APPENDIX B
COMMUNICATIONS

COMMUNICATIONS

Two primary alternatives are available for system communications: commercial circuits, or agency owned circuits. Typical systems use a mix of these alternatives, driven by costs and requirements. Excellent, extensive treatments of this topic are provided in literature, in particular the "Communications Handbook for Traffic Control Systems" published by the FHWA in 1993.

The following summary reviews those items most applicable for the I-65 project. Since the communications system is usually the most expensive component of a traffic monitoring/incident management system, it is crucial that a full range of options be considered and evaluated.

Communications technology is rapidly changing, providing faster and higher capacity circuits at lower costs. New wireless options are emerging, spurred by growth in portable computers and personal communications. To take advantage of these changes, the system communications architecture must be flexible and designed around common and commercially supported standards.

This appendix is organized as follows:

- Commercial Leased Circuits: an overview of commercially available facilities,
- Agency Owned Facilities: an overview of technologies that can be installed and owned by the agencies associated with this project,
- Fiber Optic System Architecture: a detail discussion of the architecture of fiber optic communications systems,
- Fiber Optic Network Configurations: a review of the three basic network configurations,
- Existing Louisville Communications Facilities: a brief review of existing communications facilities that may be usable for this project,
- Recommendations: recommendations for initial and ultimate communications sub-system implementation.

COMMERCIAL COMMUNICATIONS CIRCUITS

The local telephone company, cellular carriers, and other communications service suppliers provide a variety of circuits operating at a wide range of speeds. Initial installation costs and short-term monthly costs for low speed data circuits are low, and are thus advantageous for vehicle detection and variable message sign circuits. Maintenance and repair is provided by the commercial service provider, removing the requirement for special training or equipment within an agency. The drawback of this arrangement is the "finger pointing" that often occurs when multiple parties are involved. The primary disadvantages are the long-term costs (i.e., recurring monthly billings), and the expense of high speed circuits. Since the monthly costs are considered operational expenses, they must be budgeted from annual operations budgets and are thus often more difficult to obtain than initial capital funds.

Commercial communications circuits are available as either switched (dial-up) or dedicated (private line) facilities. Each of these basic types can be configured as point-to-point (2 parties) or multi-point (3 or more parties) circuits. For dial-up service, a multi-point circuit is usually referred to as a "conference call". For dedicated circuits, the term multi-drop circuit is often used interchangeably with multi-point. A further distinction is the transmission technique used: analog or digital. The original telephone network was designed as an analog system for the transmission of voice. The availability of low-cost, high-performance computer circuits has allowed the telephone system to convert much of its transmission and switching equipment to digital technologies, resulting in better quality and performance at reduced cost.

Pricing of commercial circuits typically involves a one-time installation charge, and a recurring monthly charge. Circuits can be obtained on a month-by-month basis, or on various contractual terms ranging from 1 year to 10 years. Month-by-month service provides the most flexibility since service can be terminated when required, but it is the most expensive option. Multi-year contracts provide lower monthly costs, but include penalties for cancellation prior to the end of the contract period.

Dedicated circuits typically include three cost components in both the installation and monthly charge: the channel from the customer's premises to the telephone company central office, the channel that connects one central office to another, and the interconnection (or bridging) of the multiple parts of the circuit. Because of the complexities associated with the specific central office that provides each element of a particular circuit, and the mileage between the central offices, it is not possible to provide exact circuit costs until the specific locations of the traffic operations center (TOC) and the field equipment is determined. However, reasonable assumptions regarding service locations and inter-office mileage can be utilized to develop estimates.

For a pricing comparison of dedicated circuits, two typical configurations will be utilized in the following discussions. The first circuit is a point-to-point circuit originating at the TOC, running from the TOC to central office A, then 5 miles on an inter-office channel to central office B, and terminating at an item of field equipment (for example, a VMS or a CCTV camera). The second circuit is a multi-point circuit interconnecting four locations: the TOC and three items of field equipment (for example, 170s monitoring traffic). The TOC and one of the 170s are served from central office A, the inter-office channel to central office B is 5 miles long, and the other two 170s are serviced from central office B. The cost estimates received from the telephone companies do not include any discounts for current service volumes, or existing special contracts. Thus, the following costs are conservative.

