APPENDIX I

ENABLING TECHNOLOGIES

1. SURVEILLANCE

The functional area of surveillance is broken into 9 technology areas:

- Traffic – Table I.1
- Vehicle Status – Table I.2
- Environmental – Table I.3
- Vehicle Monitoring – Table I.4
- Driver Monitoring – Table I.5
- Cargo Monitoring – Table I.6
- Obstacle Ranging and Lane Tracking – Table I.7
- Security – Table I.8
- Location Determination – Table I.9

Each of the above technology areas is detailed more extensively in the following tables. Icons indicating each technology's existing maturity are provided. These maturity assignments are defined as follows (referring to the year 2010 as the end of the "near term" deployment window):

- **Mature:** Current commercially available technology supports the identified ITS requirements in this area. Deployment of the candidate ITS Services is not predicated on further research and development of these technologies. *Candidate ITS Services with dependencies only on these mature technologies should be deployable prior to 2010 with low risk.*

- **Mature with rapid innovation:** Current commercially available technology supports the identified ITS requirements. The area is one of rapid technology growth that indicates that the basic support provided by current technologies will likely be superseded within the period to 2010. While further research and development is not required to support ITS, future deployment may benefit from technology enhancements that should not be precluded by excessive rigidity in the architecture or deployment definitions. *Candidate ITS Services with dependencies only on this class of technologies should be deployable prior to 2010 with low performance risk and medium cost risk, based on obsolescence.*

- **Mixed:** This technology area is required to satisfy a range of ITS requirements including some that are not supported by current technology. Useful services may be deployed using currently available technologies; however, satisfying all ITS Service requirements will require additional research and development to bolster the identified deficiencies. Where this assignment is made, the associated description in highlights the specific areas where technology advancement is required. *Candidate ITS Services with dependencies only on these "mixed" technologies may not be deployable prior to 2010 without significant technical risk.*

- **Immature:** Additional research and development is required before technologies in this area can be cost-effectively and reliably applied to support the candidate ITS Services. In some cases, potentially suitable technologies have been applied in defence or aerospace applications, but not in commercial transportation applications. Additional research and development is still required in these areas to address the unique mass production, safety, and cost issues associated with larger commercial markets. *Candidate ITS Services with dependencies only on these immature technologies may not be deployable prior to 2010 under any risk scenario.*

Table I.1 – Traffic Sensors

TECHNOLOGY AREA: TRAFFIC SENSORS

Traffic sensor technologies monitor overall traffic flow conditions and enable collection of basic aggregate measures such as occupancy, volume, and speed. These traffic sensors may be installed in three locations, On Pavement, In Pavement and/or on the Roadside.

On Pavement: There are a number of devices that may be placed on the pavement that may be used for vehicle detection, including loop mats, pressure plates, and magnetometers.

In Pavement: There are three devices used for detecting vehicles that are embedded in the pavement, namely inductive loops, magnetic probes, and sensing cables. Since the devices are embedded in the pavement they are disruptive to traffic flow during installation and maintenance and are prone to problems with pavement deterioration. In-pavement detection is currently the prevailing detection sensor technology.

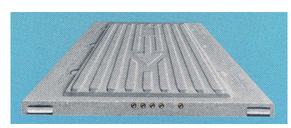
Roadside/Overhead Mounted: Off-pavement sensors such as video imaging, radar, laser, ultrasonic sensing, and automatic vehicle identification (AVI) are now challenging in-pavement technologies for market share. Off-pavement sensors are typically mounted on overhead or roadside structures and therefore are less disruptive to traffic during installation and maintenance.

Below, is a more detailed description for each of the different technologies. Each technology is grouped together in their respective location for installation (i.e. On-pavement, In-pavement and Roadside/Overhead Mounted).

ON-PAVEMENT

Loop Mats

Loop Mats are similar to conventional inductive loops, in that they generate an electromagnetic field, which is disturbed as a vehicle passes over, except loop mats are not embedded in the pavement. Designed for temporary use.



Pressure Plates

Pressure Plates detect vehicles because when wheels pass over the pressure plate electrical contact occurs. Limited to detecting axles, not vehicles, and therefore cannot measure most traffic parameters.

Magnetometer

A Magnetometer measures changes in Earth's magnetic field as a vehicle passes over.

TECHNOLOGY AREA: TRAFFIC SENSORS

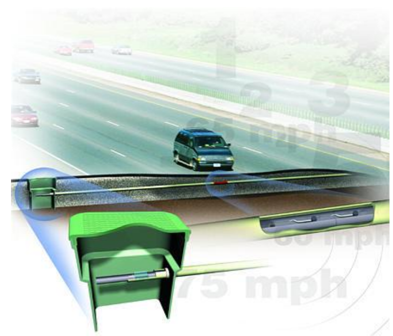
IN-PAVEMENT

Inductive Loops

Inductive Loops are the most common type of detector and generate an electromagnetic field, which is disturbed as vehicles pass over. Inductive loops are widely used in various applications such as traffic signal intersections, toll gates and free flowing highways. Inductive Loops, with the help of an amplifier, generate a magnetic field. As a vehicle passes over the loop, the loop's magnetic field decreases. The amplifier is then tuned to detect this change in magnetic field therefore detecting the presence of a vehicle.

Magnetic Probes

Magnetic Probes measure changes in the Earth's magnetic field in order to determine when vehicles pass over.



IN-PAVEMENT

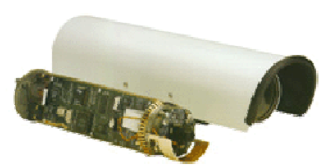
Sensing Cable

When vehicles pass over sensing cable, the wheels compress piezo-electric cable, which in turn generates an electric signal. Cannot measure most traffic parameters, limited to detecting axles.

ROADSIDE MOUNTED

Video Imaging

Video image processing sensors utilize the visible light and near infrared bandwidths to sense various user-configurable traffic parameters. Video imaging allows for traffic flow information to be obtained for multi-lane and multi-zone applications. However, the requirement to digitize the video images and invoke pattern recognition routines requires significant processing power in the field. A video imaging sensor can provide speed and volume information and can also be used for incident detection and traffic signal control. Video imaging sensors represent a very promising future standard for traffic flow detection, due in part to steadily improving performance, increased features/flexibility and decreased costs.



