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1. INTRODUCTION

The Regional Transportation Authority (RTA) Parking Management System Study will provide the design of an initial procurement of a Parking Management System (PMS) for transit station applications, along with an implementation plan for future system deployments in the RTA service area. The PMS is part of a larger effort in the Gary-Chicago-Milwaukee ITS Corridor (GCM Corridor) toward development of a Regional Multimodal Traveler Information System. The PMS is one component of this system. Other related RTA projects include Active Transit Station Signage (ATSS), Interactive Kiosks, Transfer Connection Protection, and the recently completed Itinerary Planning Service (IPS). The RTA is providing regional coordination for the development of these systems as part of its commitment to developing technologically-based solutions to traditional transit issues.

The implementation of Parking Management Systems in the RTA service area is expected to focus on providing information to patrons driving to CTA, Metra or Pace park ‘n’ ride facilities on availability of parking. The system may also include guidance to available spaces within large lots or garages and interface with the ATSS system to provide “next train” or “next bus” information.

1.1. Technology Background

Historically, most parking equipment advances have come about as ways to increase the ease and security of revenue collection. At least in the U.S., they have generally not addressed traveler information needs as planned for the PMS activities to be carried out by the RTA.

Similarly, development of parking management systems has centered on revenue collection, administrative reporting, and statistical analysis of financial and operational data for one or more parking facilities. Management of parking spaces has generally remained on a gross scale – looking at overall occupancy, and not individual space usage within the facility.

Since the advent of the federally-supported Intelligent Transportation Systems (ITS) initiatives in the early 1990’s, the focus of development efforts has begun to shift towards integration of parking management systems into other ITS systems such as Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). As a result there has been increased interest in using displays, sensors and communications developed for other ITS sub-systems in parking applications.
An example of this is the use of electronic Variable Message Signs (VMS) for displaying parking facility information and directional guidance to drivers seeking a parking space. Similarly, “smart cards” and programmable electronic tags, used successfully in the collection of fees on Illinois toll roads (I-PASS), is one of the more recent installations and is finding use as access control and revenue collection components in Parking Management Systems.

Individual space sensing may be beneficial if accurate space availability is to be provided to the RTA user, particularly in larger parking lots. However, vehicle detection in parking applications has not made great use of advanced technology to date. Although there is some use of vehicle space detection with optoelectronic/ultrasonic sensors in multi-level parking structures, there does not appear to be much use of recent advances made in video image processing (VIP) technology. Such applications offer potential for “wide-area” detection. Within parking applications VIP also has a potential role in vehicle access control and verification processes, through the use of license plate reading technology.

This report looks at the variety of Parking Management System (PMS) technologies used in parking applications around the world. Specifically, a review of these technologies and their applicability for potential use in Chicago area transit parking facilities is presented.

1.2. Organization of the Report

The report is organized to reflect the work undertaken for Tasks 2 and 3 of the Parking Management System study. The major sections of the report are as follows:

- Current Practices – This section of the report discussed the current practice of parking management in the United States and around the world, focusing on the technologies, organizations, and methods for providing parking management.

- Standards and Technology Requirements – This section reports on the types of technology available to provide the typical functions that make up a parking management system and related standards that enable flexibility and provide reliability for system components.

2. CURRENT PRACTICES

This section provides a review of current practices around the world. Many parking management systems are focused on revenue collection. Providing parking availability to potential customers beyond the entrance to a garage is a more recent focus. This information is provided by monitoring the status of the parking facility for the availability of parking spaces. That information is then passed on to potential parking customers through a variety of means. Finally, the use of advanced ITS-related technologies is increasingly common in providing the needed PMS components. These items are discussed in more detail in the following material.
2.1. Monitoring of Parking Status

The monitoring of parking status is guided by the need to keep some sort of count of the number of vehicles currently using the parking facility. This count needs to remain current, based on the entrance and exit of parking customers. A number of solutions have been used in the past to record this information, most specifically through the revenue collection system, whether through ticket provision and collection or automated payment of parking fees.

The monitoring of parking spaces in Parking Management Systems today usually takes on one or more of the three following methods. Each of these methods can be accomplished with a variety of technologies. Further discussion of the use of advanced technologies can be found shortly.

**Total Number of Spaces:** The simplest and most common means of monitoring parking status in parking lots is to count the total number of cars as they enter and exit the facility, computing the number of spaces that are currently available. This approach requires the detection of vehicle movements into and out of the parking facility, i.e. all vehicle movements at each of the parking lot's main entrances and exits are monitored. This provides a very simple overall count and allows for the real-time number of available spaces to be displayed to potential parking customers via variable message signs. In this scenario, only the total number of available spaces within the parking lot is available for provision. The signage can provide general "Space Available" information or present the actual number of spaces available.

This solution is the least complicated (and least expensive) approach. However, it provides only limited guidance information. This approach solely provides customers with space availability information. Other guidance (to specific space or to a zone/level where spaces are available) are not provided under this approach.

**Zone Specific (Area, Level, etc.):** A second approach for providing parking information and guidance refers to specific areas or levels of a parking facility. This approach operates on the same principle as the first approach in that all vehicle movements at the main parking lot entrances and exits are detected. This approach adds information about zones in the parking facility. These zones can simply be a subdivision of a parking facility by rows or area or by level in a parking garage. The vehicle movements in the zones are also monitored in this approach, providing more detailed parking availability information and the potential for enhanced guidance for parking customers.

This approach provides benefits to the parking customer in providing faster access to parking spaces via guidance to a zone with parking availability (bypassing full parking zones). This approach is more costly and complex than the first, due to the necessity of additional detection and signs for guidance.