Dial-up Analog Service: This is the basic voice-grade telephone service provided for residences and businesses. These channels are provided to support voice communications, and are universally available. Currently available modems (modulator/demodulator) provide data transmission speeds in excess of 14.4 Kbps on dial-up phone lines. These units are inexpensive ($250), and widely available with numerous features and options. They are extensively used on personal computers for data and FAX transmission, and well supported by commercially available PC software.

Dial-up telephone service is a useful alternative for occasional, relatively short-term data transmission. The dialing and connect time (15-30 seconds) does not realistically permit data collection or control of devices more frequently than every five minutes. The dial-up telephone network is designed and configured for human calling patterns and call holding periods, allowing the expensive central office equipment to be shared among many subscribers. Use of dial-up circuits for frequent data calls, or for long holding times, or for many hours of use per day, ties up the central office equipment and results in the local telephone company complaining about inappropriate usage. The project is within the Louisville local calling area, thus no "long-distance" charges would be involved.

The other concern with any dial-up configuration is security. The ability of "hackers" to break into computer systems has been widely reported, and cases of inappropriate or unsafe messages being displayed on VMSs through dial-up access have been documented. The use of dial-up/dial-back, encryption, security passwords, and other safeguards reduces the risk for these cases, but at the expense of increased system complexity and additional "hassle" for the personnel who have to support and maintain the system.

In Kentucky, dial-up analog service costs $56.50 to install and $57.00 per month. In Indiana, the installation charge is $59.00 and the monthly charge is $61.00. One dial-up circuit is needed for each field device to be accessed, and one or more circuits is required at the TOC.

Integrated Services Digital Network: ISDN is the digital equivalent of dial-up analog service. It is a technology that was developed by the telephone industry during the early 198Os, but has seen a very slow implementation. In the past three years, however, the penetration has increased significantly in many areas. The key benefit claimed for ISDN is the availability of 144 Kbps (divided into two 64 Kbps data channels and one 16 Kbps control channel) of switched digital data over two pairs of wire. Another benefit is the reduced switching/interconnect time, making it feasible to support more field devices on dial-up connections. Interface boards (equivalent to modems) for certain types of computers are coming down in price (into the $1 ,OOO-$2,000 range) and increasing in availability.

For the current generation of incident/traffic management system equipment, utilization of ISDN circuits is probably not feasible due to the lack of interface boards for the equipment. Circuit availability is also a limiting factor. However, the next generation of equipment may well be able to take advantage of ISDN. Since ISDN was developed as a digital service, its error characteristics and operational parameters will result in excellent performance. The current lack of interface boards, and limited availability of ISDN service limits the usefulness for current projects. Furthermore, since ISDN is basically a "dial-up" service, its use for full-time channels, as typically used for traffic monitoring applications, may not be effective.

In Kentucky, the installation charge for an ISDN circuit is $270, and monthly charges are $9 1. These charges are applicable to each end of the ISDN circuit. ISDN service is currently not available in the Jeffersonville area of Indiana, but is planned for January 1995.

Dedicated Voice Grade Analog Channels: These circuits have been the back-bone of many traffic management and arterial control systems over the past 20 years. Modems to utilize these circuits are included in the design of 170 and NEMA equipment. They can be configured as either point-to-point or multi-point circuits, and can support speeds in excess of 9,600 bps with current modem technology. There is a wide range of equipment available for interface to these channels. There are reports of telephone companies changing their tariffs and pricing policies to discourage use of these channels over the long term, in an attempt to move customers to digital channels. The primary advantages of these circuits is their wide-spread availability and their low cost for low speed circuits. Since these channels are designed for voice, they are not optimized for the transmission of data.

In Kentucky, an analog point-to-point circuit (per the configuration above) costs $842 to install, and $140 per month. A four drop multi-point circuit costs $1,720 to install and $320 per month. In Indiana, for a point-to-point circuit the installation charge is $820 and the monthly charge is $158. For the four drop multi-point circuit, the installation cost is $1,572 and the monthly cost is $277.