TECHNOLOGY AREA: TRAFFIC SENSORS

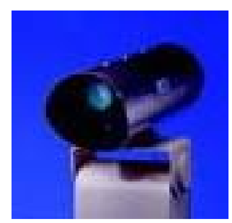
Radar

Two technologies are:

1) Doppler radar sensors provide very accurate speed measurements and can distinguish between approaching and receding traffic. The principal drawback characteristic of this technology is the inability to measure presence and therefore it cannot provide traffic flow or occupancy information. However, many traffic authorities use this sensor when collection of speed data is a priority, such as for travel time monitoring. Doppler radar technology is robust, and performs well under all ambient environment conditions. It is typically mounted overhead.

2) True presence microwave radar using frequency modulated continuous wave (FMCW) detects volume, presence and calculates speeds over multiple independent zones. Unlike Doppler microwave radar sensors, FMCW radar can be mounted in a side-fire configuration. However, speed data in side-fire mode presently has limited accuracy. The advantages of the FMCW radar sensors are its ease of installation and integration into existing systems, its high accuracy, programmability to support a variety of applications, and its low cost

Laser



Laser detection systems utilize a very narrow beam width, which allows for the spatial positioning of a vehicle on the road and the resolution of the vehicle shapes within an accuracy of ±10cm. Laser based sensor technologies offer high accuracy and reliability, however this is sensitive to mounting height and sensor position over the roadway. One drawback is the requirement for a high signal to noise ratio in all prevailing weather conditions in order to reliably process a reflection from the vehicle target. Laser sensors can collect lane specific speed, volume and occupancy and can operate remotely with batteries and a solar panel, and use a spread spectrum radio link to transmit traffic data from the remote site to a traffic control data collection/transmission location.

Ultrasonic Sensing

Ultrasonic sensors transmit and receive an acoustic wave that is analyzed to determine vehicle volume. A local microprocessor can process the data to determine vehicle speed, occupancy and perform some limited vehicle classification. Reported results indicate that ultrasonic sensing provides fairly good accuracy.

TECHNOLOGY AREA: TRAFFIC SENSORS

Automatic Vehicle ● Identification

Automatic Vehicle Identification (AVI) technology deployed for ETC and CVO applications may be used to provide road link travel time data between AVI antennae for both freeway and arterial networks. This relatively accurate travel time data is well-suited to ATIS applications. In addition, AVI technology can provide information on traffic volumes based upon measured levels of penetration of AVI equipped vehicles. Agencies such as the Inter Agency Group in the New York City area have successfully demonstrated large scale deployment of AVI probe-based ATMS/ATIS applications.

Table I.2 – Vehicle Status Sensors

TECHNOLOGY AREA: VEHICLE STATUS SENSORS

Vehicle Status Sensors which determine individual characteristics of passing vehicles. Technologies which assess individual vehicle length, weight, number of axles, lane position, and speed are available. Enforcement application technologies that monitor emissions, passenger counts, and operational status for specific vehicles are less mature.

Vehicle Classification

Classification of vehicles is undertaken for the purpose of regulatory compliance, automatic toll collection, commercial vehicle operation, and historical data collection. Vehicle classification is generally performed through devices embedded in the pavement, or mounted along the roadside. The Table below indicates what vehicle information can be obtained by the applicable technologies.

Looking ahead, there is continuing development of infrared or radar based profile technologies. The market will continue to be driven by CVO and ETC applications.

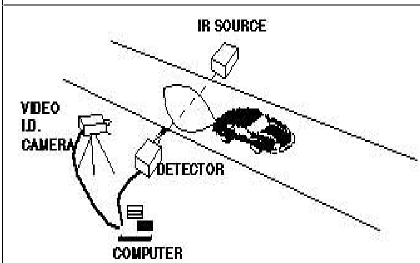
	Technology	Weigh-in-Motion	Vehicle Height	Vehicle Length	Axles
VEHICLE CLASSIFICATION	**Inductive Loops:** Inductive loops can be used for classification on the principle that the percentage change in conductance can be used to determine the type of vehicle on the basis of vehicle length. Loops are not as accurate as other classification technologies.			X	
	Pressure Sensors: Pressure sensors, such as a pressure plate, and piezo-electric strips are used extensively for weigh-in-motion applications.	X			X

TECHNOLOGY AREA: VEHICLE STATUS SENSORS

	Profile Identifiers: Profile identifiers may include a variety of mounting configurations and technologies. Most applications are either mounted overhead or side-fired and utilize reflective beam technologies such as infrared, optical, ultrasonic or microwave/radar. A beam of energy is continuously monitored by the detection device, which essentially measures the physical dimensions of a vehicle as it passes through the detection zone. Profile identifiers may also be used as overheight detectors at low overpasses.		X		

Vehicle Emissions

A variety of enabling technologies have been developed outside of the ITS arena to detect harmful vehicle emissions. These technologies include conductive polymers, fibre optic, and infrared sensors. In order to integrate these technologies into ITS applications, sensor(s) must be configured such that they can distinguish specific pollutants (HC_x, CO, and No_x), and be bundled with related field components and processing. Emission sensing may be done from the vehicle or from the roadside.



An example of an ITS application of emissions sensing is in California, where the emission sensors are used to trigger plate readers with optical character recognition for passive emissions enforcement on freeway entrance ramps. Currently, the market for this type of application is limited, however it is expected to increase as more authorities take a proactive approach to vehicle pollution.

Table I.3 – Environment

TECHNOLOGY AREA: ENVIRONMENT

Environmental Sensors

Environment sensor technologies monitor local climate (temperature, humidity, precipitation, wind, pollution) and road surface status (dry, wet, ice, snow). A road weather information system (RWIS) monitors current conditions on and immediately adjacent to the roadway. Road temperature and condition sensors embedded in the surface of the pavement typically measure road surface temperature, moisture, and residual chemical factor in either a passive or active mode. Environment sensors measure air temperature and relative humidity as well as wind speed and direction. Other atmospheric sensors may include precipitation sensors as well as visibility sensors. More modern sensors include infrared cameras to assess road surface condition.