**Space-Specific:** The third approach involves specific space or bay information. In this approach, the presence of a vehicle in every parking bay or space is detected. This information can then be used to direct parking customers directly to a specific available parking space. The display can be via simple variable message signs and/or traffic
signals. This approach is extremely expensive due to the necessary detection and guidance equipment. The size, layout, informational needs, and other related factors for a particular parking facility will ultimately lead to a logical decision on what approach(es) to parking information provision and guidance to take.

2.2. Dissemination of Real-Time Parking Information

The dissemination of real-time parking information has become an important aspect of parking management in recent years. Trial and operational tests have allowed these parking management systems to be implemented in Europe and the United States. Some of these project include the Munich COMFORT program, Nashville Traffic and Parking Guidance System, and the Minnesota Guidestar Advanced Parking Information System project. Four other systems include the following:

- Schick Electronic – individual space monitoring;
- Visolux – individual space monitoring;
- National Avionics – level and zone monitoring; and
- Data Displays Ltd – integrated with traffic control system.

2.2.1. Urban Settings – North America

**St. Paul, Minnesota (Guidestar):** The Minnesota Guidestar project is an Intelligent Transportation System (ITS) program that involves several related projects. It is directed by the Minnesota DOT. Project teams are partnerships between the public, private, and academic sectors.

The Advanced Parking Information System (APIS) is one such project. It is a one-year Operational Test sponsored by the FHWA, Minnesota Guidestar, the City of St. Paul and the AGS Group. The system encompasses over 5,000 parking spaces, involving 10 parking structures and 3 surface lots.

Controller interfaces located in participating parking facilities receive occupancy information from counters that keep track of vehicles that enter and exit. Information is sent to a central computer at the City of St. Paul, where it is processed. Information to help guide motorists to available parking is developed at the central computer and transmitted via radio communications to 10 variable message signs located throughout the city. Guidance to parking facilities is also provided by 48 static signs. Plans call for interfacing the APIS with the existing Transportation Management System in St. Paul.

**Nashville, Tennessee:** The Nashville Traffic and Parking Guidance System is a comprehensive system utilizing traffic sensors, signals, electronic and static signs, communications devices, data processing hardware, and data display equipment. Implementation of this planned system will make parking facilities in Nashville easier to
use and less disruptive for traffic both in the Central Business District and approaching routes into and out of the area.

**San Jose, California:** The San Jose Motorist Information System was developed in 1993 in conjunction with the opening of the new San Jose Sharks hockey arena with limited parking, located just west of the city’s downtown area, in a mixed residential and commercial area. The purpose of the system is to guide traffic from the freeway and arterial street system to parking facilities either near the arena, or, when the arena parking is filled, to downtown parking facilities. (Shuttle service is provided to the arena from downtown.) Parking surveillance at the arena is performed by City traffic operations personnel who also operate the City’s computerized traffic signal control system. Full-motion video cameras are located at or near the various parking facilities at the arena, and images are brought to the City’s traffic management center via fiber optic communications. Operators can determine roughly when a lot is filled through monitoring the cameras on a regular basis. Through the use of both strategically-placed Variable Message Signs (VMS) and Highway Advisory Radio (HAR), specific messages are displayed or broadcast that guide traffic to other parking facilities.

2.2.2. Urban Settings – Outside North America

**Schick Electronic, Renens, Switzerland:** The Schick *Signal Park* system combines space detectors, space signal lights, variable message signs, and a personal computer into a car park management system. An ultrasonic frequency device used as a vehicle (space) detector is mounted above each parking space and measures the return echo of the emitted signal. The round trip time of the signal indicates whether the space is occupied or vacant. Since the vehicle detector is mounted above the parking space, the *Signal Park* system is most suited for multi-level parking garages.

The control center PC polls the detectors several times per second, to sense the level of occupancy of the parking facility on a space-by-space basis. Vehicles entering the facility are detected by a sensor at the entrance and reported to the control center PC. Since the control center knows where vacant spaces are located, it can guide the entering vehicle directly to that parking space. The control center PC does this by controlling a series of messages and directional arrows displayed on a VMS.

Space signal lights mounted on the ceiling provide additional guidance to the driver on the vacant/occupied status of each space. A vacant space is indicated by six green LEDs, while an occupied space is shown by one red LED.

Detectors and VMS displays are linked to the central control computer through a five-wire communications network that provides power and bi-directional data to detectors, signs and other system components. Management functions include event logging, alarm detection and annunciation, analyses of system statistics, etc.

**Visolux, Germany:** The Visolux *Parkfinder* system from Germany features monitoring of individual parking spaces. The system consists of three basic components: sensors, communications bus system and sensor-controller.
Three types of sensors are available – optoelectronic, ultrasonic and inductive loop. The first two types are designed to be mounted in the ceiling of multistory parking decks, above each individual parking space. The choice of sensor type depends on structural and environmental conditions. The inductive loop detector is only used in special cases, such as in outdoor parking lots.

A 3-wire cable is used as the main bus, connecting up to 255 sensors to a sensor-controller. The sensor-controller can monitor 255 sensors and control 16 isolated digital outputs to control traffic lights, barriers, etc. The controller can also communicate to a host computer via an RS-232 interface.

**National Avionics, Ireland:** The Navigator Parking Guidance Information (PGI) system developed by National Avionics is designed to provide an extremely high level of accuracy of vehicle counting and reliable real-time guidance information concerning actual space availability within parking facilities.