Digital Data Channels: The telephone companies offer a range of digital channels running from 2.4 Kbps to 64 Kbps. They are often referred to as DDS (DATAPHONE Digital Service) circuits. These circuits are primarily dedicated circuits, but are occasionally available in a switched configuration. A difficulty with these circuits is that they are usually configured as "synchronous" data circuits, while most communications for incident/traffic management systems is "asynchronous," requiring adapters at each end of the circuit. Since these channels are designed for data transmission, their reliability and operational characteristics are very good. The principle disadvantages are the fundamental "synchronous" nature of the channels, and the limited availability of the Data/Channel Service Units (DSU/CSU) needed to connect to the circuits.

In Kentucky, a digital 9,600 bps point-to-point circuit (per the configuration above) costs $756 to install, and $150 per month. A four drop multi-point circuit costs $1,208 to install and $370 per month. In Indiana, for a 9,600 bps point-to-point circuit the installation charge is $770 and the monthly charge is $233. For the four drop multi-point circuit, the installation cost is $1,572 and the monthly cost is $567.

At 56 Kbps, a digital point-to-point circuit in Kentucky costs $756 to install, and $260 per month. For a four drop 56 Kbps circuit, the installation charge is $1,548 and the monthly charge is $560. The costs in Indiana for a 56 Kbps point-to-point circuit are $770 to install and $485 per month, and the four drop multi-point circuit costs $1,572 to install and $895 per month.

Digital Carrier: In the mid-1960s, the telephone companies began converting their long-haul trunk circuits from analog technology to digital technology. The basic circuit implementation was the DS-1 (Digital Service 1) channel, operating at 1.544 Mbps. Note that this channel is commonly referred to as a Tl circuit. This Tl circuit is configured to support 24 voice grade channels, each requiring 64 Kbps of digital bandwidth. There is a hierarchy of faster digital circuits, each built upon various combinations of Tl circuits. A typical combination is DS-3 (T3) at 43.232 Mbps, or 672 voice grade channels. The emerging Synchronous Optical Network (SONET) standard builds upon DS-3, and is defined in various combinations as high as OC-48 (Optical Carrier 48), which operates at 2,488 Mbps, or the equivalent of 32,256 voice grade channels.

Within the past few years, Tl service is becoming readily available to end users, driven by the demand for higher speed communications channels to link computers and local area networks together. The primary interest in Tl for traffic/incident management systems is digital transmission of video signals. Tl provides a reasonable option to agency owned fiber optic cable for a few circuits, and limited period of time, but quickly becomes quite expensive if large numbers of circuits are involved.

Tl service is only available in point-to-point configurations. The local channel that runs from the telephone company central office to the TOC or equipment location is billed on a mileage basis, usually in l/2 mile increments. For this cost estimate, it is assumed that the local channel at each end of the circuit is 2 miles long, and that the inter-office channel is 5 miles long. In Kentucky, the installation cost of this circuit is $2,650, and the monthly cost is $820. In Indiana, the installation cost is $3,385, and the monthly cost is $895.

Cellular Telephone: Cellular telephones have rapidly expanded their market penetration over the past five years, pushed by the convenience and declining prices. The cellular telephone network now covers over 93 % of the U.S. population. Off-the-shelf cellular modems permit the transmission of data over the cellular network. Note however, that cellular modems utilize different techniques for error correction and circuit initialization, and thus are often not compatible with landline modems. The use of cellular telephones by field personnel has simplified many maintenance and incident response procedures.

The ready availability of service and capability to locate equipment anywhere within the coverage area provides a high degree of flexibility, especially for temporary installations, and portable or mobile equipment. Cellular equipment eliminates the need to connect to a telephone company service point. This capability of establishing a circuit on an as-needed basis may prove cost effective for infrequent communications.