Meteorologists use the road data collected from the sensors to provide road condition forecasting services for road maintenance and various road user groups. The collected road weather information is monitored and analyzed to detect and forecast environmental hazards such as icy road conditions, dense fog, and approaching severe weather fronts. This information can be used to more effectively deploy road maintenance resources, issue general traveller advisories, and support location specific warnings to drivers using Traffic Information Dissemination. Technical advancements in this area focus on the integration of sensor data with predictive algorithms.

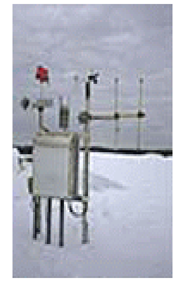


Table I.4 – Vehicle Monitoring

TECHNOLOGY AREA: VEHICLE MONITORING

Closed-Circuit Television (CCTV) ● Cameras

CCTV is an essential element of visual surveillance for ITS. CCTV consists of various elements of security industry grade equipment including the CCTV camera/lens unit, control equipment and the communication system, which connects the camera to a control centre. The primary objective of a CCTV camera is to provide surveillance of freeway / highway segments or intersections and visual confirmation of incidents, however it may also be used to detect incidents. A secondary benefit is the monitoring of environmental conditions including precipitation and visibility. CCTV supports other applications including vehicle classification and enforcement.

The performance of CCTV cameras can be affected by the speed at which they pan/tilt and their level of zoom capabilities. Digital signal processing (DSP) provides a number of improvements over conventional analogue signal processing. CCTV technologies evolve rapidly, driven by the security industry. Near term evolutions will include increasingly compact, low cost imagers, with compressed digital video output.

Table I.5 – Driver Monitoring

TECHNOLOGY AREA: DRIVER MONITORING

Driver Monitoring Sensors

Driver Monitoring Sensors are technologies which monitor driver condition by monitoring driving characteristics and/or other psycho-physiological symptoms associated with impaired performance.

A variety of organizations including major auto-makers are developing and testing sensors intended to identify driver fatigue or impairment and initiate alarms. Examples include infrared sensors to detect driver eye movement. While these technologies are in their infancy, future widespread deployment could significantly improve road and rail safety.

Table I.6 – Cargo Monitoring

TECHNOLOGY AREA: CARGO MONITORING

Cargo Monitoring Sensors

Cargo Monitoring Technologies monitor various indicators of cargo status. Load distribution, temperature, acceleration, and pressure are among potential indicators that may be monitored depending on the nature of the cargo.

Freight administration processes track cargo location and the cargo security/condition. This information can be communicated to a central fleet and freight management system via a range of wireless communications infrastructure such as DSRC. Interconnections are provided to intermodal shippers and intermodal freight depots for tracking the cargo from source to destination. Sensors can provide monitoring of various parameters such as temperature and humidity.

Table I.7 – Obstacle Ranging and Lane Tracking

TECHNOLOGY AREA: OBSTACLE RANGING AND LANE TRACKING

Obstacle Ranging Sensors

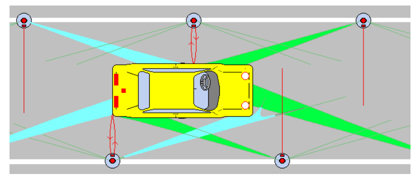
Obstacle Ranging Technologies detect and characterize potential obstacles (other vehicles, people, road debris) in a vehicle's vicinity. Supports family of applications with variable performance requirements. Advanced headway maintenance requires high frequency and

TECHNOLOGY AREA: OBSTACLE RANGING AND LANE TRACKING

precision. Driver warning systems may have reduced requirements due to human time scale. Vision enhancement sensors must support overall environment imaging.

Lane Tracking ◐ Sensors

Lane tracking technologies located on-board a vehicle monitor the position of the vehicle with respect to the travel lane and optionally support interpretation of travel lane geometry ahead of the vehicle. For situations where no roadway support (e.g. magnetic tape) is added, the technology rating drops to "immature".



The externally mounted longitudinal and lateral sensors establish definable fields for object detection. These sensors are used to detect vehicles (or objects) that the vehicle is approaching, or that are approaching the vehicle, in order to provide warnings and/or assume temporary control of the vehicle if a collision is imminent.

Longitudinal/lateral control sensing is predominantly a research and development area, with few products currently emerging into the ITS market. Enabling technologies being explored include microwave, radar, lidar, ultrasonic sensing, and video image processing. Currently, the trend in in-vehicle sensor technology is focused on radar and lidar technology.

A number of technologies are available and are being developed to enhance vision capabilities for ITS vehicles. These technologies include infrared, video image processing and ultraviolet headlamps. These enhancement systems will improve visually acquired information in situations where driving visibility is low, such as at night or reduced visibility due to an obstruction to vision such as fog or falling snow.

Table I.8 – Security

TECHNOLOGY AREA: SECURITY

Security ●

Security technologies provide surveillance of, and restrict access to, secure public areas. Card readers that restrict access and closed circuit television cameras are examples.

The ITS industry draws upon a number of security industry technologies and hence there are opportunities to add value to ITS applications through security system inter-operability. Parking facilities offer particular opportunities. CCTV can be used for occupancy monitoring and site security; and DSRC technology as deployed for toll applications can be used for access control.

Transit security provides for the physical security of transit passengers. An on-board security system is deployed to perform surveillance and warn of potentially hazardous situations. Public areas (e.g. stops, park and ride lots,

stations) are also monitored. Information is communicated to the Transit Management Subsystem using the existing or emerging wireless (vehicle-to-centre) or wireline (area-to-centre) infrastructure. Security related information is also transmitted to the Emergency Management Subsystem when an emergency is identified that requires an external response.