The Navigator system is particularly suited to multi-story car parking environments, where it can provide accurate level- and area-specific counting information. This is achieved through use of an array of infrared sensors. The sensor and its software are designed to:

- discriminate between people, trolleys, bicycles and cars;
- determine a vehicle’s direction
- be easy to install;
- be linked to other management systems;
- have low power consumption; and
- have built-in automatic failure detection

The system is in use in a 4,000 space parking facility at Dublin Airport. The objectives of the system designers were to:

- maximize the car park’s revenue potential;
- develop a management information software package which would meet the airports on-line operational and planning needs; and
- enhance the usage experience of the customers.

**Data Display Ltd., United Kingdom:** This Demand Parking Management System designed for a specific application in Dublin, Ireland uses entrance/exit loop detectors and/or barrier gate actuation; VMS displays located throughout the area; a microprocessor based control unit located in each car park facility; and a PC located at the system control center.
Occupancy of each facility is computed by a differential counter in the control unit. Each VMS device and control unit is connected to the central PC via dedicated telephone links and is polled by the PC every ten seconds. Applications software, running in a Microsoft Windows environment, provides for a graphical interface for information display and operator control. All VMS displays are automatically updated with car park information every ten seconds.

Some of the signs in the Dublin system are full VMS signs, capable of displaying four lines of text, with up to 20 characters per line. Although generally displaying car park guidance information, the VMS are also used to display information on traffic congestion, accidents, diversions, etc., as necessary. For this purpose the parking management system is linked to the City’s SCATS traffic signal control system, which generates the appropriate text messages for display. SCATS (Sydney Coordinated Adaptive Traffic System) is an adaptive signal system originally developed in Australia.

**Munich COMFORT Project:** COMFORT stands for “Cooperative Management For Urban and Regional Transport” and is the name of a transport research project in northern Munich and the surrounding region. One component of the COMFORT project is a Park-and-Ride (P+R) center. The parking facilities are managed with an automated system to control access and provide information to the traveler.

Laser scanners provide vehicle detection at the access to the facility, while single parking space ultrasound detectors provide information within the facility. A computer provides for data analysis, statistics, predictions and system operation.

Dynamic information regarding space availability and public transportation options are displayed on large-scale programmable matrix displays, as well as guidance displays within the parking facility to direct vehicles to empty spaces. These VMSs have been installed on adjacent motorways to display Park-and-Ride information.

### 2.3. Current Advanced Technology Applications

Current practice provides a number of different advanced technologies that are applied in the service of ITS projects, including parking management systems. The following presents an overview of current practice. Section 3 will include more detailed review of the technologies themselves.

#### 2.3.1. Traffic Surveillance Technologies (video monitoring, automated detection)

Current traffic surveillance technologies include a wide variety of traditional and more advanced ITS-related technologies that have been introduced more recently. The traditional surveillance techniques include loop detectors which are placed directly in pavement to track vehicle presence.

More recent non-intrusive detectors include ultrasonic (sound waves), infrared/laser (rays of light), radar (microwaves), and video image processing. Video image processing uses advanced computer technologies to track vehicles on roadways or to
"read" license plates as they are transmitted by video cameras. Video feeds also provide a manual means of detection, where an operator can view the roadway or parking facility and determine congestion or available parking spaces, respectively.

2.3.2. Integration of Information with Other Systems

The development of ITS systems in the 1990's has provided ample opportunity for simple and complex system integration projects. However, most of the parking management systems developed to date around the World have been vendor-specific or have been specially-designed and built systems. The trend is to develop standards for integration of information (roadway traffic, parking and transit, along with other information), permitting both public sector and private sector activities supporting dissemination of traveler information. The GCM Corridor initiative which incorporates the Chicago, Milwaukee and Northwest Indiana areas will provide such an opportunity. Most of the work to date has been in obtaining corridor-wide expressway and Tollway information. The GCM Corridor Strategic Plan includes more emphasis on transit information in coming years.

2.4. Summary of Current Practices

The availability of parking spaces is typically monitored at one of three levels of detail:

- **Lot Basis:** Determines the occupancy level of an entire parking lot.
- **Zone Basis:** Determines the availability of parking in sub-areas, such as aisles of a surface lot or levels of a garage.
- **Space Basis:** Determines the presence of vehicles in each parking space individually.

A variety of types of sensors are used to determine parking occupancy. Most operate on the principle of adding entering vehicles and subtracting exiting vehicles to determine total count for a particular area. Barrier-based revenue control systems often use detectors that can provide this type of information.

Parking status is typically disseminated to motorists using variable message signs that display real-time information in one of two main formats:

- Number of spaces available in a parking lot or zone, or
- Status of the parking lot or zone, such as “FULL” or “OPEN”

Individual space availability is most frequently disseminated using lights near the parking spaces.
3. STANDARDS AND TECHNOLOGY REQUIREMENTS

3.1. Types of Standards

There are a number of industry standards that are used in the design, development, and deployment of ITS projects in order to provide ease of use, flexibility in equipment use, and ease of replacement/expansion. One of the most important standards in the ITS field is the National Transportation Communications for ITS Protocol (NTCIP). The NTCIP is an emerging and evolving national standard for transportation-related electronic and information system components.

The primary goal of the NTCIP is to provide multi-vendor compatibility for essential systems communications. At one level, this capability implies that technicians faced with replacing a controller in an emergency situation will not have to worry about having the right brand on the repair truck. The potential application of NTCIP, however, goes beyond this basic objective.