The primary disadvantage of cellular service is its cost. Each cellular “telephone” incurs a monthly service charge ranging from $15 to $45 per month, and a per-minute “airtime” charge ranging from $0.10 to $0.50 per minute. Due to competition, increasing numbers of users and the resulting additional volume, prices are falling. These price decreases are being driven by reduced unit cost reductions and “innovative” service plans. However, even at $0.10 per minute, airtime costs $144 per day, making full-time cellular communications prohibitively expensive. Since the existing cellular network utilizes analog transmission, it is noisy and thus limits the speed of data transmission.

Packet Radio: Packet radio is a wireless technique that is designed specifically for the transmission of data. Commercial suppliers utilize radio base stations to communicate with multiple field transceivers via time synchronized bursts, or packets, of data. Since many field transceivers share the same frequency pair for transmitting and receiving data, a cooperation strategy (or communications protocol) is utilized to coordinate this sharing. Because of this sharing, there can be delays of several seconds in delivering a packet. The pricing structure of packet radio is based upon amount of data transmitted, measured either in bytes or packets. This pricing structure, and the basic architecture of packet radio, is most effective when transmitting short bursty messages, and not large quantities of data. Typical prices are $0.03 per 100 bytes transmitted, which results in a cost of about $5.00 per hour for real-time communications with a traffic monitoring processor. This cost is prohibitive for continuous communications, but may be attractive for occasional use.

Satellite: Satellite communications services have been available for many years, and have proven cost effective for long-distance point-to-point circuits and for wide-area broadcast applications. However, for “local” applications (distances less than a few hundred miles), the costs of ground stations and satellite transponder rentals are prohibitive for traffic management applications. A typical monthly cost for a 56 Kbps circuit is $10,000 - however, this is essentially independent of circuit distance, with a 200 or 2,000 mile circuit costing the same.

The one case where satellite communications has proven useful for traffic management is incident response in rural areas. The ability to deploy an incident response vehicle, with voice, data and limited-motion video communications to a central control facility, has proven effective in field trials. The flexibility of this approach is a significant benefit, but the cost needs to be weighed against other communications channels.

AGENCY OWNED FACILITIES

In an effort to reduce monthly operating costs, and to provide the communications bandwidth needed for large numbers of video cameras, many agencies install their own communications facilities. For cable based systems, the cable and electronics are moderately priced; but the cost of trenching, installing conduits and ducts, backfilling and patching is significant. Depending upon construction conditions, conduit installation costs can range from $20/foot to $40/foot. This translates to $l00,000-$200,000 per mile. If structures need to be crossed, if roads must be bored under, etc. these costs can even be higher. The cable, installation costs, splicing, and electronics termination equipment costs from $5/foot to $15/foot, depending upon the specifics of the installation.

Twisted Pair: Twisted pair cable has been the backbone of “the last mile” in communications systems for decades. It provides a simple, straightforward and low cost method for the short-haul circuits from the termination of high capacity back-bone (long-haul) circuits to the individual Vehicle Detector cabinets or Variable Message Signs. Twisted pair works well for speeds up to 9,600 bps for distances of several miles. It is usually installed in combination with a fiber optic long-haul system to interconnect the field equipment to the communications hub.

Fiber Optic: Fiber optic cable is being installed in all new communications systems used for incident/traffic management. Fiber optic cables provide very high data rates (2.5 Gbps) over long distances (> 25 miles) without amplification. Other advantages are the small cable diameters (a 0.5” cable can contain 72 fibers), immunity from electrical interference, and avoidance of ground loop and lightning strike problems encountered with metallic conductors.

Fiber optic cable is commonly manufactured with two internal structures: those fibers that support single-mode transmission and those that support multi-mode transmission. Single-mode fibers are used for the long-haul (> 25 miles) circuits, but require more expensive transmission and receiving equipment to take advantage of its higher performance characteristics. Multi-mode fibers are typically used to transmit video images a few miles from the CCTV camera to a communications hub, where the images are combined, or multiplexed, onto the long-haul, single-mode fiber for transmission back to the control center. Multi-mode fiber utilizes lower cost transmission and receiving equipment, but has a limited transmission range.

Because fiber optic communications is the primary technology being installed today by agencies and communications carriers, additional details are provided in the following System Architecture and Network Configurations sections.