TableI.9 – Location Determination

TECHNOLOGY AREA: LOCATION DETERMINATION
Location Determination is a technology which determines absolute position. Examples include GPS and other systems which apply multi-lateration to known locations, either terrestrial or space based. Augmenting these technologies are those that measure travel path and distance (e.g., odometer, compass, gyroscope) from a known location. Very high-precision systems associated with vehicle control applications are one remaining research area.

Global Positioning System ● (GPS)

GPS is a Satellite Navigation System that is funded by and controlled by the U.S. Department of Defense. While there are many thousands of civil users of GPS world-wide, the system was designed for and is operated by the U.S. military. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

There are two different levels of GPS service, the Precise Positioning Service (PPS) and the Standard Positioning Service (SPS). PPS uses cryptographic equipment and keys and specially equipped receivers and is limited to U.S. military and government agencies use. SPS is available to civil users world-wide, but has less accuracy when compared to PPS. Accuracy is typically within 10m, and performance in urban canyons is a particular issue. Accuracy can be significantly improved using a differential GPS (DGPS) service which uses a commercial pager network or FM subcarrier service to calibrate the GPS receiver based upon local reference points with known co-ordinates.

GPS is relatively mature technology. Looking ahead, the focus will be on integrating GPS with other applications. For example, GPS may be used in intelligent vehicles, or in cellular phones within vehicles, in order to perform Automatic Vehicle Location (AVL).

2. DATA PROCESSING

Inherent to carrying out each of the ITS user services is data processing. This is the process by which the information gathered from a variety of sources is brought together, managed, manipulated and disseminated to some output by one form or another.

Data Processing is broken into two main functional areas: algorithms and information management. Processing technology and advanced algorithms enable advanced vehicle and traffic control applications. The function of information management is made up of information storage, fusion, and retrieval systems management.

Table I.10 – Data Processing

TECHNOLOGY AREA: DATA PROCESSING

Algorithms

There are a number of custom software programs that are used to effectively and efficiently manage traffic conditions. These include incident/congestion detection algorithms, real-time traffic signal optimization, route optimization, and traffic simulation models.

Detection Algorithms: Detection algorithms include automatic incident detection (AID) algorithms, queue detection and tracking algorithms and route optimization. AID algorithms are generally based on either pattern recognition techniques or prediction models and can be classified as either comparative or single station algorithms. Comparative algorithms are those that compare traffic characteristics at adjacent stations and single station algorithms perform temporal comparisons at a single station. In Canada, two AID algorithms have had practical application for ATMS. These algorithms are the McMaster Algorithm and the All-Purpose Incident Detection (APID) Algorithm.

Looking ahead, there is increasing emphasis on congestion detection versus incident detection. Queue detection logic is used to detect congestion (with no concern as to the cause) at each detector station. Queue tracking logic is then applied to monitor the end and beginning of the queue. The major purpose of queue detection and tracking is safety. The back of a queue is turbulent and dangerous. Given proper information, DMS messages can alert a motorist of congestion ahead.

Real-time Signal Optimization: There are a number of software packages developed that may be used in real-time to optimize signal timings on a road network so that the total throughput is maximized or the total delay is minimized. This section examines two common real-time signal optimization systems, SCOOT and SCATS.

SCOOT

SCOOT (Split Cycle Offset Optimization Technique) is an advanced implementation of computer-based urban traffic control. It is an adaptive traffic control strategy that operates in concert with a discreet UTC. The key functions of SCOOT are to:

- Measure Cyclic Flow Profiles (CFP's) in real-time. This allows the arrival of platoons of vehicles at a signal to be forecast;

TECHNOLOGY AREA: DATA PROCESSING

- Update an on-line model of queues continuously. This provides an estimate of stop line congestion;

- Incrementally optimize signal settings. Split, cycle and/or offset can be adjusted by a few seconds each cycle to best address the demands on all approaches.

SCOOT uses vehicle detectors to measure traffic flow profiles in real-time. The detectors are placed near the upstream end of each link to measure the demand pattern of vehicles approaching the downstream signal. Information from the detector on the downstream link is also utilized to update the estimated saturation flow rate. The traffic data is continuously processed by the SCOOT algorithm to allow signal timing to adapt in real-time to traffic changes.

SCATS

SCATS (Sydney Co-ordinated Adaptive Traffic System) is a computer based area traffic control system. It is a complete system consisting of hardware, software, and control strategy. Operating in real-time, it adjusts signal timings throughout the system in response to variations in traffic demand and system capacity. As with any area traffic control system, the purpose of SCATS is to optimize traffic flow on an area-wide basis, rather than on the basis of individual intersections.

SCATS operates in real-time through the regional computer which analyses detector information pre-processed by intersection controllers. The algorithms in the regional computer select, in response to detected flow and occupancy data, the appropriate splits, offsets and cycle lengths for each subsystem and the offsets that apply between subsystems.

Route Optimization: Efficient route management not only reduces the number of vehicles required to perform a given operation, but also impacts on traffic and environmental conditions. For commercial fleets, especially in the pickup and delivery business, route optimization software and implicit algorithms are the key technology. This is a point-to-point or node-based routing application that automatically determines the optimum street sequences to perform a desired task.

In waste management and street/roadway maintenance operations such as snow ploughing, salting/sanding and street cleaning, a more sophisticated link-based routing is employed that considers both sides of the street and multiple lanes. Route optimization software can reduce the number of vehicles required to perform a given set of tasks by 15% to 30%.