The NTCIP is being designed as an important component of the National Intelligent Transportation Systems (ITS) architecture. The ITS architecture defines how ITS components, such as traffic management systems, traveler information systems, and others will work together. This includes the various communication protocols for communicating between field devices, between field devices and control centers, and between two or more control centers.

Section 5206(e) of the Transportation Equity Act for the 21st Century (TEA-21) requires that Intelligent Transportation Systems (ITS) projects using funds from the Highway Trust Fund (including the Mass Transit Account) conform to the National ITS Architecture and standards. The U.S. Department of Transportation has developed Interim Guidance to help in implementing this legislative requirement. Final policy is expected to be developed through formal rulemaking by the end of 1999.

The Transit Communications and Interface Profiles (TCIP) component of the NTCIP is currently under development. The TCIP framework and five business areas have been developed and sent to balloting. Formal approval of these standards is expected at the next NTCIP meeting in October 1999. The five business areas include the following:

- Common Transportation Objects
- Passenger Information
- Scheduling and Runcutting
- Incident Management
- Spatial Representations

Components of the PMS that are incorporated in these standards should be developed according to the latest version of these standards available at the time of design.
Additionally any relevant NTCIP standards should also be considered in the design of system components, including center-to-center and field-to-center communications. Conformity will be achieved in part through meeting the requirements of the GCM Gateway regional ITS architecture and mapping the components of the PMS to the National ITS Architecture. Close coordination with regional agencies that are involved in providing or sharing data through these projects will also assist in achieving conformity. Finally the latest ITS standards will be reviewed and added as appropriate to design documents and specifications.

Other industry standards, including display of information, information content, and parking occupancy measurement are discussed in the following sections.

3.1.1. Display Type (Static, dynamic)

The displays that are part of a parking management system consist primarily of signs to convey parking facility information to drivers who are in search of a convenient parking space. Products from the survey consist primarily of signs used to control access to parking facilities, generally indicating when a facility is full (or partially full), and fixed message signs that display arrows or directions to guide vehicles to areas of the facility where parking spaces are available.

More elaborate signing with programmable messages, generally referred to as Variable Message Signs (VMS), which display the number and location of spaces and/or road condition information, are used at locations remote from the parking facility and are commanded manually or automatically by computer from a central control site to “guide” vehicles to locations that have available parking spaces. In parking guidance applications these VMS frequently contain both a fixed legend and an area for variable messages.

The display format and technology of parking management system displays is selected based on:

- Type of information to be displayed
- Required visibility relative to approach speed and context
- Cost to operate and maintain

Potential display formats include the following:

- Blank-out displays
- Variable fixed messages (selection from fixed number of messages)
- Character-matrix (fixed number of characters, fixed number of lines)
- Line-matrix (fixed number of lines, character width is variable)
• Full-matrix (can accept various character heights and graphics within the matrix)

The following listing presents descriptions of some of the common variable message sign technologies.

**Light Emitting Diode (LED):** LEDs generate their own light when the diode is electrically charged. To achieve the brightness levels required for exterior use, the LED’s lamps are clustered into pixels.

**Fiberoptic Shutter:** Fiberoptic glass optical fibers direct light from a single halogen lamp to the viewing surface, whereby a lens amplifies the fiberoptic dot. Shutters rotate to either expose or block the fiberoptic dot.

**Reflective Disk:** Reflect light from some external source. The viewing face is formed by an array of permanently magnetized circular disks or rectangular indicators, which when rotated, form the message pattern. They require power only when the message is being changed.

**LED Fiberoptic Enhanced Reflective Disk:** These hybrid signs combine two VMS technologies to exhibit qualities of both. The pixels in use depend upon the reflective disk principles of operation with the LED or Fiberoptic dot shown when the disk is in the “on” position.

**Liquid Crystal Display (LCD):** This technology relies upon an electrical current to change the orientation of crystals to either block or allow back-lighting to be visible on the viewing surface. Legibility characteristics are excellent; however, this technology is very environmentally-sensitive and its low brightness output limits its applicability in daylight environments.

**Others:** The following types of VMS were not considered due to the fact that they have been succeeded by superior technologies in terms of reliability and maintenance requirements: bulb matrix (commonly used for scoreboards), rotating drum, and blank-out displays.

Sign functionality will differ depending on location and the “target” of the message. Parking guidance signing, in particular, may require a combination of static trailblazer information (e.g., parking lot identification, directional arrow) and variable information (e.g., “OPEN”, “FULL”). Advance signing on the arterial may provide advance parking information (e.g., RED LOT FULL; USE BLUE LOT), next train information (NEXT SB TRAIN IN 5 MIN.), or traffic advisories (ACCIDENT ON SB EDENS). Messages may be multi-frame in nature (i.e., alternating messages on the display), in order to impart the necessary information without requiring a large sign. However, for visibility from 800 feet at a rate of speed of 40 mph or higher, it is most desirable to include no more than seven message units at a time, with a maximum of two alternating message frames.

Display media implemented in newer VMS’s have focused on visibility and legibility. In general, this either requires reflectivity, illumination, or both. Fluorescent flip-disk signs provide reflectivity, but must be externally illuminated at night. Shuttered fiber optics displays and Light-Emitting Diode (LED) pixels provide internal message illumination
with reduced maintenance and longer life-cycle compared to older incandescent bulb display technologies.

Where displays are located in open areas facing sunlight, combinations of flip-disk signs with pixel illumination, while more expensive, can provide the “best of both worlds” (e.g., flip-fiber or flip-LED hybrid displays). These displays, however, require more maintenance, since both flip disks and fiber optics shutters include moving parts. LED signs are the only VMS media other than incandescent bulbs that contain no moving parts.