Coaxial: Coaxial cable was previously used for transmission of video images from CCTV cameras into a control center. Due to the need for active amplification every l/2 mile, the image degradation over long cables, and the maintenance problems, coaxial cable is no longer being used for this application.

Microwave: Point-to-point microwave is an attractive alternative for initial, or limited usage, transmission of video images from CCTV cameras. For those cases where it is neither technically feasible, nor cost effective to install conduit and fiber optic cable, microwave can be utilized. Depending upon performance, a microwave system (transmitter and receiver, usually with a reverse direction control channel) for video transmission costs from $20,000 to $40,000. This equipment is very useful in the initial stages of system implementation, before a fiber optic system can be installed. As the fiber optic system is installed, the microwave equipment can then be re-used to extend CCTV coverage out beyond the end of the fiber optic network. A key limitation of microwave is the requirement for line-of-sight. Another problem with microwave is its degradation under adverse weather (heavy rain, etc) conditions. A microwave installation must receive a license on a site by site basis from the FCC.

Wireless Video: A recent development in video transmission equipment is wireless video. This equipment transmits full motion video over a radio circuit, in a manner similar to that used by microwave - but without the stringent installation requirements. Wireless video does require line-of-sight, but the antennas are much less sensitive to alignment. The wireless video also does not require the licenses needed by microwave, because the equipment is class licensed by the manufacturer.

Spread Spectrum Radio: Spread spectrum radio transmission was developed nearly 50 years ago by the military as a security measure. These techniques were commercialized starting in 1985 when the FCC assigned frequency bands to spread spectrum radio. The technology spreads the signal bandwidth over a wide range of frequencies at the transmitter. The receiver knows the technique (or coding) utilized, and it thus able to recover the transmitted signal and reconstruct the original message.

Because each communications circuit within a given band utilizes a different coding technique, multiple, simultaneous circuits can co-exist. Spread spectrum generally requires line-of-sight, limiting its range to 0.3 to 6 miles. Since field equipment can be placed anywhere within the range of a base station, very flexible installations can be developed. The basic technique of spreading the transmitted signal over multiple frequencies results in high noise immunity. The FCC has assigned the 902-928 MHz band for which no facilities license is required. However, spread spectrum equipment operating in this band cannot interfere with licensed equipment, and must accept interference from licensed services.

For traffic management applications, there is significant potential for spread spectrum radio. The work that is currently under way to evaluate spread spectrum for the next generation of digital cellular telephony may result in a wide spread application of the technology. If this occurs, there will be an increased availability of equipment and resultant price reductions. However, the technological complications will result in increased personnel training and specialization, and more sophisticated equipment.

FIBER OPTIC SYSTEM ARCHITECTURE

Fiber optic communications systems were initially developed in the 1960s by the telephone companies for long haul transmission of voice and data. The technology has undergone successive refinement over the past quarter-century, and is today the technology of choice for essentially all new communications systems. Early implementations of fiber optic systems replicated the existing systems that were based on twisted pair, coax, and microwave channels, specifically implementing digital carrier systems at DS-1 (1.544 Mbps) and DS-3 (43.232 Mbps) transmission rates.

Within the past 10 years, a new standard termed Synchronous Optical Network (SONET) has been developed. The SONET standard is based upon multiples of 51.84 Mbps, which is known as an Optical Carrier 1 (OC-1) channel. An OC-1 channel carries a DS-3 data stream, plus additional control and status information. SONET systems typically are installed with OC-3 (155.52 Mbps), or OC-12 (622.08 Mbps) capacity, with some systems implementing OC-48 (2488.32 Mbps) or faster.

A key design concept of SONET is redundancy. This redundancy is achieved by the use of dual counter-rotating ring circuits. These rings provide for automatic rerouting of traffic onto the secondary ring, in the event of a failure of the primary ring. Since the secondary ring transmits data in the opposite direction from the primary ring, a cable break at one location does not result in a system failure. This re-routing capability is referred to as a self-healing ring (SHR). The switch-over from the primary to secondary ring occurs rapidly enough that most data communications can recover without data loss, however, real-time traffic such as voice or video may incur a momentary loss of communications. Restoral of full system functionality requires field repair of the broken cable. Equipment failures are also protected against by the inclusion of redundant components at all key locations. This redundancy is included in the basic design of the SONET system.