Information Management ◔

Regional Traffic Control: Regional traffic control advances Surface Street Control and Freeway Control by adding the communications links and integrated control strategies that enable integrated interjurisdictional traffic control. This regional traffic control provides for the sharing of traffic information and control among traffic management centres to support a regional control strategy. The nature of optimization and extent of information and control sharing is determined through working arrangements between jurisdictions. Regional traffic control relies principally on roadside instrumentation supported by the Surface Street Control and Freeway Control and adds hardware, software, and wireline communications capabilities to

TECHNOLOGY AREA: DATA PROCESSING
implement traffic management strategies which are co-ordinated between allied traffic management centres. Several levels of co-ordination are supported from sharing of information through sharing of control between traffic management centres. This information sharing is facilitated through the application of open systems and database technologies. ***Incident Management System:*** An incident management system manages both predicted and unexpected incidents so that the impact to the transportation network and traveller safety is minimized. Requisite incident detection capabilities are included in the Freeway Control System (or ATMS) and through regional co-ordination with other traffic management and emergency management centres, weather service entities, and event promoters supported by this market package. Information from these diverse sources is collected and correlated by the incident management systems to detect and verify incidents and implement an appropriate response. An incident management system provides Traffic Management Subsystem equipment that supports traffic operations personnel in developing an appropriate response in co-ordination with emergency management and other incident response personnel to confirmed incidents. The response may include traffic control strategy modifications and presentation of information to affected travellers using traffic information dissemination. The same equipment assists the operator by monitoring incident status as the response unfolds. The co-ordination with emergency management might be through a CAD system or through other communication with emergency field personnel. This co-ordination is facilitated through the application of open systems and database technologies. The co-ordination can also extend to tow trucks and other field service personnel.

3. CONTROL

The technology area of "Control" can be divided into three categories: Signals – Table I.11; Signs – Table I.12 and Vehicle – Table I.13.

Signal control technologies include freeway and arterial lane control signs, freeway ramp metering, and arterial intersection traffic signals.

Sign control technologies provide a variety of Dynamic Message Sings including those which include interface to vehicle-roadside communications technologies enabling complementary in-vehicle displays.

Automated vehicle control technologies that provide on-board collision avoidance and auto-navigation systems are in relative infancy.

Table I.11 – Signals

TECHNOLOGY AREA: SIGNALS

Lane Control

A lane control system provides signing for lane use and speed limits. Motorists are advised of safe maximum speeds in relation to road surface, weather and/or traffic conditions. Speeds and throughputs during congestion may be improved. Lane closures in response to incidents, maintenance or construction may be expedited. A lane control system may reduce shock waves and resultant secondary collisions. The use of lane signals also enables counter-flow operations.

Ramp Metering

The objective of a ramp metering system is to reduce the recurring congestion on freeways without increasing overall network delay. This is achieved by regulating access to the expressway by signal control of the on-ramp. The flow of entering traffic is smoothed, reducing bottleneck and shock wave effects. Drivers using metered ramps may alter their driving pattern either spatially (using an alternate route) or temporally (leaving earlier or later) which may reduce the peak load on the system.

Traffic Signals

Intersection traffic signal controllers have traditionally employed custom industry-standard controllers such as the National Equipment Manufacturers Association (NEMA) standard. Additionally, signal control can be facilitated using a standard PC-based field microprocessor known as the Advanced Traffic Controller (ATC), or the California standard 2070 controller.

Table I.12 – Signs

TECHNOLOGY AREA: SIGNS

Light Emitting Diodes (LED)

Light Emitting Diode (LED) displays use pixels comprised of clusters of high intensity LEDs. Each LED is recessed in a black cylinder to minimize the impact from direct sunlight.

The main characteristics of LED DMS are:

- Solid state construction with availability of multiple colours for a broad range of applications;
- Low routine maintenance requirements;
- Rapid pace of technological development and improvement;
- Potential for long term degradation of LED output;
- Higher power consumption and heat generation relative to other DMS technologies.

LED signs are gaining widespread acceptance and are evolving as the standard technology of the future for DMS.

Liquid Crystal Display

Liquid Crystal Display (LCD) technology has been traditionally used for a wide variety of indoor signing applications. LCDs are usually used as solid-state shutters with fluorescent tubes being used as the back light source. However, the light passed through a LCD in its "light transmission mode" is insufficient for outdoor applications and the technology has not developed to the point where it can be used with confidence in the outdoor roadway environment. Introducing reflective material to the LCD to reflect more light through it in its "light transmission mode" improves outdoor performance. These so-called transreflective LCDs have been applied to shuttering light emitted from fibre optics, but this requires two LCDs in series to effectively interrupt the light. In addition, the LCDs have a high attenuation thus demanding greater light source power. Other major obstacles to the use of LCDs for roadway applications are insufficient contrast ratios and operating temperature restrictions.

In recent years, there have been extensive amounts of research initiated to increase contrast ratio thus increasing visibility. There are several characteristics that make LCD's attractive for DMS applications, including completely solid state, compact design, and wide viewing angle. LCD may emerge as a viable DMS technology over the next five years.

TECHNOLOGY AREA: SIGNS

Hybrid Signs

There are two types of hybrid signs: Fibre/Flip Disk and LED/Flip Disk. Fibre/Flip Disk signs employ reflective flip disks with each disk having a small opening to expose the end of an illuminated fibre strand. The disk employs a shield, which blocks the fibre end, when the disk is blank. Hybrid LED/Flip disks employs a similar configuration with disk openings exposing an LED pixel. The main characteristics of these technologies are improved visibility over conventional LED and fibre displays when display is exposed to direct sunlight, uninterrupted operation in the event of power failure (if desired), and potentially high maintenance requirements associated with degradation of moving parts and reflective disks.

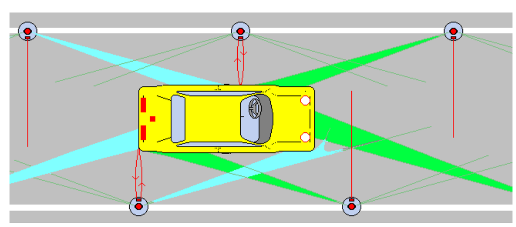
Rotating Drums

The rotating drum, or limited state, sign is capable of displaying a variety of different messages depending on the number of drums and the number of sides of its drums. For example, if a sign has two drums with 4 sides, this provides a theoretical limit of 16 message combinations. However, only a fraction of message combinations would be valid. The resulting small message library severely limits the amount and type of information that can be displayed on the sign.