The current industry and transportation agency standard for VMS displays is to provide an amber-colored message. In particular, for LED displays, amber provides the best combination of brightness and target value. A number of earlier installations (including existing displays on Metra commuter rail and CTA rapid transit platforms) utilize bright red LED’s. These provide adequate target value; however, red displays are typically associated with regulatory information (e.g., stop, yield, warning) per current traffic control standards.

Some comments on an analysis of VMS technologies are presented below.

- When all the factors are considered, monochrome amber LED is slightly superior to the other technologies. Its positive attributes are good legibility distance, matrix flexibility, slightly lower operating and maintenance costs, and long life expectancy (100,000 hours before LED’s are one-half their initial brightness).

- LED Enhanced Reflective Disk are a hybrid, and most owners display messages under bright lighting conditions using the flip disk matrix only. Therefore, the reflected light matrix has inherently less conspicuity. Visibility is particularly poor under dawn or dusk lighting conditions, or when the face of the sign faces north and is shadowed. While augmenting with the LED’s activated mitigates these conditions somewhat, the conspicuity does not compare with pure lighting emitting technologies.

- A distinct disadvantage of the LED VMS is the absence of a fail-safe system to insure that messages are displayed during a communications problem or power failure. Since the LED’s are “on” all the time, power consumption is high.

- LED Enhanced Reflective Disk requires power (between the sign and controller) only when the message is changed. If messages will not change frequently, power consumption will be significantly less when compare to light-emitting technologies.

- Since LED Enhanced Reflective Disk is a hybrid, it is mechanically more complicated and has more moving parts than pure LED signs. Experience of DOT’s indicates more maintenance is required and reliability is affected.

- LED Technology is reported to have the lowest average maintenance costs per year due to no moving parts.
3.1.2. Display Content (GCM, other regions)

Parking guidance signs have become a common feature in many European towns and cities over the last 10-15 years. They are designed to provide information to the driver seeking a parking space and to minimize time-consuming and inefficient random searching for a space in a congested urban environment. Parking guidance systems of this type are frequently interfaced to or integrated with a city’s computerized traffic signal or traffic management system. The first system of this type in the United States, which requires the integration of data from a number of otherwise separate parking facilities, has recently been installed in St. Paul, Minnesota. There is very little experience with parking management systems at transit commuter parking facilities.

The content of the parking management system displays can include both permanent (static or VMS) and real-time variable information (VMS). The following list shows three types of signage providing parking information:

<table>
<thead>
<tr>
<th>Type of Sign</th>
<th>Static</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Finger Directional Signs</td>
<td>Facility Name</td>
<td>Number of Spaces</td>
</tr>
<tr>
<td>Multiple Directional Signs</td>
<td>Facility Name</td>
<td>Number of Spaces</td>
</tr>
<tr>
<td>Full VMS</td>
<td></td>
<td>Name and Spaces or Traffic Message</td>
</tr>
</tbody>
</table>

3.1.3. Parking Occupancy Measurement

The standard means of providing and reporting parking occupancy measurement is to provide simple processing of automatically collected entrance and exit counts. This simple processing (addition/subtraction) allows for the total number of spaces available in a parking facility or specific zone to be determined automatically.

Automated calculation is not the only way of providing parking occupancy measurement. Calculation can also be accomplished manually by parking lot operators using video cameras or personal surveillance. However, the reliability of manually collected and computed information will not reach the level that is provided by automation.

3.2. Types of Technologies

Detailed descriptions and discussions of the variety of technologies available for use in a parking management system are presented in the following sections, including detection, system processing, communications, and interface/connections.

3.2.1. Detection

Detection of vehicles is typically provided via sensors, or those devices that sense the presence (or lack of presence) of vehicles. They are generally used for the purpose of
providing or prohibiting access of vehicles into or out of a parking facility and are generally linked to a barrier gate. In this manner, detection sensors often form part of the revenue collection system at a parking facility. Detection sensors are also often used to perform an auditing function by establishing an independent count of vehicles exiting the facility to be compared with revenue collection records.

They are also used in conjunction with a counting device, either locally or at a remote PC, and form the basis for estimating dynamically the number of spaces occupied at any given time. Most of the products reviewed in this survey determine the number of occupied spaces in a parking facility in this manner.

**Inductive Loop:** Inductive-loop detectors are the most extensively utilized detectors in the United States and around the world. They provide data on volume, speed, and density (occupancy). The technology consists of a loop wire of one or more turns embedded in the pavement and connected to an electronic amplifier (located in the controller cabinet). This detector identifies the presence or passage of a vehicle.

Advantages include:

- Flexible design
- Wide range of applications
- Provides basic traffic parameters

Disadvantages:

- Installation requires pavement modifications.
- Installation and maintenance require lane closures.
- Detectors are subject to traffic stresses.
- Detectors are subject to damage and dislocation by road traffic or roadway equipment such as sweepers and snow plows.

**Radar/Microwave:** This detector is not pavement-intrusive and is commonly used to monitor vehicle speeds for law enforcement and traffic management applications. Some advanced radar/microwave detectors can also be used as presence detectors and can provide traffic volume and speed data. Because they use electromagnetic energy, radar/microwave sensors are typically unaffected by weather conditions, especially when measurements are made from a short distance. They can also be used for both day and night operations. Radar/microwave systems can provide volume, speed, occupancy, and presence detection.
Advantages:

- Generally insensitive to weather conditions.
- Provides day and night operation.