While alternative configurations may be considered, SONET is the preferred choice of all new communications systems. The use of SONET by the telephone companies and long-distance carriers has resulted in a wide range of manufacturers and vendors of equipment. The resulting competition has generated a wide range of features and capabilities, and very attractive benefit-cost ratios. Other alternatives do not have the range of options and features, and typically are more expensive when compared to SONET on a functionality basis.

The advantage of SONET is also its greatest drawback: the very wide bandwidth that is supported. This communications capacity results in higher costs when compared to the lower bandwidth solutions, but extending the lower end solutions to SONET capabilities ultimately requires a higher system cost. If capital cost limitations create budget constraints, alternatives to SONET may need to be considered. The other limitation of the higher bandwidth is the impact of a system failure, in that it impacts more field devices and communications channels. However, the self-healing capability and designed-in redundancy of SONET typically results in a more reliable overall system.

The design of a SONET system utilizes four single mode fibers on each link, using 1,310 nm or 1,550 nm for transmission. The interconnection of field devices to the SONET backbone requires the use of a "communications hub." This hub serves to interconnect the low speed (1,200 bps to 9,600 bps) data streams from individual 170 controllers, VMSs, etc. to the much higher data rates of the SONET backbone. This interconnection is performed by devices knows as multiplexors/demultiplexors. Data originating at several field devices is combined together in a "time-slice" format for transmission to the central facility. This combination makes best use of the capacity of the SONET system. In the reverse direction, the data coming from the central facility is extracted from, or demultiplexed, from the combined data stream and routed to individual field devices. An equivalent set of multiplexors/demultiplexors exists at the central facility to perform the same functions of combining and separating data.

Since voice can be represented in a digital format, the SONET system can also be used for voice communications. Digital transmission of voice is extensively used by all the telephone companies and long-distance carriers, and has been the driving force behind the development of digital carrier and SONET technologies. Highly cost-effective and very reliable systems are thus available from the telephone company equipment suppliers. Agencies often utilize this voice capability of a SONET system to implement PBX-to-PBX links between various locations, and to bypass the telephone companies to reduce their long distance charges. This option is a particularly valuable consideration when reviewing the installation of fiber optic cable between major metropolitan areas.

FIBER OPTIC NETWORK CONFIGURATIONS

There are three basic network configurations, or topologies, that are used to design fiber optic systems: Star, Bus, and Ping.

Star Configuration: In a star configuration, separate fiber optic trunks are used to connect the communications hubs to the central facility. At each hub, connections are made to the field devices through a local distribution network which can consist of several different types of media, such as fiber optic cables, twisted pair, or radio based communications. The data to and from the central facility is multiplexed/ demultiplexed at the communications hub.

This type of configuration has a disadvantage in that separate "home runs" are required from each hub to the central facility, and that it is typically not configured with redundant, automatic switch-over, fibers or equipment. However, this is a proven system and has been successfully used in many traffic management systems.

Bus Configuration: In a bus configuration each communications unit, which may be a device located at a node or communications hub, or a field device such as a 170 controller, is connected to a fiber optic link or series of fibers carrying data in two directions, i.e., full duplex. Each device is assigned a channel and an address. Each device is accessed by polling it on its assigned channel, using the specified address, to retrieve data in the device and to send it control information. This bus configuration is commonly used in local area networks (LANs) used to link together personal computers.

The advantage of this configuration is the use of a single communications facility reaching from the central location to each field device. However, low cost fiber optic modems that are directly compatible with 170 controllers, VMSs, and related equipment are not readily available. This technology has not been utilized in operational traffic management systems, and thus there is very limited experience.

Ring Configuration: Ring configurations can be implemented as either a single ring, or as a dual (redundant) ring. Most ring configurations being installed today utilize a dual ring to take advantage of the automatic reconfiguration, or self-healing capability of the system. This fault-tolerant approach significantly increases system reliability.