Table I.13 – Vehicle

TECHNOLOGY AREA: VEHICLE

Vehicle Control



Automated vehicle control technologies are in relative infancy. Most of the world's major automakers have developed demonstration applications, such as the San Diego pilot by the National Automated Highway Consortium in the U.S. These technologies will emerge on the market as a collection of discrete market driven features, such as the adaptive cruise control feature offered by Daimler Chrysler. Control applications will only become viable following widespread proliferation of driver warning applications.

4. TRAVELLER INTERFACE

Technologies in this area have audio, visual and tactile interface capabilities that interact with travellers (e.g. with a driver during vehicle operation, or with an operator at a control centre). There are three main areas that traveller interface can be divided into: Driver Interface – Table I.14; Traveller Interface – Table I.15 and Operator Interface – Table I.16.

Console displays, heads up displays and synthesized speech are primary examples of mature technologies in the driver interface category. Technologies enabling voice input and non-distracting visual enhancement of the driver's view are less mature. For the traveller and operator interfaces, the same technologies used in driver interface applications are used with some varied constraints. For example, extreme portability requirements restrict interface options for hand-held devices. Additional capabilities, including hard copy options, for fixed presentation devices may also be required.

Table I.14 – Driver Interface

TECHNOLOGY AREA: DRIVER INTERFACE

Driver Interface

Drivers and passengers within a vehicle are able to obtain a variety of information, through a variety of methods. Tailored information may also be obtained based on real-time interactive response to a traveller's request and based on a submitted traveller profile. Information obtained may include: environmental conditions; road surface conditions, including sanding/salting status; traffic conditions including: indications of congestion levels, possible incidents, road maintenance or closures, and expected travel times; vehicle conditions; collision warnings; ride share/ride match; parking management; pricing.

This information may be obtained within the vehicle through audio in the form of Highway Advisory Radio (HAR), regular radio reports, interactive voice response (IVR) or visually through the use of a heads-up-display (HUD), Liquid Crystal Display (LCD) or Cathode Ray Tube (CRT). The information obtained from within the vehicle may also be used as input into a route selection and guidance system. Current efforts are focussing on the management and presentation of information to the motorist.

Table I.15 – Traveller Interface

TECHNOLOGY AREA: TRAVELLER INTERFACE

Traveller Interface

Interactive traveller information provides tailored information in response to a traveller request. Both real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveller based on a submitted profile are supported. The traveller can obtain current information regarding traffic conditions, transit services, traveller services, ride share/ride match, parking management, and pricing information.

A range of two-way wide-area wireless and wireline communications systems may be used to support the required digital communications between the traveller and the information service provider. A variety of interactive devices may be used by the traveller to access information prior to a trip or en-route, including telephone, pager, kiosk, Personal Digital Assistant, personal computer, and a variety of in-vehicle devices. Successful deployment of interactive traveller information relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.

Transit traveller information provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by transit traveller information.

Table I.16 – Operator Interface

TECHNOLOGY AREA: OPERATOR INTERFACE

Operator Interface

There is a wide range of related industries (defence, sports media, etc.) that use control centre displays suitable for ITS. The size of the market drives the size of manufacturing base and results in wide range of products and competitive prices. The main technologies used in control centre applications are:

- front projection (CRT or LCD light valve);

TECHNOLOGY AREA: OPERATOR INTERFACE

- rear projection (CRT or LCD light valve);
- monitor wall;
- LED flat screen.

Front projection technology has found a limited implementation in ITS control centre applications. It does not provide adequate picture quality in office levels of illumination. In addition, a projector unit hanging from the ceiling may obstruct the view of the operators or other staff involved. However, new technology developments offer significant improvement in picture quality.

Rear projection technology is widely used to display high-resolution graphics and live video images. The technology is configurable in the sense that it is available in a variety of forms including:

- stand-alone pedestal mounted units marketed as standard products;
- standard products stackable rear-projection cubes which can be configured to suit custom display requirements;
- custom-built rear-projection wall using standard projector components into the facility.

CRT or light valve based rear-projection technology is proven, widely available and provides suitable intensity in office level illumination. The primary drawback for this technology is the space requirements to accommodate the systems.

Traditional ITS control rooms incorporate banks of monitors, or monitor walls to display live video images from surveillance cameras. The primary drawback of this display media is the inability to display large high-resolution graphic images across a wall of monitors. The current trend is towards a media-wall approach incorporating a matrix of integrated high resolution rear projection.

5. NAVIGATION

Navigation systems use technologies that determine absolute position, which in turn can be used to plot courses, etc. Examples include GPS and other systems which apply multi-lateration to known locations, either terrestrial or space based. Augmenting these technologies are those that measure travel path and distance (e.g., odometer, compass, gyroscope) from a known location. Very high-precision systems associated with vehicle control applications are one remaining research area.

Table I.17 – Navigation

TECHNOLOGY AREA: NAVIGATION

Route Selection and Guidance

A vehicle may be equipped with a route selection and guidance device or route selection and guidance information may be obtained from an Information Service Provider (ISP). Route selection and guidance can be either autonomous or dynamic.

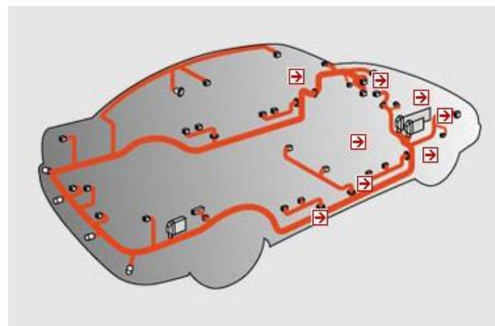
Autonomous route selection and guidance relies on in-vehicle sensory, location determination, computational, map database and interactive driver interface equipment to enable planning and detailed route guidance based on static, stored information. Information is stored in a Geographic Information System (GIS) that analyses, stores, and displays both spatial and non-spatial data.

Dynamic navigation and guidance utilizes a dynamic GIS and is therefore responsive to current traffic, weather, and road conditions. ISP based route guidance is likely to utilize dynamic route selection and guidance technology. Future technical directions in this area focus on data fusion and system integration of data sources, communication service providers, and on-board equipment.