Disadvantages:

- Requires FCC license for operation and maintenance (in U.S.).
- May lock on to the strongest signal (e.g., large truck).
- Susceptible to interference from other devices operating at the same frequency.

**Ultrasonic:** These detectors (e.g., smartsonic) are passive acoustic sensors and automated-signal and information-processing systems that listen (no energy is radiated by the system) for the noise generated by stationary or moving vehicles in a detection zone on the roadway. Only those vehicle sounds from within a specific detection zone are retained. Sounds from locations outside the detection zone (such as an adjacent lane) are severely attenuated and are ignored. The detection process for vehicle sound energy is analogous to the way the metal in vehicles is detected as those vehicles pass over a loop. It is an overhead-mounted system with limited side mount. Ultrasonic detection fully emulates loop-output signals, and thus requires no modification to existing system hardware or software. Ultrasonic systems can provide volume, speed, occupancy, presence, and classification data.

Advantages:

- Completely passive.
- Generally insensitive to weather conditions.
- Provides day and night operation.

Disadvantages:

- Relatively new technology for traffic surveillance
- Environmental conditions such as winds, heavy snowfall, and rain may inhibit the propagation of sound waves.

**Infrared:** There are two types of infrared detectors: active and passive. Active infrared detectors focus a narrow beam of energy onto an infrared-sensitive cell, and vehicles are detected when they pass through the beam, interrupting the signal. These detectors can be used either as presence or pulse detectors. Detector performance can be affected by weather conditions (fog, rain, snow) causing inconsistent beam patterns. Passive infrared detectors do not transmit energy, but measure the amount of energy emitted by objects in their field of view. Infrared detection systems can provide volume, speed, occupancy, presence, and classification data.
Advantages:

- Active detector emits narrow beam for accurate determination of vehicle position.

- Provides day and night operation.

- Provides most basic traffic parameters.

- Passive detectors can be used for strategic loop replacement.

Disadvantages:

- Operation affected by precipitation such as rain or fog.

- Difficulty in maintaining alignment on vibrating structures.

- Susceptible to sudden changes in background radiation due to rain or clouds.

- Some surfaces such as windshields and black metal and plastic car bodies are poor reflectors.

**Video Image Processing:** With video image processing, cameras provide images that are used by a video processor to emulate traffic data. It is possible to define multiple detection locations within the camera viewing area. These “pseudo detectors” are not fixed, but may be moved by the operator if desired. The type of signal processing algorithm used by the image processor dictates the type of data obtainable by the system. These systems can provide volume, occupancy, and presence detection. In more advanced systems, individual vehicles are tracked as they pass through the field of view, allowing identification of speed, vehicle classifications and travel times in the detection zone. Most processing algorithms have been optimized to compensate for shadows, illumination changes, and reflections.

Advantages:

- Location or addition of detector zones can easily be done on the PC.

- Provides basic traffic parameters.

- Provides wide-area detection.

Disadvantages:

- Inclement weather, shadows, and poor lighting can affect performance.

- May require significant processing power and a large communication bandwidth.

**Closed Circuit Television (CCTV):** CCTV systems have been used for many years in the United States and around the world to provide visual surveillance of the freeway.
Fixed location CCTV systems include video cameras that are permanently mounted either on existing structures or on specially installed camera poles. This type of system consists of various components, including the following:

- Video camera unit
- Mounting structure (existing or installed)
- Controller cabinet housing the control equipment
- Communication system connecting camera to control center
- Video monitors and camera controls located in control center

Video images from cameras may be transmitted to a control center using either full motion video or compressed video. Full motion video allows real-time video to be transmitted to the control center. Real-time video is typically transmitted at a rate of 30 frames per second. This transmission type results in no information loss; however, it requires a wide communication bandwidth, such as that provided by coaxial cable or fiber optic cable.

When it is not feasible to install the communication medium required for full motion video, compressed video can be an attractive option. An advantage of compressed video transmission is that video data can be transmitted over relatively low-bandwidth conventional telephone lines and cellular channels.

With compressed video techniques, transmission rates of 8 to 10 frames per second are possible. Because some information is lost between picture frames, the resulting image appears slightly “jerky.” The image, however, is adequate for monitoring freeway operations. A compressed video system typically includes the following:

- Compression and decompression (codec) computer for each camera/monitor link
- Appropriate software
- Communications medium (typically a leased ISDN [Integrated Service Digital Network] line).

Standard cameras, monitors, and control hardware can be used, and therefore, can be reused if the communications medium is upgraded to allow for full motion video transmission. This is a manual type of detection, requiring an operator to view the video feed to determine the location and/or number of available parking spaces.

3.2.2. System Processing

Most systems being developed for traffic management and traveler information purposes are being developed using “open systems” philosophies. This involves the use of off-the-shelf, commercially available operating systems such as Windows NT.
and UNIX; standard software development tools such as C++ and Visual Basic; and standard system interfaces and database access standards, including Structured Query Language (SQL). The use of “object-oriented programming” has been recommended for GCM Corridor applications. This permits treating of all system components as uniquely configured objects, with the ability to communicate to all of these objects from a central system through standard interfaces, and the ability to store system information within these objects in lieu of developing a centralized, relational database. However, object-oriented applications are still in their infancy, due to issues involving the speed of system processing.

3.2.3. Communications

The communications system functions as the means to transfer information among system components. Information flows from a transmitter to a receiver over a transmission path called a link or channel. This transmission path is provided by a communications medium, and may be a physical connection (copper wire, coaxial or fiber optic cable) or an air path (microwave, cellular, single channel or spread spectrum radio).

