 - INFORMATION REQUIRED FROM THE BIDDER

7.1 Business Organization

State the full name and address of your organization and, if applicable, the branch office or subordinate element that will perform or assist in performing the work. Indicate whether you operate as an individual, partnership or corporation. If as a corporation, include the State in which you are incorporated.

7.2 Project Statement

State in succinct terms your understanding of the project presented in this RFP. A proposed design, build, and integrate approach shall be included in the Bidder's proposal. Specific methods and processes used in design/build/integrate phases shall be described. The Bidder shall describe any risks and the means to mitigate those risks. A program management approach shall also be described including the roles and responsibilities of key personnel.

7.3 Proposed Schedule

Include in your proposal a timetable for completion of the project.

7.4 Bidder's Qualifications and Prior Experience

Include as part of your proposal a brief statement concerning the most recent and relevant experience of persons from your firm who will be actively engaged in the proposed project. Do not include other firm experience unless persons who will work directly on this project participated in that experience.

7.5 Authorized Negotiators

Include the names, addresses and telephone numbers of your organization's personnel authorized to negotiate and sign the proposed contract with MDOT.

7.6 Cost and Price Analysis

The bidder shall provide a summary of prices for the Firm Fixed Price line items utilizing a form similar to Table 2. The bidder shall provide a summary of costs and fee for the Cost Plus Fixed Fee line items (Traffic Sensors Only) utilizing a form similar to Table 3. The total of Table 2 (including options) and Table 3 should equal the amount bid for this project (including options). Non-shaded areas in Table 2 and Table 3 must be provided as applicable. Additional line items may be added to Table 2 where "Other" is indicated as required by the design concept developed by the Bidder. Table 3 may not have other line items added. Where the Bidder's design concept or variability in site conditions requires multiple configurations of the same line item, that item

may be expanded into multiple lines in either Table 2 or Table 3. Software may be either priced as part of the hardware in which it is embedded or as a separate item.

Two copies of this cost and price analysis shall be delivered, under separate sealed cover, to MDOT at the address specified in Paragraph 1.2 by the RFP deadline specified on the cover of the RFP.

Table 2 - Bid Sheet for Submitting Firm Fixed Prices

Item Description	Unit	Unit Price	Quantity	Total Price
I. Project Management				
Labor	hour			
Travel	lump sum		1	
Printing	lump sum		1	
Other (specify)				
Project Management Subtotal				
II. Engineering				
Civil Design	lump sum		1	
Systems/Electrical/Software Design	lump sum		1	
Engineering Subtotal				
III. Specification Development	lump sum		1	
IV. Procurement				
Ramp Meter Equipment	each site			
CCTV Equipment	each site			
CMS	each site			
HAR	each site			
Control and Data Processors	each			
Concentrator CCTV Node	each			
Communications Equipment	each site			
MITSC Equipment	each		1	
Software (non-embedded)	lump sum		1	
Other (specify)				
Procurement Subtotal				
V. Installation				
MITSC	each		1	
Field Sites	each			
Other (specify)				
Installation Subtotal				
VI. Integration/Subtotal				
System Integration	lump sum		1	
Acceptance Test	lump sum		1	
VII. Warranty, Service, Maintenance and Training				
Performance and Service Warranty	lump sum		1	
Operational Training	lump sum		1	
Service Contract – Year 2	lump sum		optional	
Service Contract – Year 3	lump sum		optional	
Service Contract – Year 4	lump sum		optional	
Service Contract – Year 5	lump sum		optional	
Maintenance Training Course	lump sum		optional	
FIXED PRICE TOTAL				

Item Description	Unit	Unit Price	Quantity	Total Price
IV. Procurement				
Traffic Sensor Equipment	each site			
COST PLUS FEE TOTAL				

SECTION 8 - PROPOSAL EVALUATION CRITERIA

The proposal will be evaluated based on the following criteria:

8.1 Content of Technical Proposal (30 Points)

An understanding of the project is essential. The Bidder's responsiveness to the technical requirements, the evidence to provide the minimum functionality as well as additional capabilities as described in the RFP will be evaluated. Ease of providing new infrastructure requirements, simplicity of installation, and ease of maintenance of the system is important.

8.2 Experience and Past Performance of Team Members (20 Points)

The experience of the Bidder's organization and team in planning, designing and implementing advanced traffic surveillance and control systems is essential. Past performance, especially on similar projects will also be evaluated.

8.3 Content of Cost Proposal (20 Points)

The completeness, accuracy and cost effectiveness of the proposal provides an indication of the Bidder's ability to understand the requirements and to offer innovative solutions to minimizing cost.

8.4 Completeness of Proposal (10 Points)

It is important to MDOT that the Bidder comply with all requirements stated in the RFP. MDOT may reject proposals that are not consistent with these requirements.

8.5 Availability of Key Personnel (10 Points)

The commitment of key personnel to the management and performance of this project is essential for its completion.

8.6 Schedule for Successful Completion (10 Points)

The timely completion of the project, including all design and construction tasks, is necessary. Proper time allocation and correct phasing of work are required.

Appendix A - Prohibition of Discrimination In State Contracts

[insert a copy of the document here]

Appendix B – Acronyms

AHAR	Automatic Highway Advisory Radio
ANSI	American National Standards Institute
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
BBS	Bulletin Board System
CATV	Cable Television
CCITT	European standards association
CCTV	Closed Circuit Television
CMAQ	Congestion Management Air Quality
CMS	Changeable Message Sign
COTS	Commercial Off-The-Shelf
CPU	Central Processor Unit
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
DFOC	Detroit Freeway Operations Center
DFOU	Detroit Freeway Operations Unit
DOS	Disk Operating System
EEPROM	Electrically erasable Programmable Read Only Memory
EIA	Electronic Industries Association
EISA	Electronic Industry Standard Architecture (computer bus standard)
EMI	Electromagnetic Interference
FC	Foot Candle (unit of light intensity)
FHWA	Federal Highway Administration
GDS	Graphic Display System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
ISA	Industry Standard Architecture (computer bus standard)
IVHS	Integrated Vehicle Highway Systems
Kbps	thousands of bits per second
Kbyte	thousand of bytes
Mbyte	millions of bytes
MDOT	Michigan Department of Transportation
MDTS	Metropolitan Detroit Transportation System
MEP	Michigan Emergency Patrol
MIPS	Million Instructions per Second
MITS	Michigan Intelligent Transportation Systems
MITSC	Michigan Intelligent Transportation System s Center
MOE	Measure of Effectiveness
MSP	Michigan State Police
NEMA	National Electrical Manufacturers Association

Appendix B – Acronyms

NTSC	National Television Standards Committee
PCS	Personal Communications Service
PDL	Program Design Language
RCOC	Road Commission for Oakland County
RCU	Remote Communications Unit
RDBS	Radio Data Broadcast System
RFI	Radio Frequency Interface
RFP	Request for Proposal
SAE	Society of Automotive Engineers
SCSI	Small Computer System Interface
SEMCOG	Southeast Michigan Council of Governments
TOC	Transportation Operation Center
TOD	Time of Day
VME	computer bus standard
lux	unit of light intensity
vph	vehicles per hour
vpm	vehicles per minute