6. IN-VEHICLE SENSORS

In-vehicle sensors encompass a broad range of on-board sensor technologies that monitor vehicle condition (e.g. engine, brake, tire, and suspension status) and performance (current speed, acceleration, yaw, traction, current steering, throttle, braking, and transmission status).

Table I.18 – In-Vehicle Sensors

TECHNOLOGY AREA: IN-VEHICLE SENSORS
In-Vehicle ● Sensors
The automotive industry has introduced a wide range of on-board vehicle sensors and diagnostics for engine management and dynamic stability. Sensors monitor parameters such as fluid levels/pressures, temperature, electrical current, etc. and initiate a response which may include control/actuation, visual signal or error code which identifies the fault condition. With the advent of the J-bus on-board communications networks, a variety of vehicle status information can be collected and reported to a centralized fleet management service using DSRC technology, interfaces at filling stations, or wide area communications. 

7. COMMUNICATIONS

Many of the technologies described in this Appendix are identified as "Mature with Rapid Innovation". Of these technology areas, perhaps none is more crucial to the initial success and continued viability of ITS than communications.

Over the last two decades, a massive worldwide telecommunication infrastructure has evolved in the developed nations, both for wired and wireless communication. The reliability and capacity of wireline networks has increased exponentially, enabling a wide array of new services and capabilities. As performance has increased, prices of most wireline telecommunication services have dropped in most countries. At the same time, the wireless communications consumer market was born and has since witnessed unprecedented growth.

Over the next twenty years, many new communication technologies and techniques, from multiple access to transport to switching, will be introduced at a rapid pace to support the demands of our information age. Presently available and emerging technologies will offer extensive opportunities to handle many candidate ITS Services.

Table I.19 – Extended Range 2-Way Communications

TECHNOLOGY AREA: EXTENDED RANGE 2-WAY COMMUNICATIONS
Personal Communication Service ● (PCS)

Analogue cellular telephone service was launched in the U.S. in 1984 and in Canada in 1986. Its subscription growth has been rapid. In Canada the analogue cellular service is available to 93 % of the population and digital PCS service presently reaches over 40 % of the population, mainly in urban areas. By the end of 1999, cellular/PCS subscriptions reached over 6.5 million accounts. In the U.S. the subscription exceeds 70 million and the ratio of analogue to PCS should be the same as in Canada. It should be noted however that the growth of the 2G PCS is accelerating due to the range of digital service features, and performance of the service.

Analog: Analog cellular telephone service provides voice communications and some data capability to 14.8Kb/s.

Digital: Several digital systems are available in the marketplace using Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA) technology. The three systems deployed in Canada are CDMA ANSI-95B operated by Former Mobility Canada and by Clearnet, the TDMA ANSI-136 operated by Cantel and the TDMA PCS 1900(GSM) operated by Microcell. The digital systems are deployed in both the 2 GHz PCS and the 800 MHz cellular bands.

TECHNOLOGY AREA: EXTENDED RANGE 2-WAY COMMUNICATIONS

Enhanced Specialized Mobile Radio (ESMR)

ESMR is a form of high mobility telephony and dispatch service that is offered using 2^{nd} generation technology systems.

Microwave

Microwave communication utilizes a number of microwave radios. Point-to point radios are connected in a serial trunk configuration, with repeater nodes connecting terminal ends. Access to a specific radio from any location is possible only through another radio, and access to a remote terminal is restricted to the one hop next to it. Repeater locations can be accessed from more than one spur direction in what is known as trunk and spur topology.

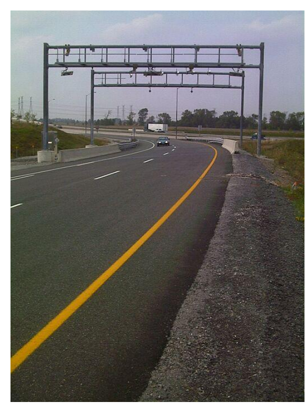
Wireless network links offer a low cost, high bandwidth alternative to a fibre network build. A network of microwave radios typically spans a large geographic area, and the network may connect to a wireline private network at various access points, or not at all.

Table I.20 – Dedicated Short Range Communications

TECHNOLOGY AREA: DEDICATED SHORT RANGE COMMUNICATIONS (DSRC)

Dedicated Short Range Communications (DSRC)

DSRC consists of wireless devices that are capable of transferring data at a high rate between mobile and/or stationary devices, but are limited to a short-range. At present, the most common application of DSRC within ITS is the communication of information between an in-vehicle transponder and a roadside antenna. This information may be used for electronic tolling, automatic vehicle location, device control, commercial vehicle operations, and traffic monitoring. However, future uses of DSRC are likely to include communication between vehicles, as well as communication between roadside devices. The 2-way communication capabilities of DSRC make it possible to use DSRC devices as a link between other wireless and wireline connections to build a complete communication network.



DSRC is a mature technology and has been widely used throughout Canada, and the world, for ITS initiatives. However, it has become apparent that there is a need to standardize DSRC and associated equipment, to provide a common path between the vehicles and devices which support ITS applications. The specific transmit/receive frequencies, as well as the

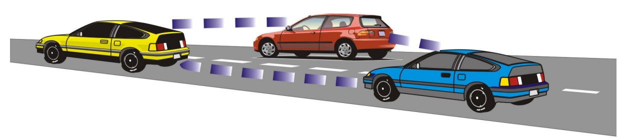
TECHNOLOGY AREA: DEDICATED SHORT RANGE COMMUNICATIONS (DSRC)
communication protocols, are issues that need to be resolved for standardization. The following table presents a brief comparison of the emerging DSRC standards in Japan, Europe, and North America.

Emerging DSRC Standards		
Region	Standard	Electromagnetic Spectrum
Japan		5.8 GHz active – A battery powered transponder receives and transmits in the 5.8 GHz frequency range
Europe	CEN-278	5.8 GHz passive backscatter – A transponder reflects transmissions in the 5.8 GHz frequency range.
North America	ASTM 6.0 / 7.0	900 MHz and 5.850-5.925 GHz active – A battery powered transponder receives and transmits in either the 900 MHz range, or the 5.8 GHz frequency range.