The communication subsystem is often the most critical and expensive element of the signal system. Control systems require that:

- Real-time (or near real-time) and other commands necessary to execute functions be communicated to the field equipment; and

- Information such as controller mode, signal status, detector data, and equipment status be transmitted to the traffic operations center or field master from the controller.

In addition, the system may be required to communicate information between the traffic control center and:

- A variety of other field equipment;

- Another control center (e.g., Illinois DOT); or

- A regional transportation management/information center.

Various kinds of information, having different communications requirements, may also be involved. For example, the requirements for communication of video signals differ significantly from data communications requirements.

Communications media are categorized as either land lines (cable of one sort or another) or wireless (air-path). The most prevalent system media is wire cable. Relevant land line communications technologies include voice grade analog channels, coaxial cable, fiber optics, and leased analog and digital services from local exchange carriers, cable television providers, etc. Air-path technologies applicable to traffic control systems include mainly “owned” radio (area radio network, microwave and
spread spectrum) and some very limited use of commercial wireless services such as cellular telephone. A summary of each applicable communication technology is shown in Exhibit 3.1 on the following pages.

Some general conclusions and trends regarding use of various media, based on past and current system designs, are:

- Fiber optic cable appears to be the choice for owned landline communications used with medium and large centralized systems. The trend is toward fiber optics for smaller systems that are required to support full motion or compressed video, especially in cases where communications resource sharing is a strong influence.

- For smaller distributed system applications, handling primarily data, copper wire remains the choice with the use of wireless (radio) communications increasing as its cost decreases. Fiber optic use may increase in smaller systems if the data rate requirements increase with more widespread application of ITS equipment.

- More and more traffic control systems use common telephone communications standards. The trend is toward increased use of these and other standards, as local systems face increasing requirements for compatibility with other local and regional systems.

The selection of communications media for the Parking Management System will depend on distances between field devices and a control / monitoring site, as well as availability of existing communications.
**EXHIBIT 3.1**
**SUMMARY OF PROPERTIES OF COMMUNICATION TECHNOLOGIES**

<table>
<thead>
<tr>
<th>Features</th>
<th>Twisted Wire Pair Channels</th>
<th>Leased Voice Grade Channels</th>
<th>Switched Voice Grade Channels</th>
<th>Fiber Optic Channels</th>
<th>CATV (Community Antenna Television) Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Media</td>
<td>Copper wire</td>
<td>Many vary along length but usually copper wire pair at user interface points</td>
<td>May vary along length but usually copper wire pair at user interface points</td>
<td>Glass or plastic fibers</td>
<td>Coaxial Cable</td>
</tr>
<tr>
<td>2. Principal Multiplexing/Modulation Technique Used</td>
<td>Time Division Multiplex (FSK)</td>
<td>Time Division Multiplex (FSK)</td>
<td>Time Division Multiplex (FSK)</td>
<td>Time Division Multiplex</td>
<td>FDM for channels. TDM for data on a channel</td>
</tr>
<tr>
<td>3. Carrier Frequency Band</td>
<td>300 – 3,000 Hz</td>
<td>300 – 3,000 Hz</td>
<td>300 – 3,000 Hz</td>
<td>850 – 1,550 nanometers</td>
<td>5 – 350 MHz</td>
</tr>
<tr>
<td>4. Bandwidth/Channel Bandwidth</td>
<td>Will exceed 2.7 kHz for most systems</td>
<td>2.7 kHz</td>
<td>2.7 kHz</td>
<td>Various</td>
<td>6 MHz/channel. Channels may be further subdivided for data transmission.</td>
</tr>
<tr>
<td>5. Data Rates per Channel</td>
<td>1,200 – 3,100 bps/second. Higher rates possible with different modulation technique</td>
<td>1,200 bps or higher</td>
<td>1,200 bps or higher</td>
<td>Up to 2.4 Gbps</td>
<td>Up to 7.5 MBPS based on channel subdivision</td>
</tr>
<tr>
<td>6. Transmission Range or Repeater Spacing</td>
<td>9 to 15 miles</td>
<td>Service level provided by communications lessor to a standard</td>
<td>Service level provided by communications lessor to a standard</td>
<td>Rarely a limitation when drop/insert units used at communication hubs or drop points</td>
<td>N/A</td>
</tr>
<tr>
<td>7. Government Regulation of Channel or Service</td>
<td>None</td>
<td>Tariffs filed with State</td>
<td>Tariffs filed with State</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>8. Types of Information Supported</td>
<td>Data, voice, slow scan TV</td>
<td>Data, voice, slow scan TV</td>
<td>Data, voice, slow scan TV</td>
<td>Data, voice, analog TV, Codec</td>
<td>Data, voice, analog TV, Codec</td>
</tr>
<tr>
<td>9. Owned or Leased</td>
<td>Owned</td>
<td>Leased</td>
<td>Dial up lines</td>
<td>Owned</td>
<td>Leased</td>
</tr>
<tr>
<td>10. Constraints on Use</td>
<td>--</td>
<td>Proximity of telephone service to field controllers</td>
<td>Compatibility with intermittent operation. Proximity to controller</td>
<td>--</td>
<td>Proximity of CATV cable to field controller</td>
</tr>
</tbody>
</table>
## EXHIBIT 3.1 (cont.)
### SUMMARY OF PROPERTIES OF COMMUNICATION TECHNOLOGIES