The operational advantages of self-healing rings have been noted. Because this configuration is being widely implemented and utilized, a full range of equipment at competitive prices is readily available. The disadvantages are the requirement for additional fibers, and redundant equipment at the communications nodes. However, the incremental costs of additional fibers within the same cable is very small (approximately $150 per fiber per kilometer). Similarly, the incremental costs of redundant equipment, when compared to the life-cycle cost of system failures is again quite small.

EXISTING AND PROPOSED LOUISVILLE COMMUNICATIONS FACILITIES

Existing Louisville City Net: The City of Louisville has an existing network that links together local area networks (LANs) in various city departments. Three buildings in the City Hall area are connected via fiber optic cable. This fiber optic cable only covers a distance of about three city blocks, utilizing conduit obtained from LGE on a franchise basis. Connection to other buildings outside of this limited area is provided by 56 Kbps data circuits leased from the telephone company.

Existing digital radio system: A digital radio transmission system is being installed in the City of Louisville. It may be use in communicating with field equipment to be installed for this project. Its functionality and availability should be explored during the detail communications system design.

Future fiber optic cable from downtown to University: A fiber optic cable may eventually connect downtown Louisville to the University of Louisville campus. Although this cable might not be routed on the I-65 right-of-way, it may be a possible option to have joint use with this project. Its routing and availability should be explored during the detail communications system design.

RECOMMENDATIONS

As discussed in Potential Improvement Options chapter, a three stage plan (Early Action, Initial System, Full System) is recommended. The Early Action items do not require any additional communications facilities. Since communications form a major portion of the cost of the Full System, communication system recommendations are structured for the Initial System to minimize these costs. The communications required for the Full System can be installed in stages over a several year period, so that the entire capital cost need not be expended within a single budget period. However, it is important that the architecture of the communications system be established initially so that each incremental addition be compatible with the overall system.

Initial System: For the 170 traffic data collectors, the Video Image Detection processors, and the Variable Message Signs, leased telephone circuits are recommended. The communications bandwidth is adequate to collect data and status from these devices every 20 seconds. The use of either microwave or wireless video transmission is recommended for transmission of video images from and control information to the CCTV cameras. This system will provide full-motion video for the CCTV cameras included in the Initial System. Most portable VMSs are controlled locally at the sign, when there is no need for centralized monitoring and control. However, if access to these portable VMSs from the control center is required, use of cellular telephone data circuits is recommended.

Full System: In order to support the full-motion video from the CCTV cameras in the Full System, the installation of a fiber optic communications back-bone, utilizing SONET as the basic carrier technology, is recommended. SONET systems are being installed by all major communications companies, resulting in a highly competitive equipment market with excellent performance and attractive pricing. Compatibility with major common carriers will simplify utilization of communications channels leased from commercial suppliers.

As discussed in the CCTV section of the Technology Overview, digital transmission of video is the technology of choice for all new project designs. Use of digital video transmission will simplify the overall transmission network, since the SONET network can be used for video, data, and voice. It is recommended that the video be converted to digital format at the communications hubs, transmitted and switched in a digital format, and converted back to analog just prior to display.

It is recommended that fiber optic cable (multi-mode or single-mode as required) be used to connect the CCTV cameras to the communications hubs. Fiber optic transmission of video images provides superior quality images, and is less costly than coax for the typical distances involved.

For the data channels to the CCTV controllers, the 170 traffic data collectors, the Video Image Detection processors, and the Variable Message Signs, it is recommended that twisted pair cable be utilized. For this usage, twisted pair is simpler to install and maintain, and provides adequate transmission bandwidth.

When planning for the fiber optic back-bone, joint use with other agencies should be considered in order to share the costs. Another option that should be considered is joint use with a communications carrier, One possibility is for the agency to install and own the fiber optic cable and equipment and to lease portions of it to the common carrier. The other alternative being explored by various states is for the common carrier to install and maintain the cable and equipment, with the agency receiving usage of portions of the communications bandwidth in exchange for the right-of-way. Between these two options are multiple variations that provide a mix of benefits to the agency and the common carrier.