Table I.21 – Vehicle-to-Vehicle Communications

TECHNOLOGY AREA: VEHICLE-TO-VEHICLE COMMUNICATIONS

Vehicle to Vehicle Communications



Vehicle-to-vehicle communications is one of the lesser-developed areas within ITS. Short-range, wireless communications is used to exchange information between vehicles in close proximity for applications such as intersection collision avoidance and vehicle platooning. Candidate communications technologies include dedicated RF, spread spectrum RF, and infrared. It is likely that the development of vehicle-to-vehicle communications technologies and standards will closely parallel the development of vehicle-to-infrastructure applications (i.e. DSRC).

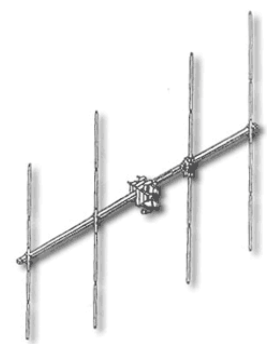
Table I.22 – Broadcast Communications

TECHNOLOGY AREA: BROADCAST COMMUNICATIONS

Broadcast **Communications**

Highway advisory radio (HAR) systems are the primary application of extended range broadcast communications within ITS. A licensed AM frequency (530-1700 kHz) or licensed FM frequency (88-108 MHz) may be used for extended range broadcast. The higher bandwidth of FM frequencies offers an improved signal, with a shorter range when compared to AM frequencies.

Digital Audio Broadcast (DAB) is a wireless audio and data transmission system developed for point-to-multipoint data broadcast applications. There are a number of ITS agencies world-wide that are considering applications that utilize DAB for traffic information broadcasting as well GPS system integration. Canadian broadcasters have adopted the Eureka 147 system and the CRTC has allocated L-Band frequency for this application. The U.S. is currently considering their own proprietary IBOC system for DAB transmission which would make use of the existing AM / FM frequency allocations. These potential differences in spectrum allocation and communication protocol may lead to significant differences in the overall standards or requirements for any future DAB ITS applications.



Europe and Japan have recently embraced DAB, which provides a significant communications improvement over FM signal capabilities. DAB service is commencing in Canada; as nineteen radio stations in Toronto and nine in Montreal are broadcasting using DAB and receivers are readily available on the market. Commercial broadcasters are active in the DAB market, and a demonstration of ATIS services using DAB is planned for the Toronto area.

It will take time before a significant number of subscribers will embrace DAB services and it can be expected that for many years the simulcasting of the same programming on existing FM or AM stations and DAB will be required to reach audiences. Also, several years will be required for the expansion of DAB coverage outside main market areas.

It should be noted that Digital TV (DTV) under a common over the air standard is quickly being implemented in the U.S. DTV technology is based on ATM and each 6 MHz TV channel can provide up to 19Mb/s which can accommodate HDTV plus approximately 3 Mb/s of datacasting, or up to 4 TV programs of advanced formats, or a mixture of TV programs and datacasting. The Canadian Industry has greatly participated in the standards, the allotment plans, and the technology, to move towards the implementation of DTV. However, so far no firm commitment has been articulated as to when the industry will begin.

Table I.23 – Fixed Wireline Communications

TECHNOLOGY AREA: FIXED WIRELINE COMMUNICATIONS

Fixed **Wireline** ● **Communications**

Dedicated and leased wireline communications wide area networks are used to integrate various ITS field components. Principal network design considerations include:

- The system must provide a high degree of reliability achieved through the use of components with a high mean time between failure, combined with a high level of redundancy in the network configuration;
- Capacity for system growth must be provided to accommodate the life of the system. Expansion is achieved through incorporation of spare fibres and a migration path for upgraded electronics;
- The system must be monitored for failures and loading using a central network management system;
- Standard industry communications protocols must be employed to minimize deployment, operations and maintenance costs.

In recent years there has been a movement away from proprietary communications architectures to industry standards such as Synchronous Optical Network (SONET) and Asynchronous Transfer Mode (ATM). As a result, there is a wide range of commercial products available for dedicated network and WAN/LAN network for ITS.

Synchronous Optical Network (SONET): SONET is a multiplexing standard for fibre-optic transmission systems. SONET was proposed by Bellcore in the mid-1980s and is now an ANSI standard. SONET defines interface standards at the physical layer of the OSI seven-layer model. The standard defines a hierarchy of interface rates that allow data streams at different rates to be multiplexed. SONET establishes Optical Carrier (OC) levels from 51.8 Mbps (about the same as a T-3 line) to 2.48 Gbps, as follows:

OC Level	Data Rate
OC-1	51.85 Mbps
OC-3	155.52Mbps
OC-12	622.08 Mbps
OC-24	1.244 Gbps
OC-48	2.488 Gbps

Prior rate standards used by different countries specified rates that were not compatible for multiplexing. With the implementation of SONET, communication carriers throughout the world can interconnect their existing digital carrier and fibre optic systems. The international equivalent of SONET, standardized by the ITU, is called Synchronous Digital Hierarchy (SDH).

TECHNOLOGY AREA: FIXED WIRELINE COMMUNICATIONS
Asynchronous Transfer Mode (ATM): Asynchronous Transfer Mode is a packetization standard which facilitates the transfer of data in cells or packets of a fixed size. The cell used with ATM is relatively small compared to units used with older technologies. The small, constant cell size allows ATM equipment to transmit video, audio, and computer data over the same network, and assure that no single type of data dominates the line bandwidth. Current implementations of ATM support data transfer rates of from 25 to 622 Mbps. This compares to a maximum of 100 Mbps for Ethernet, the current technology used for most LANs. ATM creates a virtual fixed channel, or route, between two points whenever data transfer begins. The recent deregulation of the communications environment and the evolution of industry-wide standards have lead to opportunities for sharing communication networks. Partnerships can now be developed to defray initial fibre optic installation costs either through fibre for right of way, shared ownership, or leased communication services.