<table>
<thead>
<tr>
<th>Features</th>
<th>Leased Digital Channel Services</th>
<th>Area Radio Networks (Owned)</th>
<th>Terrestrial Microwave</th>
<th>Spread Spectrum Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Media</td>
<td>Various</td>
<td>Atmosphere</td>
<td>Atmosphere</td>
<td>Atmosphere</td>
</tr>
<tr>
<td>2. Principal Multiplexing/Modulation Technique Used</td>
<td>Time Division Multiplex, modulation technique varies</td>
<td>Time Division Multiplex, modulation technique varies</td>
<td>Time Division Multiplex, modulation technique varies</td>
<td>Various modulation techniques Time Division Multiplex Code Division Multiplex</td>
</tr>
<tr>
<td>3. Carrier Frequency Band</td>
<td>Baseband and various carrier bands</td>
<td>151 – 174 MHz 405 – 430 MHz 450 – 470 MHz 928 – 960 MHz</td>
<td>928 – MHz to 40 GHz</td>
<td>902 – 928 MHz</td>
</tr>
<tr>
<td>4. Bandwidth/Channel Bandwidth</td>
<td>Various</td>
<td>25 KHz channels</td>
<td>Varies</td>
<td>Varies</td>
</tr>
<tr>
<td>5. Data Rates per Channel</td>
<td>Ranges from 2.4 KBPS to upwards</td>
<td>9.6 KBPS</td>
<td>Up to 7.5 MBPS depending on channel allocation</td>
<td>200 KBPS (typical)</td>
</tr>
<tr>
<td>6. Transmission Range or Repeater Spacing</td>
<td>N/A</td>
<td>Several miles</td>
<td>Range varies and may extend to several miles depending on frequency and other variables</td>
<td>0.5 miles to several miles</td>
</tr>
<tr>
<td>7. Government Regulation of Channel or Service</td>
<td>Tariffs filed with State</td>
<td>FCC licensing of channels for each network</td>
<td>FCC licensing of channels except for channels in 31 GHz band for each installation</td>
<td>No license in the 902 – 928 MHz band for the network</td>
</tr>
<tr>
<td>8. Types of Information Supported</td>
<td>Data, voice, Codec</td>
<td>Data</td>
<td>Data, voice, analog TV, Codec</td>
<td>Data, Codec</td>
</tr>
<tr>
<td>9. Owned or Leased</td>
<td>Leased</td>
<td>Owned</td>
<td>Owned</td>
<td>Owned</td>
</tr>
<tr>
<td>10. Constraints on Use</td>
<td>--</td>
<td>Channel availability, line of sight in 900 MHz band, multipath sensitivity, geometrics</td>
<td>Channel availability, line of sight availability, multipath sensitivity, geometrics, weather</td>
<td>Line of sight, geometrics, protocol compatibility</td>
</tr>
</tbody>
</table>

3.2.4. Communications Standards

Problems encountered in expanding a system after initial installation can generally be traced to the use of equipment which doesn't conform to standard equipment interfaces and protocols. Non-conformance to standards leads to lack of interoperability, compatibility and interchangeability.

Now, motivated by the impact of ITS projects, standards have taken on a higher priority. Standards will make possible the integration of a host of newly developed and emerging ITS devices and services.

Open system architecture, with standards and protocols defined and available for all manufacturers to adhere to, has been key to the tremendous growth in the PC computer and communication networks industry witnessed over the last decade. Almost any PC can be integrated into a network of linked workstations communicating and sharing resources.

This concept is finally being pursued by the traffic and transportation industry - by both users and manufacturers. This is evidenced by the specification and use of such standards that govern computer (especially PCs) equipment, serial data interfaces, modems, and local area networks. However, at the street equipment level this same enthusiasm has not prevailed, leaving the system user with few alternatives when the time comes for equipment spares, replacement or expansion. This has motivated the development of a most important standard called NTCIP.

The NTCIP will define how future traffic management systems will communicate with each other and with field equipment, such as traffic signal controllers, variable message signs, highway advisory radio, etc. By making use of open communications protocols that conform to the International Standard Organization's (ISO) Open System Interconnect (OSI) model, the standard will permit controller equipment, as well as ITS devices, to provide interchangeability and interoperability. This means that different controllers can simultaneously share the same communications link. This also means that a device will operate identically to one it replaces in a system even if it was manufactured by a different supplier.

The NTCIP standard, started by National Electronics Manufacturers Association (NEMA), encouraged by the FHWA, and guided by a Steering Group comprised of users, designers, software developers, manufacturers and non-manufacturers of traffic signal systems, is a major step toward integration of equipment of different types and manufacturers in a system. However, the standard is not yet complete and it remains to be seen how well it lives up to its potential to facilitate integrated systems, including parking management systems.

3.2.5. Interface/Connection with Other Systems

The coalition involved in development of the NTCIP is also developing a series of center-to-center communications standards. However, the GCM Corridor coalition has, through the Gateway Traveler Information System and the Datapipe initiative,
developed data standards for all member agencies to disseminate travel data. The Gateway will serve as a means of sharing traffic data, including incident management data, video images and VMS messages. This data sharing will be accomplished through dedicated fiber optic links between Departments of Transportation in Illinois, Wisconsin and Indiana, and with the Illinois State Toll Highway Authority. Also to be included (but perhaps not using as high a bandwidth for communications) would be the RTA and/or its service boards and the City of Chicago. There is substantial work yet to be done related to multi-modal information; the work done under the PMS and other RTA projects utilizing ITS must serve as a mechanism to better integrate transit and parking information with other GCM Corridor information.

3.2.6. Sources:


World Wide Web pages for research, manufacturers, etc.